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Test & MEASUREMENT WORLD®

THE MAGAZINE FOR QUALITY IN ELECTRONICS

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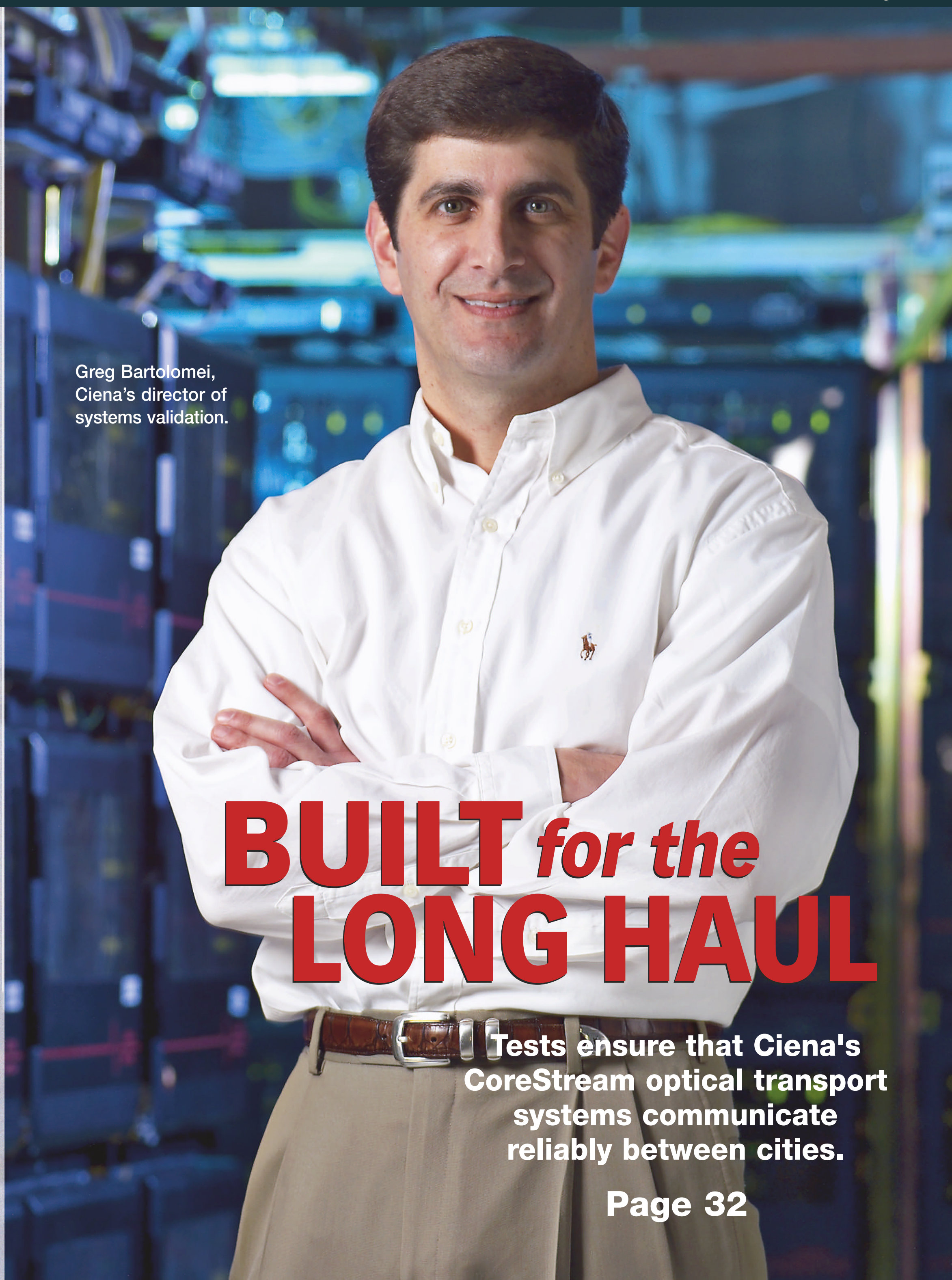

Greg Bartolomei, Ciena's director of systems validation.

BUILT *for the* LONG HAUL

Tests ensure that Ciena's CoreStream optical transport systems communicate reliably between cities.

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2.05 GHz Clock Generator

CG635...$2490 (U.S. list)

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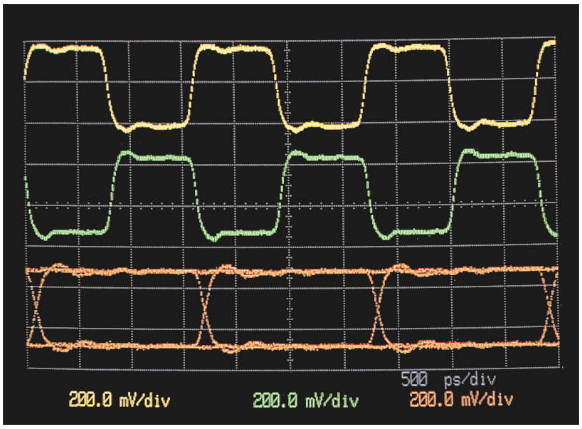

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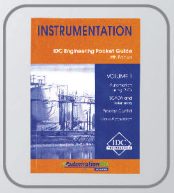

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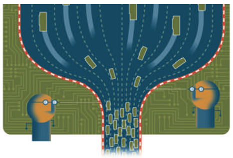

TEST REPORT SUPPLEMENT

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Machine-Vision & Inspection Test Report

- High-speed sensors address inspection
- A comprehensive imaging reference

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

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The engineering career

Is engineering a wise career choice? It's not an easy sell, according to a recent *Wall Street Journal* article, which cites the failure of a successful engineering executive to entice his sons to study engineering—they both opted for economics ("Even Tech Execs Can't Get Kids to be Engineers," March 29). That article resonated with me, as my son has also chosen to study economics.

Shall we assume that students who are accomplished in math and science aspire to control the federal funds rate rather than invent quantum computers? Anecdotal accounts regarding offspring of engineers should be taken with a grain of salt—children often want to stake out their own turf. But the *Journal* article does present hard statistics: In 1975, the US ranked third worldwide in its number of undergraduate engineers and natural scientists; today, it ranks 17th.

RICK NELSON, CHIEF EDITOR

One might speculate on reasons for a lack of interest in high tech: an aimless space program that lacks the focus of the 1960s' moon race or the outspokenness of politicians openly hostile to science that doesn't support an ideological agenda. A recent study of 2800 Silicon Valley students, the *Journal* article reports, found that 68% of the participants eschewed high-tech studies, citing tedious, intimidating subject matter pursued by socially awkward practitioners obsessed with work.

Is engineering a tedious, intimidating subject pursued by socially awkward practitioners?

Compounding the difficulty is a rather murky employment situation in the US. Economist Paul Krugman, writing in the *New York Times* ("A Whiff of Stagflation," April 18), claims the employment situation may be worse than official figures suggest. Prospective engineers might feel particularly vulnerable, with engineering skill sets more prone to outsourcing than those of health-care providers, or even economists. After all, *E=IR* in every culture and political arrangement, and a line of Verilog code looks the same regardless of the coder's native language.

And finally, letter writers responding to the *Journal* article question whether there is a shortage of engineers despite college-enrollment trends; if there were, one writer contends, starting salaries would be soaring but are not.

What's your take on the engineering profession? *Test & Measurement World* is now conducting a survey of randomly selected readers to gauge their opinions on factors including salaries, opportunities for advancement, and overall job satisfaction; we will report the results in our August issue. If you receive the survey, please complete it promptly. Even if you don't, we are interested in what you have to say. Would you recommend the engineering profession to a college student? Send your comments to me at the address below.

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[An exclusive interview with a test engineer]

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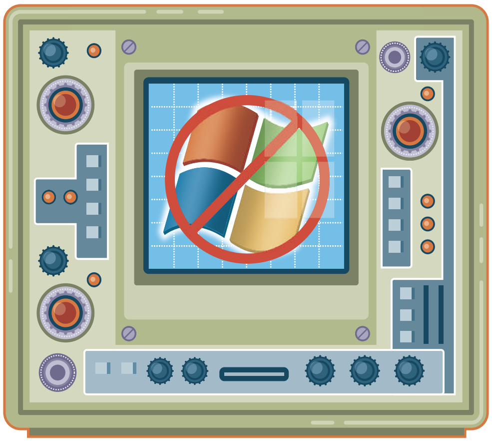

DAN GUIDERA

As a product engineer at Analog Devices' Northwest Labs in Beaverton, OR, Ron Simonson puts new IC designs through rigorous tests. His tests verify that a device meets engineering specifications, and he also develops application circuits that go into data sheets to help engineers with their designs. Simonson evaluates devices such as log detectors, rms detectors, I/Q modulators and demodulators, log amplifiers for communications circuits, and RF ICs.

T&MW: What is your role in evaluating a new IC?
Simonson: When I receive the first pieces, I measure voltages and currents to make sure that the device draws the proper amount of current and that it drives the specified load. I also test for stability and frequency response. At first, I manually test a part on the lab bench. When I reach a point where I need to repeat a set of measurements many times or I have a time-consuming test, I automate the data collection.

T&MW: What do you use to automate your tests?
Simonson: I use several software tools to automate tests and analyze test data. For instrument control and data collection, I use Agilent Vee running on Windows 98. I often write code modules and DLLs in C to enhance Vee's capabilities. I also get sample programs from the Vee e-mail user group that I can modify to suit my needs. I then move the data to a Linux PC where I use gnuplot to view waveforms and use Octave for data processing.

T&MW: Why do you still use Windows 98?
Simonson: I use it because it lets me write directly to a PC's I/O ports. Many of our devices have registers and I can use the parallel port to write to them. Writing to a parallel port is more difficult with Windows 2000 or XP.

T&MW: Why do you use Linux tools such as gnuplot and Octave?
Simonson: I'm a Linux user, although I use Windows for instrument control. I often test dozens of parts to get a feel for a design's typical performance. With Linux, I can use tools that don't bloat my data files. For example, my tests can easily collect over 1 Mbyte of data. If I move that data into Excel, the file can easily exceed 30 Mbytes when you add math and plots. Although I can use Vee to store data in a Excel files, I don't because I find that writing directly to Excel while a long test runs isn't reliable. If I run a test over a weekend and the PC crashes, I lose a lot of data and time. I prefer to save the data in binary format because it's more reliable and the files are small.

With gnuplot, I can leave the data in its original file, and gnuplot will read and plot it. If I need to manipulate data with FFTs or other functions, I use Octave, an open-source program similar to Matlab. I just write a script and Octave produces the results I need. Because I prefer Linux, I don't use Matlab, even though it comes with Vee.

T&MW: What can test-equipment makers do to make your job easier?
Simonson: Test-equipment makers may use proprietary binary formats to save data. They don't always clearly specify data formats for these proprietary files. I also find that instrument manuals have errors relating to programming. On rare occasions, example programs don't work.

I'd also like oscilloscope makers to get Windows out of their instruments. I want my scope to make measurements and collect data, not run Excel. I have scopes that run Windows 98 and I'm forbidden from connecting them to the corporate network. I had to create a local network in the lab using a PC running Linux that has two network cards. The PC lets me connect instruments to a local network while isolating them from the corporate network.

From a performance perspective, I need instruments with better dynamic range. I'd also like a scope that doesn't change its sample rate when I change the timebase setting. 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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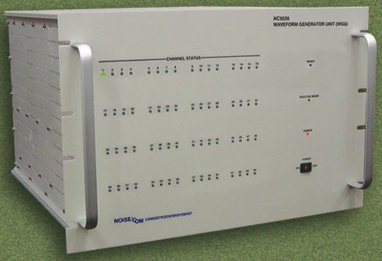

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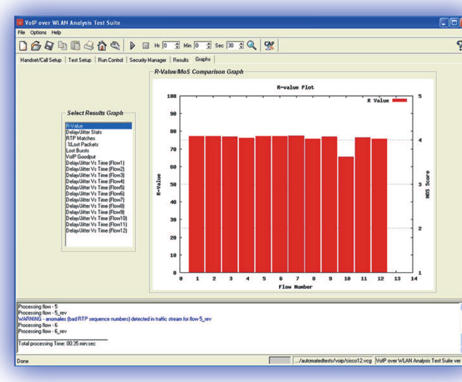
Test suite analyzes VoIP over WLAN



VeriWave has introduced what it calls a "real-world Voice over Internet Protocol (VoIP) over WLAN test solution." The VeriWave VoIP over WLAN analysis test suite runs on the company's WaveTest traffic generator/performance analyzer to assess voice-quality metrics of real-world VoIP over WLANs. It analyzes traffic prioritization, evaluates the network behavior in the presence of non-voice traffic, and measures overall call quality when users roam between WLAN access points.

