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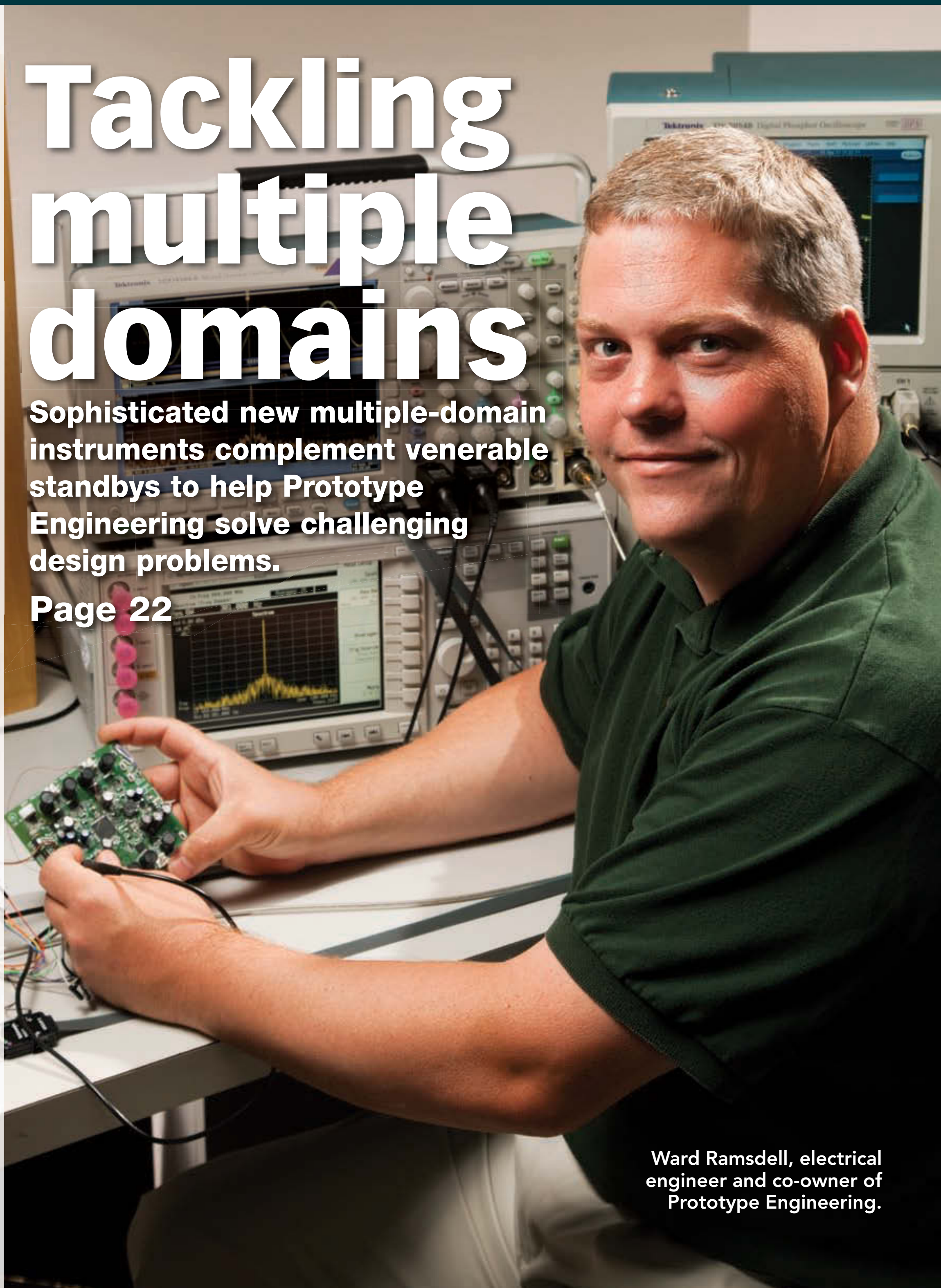
Test & MEASUREMENT WORLD®

THE MAGAZINE FOR QUALITY IN ELECTRONICS



Tackling multiple domains

Sophisticated new multiple-domain instruments complement venerable standbys to help Prototype Engineering solve challenging design problems.

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Ward Ramsdell, electrical engineer and co-owner of Prototype Engineering.

COVER BY: ROBBIE MCCLARAN

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UBM Electronics — A UBM Electronics Publication

RON WILSON
CONTENT DIRECTOR

It was 30 years ago today. . .

Well, not actually today. Fall 1981 saw the first issue of *Test & Measurement World*. We recently looked at a copy, giving us a chance to take stock for a moment.

In many ways, the entire landscape has changed. Most obviously, advancing technology has altered our notions of smart, small, and fast. An article in that first issue surveyed video-inspection systems—in those days, closed-circuit cameras bolted to microscopes or parts handlers—and warned that the technology was in its infancy. No one thought to use the word automated with video inspection. Another article profiled optical microscopes for IC inspection. In those days, you could trace circuits with a desktop microscope, and examine the quality of individual connections.

Despite all that has changed, some things from our first issue are remarkably familiar.

Frequencies have gone up a bit, too. The oscilloscope vendors in 1981 were fighting over the heart of the market—still the 50-MHz portable. Tektronix introduced a microwave spectrum analyzer that reached a sobering 1.8 GHz. It was fully programmable—meaning it accepted commands over GPIB. One leading-edge vendor had pushed the speed of LSI (large-scale integration, for those who weren't around then) test systems to a blistering 10 MHz.

The players have changed a bit as well. Industry majors advertising in that first issue included GenRad, Fairchild Instruments, Marconi, HHB, Teradyne, and Leader. Conspicuously, neither Hewlett-Packard nor Tektronix chose to advertise in that issue. Perhaps editorial ethics have changed a bit, too. The publisher, one Susan Chouinard, was also editor-in-chief. By coincidence, HP is only mentioned twice in 102 pages, both times in descriptions of someone else's product. Tek fared better, with a product brief and mention in an opinion piece.

The big event in the electronics industry was Wescon, cited several times as the location of major product announcements. But our new magazine meant to change all that, unveiling its own conference scheduled for the next April in San Jose.

Despite all that has changed, some things from our first issue are remarkably familiar. One example is the domain of the magazine, ranging from inspection systems and automated test equipment to benchtop and field-service instruments. Things to be measured varied as well, from microwaves to analog signals, digital circuits—this was the dawn of logic analyzers and microprocessor emulators—and nonelectrical questions such as surface roughness, package alignment, and light.

The magazine's approach to these subjects might seem pretty familiar today. The focus was definitely on products, but augmented by news, and by articles on people. There was even an invitation to a proto-social network: the Test & Measurement User's Forum.

The world outside was familiar too, in a grim way. The industry was in deep recession in 1981, and one article asks if vendors of automated test equipment will survive. And the world was dangerous. An article discusses instrument export restrictions and outright espionage in the wake of the Soviet seizure of Afghanistan.

Well, then, here's to change and stasis. Please lift your glass to the 30th anniversary of *T&MW*. May it see many more! T&MW

> > > *POST YOUR COMMENTS AT WWW.TMWORLD.COM/BLOG.*

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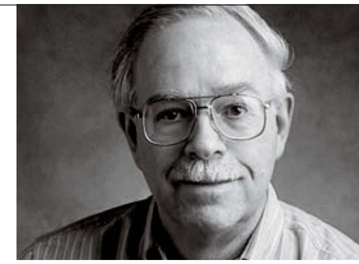


Robert Burns, test engineer?

Had all gone according to plan, this column would have compared and contrasted the capacitive ESR (equivalent series resistance) measurement capabilities of a 60-year-old Sprague TO-4 Tel-Ohmike with Agilent Technologies' U1733C, a modern handheld multifunction component-measurement meter.

As the Scottish poet Robert Burns might have noted, "…The best-laid [test] schemes… gang aft agley…" (Ref. 1). I discovered that my TO-4 was in worse shape than it first appeared (see my August column), and I used the U1733C to partially debug the TO-4, whose remaining problems include rusted ground-lug rivets, an intermittent multicontact function switch, a defective 1619 vacuum tube, and a previous owner's rewiring errors. The U1733C easily identified the TO-4's defective and suspect components (**photo**).

In contrast to the TO-4's analog displays and manual adjustments, the U1733C features an LCD and a 10-position keypad for function selection, and it occupies far less bench space than the boxy TO-4. What truly distinguishes the U1733C is its automatic component-identification mode. Connect the U1733C's test leads to a DUT (device under test), select one of several test frequencies from 100 Hz to 100 kHz, and in a few seconds, the meter sorts out the DUT's predominant function and displays its electrical characteristics.

Of course, "There is no such uncertainty as a sure thing" (Ref. 2), and as with all component testers, the user must confirm that an instrument's displayed reading agrees with the actual component. For example, my U1733C identified a short-circuited capacitor as a 0.052-Ω resistor, while my HP34401A digital multimeter misread it as a 238-kΩ resistor!

Above their self-resonant frequencies, an inductor "looks" capacitive and a capacitor "looks" inductive. When measuring an unknown inductor, I selected the lowest available test frequency, noted the displayed inductance and Q (quality factor) readings, and increased the measurement frequency until the measurement became capacitive.

As for a capacitor's ESR, Burns gets the last word: "What's done we partly may compute, But know not what's resist[or]ed" (Ref. 3). T&MW

REFERENCES

1. "To a Mouse," bit.ly/nRmPnV.
2. This quote is widely attributed to Burns, but unverified.
3. "Address to the Unco Guid" (stanza 8), bit.ly/nAUcbE.

To read past Test Voices columns, go to www.tmworld.com/testvoices.

SUGGESTED READING

To learn more about Agilent's U173xC handheld LCR meters, begin here:

bit.ly/p1G8tD

WHAT'S A "GOOD" CAPACITOR'S ESR?

To determine whether a capacitor's ESR value is excessive, identify the capacitor's manufacturer and part number (if possible—surface-mount electrolytics rarely have room for a part number, let alone a vendor ID). Consult the component's data sheet for maximum ESR, tan-δ, or dissipation factor. Select a matching test frequency and compare the measured value with the published maximum.

Lacking published data, you can measure the suspect DUT and match its capacitance, voltage rating, mechanical dimensions and temperature rating to those of similar name-brand capacitors. Here is a "typical ESR values" chart:

bit.ly/n5ao6Z

Even though you can precisely measure a capacitor's ESR, determining whether a particular ESR value would cause a circuit malfunction still involves design analysis and, on existing equipment, a certain amount of guesswork.

CAN'T MAKE IT? FAKE IT!

Incorrect capacitance and ESR measurements may indicate a defective component—or a counterfeit:

bit.ly/pE5Vsf

INDUCTANCE MEASUREMENTS CAN BE MESSY, TOO

According to Leslie Green, writing in *EDN*, we need to rethink the classic—and erroneous—model used to specify and measure inductors:

bit.ly/rnCK6P

"Why does my LCR meter say the choke has 'negative inductance'"? Find out:

bit.ly/pBywZi

PXI dominates at Autotestcon

Automated test, particularly for military and aerospace, now relies heavily on PXI, which has largely replaced VXI in new test systems. This year's IEEE Autotestcon show (September 12–15, Baltimore, MD) bore that out. New I/O modules on display included two FPGA modules from Geotest: The GX3700 (PXI) and GX3700e (PXI Express). You can use the cards to develop your own custom digital circuits and interface them to other test-system components through serial data streams.

Pickering Interfaces expanded its line of PXI RF switches with the introduction of the 40-754 (pictured), which can add up to 17 SPDT switches to a PXI chassis. The 40-754 is available in 500-MHz (one-slot) and 1.2-GHz (two-slot) versions. ZTEC also introduced an RF product on a PXI module, the ZT8651 6-GHz vector signal analyzer. The new analyzer can demodulate WiFi and cellular protocols such as IEEE 802.11ae and LTE.

Agilent Technologies unveiled several additions to its PXI product line: a controller based on a 2.4-GHz processor, a 6.5-digit digital multimeter (the M9191A) that measures DC and AC current and voltage and two-wire and four-wire resistance, and new data-streaming capabilities for its M9392A PXI vector signal analyzer and M9202A digitizer that allow the modules to stream data to a RAID-based disc array.

Just prior to Autotestcon, National Instruments introduced the NI PXIe-6556 (a 200-MHz digital I/O module) as well as the NI PXIe-4140 and NI PXIe-4141 SMUs (source-measure units). Each of the SMUs provides four SMU channels, and you can combine modules to get up to 68 channels in a system with a 600-ksamples/s sample rate. The NI PXIe-4141 lets you tune the module's output response to your load, which can improve stability over a fixed response time.

Breuer receives TTTC medal

Dr. Melvin Breuer, chairman of the Department of Electrical Engineering-Systems at the University of Southern California, received the Lifetime Contribution Medal from the IEEE TTTC (Test Technology Technical Council) during the 2011 International Test Conference (September 18–23, Anaheim, CA). The TTTC presents the medal to recognize outstanding technical contributions that have made a fundamental impact on test technology. In presenting the award to Dr. Breuer, the TTTC cited his decades of major contributions in areas such as electronic design automation, design for test, and built-in self-test.

Breuer's achievements include defining work on digital-design flows, delay and crosstalk faults, partial-scan methodologies, and error thresholds. He has authored or co-authored seminal books, including *Design Automation of Digital Systems* and *Diagnosis and Reliable Design of Digital Systems*, both from Computer Science Press.

Always just beyond the boundary of orthodoxy in fault definition and test theory, Breuer's work has broken paths that have become mainstream approaches in dealing with deep submicron faults. Additionally, many in the industry cite him as a personal mentor. www.tttc-events.org.

Editors' CHOICE

Probe and meter find pulsed signals

EMC Test Design's PI-3P electric-field probe works with the company's RFP-05 Smart Fieldmeter to detect pulses from microwave radars that can affect RF and EMI (electromagnetic interference) measurements. The probe can detect pulsed signals with durations as short at 1 µs that have repetition rates from 100 Hz to 10 kHz and that operate at carrier frequencies up to 18 GHz. That upper frequency covers test requirements for MIL-STD-461 as well as requirements for Ford and General Motors automotive EMC (electromagnetic compliance) testing.

You can also use the probe and meter for HIRF (high-intensity radiated-field) testing; the probe has a field-strength range of 70 to 1400 V/m.

Price: $7700 for a probe/meter kit. *EMC Test Design, www.emctd.com.*

CALENDAR

Vision 2011, November 8–10, Stuttgart, Germany. *Messe Stuttgart, www.messe-stuttgart.de.*

Productronica, November 15–18, Munich, Germany. *Messe München, www.productronica.com.*

DesignCon 2012, January 30–February 2, Santa Clara, CA. *UBM Electronics, www.designcon.techinsightsevents.com.*

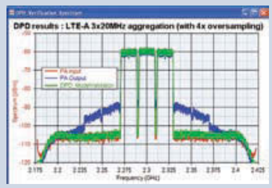
Measurement Science Conference, March 19–23, Anaheim, CA. *Measurement Science Conference, www.msc-conf.com.*

To learn about other conferences, courses, and calls for papers, visit www.tmworld.com/events.

Editors' CHOICE

Platform supports LTE-Advanced

Agilent Technologies has announced a new release of its W1716 DPD (Digital Pre-Distortion) Builder software, an add-on to the company's SystemVue environment. To help designers meet the bandwidth and linearity requirements necessary to achieve 1-Gbps data rates using over 100 MHz of bandwidth, the enhanced W1716 DPD software links to Agilent PXI instruments to support wideband stimulus/response measurements and interactive DPD modeling of 4G wireless systems. The platform integrates 4G-ready DPD algorithms for both protocol-analysis modeling and predistortion analysis; optional, standards-based reference libraries for LTE-Advanced, 802.11ac, WCDMA, OFDM, and other waveforms; and a calibrated stimulus/response measurement platform with up to 250 MHz of bandwidth (using the M9392A PXI microwave vector signal analyzer), expandable to 800 MHz (using the M9362A-D01 PXI Express microwave quad downconverter).



