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Phil Yates, manager of the Measurement Technology Center's Measurement System Group at the Jet Propulsion Laboratory.

MEASURING SPACE

Engineers at JPL develop systems to test space-bound equipment.

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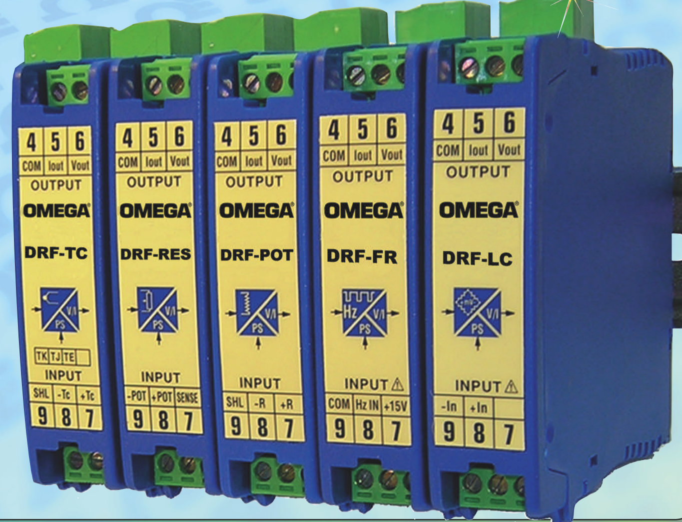

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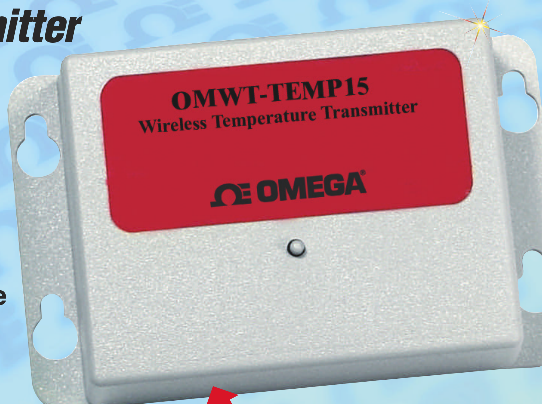

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COVER BY: STEVE LABADESSA

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TEST REPORT SUPPLEMENTS

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- **PXI Test Report**

Others wishing to read this supplement can access it in the online version of this issue at www.tmworld.com.

www.tmworld.com

▶ **BIST and boundary-scan proponents respond to August columns**

Read Asset Intertech's reply to Steve Scheiber's column, "Moving beyond boundary scan and inspection," and LogicVision's comments on our Viewpoint Q&A with Robert Hum of Mentor Graphics. www.tmworld.com/letters.

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Reed Electronics Group

Fundamentals and inspiration

In previous editor's notes and my online blog, I've commented on various detriments to students pursuing engineering careers in the US. Ray Almgren, VP of product marketing and academic relations at National Instruments, as part of a keynote event at NIWeek on August 16, cited a litany of figures demonstrating this decline—for example, a 37% reduction in interest in engineering by college-bound US high-school students over the last 12 years.

RICK NELSON, CHIEF EDITOR

In an NIWeek panel discussion held August 17, participants voiced similar concerns as they reflected on the 10th anniversary of Netscape, the emergence of Web tools like search engines, and the flat-earth hypothesis of *New York Times* columnist Tom Friedman.

During the discussion, Dr. Theodore Rappaport, professor in the wireless networking and communications group at the University of Texas, Austin, College of Engineering, questioned the source of future innovation. In response, Brian Fuller, editor-in-chief of *EE Times*, wondered whether flat-earth technologies might be applied to locating innovators in, say, the Ukraine.

That prompted Doug Marinaro, VP of software consulting services for MTS Systems, to ask why it was necessary to look to the Ukraine, and not Utah, to find engineering talent. According to Rappaport, it's because "the educational system in the US is broken with respect to engineering," with panelists concurring that inadequate teaching of math and science fundamentals, a lack of government focus on science and technology, and society's failure to celebrate technological innovation combine to hinder the emergence of prepared and dedicated engineering students.

Can we generate enthusiasm for technical careers?

According to Marinaro, a revival of interest in engineering will require two things: the ability to instill foundational skills, which will require optimal class sizes, programs, and educational tools; and a way to generate excitement about technology among students. The latter, Rappaport said, could require a massive publicity effort comparable to the dairy industry's "Got Milk?" campaign. Marinaro concurred, and added that TV is a huge influence on children today, with the program *CSI*, for example, seemingly driving increased interest in careers as medical examiners.

Dr. James Truchard, president, CEO, and cofounder of National Instruments, commented that it might take a crisis to spur on societal efforts to promote technical careers. He cites mounting foreign debt as something that might precipitate such a crisis.

For its part, NI offers a variety of educational resources (described at www.ni.com/academic) that can assist educators in building effective programs and instilling interest among students. Let's hope that such efforts bear fruit before a crisis occurs. T&MW

Contact Rick Nelson at rnelson@tmworld.com.

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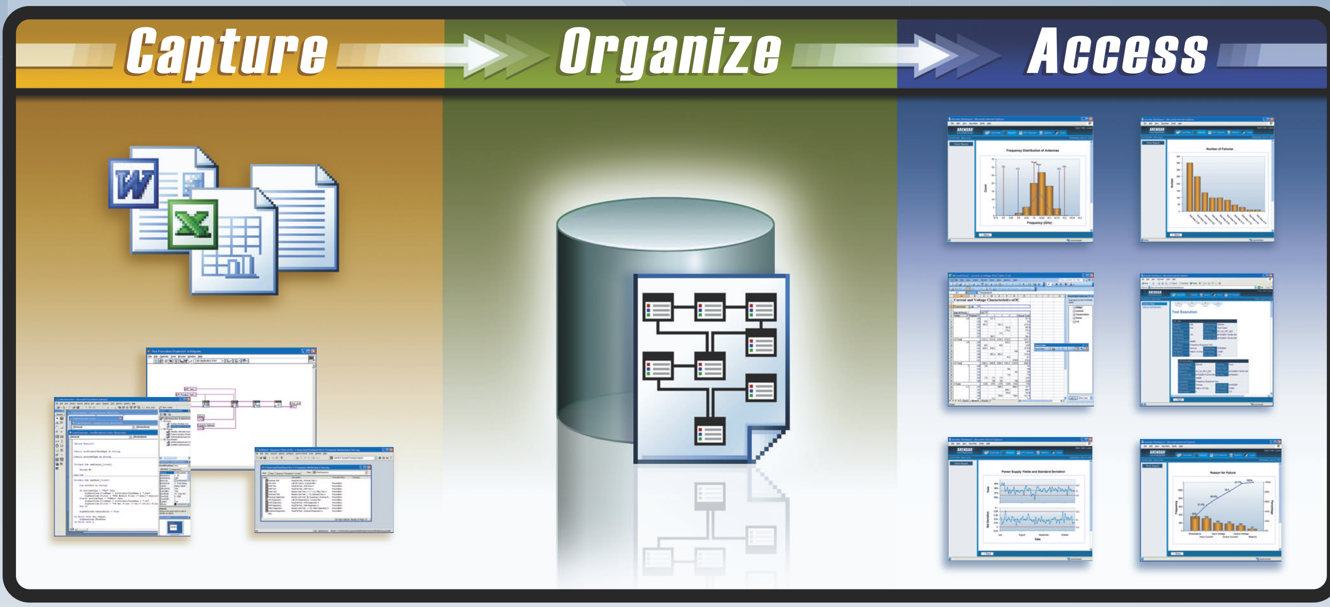

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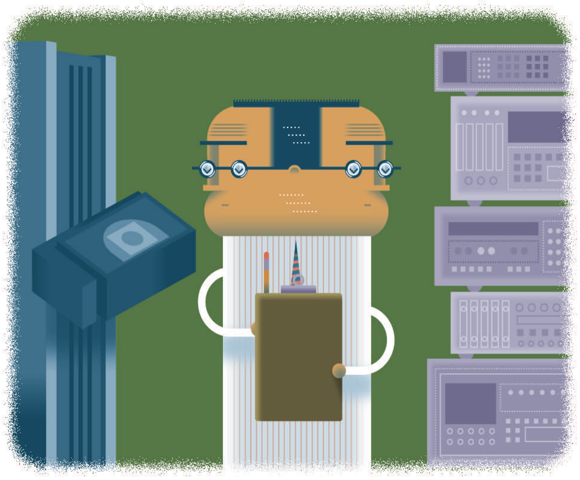
VI TECHNOLOGY

[An exclusive interview with a test engineer]

Dual test roles

Dave Olson is a product and test engineering manager at Philips Semiconductors (Tempe, AZ). He divides his time between evaluating new products, developing hardware and software for offshore production, and managing the engineers in his group.

He also was instrumental in developing software that lets engineers reuse instrument settings and drivers in numerous tests. (For a description of the application, see "Save settings, save time," *Test & Measurement World*, April 2003, www.tmworld.com.archives.)



DANIEL GUIDERA

T&MW: What products do you test?
Olson: All of the devices we test use the I²C bus. Products range from multiplexers to LED blinkers. My most recent product was a switch for the I²C bus.

T&MW: What tasks do you perform as a product engineer?
Olson: As a product engineer, I check the guaranteed specs of each device against its data sheet. I must make measurements such as propagation delay over many parts, temperatures, and power-supply voltages. Each evaluation, therefore, requires tens of thousands of measurements.

T&MW: Do you perform your bench testing manually or with automated equipment?
Olson: We take 90% of our data by running test equipment under computer control. I've developed a LabView application called "AcBench" that lets engineers choose which instrument to use, which instrument settings to use, which measurements to make, and which pins to make the measurement on.

T&MW: Do you have benches dedicated to component evaluations?
Olson: We have seven nearly identical benches, and we're working on an eighth. They have an identical pulse generator and one or two models of oscilloscope. They all have the same temperature controllers and power supplies, too. The more uniform I can keep the benches, the better off I am. If I need a new scope because of needed bandwidth, I can use the scope as soon as it arrives. With a new scope model I have to take time away from evaluating parts because I usually need to write a new instrument driver.

T&MW: What tasks do you perform as a test engineer?
Olson: When I receive a part for production test, I already know which purchased ATE system we'll use. I get a schedule for the start of production and I must have the ATE system ready before that date. Prior to receiving a new part, I have its specifications and can start developing a load board. I must work with the people at the test site, usually in Thailand or in the Philippines, to make sure that they have the proper IC handler for my package, the tester that we chose, and the custom hardware and software that I developed in my lab. I send the test fixture, software, and first parts to the production facility where all tests should work as they did in my lab.

Each engineer in my group has training in programming one or more ATE systems. For example, I support a Credence system. I needed a week of training where I learned the specs, ratings, and limitations of each instrument in the system. I also learned to program it in C.

T&MW: What are the greatest challenges you face today?
Olson: Time and distance, because we have to work with an overseas test floor. Shipping of parts takes days, and you don't get a response to e-mails on the same day. T&MW

Every other month, we will publish an interview with an electronics engineer who has test, measurement, or inspection responsibilities. If you'd like to participate in a future column, contact Martin Rowe at mrowe@tmworld.com.

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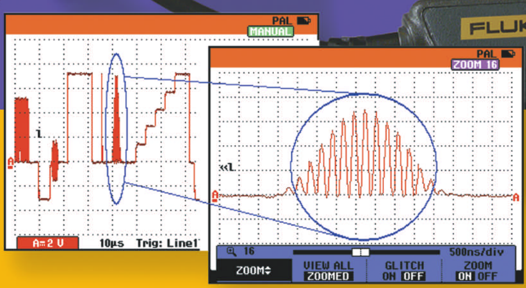

Fig. 1 *Thanks to the deeper memory, very small parts of the waveform can be studied in full detail using 'zoom'.*

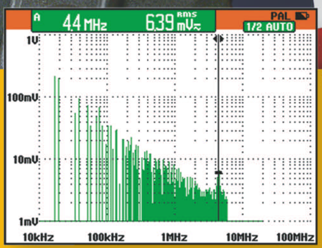

Fig. 2 *Frequency Spectrum shows an overview of frequencies contained in a signal.*

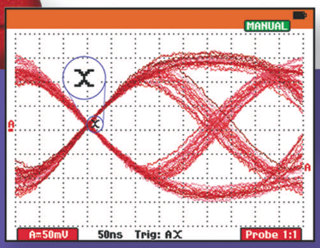

Fig. 3 *Dual-slope triggering used to capture the eye-pattern on a digital datastream.*

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Agilent to spin off semiconductor test

Agilent Technologies announced last month that it will exit the semiconductor-test and semiconductor-fabrication markets as it repositions itself as a "pure play" test and measurement concern. As a result, Agilent's memory-test and SOC-test businesses will be spun off as an independent company, according to Jack Trautman, president of Agilent's automated test group. He said he expects an IPO for the spin-off to occur in the middle of 2006. Trautman (pictured) added that personnel and geographic issues have yet to be worked out.

In addition to spinning off the semiconductor-test business, Agilent will divest its semiconductor products segment to private equity firms Kohlberg Kravis Roberts & Co. and Silver Lake Partners for $2.66 billion. Agilent will also sell its stake in Lumileds to Royal Philips Electronics for $950 million plus repayment of $50 million of debt from Lumileds. Agilent expects those divestitures to be completed by October 31.

Trautman said the divestitures would discourage investors from lumping Agilent together with volatile semiconductor stocks even though semiconductors and related test equipment constitute a small portion of the company's business. "Agilent has been undervalued for a long time," he said. See the online version of this article to read a detailed interview with Trautman. www.tmworld.com/archives.

New PXI Express standard unveiled

At a press conference held concurrently with NIWeek 2005 (August 16–18, Austin, TX), the PXI Systems Alliance (PXISA) announced its PXI Express specification, which integrates PCI Express and CompactPCI Express technology into the PXI standard. With PXI Express, engineers can achieve bandwidths up to 6 Gbps per system, representing a 45-fold improvement when compared to traditional PXI systems, while preserving software and hardware compatibility with existing PXI products, according to Eric Starkloff, director of product marketing at National Instruments.

PXI Express uses electrical features defined by the PCI Express spec, and PXI Express modules are compatible with the new CompactPCI Express (EXP.0) spec from the PCI Industrial Computer Manufacturers Group. Thus, a single measurement system will be able to support both PXI Express and CompactPCI Express modules. www.pxisa.org.

Standards to improve exchange of test info

The IEEE has begun developing two standards for using automatic test markup language to exchange test and instrument descriptions via XML.

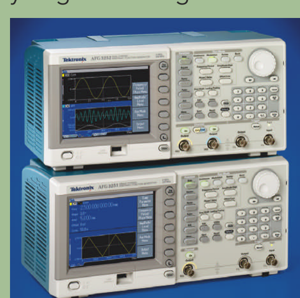
IEEE P1671.1, "Trial-Use Standard Automatic Test Markup Language (ATML) for Exchanging Automatic Test Equipment and Test Information via XML: Exchanging Test Descriptions," will define a format using XML to exchange information on test performance and conditions. It will allow the use of test descriptions to locate, align, and verify the operation of a unit under test, to help in preparing and documenting test programs, and to provide a common description for automatic test systems (ATSs) in the semiconductor, automotive, aerospace, and military sectors.

IEEE P1671.2, "Trial-Use Standard Automatic Test Markup Language (ATML) for Exchanging Automatic Test

EDITORS' CHOICE

Waveform generators fill a void

The AFG3000 line of arbitrary waveform/function generators bridge a gap between low-end and high-end signal generators. The top-end AFG3252 creates sine waves at up to 240 MHz and pulses and arbitrary waveforms with 125-MHz frequency, letting you generate signals above 100 MHz without having to use a 500-MHz RF signal generator.



The AFG3000 line consists of six models, each with an LCD that lets you see your outgoing signal without an oscilloscope. The six models consist of three bandwidths (25 MHz, 100 MHz, and 240 MHz) that create sine-wave signals on one or two channels. All models let you store up to four arbitrary waveforms, with two models storing up to 64 ksamples and four models storing up to 128 ksamples. You can use the instruments to create AM, FM, PM, FSK, and PWM-modulated signals as well as pulses and other waveforms.

The AFG3000 instruments come with ArbExpress software that lets you generate waveforms captured by Tektronix scopes or defined in Matlab files or comma-delimited text files. You can upload waveform files through USB, Ethernet, or IEEE 488 ports.

Prices: $1780 to $8500. *Tektronix,* WWW.TEKTRONIX.COM.

Equipment and Test Information via XML: Exchanging Instrument Descriptions," will focus on the test and diagnosis of electronic systems by providing common instrument descriptions to be shared across a variety of ATSs. ATML will involve applying an XML-based format to an instrument's description.

Both projects are sponsored by Standards Coordinating Committee 20—"Test and Diagnosis for Electric Systems." standards.ieee.org.

Workshop to cover new EU regulations

The National Institute of Standards and Technology (NIST) will host a workshop in early October to assist US manufacturers in meeting the new European Union Directive on Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS), which goes into effect in July 2006. Lead, which is widely used in solder, is one of the substances covered by the new directive.

Workshop participants will assess the measurement and standards needs of US companies as they respond to the EU restrictions and then produce a plan for preventing the restrictions from becoming a barrier to the global marketplace. "The Restricted Substances in Materials: Testing and Reporting Procedures" workshop will be held October 5-7 at the NIST campus in Gaithersburg, MD. www.nist.gov/public_affairs/confpage/051005.htm.

CALENDAR

International Test Conference (ITC), November 8–10, Austin, TX. Sponsored by IEEE. *www.itctestweek.org.*

Vision 2005, November 8–10, Stuttgart, Germany. Produced by Messe Stuttgart. *www.vision-messe.de.*

Productronica, November 15–18, Munich, Germany. Produced by Messe München. *www.global-electronics.net/id/21310.*

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

EDITORS' CHOICE

NetSight II family gains members

The Dalsa Coreco ipd division has announced M versions of the company's NetSight II machine-vision systems. The M versions are form and fit compatible with their predecessors but can deliver up to three times the overall performance, according to the company. They include a 1.6-GHz processor with 2 Mbytes of local cache and 512 Mbytes of high-speed program memory.

In addition to the standard analog and Camera Link interfaces, NetSight II M systems are compatible with IEEE 1394 and GigE Ethernet technologies. The new multichannel MCA product, for example, can acquire images from three digital IEEE 1394 cameras and three standard analog cameras simultaneously.

NetSight II M systems provide users with a choice of software options for building vision applications. For end users and integrators, the systems are supported by ipd's Sherlock vision software. For integrators or machine builders who wish to port their own software, the systems come with a library of C++ functions to access the individual hardware components.

Base price: $2995. *Dalsa Coreco ipd,* WWW.GOIPD.COM.

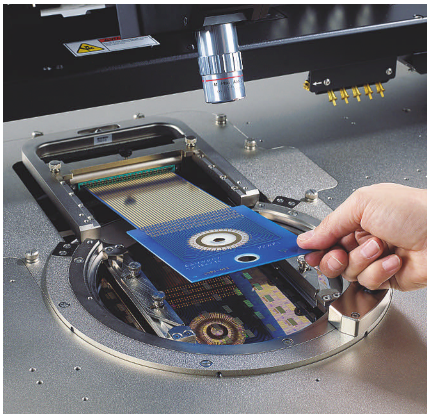
Debuts run gamut from sockets to systems

> > > Semicon West, July 11–15, San Francisco, CA, www.semi.org.

Aries Electronics (www.arieselec.com) highlighted a new high-frequency test socket for devices ranging from 28 to 40 mm^2. The socket can test devices with pitches down to 0.5 mm at frequencies from 1 to 18 GHz. **Synergetix** (www.synergetix.com) highlighted the development of a new 0.4-mm probe for BGA, LGA, QFN, and QFP test sockets. The company also demonstrated a 0.5-mm offset Kelvin probe that allows test engineers to measure package resistance to 1 mΩ while taking advantage of conventional DUT-board designs. In addition, the company described its Compliance Plus probe, which features increased travel to help test engineers deal with printed-circuit-board warpage.

The **Semiconductor Test Consortium** (www.semitest.org) confirmed **Apria Technology** (www.apriatech.com) has started shipping its OC800 OpenStar-compliant baseband arbitrary waveform generator (AWG) and digitizer modules. **Agilent Technologies** (www.agilent.com) introduced its Versatest Series Model V5500, which targets single-insertion final-test applications for multichip-package (MCP) devices and discrete flash memory. The Versatest V5500's tester-per-site architecture and optional Programmable Interface Matrix optimize single-insertion testing of MCPs with multiple memory types (flash, DRAM, and SRAM), supporting up to 16,384 pins per test head. **ProductionLine Testers** (www.productionlinetesters.com) demonstrated its IC-100 general-purpose benchtop semiconductor tester, which can mate with a handler or prober to provide a zero-footprint manufacturing test system.

GuideTech (www.guidetech.com) announced that its Femto 2000 continuous timing interval analyzer (CTIA) system has passed qualification as a certified open-architecture timing solution for the **Teradyne** (www.teradyne.com) Flex ATE platform. **Advantest** (www.advantest.com) introduced a digital module designed to enable low-cost, flexible testing of system-on-chip (SOC) devices incorporating serializer/deserializer communications interfaces. The new 6.5-Gbps digital module for the T2000 open-architecture test platform can accommodate SOCs employing a variety of Serdes standards, including PCI Express, SATA, XAUI, and FBDIMM (Fully Buffered Dual Inline Memory Module), as well as source-synchronous devices.



The eVue digital imaging system targets engineers doing process development or device characterization.

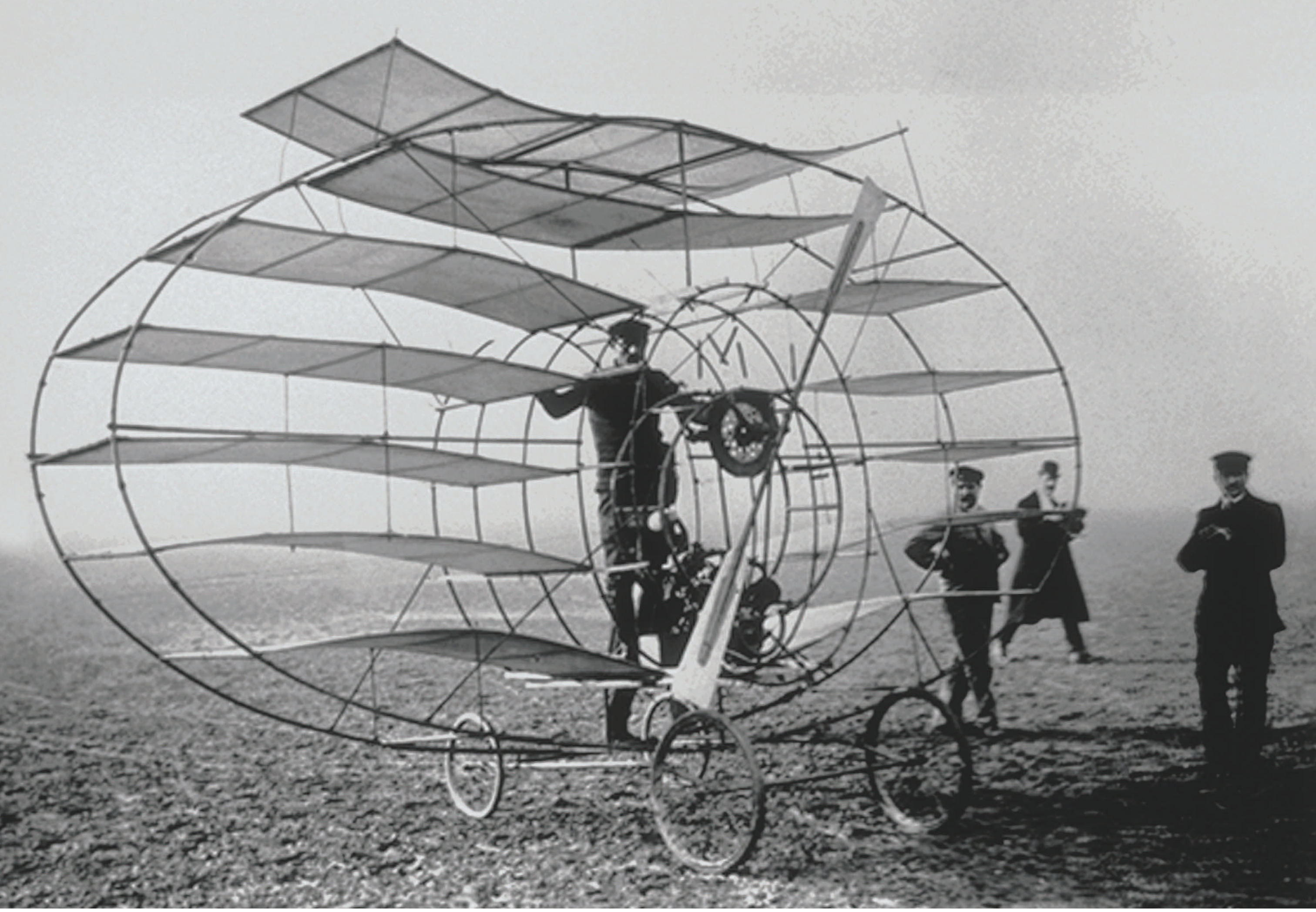
Courtesy of Cascade Microtech

Johnstech (www.johnstech.com) demonstrated a variety of products that address the challenges of testing in lead-free environments. The company's ROL200 Series production-test contactors employ a self-cleaning wipe function and an elastomer-based design to minimize oxide build-up and provide controlled contact force. **Kulicke & Soffa** (www.kns.com) announced two epoxy probe-card process technologies—involving a new probe-needle material and a scrub-optimization process—that address the challenges posed by circuit-under-pad (CUP) devices during wafer testing.

X-Tek Systems (www.xtekxray.com) exhibited its new Revolution real-time microfocus x-ray system, which offers a viewing angle to 75° over its 16x16-in. manipulator scan area. **Banner Engineering** (www.bannerengineering.com) spotlighted its D10 series of compact, DIN-rail-mountable fiber-optic sensors. **Cognex** (www.cognex.com) introduced the newest member of its wafer ID reader family, the In-Sight 1721. **Machine Vision Products** (www.visionpro.com) showcased the Supra M automated optical inspection system, which provides solder-joint inspection and measurement capabilities.

Suss MicroTec (www.suss.com) demonstrated its BlueRay semiautomatic wafer-probe system for optoelectronic devices. **Cascade Microtech** (www.cmicro.com) highlighted its new eVue digital-imaging system, which employs a multi-CCD microscope with high-definition digital video to provide support for semiconductor navigation and testing. **FormFactor** (www.formfactor.com) announced full-volume commercial production of its FormFactor NF150S wafer probe card for large-area arrays tailored to the growing NAND flash market.

Visit www.tmworld.com for more details on these Semicon West products. See also p. 17 for information on failure-analysis tools described during Semicon West. T&MW



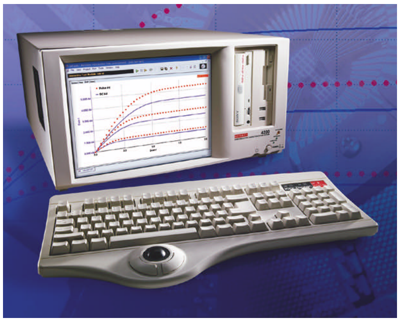
Photo, Getty Images

RICK NELSON
CHIEF EDITOR
rnelson@tmworld.com

Failure analysis gains electrical, microscopy tools

Makers of failure-analysis tools targeted Semicon West to highlight both electrical and microscopy techniques that can help isolate faults in integrated circuits. Tools brought to the forefront included probing systems as well as a new approach to microscopy that can offer millionfold magnification.

The microscopy approach comes from ALIS, whose name stands for atomic level imaging system. Although not exhibiting, company officials were on hand to describe the ALIS technique. Bill Ward, ALIS president, explained that, in contrast to traditional scanning electron microscopes, the ALIS tool uses helium ions as the imaging particles. "Since ions can be focused into a smaller probe size and have less sample interaction, we can generate higher resolution images with more contrast so more detail can be seen," he said. Initially, he said, the company will focus on a tool for semiconductor failure-analysis engineers.



The 4200 system can work with the Zyvex S100 precision manipulator to make parametric measurements.
Courtesy of Keithely Instruments.