The VoIP over WLAN test suite provides for open-air testing of mixed voice/data networks. The test suite evaluates mixed-use networks by introducing data traffic to the networks, generated by the WaveTest analyzer. The WaveTest also captures all traffic on the WLAN and calculates a variety of performance metrics to characterize the network behavior.

One company that has employed the new test suite is Aruba Networks. "Voice is quickly becoming one of the driving applications for wireless within the enterprise," said Keerti Melkote, co-founder and VP of product management for Aruba Networks. "VeriWave's VoIP over WLAN test suite has proven to be the best-suited, most reliable, and precise test tool to qualify our offering in real-world conditions."

The VoIP over WLAN analysis test suite and the WaveTest traffic generator/performance analyzer are available now. WaveTest pricing starts at $28,995. www.veriwave.com.

IEC approves Ethernet Powerlink Real-Time Industrial Ethernet

The International Electrotechnical Commission (IEC) has accepted Ethernet Powerlink (EPL) as a Publicly Available Specification (PAS), according to the Ethernet Powerlink Standardization Group (EPSG).

The Industrial Automation Open Network Association (IAONA) submitted the EPL spec to IEC SC65C as a real-time industrial Ethernet communication profile. EPSG reports that 96% of all IEC national committees voted in favor of EPL. At the same time, the SC65C subcommittee approved the spec as a new work item—a key step for Ethernet Powerlink in becoming part of the IEC Standard IEC 61784-2, "Digital data communications for measurement and control—Part 2: Additional profiles for ISO/IEC 8802-3 based communication networks in real-time applications," which is under development.

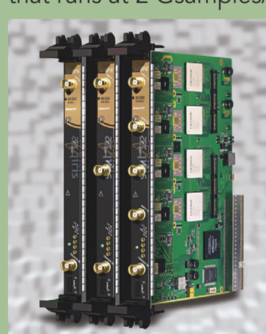
The EPSG says it and its strategic partners will also work on reformatting the EPL specification to be integrated into the next revision of the IEC-61158 Fieldbus standard. Among EPL's major advantages, EPSG reports, is the fact that the protocol can be implemented on any standard Ethernet hardware and chip without proprietary hardware components or ASICs.

EPSG claims more than 60,000 EPL-enabled devices are already in use and more than 300 industrial companies worldwide support EPL, with more than 30 companies offering EPL-enabled products or services. www.ethernet-powerlink.org.

EDITORS' CHOICE

Digitizer cards interleave for high speed

When your test application calls for high-speed digitizers, look to the CompactPCI/PXI DC2x2 series from Acqiris, which consists of three 10-bit models. The high-end DC282 is a four-channel unit that runs at 2 Gsamples/s on all four channels, interleaved to 4 Gsamples/s on two channels and 8 Gsamples/s on one channel. The DC252 is a dual-channel unit at 4 Gsamples/s and 8 Gsamples/s, while the DC222 is a single-channel, 8 Gsamples/s card. The cards bring 3 GHz of bandwidth to their analog-to-digital converters (ADCs) and 2 GHz bandwidth with an attenuator. All cards are 6U size.



When running on fewer than all channels, the cards use "ping-pong" memory that alternates memory blocks with each sample. While one of the card's ADCs is digitizing, the previous samples move out of acquisition memory to the card's output. Two ASICs provide signal conditioning, amplification, and interleaving of the channels. Software support includes drivers for Windows, Phar Lap, VxWorks, Linux, LabWindows/CVI, LabView, and Matlab.

Base price: $21,980. *Acqiris,* WWW.ACQIRIS.COM.

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Rohde & Schwarz buys scope manufacturer

Rohde & Schwarz (Munich, Germany) has bought out Hameg Instruments (Frankfurt, Germany), a 50-year-old company known mainly for its low-cost oscilloscopes. R&S has announced that the Hameg name will continue and jobs in development, production, and sales at Chemintz, Mainhausen, and Munchenbernsdorf will not change. Karl Hartmann, owner of Hameg, will step down due to his impending retirement. www.rohde-schwarz.com.

Teradyne revenues drop in Q1

Teradyne released its Q1 results in mid-April, reporting that net orders had increased over the previous quarter while revenues and earnings had dropped. The company reported net orders of $340.7 million for the quarter—an increase of 14% over Q4 2004. Yet, its Q1 sales of $305.6 million represented a 19% decrease from Q4 2004. The company also reported a Q1 net loss of $52.6 million ($0.27 per share), compared to a net income of $3.3 million ($0.02 per share) in the last quarter of 2004.

Teradyne's numbers were also down compared to Q1 2004, when the company had net orders of $551.2 million, sales of $430.6 million, and a net income of $40.2 million ($0.20 per share). www.teradyne.com.

CALENDAR

International Microwave Symposium, June 12–17, Long Beach, CA. Sponsored by IEEE. *www.ims2005.org.*

Design Automation Conference (DAC), June 13–17, Anaheim, CA. Sponsored by IEEE. *www.dac.com.*

Semicon West, July 11–15, San Francisco, CA. Sponsored by SEMI. *www.semicon.org.*

EMC Symposium, August 8–12, Chicago, IL. Sponsored by IEEE, EMC Society. *www.emc2005.org.*

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

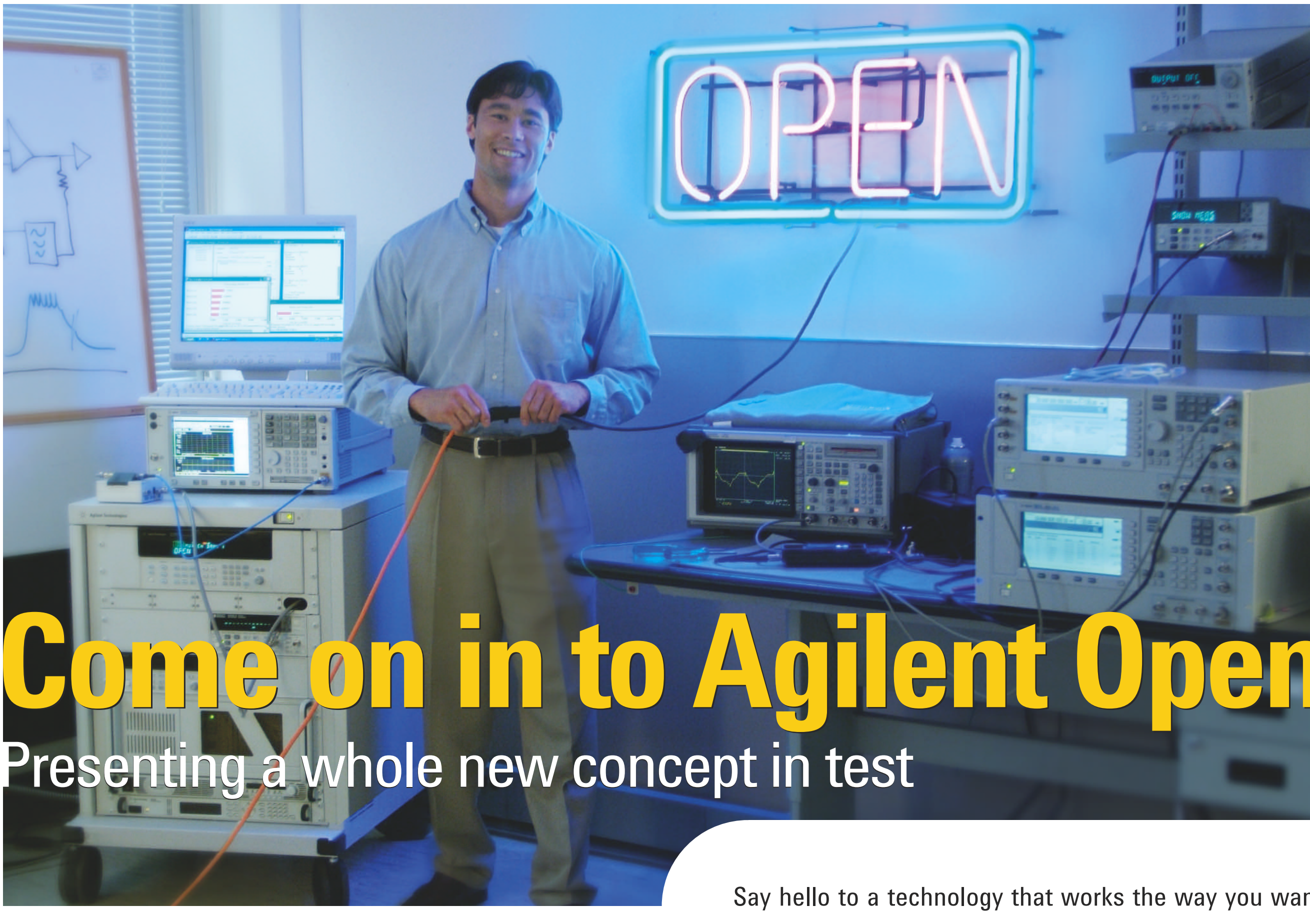
EDITORS' CHOICE

Communications service monitors support analog radio test

Aeroflex has introduced a pair of communications service monitors for analog radio testing. Aimed at the Private Mobile Radio (PMR) sector, which is used by first responders in emergency situations, the lightweight units (which, like their predecessors, weigh less than 25 lbs) provide a full-span spectrum analyzer and a tracking generator with full offset tracking. They can measure power to 150 W and have a frequency range from 400 kHz to 1.05 GHz. The 2948B also offers a low-phase-noise signal generator.

The new instruments share their predecessors' testing capability for radio service and maintenance, base station service and maintenance, and manufacturing test. Equipped with flexible audio and demodulation filters and a sunlight-readable transflective color display, the two new units include greater tracking-generator isolation. An internal battery option for the Model 2945B allows up to 60 min of field use. The new options include support for PMR's Logic Trunked Radio (available in October) and Tone Remote functions.

Base price: $17,200. *Aeroflex,* WWW.AEROFLEX.COM.



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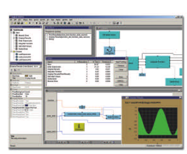

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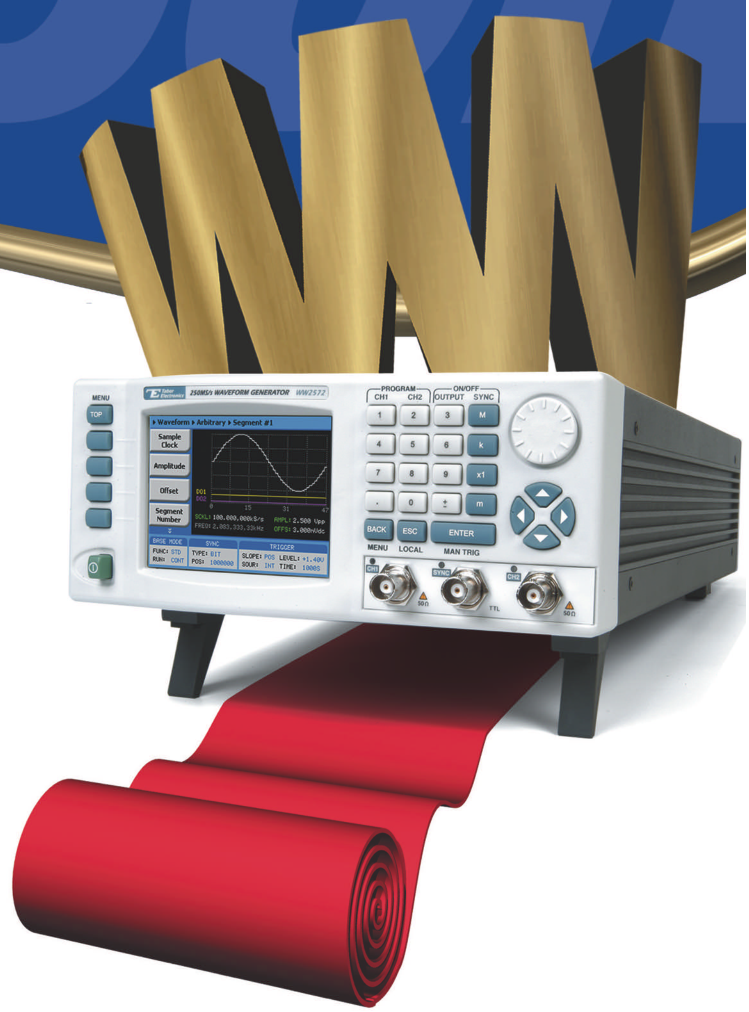

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Optical test products on the rise

> > > Optical Fiber Communications/National Fiber Optic Engineers Conference, March 7–9, Anaheim, CA. www.ofcconference.org.