The platform also supports integration with RF EDA design tools, such as Agilent Advanced Design System and GoldenGate, for predictive, simulation-based extraction, including memory effects.

Base price: $17,000. *Agilent Technologies, www.agilent.com.*

MARTIN ROWE
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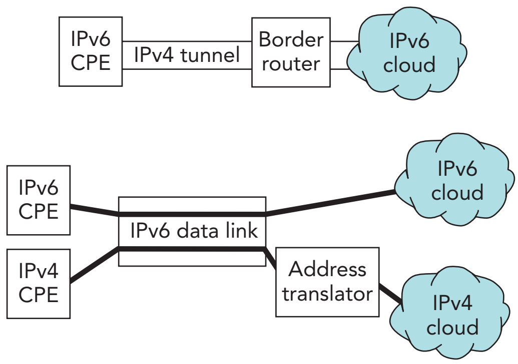
IPv6 stresses network testing

IPv6 (Internet Protocol version 6) is gaining in importance because IPv4 has run out of addresses. IPv4's 32-bit address just isn't long enough. IPv6, with its 128-bit address field, will provide enough IP addresses for a long time.

Although IPv6 has been in development for years, it is now moving into deployment. With that deployment comes the need for vendors to test equipment and networks that operate with the new protocol and also maintain IPv4 compatibility. The results of IPv6 World Test Day showed that sites that support IPv6 were able to interoperate with both IPv6 and IPv4 equipment, although the vast majority of Internet traffic on test day ran IPv4 (Ref. 1).

Core network equipment, such as switches and routers, supports IPv6 using two techniques called 6rd (IPv6 rapid deployment) and DS-Lite (dual-stack-lite). These transition techniques let network operators continue to use their IPv4 DSLAMs (DSL access multiplexers) and CMTSs (cable modem termination systems) while they deploy IPv6 CPE (customer premises equipment). The **figure** shows the concept behind both techniques.



The 6rd technique (top) lets an IPv4 network send IPv6 packets. The DS-Lite technique (bottom) lets IPv4 and IPv6 run in parallel over an IPv6 connection.

In the 6rd technique, networks encapsulate IPv6 into IPv4 headers. That passes, or "tunnels," IPv6 traffic through an IPv4 network. An edge router terminates the tunnel, letting the IPv6 packets reach their destination (Ref. 2). The 6rd technique requires little change to existing networks to run because it's based on IPv4 equipment.

In contrast, the DS-Lite technique encapsulates IPv4 over an IPv6 network. When an IPv6 CPE modem connects to an IPv6 Website, the connection remains IPv6. When either the modem or the Website supports IPv4 only, an address translator makes the conversion.

Over the last several years, IPv6 testing has focused on the core network. Now, testing is moving to edge networks and CPE. Manufacturers of home routers, for example, are implementing IPv6 in their products and they're focusing on interoperability testing. "Gateways and CPE product require extensive testing," said Alan Way of Spirent Communications.

Tim Winters, director of the IPv6 Consortium at the UNH-IOL (University of New Hampshire Interoperability Lab), noted that manufacturers of home routers test their products to make sure that IPv6 packets will pass through their products' firewalls. "The IETF (Internet Engineering Task Force) has developed a default value for a firewall. It lets engineers figure out how to implement their firewalls."

The UNH-IOL has held several IPv6 "plugfests" where manufacturers can test their products with a variety of network equipment. "We've seen a lot of interest in testing home routers for 6rd and DS-Lite compatibility as well," Winters said. T&MW

REFERENCES

1. Rowe, Martin, "The Internet was tested," Rowe's and Columns blog, June 13, 2011. www.tmworld.com.

2. "Best practices for Deploying IPv6 over Broadband Networks," Ixia, May 2011. www.ixiacom.com.

Modules measure voltage or temperature

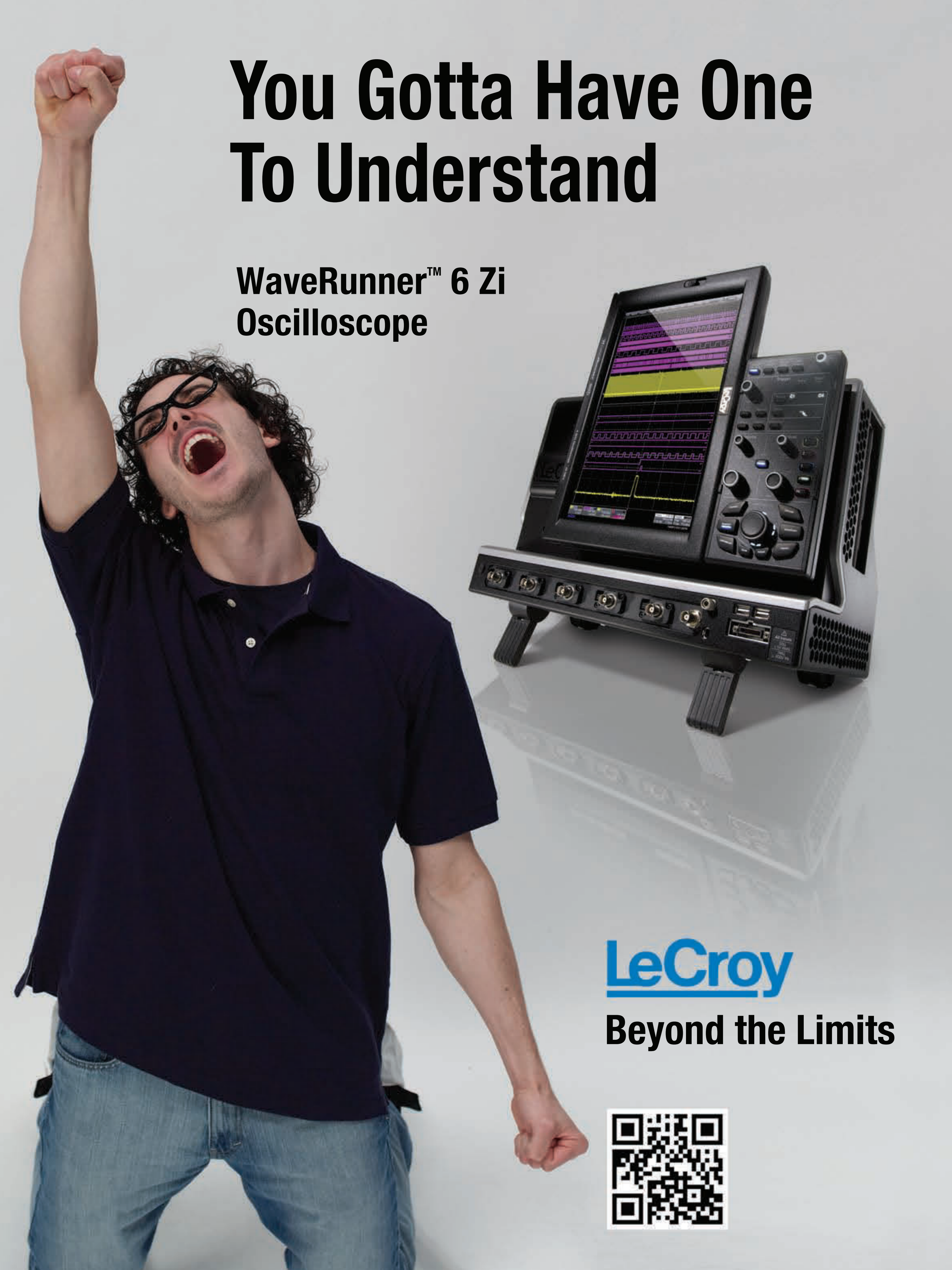
With 16 single-ended analog or eight thermocouple channels, the USB-2408 from Measurement Computing lets you measure voltage or temperature with 24-bit resolution. The module also includes eight digital I/O channels and two optional analog outputs. www.mccdaq.com.

Measure noise on AC mains

OnFilter's MSN01 EMI filter lets you measure high-frequency noise AC mains with an oscilloscope. The $389 notch filter removes signals at line frequency, letting noise pass through. It presents a 50-Ω load to an oscilloscope. www.onfilter.com.

USB modules sample at up to 100 ksamples/s.

Data Translation has added three modules to its ECON series of data-acquisition products. The DT9812A, DT9813A, and DT9814A multifunction devices are USB 2.0-compliant and sample at rates up to 100 ksamples/s. They also offer 12-bit resolution for analog I/O subsystems; eight, 16, or 24 singled-ended analog input channels; and two analog output channels. www.datatranslation.com.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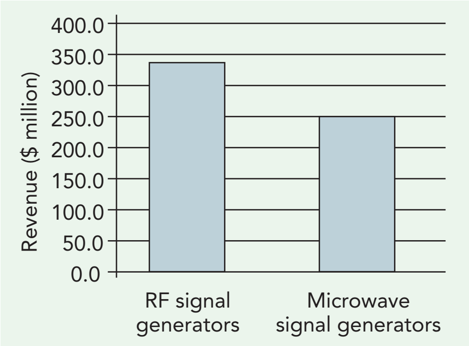
Moderate growth predicted for signal generator market

The next 10 years will be a "wireless decade," as products offering 3G, 4G, and WCDMA wireless interfaces will proliferate. We will see different types of wireless devices beyond the traditional ones, and their fast development and implementation will be the key factor driving the demand for signal generators. It will be imperative for manufacturers of signal generators to adapt their products to comply with evolving wireless standards.

Although the signal generator market has bounced back from the economic crisis of 2009 and is surpassing the levels of 2008, caution and uncertainty continue to restrain end users from making capital expenditures. The industry is demanding products that offer higher performance and higher functionality, yet at a lower cost. In the Asia-Pacific region, the manufacturing base has been increasing and the focus on production has created a much more cost-sensitive environment, boosting the market for signal generators.



RF signal generators held a larger share of the forecasted worldwide market for signal generators in 2010. Source: Frost & Sullivan.

Higher bandwidth is the number-one requirement for end users. A greater number of digital modulations transport more data in the same bandwidth, making the modulations more likely to generate imprecise levels of transmissions and phase angles. Signal generators, therefore, play a critical role in test systems. As Bob Buxton, marketing manager in the general-purpose business unit at Anritsu, said, "a signal generator is the heartbeat of the test system; power level is the strength of the heartbeat, accuracy of the instrument is the heart rate, and the quality of the signal is the profile of the heartbeat." A key driver for vendors of signal generators will be the ability to provide higher frequencies and lower phase noise in their products.

During the economic downturn of 2009, the global revenue for both RF and microwave signal generators declined by an average of 22%. According to Frost & Sullivan's analysis, the RF signal generator market held the largest market share at 57.3% and is projected to reach $365.8 million in 2011, while the microwave signal generator market accounted for 42.7% of the market and will reach $273.1 million in 2011.

Overall, Frost & Sullivan believes that the signal generator market will experience moderate growth during the forecast period. The compound annual growth rate for RF and microwave signal generators from 2011 to 2015 is estimated at 3.2% and 3.4%, respectively. T&MW

Chip sales slowing rapidly

Market-research company Gartner has joined rival prognosticators in predicting the 2011 global chip market will decline from the previous year. The company has also halved its forecast for chip market growth in 2012 with the warning that a US double-dip recession would require a further downward sales revision.

The worldwide semiconductor market has been slowing throughout 2011 and is now set to have a revenue total of $299 billion, a decline of 0.1% from 2010, according to the Stamford, CT-based firm. This is a significant change from Gartner's previous projection, given in the second quarter, for 5.1% growth this year.

"Three key factors are shaping the short-term outlook: excess inventory, manufacturing overcapacity, and slowing demand due to economic weakness," said Bryan Lewis, research VP at Gartner, in a prepared statement. "Semiconductor companies' third-quarter guidance is well below seasonal averages. The current guidance by vendors points to flat to down third-quarter growth. Typically, we see guidance for 8 to 9% growth in the third quarter because of back-to-school and the holiday build. The supply chain is also showing significant slowdown, and semiconductor-related inventory levels are still elevated."

One of the main problem areas for chipmakers is PC production, Gartner reckons. Last quarter, Gartner estimated PC production growth of 9.5%; that has now been reduced to 3.4%. The falling demand for PCs, in part highlighted by the popularity of the tablet computer and smartphone, means DRAM sales and prices have been severely impacted. The value of DRAM sales is now expected to decline 26.6% in 2011. Meanwhile NAND flash and data-processing ASIC are the fastest-growing device areas in 2011, with about 20% growth.

Peter Clarke, EE Times

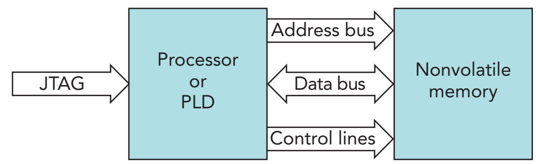
DESIGN FOR TEST

Boost NVM programming speed

Designed as a means of testing component interconnectivity on a printed-circuit board, boundary-scan technology can also support the programming of NVM (nonvolatile memory). Yet the traditional method of programming NVM via the boundary-scan TAP (Test Access Port) can be slow. Simply reading every location in a 16-bit-wide, 128-Mbit flash device can take more than 8 min, and programming the device can take much longer.

Fortunately, a design incorporating NVM is likely to include an embedded processor that has direct access to the NVM. An ARM Cortex-M3 processor, for example, includes a "Memory Access Port" for that purpose. Furthermore, an embedded processor is likely to include a boundary-scan interface that's used for processor debug. Designers can leverage the combination of direct-memory access and the debug interface to significantly improve NVM programming speed (**figure**). Designers can exert similar leverage on PLD-based designs if the PLD has full access to the NVM and is also programmable via the boundary-scan chain.

Micron has chosen to employ such leverage to speed the programming of its PCM (phase-change memory) nonvolatile devices. Engineers from XJTAG were able to employ the XJFlash capability of XJTAG's boundary-scan system to reduce the total programming time of a 128-Mbit PCM device to less than 20 s, with an average write-cycle time of less than 2 µs.



You can significantly improve NVM programming speed on processor- or PLD-based designs if the processor or PLD offers direct NVM access and includes a boundary-scan debug port.

The online version of this article (www.tmworld.com/2011_10) includes a link to a case study that summarizes the application of XJFlash to Micron's application as well as a link to a white paper that details how to apply boundary-scan technology to speed NVM programming in processor- or PLD-based designs, with specific emphasis on an example based on the Micron-supplied demo board that has two boundary-scan chains: one with an Intel/Marvell PXA270 processor and the other with a Xilinx Spartan-3 FPGA.

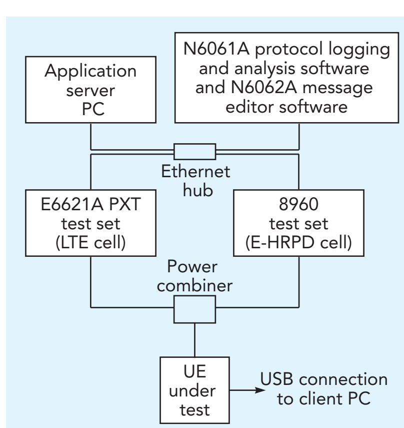
Rick Nelson
Editorial Director

WIRELESS TEST

Test sets mimic cells for LTE handover test

As LTE rolls out, old and new cellular technologies will need to coexist. UE (user equipment) must be able to adapt to the evolving environment and support smooth handover between different RATs (radio access technologies). In addition, the UE must support SVLTE (simultaneous voice and LTE), pending LTE specification releases and changes to the 3GPP2 core network that will address data and voice integration.