Looking at failures is one way to analyze them. You might also want to measure their electrical parameters with an instrument such as Keithley's 4200 semiconductor characterization system. Of course, the one failed transistor out of millions is unlikely to come equipped with convenient 50-micron probe pads, so you'll need a way to probe that transistor. That, said Keithley product manager Dave Rubin, is possible because of work Keithley has done with Zyvex, a company that shared exhibit space with Keithley at Semicon. According to Zyvex staff scientist Richard Stallcup, Zyvex's S100 offers 5-nm movement precision, probe-tip diameters of less than 20 nm, and current-measuring capabilities down to 1 pA (Ref. 1)—sufficient for making measurements on individual transistors fabricated in 65-nm processes.

Yet another approach to transistor measurements is to forego physical contact altogether. To that end, Suss MicroTec exhibited a noncontact probe system that acquires signals without loading the circuit under test. The system employs an integral atomic-force probe in combination with a prober such as the Suss PM8 to enable scanning and positioning. A tip positioned above an area of interest is stimulated with electrical pulses, while a laser monitors the probe deflection that results from the forces generated between an electrical signal from the DUT and the charged tip. From the measured deflection, system software extracts the DUT signal-voltage waveform. "It's as easy to use as an oscilloscope," said Dan Ouellette, noncontact probing manager at Suss, and having test-driven the system, I'd have to concur. T&MW

REFERENCE

1. Hochberg, Jeff, "Four Point Probe I-V Electrical Measurements Using the Zyvex Test System Employing a Keithley 4200," Zyvex, 2005. www.zyvex.com/Products/KZ00_001a.html.

IDT selects BIST Assist cards

Agilent Technologies has announced that Integrated Device Technology has purchased eight Agilent BIST Assist production-test cards to upgrade its 93000 Series SOC tester. The upgrade gives IDT the ability to test high-speed links in loop-back/BIST mode for speeds up to 6.4 Gbps. www.agilent.com.

Sapphire D-10 for mixed-signal ICs

Credence Systems has unveiled the Sapphire D-10, a high-throughput, multipurpose wafer-sort and final-test system designed to address the economic requirements of the low-cost consumer mixed-signal device market. The company says the Sapphire D-10 is optimized for the 200-Mbps probe market and supports massive multisite production test. www.credence.com.

Flex instrument debuts

Teradyne and Salland Engineering have developed a fully integrated, universal-slot, open-architecture test system in which Salland's single-board, 192-channel HDPMU (high-density parametric measurement unit) instrument installs directly into a Teradyne Flex test head. Independent software drivers install directly into the Flex IG-XL software system. The HDPMU is now testing broadband and power-management devices in production on Flex systems at customers' locations in Europe and Asia, Teradyne reports. www.salland.com, www.teradyne.com.

JON TITUS
CONTRIBUTING TECHNICAL EDITOR
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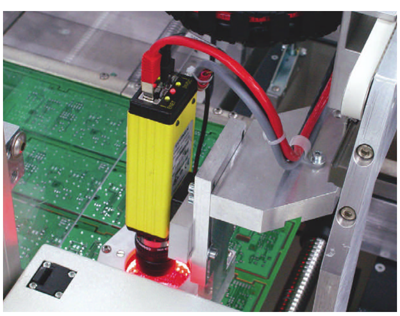
Vendors rise to vision challenges

The issue of ease of use continues to challenge vision-equipment and vision-software vendors. After all, "how do you quantify ease of use?" asked Kyle Voosen, machine-vision product manager at National Instruments. "Every company says it offers easy-to-use products. To me, it comes down to how quickly users can start to run their hardware and software and make their first useful inspections."

System developers, for example, need tools and wizards that let them run trials and test what-if conditions. After they have developed a prototype that works, they want to push a button and generate solid LabView, C, or Visual Basic code, explained Voosen. "That takes the pain out of vision-system development."



On a production line, a Cognex In-Sight 1010 vision sensor reads laser-marked 2-D Data Matrix codes from PCBs. An Ethernet connection links this sensor—and 41 others—to a control network.
Courtesy of Cognex.

A push-button approach to the current trial-and-error method of finding the best lighting arrangement would help, too. Although the industry hasn't reached that point, it has gotten closer. "Some low-end vision sensors or vision processors include a built-in light source," said George Blackwell, director of product marketing at Cognex. The sensor turns on the internal light sources at the right time and with the proper intensity. Users don't have to figure out how to create the best illumination for a given distance to the product and for the sensor's lens type.

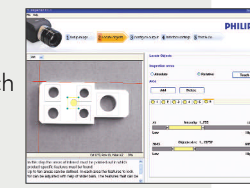
Light sources can accommodate changing conditions, too. "Some of our handheld ID products provide adaptive lighting," explained Cognex's Blackwell. The reader never "knows" the condition of a mark, such as a 1-D bar code or a 2-D Data Matrix symbol. So, the reader's internal light source quickly tests a series of light position and intensity configurations until the reader obtains good data. The reader continues to use that lighting setup until it encounters another reading problem; then, it runs through its range of lighting configurations again.

An electro-optical reader has no preconceived idea of what makes a good mark, so how does it know good from bad data? Data Matrix marks provide error-checking codes and data redundancy. Bar codes may lack those features, so the reader takes many readings in a rapid sequence to ensure it can consistently read a mark.

Ease of use also involves painless integration of vision equipment with other plant-floor machines. According to National Instrument's Voosen, inspection applications increasingly rely on motion controllers and other industrial equipment, and disparate equipment must communicate in a common language. The increasing integration of standard communication ports such as Ethernet and Controller Area Network (CAN) in vision equipment, and the adoption of open protocols such as Profibus, Ethernet/IP, and Modbus/TCP, simplify the integration of vision equipment with existing industrial-equipment controllers. Unfortunately, not all controllers know how to handle images, so although equipment communicates, it doesn't always use the same vocabulary. Some challenges remain. T&MW

No programming needed

The Inspector smart sensor system from Philips runs vision applications as a stand-alone device. The black-and-white sensor performs presence/absence inspections and analyzes position, size, and orientation of objects. Users need only attach a PC for setup, which involves five steps that establish inspection criteria. The sensor operates at 27 frames/s and offers a 1280x1028-pixel resolution. Base price: $2500. www.apptech.philips.com/industrialvision.



Brochure describes camera capabilities

A short-form capabilities brochure, "Cameras and more..." describes Kappa Opto-Electronics cameras for machine-vision, inspection, and metrology, as well as its ready-to-use software that performs 2-D measurements, reads bar codes, and corrects background information. The brochure also describes typical applications. To obtain a copy, e-mail n.avila@kappa-vision.com.

Interchangeable cameras

With the Toshiba America IK-M44A camera-control unit, developers can switch among three color-camera heads without re-adjusting camera settings or changing electrical connections. All three heads, from a micro-miniature 1/3-in. "lipstick" camera to a large C-mount camera, capture more than 470 horizontal and 350 vertical TV lines. The controller can operate a camera's shutter with a speed between 1/60 and 1/10,000 s. www.toshiba.com/taisisd/indmed.

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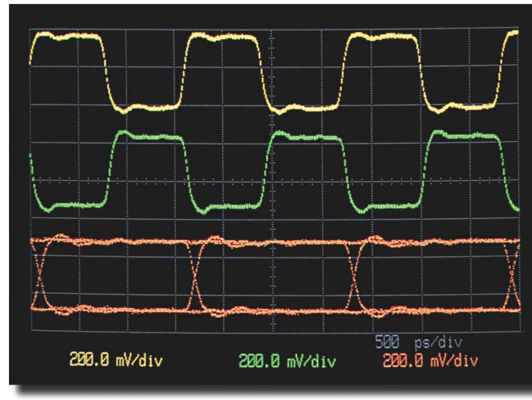
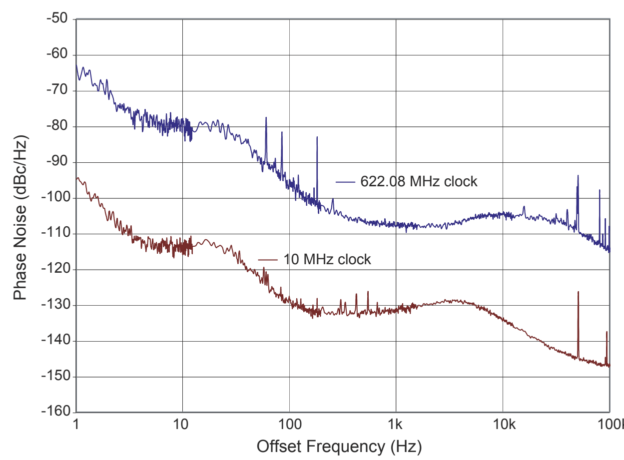
Optional OCXO and rubidium timebases improve frequency stability by 100× and 10,000× over the standard crystal timebase. And an optional PRBS helps you evaluate high-speed serial data paths.

Whether you are trying to lower the noise floor of an ADC, increase SFDR of a fast DAC, or squash the bit error rate in a SerDes, the CG635 is the tool you need to get the job done.

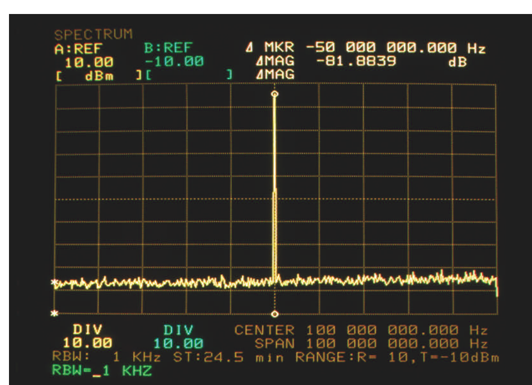


Clock and PRBS signals at 622.08 MHz

Plot shows complementary clock and PRBS (opt. 1) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).



Phase noise for 10 MHz and 622.08 MHz outputs



RF Spectrum of a 100 MHz clock

Graph shows a 100 MHz span around a 100 MHz clock. Only two features are present: the clock at 100 MHz, and the spectrum analyzer's noise floor (around –82 dBc).

SRS *Stanford Research Systems, Inc.*

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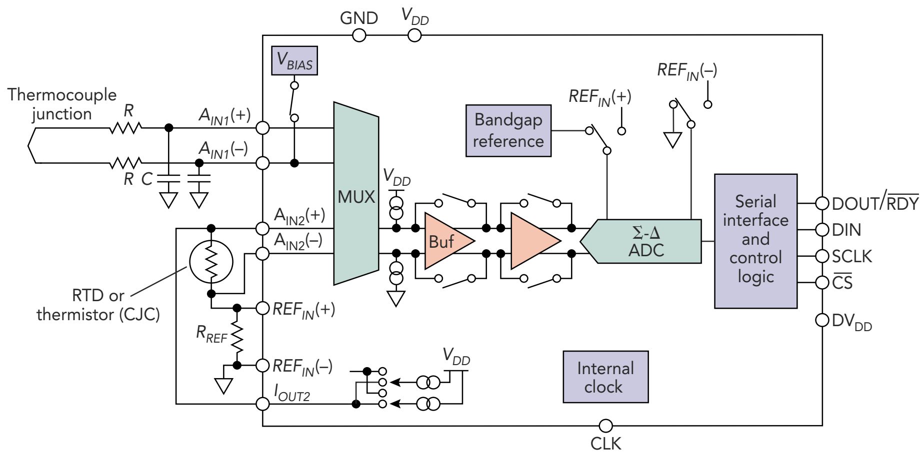
TEMPERATURE MEASUREMENT

Connect temperature sensors to an ADC



ADCs contain signal-conditioning circuits such as multiplexers, amplifiers, reference voltages, and current sources for connecting temperature sensors. A thermocouple configuration is shown.

Thermocouples, resistance-temperature detectors (RTDs), and thermistors make up the vast majority of sensors for measuring temperature, but you can also use a diode or transistor's P-N junction as a sensor. A thermocouple uses two wires of different metals to generate a small voltage as a function of temperature. RTDs and thermistors change resistance with temperature, as does a P-N junction's voltage. Each type of sensor requires a unique analog input section. ADCs now come with the signal-conditioning circuits on-chip, making designs easier to implement.

With just a few external components, you can connect temperature sensors directly to an ADC. For thermocouples, you need an RTD or thermistor as a cold-junction compensator to measure the temperature where the thermocouple wires connect to your circuits (see **figure**). You then need a reference resistor and two capacitors on the thermocouple wires to reduce noise.

To use an RTD, thermistor, or P-N junction, you need a current source, which is often available in an analog-to-digital converter (ADC). You also need signal-conditioning circuits such as a multiplexer and amplifier, which may also be included in an ADC.

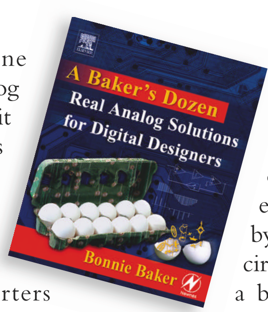
To learn more about connecting temperature sensors to an ADC and about ADC architecture, download a copy of "ADC Requirements for Temperature Measurement Systems," by Mary McCarthy and Eamonn Dillon of Analog Devices, from the online version of this article at www.tmworld.com/archives. The paper includes diagrams for connecting RTD, thermistor, and P-N-junction sensors to an ADC.

Martin Rowe, Senior Technical Editor

BOOK REVIEW

Nasty realities

A Baker's Dozen: Real Analog Solutions for Digital Designers, Bonnie Baker, Newnes (www.newnespress.com), 2005. 347 pages. $59.95.



Want to see a digital designer, especially one just entering the workforce, run a four-minute mile? Just mention the nastiest word ever spoken: analog.

The world of noise, uncertainty, and error strike fear into the digital heart. While nothing can make analog design completely painless, Bonnie Baker's book may come close.

Baker, a regular contributor to *T&MW*'s sister publication *EDN*, brings her extensive analog experience to light in this practical, well-organized book. She aims the book at designers of embedded systems, but anyone who doesn't work with analog circuits every day will benefit from reading it. Baker walks you through the fundamentals of analog circuits, starting with Ohm's law, and builds your knowledge of analog-to-digital converters (ADCs), amplifiers, filters, and systems. You'll learn how to select a converter, design a filter, select an op amp, and evaluate a circuit with just enough math to do the job without overwhelming you.

Baker's experience as a technical writer shines, as she reiterates key points throughout the text. For example, she mentions several times the importance of bypass capacitors to reduce circuit noise. She also presents a basic measurement circuit early in the book, then returns to it as she covers each part of the circuit chain. Her lively writing, sprinkled with real-world stories, shows you the importance of good analog design. *(continued)*

Nasty realities *(continued)*

Baker doesn't stop once an analog signal becomes digital. She takes you through the process of interfacing ADCs to microcontrollers and shows you how to solve some analog problems digitally. But she stresses that some problems are best solved with analog circuits.

Baker's Dozen doesn't cover the analog characteristics of gigabit-per-second digital signals. Instead, it focuses on analog signals from sensors and how to reliably convert them to digital. (Disclosure: The book's publisher is owned by *Test & Measurement World*'s parent company.)

Martin Rowe, Senior Technical Editor

SEMICONDUCTOR TEST

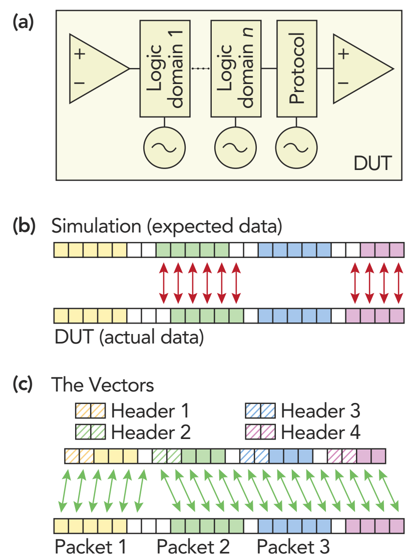
Header-hunt feature handles nondeterministic data

High-speed serial communications devices implementing standards such as PCI Express 2 and XAUI 2 and operating upwards of 6 Gbps can pose significant test challenges. "Today, we have to test and debug these devices in mission mode, with real data," says Dave Armstrong, director of SOC product engineering at Advantest.

The difficulties stem from the inability to precisely control phase relations among multiple clocks, he says, adding that precise control of output data streams in the presence of thermal variations and jitter is impossible. In addition, DUT protocol engines generate information packets separated by logical idle states (shown in white in the **figure**), and the number of such states between packets can vary.

Consequently, the data stream that a DUT generates and a tester detects may not match expected values derived from simulations, resulting in a failure flag even though the DUT operates properly. In the figure, for example, the misalignment of the green and pink packets will result in intermittent test-failure indications. This misalignment introduces significant consequences for test, mandating, for example, the use of repetitive tests involving nonfunctional patterns or the use of extensive, time-consuming post-processing of test data obtained from real-world functional patterns.

As an alternative, Advantest has incorporated a "header hunt" feature in a 6.5-Gbps digital module it designed for its T2000 test system. Header hunt, says Armstrong, allows pattern comparison to proceed unhampered by nondeterministic breaks between the data; it tolerates intermittent pauses of unknown duration to ensure that good parts aren't flagged as failed ones.

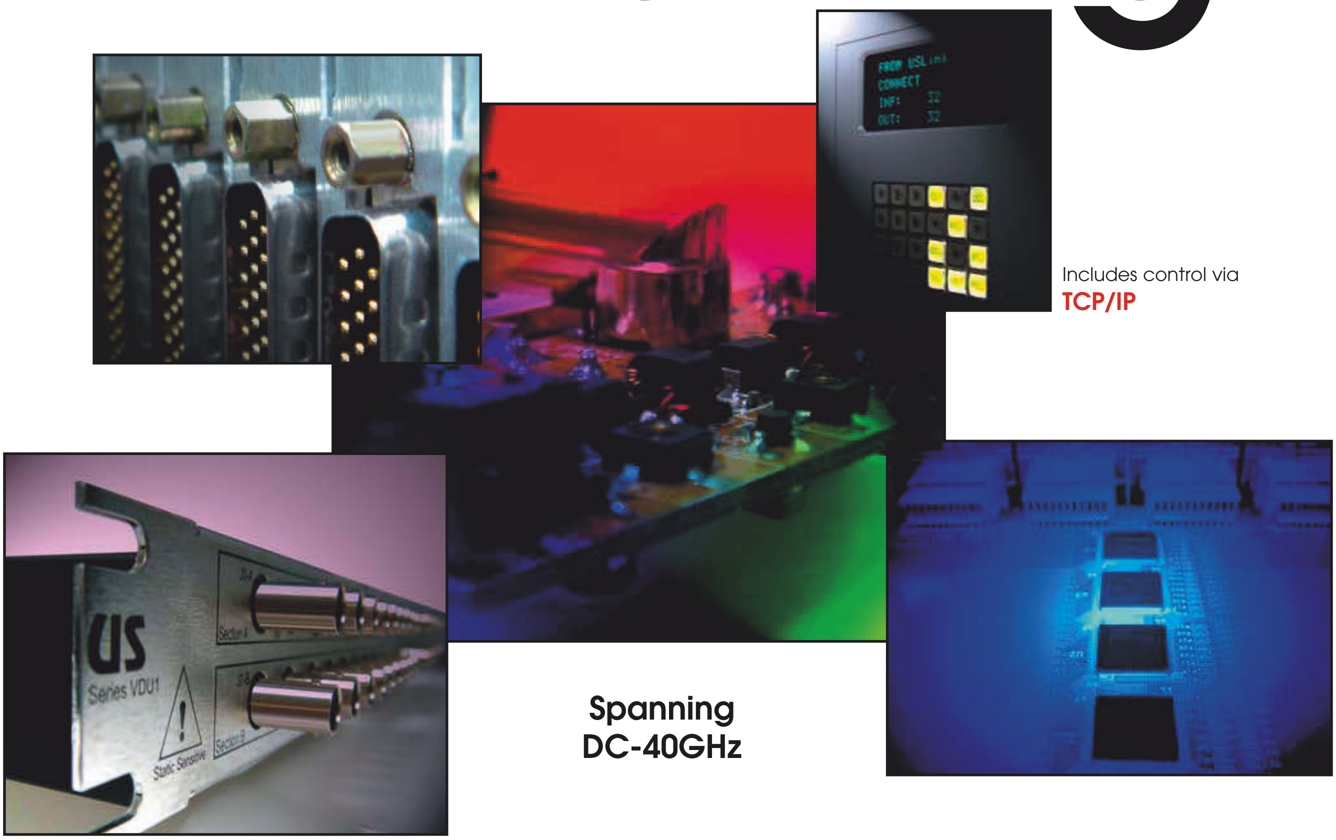


The protocol engine of a fully functional DUT (a) may spit out indeterminate numbers of logical idle states between data packets, resulting in differences between actual and expected data (b) that causes a tester to fail good devices. A header-hunt feature (c) overcomes this limitation.

The concept is conceptually simple, Armstrong says: "If we are looking for a new sentence 'The quick brown fox jumps over the lazy dog,' we simply look for a period and then wait for 'The.'" He adds, though, that implementation required many engineering-years of effort.

Rick Nelson, Chief Editor

Switching?



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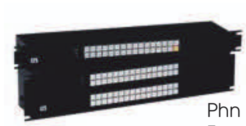

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FIBER-OPTICS TEST

Guide the light

DEVICE UNDER TEST

Optical triplexers used to transmit data and receive data, voice, and video in fiber-to-the-home applications. The devices transmit light on 1310 nm and receive on 1490 nm and 1550 nm. Wavelengths carry data at 1.25 Gbps.

THE CHALLENGE

Test the filter optics while the device is still in unpackaged form to verify that the fabrication process is within tolerance. Filter optics are inaccessible on complete devices, requiring special on-wafer devices just for testing the fabrication process.

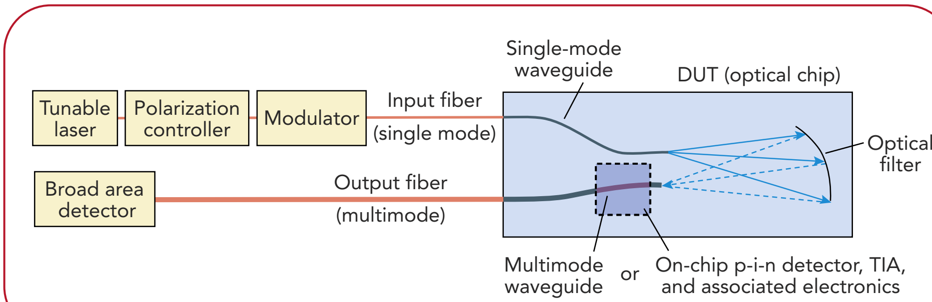
THE TOOLS

- Agilent Technologies: polarization controller, tunable laser, broad-area optical detector, digital communications analyzer, and bit-error-rate tester. www.tm.agilent.com.
- Cascade Microtech: microprobes. www.cmicro.com
- JDS Uniphase: optical modulator. www.jdsu.com.
- Keithley Instruments: nanoammeter. www.keithley.com.
- Melles Griot: fiber alignment stage. www.mellesgriot.com.
- Suss MicroTec: microprobes. www.suss.com.
- Polytec PI: fiber-alignment stage. www.polytecpi.com.

PROJECT DESCRIPTION

Engineers at Enablence (Ottawa, ON, www.enablence.com) need to test optical triplexers for design verification and in production. While they test fully packaged devices, they also test unpackaged devices to characterize optical filters. Production tests on optical filters let engineers verify that the manufacturing process is within tolerance.

To run the optical-filter tests, engineers build devices onto wafers that contain only the optical components. "Electronic components such as detectors can't be on the devices for these tests because they limit our access to the optical filters," said Enablence director of R&D Ashok Balakrishnan. "For testing purposes, we replace the optical detector with a multimode waveguide to steer the filtered light to the edge of the chip."



Multimode fibers let engineers test optical filters in unpackaged devices.

The **figure** illustrates an unpackaged device used for test. The multimode waveguide must be wide enough to capture all of the filtered light, and its optical-index contrast must be high enough to steer the light to the edge of the chip while preserving it. Upon reaching the chip's edge, the light must pass to the multimode fiber with minimal loss, before it then travels to an external detector. The acceptance angle of the output fiber must be greater than that of the output waveguide, and the aperture of the broad-area detector must be larger than the core diameter of the multimode fiber. A characterized and calibrated detector converts the filtered light to an electrical signal for bit-error rate (BER) measurements and eye-diagram tests with a digital communications analyzer (DCA). A tunable laser supplies incoming light, and the modulator digitally modulates the light.

Engineers use a multimode waveguide and multimode fiber because attaching a single-mode fiber to the DUT's output requires tight alignment—the light's diameter is just 5 µm. Single-mode fibers have core diameters of about 10 µm, but multimode fibers have core diameters ranging from 50 µm to 200 µm. Thus, multimode fibers are easier to align to the DUT. Enablence uses six-axis stages to align the input and output fibers to the chip.

In addition to testing optical filters on unpackaged ICs, Enablence engineers test fully packaged ICs and unpackaged devices that have optical detectors in place of the waveguides. For testing packaged devices, they use a modulator, a BER tester, and a DCA. Because the devices are complete, engineers can use a test board and fixture. When a device has a detector but is unpackaged, engineers use microprobes to gain access to the device, and they use a nanoammeter to measure its photocurrent at low frequencies.

LESSONS LEARNED

Enablence engineers found that active elements such as lasers and detectors contain passive optical filters that compound their test problems. Customers rely on tests of fully packaged devices, but Enablence must obtain other details of device performance. Engineers must design-in methods of testing at the more detailed levels. Multimode waveguides and fibers work well to bypass the electrical output of an integrated device.

Martin Rowe, Senior Technical Editor

VOTE for the 2006 Test Engineer of the Year

Name a successful electronics component, system, or end product, and you'll likely find one common ingredient: quality. And more than any other technical professional, the test engineer is responsible for ensuring a product's quality—all the way through from design to production to field service.

To salute the essential role that the test engineer's ingenuity and hard work play in reliable, safe, and affordable products, *Test & Measurement World* announces its third annual Test Engineer of the Year competition. Thanks to the generosity of National Instruments, the winning candidate will designate a $20,000 donation to an engineering school. "This award not only recognizes an outstanding engineer for his or her innovative work, but it is a way to help future engineers through an educational grant," commented James Truchard, CEO of National Instruments.

Test & Measurement World will present the 2006 Test Engineer of the Year award at our "Best in Test" gala during the 2006 APEX Show (February 8–10, 2006, Anaheim, CA). In addition, the cover story of our March 2006 issue will profile the winning engineer.

In recent months, we've received many nominations of pacesetting test engineers from a range of test fields. Our editors have selected six individuals as the finalists for the award. Please review their profiles both for their special on-the-job skills as well as their overall contributions to the test field and the industries they serve. Then, cast your vote by visiting www.tmworld.com/teoty, where you will find additional links to related information on the candidates and their companies.

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SOFTWARE DEVELOPMENT

Zafer Boz

STMicroelectronics

It's tough enough for an immigrant to adjust to life in a new country; it may even be more daunting to win the recognition of peers on an engineering team of a global semiconductor giant. But Zafer Boz, a Turkish national who earned his EE degree from the University of Ankara, has met those challenges.

Using such tools as LabWindows/CVI and C++, Boz developed a new software suite for his engineering colleagues at ST's Reading, England, business unit, which makes chipsets for wireless LAN applications. Called STE (ST Test Executive), the software can be easily reconfigured to handle a number of different applications—functional tests, debugging, soak testing, calibration, and production test. "I wanted our engineers to be able to focus on their test work, rather than compiling code," said Boz.

The software is getting rave reviews from ST engineers in the UK and France, as well as from contractors in the US that are doing work for ST's UK business unit. While STE remains an internal tool, Boz would like to patent it for wider use. Meanwhile, he is working on his master's degree in electrical engineering, and he hopes to build a career in managing automated test projects.

TEST DATA MANAGEMENT

John Kauffman

Rockwell Collins

Thanks to the work of manufacturing electrical engineer John Kauffman, Rockwell Collins has taken a giant step in trimming labor, service, and warranty costs on products it builds for the military's Joint Tactical Radio System. The 20-year test veteran has fashioned a data-management system that both streamlines the test flow for this important product line during manufacturing and tracks the tests performed on the equipment throughout the product life cycle. In this system, data from field tests is uplinked to a central data base. This enables test and development teams to spot defect patterns earlier and, if needed, make essential design changes. "It allows us to be proactive, rather than reactive," said Kauffman, who adds that other product lines at Collins are also adopting the system.

The biggest challenge in setting up the system was gaining the consensus of design, test, and quality engineers in a large organization. But that is nothing new for Kauffman, who spent 15 years in the Marines, where he served as West Coast coordinator of metrology services, a task that involved calibrating some 4000 avionics devices. That experience taught him the value of sharing technical ideas among engineers from government, military contractors, and test-equipment vendors.