At this year's OFC/NFOEC, one thing became apparent—fiber to the home (FTTH), fiber to the premise (FTTP), or fiber to the whatever you want to call it (FTTx) is the technology driving the communications business. That includes test and measurement, as numerous test equipment makers displayed handheld equipment such as OTDRs that can test newly installed short-run fiber.

Anritsu (www.us.anritsu.com) demonstrated a 40-Gbps jitter and BER tester used in R&D labs. For development of 10-Gbps products and networks, Anritsu introduced the MP 1590B SONET tester, which complies with ITU-T recommendation O.172 for jitter measurements. **Yokogawa** (www.yokogawa.com) displayed light sources, OTDRs, an optical sampling scope, laser sources, optical packet switches, and a 10-Gbps BERT. **Circadiant Systems** (www.circadiant.com) demonstrated an optical standards tester (OST) that automates BER vs. optical power and BER vs. OSNR tests. The company introduced the A3318, an interface between electrical signals and 850-nm multimode fiber for the OST.

The MP 1590B SONET tester complies with ITU-T recommendation O.172. Courtesy of Anritsu.

Peleton (www.peleton.com) introduced the TM3100C multiwavelength laser source that can produce light in the C band at up to 40 wavelengths at 100-GHz spacing. The TM3050C can produce 80 wavelengths at 50-GHz spacing. **Agilent Technologies** (www.agilent.com) introduced an 8X Fibre Channel tester and displayed the E6000 series OTDRs.

Newport (www.newport.com) exhibited power meters and polarization measurement-and-control units that you can use to build an optical control loop. **SHF Communication Technologies** (www.shf.biz) showed a BERT that the company says operates at 50 Gbps. **dBm Optics** (www.dbmoptics.com) introduced an optical power meter and displayed a component spectrum analyzer that characterizes transmitters and receivers.

EXFO (www.exfo.com) demonstrated its FTB-400 test platform, which consists of several mainframes that accept 15 different input modules such as an OTDR and optical spectrum analyzer. **Acterna** (www.acterna.com) displayed test equipment for physical-layer testing, including the ONT-506, an optical spectrum analyzer with BERT capabilities. **Apex Technologies** (www.apex-t.com) exhibited an optical spectrum analyzer and optical vector analyzer.

LeCroy (www.lecroy.com) demonstrated its Serial Data Analyzer and its WaveSurfer oscilloscope. **ILX Lightwave** (www.ilxlightwave.com) displayed laser-diode test equipment, including a current source, parameter analyzer, and burn-in tester. **PXIT** (www.pxit.com), a maker of PXI modular instruments, showed its power meter, BERT, and optical attenuator.

Continuum Photonics (www.continuumphotonics.com) showed its optical switches working with test equipment from Agilent Technologies. **NetTest** (www.nettest.com) displayed the CMA 5000 multilayer test platform along with several handheld instruments for field applications.

Synthesys Research (www.bertscope.com) displayed its BERTscope line of BER testers that also display eye diagrams and operate on data streams up to 12.5 Gbps. **OptoTest** (www.optotest.com) introduced modular power meters that connect to a computer's USB port for portable, low-cost measurements. T&MW

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May 2005

Test & Measurement World

Machine-Vision & Inspection

TEST REPORT

IMAGE ACQUISITION

High-speed sensors address inspection

Stephen F. Scheiber, Contributing Technical Editor

People who aren't experienced with machine vision may think that measuring a linewidth on a printed-circuit board and determining the presence or absence of a component on that same board are essentially the same task. But the equipment and techniques used for each application will be very different. Similarly, equipment used to inspect an expensive, high-margin product like a cellular-network base station requires features quite different from those used to inspect a high-volume, low-margin (or zero-margin) product such as a cellular phone. According to Terry Guy, product marketing manager for Eastman Kodak's Image Sensor Solutions Group in Rochester, NY, success in any vision application requires keeping the needs of that application firmly in mind.

At the "heart" of the system

Consider the image sensor, what you might call the "film" part of a camera, computer, or imaging system. Light-sensitive sites (pixels) on the sensor capture the image in much the same way that the retina of the eye captures its image. The sensor then converts the pixels into electrical signals and transmits those signals out of the sensor and eventually to the computer system for analysis. **Figure 1** shows a block diagram for a typical machine-vision camera.

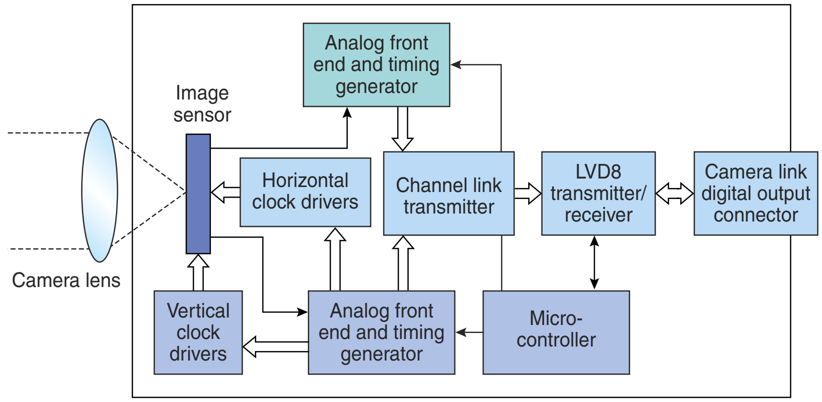

Fig. 1 A block diagram of a typical camera system. The sensor serves the same purpose as the retina of the eye. Courtesy of Eastman Kodak Image Sensor Solutions.

The sensors capture an image using either progressive-scan or interlaced techniques. In progressive-scan, the sensor exports the entire image in a single read-out cycle. An interlaced imager reads out the even-numbered lines of the image in one cycle and the odd-numbered lines in the next. The use of two read cycles for each image might suggest that this technique can provide increased image resolution. In many situations, however, interlaced images suffer from motion-based blurring because of the time delay between the two cycles.

Guy suggests that selecting a camera with the right sensor becomes critical to an application's success, because the sensor defines the maximum speed and resolution of the imaging system as a whole. Assuming comparable processing software and comparable computer capability, the time required to analyze the image remains relatively constant. Capturing the image is the only real variable in the process.

Traditional sensors could capture 30 to 60 images per second at a resolution of 640x480 pixels. Inspection systems based on that technology could achieve higher resolution, but only by operating at a slower frame rate. On the other hand, Guy notes that new sensors (**Figure 2**) are available that increase the clock rate, and thereby raise image-capture rates to 110 or 210 frames/s. These sensors increase resolution as well. They can achieve resolutions of 1k-x-2k pixels at that frame rate. Again, this solution permits higher frame rates at the expense of image resolution.

Some higher-resolution applications demand the ability to capture even more information in each frame. One new sensor manages up to 11

continued on page M8

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EDITOR'S NOTE

Looking outside the box

Steve Scheiber, Technical Editor

In the past few years, machine-vision technology has become a vital component in the inspection and test arsenal. Frame grabbers and analysis hardware have gotten faster. Resolution has increased enormously. Memory has soared.

Yet if you look closely, most of the vision features and capabilities that we take for granted did not start here. Bar code readers that keep track of board serial numbers and firmware versions in high-throughput production began in supermarkets and retail stores as handheld and stationary devices to improve sales volumes and inventory control. Ditto optical character readers that today read labels on the tops of devices on assembled PCBs.

The trend continues. Dr. Stein's (see facing page) toll-enforcement vision system for German motorways requires high-speed high-resolution imaging that can also address high-throughput electronic component production. Developed to inspect aluminum ingots in Australia in real time, parallel-camera 3-D imaging systems can examine the "flatness" of PCB substrates. State-of-the-art vision systems may also come from the pharmaceutical or medical-imaging industries.

As electronics manufacturers face ever greater challenges, we should look beyond our own narrow applications to find solutions. Our universe is too small to support innovative development for us alone. We can adapt engineering cleverness from elsewhere to our own advantage. □

Contact Steve Scheiber at sscheiber@aol.com.

NEWS

Matrix Vision names North American distributor

MATRIX VISION of Oppenweiler, Germany, has selected Digital Network Vision of Waltham, MA, as its distributor for North America. Matrix Vision's products include the BlueLYNX line of intelligent cameras and the BlueFOX line of USB CCD cameras. In addition, the company offers mvIMPACT software, which performs measurement tasks and also reads Data Matrix codes. Digital Network Vision is a distributor of vision hardware and software focused on the machine/industrial vision, image analysis/biomedical imaging, and security markets. www.digitalnetworkvision.com. □

Cognex announces .NET support

VISIONPRO PC vision software from Cognex supports the Microsoft Visual Studio .NET programming environment, enabling VisionPro users to integrate third-party .NET objects into their vision applications and integrate vision applications with their automation systems.

VisionPro with Visual Studio .NET allows users to speed the development of vision applications in several ways: Vision applications can be merged with motion control, I/O, and factory communications; custom tools can be integrated with VisionPro tools; and databases and charting functions can be incorporated into vision applications.

PC-based VisionPro includes a vision-tool library and supports a variety of Cognex frame-grabber and industrial-camera options. www.cognex.com. □

RVSI sells semiconductor inspection business

ANCORA MANAGEMENT has purchased the assets of the Semiconductor Equipment Group from Robotic Vision Systems Inc. (RVSI) and will operate the business as RVSI Inspection. Robotic Vision Systems has been operating under bankruptcy protection since November 2004.

RVSI Inspection manufactures inspection systems for wafers and ICs. The company will remain in its Hauppauge, NY, location. □

Calendar

The Vision Show West
May 17–19
San Jose, CA
Sponsored by: Automated Imaging Association
www.machinevisiononline.org

Introduction to Infrared Thermography
FLIR Systems is conducting a series of half-day seminars on infrared (IR) imaging and IR temperature measurement. Upcoming sessions:
June 9—Orlando, FL
June 17—Lexington, KY
seminar@flir.com

Coordinate Metrology Systems Conference (CMSC) 2005
July 17–22
Austin, Texas
Sponsored by: CMSC Society
www.cmsc.org

International Robots & Vision Show
September 27–29
Chicago, IL
Sponsored by: Automated Imaging Association
www.machinevisiononline.org

To learn about other conferences and courses, visit www.tmworld.com.

Vitronic executive receives AIA achievement award

Steve Scheiber, Contributing Technical Editor

In recognition of his "outstanding contributions in promoting market acceptance of industrial and/or scientific imaging" through vision-based products such as an innovative bar-code reading system that handles small, dirty, or distorted bar codes accurately at high read rates, the Automated Imaging Association (AIA; www.machinevisiononline.org) has awarded Dr.-Ing. Norbert Stein its Achievement Award for 2005. Dr. Stein, owner, founder, and president of Vitronic (Wiesbaden, Germany), has spent more than 20 years developing new vision technology applications.

Dr. Stein (left) accepts the 2005 Achievement Award from Jeff Burnstein, executive director of the AIA.
Courtesy of AIA.

The company recently installed more than 300 toll-enforcement systems along German motorways, providing fully automated free-flowing multi-lane enforcement of road-use charges for more than 1 million vehicles every day. Their 3-D shape-recognition capability counts axles, detects trailers, and can recognize license plates from all over Europe. According to Dr. Stein, this same technology can inspect electronic components and boards in high-volume production.