Within the complex and evolving environment, the UE must interpret and respond to protocol messages for each network technology it supports, and it must establish a connection with an available network to deliver required services to the user. Existing GSM networks provide a relatively smooth path toward LTE, but LTE exhibits major differences from non-GSM networks, complicating the handover process as networks migrate from CDMA through eHRPD (Evolved High Rate Packet Data) and on to LTE. Testing under controlled and repeatable conditions can help determine how well the UE performs in such an environment.



Two communications test sets and optional software can help you evaluate the handover capabilities of user equipment.

The application note "Testing Handovers Between LTE and 3G cdma2000/1xEV-DO Cellular Networks" from Agilent Technologies (bit.ly/qjCg0N) describes how you can use Agilent instruments to establish controlled and repeatable conditions to test your equipment's handover capability. You'll need a test SIM (subscriber identity module) configured for inter-RAT handovers and two communications test sets (**figure**): a Model E6621A PXT preconfigured to represent an LTE cell and a Model 8960 preconfigured to represent an eHRPD cell.

Optional protocol-logging and analysis software can facilitate the test. Optional message-editing software can help you make use of the Model E6621A PXT scenario file provided in an appendix to the application note.

Rick Nelson
Editorial Director

OSCILLOSCOPES

Math functions reveal circuit parameters

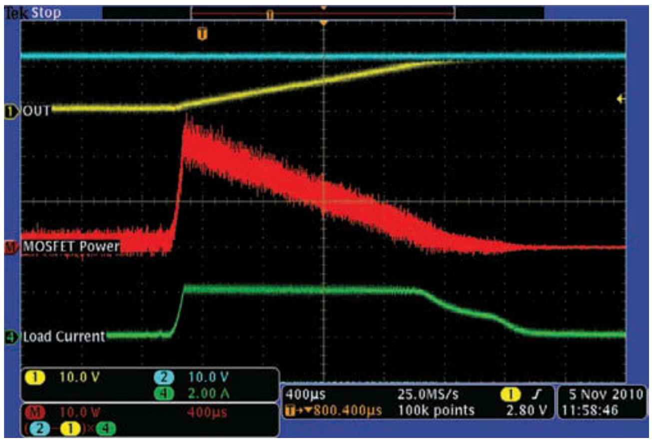
Oscilloscopes can do much more than simply display waveforms, but many engineers don't take advantage of their instrument's advanced features. For example, oscilloscopes have math "channels" that can process signals and display the results. You can use those results to gain insight into a circuit's performance.

Oscilloscopes, even analog ones, have long been able to display the sum of two channels, but often you need more. When you need to view a device's power dissipation, for example, you need to multiply voltage and current.

Dwight Larson, senior member of the technical staff at Maxim Integrated Products, has written a paper that explains how to multiply voltage and current in order to display the power dissipation on a MOSFET that is part of a hot-swap power-controller IC. You can download his paper, "Oscilloscope math functions aid circuit analysis," from the online version of this article at www.tmworld.com/2011_10.

The **figure** shows how Larson calculated power dissipation. The red trace (middle) represents power, derived by multiplying output current (green trace, bottom) and voltage across the MOSFET (yellow trace, top). Larson also explains how to use an oscilloscope to calculate a circuit's load capacitance.

Martin Rowe
Senior Technical Editor



Oscilloscopes can calculate parameters such as power (middle trace), from current (bottom trace) and voltage (top trace).

Test ideas

Measurement tips from readers

Minimize noise in power-supply measurements

Eliminating excess noise from an oscilloscope probe yields better measurements.

John Lo Giudice, STMicroelectronics, Schaumburg, IL

You must minimize noise when measuring ripple in power rails, because the ripple's amplitude can be low. Oscilloscope probes are essential measurement tools, but they can introduce noise and errors. Ground leads, such as those that attach to standard oscilloscope probes, can add noise that's not present in your circuit to an oscilloscope's trace. The wire loop acts as an antenna that picks up stray magnetic fields. The larger the loop area, the more noise it picks up.

To prove this theory, connect the oscilloscope ground lead to the probe tip and move it around. The oscilloscope will show the noise increasing and decreasing with the ground-lead movement. You can use an oscilloscope probe with its ground lead and sockets (**Figure 1**) to build a simple interconnect board.

Start by removing the probe's cover, which reveals the probe tip. There is a short distance between the tip and the ground ring. You need one of two sockets: a right-angle, or horizontal, socket or a vertical socket, similar to those in Figure 1. Solder the center leg of the socket to the output of the power supply and solder the other leg to the power-supply return. Connect a 0.1-μF surface-mount, stacked ceramic capacitor between the two sockets. This step limits the probe bandwidth to approximately 5 MHz, which further reduces high-frequency noise and lets the lower-frequency ripple pass through.

Figure 2 shows the completed interconnect board, and **Figure 3** shows a schematic of the board. Insert the probe tip into the socket to measure ripple. You will get a ripple measurement without spikes or other noise.

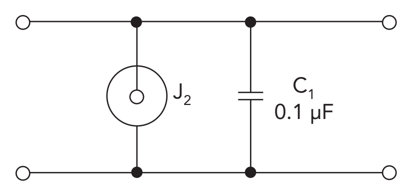


Figure 3 A ceramic capacitor further reduces high-frequency noise.

You should use a multilayer stacked ceramic capacitor because such capacitors are better at decoupling high-frequency noise. Electrolytic, paper, and plastic-film capacitors comprise two sheets of metal foil. A sheet of dielectric separates the metal-foil sheets, and these three components form a roll. Such a structure has self-inductance; thus, the capacitor acts more like an inductor than a capacitor at frequencies higher than a few megahertz. **Figure 4** shows the impedance to the power supply for various stacked ceramic-capacitor values. T&MW

This article originally appeared in the July 28, 2011, issue of *EDN*.

Figure 1 A standard oscilloscope probe has a ground lead that can pick up noise.

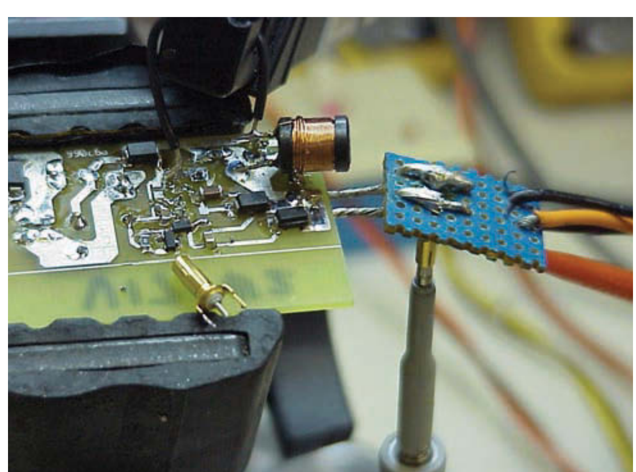


Figure 2 Solder wires from the power supply under test to an interconnect board reduce ground-lead length.

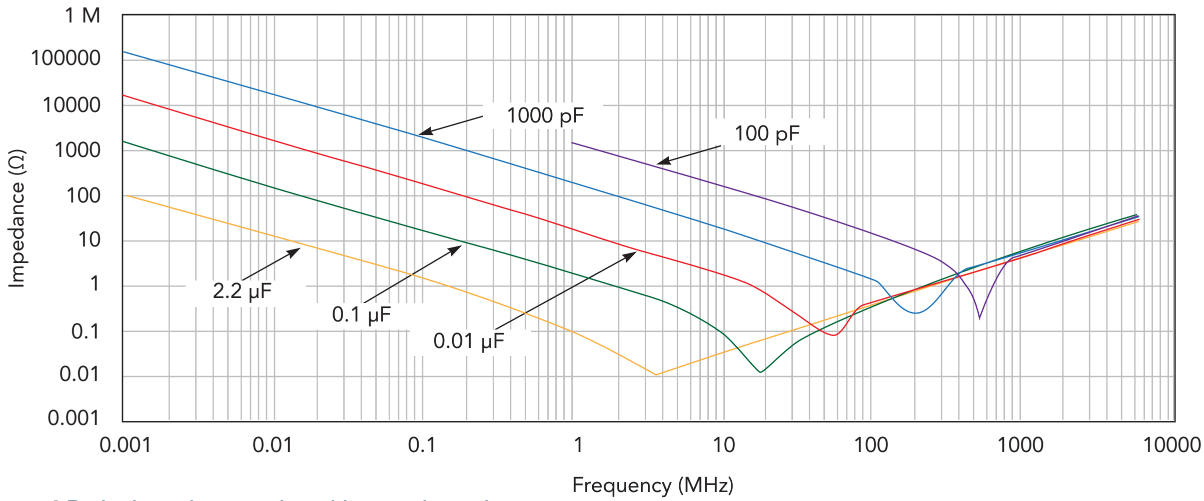


Figure 4 Probe impedance varies with capacitor value.

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Tackling multiple

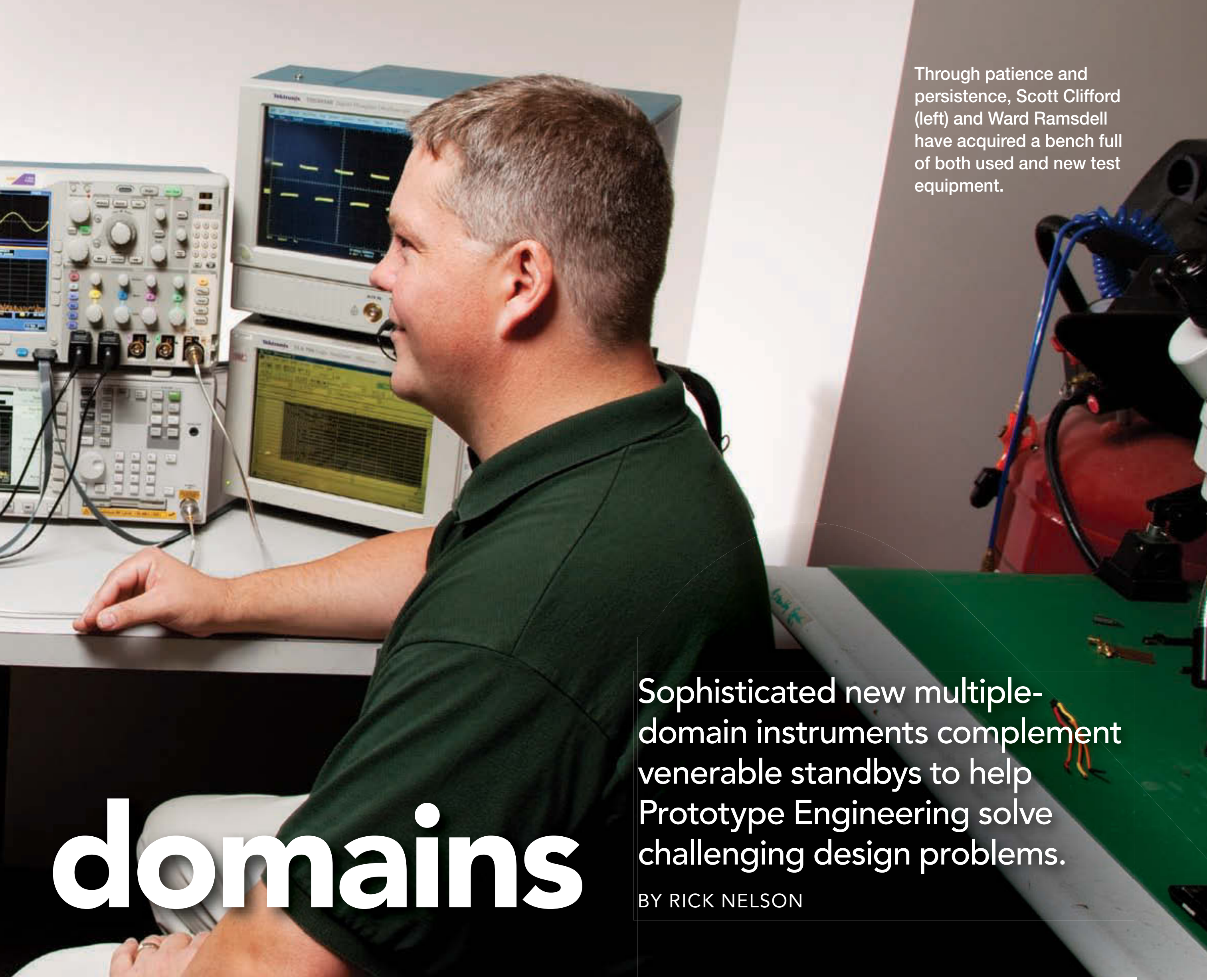
Hillsboro, OR—Take a look inside today's electronic products and you'll see traditional analog and digital circuit blocks, but you will also find high-speed serial I/O buses and, increasingly, RF circuitry. And when you are designing and testing such products, you cannot afford to treat the analog, digital, serial-bus, and RF domains in isolation. To speed up the design and debug process, you need to be able to correlate events in one domain with anomalies in another.

As electrical engineer and co-owner of Prototype Engineering, Ward Ramsdell leverages his expertise in the multiple domains to provide design-consulting services to serve a variety of customers: those with no in-house engineers, those whose in-house engineers are already over-tasked, and those whose in-house engineers lack expertise in a particular domain—often the RF domain. Said Ramsdell, "We provide turnkey product design—we work with customers who for whatever reason can't complete their design themselves."

Ramsdell cited several examples of designs he has completed: a consumer GPS receiver, an Ethernet-to-RF gateway, a USB software license dongle, a wireless speaker, and an I/O expansion board for the Arduino prototyping platform. He noted that his customers are generally savvy about their products: They know their market, they know what they want from a usability standpoint, and they can develop a coherent technical specification. But Ramsdell might be able to address some subtleties that the customer overlooked.

For example, Ramsdell said, the spec for the GPS device called for it to operate on AAA batteries. But consumers will plug in any type of battery that fits, so the product must tolerate the discharge properties of lithium, alkaline, and any other battery chemistries available on the market. Such tolerance for different battery chemistries isn't explicitly called out in the customer spec, Ramsdell said, adding, "We have to read between the lines."

To serve a diverse range of customers and support the design of a variety of products, Ramsdell maintains a lab equipped with everything from simulation software to mechanical-assembly equipment for building prototypes and machining test fixtures. A critical part of the lab is a bench full of test equipment ranging from brand-new, state-of-the-art instruments to used but fully serviceable models picked up at auction over the years.



Through patience and persistence, Scott Clifford (left) and Ward Ramsdell have acquired a bench full of both used and new test equipment.

domains

Sophisticated new multiple-domain instruments complement venerable standbys to help Prototype Engineering solve challenging design problems.

BY RICK NELSON

PHOTOS BY ROBBIE MCCLARAN

And in many cases, Ramsdell said, used equipment is just fine. "I always say, the physics doesn't change, and a good power supply is a good power supply." Indeed, the lab is equipped with models still sporting the old Hewlett-Packard logo. Other venerable instruments he uses include discrete instruments such as signal generators, a VNA (vector network analyzer), multimeters, and power meters, as well as a rack of VXI gear. He said he would consider PXI if he were involved in high-volume manufacturing, but for his lab work, the VXI instruments are sufficient.

One service that Prototype Engineering offers that many consultants don't is extensive automated characterization. "We do a lot of automated testing throughout the product's expected range of temperature and voltage operation." With respect to the GPS unit, he said, he ran thousands of power-on/power-off cycles and found that at low battery voltages and certain satellite orientations, the device would not shut off properly. It would have appeared to have powered-down to the consumer but would have continued to drain significant battery power. He traced the problem to a software bug that was easily fixed but could have been overlooked with a less-rigorous test.

"Automated testing is essential to cover all the corner cases to make sure the design is sound," he said. As for high-volume manufacturing, Ramsdell said, "We would be happy to write automated test plans, but the ODMs [original design manufacturers] and CMs [contract manufacturers] often choose to do that to make use of their own test flows." He noted that Prototype Engineering will provide support at the manufacturing stage, answering questions throughout the test-program-development phase and addressing yield issues during high-volume production.