THERMAL MANAGEMENT

Herman Chu

Cisco Systems

Power-hungry electronic devices create a lot of cooling problems, which is why Herman Chu has been so valuable to blue-chip companies like General Dynamics, Amdahl, Hewlett-Packard, and Cisco. Over a 20-year career devoted exclusively to tackling difficult thermal-management challenges, Chu's talents in computational fluid dynamics (CFD) analysis, design of experiments, and test procedures have delivered cooling solutions on products as varied as F-16 fighters, mainframe computers, and network systems.

Over the years, Chu has set up thermal-engineering labs at several locations, including a new facility at Cisco for cooling high-power network routers. In that work, he is setting up system-level testing for flow visualization, IR imaging, airflow impedance, and thermal characterization. Chu is most proud of innovative methods that he has developed to measure CPU case temperature, which have wide industry applications. Also significant: a new Cisco project to design a thermal tester for measuring different classes of thermal-interface materials.

On an industry level, Chu, who holds a master's in thermal systems design, has written papers and chaired several workshops for the International Microelectronics Packaging Society. As a personal crusade, he calls for more creative solutions in design and software for stemming the ever-increasing power consumption of electronic devices.

METROLOGY

Georgia Harris

National Institute of Standards and Technology

If you doubt the importance of accurate metrology, consider this: Half of this country's gross domestic product is bought or sold on the basis of weights and measures. As leader of the Metrology Group in the Weights and Measures division of the National Institute of Standards and Technology (NIST), Georgia Harris oversees the accreditation program for more than 50 state laboratories engaged in about 350,000 calibrations annually. During her 15 years at NIST, Harris has spearheaded numerous quality programs for calibration labs, instituted metrology training programs for government and industry personnel, and established proficiency tests for metrologists.

A physical scientist with a master's in technical management from Johns Hopkins, Harris makes it a priority to identify the long-term needs of metrology. She has authored many papers, collaborated with government and industry professionals worldwide, and helped shape many standards on weights and measures. Noting that her "real passion" is education, Harris worries that too few engineers are choosing metrology as a career—a concern she now addresses as the education and training director for the National Conference of Standards Laboratories. After a six-month sabbatical to hike the Appalachian Trail, Harris plans to pursue a PhD in leadership and organizational development, while continuing with NIST.

FUNCTIONAL TEST

Michael Freeman

Broadcom

Engineers in the fast-paced communications market know that cutting time-to-market is vital. That's why Michael Freeman is such a key player on an R&D team that develops chipsets for broadband applications. The veteran test engineer has created and deployed a whole series of custom automated test systems—both hardware and software—for evaluating such products as complete cable modems on a chip.

Among the testers he has designed is a downstream impairment test system that stresses RF tuners with a mixture of analog, QAM, and wideband noise to simulate worst-case CATV plant conditions. Freeman is particularly proud of a custom system he designed to test the interoperability of cable modems, wireless cable routers, and related products. This tester helps Broadcom and its customers prepare products for required industry certification. His latest challenge: testing embedded multimedia terminal adapters for the burgeoning voice-over cable market.

Earlier in his career, Freeman developed extensive skills in environmental testing on defense systems. He has authored several technical papers on topics ranging from modular test to Visual Basic programming, and he has written a book on shock and vibration testing. Freeman serves as the president of the Atlanta chapter of the American Society of Test Engineers and maintains the ASTE's Web site.

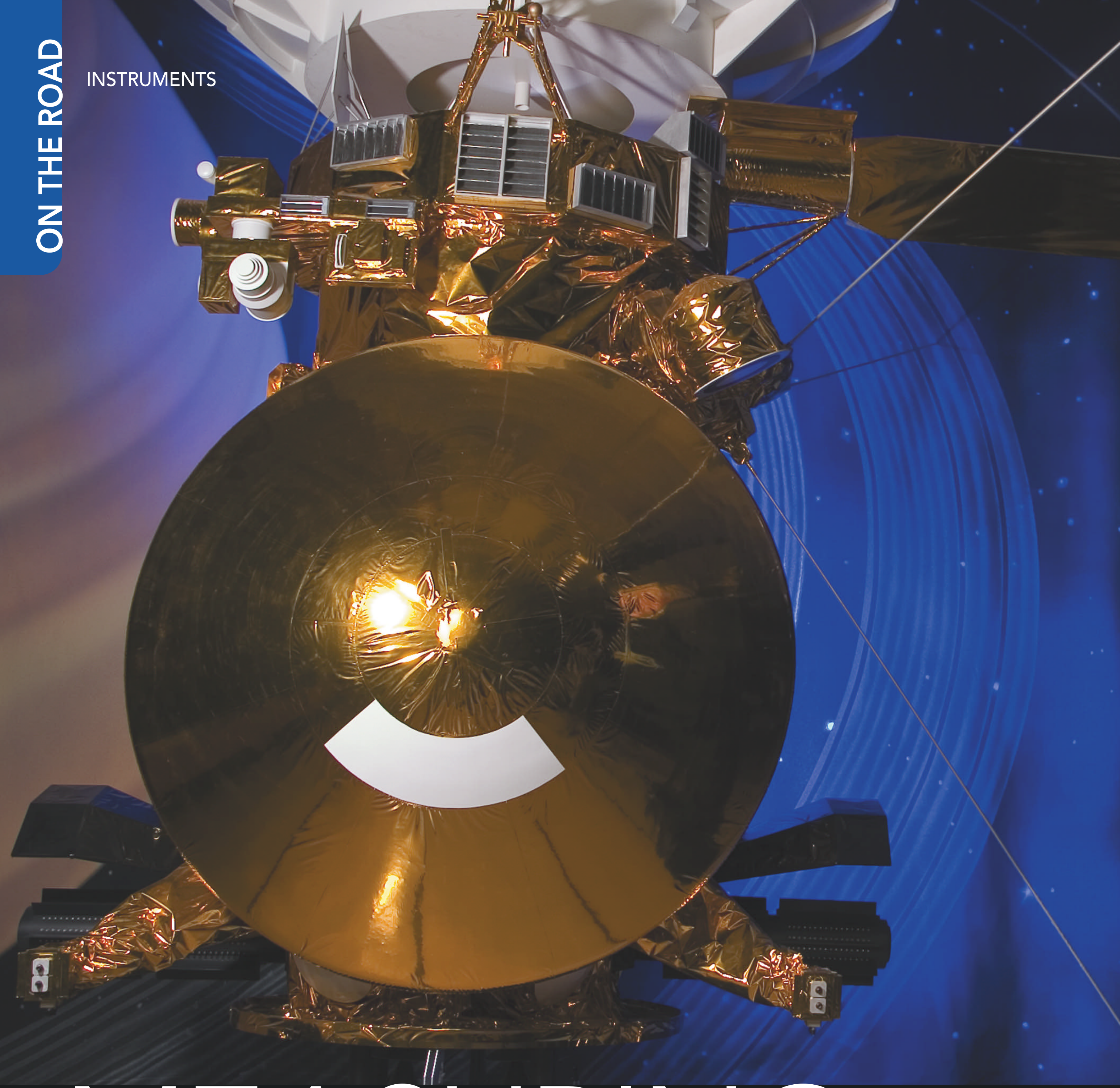
CONSUMER ELECTRONICS TEST

Ed Coleman

Lexmark International

In the highly competitive inkjet printer market, test engineers can't afford to rest on their laurels. New designs are constantly coming on stream, and new tests must be devised under tight deadlines. At Lexmark, Ed Coleman employs the latest 100-MHz digital I/O cards and 100-MHz oscilloscope cards to test inkjet print heads. When a prototype inkjet print head chip arrives on a wafer, Coleman must write the initial software to electrically test and address the nozzle heads. He also works with material-handling vendors to incorporate electrical tests for print heads into automated manufacturing lines in Mexico, Scotland, and the Philippines. And when a manufacturing tester goes down at a Lexmark facility anywhere in the world, Coleman frequently gets the call to solve the crisis.

In nearly three decades of engineering work, Coleman has tackled many projects in development, test, and manufacturing. While at IBM, he received patents on the buckling spring keyboard, which Big Blue manufactured at the rate of more than 3 million annually in the late 1980s. He also developed the software to control production-line robots used for force displacement measurements on keyboards. In addition, Coleman served on a major industry committee to address concerns over carpal tunnel syndrome in office workers. T&MW



MEASURING SPACE

Phil Yates manages engineers with backgrounds in electronics, software, physics, and mechanical engineering.

STEVE LABADESSA

ENGINEERS AT JPL DEVELOP SYSTEMS TO TEST SPACE-BOUND EQUIPMENT.

MARTIN ROWE, SENIOR TECHNICAL EDITOR

PASADENA, CA—Unmanned spacecraft such as Voyager, Galileo, Cassini, and Spirit explore the unknown and expand human knowledge. The job of testing these spacecraft systems—and the measurement instruments they carry—falls to the Measurement Technology Center (MTC) staff at NASA's Jet Propulsion Laboratory (JPL). Headed by manager Phil Yates, a group of 13 engineers and one technician build interfaces for equipment chassis, write test software, develop control systems, and create data-acquisition systems.

MTC team members (Ref. 1) have backgrounds in electrical engineering, computer science, physics, mechanical engineering, and measurement sciences. But if you ask what they do, the engineers will say "we're measurement systems integrators." Because every project requires knowledge in several engineering disciplines, each engineer takes on tasks outside his area of expertise. "Even the computer science guys know how to wire a chassis," said Yates. "They resist at first, but we wear them down."

MTC engineers provide measurement expertise to projects at JPL and at other NASA sites. They also assist engineers and scientists at Pasadena's California Institute of Technology (Caltech), located a few miles away. Thus, not all MTC projects revolve around space-based systems. MTC engineers work on 20 to 25 projects at any time. Project engineers at JPL, other NASA sites, and Caltech may request MTC's help at any point in a project. "About 50% of the time, we're involved at the beginning of a project, which we call 'prephase A,' and that's what we prefer," said Yates. "Other times, we're called in when an engineer isn't getting predicted measurements."

Project engineers (MTC's customers) often have only a basic idea of what they need in a measurement system, so MTC engineers will study a project's technology and plan a measurement system. "When a project engineer comes to MTC," added Yates, "we set up a work agreement with as many requirements as we can. We'll take their high-level requirements and synthesize our detailed requirements, looking at things like flight safety issues, measurement uncertainties, and data display requirements." A project definition generally takes from a day to a month to develop.

A JPL project consists of milestones, schedules, budgets, demonstrations, and design reviews. A project must pass through a requirements review, a preliminary design review, a critical design review, and a pre-ship review. MTC engineers participate in project design and delivery reviews.

MTC engineers often hold their own design reviews where they discuss the details of the project from a measurement perspective. At these reviews, MTC engineers discuss the details of a measurement system's hardware, software, and workmanship. > > >

For example, they will open any custom chassis they build and inspect the chassis for workmanship and safety compliance. They review front and rear panels for clear labeling and for a logical and effective layout. They also inspect software for its architecture, implementation, and documentation. Finally, they review a spacecraft system's requirements for test and validation.

Because the customer isn't present at these reviews, MTC engineers freely discuss ways they could have done better. From each project, they learn how to improve future projects.

Space bus

In a recently completed project, MTC engineers built a test system for a spacecraft's radar controller. The test system emulates a spacecraft's data bus—a BCP 2000 from Ball Aerospace—by generating and receiving commands from the spacecraft's instruments. MTC engineers have also emulated the Japanese ADIOS spacecraft bus and are currently working to simulate the bus that will go into the Argentine SAC-D spacecraft, scheduled for launch in 2008.

FIGURE 1. To prepare the Dawn spacecraft for flight, MTC engineers placed it in a vacuum chamber and heated the spacecraft with lamps.

To emulate a spacecraft bus, MTC engineers often build custom hardware that includes a bus interface that lets a PC communicate with the spacecraft's payload, which are usually scientific instruments. The interface often consists of an RS-422 (or open collector) three-wire interface with data, clock, and enable lines. A bus may also contain analog and digital control lines.

To use a standard bus such as MIL-STD-1553, the MTC engineer simply buys an interface card for a PC. Even for standard buses, the spacecraft bus emulator will need custom software to generate the command sequences and display telemetry.

MTC engineers not only design, build, test, and deliver electrical and electronic systems, they also build systems that perform environmental tests. One such system is for the Dawn spacecraft, so called because its mission is to study the Ceres

MTC and LabView

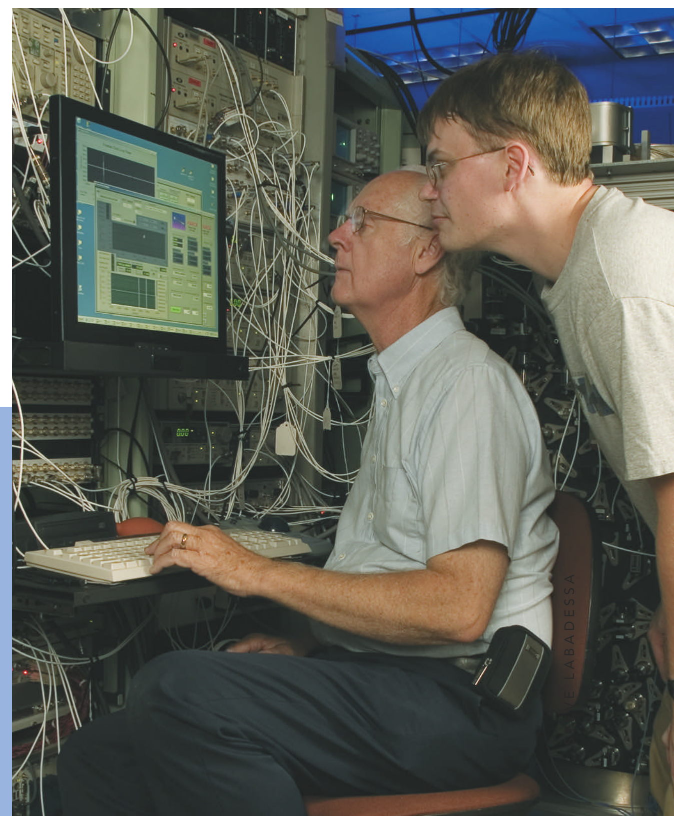
MTC's engineers have experience ranging from just a few years to almost 40 years. Senior software engineer George Wells has been with JPL since before Neil Armstrong walked on the moon in 1969. Wells is one of the world's first LabView programmers and was Erik Peterson's mentor.

Edmond Baroth, MTC's manager prior to Yates, introduced Wells to the then Macintosh-based graphical programming language. "Ed was smart in his introduction," said Wells. "He didn't try to sell it, he just asked me to evaluate it. I wasn't impressed at first because I didn't see the point in drawing pictures to add 2+2, but after two weeks working with LabView, I understood why it was a big deal. And that was version 1."

"LabView 1 wasn't quite ready for our use at first," he added. "It was an interpreted language, which made it slow. When you wanted to move an icon, you had to unwire it and rewire it." When National Instruments addressed his issues in LabView 2, Wells lost interest in building his own 6502-based computer systems in favor of using inexpensive computers. Since then, he's moved almost entirely into developing LabView programs and mentoring young engineers.

Wells gained some notoriety around JPL for his programming skills. On November 25, 1999, the Galileo spacecraft photographed a lava fountain from an eruption on Jupiter's moon Io. Io orbits the planet in an area where radiation interfered with transmissions of photographs that had been taken in October of that year. From the October images, Wells developed an algorithm that reconstructed them. He used the same algorithm on the November 25 images, giving scientists their views of the eruption. (Source: www.jpl.nasa.gov/releases/99/glliofire.html. Images from Io are at www.jpl.nasa.gov/pictures/io.)

Martin Rowe



Longtime JPL engineer George Wells (left) mentors Erik Peterson and others in software development.

STEVE LABADESSA

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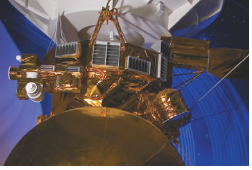

STEVE LABADESSA

Brian Franklin designs embedded systems and builds electronics chassis for testing spacecraft and earth-based systems.

and Vesta asteroids that may give clues as to the origins of our solar system. Scheduled to launch in June 2006, Dawn will use an ion propulsion system on its 10-year mission.

Dawn's three ion engines will use xenon gas to propel the spacecraft once it is out of earth orbit. For the engines to work, they need pure xenon. Chemical contaminants from Dawn's xenon tank must outgas before the spacecraft can launch.

To perform the outgassing, JPL engineers place the spacecraft in a vacuum chamber, pump out the air, and heat the spacecraft to 50°C before pumping pure xenon into the spacecraft's fuel tank. At the end of the test, JPL engineers will remove the xenon and analyze it for purity. Only when the xenon is sufficiently pure can Dawn get the gas it will use in flight.

During the outgassing process, the spacecraft resides in a mylar-covered frame that must meet cleanliness standards because it's in the vacuum chamber (**Figure 1**). Six lamp arrays heat the spacecraft main structure and internal xenon tank on four sides plus above and below. MTC engineer Mike McKee designed six power supplies and an interface box for Dawn. He also selected the purchased test equipment and wrote the software. Each power supply provides power for the lamps (**Figure 2**).

The data-acquisition system monitors 48 thermocouples, eight in each of the six temperature zones. A PC collects the data through an IEEE 488 port and controls the power to each lamp based on the highest temperature measurement in each zone. A National Instruments analog-output card in the PC drives silicon-controlled rectifiers that regulate power from the supplies to the lamps.

Each power supply contains an emergency stop button with interlocks that disable the vacuum pump and heat lamps. The data-acquisition system can trigger alarm signals should any temperature exceed preset limits. Alarm outputs go to a watchdog timer in the interface box that shuts down the system if it doesn't receive a pulse from the PC after 1.5 s (the PC produces a pulse every second.) When an alarm condition occurs, the signal will block the pulse from reaching the timer, shutting down the test. The timer will also terminate a test should the PC crash and stop producing pulses.

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The tank test system is one of three projects that MTC engineers participated in for the Dawn mission. Others were a tester for the spacecraft's Ion Propulsion Gimbal Actuator motors and a tester for its digital control interface unit (DCIU), which controls Dawn's ion engines. MTC developed a DCIU simulator that mimics the input and output signals. The simulator went to Orbital Sciences for integration testing.

Earthbound

Because of changing priorities, some of the products that MTC engineers test never go into space—yet they remain viable, useful products. One example is a cesium-fountain atomic clock. Intended as a science experiment in accurate timing, the clock could have provided a 10x increase in timing accuracy because of zero gravity.

Although earthbound, the clock is still one of the most accurate in the world. From its location at JPL, it can provide a timing reference for the Deep Space Network (DSN) where precise timing and low noise signals contribute to improved navigation and tracking and a greater dynamic range for the DSN receivers. JPL can compare this clock to other clocks on the campus or to Universal Coordinated Time. Other cesium-fountain clocks are located at NIST and at USNO (Ref. 2, 3).

A cesium-fountain clock uses the atomic transition of cesium atoms as they free fall as a result of the earth's gravity. The fall produces an oscillation at 9,192,631,770 Hz, which serves as a reference for a microwave signal source. The clock's two instrument racks also contain lasers, laser controllers, oscilloscopes, and other equipment (**Figure 3**). Laser controllers from ILX Lightwave, power supplies and mi-

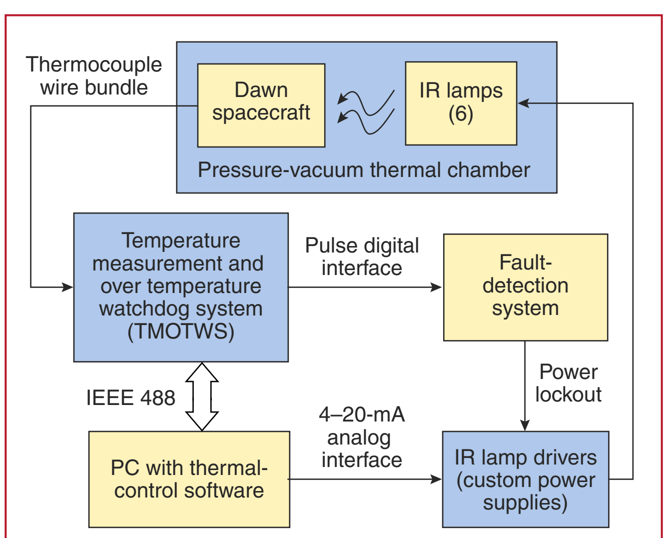

FIGURE 2. Custom power supplies power the lamps that heat Dawn while it is in the test chamber. A data-acquisition system measures Dawn's temperature during outgassing.

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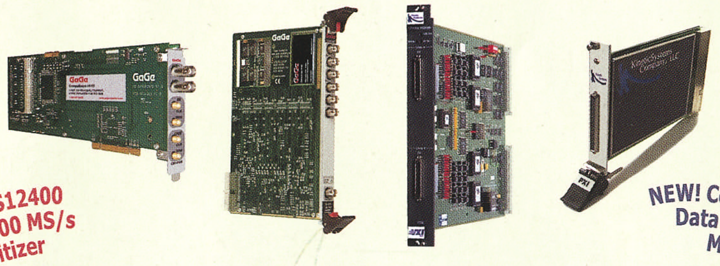

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crowave sources from Agilent Technologies, oscilloscopes from Tektronix and Kenwood, and other products populate the racks. The clock also has a chamber that contains the cesium atoms.

To develop the clock's control system, Yates assembled a team of MTC engineers with expertise in electronics, microwaves, real-time control systems, and physics. Physicists collaborated with hardware engineer Brian Franklin and software engineer Erik Peterson so they could develop the clock's hardware and software. Senior engineer James Granger designed a microhertz resolution X-band synthesizer with ultra-low phase noise for this task.

Three computers run the clock. A single-board computer (SBC) in a VME chassis runs the clock's equipment, a PXI chassis handles timing calculations and data acquisition, and a Windows-based PC handles the user interface. If the clock had gone into space, another embedded controller would have replaced the PXI chassis. A PC now emulates the Space Station interface and sends commands and receives data packets from the SBC.

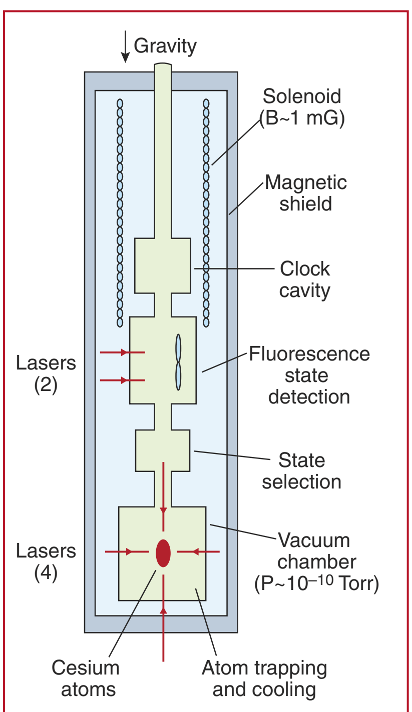


FIGURE 3. A cesium fountain clock uses a vacuum chamber to excite the cesium atoms, which generate a known, repeatable frequency.

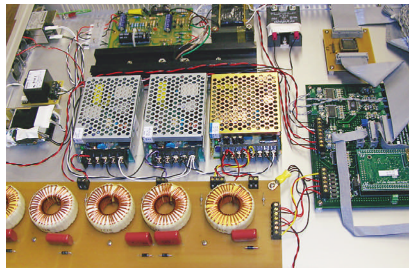


FIGURE 4. A chassis contains control electronics and power supplies for an atomic-force microscope.

All three computers run LabView, with the SBC running a prototype version of embedded LabView on the VxWorks real-time operating system. "When we took on the project," said Yates, "we knew that we had to write the software in LabView because that's where we have our greatest depth in programming, although we use C, C++, and Visual Basic, too." JPL's experience with LabView dates to the 1980s with version 1. "MTC and LabView," p. 30, traces MTC's experience with the programming language.

Beyond JPL

MTC engineers support projects outside of JPL, too. Recently, Franklin and Peterson automated a 10-nm atomic-force microscope for Caltech that researchers use to study molecular interactions.

The original microscope used a commercial off-the-shelf controller from Digital Instruments. The Caltech researchers who built the microscope manually operated its control loop. "When we arrived," said Franklin, "we saw them controlling optics' offsets and gains with knobs mounted in 14 little boxes." So, they reverse-engineered the manual control system and designed an automated control system that drastically cuts focus time. "The reverse engineering cost was 50% of the entire cost of designing and building the control chassis," noted Yates. "Brian had to figure out what the Caltech people were doing and why before he could design the hardware."

Franklin designed a custom chassis (**Figure 4**) that includes a PCB with a four-channel, 16-bit analog-to-digital converter (ADC) and three 14-bit digital-to-analog converters (DACs). Each of the three analog outputs controls a switching power supply. One is a 100-V supply that drives the probe tip's height (z-axis) for

image focus. The other two power supplies control the mirrors for movement of the sample in an x-y plane. They drive a nanopositioner from Mad City Labs that moves mirrors so that they can scan a laser across the sample in a raster pattern. The large inductors filter the power supplies' outputs to levels cleaner than those from linear power supplies. The ADC reads data from a nanopositioner, which indicates the x and y positions of the microscope's probe tip relative to the stage that holds the sample. The controller's software keeps the laser in position relative to the sample. Peterson developed the software in LabView.

Franklin explained that as the stages move, the probe tip oscillates just above the sample. "At the top of its movement, the tip's output signal is down in the noise," he said. "As it approaches the sample, the signal amplitude grows because the probe tip detects more photons." A National Instruments' high-speed data-acquisition card in a PXI chassis digitizes the height signal, so the embedded controller knows the tip's height from the sample. Software in the PXI chassis subtracts the noise from the acquired signal.

As the stages move, a photon detector in the microscope probe counts photons at each stage location and produces a pulse train that represents light intensity. In effect, it counts photons. A counter card in the PXI chassis counts the pulses, from which software in the PXI chassis' controller creates images and sends them to the host PC over an MXI link. Researchers can view the images and study how a sample's molecules interact.

Whether they need a test system for spacecraft hardware or they need automation and programming expertise, project engineers from JPL, other NASA sites, or Caltech rely on MTC for help. With measurement systems developed at MTC, missions such as the Mars Rover and Voyager will keep expanding our knowledge of the universe for years to come. T&MW

REFERENCES

1. JPL's Measurement Technology Center consists of two groups. A metrology group and the Measurement Systems Group. The Measurement Systems Group has become synonymous with MTC.

2. "NIST-F1 Cesium Fountain Atomic Clock: The Primary Time and Frequency Standard for the United States," National Institute of Standards and Technology, Boulder, CO. tf.nist.gov/cesium/fountain.htm.

3. "The USNO Cesium Fountain Project," United States Naval Observatory, Washington, DC. tycho.usno.navy.mil/clockdev/cesium.html.

Related Web sites

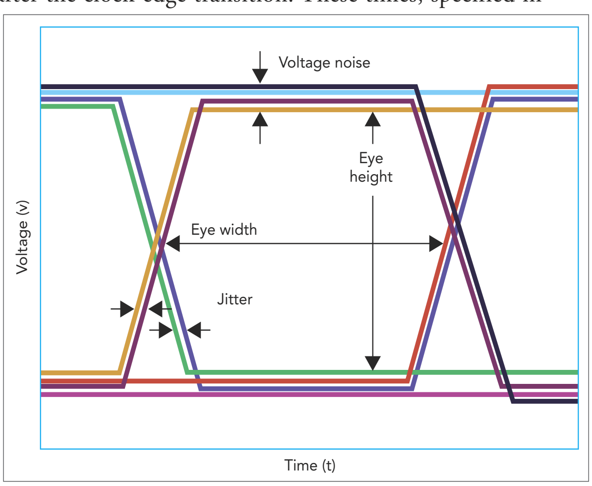
- Caltech, www.caltech.edu
- Dawn spacecraft, www-ssc.igpp.ucla.edu/dawn
- Galileo spacecraft, galileo.jpl.nasa.gov
- JPL, www.jpl.nasa.gov

THE DATA DETECTIVE

Digital Signals Arrive on Time

Clock signals comprise rising edges (logic-low to logic-high transitions), and falling edges (logic-high to logic-low transitions). A clock signal can exist as square waves with a regular period and duty cycle or as a continuous series of periodic pulses. The latter type of signal can trigger a latch to accept data, interrupt a microcontroller, and so on. Regular clock waveforms govern the timing of microprocessor-based controllers, communication systems, memory chips, and other devices that perform operations at regular intervals. Depending on the clocked device, either a rising or a falling clock-signal edge causes an action. A device such as a double data-rate (DDR) memory uses both clock edges to trigger actions.