Dr. Stein received his PhD from Technical University Darmstadt in 1984. He founded Vitronic that same year, introducing the bar-code reader in 1986, an equally sophisticated optical character reader (OCR) in 1987, a vision system in 1989, and the first real-time 3-D system in 1990. The latter utilized cameras in parallel to produce the real-time response. In 1995, the company introduced a 3-D whole-body scanner that adapts easily to a plethora of inspection tasks. What began as a one-person operation has evolved into a market leader with a staff of 250 and more than $90 million in sales serving numerous automation, inspection, and measurement applications.

In 2004, as VP of the Robot and Automation Division of the German Machinery and Plant Manufacturers' Association (VDMA), Stein helped launch the Automatica international trade show for robots, assembly, and machine vision in Munich. (The next Automatica will be held May 16–19, 2006, in Munich.) In addition to his technical accomplishments, Dr. Stein sponsors numerous educational activities. He gives lectures to open students' eyes to the world of engineering and serves as a university lecturer on machine vision. He supports "robot discipline in the classroom"—encouraging students to "learn while doing" with special robot kits designed specifically for education. He also serves on juries for school competitions in Wiesbaden and organizes school visits to technical fairs. □

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DVT Solution: Sky-Trax Inc. applied DVT machine vision technology to create a Local Positioning System (LPS) that works like a Global Positioning System (GPS), but operates reliably indoors. Sky-Trax LPS ™ tracks lift trucks in real time and automatically provides accurate location information about the lift truck location, and therefore the pallet load location, to operators and managers. At the heart of the system is a DVT smart camera that mounts on the lift truck and views Sky-Marx ™ optical position markers, which are placed overhead. The camera calculates vehicle position and directional heading, and transmits the data to the on-board driver's console and to the manager's console via a wireless network. Sky-Trax controller software does the rest; creating navigation screens, warehouse graphic views, and inventory reports. While solving the primary problem of locating goods, Sky-Trax LPS is finding additional applications in optimizing warehouse management, providing fleet management data, and improving safety.

Richard Ungerbuehler
General Manager
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TECHNICAL RESOURCES

A comprehensive imaging reference

Steve Scheiber, Contributing Technical Editor

To help you get up to speed on a variety of machine-vision topics, Edmund Industrial Optics has assembled a collection of application information into its 2005 edition of *The Best of EO Application Notes*. You can download a copy of the entire book from the company's Web site: www2.edmundoptics.com/techsup/bestofeoappnotes2005.pdf. Here are some highlights:

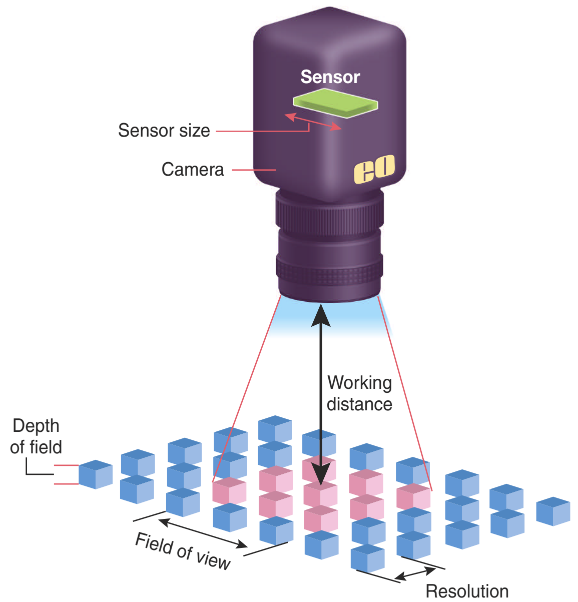
"Optics and Machine Vision"

Anyone building or buying a machine-vision system has to understand the fundamental image-quality specifications (see **figure**) and how they interrelate to define the system's overall performance. The goal is to get sufficient image quality to meet your inspection needs without overbuying.

This note explores many of the obvious and not-so-obvious factors that determine the suitability of a particular piece of hardware to a specific application. For example, it defines depth of field—an often overlooked specification that in printed-circuit board inspection can ensure that the tops of tall devices, device leads, and traces on the board surface all remain in focus in a single image. Sensor size is important to determine the appropriate lens magnification required to produce a desired field-of-view.

The discussion also explores the impact of contrast, perspective error, and distortion on overall image quality. Although most data sheets specify resolution and contrast separately, they are closely related. Contrast—expressed as gray-scale or signal-to-noise ratio—describes how effectively an image reproduces differences between boundary areas relative to one another. Although its meaning is usually well-understood, its importance to image accuracy is often underestimated.

The note's author contends that resolution can be meaningless unless it is defined relative to a specific contrast and vice versa. Consider an image consisting of two dots. If the dots are far apart, the distinction between them is unambiguous. As they get closer together, the ability to resolve them rather than perceive them as a single object depends both on the resolution of the camera and the level of contrast between the dots and their background. The author further explains how you can use the modulation transfer function, which describes the relationship between contrast and resolution, to determine a vision system's expected performance.



The fundamental parameters of an imaging system, including the resolution, field of view, and depth of field. Courtesy of Edmund Industrial Optics.

"10 Lens Specifications You Must Know For Machine Vision Optics"

Another discussion of vision fundamentals, this piece serves as a kind of "cookbook"—a useful checklist of considerations for specifying the lens of a vision system. Overall, the note aims to provide you with information about lens characteristics so you can assemble a vision system that provides the best possible performance at the lowest possible cost. For example, the author recommends specifying field-of-view rather than magnification to ensure that the vision system can inspect the entire region of interest. The author also suggests considering factors such as illumination integration, charge-coupled device (CCD) format, operator error, and software development to help reduce setup costs and system downtime while optimizing reliability and repeatability.

The paper also explores factors that affect lens distortion and suggest ways to minimize their impact. Distortion is an optical error that causes differences in object magnification at different points in the image. There is no loss of information, but it is "misplaced." Software can compensate for lens distortion before analyzing or producing the final image.

The author also suggests that, despite manufacturers' reluctance to share it, you should try to get as much information as possible about the lens's design criteria. In particular, inquire about the optimal distance from the object plane to the lens. If you need a lens for a short working distance, you don't want one that was designed to focus at infinity.

(continued)

Imaging reference • from page M5

"Correcting Perspective Errors with Telecentricity"
This note, one of several in the book that discuss specific applications, relates how one manufacturer required a system to inspect the prototype of a hardware computer key connector to verify the placement of its pins. The author describes the customer's system requirements and shows how to select the appropriate components to meet them.

Because conventional lens designs suffer from perspective errors when imaging objects with significant height or depth, the note recommends telecentric lenses to correct the problem.

"Designing a Vision System to Meet Your Space Constraints"
The author of this piece contends that planners sometimes begin working on the design of the optical system only after completing mechanical and other system designs. Therefore, the vision system must fit into whatever space is left.

This note outlines a series of steps you can take in order to assemble a workable imaging system in a too-small box:
1. Define your mechanical constraints;
2. Define your fundamental parameters;
3. Lay out the imaging system as though it were in a straight line;
4. Place the illumination and determine the minimum f-stop;
5. Compare the optical design with mechanical constraints; and
6. Bend the system.

To determine the mechanical constraints, for example, you must first determine how much space is available for the imaging system. Determine the size of the box the system must fit in and measure the length of the space allotted for optics. Remember that the space will have to accommodate the length of the camera lens and the length of cables and, in most systems, the illumination components.

The author recommends that you first lay out the system in a straight line to ensure it works before fitting it into the allotted space. If the system doesn't fit, then you may need to introduce "bends" into the optical path with prisms, mirrors, or beam splitters. The author briefly discusses the pros and cons of each option and shows how an effective optical system can be designed for a space that initially seemed too small to hold it. □

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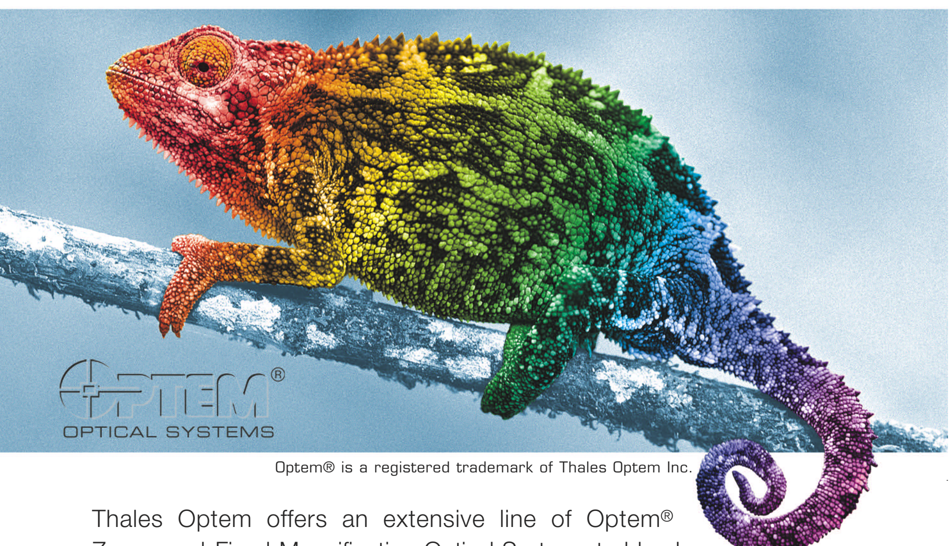

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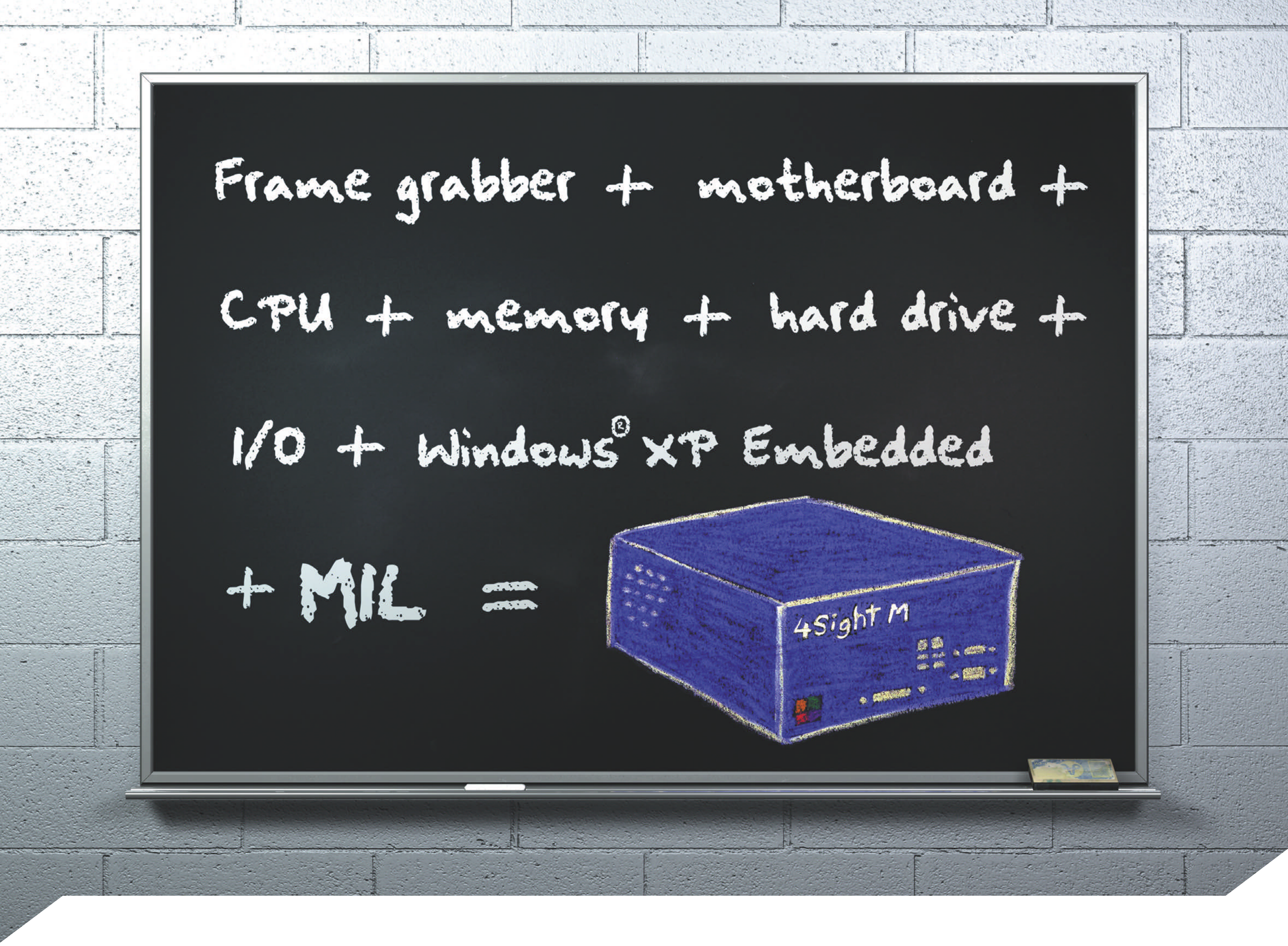

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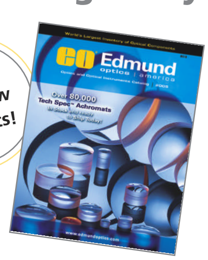

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Sensors • from page M1

Mpixels—4008x2672 pixels. Higher resolution also permits users to increase the field of view captured in each frame. With twice the resolution, each image contains four times the area at the same level of detail. In that case, the camera can cover a large surface with only a quarter as many images. In some situations, that might mean fewer images required of each camera. For high throughput, it can mean that the system includes only a quarter as many cameras—substantially reducing system cost.