Acquiring test equipment

A key to putting together Prototype Engineering's line-up of test equipment has been patience and persistence, said co-owner Scott Clifford, who handles sales and marketing for the company but who has acquired on-the-job engineering experience. He said that a consulting engineer or small engineering firm that suddenly needs a VNA could be in real trouble: Acquiring a VNA—even a used one—could be cost prohibitive. With a view toward starting Prototype Engineering, which began operations in 2005, Ramsdell and Clifford spent years seeking out bargains at year-end clearance sales, auctions, and used-equipment venues.

"We had time to sit back and know where we were going and wait for the right pieces of equipment to present themselves so we could acquire them at a reasonable cost," Clifford said, adding, "That allowed us to build a pretty well-rounded equipment base."

Used equipment doesn't always fill the bill, however. Although Prototype Engineering purchased a used VNA, Ramsdell said that state-of-the-art features such as auto-calibration and fast measurement speeds make new models attractive, even though there have been no fundamental improvements in the Smith chart since it came out in 1939. And the oscilloscope, said Ramsdell, is one class of instrument that is evolving rapidly and for which it makes sense to acquire a new model that has mixed-signal or multiple-domain capability.

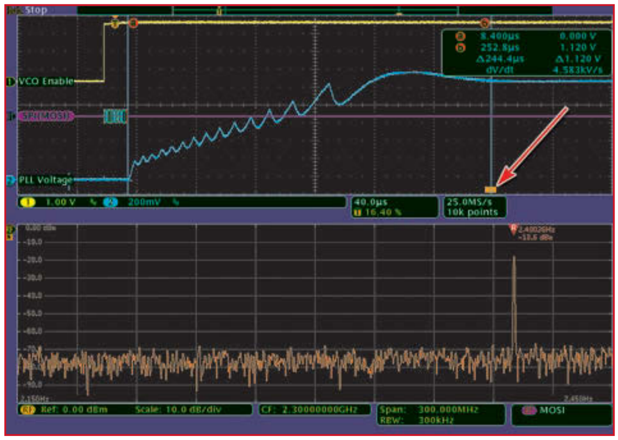


FIGURE 1. By moving the MDO4000's Spectrum Time window throughout the time-domain acquisition, designers can see the RF spectrum for any point in their acquisition while simultaneously viewing time-domain information. Shown here is a VCO output spectrum (bottom) captured after the PLL voltage settles out. Sliding the Spectrum Time window (orange bar in the time-domain display; indicated by arrow) to the left would let a designer see how the frequency changes after assertion of the VCO enable signal. Courtesy of Tektronix.

"Oscilloscopes are a place where people are still doing a lot of innovation," Ramsdell said. "The logic analyzer seems to have gone the way of the dinosaur—a lot of people build the logic-analysis function either inside an FPGA or more-complex digital systems and access it using JTAG. But it is still nice to have 16 logic channels available on your oscilloscope to look at what's happening" with the digital signals. He added, though, that he does occasionally break out a logic analyzer to debug system-level designs incorporating flash and RAM.

Ward Ramsdell: "We want to pride ourselves on our ability to build a company that fits the abilities of our employees."

Of particular value, Ramsdell said, has been the new Tektronix MDO4000 mixed-domain oscilloscope, introduced August 30. As a beta-site customer who has been using the instrument for several months, Ramsdell said the MDO4000 is a valuable complement to his lab bench, minimizing the time from power-on to useful data. He added that the integration of domains eases visualization of system-level issues and allows him to focus on the product, not the test.

Specifically, the MDO4000 can capture time-correlated analog, digital, and RF signals across four analog, 16 digital, and one RF channel. The RF input frequency range extends up to 6 GHz and provides a capture bandwidth of 1 GHz or better at all center frequencies. The instrument can display up to four decoded buses—serial, parallel, or a combination of both—at one time. The time correlation between domains enables engineers to make accurate timing measurements to understand delays and latencies between command and control events in their design and changes in the RF spectrum.

Correlation is key

The key word with respect to the MDO4000 is correlation, Ramsdell said. "You are correlating operation of one part of the system to operation of another part of the system. And that is something that has not been done well before. It is something you have been able to do only with a whole lot of effort on your part." And that effort, he said, must be repeated to address every specific test scenario you face. "The reason the MDO is attractive," he said, "is that it addresses the general case of something that is transmitting a radio signal or otherwise exhibiting electrical activity, which is everything under the sun."

He likens an engineer making tests without an instrument such as the MDO4000 to a doctor trying to make a diagnosis by taking x-rays of an elbow and wrist—the hyperfocus on the wrist and elbow misses the fractured forearm between the two. The MDO4000 makes the hyperfocus approach unnecessary, he said. "Being able to grab a broader swath of information and dig into it quickly and efficiently is really what speeds up the process." The alternative of devising many different test scenarios to each of many possible causes for a single problem is just a time sink, he said. For each scenario that doesn't pinpoint the problem, he added, "You are not really learning anything, you are not gaining insight, you are just spinning your wheels."

To help designers avoid spinning their wheels, the MDO4000 allows designers to see the RF spectrum of a signal at any point in time within a long acquisition to see how the spectrum changes over time or with device state. By moving the instrument's Spectrum Time window throughout the time-domain acquisition, designers can see the RF spectrum for any point in their acquisition while simultaneously seeing their analog, digital, and decoded buses at the same point in time. For example, users can use the instrument to view the spectrum as a VCO/PLL turns on (**Figure 1**) or measure the transition characteristics of a frequency-hopping RF signal. In addition, they can find the source of intermittent, device-state-dependent EMI (electromagnetic interference) noise.

(continued)

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innovation all along the line

Scott Clifford: "We had time to sit back and know where we were going and wait for the right pieces of equipment to present themselves so we could acquire them at a reasonable cost."

EMI issues present challenges for virtually every electronic product, whether it's an intentional radiator or not. Said Ramsdell, "Spurious emissions from your circuit are 90% of the time not even related to the radio—they are related to some transient condition that exists elsewhere in the product. The system may be transitioning into some weird mode, generating a blip in the radio spectrum that causes you to fail" your EMI-certification tests. The MDO4000's ability to relate RF spectrum and time-domain events, he said, can help users quickly pinpoint problems.

Prototype Engineering does not have a large anechoic chamber but works in conjunction with companies that do, such as Northwest EMC, to help customers achieve compliance. For an intentional radiator, he said, the certification process can cost the customer about $10,000 and take one month, including one week in the chamber plus a big paperwork exercise.

Growing the company

Ramsdell and Clifford are looking to leverage their collection of equipment and combined expertise to expand Prototype Engineering, providing consulting engineering services and completing their own designs. Ramsdell brings to the company his electrical engineering education at Rochester Institute of Technology, where he also taught graduate and undergraduate lab courses, plus experience at companies large and small, including at Nortel, TriQuint Semiconductor (where he met Clifford), and Beaverton-based start-up Avnera.

Ramsdell said he always knew he wanted to be an engineer and acquired his first oscilloscope at age 11. He said that when he reached college in the mid-'90s, many students were focusing on digital technology, but he chose to study RF, in part because the discipline was perceived as difficult and in part because, with cellphones proliferating, he thought wireless technology would take off.

Clifford came to Prototype Engineering via a different path, having studied finance and management at the University of Oregon and working for a couple of years at an insurance company. Finding that work not to his liking, he moved to the high-tech field and gained experience in both R&D and manufacturing.

The company's next step might be to hire a firmware specialist to complement the skills that Ramsdell and Clifford already bring to the firm. Ramsdell added that the direction the company takes would be affected by the character of the people brought on board. "We want to pride ourselves on our ability to build a company that fits the abilities of our employees," he said. He added that one former colleague accused him of wanting to start a "lifestyle" company. His response: "We want to build a company where people are comfortable, enjoy what they are doing, and feel valued. If you want to call that a 'lifestyle' company, great." T&MW

Rick Nelson *was editorial director of* T&MW *when he wrote this article.*

Mixing domains

Engineers are increasingly working in both the time and frequency domains as the products they are designing increasingly incorporate wireless functionality. To help them out, Tektronix has introduced what it calls an MDO (mixed-domain oscilloscope), which combines the functionalities of an oscilloscope and a spectrum analyzer in a single instrument. The combination saves bench space, obviously, but the key benefit is that the combined instrument lets engineers capture time-correlated analog, digital, and RF signals.

The MDO4000 mixed-domain oscilloscope combines the functionalities of an oscilloscope and a spectrum analyzer. Courtesy of Tektronix.

Speaking at a prelaunch briefing at the International Microwave Symposium in June, Ward Ramsdell, an electrical engineer and principal at Prototype Engineering, discussed his application of the new instrument to academic, RF semiconductor, mixed-signal semiconductor, and consumer-electronics product-development efforts. Ramsdell provided specific demonstrations of the MDO4000, including exploration of digital RF modulation in an academic setting, mixed-domain analysis of a cellular power amplifier, the analysis and debug of a wireless audio IC, and debug of a 900-MHz low-data-rate radio.

Also speaking at the prelaunch briefing in June, Roy Siegel, GM of oscilloscopes at Tektronix, said that more than 60% of oscilloscope users also use a spectrum analyzer to troubleshoot embedded system designs with integrated wireless functionality, requiring them to work in both the time and frequency domain. Putting the spectrum analyzer within the oscilloscope, he said, supports cross correlation to enable engineers to determine what time-domain events cause frequency-domain anomalies. Siegel said the integrated instrument can help save days or even weeks of debug time.—*Rick Nelson*

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SMUs simplify LVR measurements

Linear-voltage regulators need stimulus voltage and current on their inputs and measurements on their inputs and outputs.

BY JENNIFER CHENEY AND QING D. STARKS, KEITHLEY INSTRUMENTS

LVRs (linear-voltage regulators) are essential elements of power supplies and power-management systems. They provide the constant voltage rails that most electronic circuits need. A properly designed voltage regulator will maintain the specified output voltage continuously, regardless of changes in the input voltage or load current.

The two main types of LVRs, conventional and LDO (low dropout), function on the same principle, but an LDO LVR requires a lower input voltage in excess of the output voltage to operate than does a conventional LVR. That smaller difference reduces the amount of power needed to operate the device. As a result, LDO regulators are better suited for battery-powered electronics and handheld communication devices.

You can characterize some common DC electrical parameters of both conventional and LDO LVRs—including line regulation, load regulation, dropout voltage, and quiescent current—by using SMUs (source-measure units). SMUs are able to produce and measure voltage and current at an LVR's input and output. You'll need two SMUs to make the measurements. One operates as a power source on the LVR's input side, while the second simulates a load at the output.

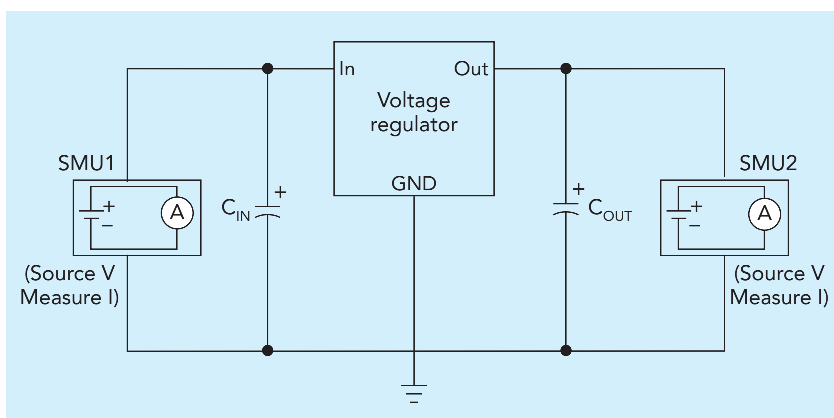

FIGURE 1. Connect an SMU to the input and output of an LVR to produce an input voltage and measure output voltage and current.

In the setup shown in **Figure 1,** SMU1 sources voltage and measures current on the LVR's input side. To measure the current with this setup, set the output voltage of SMU1 to the desired input voltage. Set the current limit to a value higher than the voltage regulator's maximum output current to account for the LVR's rated current consumption.

SMU2 connects to the regulator's output side where, in this configuration, it also sources voltage and measures current. In this instance, SMU2's output voltage is a fixed value that's lower than the regulator's expected output voltage. That forces SMU2 to sink current from the regulator, thereby acting as a load. Set SMU2's current limit to the desired load current. Given that an SMU operates within voltage and current ranges that you control, you must ensure the LVR's expected output voltage regulator falls within SMU2's voltage range so SMU2 can correctly measure the LVR's output voltage.

LVRs may require external capacitors to achieve stable operation. These are usually bypass capacitors to ground, indicated as C_{IN} and C_{OUT} in Figure 1. Large capacitors at these terminals may cause the SMUs to become unstable at small current ranges. To improve stability, try adding a series resistor or back-to-back parallel diodes at the LVR's input or output terminals.

When you set up an LVR measurement, consider adding heat sinks to the device under test. An LVR's parameters are sensitive to temperature, and overheating a packaged regulator will produce unintended damage. Therefore, you must remove heat from the device, taking power dissipation and the ambient temperature at the intended operating conditions into account.

Line regulation

Line-regulation testing characterizes an LVR's ability to maintain the specified output voltage as the input voltage changes under a constant load condition. Typically, the output voltage should vary less than 100 mV. Be sure to monitor the LVR's power dissipation to reduce the effect of temperature change on the device.

In a line-regulation test, SMU1 should sweep the input voltage within the LVR's maximum allowed input voltage. SMU2 should source a fixed voltage that is less than the expected output voltage of the regulator, which forces SMU2 to sink current. Set the maximum current to the desired constant-load condition.

Figure 2 illustrates the results of a typical measurement taken in a line-regulation test, sweeping V_{IN} from 8 V to 20 V with the compliance current set to 5 mA, 500 mA, and 1 A. Depending on the size of the bypass capacitor on the input side, you may need to add a delay to allow sufficient time for charging the capacitor prior to continuing the sweep.

Load regulation

A load-regulation test measures the LVR's ability to maintain the specified output voltage under varying load current while the input voltage remains constant. The LVR's output voltage should vary less than 100 mV. You must remove heat from the regulator for this test.

In the load-regulation test, SMU1 produces a fixed input voltage while SMU2 sources a fixed voltage less than the regulator's expected output voltage, as it does in the line-regulation test. SMU2 will again operate as a current sink. Set SMU2's maximum output current to reflect the desired load current level. **Figure 3** illustrates the results of a typical measurement of V_{OUT} vs. I_{OUT}, where I_{OUT} varies from 0 A to 0.95 A at V_{IN} levels of 8 V, 15 V, and 20 V.

Dropout voltage

For an LVR, the input voltage must always be higher than the output voltage. An LVR's dropout voltage specifies the minimum input voltage in excess of the output voltage that achieves the LVR's specified output voltage. LDO LVRs operate at a smaller input and output voltage differential than conventional LVRs.

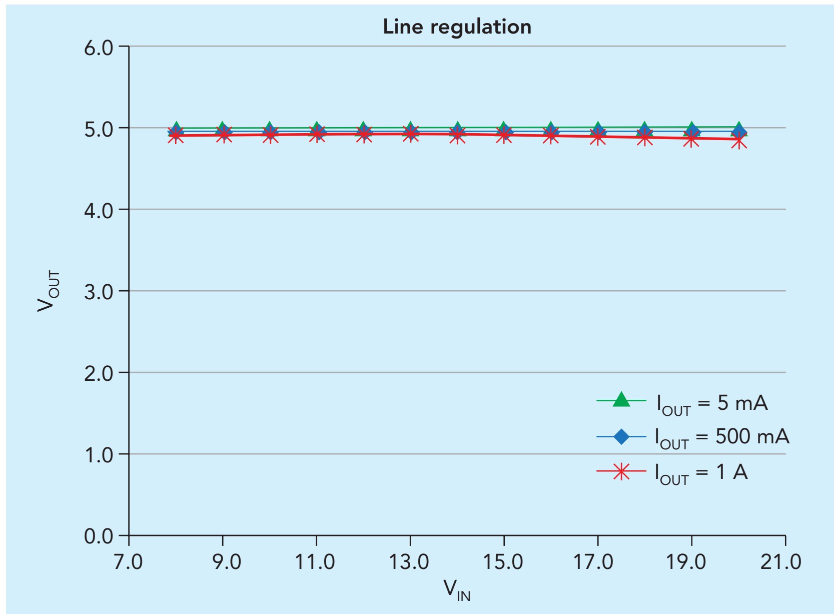

FIGURE 2. A line-regulation measurement shows that a voltage regulator holds its output voltage over a wide range of input voltages.