Clock signals do not cause instantaneous actions, though. A memory device, for example, requires the presence of unchanging data during a fixed amount of time, called the set-up time (t_{su}), prior to the arrival of a clock signal. The data must then remain stable for a specified hold time (t_H) after the clock-edge transition. These times, specified in



In this eye diagram, the overlaid samples of all 3-bit states show how jitter and voltage noise appear on a clock signal. Many communication signals must conform to standard templates that define minimum eye values (colored lines exaggerated for emphasis).

chip manufacturers' data sheets, ensure designers know the timing requirements for the data and clock signals input to a device. A hand-drawn timing diagram may show the theoretical action of clocked circuits, but the design of complex circuits requires simulations that account for timing values such as t_{su} and t_H.

Unfortunately, clock signals come with imperfections such as jitter and drift. Drift occurs when the period of two clocks differs slightly over time. These slight timing differences can accumulate and affect a system adversely. For example, assume researchers have two data-acquisition devices that each supply a 100-MHz clock. Even if the two devices are synchronized to start together perfectly, over time one device may begin to run slightly faster than the other due to circuit imperfections or due to an external factor such as temperature. That difference badly skews the data the researchers expect will align perfectly in time. Timing techniques can reduce or eliminate drift.

Jitter represents a slight deviation in the timing of a signal's edges during a clock cycle, and it can arise from signal cross-talk, switching transients, and the effect of other signals. Engineers generally measure jitter as a time difference between the clock signal of interest and a reference clock signal at their zero-crossing points. Jitter measurements range from a visual estimate on an oscilloscope to quantitative measurements that extract statistical data from many signal samples.

The sequential acquisition of a clock signal over three periods produces a diagram that reveals both jitter and voltage noise. Because the signal may produce any of eight binary patterns during an acquisition, a measuring instrument overlays millions of signal samples to create an "eye" diagram (see figure). The overlay diagram lets engineers determine a signal's maximum jitter and voltage noise. As these errors increase, the eye width and height decrease. The better the quality of a digital signal, the more open the eye. Said differently, engineers strive to maximize eye width and height.

When an eye diagram comprises millions of samples, the eye width indicates the time the data lines remain stable. Thus, engineers can determine how much set-up and hold time a clock signal provides.

A Case of the Jitters?

The microcontroller board Jane designed seems to suffer from intermittent problems. The microcontroller's specifications list tight timing requirements, so the cause of intermittent behavior may rest with Jane's new clock circuit.

Can you help Jane analyze her clock signal to identify possible problems?

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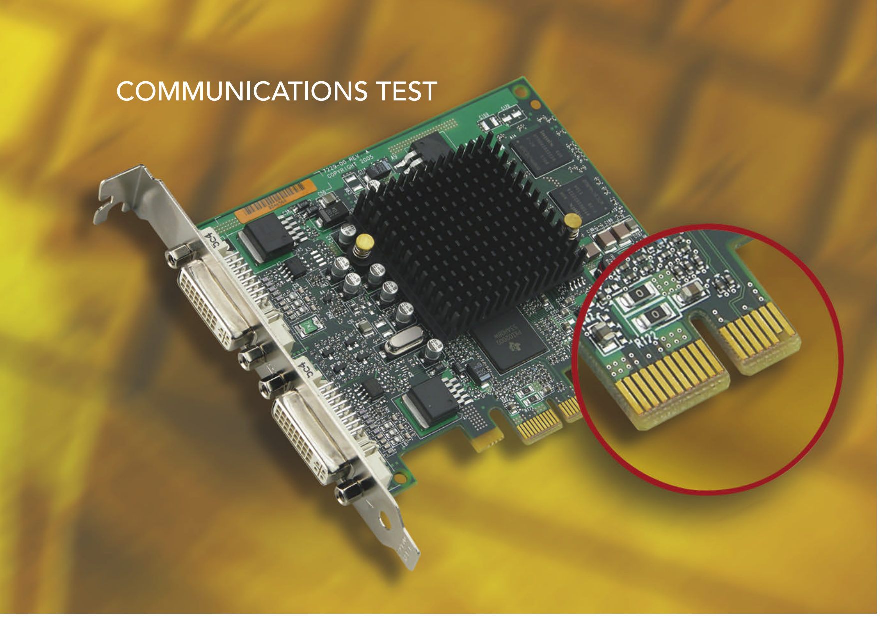


Physical-layer and protocol-layer tests can minimize interoperability problems.

TESTS RIDE *the* PCI EXPRESS

EUGENE SUSHANSKY AND
JOHN GUDMUNDSON,
PLX TECHNOLOGY,
AND
CHUCK TREFTS,
CATALYST ENTERPRISES

Riders on city buses must follow certain rules: move to the rear, signal the driver to stop, and give up your seat to someone who needs it more than you do. Likewise, devices that "ride" the PCI Express—bridges, endpoints, motherboards, add-in cards, root complexes, and switches—must follow rules as well. You can ensure your PCIe devices follow these rules—and work with other PCIe devices—by performing a series of compliance tests.

Because it's a serial bus, PCIe requires testing at the physical layer (PHY) and at the protocol layers above it (**Figure 1**). Each layer must comply with many pages of specifications published by the PCI Special Interest Group (PCI SIG, www.pci-sig.com). The PCI SIG also publishes a series of compliance checklists and organizes workshops where you can run interoperability tests. Before attending a workshop, you can perform tests in your lab using the checklists as a guide. (See "Checklists and workshops," p.42.)

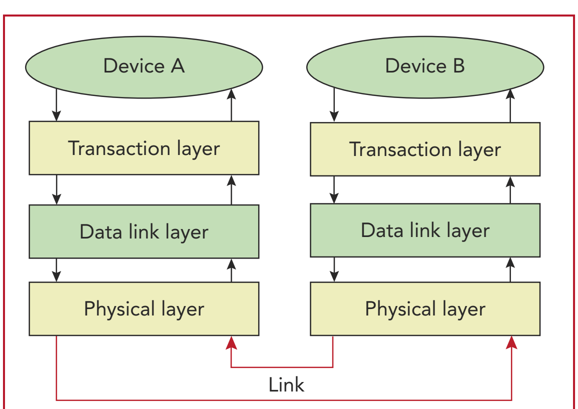


FIGURE 1. PCI Express uses two protocol layers on top of a physical layer.

Start at the PHY

Successful PCIe interoperability starts at the PHY, which consists of logical and electrical sub-blocks that manage data encoding and decoding as well as lane configurations and variations. They also cover a myriad of electrical signal specifications. PCIe products must link at the PHY layer before higher layer connections—and data transfer—can occur.

PHY testing begins with the differential signal lanes on the PCIe bus. Transmitted (TX) bits come in two versions: transition bits (**Figure 2**) and nontransition bits (**Figure 3**). For each, you need to analyze data streams by using eye diagrams to measure their amplitude and jitter.

You can test the signals on TX lanes for electrical compliance by using an oscilloscope with a differential probe. You can generate a compliance-test pattern from any PCIe device through a device's state machine. To invoke the test pattern, terminate the TX lane with a 50-Ω resistor or 50-Ω oscilloscope probe. If the device's receiving (RX) lane has no activity on power up, the state machine will transmit a compliance test pattern.

To make eye-diagram measurements, you need to generate 3500 unit intervals (UIs). Use an oscilloscope to make the measurements on the 250 UIs that occur

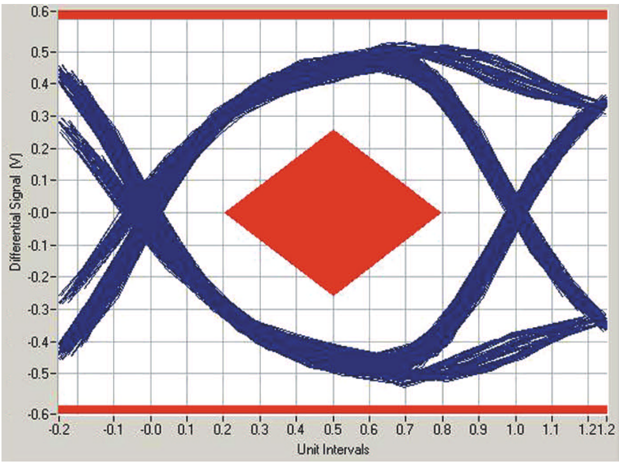


FIGURE 2. Transition bits, which occur when a bit changes state, form a complete eye opening.

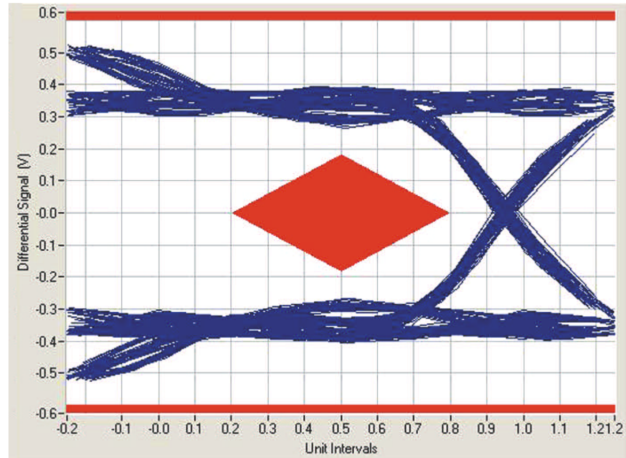


FIGURE 3. Nontransition bits must comply with eye-diagram specifications such as eye opening and amplitude.

in the center of the 3500-UI pattern. A compliant eye opening will show transition bits with a minimum differential amplitude of 800 mV_{p-p}. Nontransition bits should have a minimum differential amplitude of 505 mV_{p-p}. But higher amplitude values aren't necessarily better. Compare the signal's eye opening and amplitude to specified limits.

A perfect eye, if one existed, would have an opening of 1.0 UI. PCIe specifications allow no more then a 30% loss from 1.0 UI (0.7 UI or greater) for TX, and they require 40% (0.4 UI) or larger UIs at a receiver's input. The 30% loss is a jitter budget allocated for board layout and other possible loss contributors between a transmitter and a receiver.

PCI SIG specifications require that you test a receiver's ability to extract a clock that's embedded in transmitted data. Like several other serial buses, PCIe uses 8b/10b encoding to minimize long runs of the same bit, thus making transition bits frequent enough for a receiver to extract the clock. "PHY encoding," p.44, explains why 8b/10b character encoding improves a receiver's ability to recover a clock from a data stream.

PHY problems can appear as errors at the protocol layers. For example, problems in the electrical portion of the PHY will often result in invalid characters or disparity errors. You can use a protocol analyzer to track such errors over a specified time interval.

A protocol analyzer can simulate a PCIe device by sending two transaction layer packets (TLPs) to a device under test (DUT). The packets should generate several responses from the DUT across all three layers, and the protocol analyzer can check these responses for errors. You should perform this test before diving into other protocol tests to make sure that the link's physical integrity is intact.

Data-link layer

Once you complete the electrical and logical PHY tests, you can move to protocols. Testing progresses up the protocol stack, through the data-link and transaction layers, where you must verify the operability of devices working under control of their drivers and applications.

The PCIe data-link layer ensures the integrity of communications between the two directly communicating devices. The data-link layer serves many functions, including:

- flow control initialization,
- flow control updates,
- ACK/NAK protocol,
- power management control,
- cyclic redundancy checks (CRCs),
- transaction sequencing, and
- replay of failed transactions.

Communications between PCIe devices occur in data-link-layer packets (DLLPs). In addition to providing origin and terminus to various DLLP communications, the data-link layer adds or removes information and checks for proper transaction sequencing and data integrity. When a PCIe transaction passes from the transaction layer to the data-link layer, the data-link layer appends it with a sequence number and a 32-bit link CRC (LCRC).

A PCIe receiver uses the sequence number to verify correct transaction ordering, and it checks the LCRC to verify error-free

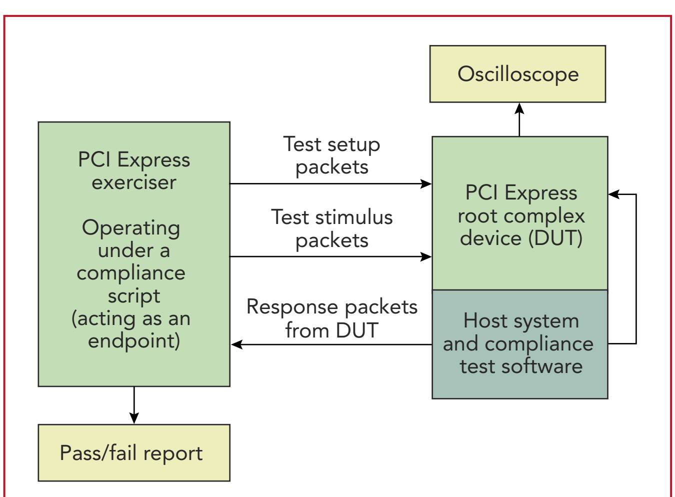
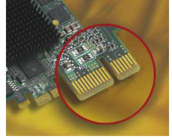


FIGURE 4. A typical test setup for a PCI Express device requires setup, stimulus, and response packets. An oscilloscope lets you measure jitter and eye openings.



data. If a receiver detects sequencing or packet-integrity errors, it will instruct the transmitter to resend the failed transaction. If a device receives DLLPs without error and in the proper order, the receiver strips away the sequence number and LCRC fields before it passes the packets to the transaction layer.

As part of a PCI SIG compliance test, you need to test a device's ability to react to malformed packets, including whether the device properly reports errors to system registers through the root complex. See **Figure 4** for the compliance test setup. A PCIe bus exerciser acting as a bus endpoint, and under control of an automated compliance test script or used manually, emulates a transmitting device. With the exerciser, you can force noncompliant data-link-layer responses, transaction-layer responses, or no response.

The exerciser can also simulate a transmitter to test another device's error-handling characteristics, its device driver, or its application software. Operating as an endpoint, the exerciser can send a pre-queued DLLP, such as an ACK or NAK packet with a corrupt 16-bit DLLP CRC, in response to a received transaction. Or it can send an incorrect sequence number embedded within a complete transaction. Logging and evaluation of such responses can help you identify interoperability problems and their root causes.

Transaction layer

The PCIe transaction layer encapsulates data-link-layer information and control characters into TLPs that move information from point to point and throughout the PCIe fabric. These transactions echo PCI and PCI-X transactions, with a message transaction added for PCIe communications. Message transactions, used for power management, interrupt signaling, hot-plug support, error reporting, and vendor-specific purposes, eliminate the need for sideband signaling.

The transaction layer performs various error checks, including:

- TLP packet format,
- timeout errors on completion packets,
- flow control operation,
- notification of unsupported requests,
- data corruption (through data poisoning),
- end-to-end CRCs (ECRCs), and
- unexpected completions.

Transactions at this layer come in two variations: posted or nonposted. Memory

Checklists and workshops

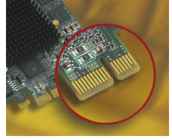
The PCI Special Interest Group (PCI SIG) workshops divide testing into two distinct areas: interoperability testing among devices and systems from the various attending companies and Gold Suite testing performed by the SIG. Your product must successfully pass both types of testing for it to comply with the PCIe specification. To help you prepare for a compliance workshop, the SIG has developed several checklists that provide detailed requirements for PCIe bridges, endpoints, motherboards, BIOS, add-in cards, root complexes, and switches.

Interoperability testing at the workshops lets you confirm proper and reliable operation between PCIe systems and devices. You may uncover interoperability issues between systems and devices that you may not find from either the SIG Gold Suites testing or the checklists.

PCI SIG tests range from low-level physical testing to protocol-oriented tests. But they aren't exhaustive, because the PCIe specification contains thousands of rules across all layers, and testing time is limited at workshops.

If your product meets compliance specifications, you can get it on the PCI SIG's integrator's list. To get on the list, a company must submit self-completed checklists for its products after they pass the tests at a workshop. Each checklist contains a common cross-section of test areas, including electrical, link and transaction layer, system architecture, power management, and configuration testing. Plug-in cards and motherboards also need an electromechanical section. The motherboard checklist also includes a test section on BIOS operation.

Eugene Sushansky, John Gudmundson, and Chuck Trefts



writes and messages are posted transactions, which don't require transaction-layer completion packets. Memory reads, I/O reads and writes, and configuration reads and writes are nonposted, and thus require a completion packet. Nonposted transactions are modeled similarly to the PCI-X split-transaction protocol (request/completion).

Compliance testing at the transaction layer requires that you simulate a device and verify that the DUT responds properly to errors. A protocol analyzer, for example, must intentionally transmit a packet with a header bit set to indicate data poisoning, with the analyzer programmed to provide a pass/fail indication based on the receiving device's response.

The error-poisoned (EP) bit in a TLP's header indicates corruption of payload data. Devices may send a corrupt payload in various ways. A requester can fetch data from memory that may include a parity error or internal data corruption. Device responses to a poisoned packet might include a returned completion TLP with a status field set to unsupported request (UR), appropriate updates to error registers, or the disposal of the received payload data.

A formatting error associated with the packet will produce a malformed TLP. Examples include mismatches between the payload size and the header's payload length field, byte-enable violations, incorrect type field values, and improper transaction routing. Each possible malformation requires an individual test case to confirm compliance.

The transaction layer also handles proper flow control, which ensures that a device won't send data across the link until a receiver is ready to receive. The transaction layer must ensure that a receiver has enough buffer memory to

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PHY encoding

The PCIe bus uses the popular 8b/10b encoding scheme, which formats every eight bits into 10-bit characters. The 8b/10b format provides sufficient bit-level transitions for a receiver to recover an embedded clock, which eliminates the need for a separate clock. The 8b/10b scheme also produces a balanced DC link because it eliminates long streams of 0's or 1's. Most of these 8b/10b characters have both negative and positive variants, and some provide a neutral disparity. Some examples include:

Positive disparity (more 1's than 0's):
0 0 1 1 1 1 0 1 0 1

Negative disparity (more 0's than 1's):
1 1 0 0 0 0 1 0 1 0

Neutral disparity (equal number of 0's and 1's):
0 1 0 1 0 1 1 1 0 0

To maintain the DC balance, a running-disparity function in the transmitting device makes on-the-fly decisions on the polarity of each transmitted character. That is, it determines whether the number of 1's transmitted approximates the number of 0's transmitted. This encoding mechanism eases link synchronization, simplifies receiver and transmitter designs, and improves error detection based on the characterized data at the 2.5-Gbps data transfer rate.

PCIe also scrambles the data just prior to the 10b encoding in the transmit device's PHY logic. Scrambling removes repetitive patterns in the bit stream, which otherwise could concentrate energy at discrete frequencies. Scrambling also spreads energy over a frequency range, resulting in a more EMI-friendly architecture. Not all information moving across the link is scrambled; control characters and physical layer ordered sets are not scrambled.—*Eugene Sushansky, John Gudmundson, and Chuck Trefts*

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handle the next transaction. Protocol errors can cause a device to refuse to send transactions or to overrun buffers on the receiving device. You need to test flow control for proper passing of data as part of your compliance tests.

Flow control is important because different types of packets need different priorities. A time-critical application such as video needs a higher priority than data retrieved from a hard drive. PCIe devices use the virtual channel/traffic class (VC/TC) concept to prioritize data, which further complicates compliance testing. Application programs and device drivers make the TC assignments and allocate memory to VC buffers (hardware on switches, endpoints, and root complexes). PCIe switches route traffic based on the VC/TC mapping.

You can test prioritization once a PCIe bus exerciser or application software classifies data to a given TC. Use a protocol analyzer to verify the packet header has the proper 3-bit TC tag. Then, once a PCIe device maps data to the VC configured for that TC, use the analyzer to view the data.

Compare the TC characteristics of this egress data to the source data and verify the expected output. The expected TC packets should match each type of known ingress TC packets and the relative weighting of TC to VC.

A variety of physical and logical factors can produce data-transmission problems. Examples include marginal quality of the transmitted data, corrupt physical media, marginality at the receiving device, or a noncompliant optional reference clock. But with thorough testing of all layers of the PCIe protocol stack and their interactions with drivers and application layer software, you can minimize interoperability problems. T&MW

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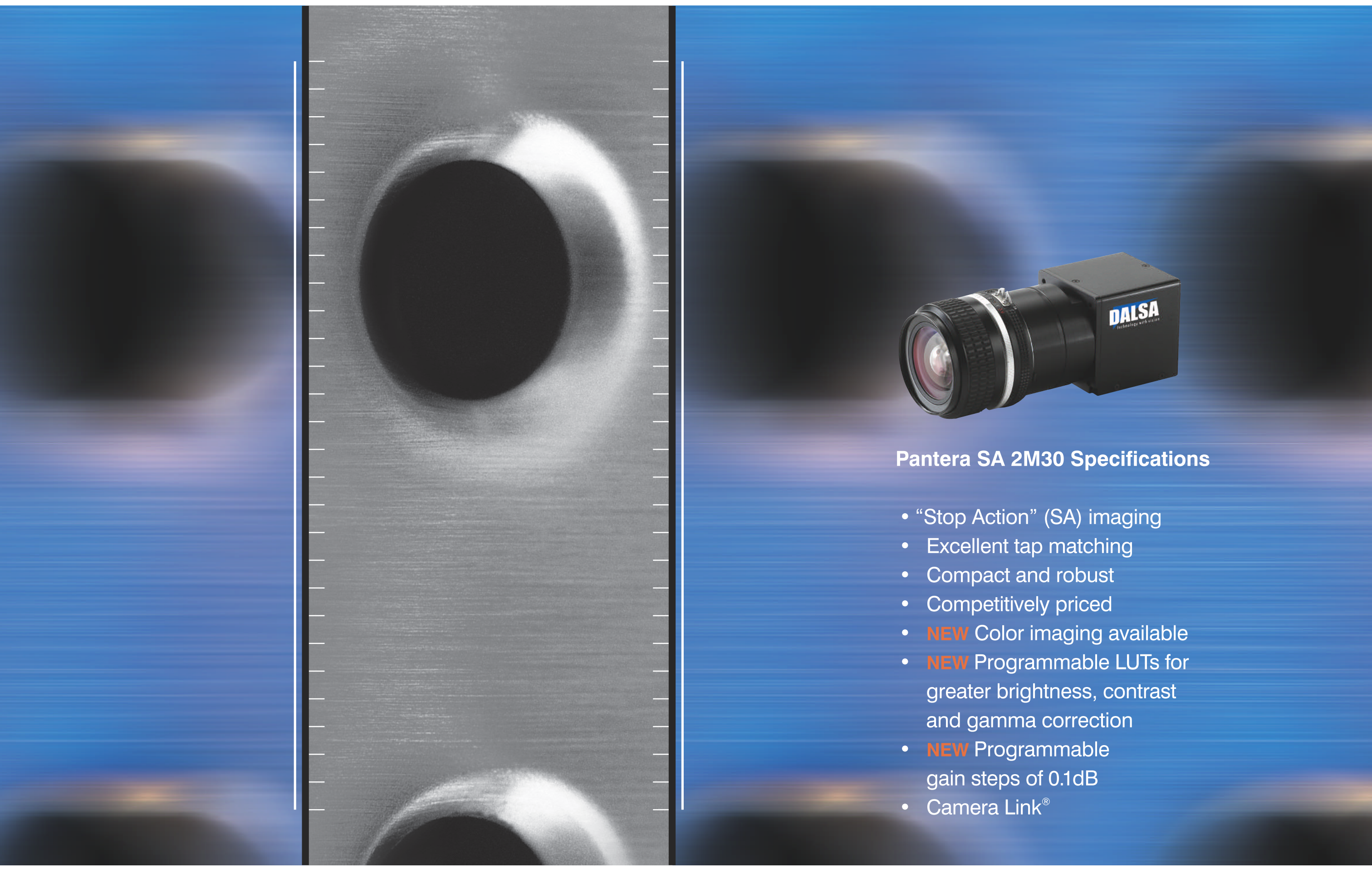

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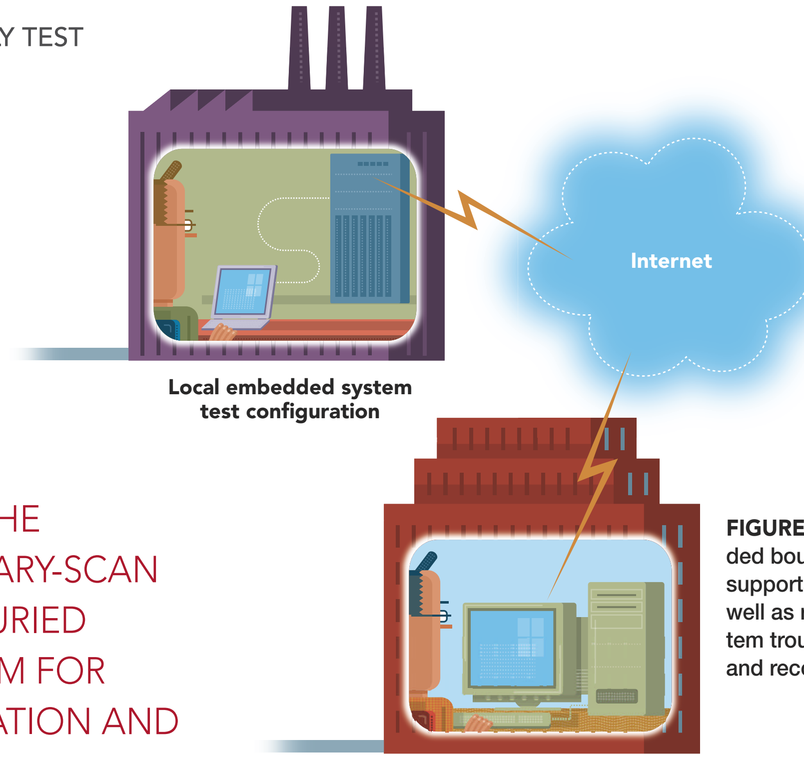

FIGURE 1. Embedded boundary scan supports local as well as remote system troubleshooting and reconfiguration.

BOUNDARY SCAN GOES UNDERGROUND

DAVE BONNETT, ASSET INTERTECH

Boundary scan (IEEE 1149.1) evolved as a board-level test method, but new developments are making the technology attractive for embedded and system-level test and in-system programming operations. With boundary scan entering its second decade, new and exciting vistas are certainly in the offing.

If you use boundary-scan for manufacturing test and configuration, you already have a great deal of boundary-scan infrastructure embedded in your chips, boards, and systems. You can put that infrastructure to good use throughout your product's life cycle if you take the next step and embed hardware and software boundary-scan controllers, test patterns, logic reconfiguration operations, and other facets of the technology.

The motivation behind embedding and applying boundary scan across a broader, system-wide spectrum is significant cost savings. For example, making a field upgrade to the firmware stored in programmable logic devices or flash memories might require a veritable army of field engineers and untold hours of labor. Instead, with embedded boundary scan and a little planning, you can use the Internet to upload firmware upgrades to systems in the field. In the same way, remote diagnostics could determine the cause of a poorly performing system, isolating the fault before a technician is dispatched or perhaps eliminating the need for an onsite technician altogether (**Figure 1**).

Embedding boundary scan

Embedding boundary-scan operations into a system implies that the system has the ability to execute JTAG operations independently of any other system, test controller, or boundary-scan engine. Of course, this capability does not vitiate the importance of externally applied boundary-scan operations. The bulk of JTAG operations are applied to the unit under test (UUT) or the unit being programmed from an external boundary-scan system linked to the UUT by a standard cable connection. Embedded boundary scan can certainly be used in both manufacturing and field service, although most embedded boundary-scan applications are limited to pass/fail testing. Pass/fail tests can be useful in a manufacturing setting to identify problems. Then, the

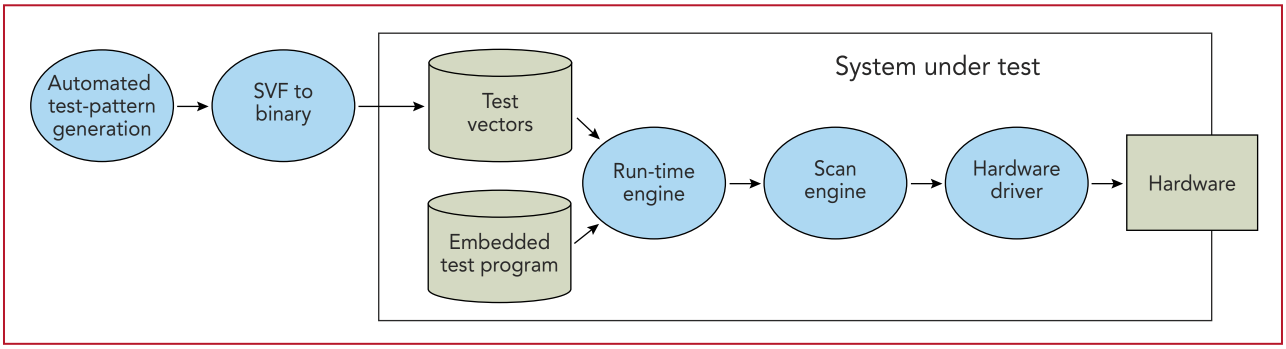

FIGURE 2. In a typical embedded boundary-scan test flow, boundary-scan software generates test vectors and converts the resulting serial vector format (SVF) information to binary test vectors stored on the system under test. An embedded test program applies the vectors to the hardware under test.

more extensive diagnostic capabilities of an external boundary-scan system can be applied to diagnose failures offline from the manufacturing process.