On the factory floor

Two of the largest users of high-speed cameras are manufacturers of electronics and manufacturers of semiconductors. Vision-based inspection systems look at patterns on silicon wafers in real-time production to identify shorts and opens. The goal is to eliminate defective material and provide process information to increase future yields. On diced chips, a system may look at lead-bonding operations, including examining the edge of the die. On both packaged components and finished boards, a system looks for bent or broken leads; on boards, it also looks at the interface between device leads and the board surface, including the quality of the solder joints.

Production-rate requirements have increased dramatically over the past few years. Until a few years ago, for example, a wafer inspection system at full speed could examine 100 wafers/hr. With higher production rates and demands to reduce factory floor space, new systems must handle 150 wafers/hr with no compromise in frame rate or image resolution. A manufacturer must choose a camera that can achieve the necessary resolution even at the higher speeds.

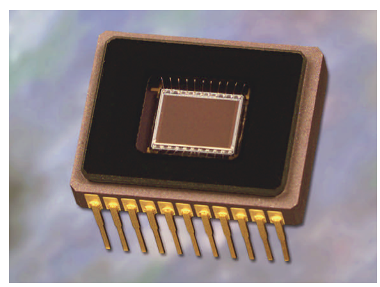

Fig. 2 A high-speed, high-resolution sensor.
Courtesy of Eastman Kodak Image Sensor Solutions.

Let it be a challenge

Imperx designs and manufactures imaging products that produce high-resolution black-and-white and color still images and full-rate motion images for high-demand applications. President and CEO Petko Dinev underscores the importance of attaining the highest possible frame rate and resolution, including high-speed sensors, in his camera designs.

As an example of a high-demand application, he cites the explosive growth in the manufacture of flat-panel liquid-crystal displays (LCDs)—relatively small ones for notebook computers and computer monitors as well as the large panels that have appeared for presenting high-definition television (HDTV). Dinev notes that supplying high-speed cameras for LCD inspection represents a substantial portion of Imperx's business.

LCD manufacture is a complicated multi-step process that requires testing at every step to weed out bad panels. As with any product aimed at consumers, manufacturers must drive costs down—which requires increasing factory throughput as much as possible—while keeping yields and quality up. A 21-in. flat-panel monitor with 1600x1200 resolution, which only a few years ago would have sold for thousands of dollars, can cost less than $700 today.

Flat-panel displays consist of two pieces of glass spaced 0.8 mm apart. Companies manufacture the panels in sheets larger than 2 m^2 and then cut individual displays from the sheets. As a first step, inspection must verify that the glass is perfectly flat and defect-free. Then, tiny spacers are placed between the two pieces. Another inspection step ensures that the spacer positions are correct and that the glass panels are parallel, with the distance between them remaining strictly constant. Any spatial variation will cause pixel colors to bleed and therefore cause the panel to be rejected.

Once the crystal cells are in place, the displays must be inspected again. The size of the panels and the necessary throughput require manufacturers to use many cameras simultaneously for each inspection. The use of high-speed imaging sensors with high-resolution can reduce the number of cameras needed to acquire information in real time.

Flexibility is key

Dinev says that there is another advantage to designing a camera around a high-speed sensor: flexibility. For example, his company's 11-Mpixel camera inspects the LCD panels in high resolution at 210 frames/s. With that same camera, NASA can inspect jets from the Space Shuttle at more than 1000 frames/s. In extreme cases, you might even look at a small field of view at 3000 frames/s.

In addition, building a camera around a high-speed sensor dramatically reduces the cost of that level of performance. With a tweak of the software, the same camera hardware can offer lower-resolution images even at slower speeds, when that is what an application demands. Because they contain fewer bits of information, such images permit faster analysis than their high-resolution counterparts and take up less storage space.

Imaging flexibility can offer enormous advantages to users. Consider the plight of the contract manufacturer. For vertical manufacturers, the next product generally resembles the last one, at least to some extent. Manufacturing and inspection and test strategies remain relatively constant as well. But a contract manufacturer never knows what the next project might be. Since inspection has become such an integral part of the contract manufacturer's arsenal, the freedom to specify a single camera that will meet needs ranging from low speed with low resolution to the most demanding high speed with high resolution has enormous appeal.

Time marches on

Like all electronics technologies, the capability of image sensors has grown dramatically in the past few years, while prices have fallen. Incorporating such sensors into camera designs permits a single system to perform a plethora of inspection tasks, from the relatively mundane to the most demanding. While one size does not fit all, this type of versatility simplifies the task of specifying a camera that will meet uncertain and ever-changing needs. □

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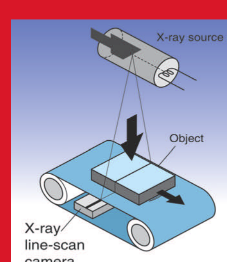

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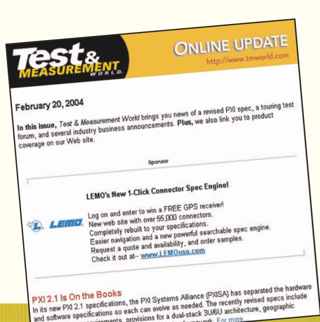
Test & Measurement World — ONLINE UPDATE — http://www.tmworld.com

February 20, 2004

In this issue, *Test & Measurement World* brings you news of a revised PXI spec, a touring test forum, and several industry business announcements. **Plus,** we also link you to product coverage on our Web site.

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PXI 2.1 Is On the Books
In its new PXI 2.1 specifications, the PXI Systems Alliance (PXISA) has separated the hardware and software specifications so each can evolve as needed. The recently revised specs include enhanced power requirements, provisions for a dual-stack 3U/6U architecture, geographic addressing, and an improved hardware description framework. For more...

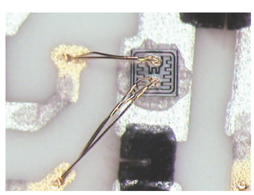
PRODUCTS

Electron microscope

FEI has announced the Titan 80-300 scanning/transmission electron microscope (S/TEM), which yields atomic-scale imaging with resolution below 0.7 Angstrom. The Titan announcement comes one year after FEI achieved sub-Angstrom resolution on its Tecnai microscope using a monochromator and an aberration corrector. FEI says the Titan 80-300 is designed as a dedicated and upgradeable aberration-corrected system that will enable corrector and monochromator technology to enter into mainstream nanotechnology research and industrial markets. *FEI Co., www.feicompany.com*.

AOI system

To verify the adhesive integrity of bond connections on SMD assemblies and to identify deficient wires in multiple bonds, Viscom AG has introduced the S6053BO automated optical inspection system. During inspection, the system scans all bond positions and bond leads with high-resolution cameras and evaluates them with the assistance of Viscom's inspection software. The system inspects ball bonds, leads, wedge bonds, the die itself, and the position of the components, and it can inspect heavy-gauge aluminum as well as light-gauge aluminum and gold leads in a single pass. The S6053BO can also check for the emergence of conductive adhesive beneath dies and recognize scratches and eruptions on die surfaces. *Viscom, www.viscom.de*.



Line-scan cameras

With resolutions of 8k and 12k and with line rates up to 33 kHz and 23 kHz, Dalsa's new Piranha3 cameras target the throughput demands of flat-panel display and electronics manufacturing inspection. Dalsa claims that the 12k resolution surpasses that of other line-scan cameras and that the Piranha3 series' 320-MHz throughput allows users to inspect more material in less time. A Camera Link interface makes it easy to integrate the Piranha3 cameras into existing systems.
Dalsa, www.dalsa.com

Single-board smart camera

Vision Components has introduced the SBC4018, the first member in its 40xx series of single-board smart cameras aimed at OEM applications and inspection. The rugged SBC4018, which offers 3200 MIPS of onboard DSP computational power, features 16 Mbytes of onboard SDRAM image memory and 2 Mbytes of flash EPROM for data and program storage. The camera also offers outputs for lighting control, progressive scan CCD, instant triggering, full-frame integration, and electronic shutter, all in a 60x80-mm package. A Fast-Ethernet remote-head option addresses applications where space is scarce. Pre-emptive multi-tasking permits users to run several processes simultaneously so they can change parameters on-the-fly without affecting either inspection or communication processes. *Vision Components, www.vision-comp.com.*

High-precision measuring

Combining two high-precision measuring systems into one, the MarSurf XCR20 from Mahr Federal permits taking both roughness and contour measurements on the same unit with the same setup. The combined station incorporates drive units from the MarSurf XR20 roughness and the XC20 contour systems. The arrangement eliminates the need to change the drive unit or the probe when changing from roughness to contour measurements, saving time, work space, and financial resources. The unit also allows users to semi-automate some operating sequences, such as measuring stand position and drive-unit position. *Mahr Federal, www.mahr.com.*

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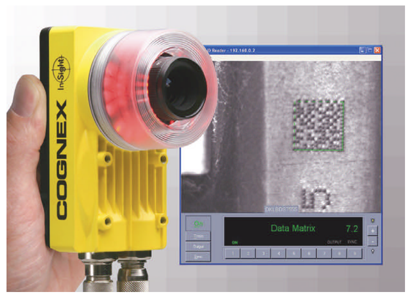
For more information about machine-vision and inspection topics, visit our Web site:
www.tmworld.com/ins