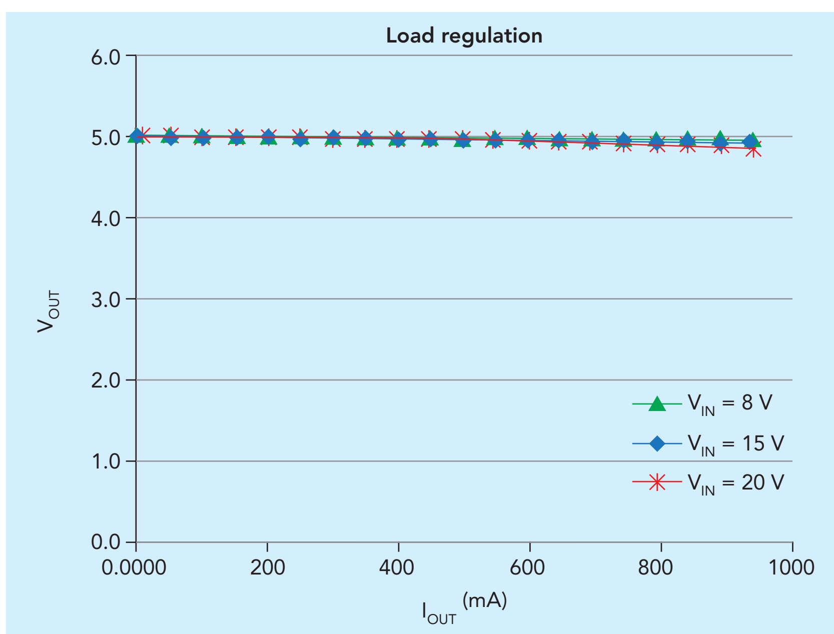

FIGURE 3. A regulator should hold its output voltage nearly constant for load current.

This characteristic is important in battery-powered applications, where current efficiency and low power consumption are critical.

In a dropout-voltage test, SMU1 sweeps the LVR's input voltage, while SMU2 operates as in the line-regulation and load-regulation tests. As before, set SMU2's current limit to the desired constant load condition. Measure the voltage on both the input and output sides during the sweep, which will reveal the LVR's characteristic dropout voltage.

Figure 4 illustrates the typical dropout voltage with I_{OUT} = 1 mA and 1 A. An LDO LVR's output voltage will drop out when V_{IN} is close to 5 V. In contrast, a conventional LVR's output voltage drops out when V_{IN} = 6 V or even higher.

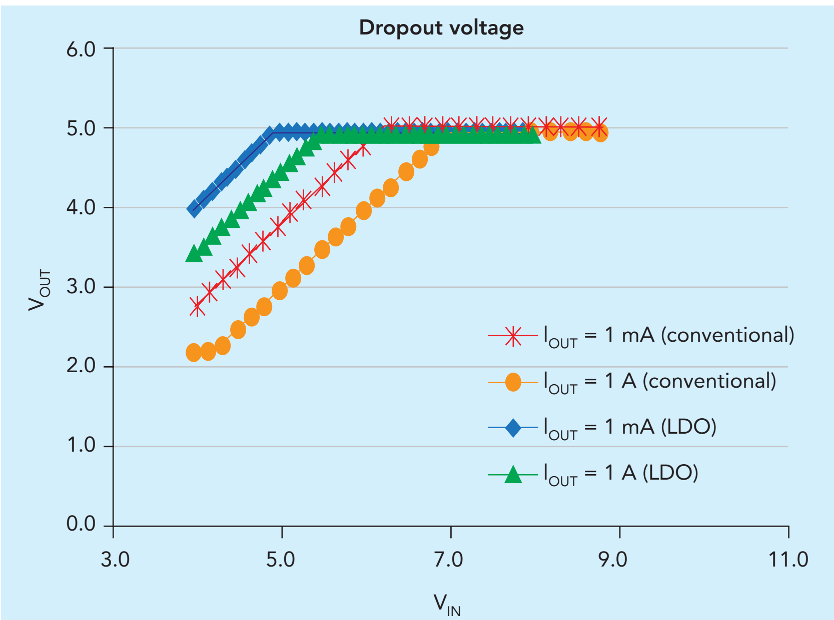

FIGURE 4. Dropout occurs when V_{IN} is too low but recovers when V_{IN} is sufficient.

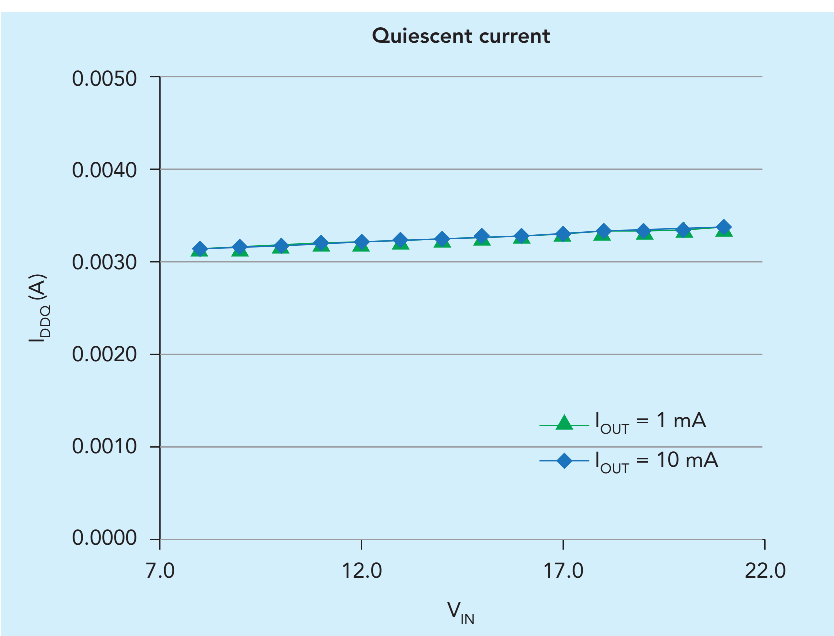

FIGURE 5. An LVR's quiescent current (I_{DDQ}) should hold nearly constant over a wide range of input voltages.

Quiescent current

I_{DDQ} (quiescent current) represents the difference between an LVR's input current and its output current. That difference in current keeps the LVR running, and the current returns to its source through the LVR's ground pin. I_{DDQ} doesn't get delivered to the load. It's normally specified at no-load or very small load conditions. As with dropout voltage, I_{DDQ} is critical in battery-powered applications.

To measure quiescent current, set SMU1 to sweep the LVR's input voltage. Configure SMU2 to source a fixed voltage less than the LVR's fixed voltage, forcing SMU2 to sink current. Set SMU2's current limit to the desired constant-load condition and measure the input current and output current. The differences in current measurements between the LVR's input and output sides at different load conditions will indicate the LVR's quiescent current characteristics. **Figure 5** shows the results of a typical quiescent-current measurement.

SMUs let you source and sink both voltage and current, and they can operate as a precision power supply or as a variable load with accurate measurement capabilities. You can also use their voltage and current measurements to calculate a device's power consumption. You can use SMUs manually, under computer control, or you can write scripts within the unit when you need to automate your measurements. T&MW

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Testing 18-bit ADCs

You will want to construct and verify your own test setup for testing analog-to-digital converters.

BY JIM WILLIAMS AND GUY HOOVER, LINEAR TECHNOLOGY

The ability to faithfully digitize a sine wave is a good measure of the fidelity of a high-resolution ADC. Testing this ability on an 18-bit ADC demands a sine-wave generator with residual distortion products near 1 ppm (part per million). You will also need a computer-based ADC-output monitor to read and display the converter's output spectral components.

To perform this test at a reasonable cost and without letting complexity get out of control, you will want to construct the oscillator yourself and verify that the circuit you've built is generating a pure enough sine wave before you begin testing the ADC. A low-distortion oscillator drives the ADC through an amplifier (**Figure 1**). The ADC's output interface formats the converter output, which communicates with the computer. The computer executes spectral-analysis software and displays the resulting data.

Oscillator circuitry

The system's oscillator is the part of the circuit that is the most difficult to design. The oscillator must have transcendentally low levels of impurity to meaningfully test 18-bit ADCs. You must then verify these impurity characteristics by independent means.

Start with a design based on the work of Winfield Hill, director of the electronics-engineering laboratory at the Rowland Institute at Harvard University. You can then adapt this design for a 2-kHz Wien-bridge design (**Figure 2**). Using all of the amplifiers in inverting mode eliminates CMRR (common-mode-rejection-ratio) errors from the signal path.

Low-distortion amplifiers A_1 and A_2 are the active components of this oscillator. The JFET of the original design would introduce conductivity-modulation errors, so you can replace it with an LED-driven CdS (cadmium-sulfide) photocell isolator. You then combine the output of A_2 with a filtered DC offset at the input to A_3. The capacitor in A_3's feedback network limits the bandwidth of the amplifier. The output of this 2.6-kHz filter drives the input amplifier of the ADC under test.

The A_1/A_2 oscillator needs AGC (automatic gain control), so you AC-couple the circuit's output to a high-impedance, low-noise JFET-input amplifier, A_4, which feeds precision rectifier A_5. A_5 in turn drives integrator A_6. A_6's DC output represents the AC amplitude of the circuit's output sine wave.

Current-summing resistors can be used to balance the DC value against a voltage reference that the Linear Technology LT1029 IC creates. The current-summing resistors feed the AGC single-supply amplifier, A_7. This amplifier drives Q_1, which sets the LED current. The LED current closes a gain-control loop because it ultimately varies the CdS cell's resistance, stabilizing the oscillator's output amplitude.

By deriving the gain-control feedback from the circuit's output, you maintain the output amplitude, despite the attenuating, bandlimiting response of A_3 and the output filter. This topology also

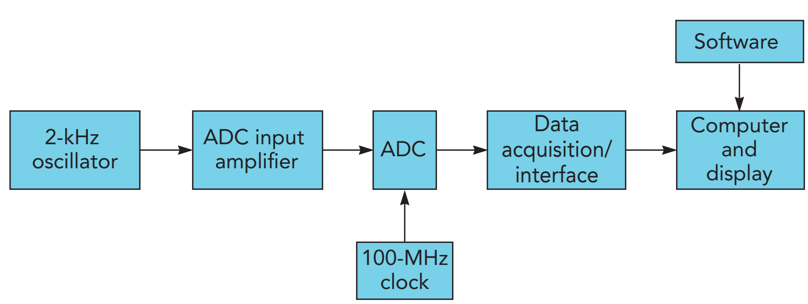


FIGURE 1. In a spectral-purity test system for an ADC and a distortion-free oscillator, the computer displays the Fourier components due to amplifier and ADC infidelity.

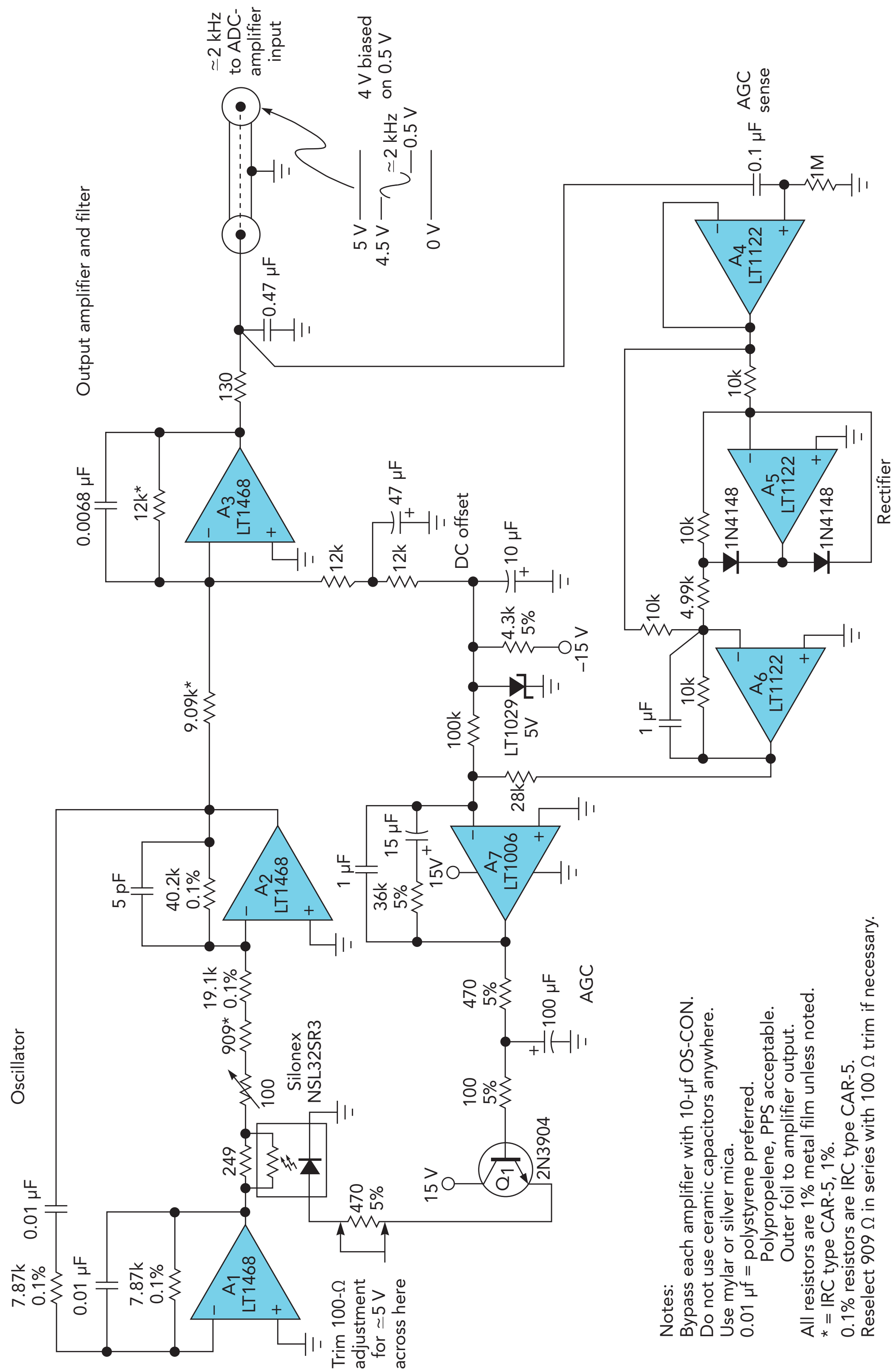


FIGURE 2. A Wien-bridge oscillator uses inverting amplifiers in the signal path and achieves 3-ppm distortion. An LED photocell replaces the usual JFET as gain control.

places demands on the loop-closure dynamics of amplifier A_7.

The bandlimiting response of A_3, the output filter, the lag of A_6, and the ripple-reduction components that attach to Q_1's base combine to generate a significant amount of phase delay. You can accommodate this delay with a 1-µF dominant pole at A_7, along with a zero-value RC (resistor/capacitor), to achieve stable loop compensation. This approach replaces closely tuned high-order output filters with simple RC roll-off responses, minimizing distortion and maintaining constant output amplitude.