To embed boundary scan, you must design some of the capabilities of an external boundary-scan engine into the system. To what extent you embed the facilities of an external JTAG system into a particular product will depend on how embedded boundary scan will be used once the product is in the field.

At a base level, embedded boundary scan requires the capabilities of a run-time JTAG engine and storage space for test vectors and programming algorithms. **Figure 2** shows a typical scenario where a stand-alone boundary-scan system in the factory generates JTAG test patterns and programming algorithms, converts them to a compact binary format, and stores them in the system before it is shipped to the field. An embedded run-time engine assembles boundary-scan operations and passes them to a scan engine for application on the system.

Several commercially available software and hardware products can help you embed boundary-scan test and programming operations. Texas Instruments, National Semiconductor, Firecron, and Alliance Semiconductor provide devices that act as embedded boundary-scan controllers or test sequencers. These vendors also provide example application programs. Boundary-scan system providers supply other tools. Asset Intertech, for example, provides vector translation tools to convert test programs into Serial Vector Format (SVF) for Texas Instruments applications, Embedded Vector Format (EVF) for National Semiconductor devices, or Binary Vector Image (BVI) for Firecron and Alliance Semiconductor applications.

Test results may be reported as simple pass/fail results and communicated to a predefined location outside of the system. For this case, you need little in-system memory to store test results. If you intend the tests to trigger follow-on diagnostic routines, then you'll need to provide more memory to store test results in-system.

Architectural issues

Systems with embedded boundary scan will typically consist of more than one circuit board or subassembly. Often a backplane is involved. Architecturally, you must determine how best to implement the boundary-scan interface across multiple circuit boards and subassemblies. You might choose star or ring architectures, but both have inadequacies. Most often, a multidrop architecture is effective for deploying embedded boundary scan.

In a multidrop architecture (**Figure 3**), you route all boundary-scan signals to all boards or subassemblies in the system. Each board has an addressable JTAG gateway device that is capable of recognizing the boundary-scan information intended for it. The gateway device intercepts the information addressed to it, configures the local scan paths accordingly, and applies the boundary-scan operations to the devices and structures on the board. You can obtain boundary-scan gateway devices from a number of semiconductor vendors like TI, National Semiconductor, Firecon, and Alliance. In addition, you can implement boundary-scan gateway functionality in the form of an intellectual property (IP) core into a programmable logic device (PLD). Lattice Semiconductor, for example, provides an IP core supporting scan linking functionality. In addition, Asset provides device models of these gateway devices. Device models automate the inclusion of the gateway devices into boundary-scan test and programming operations.

Costly NTF

Any dent in a manufacturer's "no-trouble-found" (NTF) predicament would reduce maintenance and support costs tremendously. The NTF predicament comes about when a field technician replaces what seems to be a faulty circuit board or subassembly in an effort to return a critical system to full service quickly. Later test of the removed circuit board often results in an NTF indication, but by that time, the manufacturer has incurred significant costs by dispatching the technician and by testing and requalifying the circuit board. One manufacturer of high-end computers has estimated that it can cost as much as $25,000 to return a circuit board to service.

Embedded boundary scan enables more precise structural diagnostics that can be applied either remotely or locally to more accurately determine the module that is causing the problem. No matter how it is applied, embedded system-level boundary scan can greatly diminish a manufacturer's NTF problem.—*Dave Bonnett*

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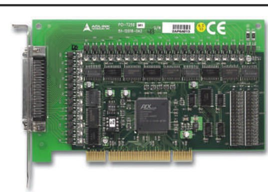

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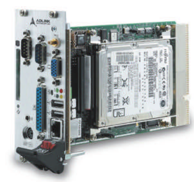

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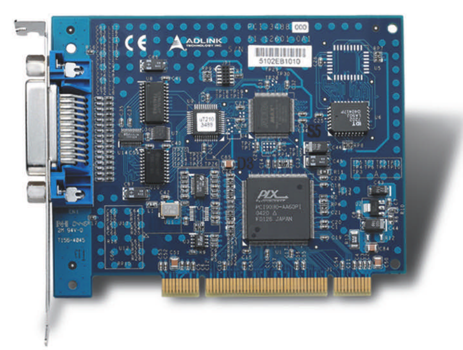

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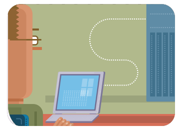

Once you have established a multidrop architecture for embedded boundary scan, you can locally configure the elements in the system in any of four ways:

- **No master, all slaves.** With no master over JTAG operations, an external boundary-scan bus master or controller must apply the boundary-scan operations. A commercially available boundary-scan test system generally manages all boundary-scan operations, so you don't need to dedicate an onboard processor to that task, nor do you need to develop coordination software for a master processor. And since the external system monitors the results of the boundary-scan operations, you need not provide in-system storage for those results. The tradeoff for not having a master processor, however, is that a technician must connect an external boundary-scan system to the unit under test to execute the boundary-scan operations.
- **Single master, multiple slaves.** With an embedded JTAG master processor in a multidrop architecture, the system can be remotely tested, reprogrammed, reconfigured, or monitored in real time. Of course, having just one JTAG master represents a potential point of failure with no fail-safe redundancy. In addition, the JTAG master processor will require software for coordinating embedded boundary-scan operations. And the system will require memory for the software as well as for storing the results of JTAG operations. Because of the system-specific nature of embedded boundary scan, the embedded JTAG master processor is usually a proprietary program developed by the user specifically for the system under test. The JTAG master supports the communications link between the system under test and any remote boundary-scan test or diagnostic system.
- **Multiple masters with a backplane.** For a mission-critical system, you can design in multiple JTAG masters for fail-safe redundancy. In addition to requiring the other facets of a single master configuration, multiple masters would need software to facilitate an effective handoff from one master to another should the initial JTAG master fail. A variety of standard programming tools can be used to develop these embedded application-specific capabilities, but close consultation with the boundary-scan system provider will ensure that the embedded boundary-scan processes conform to the requirements of the JTAG standard while minimizing the internal resources devoted to embedded boundary scan.
- **Multiple masters without a backplane.** If you want to keep the JTAG signals off the backplane, you can provide a JTAG master on each circuit board or subsystem. Each JTAG master is connected to an external communication link through which you can initiate boundary-scan operations and retrieve test results. All boards can be tested or re-

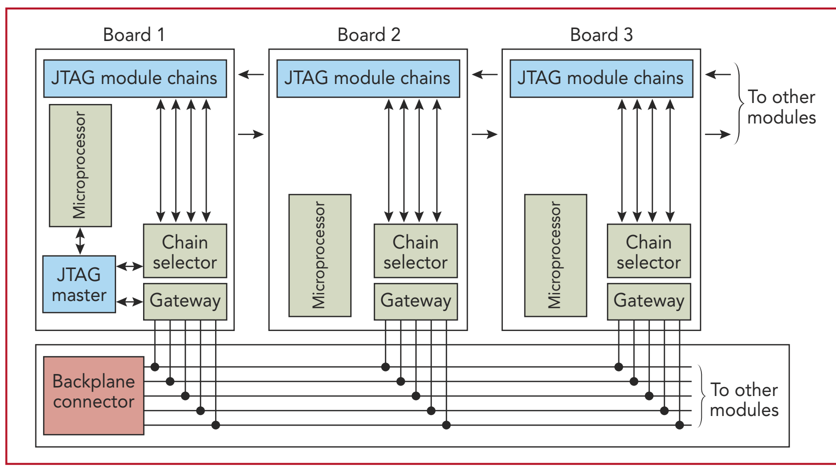

FIGURE 3. A multidrop architecture routes boundary-scan signals to all system boards. In this "single master, multiple slaves" configuration, an embedded JTAG master on one board controls system-wide boundary-scan operations. For fail-safe redundancy, you can choose to embed a JTAG master on each board. Boundary-scan signals can travel over a backplane or along dedicated paths.

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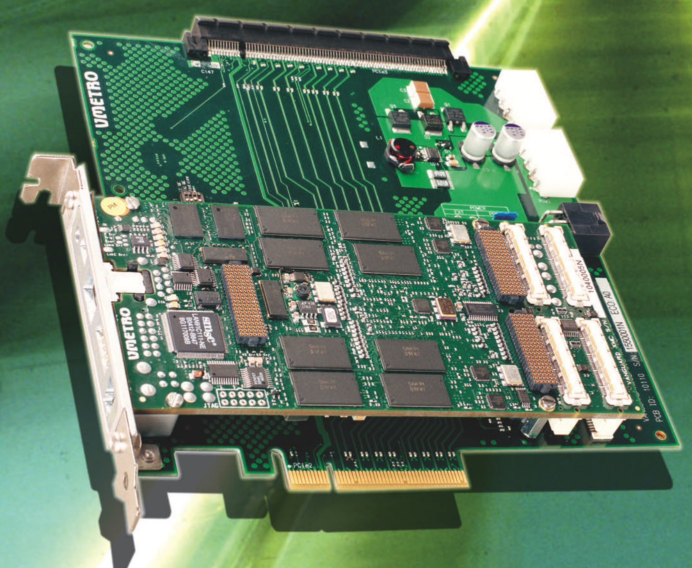

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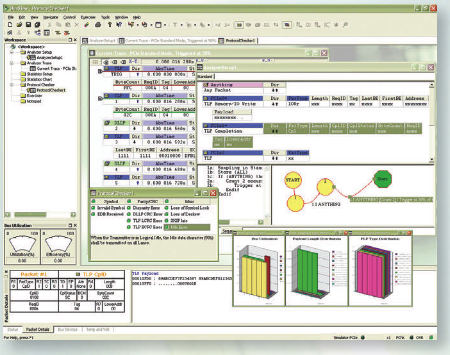

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configured simultaneously. This approach eliminates the need for a JTAG gateway device on each module, but it increases the complexity of JTAG operations because test vectors and programming algorithms for module-to-module operations must be put together for the entire system instead of a single module at a time. This approach still supports remote monitoring, testing, and programming.

Implementation issues

Deploying embedded boundary-scan test as well as in-system programming and reconfiguration of PLDs raises additional questions beyond those involving the architecture. For example, will the configuration of systems in the field be static, or could new circuit boards or assemblies be introduced to alter the configuration at a later time?

A static system-level configuration simplifies the implementation of embedded boundary scan since the composition of the embedded boundary-scan operations is not subject to change. But if the system configuration is dynamic, as it is with most computer and communications systems, then its suite of embedded boundary-scan operations could change every time a new circuit board or subassembly is installed.

Even a system with a static configuration can require sophisticated boundary-scan test-management software. For example, in a system that contains different versions of the same circuit board, the boards could have different boundary-scan characteristics. The test-management software would have to determine the version number of the boards in the system before configuring a set of tests.

This implies the need for a repository of object-oriented boundary-scan modules that can be assembled to match any system configuration. In addition, the embedded JTAG run-time engine and scan engine must be made aware of the new configuration and adapt the system's boundary-scan operations accordingly. Of course, the question of how executable boundary-scan modules are downloaded from a central repository to a reconfigured suite of JTAG operations in a system in the field leads to issues of protocols and other facets of data communications.

Communications mechanisms also come into play with regard to remote access for firmware downloads, real-time monitoring of system status, and the application of JTAG tests and diagnostics. Consultant Ben Bennetts and representatives of system manufacturers, boundary-scan companies, and semiconductor vendors have begun *ad hoc* discussions on standardizing the communications protocols supporting embedded boundary scan (www.dft.co.uk/SJTAG/), but at this time, no formal study group has formed.

Of course, with a system-wide BIST capability based on embedded boundary

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scan, you must define how the system reacts to test results. For example, the system might launch a regularly scheduled structural test suite and discover a malfunctioning device that is critical to the overall operation of the system. This test result could set off an alarm that technicians in a centralized monitoring facility could handle manually. Or the system itself might launch a diagnostic suite that determines that the firmware in a certain PLD has been corrupted. With this information, the personnel in the monitoring facility could download a new image of the firmware via the system's embedded boundary-scan infrastructure, making it unnecessary to dispatch a service technician.

Transitioning to embedded boundary scan

Boundary scan has been applied in board-level test and in-system programming applications for more than 10 years. The technology is well understood and well supported by tools that simplify the development and application of JTAG operations. As a result, the transition from board-level to system-level and embedded boundary scan is a natural progression.

Indeed, in some cases the board-level infrastructure may already be in place to ease the transition to embedded system-level boundary-scan operations. If board-level boundary-scan operations have already been deployed for manufacturing test, much of the work that has been done developing the board-level JTAG tests and programming algorithms can be reused in a suite of operations for the entire system. The resulting payback for system-level embedded boundary scan can be quite rapid. T&MW

Dave Bonnett *is the technical marketing manager at Asset Intertech (Richardson, TX), a suppler of boundary-scan tools for test and in-system programming. He holds a BSEE from Southern Methodist University.*


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JON TITUS, CONTRIBUTING TECHNICAL EDITOR

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In a machine-vision system, a camera lens serves one purpose: It gathers light and focuses an image on the camera's sensor. Thus, vision-system designers must treat lenses as key elements in inspection equipment. If cameras cannot gather light and properly "see" what engineers need to inspect, they cannot provide good inspection results. The following sections explain specifications found in lens data sheets and relate them to image-acquisition needs.

WAVELENGTH RANGE. The wavelengths of light that a camera must detect determine which type of lens you must use. Lenses do not pass all wavelengths equally well, so if you plan to inspect in the infrared (IR) portion of the spectrum, for example, you'll need a lens designed for use with IR cameras. Most inspections use visible light, so this article concentrates on lenses for those wavelengths, 400–700 nm.

FOCAL LENGTH (FL). The focal length value specifies the distance between the back end of a lens and the point at which the lens focuses an image on a camera's sensor (**Figure 1**). A lens operates with a fixed focal length, and a camera's sensor is positioned a fixed distance from the camera's lens mount. Thus, lens manufacturers match their products to camera characteristics and provide lens-and-camera compatibility information.

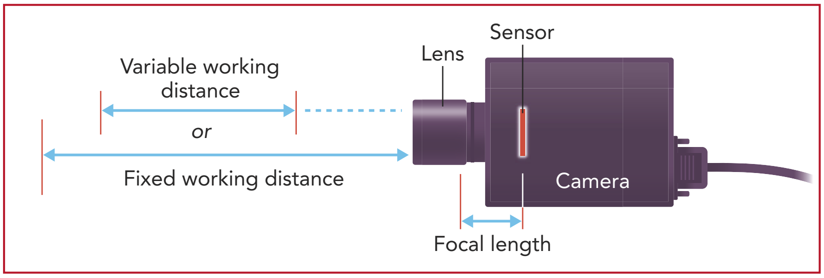

FIGURE 1. Focal length describes the distance from a lens to a camera's sensor. Working distance indicates the distance at which the lens can focus on an object; a camera can have either a variable or a fixed working distance.

SENSOR SIZE. Specifications for lenses that work with solid-state cameras list the dimension of sensor they work with. Sensors come in standard sizes (**Table 1**). The "inch" specification relates to an older technology, but people continue to use it in preference to sensors' metric dimensions. Thus, you will see lenses specified as working with a 2/3-in. sensor, a 1/2-in. sensor, and so on.

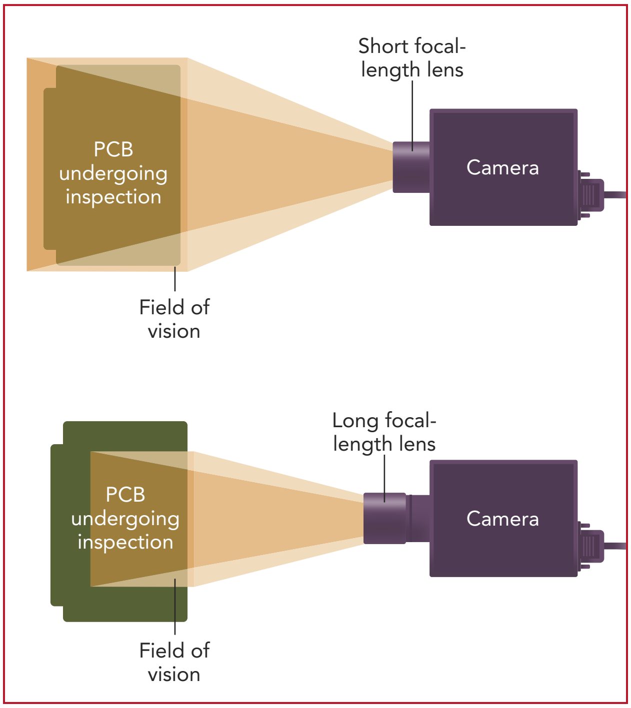

FIGURE 2. A short focal-length lens (top) produces a larger field of view (FOV) than a longer focal-length lens (bottom). The larger FOV includes an entire PCB, but the smaller FOV may better resolve what it inspects. (Image is not to scale.)

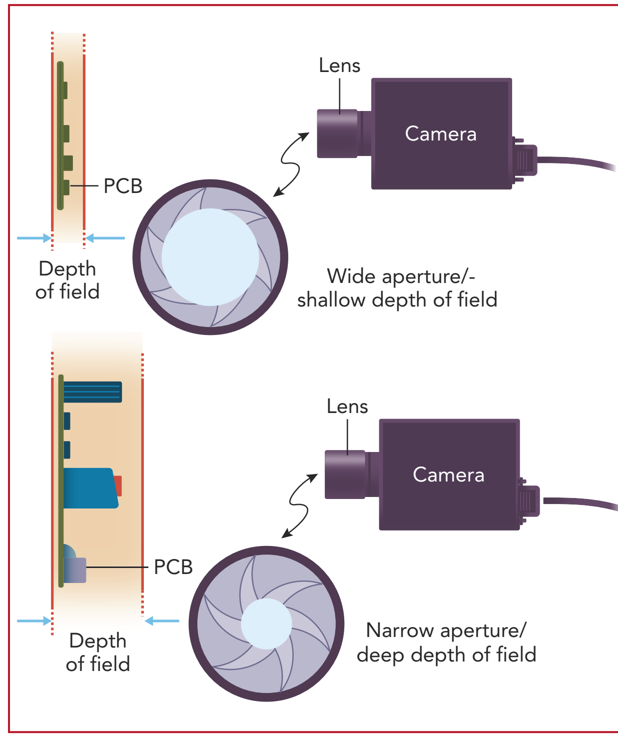

FIGURE 3. Varying the aperture of a lens changes the depth of field so a camera can inspect SMT components in a shallow space or inspect tall components in a deeper space.

WORKING DISTANCE. The front-working distance, or simply working distance, defines the allowable gap between the lens and an object it can properly focus. Machine-vision lenses have a fixed or a variable working distance that ranges from several inches to several feet. Some lenses may focus out to infinity. Often, a testing environment dictates a working-distance requirement. For inspection on a conveyor belt, you may be able to position a camera just inches from the product, but for inspection during the manufacturing stage, you may find that the manufacturing equipment's robotic manipulators require you to position a camera several feet away.

FIELD OF VIEW (FOV). A lens "sees" only the portion of an object within its field of view, the size of which relates directly to the lens's focal length. The shorter the focal length, the wider the field of view. A camera with, say, a 50-mm focal-length lens can take images of an entire PCB (**Figure 2**). Switch to a 200-mm focal-length lens, and you will see just one area of the board. This smaller FOV can offer a resolution benefit: Because the sensor images a reduced area, more pixels cover each square centimeter, thus improving the resolution of small features.

If a vision system must examine an entire PCB, the camera's lens must provide a sufficiently large field of view to "see" all components and features on the board. Suppliers often specify linear field-of-view dimensions (horizontal and vertical) over a lens's working distance.

You can calculate the *angular* field of view based on a sensor's dimensions and a lens's focal length:

$$\text{angular FOV} = 2 * \arctan[(d/2)(1/FL)]$$

where:

d = the sensor's dimension, and
FL = the lens's focal length.

Thus, for a 1-in. sensor (16-mm diagonal) and a 75-mm focal-length lens, the angular FOV equals:

$$2 * \arctan[(16\text{ mm}/2)(1/75\text{ mm})] = 12°$$

For the same sensor, a 20-mm focal-length lens provides a 44° FOV.

Keep in mind that the field of view varies depending on the sensor dimensions you use to calculate it. Thus, the 20-mm focal-length lens and the 1-in. sensor provide a FOV of 35° parallel to the sensor's horizontal dimension (12.7 mm) and a 27° FOV parallel to its vertical dimension (9.5 mm). Remember, too, that a rectangular sensor provides a rectangular field of view.

(continued)

Table 1. Solid-state sensor dimensions

DETECTOR FORMAT (IN.)	DIAGONAL (MM)	HORIZONTAL (MM)	VERTICAL (MM)
1/7	2.3	1.9	1.5
1/6	2.7	2.2	1.6
1/5	3.2	2.6	2.2
1/4*	4.5	3.6	2.7
1/3*	6.0	4.8	3.6
1/2*	8.0	6.4	4.8
2/3*	11	8.8	6.6
1*	16	12.7	9.5

** indicates sensors found in most machine-vision cameras*

DEPTH OF FIELD. The depth of field specifies the distance over which an object remains in focus for a given lens setting (**Figure 3**). If you plan to inspect solder paste on a bare PCB, you can work with a shallow depth of field—the distance from the PCB surface to the top of the solder paste. If you must inspect both surface-mount (SMT) components and tall components on a PCB, you will require a lens with a deep depth of field.

Manufacturers may specify a depth of field for various lens settings, but you should determine depth-of-field values by experimenting with several lenses that meet most of your other needs. The size of a lens's aperture also affects depth of field, as described in the next section. (You can calculate depth of field, but the theory and math go beyond the scope of this article.)

F. No one seems to know what word the letter f stands for in lens specifications, but it denotes a focal-length to aperture-size ratio, shown in data sheets and on lenses as the letter "f" and a number, or as a ratio. Thus, if you have a 100-mm focal-length lens with a 50-mm maximum aperture (100/50 = 2), the lens carries the designation f/2, which is spoken as "f two." Or the lens may have the ratio 1:2.0 printed on it.

Manufacturers often sell a lens family with fixed apertures such as f/2 (1:2.0), f/2.8 (1:2.8), and f/4 (1:4.0). The larger the ratio, the larger the aperture, and the more light a lens passes to a sensor. Thus, a 100-mm f/2 lens admits more light than a 100-mm f/4 lens. For a given focal length, larger-aperture lenses cost more to make, though. So, if you have plenty of light, you might choose a less expensive f/2.8 lens instead of an f/2 lens.

Many lenses include an adjustable iris that changes the aperture in preset steps so engineers can vary, or "stop," the amount of light that reaches a camera's sensor. By adjusting the light, they ensure good contrast between light and dark areas in an image, which simplifies image-processing tasks. (And they avoid saturating the sensor.)

Aperture closures occur in preset "f stops" numbered 1, 1.4, 2.8, 4, 5.6, 8, 11, 16, and 22. From left to right, each stop cuts in half the light that passes through a lens. As the number increases, light decreases and depth of field increases. To compensate for the reduced light transmission of a smaller aperture, you can use bright LEDs or a strobe light to illuminate products undergoing inspection.

Lenses also can have "in-between" f stops, but the series of numbers shown above are the most common. That numerical series represents integer powers of the square root of 2—the ratio of the aperture diameters that result in a twofold change from one f stop to the next. Specs for variable-aperture lenses note a range of values from the minimum to the maximum, say f/1.4–16, which means full-open aperture of f/1.4 and full-closed aperture of f/16.

FOR MORE INFORMATION

* On machine vision, visit WWW.TMWORLD.COM/INS

RESOLUTION. Resolution specifies the ability of a lens to separate small nearby objects in an image. (Image resolution also depends on the number of and dimensions of the pixels in a sensor.) To determine resolution, lens manufacturers measure a lens's modulation transfer function (MTF). The MTF expresses how well a lens separates pairs of equal-width black and white lines (100% contrast) in a pattern.

Because no lens is perfect, the lines start to blur in the camera's image as they become narrower and narrower. At some small spacing, the camera cannot resolve

Machine-vision lenses come in a variety of sizes. Note the marks for f-stop and focus settings on the lens barrel. Each lens also carries a notation of its focal length and maximum aperture. Courtesy of Linos.

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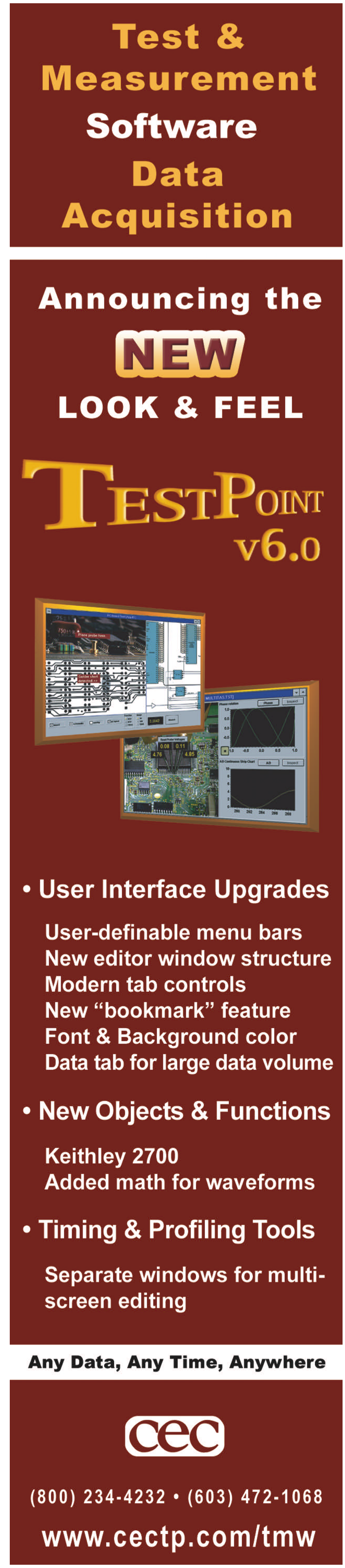


individual lines. Eventually, the image becomes all gray (0% contrast).

Resolution requirements vary by application, so lens suppliers graph MTF test results. A graph plots percent contrast vs. the number of line pairs per millimeter so you can evaluate resolutions and lens types. (For more about MTF, see Ref. 1).

LENS MOUNTS. Most machine-vision cameras accept C-mount (cine-mount) or CS-mount (cine-short-mount) lenses, although some cameras offer less popular lens mounts, too. An adapter lets a C-mount lens work with a camera designed for CS-mount lenses. This adapter extends the lens an additional 5 mm from the camera body. A CS-mount lens will not work with a C-mount camera, though. Always check focal-length and lens specs before you mix lens-mount and camera-mount types.

FILTER MOUNTS. Lenses may accommodate filters on the front or the back, depending on model and manufacturer. A data sheet should list the specifications for the filters a lens can accept and the filter-mount mechanical requirements, usually a diameter and thread type. Lens manufacturers and third parties sell a variety of filters.

Color filters can enhance the contrast of components or markings and eliminate extraneous information from an image. A red filter, for example, enhances blue markings while it reduces the contrast of red objects.

If you consider using a color filter, ensure a match of camera, filter, and light-source spectral characteristics. Polarizing filters can reduce or eliminate reflections from nonmetallic surfaces, although they attenuate all wavelengths somewhat.

Neutral density filters attenuate all frequencies equally and have the same effect as adjusting a lens to a higher f-stop. A neutral-density filter, however, attenuates light so users don't have to reduce a lens's aperture. This enables a user to reduce light without changing the lens's depth of field. (You also can reduce the quantity of light that reaches a sensor and maintain depth of field by increasing a camera's shutter speed.)