Products • from page M10

ID readers

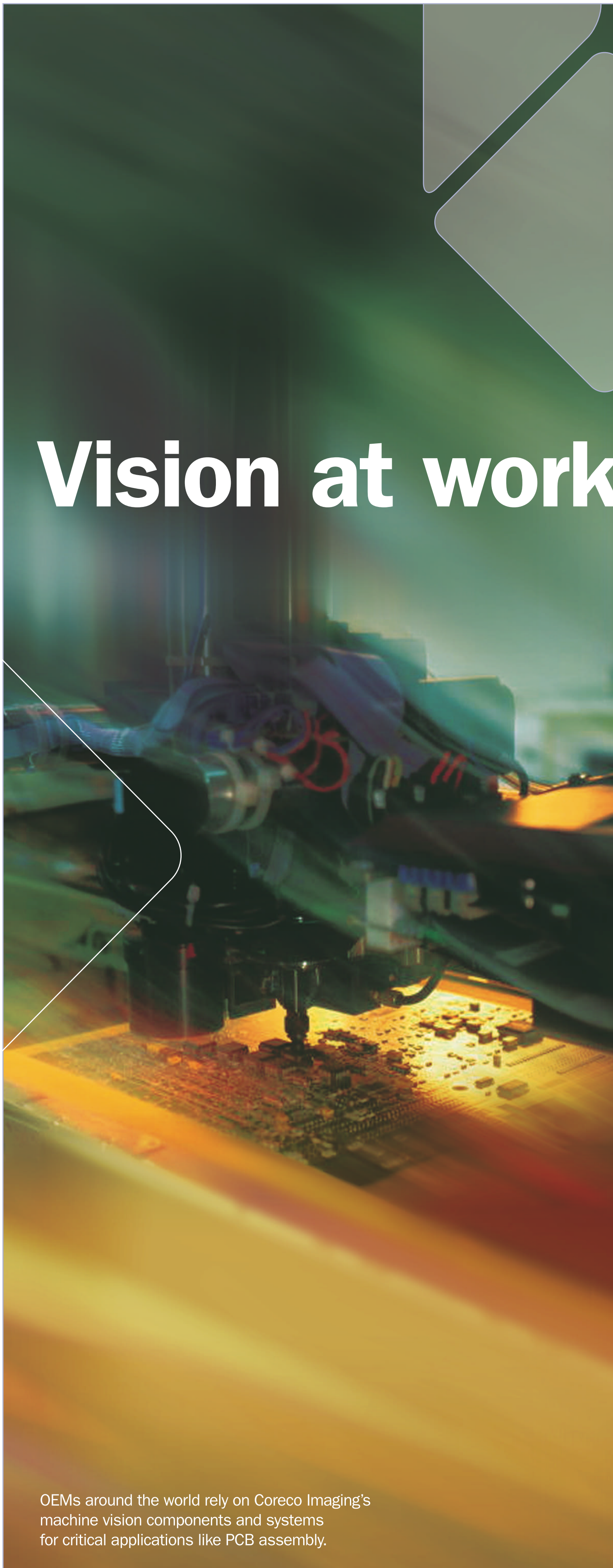
For reading 1-D and 2-D codes marked on parts, packages, or labels, Cognex has introduced the In-Sight 5410 and the In-Sight 5411. The 5410 can read at line speeds of 7200 ppm with a

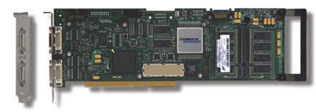


640x480 resolution. The 5411 offers higher resolution (1024x768) for a larger field of view or to handle greater variation of position and orientation of parts and packages. The new systems offer omnidirectional reading of 1-D and 2-D bar codes and support a wide variety of standard formats. *Cognex, www.cognex.com.*

Progressive-scan camera

JAI Pulnix's CV-M71 compact 1/2-in. digital progressive-scan RGB color machine-vision camera offers an improved digital interface over the company's CV-M70 model. The CV-M71 features a Sony ICX415AQ imager with 782x582 pixels and operates at 60 frames/s at full resolution and at 250 frames/s with 1/8 partial scan 24-bit RGB output via a Camera Link base configuration. The camera is capable of a range of speeds, from 1/60 s to 1/300,000 s. Features include edge preselect, pulse width, RCT trigger modes, programmable exposure, and auto shutter. *JAI Pulnix, www.jaipulnix.com.*





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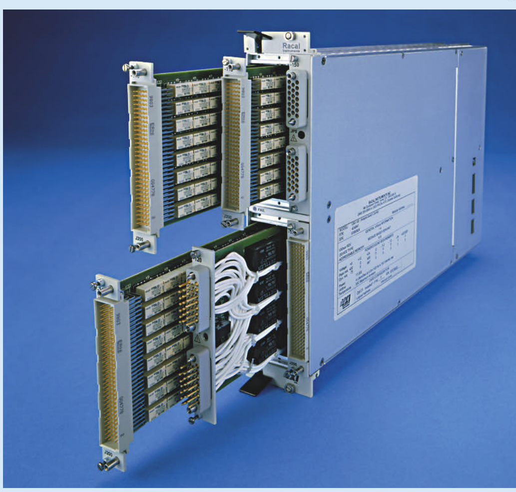

High Performance in a Compact Package. Racal Instruments' **Model 1256** controls up to eight Adapt-a-Switch® plug-ins for high-density switching capability in a compact, 2U, rack mountable package. With intuitive front panel control, it provides high-speed switching, a wide variety of plug-ins, and Ethernet, GPIB and RS-232 remote interfaces – which means high throughput, ease of testing, and reduced test time.

Revolutionary Modular Switch System. The **Model 1260-100** delivers unprecedented density and flexibility in a two-slot, C-size VXIbus module. It accommodates up to six plug-in switch cards, providing optimum switching solutions while reducing the ATE size requirements. The plug-ins are conveniently inserted from the front panel without removing the carrier module. (Single-slot, 2 plug-in carrier also available.)

High Density Saves Money. Racal Instruments' **Model 1255A** utilizes 1260 C-Size VXIbus Switch cards. Its built-in controller with both IEEE-488 and RS-232 interfaces eliminates the need for a VXIbus mainframe or Slot 0 Controller.

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CHIEF EDITOR
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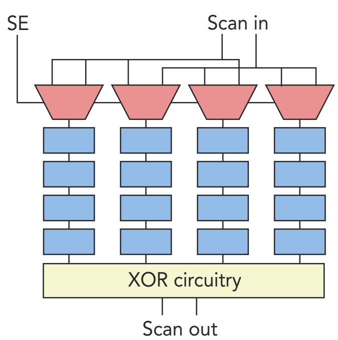
Technology adapts to user needs

Increasingly, innovation occurs in the ways in which technology is deployed—not in technological functionality itself. In April's "Editor's Note," I facetiously commented that gigahertz and gigabytes no longer cut it, with fashion outstripping technology in attracting consumers. But even within the technical community, it's often not technology itself, but the way it's deployed, that best serves customers.

A case in point is Teradyne's microFLEX zero-footprint semiconductor test system, which packs the features of Teradyne's FLEX architecture in a single test head that can mount directly on a handler. "We designed the microFLEX platform to address markets such as automotive, where maximizing production floor space is critical," said Jim McEleney, platform marketing manager at Teradyne, adding that Japanese semiconductor manufacturers have found the microFLEX format particularly attractive.



Synopsys's DFT Compiler MAX deploys multiplexers to enable adaptive alliances between scan inputs and scan chains.

Another example is Agilent Technologies' InstaPin program for 93000 SOC Series testers equipped with Pin Scale cards. The program offers per-pin licenses that can be shared among pins of one card, one tester, and multiple testers.

According to Tom Newsom, VP and GM of Agilent's SOC business unit, "Each pin of the 93000 Pin Scale digital cards can be software-scaled over its memory depth and speed range, allowing test systems to be configured to match device requirements, pin by pin." If, for instance, a test requires two differential pins at 2.5 Gbps for PCI Express, a license needs to be purchased for only two pins, not the whole card. Because no hardware is moved, there is no need to recalibrate and risk hardware damage.

Yet a third example is the Synopsys DFT Compiler MAX, a DFT synthesis tool that offers one-pass test-data compression capabilities to address design and test challenges occurring in 130-nm and smaller process technologies. DFT Compiler Max, said Bijan Kiani, Synopsys VP of marketing, provides some of the features of Synopsys's SoCBIST (aimed at high-end customers) in an easy-to-use tool that meets the needs of mainstream customers who are moving from 180-nm to 130-nm designs for the first time.

All three cases did involve technical prowess: Teradyne engineers pulled off some deft engineering to fit standard FLEX cards into the microFLEX enclosure while ensuring adequate electrical and thermal performance; Agilent had to develop the Pin Scale cards that make the InstaPin program possible; and Synopsys tailored its adaptive-scan technology for use in DFT Compiler MAX.

But in all three cases, it's not the gigahertz, or test-vector compression ratios, that count. As Agilent's Newsom put it, the goal is "maximum asset utilization and minimum capital expenditure" for the firms' customers. T&MW

Advantest debuts memory tester

Advantest says its newest memory tester, the Model T5372, reduces wafer test time by more than 30% for DRAM, SDRAM, double-date-rate (DDR) SDRAM, flash-memory, and other general-purpose memory chips, as well as for multi-chip packages and other specially packaged memories. The T5372 offers test speeds to 143 MHz (286 MHz in DDR mode)—double those of its predecessor, the T5371. www.advantest.com.

High-power burn-in

Micro Control Co.'s HPB-5B high-power burn-in system performs burn-in-with-test of both high-power VLSI devices (up to 150 W) and memory devices. It features individual pattern and temperature zones per burn-in board, allowing device types to be mixed within one oven. The HPB-5B provides precise, individual temperature control for up to 48 devices per burn-in board. www.microcontrol.com.

SST chooses PK2

Credence Systems has announced that Silicon Storage Technology (SST) has chosen the Personal Kalos 2 (PK2) test system to test its FlashFlex51 microcontrollers, which are used in the portable appliance and digital consumer markets. "The fact that Kalos 2 addresses both our memory and logic requirements improves the overall cost effectiveness of the test system," said Chen Tsai, senior VP of worldwide backend operations at SST. www.credence.com; www.sst.com.

DVT
machine vision

Machine Vision Takes Flight

Precision Alignment Enables Rapid Attachment of Raptor Wings

Customer Challenge: Mate two large fuselage sections of a supersonic fighter jet – Lockheed Martin's F/A-22 Raptor – with an accuracy of 0.004 inches across 18 wing lugs on each side of the aircraft over a 16 foot wing root. Approximately half of the wing lugs are on the mid-fuselage section, while the other half are on the aft-fuselage.

DVT Solution: DVT certified integrator Delta Sigma Corporation, working with Automation Solution Provider Advanced Control Solutions, placed a DVT Smart camera inside of a "pin" that was the identical size of the pins that attach the wing to the fuselage. There are 16 of these special "vision pins" which are placed into jigs that simulate an ideal wing. While the cameras monitor the position of the key fuselage points and supply real-time 3-dimensional data to the control computer, the computer sends position commands to 14 servo motors that position both of the fuselage sections in six degrees of freedom with an accuracy better than 0.001 inch. When the alignment is complete – typically a 30 second operation – the fuselage sections have relative positions for ideal wing attachment.

For more information visit Delta Sigma Corporation at: **www.deltasigmacorp.com**; or Advanced Control Solutions at: **www.acs-ga.com**.

Roger C. Richardson
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Photo of F/A-22 Raptor courtesy Edwards Air Force Base.

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JON TITUS
CONTRIBUTING TECHNICAL EDITOR
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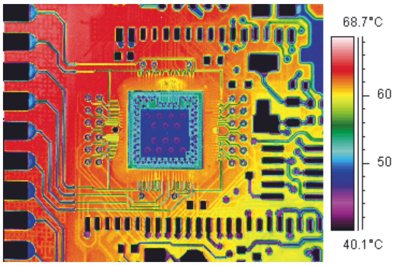
IR cameras ride again

Although infrared (IR) inspection technologies seemed to fade from the T&M scene several years ago, lower costs and new technologies should rejuvenate engineers' interest in IR cameras.

Buyers have already seen a steep decrease in camera prices, according to Art Stout, VP of sales and marketing at Electrophysics. By way of example, a basic IR-camera system that cost $50,000 a few years ago now sells for $25K. Prices should continue to drop, probably to about $10K over the next two years.

Stout doesn't expect low-cost cameras to appear in many new applications, though. Instead, he thinks people who couldn't afford a camera will now buy one and use it as a bench instrument. "Engineers will use IR cameras as they design and validate the operation of new products," said Stout. When they need to test a new PCB design, they won't use individual thermocouples that measure temperature at only a few points. An IR camera will let them see the entire board.



A ThermaCAM IR camera can detect energy sources as small as 15 μm on an integrated circuit. A thermocouple would act as a heat sink on such a small area, thus altering the measured temperature. Courtesy of FLIR Systems.

To emphasize the importance of falling prices, Tom Scanlon, VP of the thermographic group at FLIR Systems, noted that most IR cameras used to include display screens, viewfinders, and so on. Removing those accessories automatically reduced costs. Labs, after all, have PCs that provide processing and display functions.

The availability of sensors that operate at room temperature also reduced the cost of IR cameras. "People can buy an IR camera with a 160x120-sensor array for between $10K and $15K," explained Scanlon. People who repair PCBs, for example, can power a board and look for parts that operate outside a known-good thermal range. Often, a thermal signature will identify a defect faster than other techniques.

The appeal of IR cameras goes beyond lower prices. Doug Malchow, an applications engineer at Sensors Unlimited, explained that new technologies open new applications. The company's latest cameras operate from 400 nm (blue) to 1700 nm (IR). That extended range lets cameras "see" both visible light and invisible IR radiation.