It is essential that you eliminate oscillator-related signal components from the LED bias to maintain low distortion. Any such residue modulates the oscillator's amplitude, introducing impure frequency components. The bandlimited AGC signal path is well-filtered.

The heavy RC time constant in Q_1's base provides a final, steep roll-off response. Q_1's emitter current shows approximately 1 nA of oscillator-related ripple from a 10-mA total—less than 0.1 ppm (**Figure 3**). The oscillator needs only one 100-Ω trim to achieve its performance. This adjustment is set in accordance with the notes in Figure 2 and centers the AGC's capture range.

Oscillator distortion

Verifying oscillator distortion necessitates sophisticated measurement tech-

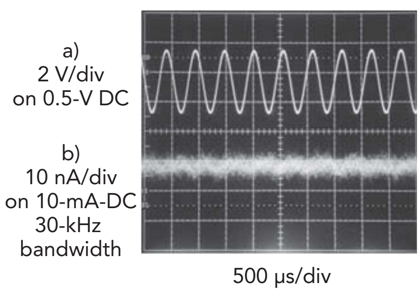


FIGURE 3. Trace a is the oscillator's output. Related residue (Trace b) is just discernible in Q_1's emitter noise. At approximately 1 nA, it represents 0.1 ppm of LED-current variation. Heavy AGC signal-path filtering prevents modulation products from influencing the photocell response.

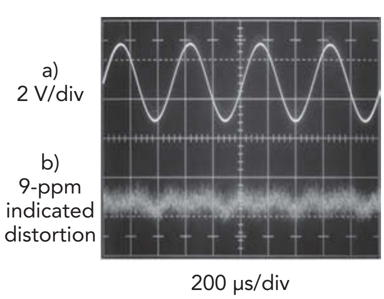
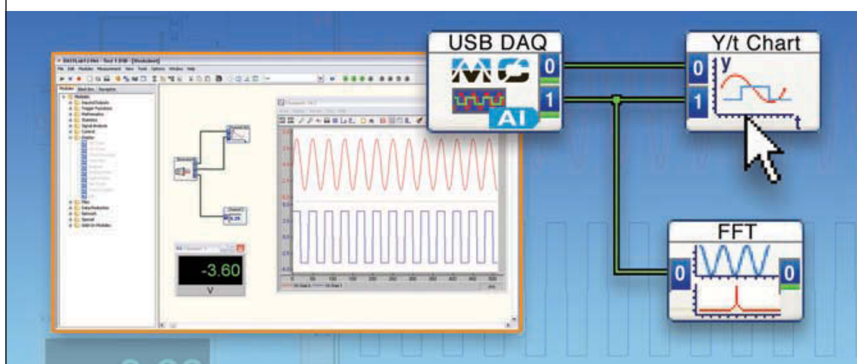


FIGURE 4. An HP339A distortion analyzer operating beyond its resolution limit provides misleading distortion indication (Trace b). The analyzer output contains an unreliable combination of oscillator and instrument signatures. Trace a is the oscillator's output.



niques. You will encounter limitations if you attempt to measure distortion with a conventional distortion analyzer, even a high-grade type. An oscilloscope can be used to indicate distortion residuals at the analyzer's output (**Figure 4**). The amplifier's floor faintly outlines noise and uncertainty on any signal activity that relates to the oscillator.

The Hewlett-Packard HP339A analyzer specifies a minimum measurable distortion of 18 ppm. Figure 4 shows the instrument indicating 9 ppm, which is beyond the unit's specification and, hence, highly suspicious. Measuring distortion at or near the limits of your equipment yields pronounced uncertainties. Distortion measurements at or near equipment limits are full of unpleasant surprises (Ref. 1).

Specialized analyzers with low uncertainty floors are needed to meaningfully measure oscillator distortion. The Audio Precision 2722 analyzer has a maximum 2.5-ppm THD+N (total harmonic distortion plus noise) and a typical THD+N of 1.5 ppm. This instrument measures the oscillator's THD in three tests and finds THD figures of −110, −105, and −112 dB at 3, 5.8, and 2.4 ppm, respectively (**Figure 5**). These measurements provide confidence in applying the oscillator to ADC-fidelity characterization.

ADC testing

When you test ADCs, you route the oscillator's output to the ADC through its input amplifier. The test measures distortion products produced by a combination of the ADC and the ADC's input amplifier. You then examine the ADC's output with a computer, which quantitatively indicates spectral-error components (**Figure 6**).

From the Linear Technology Website (www.linear.com), you can download free PScope data-converter evaluation software to take measurements (www.linear.com/designtools/software), and you can also obtain input-amplifier, ADC, computer-data-acquisition, and clock boards. Appropriate parts include an oscillator; the Linear Technology LT6350 amplifier; the LTC1279 ADC; the DC718 interface card; and any stable, low-phase-noise, 3.3-V clock capable of driving 50 Ω.

The computer display includes time-domain information showing the biased

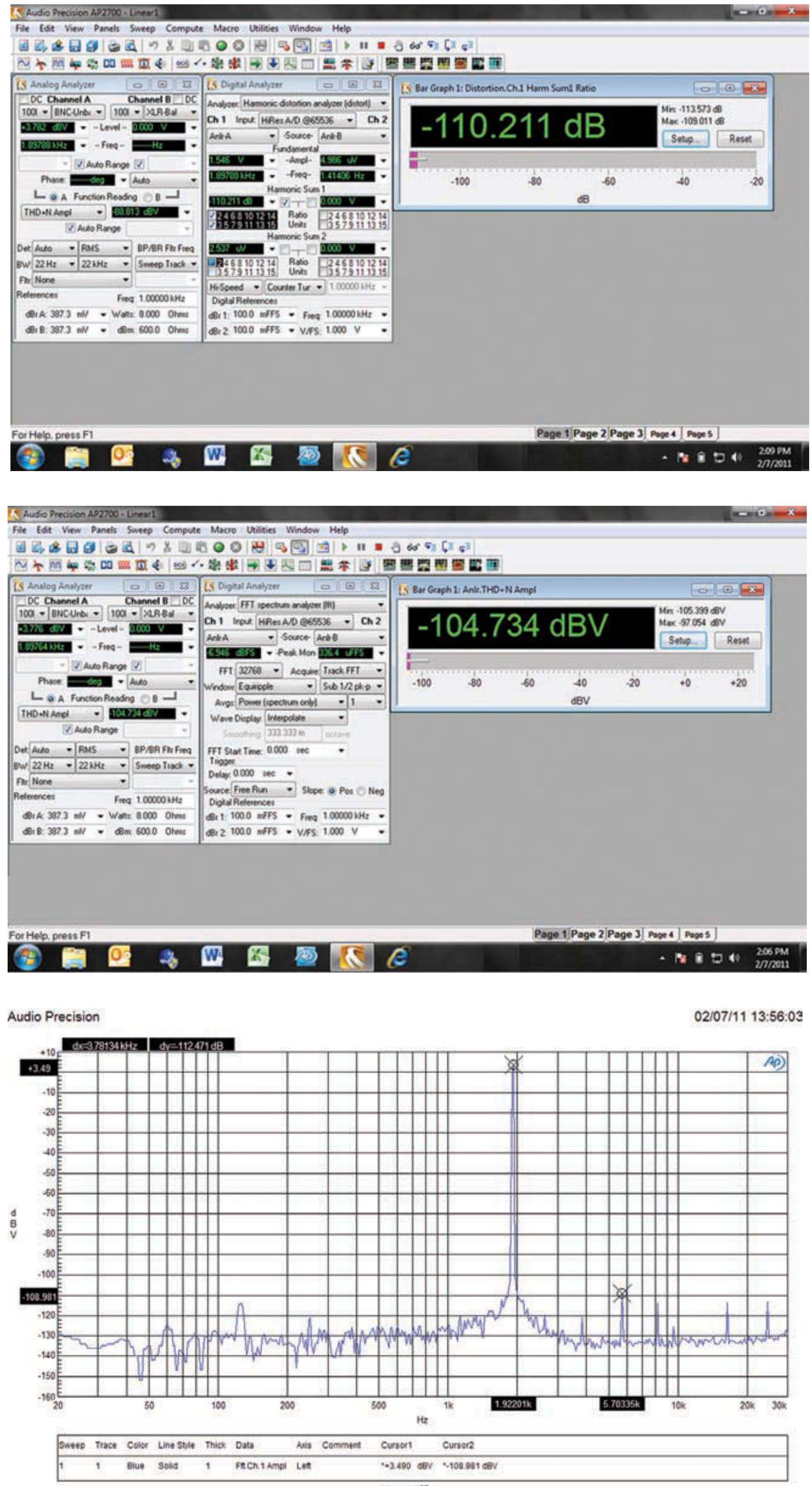


FIGURE 5. The Audio Precision 2722 analyzer measures oscillator THD at –110 dB, or approximately 3 ppm (top). The analyzer measures oscillator THD+N at –105 dB, or approximately 5.8 ppm (middle). Its spectral output indicates a third harmonic peak at –112.5 dB, or 2.4 ppm (bottom).

sine wave centered in the converter's operating range. It also displays detailed tabular readings and a Fourier transform indicating spectral-error components.

The amplifier/ADC combination under test produces second harmonic distortion of −111 dB, which is approximately 2.8 ppm. The higher-frequency harmonics are well below this level, indicating that the ADC and its input amplifier are operating properly and within specifications. Harmonic cancellation may occur between the oscillator and amplifier/ADC combo, mandating that you test several amplifier/ADC samples to enhance your confidence in the measurement. T&MW

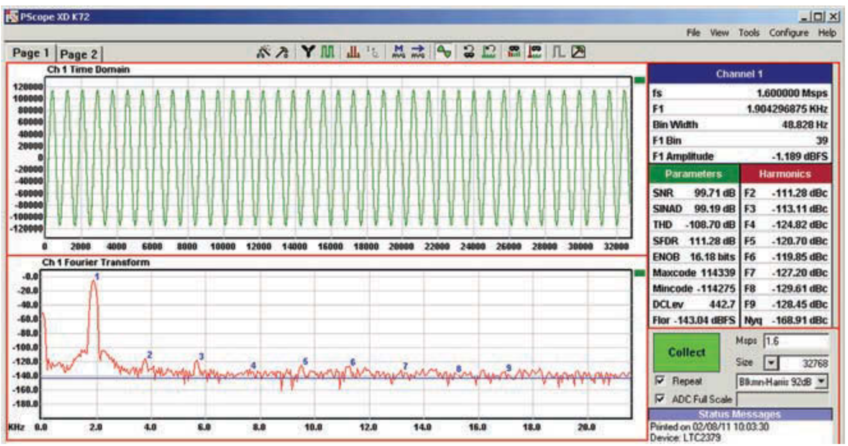


FIGURE 6. A partial display of the test system includes time-domain information, a Fourier spectral plot, and detailed tabular readings for an LT6350-driven ADC.

REFERENCE

1. Williams, Jim, "Bridge Circuits: Marrying Gain and Balance," Application Note 43, Linear Technology, June 1990. bit.ly/pF8qsv.

Jim Williams *was a staff scientist at Linear Technology, where he specialized in analog-circuit and instrumentation design. He served in similar capacities at National Semiconductor, Arthur D. Little, and the Instrumentation Laboratory at the Massachusetts Institute of Technology. He was a former student at Wayne State University and enjoyed sports cars, art, collecting antique scientific instruments, sculpture, and restoring old Tektronix oscilloscopes. A long-time* EDN *contributor, Williams died at age 63 in June 2011 after a stroke.*

Guy Hoover *is an applications engineer at Linear Technology in the mixed-signal-products group supporting SAR (successive-approximation-register) ADCs. He has a bachelor's degree in electronics-engineering technology from DeVry Institute of Technology. Hoover has written several application notes and articles.*

This article originally appeared in the August 11, 2011, issue of *EDN*.

Goepel delivers PXI digital I/O module

Goepel Electronic has introduced the PXI 5396-DT/x JTAG digital I/O modules that support structural JTAG/boundary-scan tests as well as dynamic I/O operations up to 100 MHz for functional test execution. The PXI modules feature an impedance-controlled interface from Virginia Panel Corp. for direct coupling to signal-critical load boards or other verification environments. Consequently, engineers can use the same test hardware for laboratory verification and for fixture-based production line systems. The PXI 5396-DT/x modules are based on a two-component approach, consisting of a PXI-supported interface module (IFM) and an offset desktop module. The modules can be separated up to 2 m without loss of performance. The desktop module is equipped with a front connector that allows it to be connected directly to the test environment.

The PXI 5396-DT has 72 Mbytes of onboard memory, while the PXI 5396-DT/XM offers 144 Mbytes. Both variants provide 96 single-ended channels, configurable as input, output, and high-impedance. While the signals are processed synchronously to the test bus operations in the JTAG mode, the dynamic I/O mode allows functional testing with freely programmable clock rates within the range of 500 Hz to 100 MHz. Therefore, the same instrument can execute structural boundary-scan tests and the succeeding functional tests.

Both models are supported by the integrated System Cascon boundary-scan development environment. The execution of functional dynamic tests and the subsequent failure diagnosis are based on the standard IEEE 1445 Digital Test Interchange Format, which is now integrated in System Cascon.

Goepel Electronic, www.goepel.com.

SuperNova supports TestStand

Alfamation has released SuperNova, a visual, configuration-based development environment for automated test. Built on National Instruments' TestStand test-management software, the SuperNova integrated test application framework helps engineers create and manage test applications—from development to deployment in the electronics manufacturing-test environment.

Alfamation designed SuperNova to save time, resources, and development costs by simplifying management of NI TestStand custom configurations, providing a visual interface that supports easier maintenance without sacrificing quality. A key feature is the Test Project Concept function, which stores all information about a single device under test and the device's product variants. Test engineers can export Test Product Concept information and send it to a production environment to be loaded on test equipment, offering increased efficiency with less risk of lost or missing files.

SuperNova includes a release-management system, and it supports product-variant management, management of communications messages and commands, signal management (for naming, compensation, and calibration), visual and interactive test reporting and label customization, and simplified parallel-test management.

Base price: development license—$9300; runtime version—$1030. SuperNova comes with the necessary TestStand licenses. *Alfamation, www.alfamationglobal.com.*

Keithley enters power-supply market

Keithley Instruments, known among engineers for its precision measurement instruments and source-measure units, has entered the bench power-supply market. The company's new 2200 series consists of five linear power supplies with power outputs from 86 W (72 V, 1.2 A) to 150 W (60 V, 2.5 A). Dual displays on the instruments provide programmed and measured voltage and current. When using remote sensing, the instruments display voltage at the sense point.

You can program the power supplies from their front panel or with SCPI commands through their GPIB or USB interfaces. Like other instruments from Keithley, the 2200 series can store seven 80-step sequences that you can step through using software or an external hardware trigger, thus saving a host computer from programming the instrument for each setting. The power supplies can also store up to 40 settings that you can recall from the front panel or through programming commands. A front-panel lock-out function lets you disable the front panel when you don't want operators changing settings. Programmable limits prevent the instrument from potentially damaging a device under test with excessive current.

Basic DC accuracy is 0.03% for voltage and 0.05% for current. Programmable resolution is 1 mV and 0.1 mA. The supplies have front and rear outputs for use on the bench or in a rack, plus rear-panel status and control lines.

Base price: $925. *Keithley Instruments, www.keithley.com.*

Positional probe measures current in PCB tracks

Aim-TTi has launched the I-prober 520, a positional current probe that allows you to observe and measure current in PCB (printed-circuit board) tracks and other conductors without the need to break or surround the conductor. Used with an oscilloscope, this compact handheld probe provides a bandwidth of DC to 5 MHz and a dynamic range of 10 mA to 20 A pk-pk.