Choosing a lens involves trading off depth of field, working distance, and field of view as well as evaluating resolution and mechanical mounting needs. If you rely solely on data sheets for information, though, you may find that no off-the-shelf lens meets your requirements. Lens vendors employ application engineers and optical scientists who can analyze your requirements and offer suggestions. Their experience may lead to a compromise you hadn't thought of. T&MW

REFERENCES

1. Sadoulet, Samuel, "Transfer Functions Influence Lens Choices," *Test & Measurement World*, August 2000. p. 21. www.tmworld.com/archives.

Test & MEASUREMENT WORLD

PXI
TEST REPORT

COMMUNICATIONS TEST

Automating wireless RF test

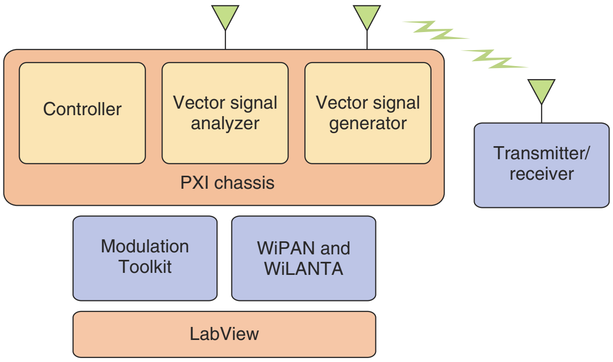
Richard A. Quinnell, Contributing Editor

The testing of wireless networking designs has been getting simpler as companies have begun offering specialized test equipment for the task. Wireless standards are still evolving, however, which makes it challenging for test equipment vendors to keep pace. One recent entry into the market, from National Instruments, uses a PXI-based approach that can evolve to match changes in the standards.

The NI setup handles two wireless standards: IEEE 802.11 (WiFi) and IEEE 802.15.4 (ZigBee). The hardware consists of a PCI chassis, an NI PXI-5660 vector signal analyzer, and an NI PXI-5670/1 vector signal generator. The core of the design is not the hardware, however. It's the software.

To meet the needs of wireless networking test, NI joined forces with software developer SeaSolve Software. The SeaSolve WiPAN and WiLANTA software includes compliance test packages for both WiFi and ZigBee as well as software packages for implementing the protocols in chip designs. The SeaSolve software, combined with NI's LabView graphical development tool and NI's Modulation Toolkit, gives developers a suite of tools for developing customized wireless measurement systems.

Combining SeaSolve's WiPAN and WiLANTA measurement software with NI's vector signal generator, vector analyzer cards, and Modulation Toolkit makes for a modular platform capable of handling a variety of wireless networking RF tests.



"As product technology evolves, so does test," said Darcy Dement, product marketing manager for NI's modular test instrument team. "Often the product is software driven to enable upgrades, so the test has to be software driven, too." Dement also pointed out that the wireless networking products are evolving rapidly and that software-driven testing is the only way to keep up.

Software keeps things flexible

The open nature of LabView-based software is a key component of NI's product offering, said Dement. "The open architecture allows you to get into the parameters so that you can do something out of the norm that standards-based testing won't." She noted that traditional instruments use firmware, so if standards change, developers must wait for the instrument maker to offer a new firmware release.

The foundation hardware, being PXI-based, is able to handle the needs of wireless testing, said NI's RF product marketing manager Joseph E. Kovacs. "These products lend themselves to test because of PXI's speed—132 Mbps. It's much faster than the 1 to 3 Mbps available over GPIB." The PXI and LabView base also means that developers will be able to use any other test software developed by members of the NI Alliance program.

The open and modular nature of the platform was a significant factor in SeaSolve's decision to port its test software to the NI system, according to SeaSolve's business development manager Nadeem Sayed. "We chose to develop this solution on the NI platform because of PXI's inherent speed advantage as well as the short time to market that the platform offers as a whole."

The modular nature also means that the hardware platform's utility is readily extended with software. For example, developers can compensate for frequency deviations in the device under test by using the Modulation Toolkit software rather than having to adjust the hardware. They also can change the filters used in the simulation of channel fading, choosing Rayleigh and Gaussian filters as well as custom ones.

The software-based platform also leaves the door open to adding other wireless system tests. One such test currently under development at SeaSolve would handle testing for the IEEE 802.16 WiMax standard. Other Alliance members are investigating GSM test using the platform. □

INSIDE *this issue*

EDITOR'S NOTE

What will you do with the bandwidth?

Richard A. Quinnell, Technical Editor

Just before this issue went to press, the PCI Industrial Computer Manufacturer's Group (PICMG) released the CompactPCI Express (EXP.0) specification. This spec provides a means of adding the high-bandwidth capacity of PCI Express to the CompactPCI (cPCI) form factor

while maintaining compatibility with existing cPCI hardware. Depending on the type of board used, this gives equipment developers, including PXI users, access to data pipes running as fast as 6 Gbytes/s in each direction.

The spec defines several types of boards and backplane slots, including a Hybrid Slot that supports CompactPCI, PXI, and Compact PCI Express peripheral boards. The board definitions include System Boards, Type 1 Peripheral Boards, Type 2 Peripheral Boards, and Switch Boards. Type 1 Peripheral Boards share the same pin definitions as System Boards, so a CPU board could be designed to work in both slot types. Type 2 Peripheral Boards can be used in Type 1, Type 2, and Hybrid Slots.

The specification defines the System slot and board to have up to 24 lanes and up to four links of PCI Express for up to 6 Gbytes/s of system bandwidth per direction. Type 1 peripheral slots and boards can have up to 16 lanes of PCI Express for up to 4 Gbytes/s bandwidth per direction and Type 2 peripheral slots can have up to 8 lanes of PCI Express for up to 2 Gbytes/s bandwidth per direction.

So the question is: With bandwidth no longer a limiting factor, what are the possibilities? □

Contact Richard A. Quinnell at richquinnell@att.net.

NEWS

PXI Express debuts

In mid-August, the PXI Systems Alliance (PXISA) released the PXI Express specification, which integrates PCI Express and CompactPCI technology into the PXI standard. With PXI Express, engineers and scientists can achieve bandwidth of up to 6 Gbytes/s per system (a reported 45 times improvement over traditional PXI systems) while preserving both software and hardware compatibility with existing PXI products.

PXI Express makes use of the electrical features defined by the PCI Express specification, and PXI Express modules are compatible with the new CompactPCI Express (EXP.0) specification from the PCI Industrial Computer Manufacturers Group (PICMG) (see "Editor's note" at left). Thus, a single measurement system will be able to support both PXI Express and CompactPCI Express modules.

"PXI has always incorporated CompactPCI, and the PXI Systems Alliance has been working within the PICMG technical committees since early 2004 to ensure compatibility with PXI," said Loofie Gutterman, president of the PXI Systems Alliance. "PXI Express products will provide engineers with the bandwidth and performance required by tomorrow's applications while maintaining compatibility and interoperability with today's PXI products and applications."

"Both CompactPCI Express and PXI Express use a new Advanced Differential Fabric connector," said Mark Wetzel, technical chair of the PXI Systems Alliance. "Using this new ADF connector, we can bring PCI Express to PXI, incorporate advanced synchronization signals, and create hybrid slots that accept both PXI and PXI Express signaling."

The PXI Systems Alliance anticipates its members will pass the PXI Express specification in the fourth quarter of this year, with vendors beginning to supply products in 2006. www.pxisa.org. □

Boundary-scan controllers unveiled at NIWeek

DURING NIWEEK 2005 (August 16–18, Austin, TX), Göpel electronic introduced a new family of PXI-based boundary-scan controllers for its Scanflex boundary-scan hardware. Like the company's PCI- and USB 2.0-based controllers introduced earlier this year, the PXI modules are available in three performance classes that in differ in the upper TCK frequency limit (maximum of 20, 50, or 80 MHz, respectively) as well as the level of implementation of the enhanced SPACE II chip set for high-performance scan operations.

The new SFX/PXI1149-(x) controllers support all trigger features provided by the PXI specification. www.goepel.com. □

Geotest awarded contract for PXI missile field test sets

Raytheon Missile Systems will be purchasing four MTS-206 Maverick Missile field test sets from Geotest. Raytheon has been awarded a contract from the UK Ministry of Defense for the test sets. The MTS-206 performs parametric functional tests on Raytheon's AGM-65 and other Maverick missile system components and will be used by the Royal Air Force to maintain the Maverick missile system.

The MTS-206 uses a modular chassis secured via five shock absorbers to enable the unit to meet stringent shock, vibration, and other environmental requirements. www.geotestinc.com. □


SERIES 7000

WEBCAST

Choosing a PXI digitizer

Richard A. Quinnell, Contributing Editor

A rising application for PXI systems is the creation of virtual instruments, a collection of hardware elements that can be linked in software to perform the function of many different desktop instruments. A core element of such virtual instruments is the high-speed digitizer. Recently, the PXI Systems Alliance (PXISA) released a Web seminar that can help test engineers choose a digitizer for virtual instrumentation.

The seminar, "PXI Instrumentation and Replacement of Conventional Instruments," originally broadcast on June 28, 2005, and now archived on the PXISA Web site, has two parts. The first is a brief introduction to virtual instrumentation using PXI. The second provides a more in-depth discussion on choosing a digitizer; it is presented by Richard Soden, product manager at instrument maker Acqiris.

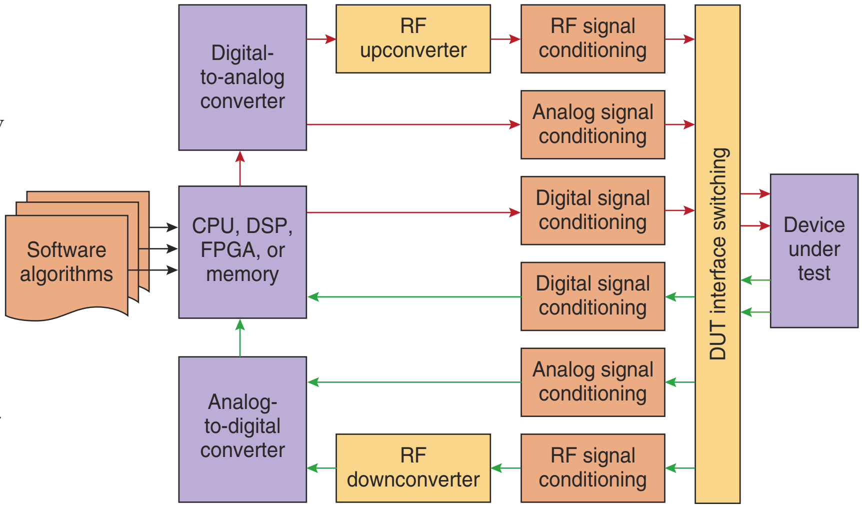


Fig. 1 Synthetic instruments combine a set of hardware blocks with software that allows the set to operate as a variety of bench instruments. Source: Synthetic Instrument Working Group. Courtesy of PXI Systems Alliance.

The basic idea behind virtual instrumentation is simple. Most bench instruments have many hardware elements in common, such as displays, control panels, power supplies, and signal-processing stages. A virtual instrument would have one of each hardware element (**Figure 1**) and would route data through the hardware set under software control to duplicate the function of a bench instrument. Different combinations of hardware elements and data paths would allow the single hardware set to function as any of an entire suite of test instruments.

Banner specs: Good start but not enough

A key hardware component for making measurements is a high-speed digitizer. Soden cautions test engineers to look beyond what he calls "banner specs" when choosing a digitizer to ensure that the component will perform as expected. Banner specs are performance specifications that serve as a quick guide to choosing a product, but if you limit your evaluation to only those specs, you will get a false sense of the product's capabilities.

Three banner specs that Soden identifies for high-speed digitizers are resolution, sampling rate, and bandwidth. These specifications are useful as a pre-filter when selecting a digitizer, and if a product's banner specs do not meet or exceed application requirements, then no further evaluation is needed. If the banner specs do meet requirements, though, you will need to perform further investigation before making a final choice.

The resolution banner spec, for instance, is an indication of a digitizer's accuracy. Soden notes, however, that the presence of noise and distortion in the conversion process can erode accuracy, so he suggests that you examine the effective number of bits (ENOB) that the digitizer provides. You can calculate the ENOB with the equation below (Ref. 1); the signal-to-noise-plus-distortion (SINAD) ratio is generally a function of frequency and signal strength presented as a graph:

$$\text{ENOB} = \frac{\text{SINAD} - 1.76}{6.02}$$

Another banner spec is the digitizer's sample rate, which is an indication of its timing accuracy. But knowing the sample rate alone is not enough. To fully understand a digitizer's timing accuracy, especially if it uses a built-in clock, you also must study its clock accuracy and clock jitter.

The clock accuracy, or frequency drift, will limit the accuracy of frequency measurements the digitizer can provide. Clock jitter will disperse the incoming signal's energy randomly throughout the spectrum, where it will be manifested as noise, reducing the ENOB.

Another important sampling parameter is the time to conversion. If a

Choosing a PXI digitizer • from page P5

sample is assumed to be instantaneously captured, then there will be a phase error in the reconstructed waveform. By knowing the time to conversion, you can correct the phase information.

Bandwidth is the third banner spec that Soden notes is often misinterpreted. When the spec is provided as simply the 3-dB point, you might assume that the gain curve is flat and then falls off linearly. As shown in **Figure 2,** though, the gain curve of a digitizer may not be flat, but it can have the same 3-dB point, and hence the same bandwidth banner spec, as another digitizer with higher gain fidelity.

Looking beyond banner specs

The key to making an accurate evaluation of a digitizer, therefore, is to look deeper than the banner specs. As a starting point, Soden recommends that you evaluate several secondary specifications. These secondary specs are direct measures of signal integrity and measurement fidelity, both of which will affect the accuracy of the digitizer's final output.

Along with ENOB, clock accuracy, and clock jitter, the secondary specifications include:

- **Time-to-digital conversion (TDC).** Knowing when the sampling trigger occurs relative to the sample clock helps reduce phase-measurement errors.
- **Gain flatness.** Examining the digitizer's Bode plot gives you a much better measurement of the digitizer's useful bandwidth than the bandwidth banner spec.
- **Signal-to-noise ratio (SNR).** To be useful, the SNR should always be quoted with the input frequency range for which it is valid, the digitizer's full-scale voltage range, and the input signal voltage.
- **Spurious free dynamic range (SFDR).** SFDR is a measure of the strength of the first spurious signal that the digitizer generates, relative to the input signal. As with SNR, this specification should include the input frequency and full-scale voltage ranges along with the input signal voltage.
- **Total harmonic distortion (THD).** THD tells you the relative strength of the signal and the first several harmonics that the digitizer generates. Unlike many analog systems, however, the higher order harmonics in digitizers may be stronger than lower order ones. Look to see how many harmonics are included in the calculation when making comparisons.
- **Differential nonlinearity (DNL).** The DNL indicates the input signal

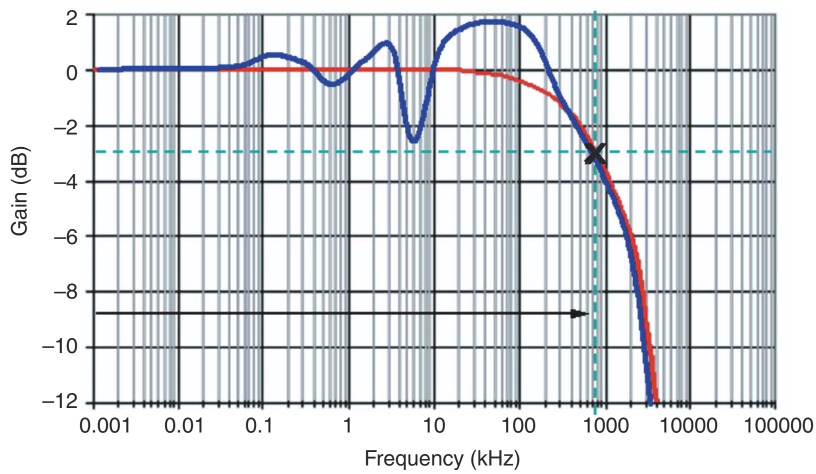


Fig. 2 While bandwidth is an important specification for digitizers, engineers should look beyond the simple 3-dB number to examine how the digitizer's gain varies with frequency.
Source: Acqiris Technology. Courtesy of PXI Systems Alliance.

difference that results in the output moving between two adjacent bit codes.

• **Integral nonlinearity** (INL). INL is a measure of the difference between the input signal that produces an output code and the idealized interpretation of that code. Both INL and DNL represent deviations from the assumed ideal mapping between the digital output value and the input signal. Errors here can affect measurements of signal gain and offset. Matching the INL and DNL of digitizers is particularly important when using multiple digitizers with interleaved outputs to sample high-frequency signals.

A more in-depth discussion of these secondary specifications and of high-speed digitizers in general can be found at the PXISA Web site (www.pxisa.org). A recorded version of the Webcast is available to registered users (registration is free) along with Webcasts on other topics. □

Reference

1. "Defining and Testing Dynamic Parameters in High-Speed ADCs, Part 1," Maxim. www.maxim-ic.com/appnotes.cfm/appnote_number/728.

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ADVERTISER INDEX

PRODUCTS

PXI control

Using National Instrument's MXI-Express kits, engineers can now control PXI and CompactPCI systems over the PCI Express bus. Based on PCI Express, MXI-Express delivers bandwidth of up to 110 Mbytes/s to PXI systems, making it appropriate for mixed-signal test for the manufacturing, communications, consumer electronics, and military/aerospace industries.

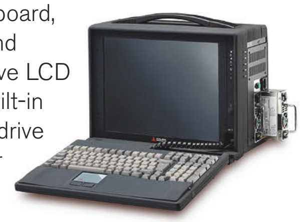
MXI-Express is available in two configurations. The NI PXI-PCIe8361 kit includes a PCI Express board with one x1 cabled PCI Express link. The NI PXI-PCIe8362 kit provides two x1 PCI Express links from the host PC, each of which can cable to individual PXI chassis, letting engineers control two PXI systems from one PCI Express slot in the PC. *National Instruments, www.ni.com.*

RF signal generator

Building on the success of the company's PXI 3000 series RF test systems, Aeroflex has unveiled the 3020A 2.7-GHz digital RF signal generator, the 3030A 3-GHz RF digitizer with 33 MHz bandwidth, and a cdma2000 reverse link software measurement library. Together with the Aeroflex 3010 RF synthesizer, the 3020A (pictured) forms a compact 3U-high precision digital RF signal generator (complete with integrated dual-channel arbitrary waveform generation) that occupies just three PXI slots. Similarly, the 3010 RF synthesizer and 3030A digitizer combine to make a compact 3U-high precision RF digitizer that also occupies just three PXI slots. The measurement software for the Aeroflex 3000 series, the cdma2000 Measurement Suite, is an ActiveX control software measurement library that provides measurement functions for power, spectrum, and modulation analysis of cdmaOne and cdma2000 reverse link transmissions. *Aeroflex, www.aeroflexstore.com.*

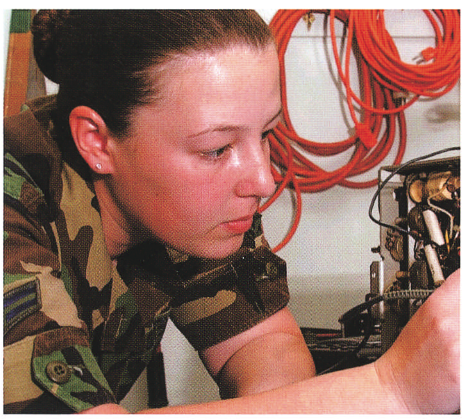
Portable instrument chassis

ADLINK Technology has unveiled the PXIS-2680P, a portable 3U PXI instrument chassis. The PXIS-2680P provides an eight-slot capacity for PXI/CompactPCI modules. The unit includes a keyboard, touch-pad, and touch-sensitive LCD monitor. A built-in DVD combo drive is suitable for high-speed recording or backup of data. A 300-W + 300-W mini-redundant power module is included with the chassis and reduces mean time to repair. The temperature and power-supply status are monitored by an alarm module integral to the chassis. When a failure is detected, an LED and buzzer will be actuated. *ADLINK Technology, www.adlinktech.com.*

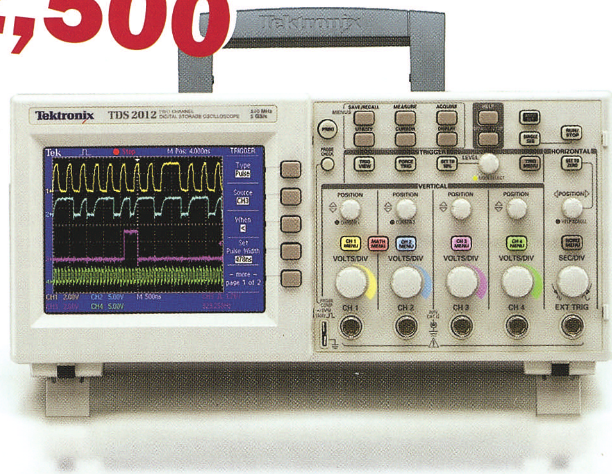


Modular oscilloscopes

Z-Tec has expanded its ZT450 modular instrument family with six 8-bit digital storage oscilloscopes in PXI, VXI, and PCI formats. The expanded family offers sample rates up to 2.5 Gsamples/s and bandwidth options up to 1 GHz for high-end ATE applications. The ZT450 product family provides capabilities such as deep onboard sample memory (up to 32 Msamples for PCI/PXI and 64 Msamples for VXI). Multiple DSOs as well as other bus board products can be synchronized using the local timing and trigger bus. The ZScope soft front-panel software provides complete interactive instrument control. The instruments also come with plug-and-play instrument drivers for LabView, LabWindows/CVI, Visual Basic, and C/C++. *Z-Tec, www.ztec-inc.com.*



ALL TDS1000 & TDS2000 OSCILLOSCOPES NOW UNDER $2,500



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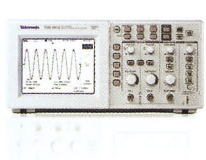

TDS1000 Series

***NEW* Digital Oscilloscope**

Model	Bandwidth	Rate	Channels
TDS1002	60MHz	1GS/s	2
TDS1012	100MHz	1GS/s	2

TDS3000 Series

***NEW* Digital Oscilloscope**

Model	Bandwidth	Rate	Channels
TDS3012B	100MHz	1.25GS/s	2
TDS3014B	100MHz	1.25GS/s	4
TDS3024B	200MHz	2.5GS/s	4
TDS3052B	500MHz	5GS/s	2
TDS3054B	500MHz	5GS/s	4

SPECIAL SALE PRICES

TDS2000 Series

***NEW* Digital Oscilloscope**

Model	Bandwidth	Rate	Channels
TDS2012	100MHz	1GS/s	2
TDS2014	100MHz	1GS/s	4
TDS2022	200MHz	2GS/s	2
TDS2024	200MHz	2GS/s	4

TDS5000 Series

***NEW* Digital Oscilloscope**

Model	Bandwidth	Rate	Channels
TDS5052B	500MHz	5GS/s	2
TDS5054B	500MHz	5GS/s	4
TDS5104B	1GHz	5GS/s	4

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Automotive & Aerospace TEST REPORT

TEST SERVICES

Caterpillar opens doors at EST&S

Greg Reed, Contributing Technical Editor

Earlier this year, I visited Caterpillar's Engine Systems Technologies & Solutions (EST&S) technical center in Mossville, IL, to learn how this manufacturer of heavy equipment handles test and measurement diagnostics on engines. The EST&S facility is located within a Cat campus where other buildings house a variety of manufacturing operations. What I got was a behind-the-scenes look at this state-of-the-art facility in terms of test equipment, plant infrastructure, and, most of all, dedicated personnel who develop cutting-edge test solutions.

My tour guide was Stephen Butler, a 30-year Cat veteran who specializes in fuel systems and thus has interacted with almost all the specialized test cells. Besides intimate knowledge of numerous test and measurement processes, Butler had built enduring relationships with co-workers such as Ron Anderson, another veteran engineer, who accompanied us and provided additional practical commentary on several test systems.

We spent time discussing calibration and instrumentation systems, simulation software, inspection tools, metrology methods, and technology innovation—all as we walked around the facility's maze of nearly 100 specialized test cells and watched engineers and technicians perform diagnostics on engines from 85 to 9000 hp.

To satisfy stringent internal rules that are beyond the scope of some commercial, off-the-shelf test equipment, Caterpillar engineers routinely "invent" test and measurement tools, systems, and processes. Engineers from the simulation wing of Cat's facility have developed software that mimics subsystems within trucks. The tool analyzes the mechanical, electronics/electrical, thermodynamic, and hydraulic systems on a vehicle. Other software characterizes the dynamic behavior of shifting loads on trucks as the vehicles maneuver through an obstacle course. Individual test cells contain Ethernet connections that feed test results back to a central nerve center hub of office cubes where personnel parse the data.

The EST&S operation has a clear mandate to operate as a revenue-generation facility. As such, its test bays are filled with all manner of trucks, recreational vehicles, military ground vehicles, construction machinery, cranes, and other industrial equipment from many major vehicle OEMs. Rick Alford, EST&S director, explained that "Cat's testing capabilities are a unique resource now available to engine manufacturers, OEMs, and component suppliers on a completely confidential basis. We have taken steps to ensure that everything learned at EST&S stays here."

A Caterpillar test engineer runs diagnostic tests measuring engine exhaust particulates. Courtesy of Caterpillar.

Future growth

EST&S typifies one of Cat's core competencies that the company has decided to offer for sale to external markets. By offering patented test technologies as a service outside its core markets, Cat further justifies the cost of internal R&D efforts. Cat test programs are already being devised for several suppliers that build blocks, crankshafts, pistons, rings, cylinder liners, and fuel systems. □

For a list of the test services that Caterpillar offers, see the online version of this article at www.tmworld.com/cattest.

INSIDE *this issue*

EDITOR'S NOTE

AUTOSAR motors toward test phase

Greg Reed, Technical Editor

The Automotive Open Systems Architecture (AUTOSAR) partnership, formed to promote an open standard for automotive electric/electronics architecture, foresees that it will deliver its standard on schedule in 2006. Formed in 2003, the network of automotive, electronics, and software companies intends the new standard to serve as an infrastructure for managing functions within applications embedded in vehicles.

Adhering to an internal roadmap, working committees defined specifications in 2004. The schedule calls for a test phase beginning in late 2005, with delivery of a bona fide standard by August 2006. With participation from OEMs, suppliers, semiconductor manufacturers, and software firms, AUTOSAR promises a standard that ensures cooperation while protecting intellectual property.

What's in this for test engineers? The consortium says greater scalability to vehicle test platform variants, transferability of functions throughout the network, integration of modules from different suppliers, more off-the-shelf hardware, and ongoing upgrades over a vehicle's lifetime.

Organizations often promote their own solutions regarding modularity and configurability enhancements, standardized interfaces, and global cooperation, much like the one that AUTOSAR advocates. While I maintain a healthy dose of skepticism, it's hard to argue with the Tier1 automotive companies assembled behind this initiative. To check it out for yourself, visit www.autosar.org. □

Contact Greg Reed at editor@aatr.net.

NEWS

Shuttle sports Endevco sensors

DURING ITS RECENT mission, the shuttle Discovery was carrying a network of miniature temperature and impact-detecting accelerometer sensors supplied by Endevco. Each of Discovery's leading wing edges was outfitted with 22 temperature sensors that measured how heat was distributed across their spans. Each wing also had 66 accelerometers that detected particle impacts and gauged their strength and location. According to Endevco, the network of sensors provided an electronic nervous system that enabled flight engineers to monitor wing conditions in real time.