"Technicians often align optical fibers and waveguides," explained Malchow. "An IR camera lets the technicians see the IR signals from the fibers, but they cannot see visible reference points on the fibers or waveguides. The extended-range sensors let them see both, which means they can align precise components faster."

In addition, because silicon starts to become transparent at about 1000 to 1200 nm, failure analysts can use backside emissions from silicon wafers to locate circuit faults. Simultaneously observing visible reference points helps them relate circuit defects to physical features on the wafer.

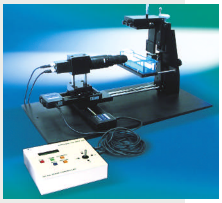
Will the new technologies and price reductions move more IR cameras into labs and test facilities? Only time will tell. If you use an IR camera now or plan to buy one, I'd like to hear from you. T&MW

Grab four frames

The PC_Eye/Async frame-grabber board from American Eltec can gather images from as many as four video sources. The PCI Express board works with monochrome cameras, and its four independent ADCs acquire 8-bit video data at 25 Msamples/s. Data can flow into a host PC's graphics or main memory through a DMA channel. Developers receive basic tools that run under Linux and Windows NT/2000/XP, or under the VxWorks or OS-9 real-time operating system. Price: $1195. www.americaneltec.com.

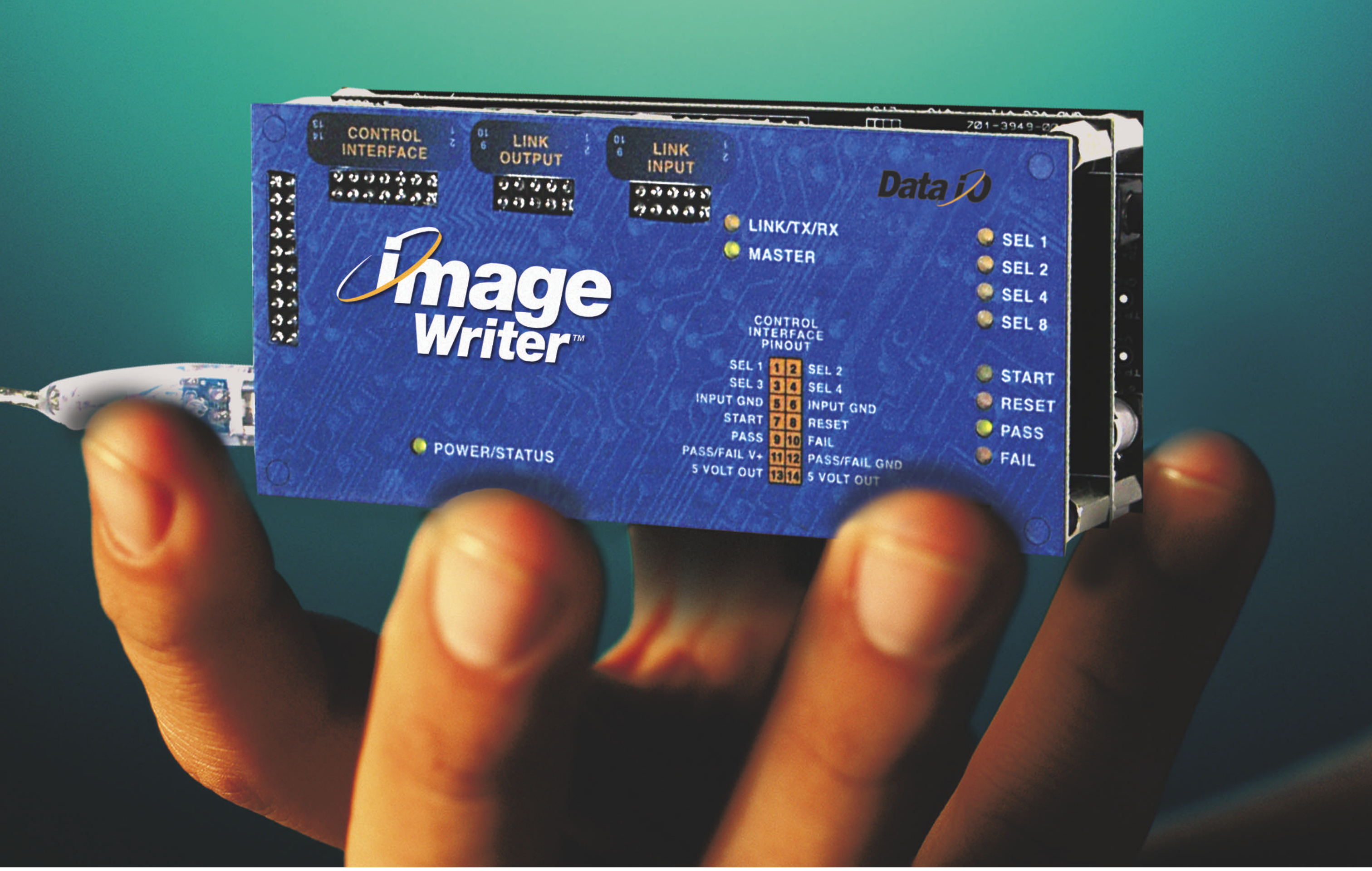
Watch a drop

The Drop Watcher III system captures images of ink droplets as they emerge from an ink-jet print head, and users can focus the 50-mm camera at individual nozzle openings. Image-analysis software ($5000) lets users examine the formation and flight characteristics of droplets. Price: $34,000. www.imagingtechnology-corp.com.



Small camera runs fast

Prosilica's compact EC750 camera (29x39x22 mm), which provides a FireWire interface, does not require the use of a frame grabber. Available in monochrome and color versions, the 1/3-in. progressive-scan sensor offers 752x480-pixel resolution. The camera operates at 60 frames/s, but can run faster over a small region of interest. Because the camera complies with the DCAM standard, it works well with many machine-vision software packages. Price: $950. www.prosilica.com.



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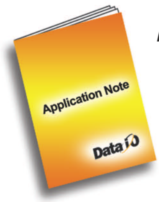

*Read our application note on "Tips for In-System Programming." You'll find it at **www.dataio.com/isp***

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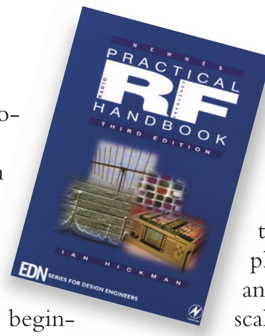
BOOK REVIEW

RF design handbook provides test tips

Practical RF Handbook (third edition), by Ian Hickman, Newnes (www.newnespress.com), 2002. 278 pages. $41.95.



The *Practical RF Handbook* by Ian Hickman is primarily a design book, published as part of the "*EDN* Series for Design Engineers," and as a design book, it is clear, concise, and accessible. (*EDN* is our sister publication that targets the design and development community.)

The first two editions were published in 1993 and 1997. This third edition updates the maximum "RF" (as opposed to microwave) frequency limit from 1000 MHz to beyond 2.5 GHz. In part, says Hickman in his preface, multiple gigahertz frequencies are no longer the sole domain of microwave "plumbers," who wield waveguides and cavity resonators to make their millimeter-wave signals behave. Thanks to advances in surface-mount technology and high-frequency transistors, miniature circuit boards in portable cellular, GPS, and Bluetooth products can readily accommodate 2.5-GHz signals.

The book is organized in such a way that you can jump in where you want, based on your background and interests. If you need a thorough review, you can begin at the beginning—chapter 1 provides the math describing capacitors and inductors, presented with an RF slant. Subsequent chapters present transmission lines, transformers, couplers, active components, and modulation and demodulation techniques. Other chapters describe transmitters, receivers, RF propagation, and antennas.

Of particular note is the 10-page chapter on measurements. It provides a concise description of ways to make CW amplitude measurements (through, or bridging, vs. terminated, and linear vs. RMS). It describes the use of a spectrum analyzer to make harmonic and phase-noise measurements, and it describes when to use scalar or vector network analyzers. It concludes by describing signal generators and synthesizers, and it introduces special-purpose radio-communications test sets, which combine the functions of several standalone benchtop instruments into one convenient system.

The book is limited in the number of specific instruments it discusses; for that, you will still need magazines. (Disclosure: The book's publisher is owned by *Test & Measurement World*'s parent company.)

Rick Nelson, Chief Editor

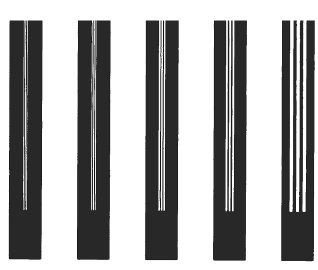
INSPECTION

Calibrating acoustic micro-imaging systems

As the sizes of features within semiconductor packages shrink, acoustic micro-imaging (AMI) systems have evolved to keep pace, resulting in the development of transducers that pulse higher ultrasonic frequencies that achieve higher spatial resolution. Once, 100 MHz was the upper frequency limit for imaging deep within a package. As target sizes shrank, transducers of 180, 240, and 300 MHz emerged.

The ultrasonic transducer in an AMI system scans a semiconductor package while alternately pulsing ultrasound into the package and receiving the return echoes. Both of these events occur several thousand times a second and produce the pixels from which the acoustic image is made.

Ultrasound pulsed into the package reflects from internal interfaces—where the molding compound is bonded to silicon, for example. The strongest reflections come from an interface between a solid and a gas, such as at a delamination between molding compound and silicon. A solid-gas interface is characteristic of delaminations, cracks, and voids—the vast majority of internal packaging defects that create field failures.



A calibration wafer permits you to calibrate an acoustic micro-imaging system. These calibration lines are for feature sizes at the 25-μm to 100-μm level.

A delamination covering half of a die face can easily be imaged at low frequency. But imaging a tiny 20-μm void nestled beside a flip-chip solder bump that is itself only 60 μm in diameter requires high resolution. To ensure that the transducer and the operating system are functioning optimally and that the acoustic image you see best represents the internal features, you can employ a calibration wafer such as the one in the **figure**, a 2-in. glass/silicon anodically bonded sandwich with features of various sizes etched into the silicon. The range of feature sizes permits the wafer to be used to calibrate AMI systems having transducers that operate at 100 MHz or above and produce resolution down to the 5-μm level.

Etched into the silicon portion of the calibration wafer are groups of lines and dots of successively smaller sizes. Bond-

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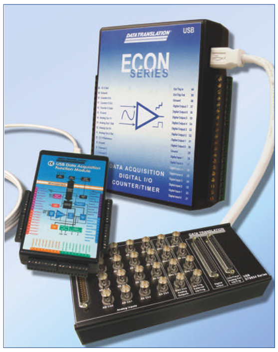

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Calibrating acoustic micro-imaging systems *(continued)*

ing the glass layer onto the silicon wafer creates the solid-gas interfaces that make the lines and dots visible acoustically.

The smallest feature groups (for example, three parallel lines each a few microns wide and spaced only a few microns apart) give you a known standard against which to measure a system. You can select and image a pattern group on the wafer to determine both the AMI system's detection (the ability of the system to image a feature of a certain size) and resolution. A low-frequency transducer, for example, might image a group of three fine lines as a single feature. It is detecting the lines, but not resolving them. A high-frequency transducer should be able to resolve the individual lines in the group.

The difference between detection and resolution is important in specific applications. If a flip chip has a tight group of small underfill voids, then a low-frequency transducer may image the group as a single feature. But a high-frequency transducer will resolve the individual voids and facilitate the search for the cause of this anomaly.

The calibration wafer is useful when you are aiming for compliance with an ISO 9000 program, where thorough documentation of system functions and capabilities is essential. It is also a candidate for selection by a joint IPC/JEDEC task group that is currently considering the adoption of a test sample as a calibration tool for AMI systems.

Tom Adams, Consultant, Sonoscan

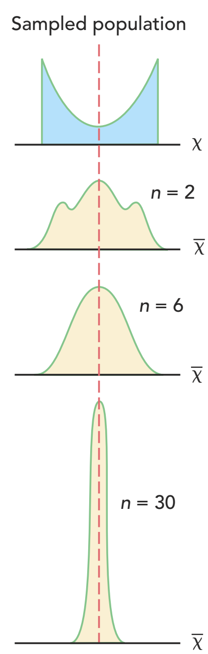
STATISTICS FOR TEST

Keep test variables in line

How accurate is your ATE system? How do you know?