When a user places the insulated tip of the probe onto the conductor, the current flowing in the track can be observed and measured. The I-prober 520 operates by sensing the field in very close proximity to the track. To achieve a calibrated measurement, the field sensor maintains a precise distance from the track.

The I-prober 520 employs a miniaturized version of a fluxgate magnetometer, developed in conjunction with Cambridge University, that enables the probe to measure the field at a precise point. In addition, Aim-TTi says the miniature sensor has much lower noise and much wider bandwidth than a conventional fluxgate magnetometer.

The current probe has a safety rating of CAT II, 300 V (CAT I, 600 V) and is suitable for connection to any 1-MΩ input of an oscilloscope. The I-prober 520 comes with a control box and calibrator, power supply, and a clip-on toroid assembly that converts it into a conventional closed magnetic-loop current probe.

Price: $850. *Aim-TTi, www.tti-test.com.*

PXI modules characterize semiconductors

National Instruments has expanded the capabilities of its PXI platform for semiconductor characterization and production test with new PPMU (per-pin parametric-measure unit) and SMU (source-measure unit) modules. The company claims that the modules reduce the cost of capital equipment, decrease test times, and improve mixed-signal flexibility for a variety of DUTs (devices under test).

With the PXIe-6556 digital I/O module with PPMU, you can generate and acquire a digital waveform at up to 200 MHz or perform DC parametric measurements with 1% accuracy on the same pin, simplifying cabling, reducing test times, and increasing the density of the tester. In addition, NI says the PXIe-6556 nearly eliminates timing skew caused by different cable and trace lengths to the DUT with its built-in timing-calibration feature, which automatically adjusts timing for these differences. The PXIe-6556 also comes with an option to switch in another SMU for higher precision, and you can trigger parametric measurements based on hardware or software triggers.

The PXIe-4140 and PXIe-4141 SMU modules provide four SMU channels per single-slot 3U PXI Express module and up to 68 SMU channels per PXI chassis in 4U of rack height. With sampling rates of up to 600,000 samples/s, the modules reduce measurement time and capture important transient characteristics of the DUT. In addition, the PXIe-4141 features SourceAdapt technology that you can use to custom-tune the SMU output response to any given load to achieve maximum stability and minimum transient times.

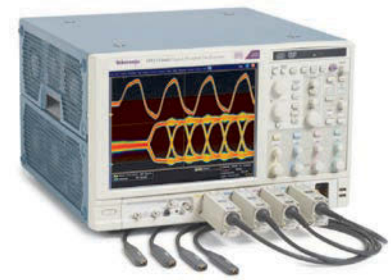
Base prices: PPMU—$11,299; SMU—$8999. *National Instruments, www.ni.com.*

Oscilloscopes run at 33 GHz

Tektronix has made its latest move in the high-end, real-time oscilloscope market with the DPO/DSA70000D—two models with bandwidths of 33 GHz and 25 GHz. Such bandwidths let you view and characterize serial data streams with today's highest data rates. When operating in real-time sampling mode, the 33-GHz model can reach 100 Gsamples/s on two channels or 50 Gsamples/s on four channels.

The DPO/DSA70000D oscilloscopes can also operate as equivalent-time-sampling oscilloscopes. In that mode, the effective sample rate can reach 10 Tsamples/s on all four channels. That lets you view and analyze eye diagrams on streams that can reach 28 Gsamples/s when you use repetitive data patterns.

As data streams use ever-smaller voltage levels, an oscilloscope's input



sensitivity increases in importance. To address those issues, the new instruments have a 62.5-mV full-scale setting, which is 6.25 mV/div. An oscilloscope's rise time can also affect the slope of an incoming signal, but the 9-ps rise time of the DPO/DSA70000D scopes minimizes their effect on viewable rise time and, thus, jitter.

The oscilloscopes also let you capture and analyze data streams through jitter-analysis software. The DPO-JET option lets you define up to eight custom waveform shapes, and then the oscilloscope can trigger on anomalies. Using the software and triggers, you can trigger an acquisition when a signal enters or exits an eye mask. The instruments also let you decode serial encoded 8b/10b signals and search for patterns in decoded data traffic.

Because many engineers use third-party software to analyze signals, the oscilloscopes have what Tektronix calls the DataStore Public Interface. That lets you easily share data with programs such as Matlab or your own applications.

Base price: $211,000. *Tektronix, www.tektronix.com.*

Portable Ethernet tester measures one-way delay

EXFO now brings one-way delay measurement to the Power Blazer modules used in the company's portable Ethernet backhaul test platform, adding to the existing bidirectional test functions of the platform to strengthen its use in IP/Ethernet service validation. Housed in either the FTB-200 or FTB-500 field-testing platforms, EXFO's Power Blazer modules allow users to validate IP/Ethernet performance and service quality with the added flexibility of a portable solution. According to EXFO, the new capability of the modules enables network operators and service providers to perform simultaneous one-way measurements of all key performance indicators included in service-level agreements.

EXFO, www.exfo.com.

FIB/SEM performs 3-D imaging

The Versa 3D DualBeam system from FEI combines a high-resolution SEM (scanning electron microscope) with an integrated FIB (focused ion beam) to provide three-dimensional imaging and analysis on a wide range of sample types. What's more, this configurable platform allows you to adapt the system's capabilities to your requirements.

Versa 3D is available with either high-vacuum-only or both high- and low-vacuum electron-imaging hardware. The high-vacuum-only version can be used for routine imaging of conductive or coated samples. Low-vacuum imaging capabilities enable the system to accommodate contaminating or outgassing samples that are incompatible with high-vacuum operation. Low vacuum also provides the ability to compensate for charge buildup in nonconductive samples, even at the high currents required for analysis techniques, such as energy-dispersive spectroscopy and electron backscatter diffraction. You can also configure the Versa 3D with optional ESEM (environmental scanning electron microscopy) for in situ analysis.

SEM scanning and FIB patterning yield powerful imaging and milling performance, while features such as SmartScan and DCFI (drift-corrected frame integration) facilitate electron beam imaging of sample types with a range of different properties. Backscattered electron techniques, as well as secondary electron and ion detectors, collect a wide variety of topographic, elemental, and compositional information from every angle.

FEI, www.fei.com.

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TEST REPORT

How many cameras does a system need?

By Ann R. Thryft, Contributing Technical Editor

Joost van Kuijk
VP of Marketing & Technology
Adimec

Multiple-camera vision systems can contain anywhere from three cameras for simple applications, such as pick-and-place component inspection, to as many as 20 cameras for applications that require complex algorithms for defect detection, such as wafer inspection and metrology. How many cameras and what mix of high-end and lower-end models you need depends on how you will use them, said Joost van Kuijk, VP of marketing and technology for Adimec.

Q: What are the reasons for having multiple cameras?

A: The number and type of cameras you need depend on your main objective. Your goal could be speeding up a production line, so you would need to take images of many moving objects from similar angles with parallel cameras and similar fields of view. Another type of speed increase would be increasing the number of images taken of each object, to increase the amount of data available to complex algorithms that detect defects. Or you might need images of a stationary object from different angles or using different fields of view.

If you want to speed up the line, you can simply use more cameras in parallel. It's sometimes easier to have two parallel stations than a single one with twice the speed, because inspection tool mechanics can be a limiting factor at the rate of 50,000 or 100,000 components per hour in electronics manufacturing.

In other cases, you need to break up the field of view—whether you are inspecting boards or components on a moving production line or are inspecting stationary objects—into several different fields of view with different cameras. For example, you might be looking at different sections of a board with different feature sizes. Another reason might be because you need multiple wavelengths, such as infrared and visible light in solar-cell manufacturing. We've heard of some customers requiring up to 10 different wavelengths.

Q: What are some different types of cameras and configurations?

A: Sometimes it's less expensive to have two simple, low-end cameras taking different images of an object, and other times it's best to use a single, higher-performance, more-complex camera. In a multiple-camera system, you don't want to simply multiply cameras, frame grabbers and cables, as well as CPU processing algorithms. One system we helped a customer configure acquires images quickly, then moves them to a processor for analysis. It makes sense to use a camera with a high image-acquisition rate that can store the images, and then use a lower-speed link to the frame grabber while the station is moving into the next position. Some camera suppliers have added burst modes so their cameras can more easily fit into legacy systems.

For example, our 4-Mpixel Q-4A150 camera has a sustained 157-fps image-acquisition rate, when paired with an eight-tap Camera Link frame grabber, and a 180-fps burst-acquisition mode. It also has a slower, 10- to 30-fps output for sending images to the PC for processing. Decoupling the sensor speed from the interface speed lets you tune the image and system speed you need without shifting to a complete 10-tap configuration, which would require more expensive frame grabbers.

Q: What are other ways to lower system cost?

A: Storing images and performing some image-handling tasks in the high-end camera, if it has enough buffer memory, can speed up the system's performance. This would be more economical than adding multiple systems to the line. □

INSIDE THIS REPORT

EDITOR'S NOTE

A new vision alliance

By Ann R. Thryft
Contributing Technical Editor

More than a year after the world's three machine-vision consortia signed their "G3" agreement, a new cross-industry vision alliance has formed. The EVA (Embedded Vision Alliance) hopes to bring together manufacturers and developers of vision hardware and software for many vertical markets, including machine-vision and industrial inspection (p. 45).

As vision technology moves into consumer territory at a rapid clip, the sheer volumes that consumer applications command will begin to affect the processors, sensors, development tools, and algorithms that are also available for industrial applications. The entrance of CMOS vision sensors into what used to be the CCD-ruled domain of electronics inspection is a telling example.

The EVA may also help create cross-industry standards that will ease product development, such as chip-level interfaces, vision data formats, and cross-language, cross-platform application programming interfaces. Standards work could include performance metrics. For example, if a sensor has a certain performance level, what exactly does that mean for a specific application type, and how would that performance differ for a machine-vision camera on a pick-and-place line, versus for a cellphone camera? EVA membership currently includes Analog Devices, Freescale Semiconductor, Intel, National Instruments, Nvidia, Texas Instruments, and Xilinx. □

Contact Ann R. Thryft at athryft@earthlink.net.

HIGHLIGHTS

JAI's 2-Mpixel HD cameras run at 64 fps

Offered in both color and monochrome versions, two new Camera Link cameras from JAI deliver full high-definition resolution of 1920x 1080 pixels at a frame rate of 64 fps. The AB-201CL (color) and AM-201CL (monochrome) progressive-scan cameras employ quad-tap CCD sensors from Kodak for rapid image acquisition.

JAI says that an automatic channel-balancing algorithm continuously adjusts gain and offset of the individual channels to provide results that surpass the typical one-time balancing methods of other multitap cameras. The four taps are combined into two for monochrome or raw Bayer readout at 64 fps.

To simplify integration, the two taps are multiplexed using an 80-MHz data clock to provide 8-bit, 10-bit, or 12-bit output over a single-cable Camera Link base configuration. The AB-201CL color model can also perform in-camera color interpolation, producing 24-bit RGB output at 32 fps.

The cameras offer user-configurable AOI scanning (partial scanning) and a variety of acquisition modes, including continuous, single-frame, and multiframe capture. Image preprocessing functions range from auto-gain, auto-shutter, and auto-white balancing to pixel-blemish compensation, flat-field compensation, and a 256-point look-up table for gamma customization. www.jai.com.

Toshiba shrinks three-sensor camera

Toshiba claims that its IK-HD1 is one of the smallest three-sensor high-definition camera heads available for 3-D applications. The tiny camera, which measures only 1.6 in. and weighs 2.3 oz, provides a resolution of 1920x1080 pixels at a frame rate of 30 fps.

Using Toshiba's three-CCD prism-block technology, the IK-HD1 delivers realistic colors, sharp detail, and a wide dynamic range, and it avoids the rolling-shutter artifacts that are produced by many CMOS-based cameras. A comprehensive menu allows you to customize scene painting and adjust the output for virtually any environment. A C-type lens mount, RS-232 interface, and multiple outputs for HD-SDI (SMPTE 292M), analog (RGB), and Y/Pb/Pr are standard.

Accessories for the remote-head system include interface cables in lengths of 3, 6, 10, and 30 m and an optional 50/60-Hz switchable control unit that provides either 1080i/25 or 1080i/30 output. www.cameras.toshiba.com.

Camera series spans VGA to 12 Mpixels

The new Genie TS series of CMOS-based cameras from Teledyne Dalsa offers a wide choice of resolutions with speeds reaching 300 fps and a global shutter for crisp, smear-free images of high-speed action. Available in both monochrome and color versions, the cameras provide resolutions of VGA (640x480 pixels), 1.2 Mpixels, 1.4 Mpixels, 2 Mpixels, 4 Mpixels, 5 Mpixels, 8 Mpixels, and 12 Mpixels.

Equipped with a GigE Vision-compliant, direct-to-PC interface, the Genie TS can be used in semiconductor and electronics manufacturing processes. It provides image filtering, image compression, color correction, color space conversion, and image transfer on demand. A motorized lens control with image-to-image aperture, zoom, and focus functionality is built in, as are RS-232 and RS-485 ports to control peripherals around the camera.

The Genie TS series cameras are supported by the company's Sapera Essential vision software and Genie Framework package for camera setup. www.teledynedalsa.com.

Embedded Vision Alliance debuts

By Ann R. Thryft, Contributing Technical Editor

A new consortium is working to speed the adoption of computer vision technology in embedded systems. Founded in May 2011 by BDTI (Berkeley Design Technology Inc.), an independent technology-analysis and engineering-services firm, the Embedded Vision Alliance now has 17 member companies, said Jeff Bier, BDTI president.

"Until recently, embedded computer vision remained in low-volume applications like industrial machine vision, because it's been expensive compared to technologies used in more price-sensitive, higher-volume applications," said Bier. "In the mid-2000s, image sensors crossed the price/performance threshold as increasingly higher-performance sensors were made in CMOS versus CCDs. Prices subsequently came down, driving adoption in high-volume applications. Similarly, embedded processors with sufficient performance for vision applications have begun to reach price and power consumption levels suitable for consumer markets."

BDTI evaluates processors, development tools, and algorithms, working primarily with DSP enabling technologies, Bier explained. "We believe that embedded vision will be the next application driver of DSP growth, as digital wireless was in the mid-1990s."

The growth of embedded vision in consumer products is evidenced by tablet PCs, camera phones, and vision-based automotive driver-safety systems, said Bier. An exponential increase in investment dollars is going into R&D for embedded vision, primarily targeting high-volume applications. The results of that investment—including sensors, processors, development tools, and software algorithms—will also be available for industrial applications.

"This will create new markets and high-growth opportunities for suppliers of electronic vision equipment and components," Bier said. "Industrial machine-vision suppliers that are currently vertically integrated may want to consider broader-sourced business models and explore opportunities in other vision markets."

One opportunity for machine-vision suppliers is the huge investment in software infrastructure. Optimizations made to the OpenCV computer vision library by microprocessor vendors targeting consumer markets are also applicable to industrial applications using those same processors and algorithms.

Hundreds of companies in vertical markets such as the industrial machine-vision, automotive, medical, and consumer markets are involved in different aspects of computer vision, said Bier. "We want to help companies developing embedded-vision components, products, and applications to share ideas and best practices, and catalyze industry-wide cross-fertilization among these vertical markets," he said. "We also want to help design engineers incorporate vision capabilities in new systems."

The Embedded Vision Alliance may also help develop standards, said Bier. "For example, there are many kinds of image sensors, with different chip-level interfaces to the processor. Standardizing those interfaces would be helpful to developers, as would the standardization of vision data formats. And it would be nice if there was a standard, cross-language, cross-platform application-programming interface that worked on the development PC so developers could port vision application software to other target processors, such as GPUs [graphics processing units] and DSPs." □

Lighting for vision gets easier

By Ann R. Thryft, Contributing Technical Editor

The TechSpec telecentric illuminator increases edge contrast and measurement accuracy in the object under inspection by decreasing diffuse reflections from the object. It does so by directing light from a fiber-optic light guide or LED onto the object to produce a high-contrast silhouette. Courtesy of Edmund Optics.