"It is an honor to be utilized by NASA and recognized as a leader in our industry. Knowing that our sensors and accelerometers contributed to the shuttle's safe mission is extremely rewarding, and with Discovery back safely on the ground, the team at Endevco looks forward to its future with NASA and many more exciting space missions," said Rob Meyer, president of Endevco. www.endevco.com. □

SAIC supports Air Force test and evaluation center

SCIENCE APPLICATIONS International Corporation (SAIC) has been awarded a five-year contract to provide engineering and technical services to support the Air Force's operational test and evaluation center (AFOTEC). Services provided will support the Air Force, Department of Defense (DoD), and other government agencies by evaluating operational capabilities and limitations of systems to meet war fighter mission needs by conducting, or participating in, operational testing. Under this contract, SAIC will provide testing services to evaluate capabilities of combat and combat support systems such as aircraft, missiles, motor vehicles, communications, ordinance, instrumentation, computer systems, automated information systems, and simulators and trainers. www.saic.com. □

Lord Corp. expands test lab

LORD CORP. HAS expanded its Erie, PA, custom applications lab to include test capabilities. The 10,000-ft^2 facility now offers customers the ability to test coatings and adhesives on small sample batch runs

for new product introductions. This pilot production test service ensures realistic testing conditions by including abrasion, vibration, tensile, cold-flex, and environmental test equipment. www.lord.com. □

Faro Technologies lands Boeing order

FARO TECHNOLOGIES reports that it has received an order from Boeing's rotorcraft facility for 10 laser tracker units. The portable systems employ laser technology to measure large parts, tooling, and machinery within its 230-ft. range. Boeing will use the units in the manufacture of the twin-turbine, tandem-rotor CH-47 Chinook helicopter and the tilt-rotor V-22 Osprey aircraft for the US Army and Navy. www.faro.com. □

Calendar

SAE AeroTech Congress & Exhibition
October 3–6
Dallas/Ft. Worth Airport, TX
www.sae.org/events/atc

International Congress on Electronic Systems for Vehicles
October 6–7
Baden-Baden, Germany
www.vdi.de

CAN/CANopen Training
October 18, Mississauga, ON, Canada
October 27, Boston, MA
December 1, Richfield, MN
Conducted by CAN in Automation
www.can-cia.org

Ricardo taps LMS for vehicle testing

RICARDO HAS SELECTED LMS's Test.Lab software suite as its new standard environment for noise and vibration testing and engineering. The company intends to deploy more than 20 systems for powertrain and full-vehicle NVH engineering at its technical centers throughout Europe and the US. www.lmsintl.com. □

IAC builds anechoic test chamber for FG Wilson

IAC HAS BUILT AN anechoic test chamber to provide engine testing capability for FG Wilson (a business unit within Caterpillar Group) in Larne, Northern Ireland. The new facility eliminates environmental impact by keeping noise in, and also provides a repeatable sound testing environment, keeping wind and weather interference out. The project aids manufacturing and R&D, meeting the ISO 3744 and 3745 standards. www.iacl.co.uk. □

DATA ACQUISITION

Customized system gathers aircraft subsystem tests

Dave Baker, G Systems

Lockheed Martin Aeronautics recently contracted with G Systems to develop a data-acquisition system for its F-35 vehicle systems integration facility (VSIF). The system that G Systems developed acquires various types of data including analog, digital, video, and data transferred from other systems through reflective memory. Additional features include a real-time display capability and the ability to configure all aspects of the system from transducer setup to data management.

Figure 1 illustrates the general architecture of the data-acquisition system. The system is distributed across several servers to enable load balancing and to achieve the required performance. The distributed software architecture includes six major custom applications and is scalable to provide for future expansion.

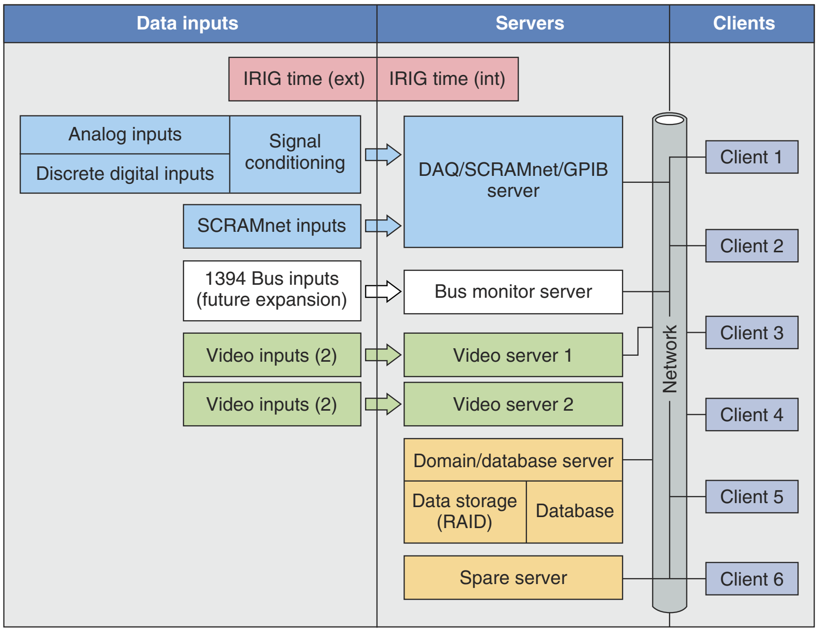


Fig. 1 The test system uses multiple servers for individualized client use.

Data acquisition

G Systems used five National Instruments PXI chassis populated with a mixture of NI data-acquisition boards to achieve a total of 640 analog channels and 480 digital channels. The ability to "mix and match" different types of data-acquisition boards while maintaining time synchronization was important for controlling the overall hardware costs.

The time synchronization is maintained in the distributed system through the use of an IRIG-B time signal that can be provided by the data-acquisition system itself or by another source within the VSIF lab. The time source provides the start pulse and the 10-MHz clock that is routed through PXI-6653 synchronization boards in each chassis.

The application that acquires the analog and digital data also performs PXI board verification and internal calibration as well as signal path calibration operations using an external DC source controlled over GPIB. This automation of the signal path calibration allows a system verification to be performed automatically within 20 min with minimal operator involvement.

All data is delivered to the end user in engineering units and takes into account the calibration values for the analog-to-digital converter, the signal-conditioning module, the transducer, and zero nulling values where appropriate. Derived channels (i.e., channels that are calculated from information contained in other channels, like Watts=Volts*Amps) can be calculated. Additionally, one interface allows users to "plug in" user-defined dynamic link libraries (DLLs) to create more complex derived channels.

A graphical user interface allows the system administrator to configure every aspect of the system, and the configuration information is stored in a SQL server database. The user interface provides capabilities such as column sorting and filtering, channel group definitions, multi-record editing, and copy/paste functions—features that help the system administrator manage the system's numerous channels. The software also helps users to

- administer eight levels of user privileges,
- manage the available hardware (such as PXI boards and transducers) and the hardware connections,
- update calibration information,
- define derived channels,
- archive or export data and a database to other media,
- create standard configuration reports (including historical calibration data), and
- create user-defined reports.

Data display and management

Because the system is used by many different groups to test out various aircraft subsystems during integration tests, a single, static user display was not a good option. Instead, we used a dynamic, user-configurable data display that enables users to create custom views with several choices of indicators.

All information for an individual user configuration is stored in the database and can be exported along with test data for stand-alone review or playback. This makes it possible for a user to take a snapshot of test data (including all calibration and transducer information) from several test runs and use it independently of the main database, which can be useful for off-line analysis or a group presentation.

The test control/monitoring/playback application provides users with several modes of operation. The system constantly acquires data and publishes it in a "low-resolution" format to client workstations. As the published data is received, it is buffered continuously on the local client in a 30 min rolling buffer. From this buffer, a user can scroll back in time to data that was published or logged and replay it in real time if desired.

When the operator chooses to log data, the "high-resolution" data is logged to file and is later transferred to a central repository. These test runs can be downloaded from the repository to a workstation for detailed review of the data in the playback mode.

For both live and playback data, the software supports advanced navigation functions for traversing data sets. Users can set triggers and alarms to quickly find points of interest in data. The user can also set a bookmark to highlight areas of interest in the data.

All logged data is controlled and protected in the system. The data is automatically moved from the acquisition servers to a central RAID (redundant array of inexpensive disks) data-storage unit when a user stops logging a test run. Both the data display and the data-analysis export application can directly recall data that exists either on the RAID or in an archived dataset.

Data-analysis capabilities are provided by a custom application that exports data to the NI DIAdem analysis package or to ASCII text files. This custom application feeds data directly into DIAdem through an object linking and embedding (OLE) interface. The operator can select the test run(s) and channel(s) to export to DIAdem and also has the option of merging data from several test runs. □

Dave Baker is VP of engineering at G Systems, Plano, TX. dbaker@gsystems.com.

DATA ACQUISITION

Onboard system tests diesel aircraft engine

John Gyorki, IOtech

Before a new engine can be approved and commissioned for general and experimental aircraft, it must log hundreds of operating hours on a dynamometer test stand without failure. Unfortunately, the work needed to successfully carry out such an undertaking can be daunting for an engineering crew. A crew member must be present during the entire test, even when the event runs around the clock.

The test situation became quite acute for the various teams of engineers, technicians, and volunteers at DeltaHawk Engines in Racine, WI, when the company began endurance testing a new 160-hp, four-cylinder diesel engine. Test observers were required to make minor adjustments or fine tune the test setup on the fly any time a measured variable from one of the numerous sensors placed around the engine exceeded a preset limit. In addition, the equipment had to be relatively easy to program and operate by people with a wide range of skill levels.

The company had used conventional temperature, pressure, and flow gauges in the past, but this approach did not provide the trend data for future analysis. Also, during initial tests, the engineers employed a data-gathering system that worked well, but the desktop computer and rack-mounted hardware were too large and heavy to use on the aircraft for in-flight tests. Moreover, the equipment was relatively difficult to program and maintain during a test—it runs most reliably under the hands of a programmer and other skilled technicians and thus was not practical for the less-skilled staff members who manned the tests at odd hours of the day and night.

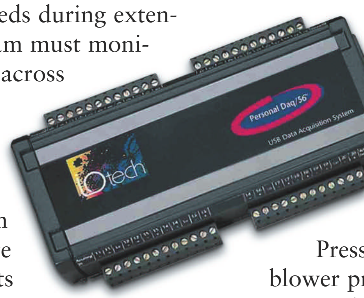
The company found a more compact solution in an IOtech Personal Daq data-acquisition system connected to a laptop computer. This portable system runs with 12-VDC input and gathers the data from an engine and dynamometer on a nearby trailer. Because the Personal DaqView software displays virtual gauges on the laptop screen with programmed, color-coded upper and lower test limits, operators of all skill levels can easily see when a variable crosses over the color-coded limit lines.

Measuring oil pressure

One critical variable that the DeltaHawk team must measure is the oil pressure, which normally runs between 20 and 100 psi over a specific range of engine speeds during extensive testing. The team must monitor the oil pressure across numerous temperatures while checking for component wear and cracks. Eventually, the team dismantles the entire engine and then puts it back together. The DeltaHawk team performs the tests on two engines, one of which usually runs in an airplane while another runs on the trailer. In the plane, the test equipment charts 10 channels of sensor data with a laptop computer. On the trailer, data are collected through 20 channels.

Typically, USB lines run from the engine area to the laptop computer on a table over 25 ft away. The only electronic components on the engine are the sensors collecting the data. This engine is a straightforward diesel and does not require sophisticated electronic ignition systems or computers. Even the fuel pump is mechanical, but an alternator charges the battery that runs the boost pump. If the system should lose power in flight, the pilot's instruments would be the only components that fail. The plane would still fly just as reliably without them.

The engine is a four-cylinder V-configuration. The test system lets the test team monitor the engine speed and the temperature of each cylinder head in a water jacket, which is divided into two sections between the one/three cylinder bank on one side and the two/four cylinder bank on the other side. A water temperature sensor in each bank monitors the respective temperature. Since the engine has both a turbocharger and a super charger, the exhaust gases are monitored with a sensor in the inner blower, between the two chargers.



The Personal Daq data-acquisition system compiles results on diesel aircraft engine performance across a broad range of test inputs.

Pressure sensors record inner blower pressure and manifold pressure under the supercharger. The system measures oil temperature as the oil goes into the engine and again as it exits the engine on its way to the heat exchanger.

For the engine installed on the plane, the engineers also monitor static and dynamic pressures. The static pressure is the ambient pressure, and the dynamic pressure is the air pressure inside the air scoop on the bottom of the plane—the air over the heat exchanger. Test programs vary sensor number and placement. The team analyzes the data with a spreadsheet that indicates the length of the run and rpm level. The system archives charts of data that the team can use to compare all the runs made with one engine or several engines. □

John Gyorki is senior project engineer at IOtech, Cleveland, OH. johng@iotech.com.

PRODUCTS

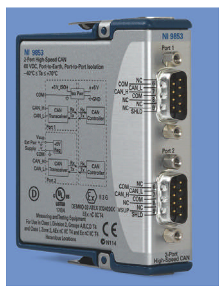
Transient generator

The TGAR transient generator system from AR Worldwide is designed to handle many of the existing specifications covering automotive conducted immunity testing. The complete TGAR system (consisting of the TG6083BU, TG6083PS, TG6083AS, and TG6000LD) is designed to meet the requirements of ISO 7637-2 (2004) and SAE J1113-11 international automotive standards as well as the requirements of Ford, DaimlerChrysler, and General Motors; the system also accommodates many of the test specs of automakers Toyota, Honda, BMW, and Mercedes Benz, among others.

The TGAR System offers a variety of features, including a base current rating of 83 A, a built-in oscilloscope for easy pulse verification and self-calibration, and LabView-based software and built-in arbitrary waveform generators for creating custom waveforms. *AR Worldwide, www.ar-worldwide.com.*

CANbus interface module

Leveraging reconfigurable I/O, the NI 9853 two-port CANbus interface module plugs into National Instruments' CompactRIO chassis to perform in-vehicle measurement and control. You can use the platform to monitor in-vehicle CAN buses, read and write values to CAN devices such as electronic control units and actuators, and communicate with industrial devices such as motion drives and motors. The NI 9853 provides 11-bit and 29-bit arbitration ID support for communication on J1939 networks. Base price: $995. *National Instruments, www.ni.com.*



Laser scanning probe

Capturing up to 50,000 points/s, the SLP-330 is a fast laser scanning probe mounted on an articulated arm. The SLP-330 is able to scan parts with dimensions as long as 12 ft without having to move the base of the arm, and it can scan parts of any size if the arm is moved. Dual detectors view the laser line from two different angles, reducing the number of scanning passes required to capture steep sidewalls and deep geometries. The SLP-330 works with the Romer CimCore Infinite, 3000i, and Stinger II portable CMM articulating arms. It is intended for applications that require

Products • from page 73

the scanning of large parts, such as automotive, aerospace, off-road equipment, and trucking industries. Price: $32,000, including the probe and Romer CimCore arm. *Laser Design, www.laserdesign.com.*

Digital I/O card

Built on a single-width 6U CompactPCI/PXI module, the CP387 supplies 128 TTL-level digital I/O channels, plus four expansion sites to accommodate up to 128 additional digital channels. These sites can be populated with an assortment of optional I/O mezzanine cards, including isolated input, isolated output, relay output, AC switch output, and differential I/O. Data transfers to and from the CP387 are programmable and support 16-bit and 32-bit data words. Onboard flash memory can be used to restore basic digital input and output configuration parameters on power-up. These parameters include the connection of either pull-up or pull-down resistors, the direction of digital I/O channels, and the initial power-up values of digital output channels. Price: $2130. *KineticSystems, www.kscorp.com.*

High-strain-rate test system

A fully integrated servohydraulic test system, the VHS 8800 performs a wide range of high-strain-rate testing, including tensile, puncture, compression, and flexure of materials, joints, and components. It uses high-performance actuators, specially designed test fixtures, and low-inertia/high-resonant frequency load measurement systems to achieve strain rates of up to 1000^{-1}. The system's ability to perform tests from quasi-static to high speed allows materials and components to be characterized over a full range of strain rates using a single instrument. Dynamic load capacities range from 25 kN to 100 kN with velocities of up to 25 m/s. *Instron, www.instron.com.*

Virtual prototype simulation environment

LMS Virtual.Lab offers an integrated software suite to accurately simulate and optimize the real-life behavior of mechanical designs. Revision 5 offers new applications for structural analysis, vehicle ride and handling, interior acoustics simulation, road noise, and durability analysis. With Revision 5, LMS Virtual.Lab also gains new capabilities to automate repetitive simulation tasks and to capture complex simulation processes into easy-to-use application templates. *LMS, www.lmsvirtuallab.com.*

Test & MEASUREMENT WORLD

Compliance
TEST REPORT

STANDARDS

EMC Directive to cut red tape

Richard A Quinnell, Contributing Editor

One of the hot topics at the 2005 IEEE EMC Symposium (August 8–12, Chicago, IL) was the impact of a new EMC Directive from the European Parliament and Council. The directive seeks to ease the regulatory burden on manufacturers of electronic equipment by transferring responsibility for determining compliance from regulatory bodies to the manufacturers. This will have an effect on when and by whom EMC testing is performed and will change the documentation requirements for products aimed at the European market.

EMC Directive 2004/108/EC, which entered into force on January 20, 2005, and will take full effect on July 20, 2007, replaces Directive 89/336/EEC. Any national provisions that are incompatible with the old directive became inapplicable when the new one entered into force. The delay of full implementation until 2007 will give member states time to incorporate the new requirements into their own national standards.

In place of the mandatory outside testing required by the previous directive, manufacturers will now be able to document their EMC assessment and then self-declare compliance. They also have the option of having a "Notified Body" review and approve their documentation. If manufacturers follow any of the "harmonized standards" (Ref. 1) prepared by a recognized European standards body in making their EMC assessment, then their equipment will be presumed to conform.

If harmonized standards are not used, do not apply, or only partially apply, the documentation requirements become more involved. The manufacturer may need to create a technical construction file containing schematics, tests parameter rationales, and a host of additional justification. The company may also need to have testing performed by the Notified Body to assure conformity. The documentation will have to be retained and available for review for seven years following the discontinuation of product manufacturing.

The new EMC Directive will allow manufacturers to self-declare conformance and mark their products with the approval symbol.

Documentation requirements

The new requirements will allow compliance monitoring agencies to act effectively if noncompliance problems arise in the field. Under the terms of the new documentation requirements, a manufacturer must provide the following with each product:

- clear identification of the product, including type, batch, and serial number;
- name and address of the manufacturer, authorized representative, and person responsible for placing the equipment in the European market if manufacturing is not performed in the EU;
- information on precautions a user must take when assembling, installing, using, and maintaining the equipment;
- instructions for using the product for its intended purpose;
- any restrictions on use; and
- a declaration of conformity with the EMC Directive.

For fixed installations, such as networks and systems that may evolve over time, the new directive calls for documentation of the installation effort. Installation must follow good engineering practices and must follow the restrictions provided with each piece of equipment. Installers must document their work, and those documents must be held available for inspection as long as the installation remains in operation.

Until the new directive goes into full force in 2007, manufacturers must still follow the provisions of Directive 89/336/EEC. Once the new directive goes into full force, new equipment that follows the new directive can be introduced and a transitional period for compliance begins. Equipment that follows the old directive cannot be marketed after July 20, 2009.

More details about the new directive are available at europa.eu.int/comm/enterprise/electr_equipment/emc/revision/workshop.htm. □

Reference

1. List of Harmonized Standards, europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/emc.html.

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EDITOR'S NOTE

The ups and downs of compliance

Richard A. Quinnell, Technical Editor

Most engineering work is cyclical. There is a period of intense activity followed by lulls, followed by another intense period.

For compliance test engineers, a surge of new responsibilities comes each time there is a change in the regulatory environment. In addition to your routine tasks, you must interpret the new requirements, establish new test procedures, and perhaps create new company test capabilities. Then, you must implement and refine all these changes in time for the company to become certified or to establish its ability to achieve compliance and meet the regulatory implementation schedule.

As a professional, you are expected to shoulder these occasional increases in work demand. The biggest problem is: They are hard to plan for. Experienced design engineers have learned which design stages will require midnight oil, and they plan accordingly. With regulatory changes, it is a little harder to plan. No one knows when the bureaucratic powers-that-be will require changes, although with careful watching, an intelligent guess can be made.

Here at *Test & Measurement World*, we will continue to help, by keeping an eye on the regulatory processes and letting you know when change is imminent. If you hear of something in the wind, drop us a line so we can look into it. You can't avoid the work surges, but you can plan for them. We can help. □

Contact Richard A. Quinnell at richquinnell@att.net.

NEWS

News from the EMC Symposium

THE 2005 IEEE EMC Symposium (August 8–12, Chicago, IL) featured more than 200 technical papers presented as open forums, technical sessions, and tutorials. Tutorials covered topics such as Europe's EMC Directive, the fundamentals of EMC design, the fundamentals of signal integrity, and antenna and probe use.

One session featured papers on EMI measurements above 1 GHz. Andrew Marvin presented "Toward Evaluating the Shielding Effectiveness of Enclosures with Contents at Frequencies above 1 GHz." Marvin and co-author Yong Cui experimented with a 480x480x120-mm enclosure that contained a board that radiated EMI. They found that the position of the board inside the enclosure greatly affected the emissions that radiated outside the enclosure. To measure emissions, they rotated the enclosure and scanned across a rectangular area.

Alexander Kriz presented "Validating Anechoic Chambers above 1 GHz Using a Reciprocal Site VSWR Technique." EMI antennas take on different characteristics above 1 GHz, which affects your ability to validate the electromagnetic fields inside a chamber. Kriz showed test results for three test methods, pointing out the advantages and disadvantages of each.

EMC consultant Doug Smith demonstrated how a common ground between two chassis creates interference from one to the other. He used a SPICE simulation to model two equipment chassis placed 1-cm apart and connected to a common ground. With a 1-V, 150-V source, he simulated an excitation on one chassis. Capacitance between the two chassis combined with inductance in the ground wires formed a resonant circuit. At the resonant frequency, the circuit produced a current in the unexcited chassis that was greater than the source current.

In "Shielded Enclosure Accuracy Improvements for MIL-STD-461E Radiated Emissions Measurements," Andy Wang and David Wartenkin explained how they discovered inconsistencies in measurements made in shielded enclosures that complied with the MIL-STD-461E standard. www.emc2005.org. □

Schaffner to quit T&M business

SCHAFFNER HAS announced plans to sell its test equipment businesses in order to concentrate on EMC safety components, which constitute 70% of overall sales. The Schaffner Group will sell the Test Systems Division, which manufactures EMC instrumentation as well as products for cable test, electro-emulation, and RF test. www.schaffner.com. □

FCC modifies AWS rules

The Federal Communications Commission (FCC) advanced its efforts to make spectrum available for voice, data, video, and other wireless broadband services offered over 3G mobile networks. Order FCC 05-149 modifies the band plan (originally adopted in October 2003) and licensing and service rules for the 90 MHz of Advanced Wireless Service (AWS) spectrum at 1710–1755 MHz and 2110–2155 MHz.

The new band plan splits the original 30-MHz E block at 1740–1755 MHz and 2140–2155 MHz into one 10–MHz block (new block E) and one 20–MHz block (new block F). It also restructures the band plan by aligning the CMA, EA, and REAG spectrum blocks. In addition to the changes made to the AWS band plan and geographic licensing areas, the order removes a restriction on transmitter output power levels. www.fcc.gov

WHISKERS

Tackling tin whisker test

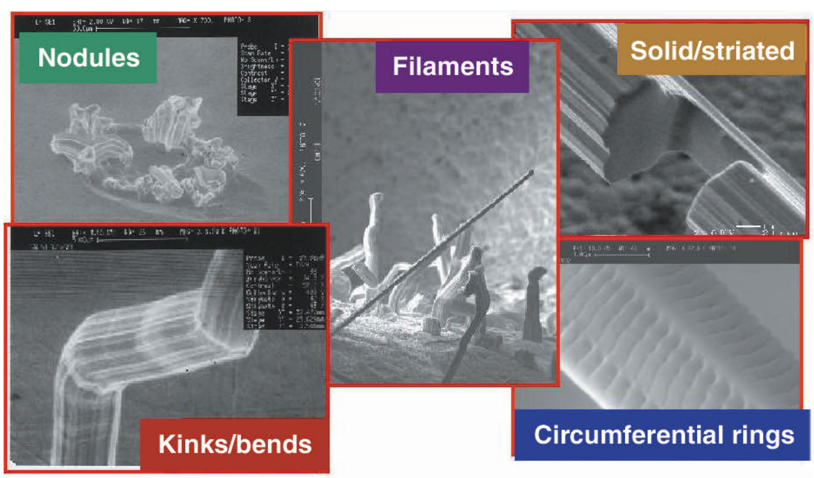
Richard A. Quinnell, Contributing Technical Editor

The European Union's Restriction of certain Hazardous Substances (RoHS) initiative to reduce the use of lead (Pb) is driving the electronics industry to consider alternatives to tin-lead alloys in component plating. The industry's preference, with respect to factors such as solderability, ease of manufacture, and compatibility with existing assembly methods, would be to use pure tin plating as a simple and cost-effective alternative.

Unfortunately, pure tin and high tin-content alloys can grow fine metallic extrusions called "whiskers." The cause of their growth is uncertain, but whiskers lengthen over time after a plating has been applied or reflowed, and they can become as long as several millimeters, sufficient to create short-circuits in high-density packaging. Unlike dendrites and electromigration, tin whiskers grow in normal environmental conditions without needing the action of a solvent, and they grow with or without electric fields present.

Whiskers can pose a significant threat to product reliability, yet many electronics manufacturers have never heard of them. As a result, they may not consider the propensity for tin whisker growth during the validation of new plating systems.

Those who do know of the phenomenon have used different methods for evaluating their likelihood, with the result that there has been no consistent evaluation of the various plating alternatives. Recently released test standards can now help the industry prepare consistent measurements of whisker growth and, thus, enable manufacturers to properly evaluate plating technologies.



Many different types of whiskers can grow from tin platings, but all of them are potentially hazardous to electronic systems. Courtesy of NASA Goddard Space Flight Center.

Lost by a whisker

Whisker growth can cause a number of failure conditions. In high-impedance, low-current circuits, a whisker can form a permanent short-circuit; it can take as much as 50 mA to burn out a whisker. In other circuits, a whisker would form a temporary or intermittent short before being vaporized. In some space applications, however, the whisker's vaporization can create a current-carrying plasma that can then grow to a capacity of hundreds of amperes.

Tin whiskers can also have an effect even when they do not form short-circuits. In high-frequency RF (above 6 GHz) or in fast digital circuits (with a rise time under 59 ps), the whiskers act as a stub, affecting the circuit impedance and causing reflections.

In electromechanical systems, such as disk drives, whiskers may break off and cause head crashes or contaminate bearing surfaces. Similarly, they may contaminate the optics in electro-optical systems, and they may reduce the effective isolation of high-voltage components in power-supply systems.

Standard measurements arise

To help manufacturers evaluate the various plating processes, JEDEC (www.jedec.org) has introduced JESD22A121, "Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes." In addition to describing a series of tests, the standard provides a consistent inspection protocol for measuring the results and offers a standard reporting format for documenting them. Embracing the standard would give the industry a consistent means of comparing plating alternatives.

JESD22A121 contains three sets of tests designed to accelerate whisker formation under a variety of conditions (**Table 1**). One test uses temperature cycling; the other two tests use static storage conditions.

After performing these stress tests, a manufacturer must evaluate whisker growth. The standard specifies which surfaces to examine, how

Tin whiskers • from page 79

to employ optical or scanning electron microscope (SEM) imaging, and how to select samples for further study. Using the selected samples, the manufacturer must measure the occurrence and length of whiskers.

The specification also provides an optional test sample pre-conditioning step (**Table 2**). These four pre-test conditions are intended to simulate the environments that the component might experience:

- Condition A imposes no preconditioning and is used in conjunction with the ambient temperature/humidity storage test.
- Condition B simulates component storage, such as in a stockroom, and is used in conjunction with the remaining tests as well as being used prior to preconditioning types C and D. It applies to samples that do not use whisker mitigation techniques such as under-plating or post-bake mitigation.
- The remaining two conditions mimic the temperature cycles used in the soldering of components onto a circuit board. Condition C simulates backward-compatible soldering processes that use tin-lead. Condition D simulates assembly using lead-free soldering processes.

If the standard is used as part of a qualification test, companies should be certain to agree on the preconditions to be used in the tests.

Table 1. JESD22A121 tests for accelerating whisker growth.

STRESS TYPE	REF. SPEC.	TEST CONDITIONS	INSPECTION INTERVALS	MINIMUM DURATION
Temperature cycling	JESD22-A104	Min Temperature: −55 to −40°C (+0/−10°C) Max Temperature: +85°C (+10/−0°C), air to air; 5–10-min soak; ~3 cycles/hr	500 cycles	1000 cycles
Ambient temperature/ humidity storage		30 ±2 °C and 60 ±3% RH	1000 hrs	3000 hrs
High temperature/ humidity storage		60°C, ±5°C and 87% RH, +3/−2% RH	1000 hrs	3000 hrs

Table 2. Optional preconditioning treatments.