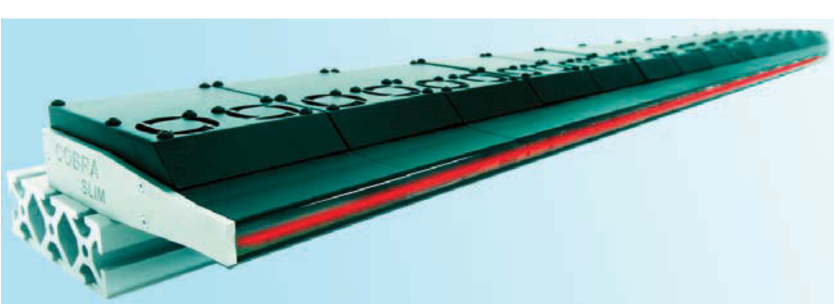
Lighting options for vision and inspection systems are getting more complex because of the introduction of LEDs (light-emitting diodes), but LEDs are also making it easier to configure the lighting an application requires. Although they are not as bright as halogen or as uniform as fiber optics, LEDs consume less electricity, generate less heat, and last longer than those options, and they are also more flexible and easier to control.

Lighting can be divided into three groups based on imaging type, said Simon Stanley, managing director of ProPhotonix. One-dimensional imaging uses linescan cameras. Two-dimensional imaging uses backlights, front lights, and low-angle lights. "It's about positioning lights at different angles around the camera to illuminate the target in different ways," he said. "With three-dimensional imaging, you're looking for height information about the product, and lasers are typically used here."

There's definitely a transition to the use of LEDs in vision, said Stanley. Compared to the larger lighting market, machine-vision lighting has two major requirements: bright enough light to get a bright enough image, and uniform light to get a uniform image. "Its [machine-vision's] requirements tend to be more monochromatic. It's also more performance oriented rather than cost oriented." Machine-vision systems need to take images of moving objects at high speeds and in finer detail, so they generally require more and better-quality light, and users are willing to pay for that performance. Since LEDs are semiconductors, they can also be easily controlled with electronic circuits to produce different levels or colors of light.

LEDs lend themselves especially well to applications that need no downtime as well as to those that are completely enclosed, since LEDs have no heat buildup, said Nicholas James, Edmund Optics' product line manager. "In the past, everyone used traditional fiber-optic illuminators with halogen-bulb sources. Now, there are fiber-optic illuminators with LED-based sources that still use traditional fiber-optic light guides."

One of the biggest benefits to LED light sources is their very long lifetime of 10,000 to 50,000 hours, said James, versus only 1000 to 5000 hours for halogen-bulb-style illuminators. And if a halogen bulb gets too hot, it can melt the fiber-optic guide or the color filter that is placed in front of the light to provide the necessary color illumination. In small, cramped spaces, halogen can overheat other electronic components. With LEDs, you don't need color filters, since you can specify the exact wavelength you want. You can also get nonstandard configurations, such as color-tunable lighting, since LEDs are more customizable than halogen or fiber optics. There's also purely LED lighting, where LEDs are



The Cobra Slim LED Linescan Illuminator features a higher LED chip density for high brightness, an adjustable focal length and working distance, greater uniformity, and improved alignment in a form factor similar to that of fiber-optics illuminators. Courtesy of ProPhotonix.

both the source and the illuminator in a single-piece LED system.

Over the last couple of years, LEDs have come very close in brightness to, and sometimes surpassed, the brightness of halogen sources, said James. This is true mostly of lower-cost,

LED light sources such as the LLS A20960, with remote Ethernet or RS-232 control capabilities, are replacing halogen-lamp light sources, because of their reduced power consumption and longer lifetimes.
Courtesy of Moritex U.S.A.

lower-brightness halogen sources, and the brighter LED sources still cost two to five times more than a halogen bulb of equal lumen output.

In most cases, the initial cost is a little higher for LEDs than for fiber, but the operating cost is much lower, said Jason Baechler, manager of sales and marketing, machine-vision division, for Moritex U.S.A. "The overall cost of LED systems is coming down, making them very attractive, especially for lower-end applications," he said.

Some applications benefit more from fiber-optic lighting and others more from LEDs, said Baechler. "The choice depends on the level of uniformity required, the specific wavelengths that can make the features that you want emphasized to stand out, and how much power consumption and heat generation your application allows." Typically, fiber optics still provide better uniformity, since LEDs are discrete light sources, and brightness can vary from one chip to the next. "For large fields of view or high-speed inspection, such as large glass panels and other linescan applications, you often need very bright, uniform light," he said. "For semiconductor applications and even for PCBs [printed-circuit boards] and flat-panel displays, ring lights are still the most common geometry, next to on-axis lights."

LEDs have been extremely successful in replacing fiber in lower-end applications, such as alignment or positioning, said Baechler. Their bandwidth is smaller compared to halogen, so they can be matched to specific bands. "In positioning, you are typically looking at an alignment mark or the edge of an object with a known size, or with a known type of finish or material. So, you can choose an LED with a specific wavelength and a specific size and geometry for your particular application. For on-axis alignment applications, they've replaced fiber almost entirely."

LEDs offer more flexibility in packaging, although individual fibers take up somewhat less space, said Baechler. And because they are small and one chip gives you an area of light, not merely a point like a fiber, you can more easily create different geometries with LEDs. "As these chips become smaller, LEDs will challenge fiber-optic lighting in lightlines and other configurations." □

FOR MORE INFORMATION

Gorelik, D., "Light Emitting Diode Illuminators for Video Microscopy and Machine Vision Applications," Navitar. machinevision.navitar.com/pdfs/led_white_paper.pdf.

JIIA debuts lighting guidelines

Neither formal nor de facto industry standards currently exist for either LED or halogen illumination technologies used in machine-vision lighting, said Nicholas James, Edmund Optics' product line manager. "This is primarily because there are so many different manufacturers in different world regions, and the way that lighting is manufactured is pretty fragmented," he said. "For example, LED manufacturers all make different styles of illumination systems: Some are for industrial use while others are more compact. And they have different mounting-hole patterns, even though they are mounted to the same range of objects."

Another reason is because of the way lighting is used on the factory floor. "Usually, you are building a superstructure that you mount lights onto," said James. "Since these superstructures are semi-custom, standardization isn't as beneficial." Also, lighting isn't typically attached to other components in the vision system, so standardization is not as critical in lighting as it is for other machine-vision components or for the interfaces between them, such as the mount between the lens and the camera.

Lately, however, there's been a push to standardize how users evaluate lighting, led primarily by the JIIA (Japan Industrial Imaging Association), said Jason Baechler, manager of sales and marketing for Moritex U.S.A.'s machine-vision division. "Last December, [JIIA] introduced suggested guidelines for specifying lighting in image processing," he said. "The guidelines are not aimed at what products or technology you use, but at the evaluation process, and how you go about deciding what to use." The suggested guidelines cover the evaluation of specifications governing brightness, and methods for optimizing desired variations in machine-vision lighting by the use of different lighting system designs.—*Ann R. Thryft*

FOR MORE INFORMATION

"JIIA introduces lighting standard," *Imaging & Machine Vision Europe*, January 25, 2011. www.imveurope.com/news/news_story.php?news_id=643.

"Lighting for Machine Vision/Image Processing System—Fundamentals of Design and Specifications of Brightness of Optical Irradiation," Japan Industrial Imaging Association, December 28, 2010. www.jiia.org/jp/pdf/LI-001-2010-01.pdf.

Failure analysis of 3-D packages speeds up

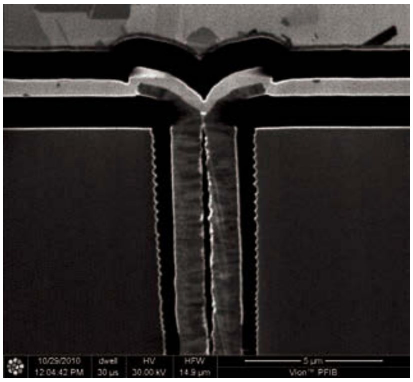
By Ann R. Thryft, Contributing Technical Editor

In 3-D packaging integration, stacking wafers and dies of mixed, heterogeneous technologies is fraught with difficulties. Wire-bond and TSV (through-silicon via) connections between wafers must be highly reliable, yet ultra-thin ICs and MEMS (microelectromechanical systems)-based sensors are fragile and can be easily damaged. In addition, researchers working on 3-D packaging integration techniques need to get failure data quickly, but analyzing failures on complex structures such as combined MEMS/ICs has been time-consuming using standard technologies, said Peter Ramm, head of the Device and 3D Integration department of the Fraunhofer EMFT (Research Institution for Modular Solid State Technologies) in Munich.

"Traditionally, for analyzing 3-D stacked ICs, we have used a conventional FIB [focused ion beam] system with a low milling rate for sample preparation, and then a SEM [scanning electron microscope] for structural and failure analysis," said Ramm. "The cross section produced by the FIB enables you to see the TSV structures with very good resolution. For examining feature sizes of 20 microns or so, this makes sense."

But the analysis of deeper TSVs with all the interconnections and redistribution layers of the 3-D stack in a single shot is a big challenge, said Ramm. Especially for complex 3-D MEMS/IC structures, Ramm's department typically works with feature sizes of 100 microns or larger. "The conventional FIB, based on a gallium liquid metal ion source, would take tens of hours, or even days, to mill all the way through the many layers of a MEMS structure," he said. "For 3-D MEMS/IC structures, therefore, there has been no good existing solution that gives feedback quickly enough."

Ramm and his colleagues began talking to FEI in 2009 about how to solve this problem. FEI was developing a new FIB source technology based on ICP (inductively coupled plasma) to produce a high-current xenon ion beam. The EMFT's Device and 3D Integration department became a beta site for the prototype tool, FEI's Vion PFIB (plasma FIB) system, which was developed during EMFT's participation in the European JEMSIP-3D (Joint Equipment and Materials for System-in-Package and 3D Integration) project in 2010.



This close-up of a cross section made by the FEI Vion PFIB system shows the vertical TSV bonding with horizontal SLID (solid-liquid interdiffusion) at the top of the TSV.

Courtesy of Fraunhofer EMFT.

"We have been using it for about six months in several projects, and it is now working in a stable way," Ramm said. "The improvement in milling time is a quantum jump. We can perform analyses in minutes instead of several hours on a conventional FIB."

The second phase of using the Vion PFIB will provide the technology to the institute's industry partners and other companies, said Ramm. One EMFT project that he said will help facilitate further improvements in the tool is e-BRAINS (European Best Reliable Ambient Intelligent Nanosensor Systems), which was launched in September 2010 and will last through August 2013. This project, coordinated by Infineon Technologies and with technical management provided by EMFT, aims to integrate heterogeneous technologies, such as nanosensors, ICs, power semiconductors, and wireless communication modules, in 3-D structures to shrink package volume, weight, and cost. The project's goal is to come up with ways of enhancing energy efficiency, cost-effectiveness, product lifetime, and reliability in applications such as smart biosensors and environment-monitoring systems. The EMFT's industry partners in this project include Infineon, Sensonor Technologies, and Siemens.

"Integrating heterogeneous technologies is the most challenging application in 3-D stacking because of the wide range of dimensions on a single sample," said Ramm. "You can have a dielectric layer that measures 10 or 20 nm and an 80-micron TSV in the same sample. Typically, you are integrating a fragile sensor chip with ICs, and sensors can't usually be thinned as extremely as ICs. It's not reasonable to stack wafers, since their die sizes vary, so we have to stack chips on the device wafer instead. A major task is ensuring reliability of the finished product with failure analysis, and the plasma FIB tool greatly helps to facilitate this task."

Ramm said that, given the unexplored potential of this novel technology, EMFT and FEI intend to extend their cooperation beyond the JEMSIP-3D project. "Further tool upgrades, the development of an integrated plasma-FIB/SEM analytical platform, and even of a full wafer platform for TSV manufacturing monitoring are currently seen as potential scenarios for better serving the characterization and failure-analysis needs in this rapidly growing 3D-IC integration field," he explained. □

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VIEWPOINT

[An exclusive interview with a technical leader]

DAVID OKA
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Test Evolution
Hopkinton, MA

David Oka has spent 30 years in the ATE (automated test equipment) field, working on high-speed digital instruments and low-cost mixed-signal test systems. He has co-founded two companies, LOA Technology in 2003 and Test Evolution in 2007. At Test Evolution, he serves as VP of engineering and is responsible for developing test equipment based on open standards. Previously, at LOA, Oka led development of advanced-timing-formatter ASICs for ATE. Prior to LOA, he worked at StepTech, developing OEM instrumentation for major semiconductor ATE companies. Oka holds BSEE and MSEE degrees from MIT.

Contributing editor Larry Maloney interviewed David Oka at the Test Evolution office on trends in ATE technology and about the emerging AXIe modular instrumentation standard.

Open-standard systems enhance ATE

Q: What is Test Evolution's niche in the ATE field?

A: "Big-iron" semiconductor ATE companies traditionally have focused on large global semiconductor manufacturers. Test Evolution targets a much broader audience. Our focus and core competency is standards-based test instrumentation, subsystems, and systems, often partnering with firms like Aeroflex, Agilent Technologies, National Instruments, and ADLink Technology.

We believe that the PXI and AXIe standards offer the infrastructure to support the kind of test functionality and performance that traditionally were available only from big-iron ATE. Test Evolution can design a whole variety of cards for ATE—RF, power supply, digital—and integrate them into a system calibrated by high-level software. For example, if you need a four-port RF subsystem for characterization on the bench, we can provide the building blocks. Or we can enhance your existing systems or transition a characterization system into a production ATE system.

Q: What are the primary advantages of open test systems?

A: From the customer's perspective, you've got a much broader ecosystem of suppliers for PXI and AXIe equipment, rather than being limited to a few vendors with proprietary systems. And because of this more-competitive landscape, you have a better chance of meeting your price-for-performance targets.

Ultimately, this adds up to lower initial capital costs, because these standards-based instruments with their simple form factors are inherently inexpensive. Moreover, their modularity allows you to modify and optimize configurations as your market needs change, and that is important in fickle markets like consumer electronics. So, compared to proprietary ATE systems, you get longer-term protection for your investment by going with systems based on PXI and AXIe standards. Just like the old VXI standard, which customers are still using, PXI and AXIe could have 30- to 50-year life spans.

Q: Which customer sectors account for the bulk of your business?

A: The biggest segment is system integrators, including independent integrators as well as those who do integration internally for semiconductor integrated-device manufacturers and test houses. We also do custom work for some semiconductor test companies. In working with systems integrators, which many manufacturers rely on to design ATE systems, we can provide individual components or, say, an entire RF subsystem, with signal generators, digitizers, splitters, power supplies, and port modules. And there are instances where we serve as the integrator and combine PXI and AXIe test chassis for customers.

Q: What are AXIe's major technical improvements over PXI?

A: The primary advantages are increased power-supply capacity, better cooling, larger real estate, and enhanced star triggering. For example, AXIe offers 200 W per slot, versus only 30 W per slot for PXI, and 900 cm^2 of board space per slot compared to 160 cm^2 for PXI.

Q: What are AXIe's growth prospects?

A: The standard was introduced at the end of 2009, so it is only two years old. Yet the growth prospects look very promising. Agilent has announced several instruments in this form factor, such as waveform generators and logic analyzers, and has an ambitious roadmap for this technology. Test Evolution has already released three AXIe cards, with more in the pipeline. Participation in the standards group is strong, and we expect it to grow as the market embraces the initial products. We don't see any major obstacles. T&MW

David Oka answers more questions on open standards and new modular instruments in the online version of this interview: www.tmworld.com/2011_10.

To read past "Viewpoint" columns, go to www.tmworld.com/viewpoint