CONDITION	PRECONDITIONING TEMPERATURE EXPOSURE	THERMAL PROFILE EXPOSURE	USE GUIDELINES
A	None	Normal ambient exposure	Intended to test for whisker growth under ambient temperature/humidity storage.
B	Room temperature storage for a minimum of 4 weeks after the finish is applied	15–30°C 30–80% RH	Intended for samples without underplating or post-bake mitigation before exposure to high temperature/humidity storage, temperature cycling or preconditioning per conditions C or D.
C	Sn-Pb temperature preconditioning	Sn-Pb profile per clause 5.1.2.1	Intended to test for whisker growth after thermal exposure to Sn-Pb SMT assembly temperatures (backward compatibility).
D	Pb-free temperature preconditioning	Pb-free profile per clause 5.1.2.1	Intended to test for whisker growth after thermal exposure to Pb-free SMT assembly temperatures (Pb-free compatibility).

Another option

For those without the interest or means of conducting their own plating evaluation tests using the JEDEC standard, there are other options. One comes from the International Electronics Manufacturing Initiative (iNEMI; www.inemi.org), which developed the original test methods that formed the basis of the JEDEC standard.

The organization's Tin Whisker User Group, made up of 11 manufacturers of electronic assemblies, has published a report that includes an evaluation of lead-free finishes for various applications. The report, "Recommendations on Lead-Free Finishes for Components Used in High-Reliability Products, Version 3," was updated in May 2005 and is available on the iNEMI Web site.

While the JEDEC standard and the iNEMI report can help developers and test engineers pick out and evaluate a finish that will minimize their risk of tin whiskers, they do not provide a guarantee. JEDEC clearly warns that the test conditions and preconditions have not been correlated with field results under similar conditions.

Nor is there a way of extracting a failure probability from the test data. As long as the mechanisms that produce tin whiskers are not understood, the tests can only serve as a guideline and a means of comparison.

The industry has known about tin whiskers for decades, but they were not the subject of prolonged study until recently. As new information and insights are gathered, the JEDEC specification and the iNEMI recommendations will continue to evolve. But they currently provide a starting point for consistent test and evaluation, which is the first step toward solving the problem of tin whiskers in electronic systems. □

PRODUCTS

The following products were on display during the 2005 EMC Symposium, held August 8–12 in Chicago, IL.

Immunity tester

Haefely EMC Technology's ECompact4 transient immunity tester performs pre-compliance EMC immunity tests to the IEC 61000-4-x series. Tests include surges, surge combination waves, electrical fast transients, AC dips, DC dips, and AC magnetic fields. *Haefely EMC Technology, www.haefelyemc.com.*

Aircraft lightning tester

HV Technologies introduced a lightning simulator for testing aircraft to the DO-160D military standard. The instrument produces voltages to 3200 V and current to 128 A at frequencies of 1 MHz and 10 MHz and performs single-stroke, multiple-stroke, and multiple-burst testing. *HV Technologies, www.hvtechnologies.com.*

Active EMI antenna

Credence Technologies introduced an active dipole EMI antenna. The CTS011 has a built-in equalizing pre-amp that increases its sensitivity at lower frequencies, making it comparable to a conventional log-periodic antenna. The antenna works over the 30 MHz to 2 GHz frequency range. *Credence Technologies. www.credencetech.com.*

EMI receiver

AR Worldwide's CER2012 EMI receiver uses a modular design containing plug-ins with several frequency ranges. The mainframe receives signals from 20 Hz to 12 GHz. Plug-ins extend the range from 12 GHz to 26.5 GHz, 40 GHz, 60 GHz, and 90 GHz. To run the unit from 20 Hz to 90 GHz, you need one of each plug-in. The mainframe features a remote fixture that lets you make measurements up to 500 ft from the receiver without signal loss. *AR Worldwide, www.ar-worldwide.com.*

Laser-powered E-field probes

The LaserPro E-field probes from ETS-Lindgren get their power from a fiber-optic cable that carries infrared light from a light source and converts the infrared energy into electric power. For single-probe applications, you can use a power converter powered from a USB port. For larger applications, the company has introduced the HI06100 field monitor, which powers four probes and serves as a stand-alone field monitor. *ETS-Lindgren, www.ets-lindgren.com.*

Microcontrollers target low-power applications

Texas Instruments has expanded its MSP430 microcontroller portfolio to include ultra-low-power versions for use in portable instruments and other products demanding low power consumption. The first devices in this expanded lineup include 16-bit units in the MSP430F20xx series, which offer a 14-pin, 4x4-mm footprint and execution speeds of 16 million instructions per second (MIPS). They are code-compatible with existing MSP430 devices.

Fabricated in the vendor's F2xx process, the MSP430F20xx units operate over a 1.8- to 3.6-V range. Active current is 200 µA/MIPS, and standby current is less than 1 µA. Each device can switch from standby mode to full 16-MIPS operation in less than one µs. A flexible clock system permits operation to 16 MHz with no external components.

All MSP430F20xx units offer in-system-programmable flash, 128 bytes of RAM, a zero-power brownout-reset function, programmable pull-up/pull-down resistors on I/O pins, and a universal serial interface that can be configured as an I²C or SPI master or slave. To get started, users can purchase the MSP-FET430U14 kit, which contains a USB-based IEEE 1149.1 interface board and complete integrated development environment.

Base price: $0.49 in quantities of 100,000. Availability: samples now, production quantities in Q4. MSP430F20xx versions to be introduced over the next 18 months will add functions such as additional memory and sigma-delta ADCs. *Texas Instruments, www.ti.com/mcu.*

Aeroflex adds PXI RF instruments

Building on the company's PXI 3000 series of RF test systems, Aeroflex has unveiled two new PXI modules and a new software suite that expands the range of use, speed of operation, accuracy, and flexibility of its PXI test systems. The new products are the 3020A 2.7-GHz digital RF signal generator, the 3030A 3-GHz RF digitizer with 33-MHz bandwidth, and a cdma2000 reverse-link software measurement library.

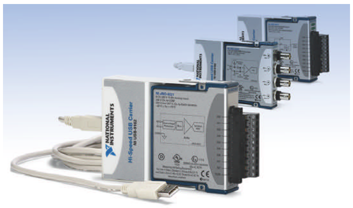
The Aeroflex 3020A combines with the Aeroflex 3010 RF synthesizer to form a 3U digital RF signal generator with integrated dual-channel AWG that occupies three PXI slots. Similarly, the 3030A RF digitizer and 3010 RF synthesizer combine to make a 3U RF digitizer that also occupies three PXI slots.

The new measurement software for the Aeroflex 3000 series, the cdma2000 Measurement Suite, is an Active X control-software measurement library used in conjunction with the 3030 RF digitizer to provide measurement functions for power, spectrum, and modulation analysis of cdmaOne and cdma2000 reverse-link transmissions.

Prices: 3020A digital RF signal generator—$8596; 3030A RF digitizer—$12,940; cdma2000 Measurement Suite—$3893. *Aeroflex, www.aeroflexstore.com.*

USB data-acquisition line grows

National Instruments' line of USB data-acquisition modules includes eight new models, all of which run at USB 2.0 speeds. The line includes a 24-bit, four-channel thermocouple model ($395); a 24-bit, four-channel, 50-ksample/s model ($1295); and a 16-bit, 100-ksample/s, four-channel, simultaneous-sampling model ($475). Two 12-bit, eight-channel analog-input modules are also available: one samples at 500 ksamples/s ($595), while the other can handle ±60 V at 800 ksamples/s ($745). Digital I/O modules include eight-channel input and output modules and a relay module ($295 each).



All models feature 250 Vrms channel-to-ground isolation. Analog-input units include software for logging data or controlling digital I/O. Connection options include screw-terminal connectors for temporary hookups or 25-pin D connectors for more permanent connections.

National Instruments, www.ni.com/dataacquisition.

Probes handle LED board test

Optomistic Products has introduced a range of sensors and probes that serve as optical counterparts to electrical probes in printed-circuit-board test applications. The products check for color and intensity on circuit-board-mounted LEDs. Through embedded digital signal processing, they provide the unambiguous detection and indication of any LED color—from near UV, through the visual range, and down to near IR. The probes offer a choice of 13 probe tips, including very fine 1.2-mm and 2.1-mm diameter tips for inspecting close-spaced LEDs. Models are available with USB interfaces, including software.

Base price: $53 each in production quantities. *Optomistic Products, www.optomisticproducts.com.*

Signal-conditioning boards

Intended for use with Microstar's Data Acquisition Processor (DAP) boards, the MSXB 064 and MSXB 065 signal-conditioning boards provide eight instrumentation amplifiers with user-selectable sample-and-hold circuits for each channel and gains of 1, 5, and 25. The MSXB 065 also includes fourth-order low-pass filters on optional daughterboards that eliminate alias errors. Both cards let you sample all channels simultaneously. The boards fit into a standard 3U Eurocard B slot. Base price: MSXB 064—$1195; MSXB 065—$1395. *Microstar Laboratories,* *www.mstarlabs.com.*

Pulse generator

Configured with a combination of input and output modules, the 9800 pulse generator offers a flexible setup for generating and synchronizing multiple pulses for electronic R&D and test lab environments. Outputs are provided in banks of two outputs per module. A four-channel generator uses two modules, while an eight-channel generator employs four. Base price: $1990. *Quantum Composers,* *www.quantumcomposers.com.*

UMTS protocol analyzer

GL's UMTS protocol analyzer captures and analyzes various UMTS protocols and performs a range of measurements to troubleshoot complex 3G networks. The tool lets you monitor, capture, decode, and collect essential information across several interfaces, including IuB, IuR, IuC, and IuP. To assist in fault diagnosis, the analyzer simultaneously handles ATM-based AAL2 and AAL5 virtual channels with reassembly. It also supports various control plane protocols, user plane protocols, and NAS protocols, as well as UTRAN-specific protocols. *GL Communications, www.gl.com.*

Machine-vision camera

To eliminate jitter and make image capture more accurate at a resolution of 1024x768 pixels, the IK-TF7 color camera incorporates three 1/3-in. progressive-scan CCDs. The camera's small size (44x44x78 mm) and light weight (5.82 oz) make it useful for machine-vision applications. A variable-speed electronic nine-step shutter operates from 1/100 s to 1/100,000 s, allowing the capture of fast-moving items under test. The IK-TF7 provides full-pixel independent readout at 30 frames/s, with partial-scan speeds of up to 90 frames/s. *Toshiba America Information Systems, www.toshiba.com/taisisd.*

JTAG emulator

When used with the Raza Microelectronics (RMI) XLR processor, the CodeRunner-XLR JTAG emulator software offers source-level debugging for multiple processors that effectively partitions the individual processor's hardware and software into a multi-windowed environment. The emulator is available with PCI, USB 2.0, and Ethernet JTAG controllers that provide a sustained JTAG test clock frequency as high as 80 MHz and file download speeds of up to 1 Mbyte/s. CodeRunner-XLR also offers an extensive macro and scripting capability and can interpret command files written in a structured C-like language. You can use the emulator for board bring-up, driver and firmware development, and software application debugging. *Corelis, www.corelis.com.*

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WLAN power analyzer

Small enough to fit in the palm of your hand, the Caterpillar sweeping analyzer performs frequency and power measurements on an array of IEEE 802.11 (b, a, g) WiFi network gear. The receiver attaches directly to an access point, bridge, or network interface card using the supplied SMA antenna connection kit. The Caterpillar measures both 2.4-GHz and 5-GHz frequency bands to verify and analyze output power levels, report their channel and frequency, and create an 802.11 power profile. Price: less than $750. *Berkeley Varitronics Systems, www.bvsystems.com.*

Analog-input module

A single ADAM-4019+ module offers eight 16-bit differential analog-input channels, each of which can be individually configured to accommodate thermocouple, mV, V, or mA input. The module's mixed input ranges, including a 4- to 20-mA range, enable it to satisfy most industrial automation requirements. The ADAM-4019+ also provides 3000-VDC isolation, a watchdog timer, and a burnout detection function to indicate sensor failure. It can be programmed in ASCII or Modbus. Price: $350. *Advantech, www.eautomationpro.com.*

Multiphysics modeling CD

The Electronics Kit CD, an interactive learning aid, introduces the benefits and straightforward implementation of multiphysics modeling and simulation using FEMLAB. The CD combines a movie introducing the FEMLAB software and actual model files that you can open and explore with the included multiphysics viewer application. The free kit supplies eight FEMLAB models, covering devices from discrete transistors and inductors to memory arrays, as well as documentation that discusses the theoretical underpinnings of the driving physical phenomenon. *Comsol, www.comsol.com.*

Four-decade divider

The PRL-230, a self-contained frequency divider pod from Pulse Research Lab, accepts TTL clock signals from DC to 100 MHz and generates f/10, f/100, f/1000, and f/10,000 divided outputs. All divided outputs are synchronous with the input frequency and can be used for triggering data-acquisition systems, pattern generators, oscilloscopes, and networking/telecommunications devices. The TTL input has a switchable 50-Ω/500-Ω input impedance and can toggle up to 100 MHz. Each output delivers greater than 2.2 V into a 50-Ω load. *Pulse Research Lab, www.pulseresearchlab.com.*

VoIP test suite

An optional VoIP test suite for the CoLT-450 DSL test set lets you quickly and effectively determine the level of quality of service customers are receiving. The handheld tester provides a comprehensive display of VoIP call flow; monitors IP, ATM, and DSL framing errors; supports SIP and MGCP; furnishes bandwidth usage statistics for ADSL, ATM, and IP layers; and supplies a running histogram view of jitter and delay distribution to verify overall VoIP quality. *Consultronics,* www.consultronics.com.

RF connectors

Part of the GORE blindmate/push-on connector family, the GORE 100 series is a high-density microwave interconnect system offering operation through 100 GHz. The blindmate interfaces, which are extensions of the SMP and SMPM families, accommodate both radial and axial misalignment with negligible VSWR change. Price: less than $5, based on volume and configuration. *W.L. Gore & Associates,* www.gore.com.

320-W switching supplies

Enclosed switching power supplies in the SP-320 series produce 320 W of output power for low- to moderate-power telecommunication, industrial control, and embedded system applications. All models accommodate an input range of 85–265 VAC with active power factor correction to 0.98. Units are available with single, dual, and triple outputs ranging from 5 VDC to 48 VDC. Price: $79 (OEM quantities). *Astrodyne,* www.astrodyne.com.

Communications library

With enhanced features for model-based design, the Communications Blockset 3 from The MathWorks lets you design and simulate the physical layer of communication systems and components, such as commercial or defense wireless and wireline systems. In addition to an extensive set of block libraries, this version of the product includes new channel visualization and bit-error-rate analysis functions that enable you to access the communications system simulation capabilities of Matlab and Simulink within one GUI environment. The Communications Blockset 3 also adds synchronization and equalization libraries and is available for Windows, Macintosh, and Unix/Linux platforms. Base price: $1000. *The MathWorks,* www.mathworks.com.

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CATALOGS & PRODUCTS

The following write-ups were supplied by advertisers in this issue.

Power products

AMREL/American Reliance manufactures the eLOAD line of programmable air- and water-cooled loads (800 W to 100+ kW, 600 VDC/1500 ADC) as well as the ePOWER line of programmable linear and switching power supplies (20 W to 900+ kW, 800 VDC/2700 ADC). *AMREL/American Reliance, www.amrel.com.*

EMC services

TÜV America's EMC services include HIRF testing up to 9500 V/m, emissions, immunity, multiple-burst/multiple-stroke lightning, and more. For more information, visit the company's Web site or call 866-EMC-AERO. *TÜV America, www.TUVamerica.com.*

Programmable switching systems

Cytec offers programmable switching systems for ATE data-acquisition, communications LAN, telephony, and microwave and RF systems. Products include matrices, multiplexers, and discrete relays. DC to 18-GHz systems are available, as are custom and OE systems. *Cytec, www.cytec-ate.com.*

Kelvin sockets

Armel Electronics offers 15-A rated phosphor bronze Kelvin contacts (eight count) in molded DAP housings for facilitating electrical measurements in test lab and factory production equipment testing applications. *Armel Electronics, www.armel.us.*

Toolkits and accessories

The Contact East/Jensen Tools Master Catalog features JTK toolkits and cases, test and measurement equipment, telecom and fiber-optic equipment, hand and power tools, specialty tools, soldering and desoldering equipment, and electronic production supplies. *Contact East/Jensen Tools, www.contacteast.com.*

Waveform generators

Tabor Electronics 2005 catalog provides specifications for the company's entire span of instruments: waveform generators, amplifiers, and counters. A

short-form catalog and brochure describing the new Wonder Wave series of high-sample-rate arbitrary waveform generators is available. *Tabor Electronics, www.taborelec.com.*

LED board test

Celebrating its 15th anniversary, Optomistic Products now has a new range of Smart LightProbes for unambiguously checking LED color and intensity. Prices are as low as $53 each. *Optomistic Products, www.optomisticproducts.com.*

Troubleshooting guide

A free CD, *Interactive Test & Measurement Troubleshooting Guide: How to Avoid Common Measurement Errors*, lets users explore the symptoms and causes of errors associated with low voltage, low current, low resistance, high resistance, and voltage from high-resistance source measurements. *Keithley Instruments, www.keithley.com/at/229.*

Precision RTD recorder

The OM-CP-RFRTDTEMP101A is a battery-powered, precision temperature recorder and wireless transmitter. This all-in-one, easy-to-use, portable device measures and record up to 5461 measurements. $449. *Omega Engineering, www.omega.com.*

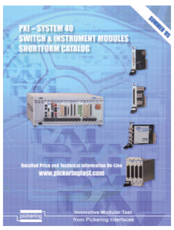
Portable instrumentation cases

Fieldtex, a long-time manufacturer of soft-sided carrying cases, is now introducing a line of blow-molded and injection-molded cases with custom foam inserts or pluck foam. *Fieldtex, www.fieldtexcases.com.*

Boundary-scan tools

Corelis offers a complete line of JTAG (boundary-scan) tools called ScanPlus and ScanExpress for interconnect testing and JTAG in-system programming of flash memories and CPLDs. *Corelis, www.corelis.com.*

PXI shortform catalog



Pickering's 36-page PXI catalog presents the company's range of PXI switch modules as well as its PXI instrumentation and chassis. Data sheets and pricing are available on the company's Web site. *Pickering Interfaces, www.pickeringtest.com.*

Probes and test leads

Probe Master's catalog features 500-MHz oscilloscope probes and a new series of differential probes. Other products include DMM test leads, BNC cables, probe test clips, SMD probes, and grippers. *Probe Master, www.probemaster.com.*

USB data acquisition

The new usbDAQ modules from CEC are low cost and ship with a free TestPoint application to have you up and running in minutes. These modules are multifunction units with eight analog inputs and two analog outputs. *CEC Capital Equipment, www.cectp.com/tmw.*

Optical path target

Edmund's Clear Optical Path USAF targets are manufactured from an extremely thin electroformed nickel substrate. Because there is no glass in the pattern area, light travels only through air, eliminating chromatic and absorption issues. *Edmund Optics, www.edmundoptics.com.*

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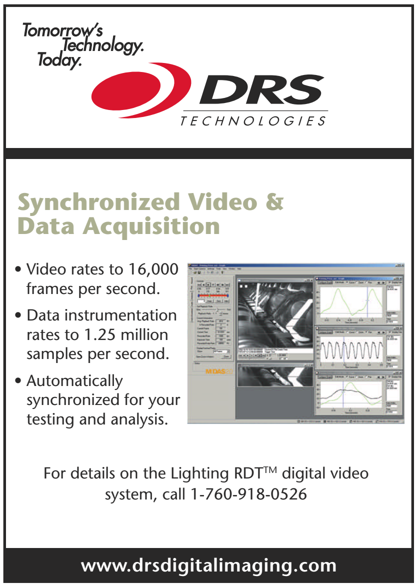
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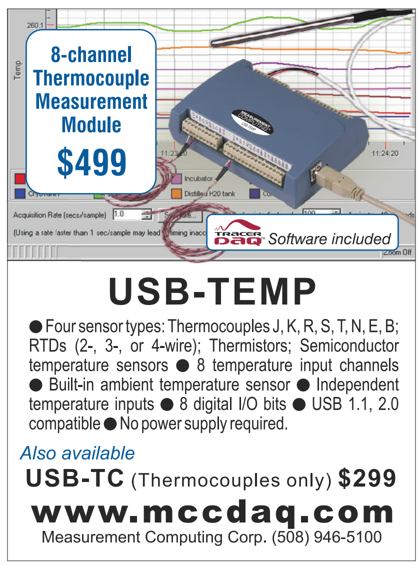
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GORDON TAYLOR
President and CEO
Racal Instruments
An EAD North America
Defense Co.
Irvine, CA

Gordon Taylor joined Racal Instruments in 1963 as a design engineer. Progressing through several engineering and technical posts, he became deputy managing director of Racal-Dana Instruments in 1978, president in 1980, and managing director and CEO in 1988. He continued to head the company through an acquisition by Thales in 2000, a management-led leveraged buyout in November 2001, and ultimately, through a successful sale to EADS North America in October 2004. Gordon Taylor is the president of the newly formed Test & Services Business Unit of EADS North America Defense.

Test industry stalwart gears up for growth

Now a part of EADS, a worldwide aerospace and defense industry giant, Racal Instruments will be devoting even more resources to new product development, says CEO Gordon Taylor. *T&MW* spoke with him about the state of the communications-test and modular-instrument markets.

T&MW: What is Racal Instruments' niche in the test business?

Taylor: We started as an instrument company more than 45 years ago, but we have increasingly evolved into a full-service company that offers a great deal of system integration, as well as field support for our equipment right up until the end of its useful life. We are strongly rooted in functional test for the military and commercial markets.

T&MW: How will the acquisition of Racal Instruments by EADS North America affect your strategy?

Taylor: It's a dramatic change. At Autotestcon, we will announce our new name, EADS North America Defense, Test & Services. We were in the right place at the right time in that we have worked with EADS Test & Services in Europe for many years. Now, EADS is encouraging us to grow in North America both internally and through aggressive acquisition. In the first half of this year alone, we recruited more than 50 employees—90% of whom are engineers. This will bolster our product-development efforts in modular instruments and in major systems, such as engine testers.

T&MW: What factors are driving the growing interest in modular instruments?

Taylor: Everyone wants to pack more and more capability into smaller spaces. In addition, engineers who must communicate with their test systems are not always as software savvy as they would like to be. They need simple, easy-to-use systems, which is another driving factor for modular instruments. Our company has delivered thousands of software tools to simplify the connection between the engineer doing the job and the test system he's using.

T&MW: As a founding member of the VXIbus consortium, how do you assess the demand for VXI today?

Taylor: Racal Instruments is still a major player in VXI. I wouldn't say the market is growing, but neither is it shrinking, as naysayers claim. There is strong demand for VXI products from the military.

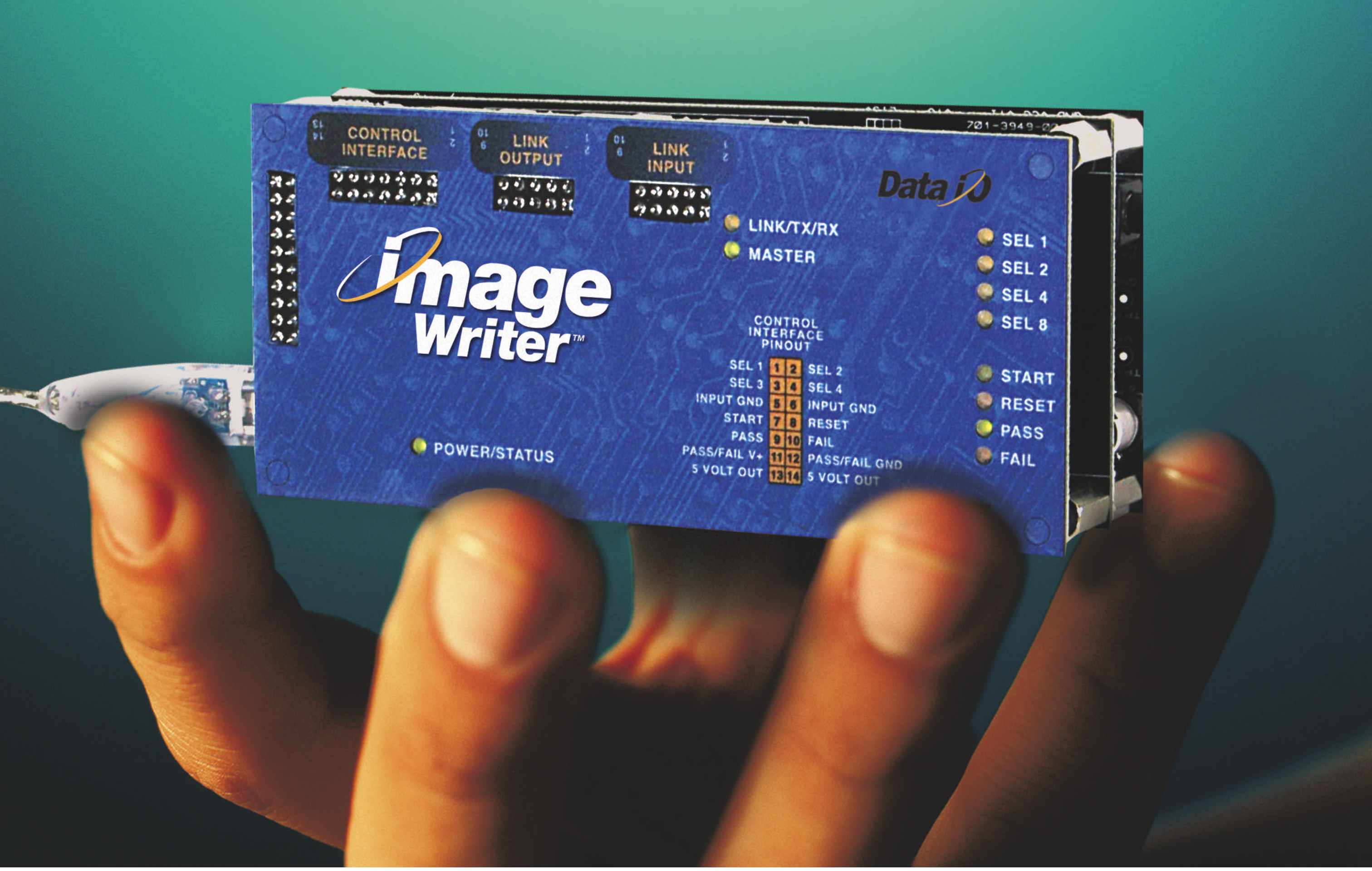
T&MW: Over the last couple years, your company has introduced new products with the PXI platform. Where do you see the greatest demand for PXI?

Taylor: PXI wins in applications where simplicity, limited functionality, and compact size are important. It doesn't compete with VXI at the top end. We use PXI in some of our engine testers, and there is demand for PXI in lower-frequency, data-acquisition applications. We work across quite a few platforms, but what ties it all together is that we are a modular-instrument company.

T&MW: Do you see signs of a comeback in the communications test market?

Taylor: We had our own radio-test arm, but our previous owners sold it off to Aeroflex last year. So we are now out of the mobile radio tester market. We intend to grow our business in RF test, primarily aimed at the military market. When the bubble burst in the commercial communications market, test companies suffered huge cancellations of business. We made a laser tester that grew to more than $14 million in sales in less than two years, and then crashed to nothing within a year. We still sell laser testers, but it is not a major area for us. One segment where we do see a lot of activity is in satellite and RF markets, where products like our 1257, a configurable microwave and optical switching platform, are selling well. T&MW

▶ *The online version of this article includes more Q&A with Gordon Taylor on switching products, military test, and global technology:*
www.tmworld.com/archives



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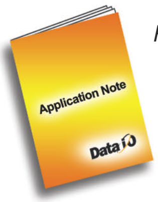

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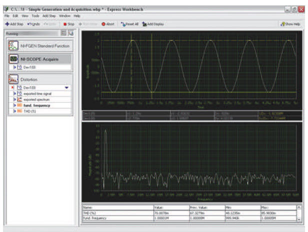

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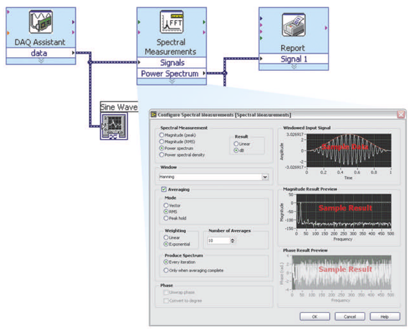

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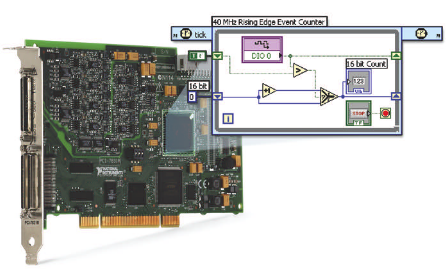

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