An inaccurate ATE system will yield poor test results, which in turn can reduce profits by causing you to fail good parts or pass bad parts. Using a statistical method, you can predict the accuracy of your ATE system and the measurements it makes.

John Gresham, test engineering manager at Exar, uses bench instruments and statistics to correlate and verify ATE measurements. He first uses several ATE systems and bench instruments to take numerous measurements on a "golden" device. Then, he uses statistical methods to calculate a mean and standard deviation of the measurements. He has developed his own software tool for calculating guard bands from the measurements, and this lets him set measurement limits for production test that are tighter than a part's published specifications. Thus, Gresham ensures that customers will receive acceptable parts.



When the number of samples reaches 30, the distribution of results takes on a normal, Gaussian shape.

Gresham bases his statistics on the Central Limit Theorem: "The distribution of an average tends to be Normal, even when the distribution from which the average is computed is decidedly non-Normal" (Ref. 1). To achieve a normal distribution, Gresham always takes at least 30 measurements of each electrical parameter, from which he calculates the mean and standard deviation.

Gresham provides more details about his method in "The Economics of Using SPC in a Manufacturing Test Environment," a paper that you can download from the online version of this article at www.tmworld.com/archives.

Martin Rowe, Senior Technical Editor

REFERENCE

1. Annis, Charles, PE, www.statisticalengineering.com/central_limit_theorem.htm.

Successfully Conquering .NET Test and Control Challenges

by Nate D'Anna, nate.danna@ni.com
National Instruments Product Engineer

Whether you are an experienced .NET developer or considering your first .NET program, it is essential that you learn to conquer the challenges you face when developing test and control applications on the .NET platform. With the emergence of .NET in 2002, Microsoft introduced a completely new technology that brings many benefits to engineers, especially for Web and database connectivity. As with many disruptive technologies, .NET presents new challenges, especially because it was not designed from a test and control engineer perspective, but from that of a system and IT developer. This article introduces you to .NET for test and control applications and teaches you how to successfully implement your next-generation .NET system.

Learning about .NET

.NET is more than just a programming language or paradigm; it is a completely new development framework for creating everything from simple Windows forms to advanced multitier distributed acquisition applications. This framework is based on a set of common libraries ranging from network communication to multithreading to file I/O to database connectivity. With this common base, you can reuse existing libraries and not reinvent the wheel every time you need to use common constructs such as hash tables or thread synchronization locks.

In addition to common libraries, there are more than 20 .NET programming languages - most important for test and control applications are Visual Basic .NET, an object-oriented version of Visual Basic, and C# .NET, a completely new language with roots in Java and C++. In addition to these languages, other languages such as Fortran .NET and Cobol .NET have joined the .NET family. Regardless of the .NET language you choose, each compiles to a common form called Microsoft Intermediate Language (MSIL). MSIL code is contained in the fundamental building block of all .NET applications, called assemblies. An assembly is similar to a DLL, except it also contains self-describing metadata. Because MSIL is common to all .NET languages, you can create an application in Visual Basic .NET and a colleague can seamlessly add and reuse the assembly in a C# .NET project. As shown in *Figure 1*, a simple function that adds two integers in both Visual Basic .NET and C# .NET generates identical MSIL code.

```
[VB .NET]
Namespace VisualBasic.NET
    Public Class Class1
        Private Function Add(ByVal x As Integer, _
            ByVal y As Integer) As Integer
                Return x + y
        End Function
    End Class
End Namespace
```

```
[C#]
namespace CSharp
{
    public class Class1
    {
        int Add(int x, int y)
        {
            return x+y;
        }
    }
}
```

```
.method private instance int32 Add(int32 x, int32 y) cil managed
{
    // Code size       4 (0x4)
    .maxstack  2
    .locals init (int32 V_0)
    IL_0000:  ldarg.1
    IL_0001:  ldarg.2
    IL_0002:  add.ovf
    IL_0003:  ret
```

Figure 1. C# and Visual Basic .NET Code Compiled to MSIL

To run a .NET application, your computer must have the Common Language Runtime (CLR) installed. This runtime engine just-in-time compiles your MSIL code into machine-specific code which actually executes on your computer.

Microsoft Visual Studio .NET 2003 brings everything together in a single development environment (*see Figure 2*). Visual Studio .NET provides a source code editor for C# .NET, Visual Basic .NET, C++ .NET, and J# .NET, as well as a graphical user interface editor and a debugger.

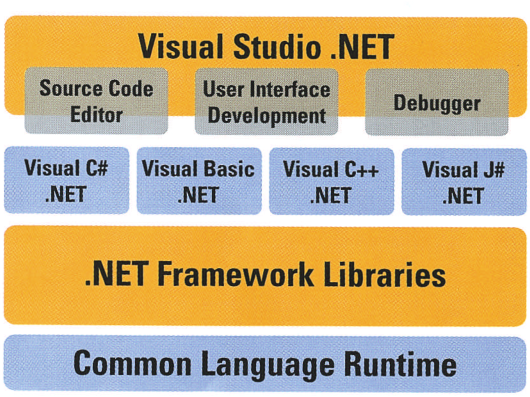


Figure 2. The Visual Studio .NET Architecture

Identifying Four .NET Challenges

.NET brings a completely new set of benefits to your applications, including connectivity to the Web via Web services, support for many languages, object orientation, and a completely managed environment with garbage collection. With these benefits, however, come challenges. When .NET was designed, the needs of test and control engineers were not at the forefront. Here are some common challenges that you may face, and how to successfully conquer them.

Challenge 1 – .NET is general-purpose, but I need test- and control-specific functionality.

Because .NET is a complete framework for program development, you can create a wide range of applications from financial, to information technology, to test and control. This is possible because the .NET Framework provides an array of libraries ranging from database connectivity, to threading, to remoting; and user interface controls ranging from text boxes, to calendar controls, to data grids. For test and control applications that require graphing, analysis, and hardware I/O, you could use the default controls provided with Visual Studio .NET to create a business application (*see Figure 3*), but not to graph and visualize test data. Also, consider that scientific analysis libraries such as a fast Fourier transform (FFT) are not provided by the .NET Framework, thus requiring you to design and implement these libraries from scratch. Finally, it would be ideal to interact with your instruments and control systems before actually writing all the code.

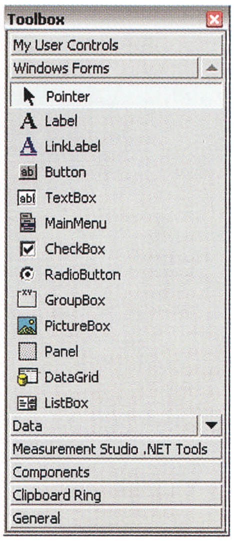


Figure 3. General-Purpose User Interface Controls

Challenge 2 – This is new technology, but how do I preserve my existing investment?

Your company may have spent years developing thousands, if not millions, of lines of code that you do not want to simply throw away and rewrite in .NET. You may have also seen your applications first incorporate C code, followed by ActiveX, then COM+, and now .NET (*see Figure 4*). The big question is, "What is coming after .NET?"

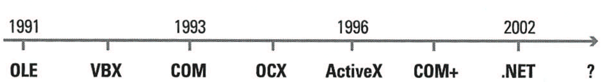


Figure 4. The Evolution of Microsoft Technology

This rate of change may be acceptable for IT applications whose life spans are on the order of months, but not for test and control applications whose life spans may be on order of years or decades. So, when moving to a new technology, the first question you should ask is, "How can I reuse my existing programming investment?"

Incorporating existing C, C++, or Visual Basic 6.0 code into a .NET application is not trivial. With C or C++, you can create DLLs out of your existing code and call them from a .NET application. Calling a DLL from .NET requires Platform Invoke (P/Invoke) to call unmanaged code from the managed world. As shown in *Figure 5*, this requires manually declaring each function from the DLL you want to import. If you have 500 functions that you want to reuse, you need to manually wrap all 500 functions with DllImport in C# or Declare Function in Visual Basic .NET. The most challenging part, though, is not just declaring the function name, but ensuring that all the .NET data types match the data types in the DLL. For example, character arrays become strings, C pointers become IntPtr, and so on. You might think you are done after your program successfully compiles, but data type mismatches will be discovered only at run time when the CLR actually invokes the DLL.

With existing Visual Basic projects, Visual Studio .NET provides the Visual Basic Upgrade Wizard to upgrade existing Visual Basic 6.0 applications to Visual Basic .NET. Although this process does eliminate the majority of manual work in the upgrade process, you must realize that Visual Basic 6.0 and Visual Basic .NET are two distinct languages that are not fully compatible. Variants are one of the most common data types in Visual Basic 6.0. Because Visual Basic .NET is strongly typed, you have to remove all variants from your code and replace them with the actual .NET data types such as strings or integer arrays.

```
[Visual Basic .NET]
Declare Function MessageBeep Lib "User32.dll" ( _
   ByVal beepType As UInt32) As Boolean

[C#]
[DllImport("User32.dll")]
static extern bool MessageBeep(UInt32 beepType);
```

Figure 5. Calling DLLs from .NET

Incorporating ActiveX components into a .NET application is easier than doing so for DLLs because Visual Studio .NET automatically generates a runtime callable wrapper (RCW) around existing ActiveX components. This .NET wrapper exposes ActiveX components as objects in your .NET application. Similar to Visual Basic 6.0, many ActiveX components use variants which you must manually cast to actual .NET data types.

Challenge 3 – .NET is managed, but I need access to low-level I/O

.NET is a completely managed environment, isolating you from the underlying hardware. The .NET CLR provides a programming infrastructure that automatically handles programming tasks that used to be manual coding challenges. One example is memory management. Languages such as C and C++ require you to track and delete unused memory manually. With both Visual Basic .NET and C#, you can allocate

```
[Visual Basic .NET]
Try
   'Place hardware I/O code here
Catch e As Exception
   'Place code to handle error here
End Try

[C#]
try
{
// Place hardware I/O code here
}
catch(Exception e)
{
//Place code to handle error here
```

Figure 6. Try-Catch-Finally Blocks

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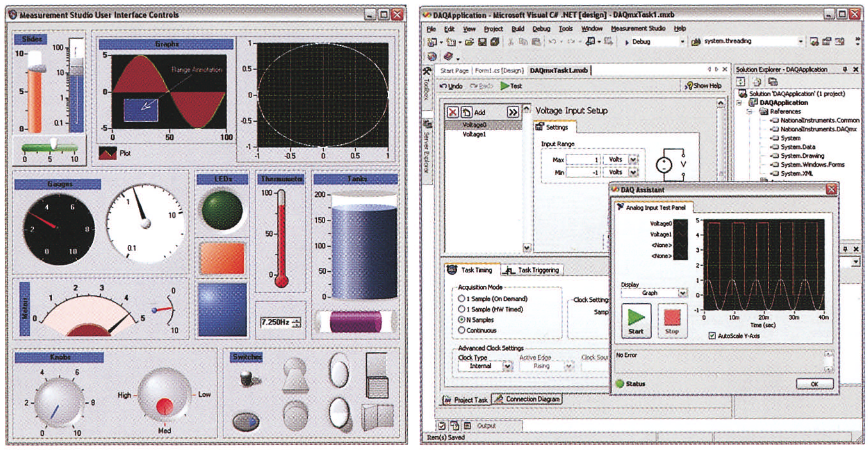

Figure 7. Measurement Studio User Interface Controls and the DAQ Assistant

memory on the heap with the new keyword and rely on the CLR to track and clean up ("garbage collect") unused memory automatically. Another value-add of .NET is managed exception (error) handling. With it, you can logically separate program code from error handling code as shown in *Figure 6*. When an exception occurs, code in the catch block is automatically executed to handle the error.

This managed environment is fantastic if you deal purely in the realms of software, but poses limitations when accessing hardware. The CLR acts as a buffer between your application and the actual memory on the host computer, thus preventing direct access to memory and registers. To control devices such as GPIB boards, serial ports, and data acquisition devices, your program still needs direct memory access. This is typically done through a DLL. But, according to challenge 2, you must manually wrap every DLL function using P/Invoke and then ensure all data types match. If you want to write your own device driver, you need to choose an unmanaged language such as C that can run in the low-level "kernel mode" of your OS and not just in "user mode" to which .NET applications are restricted.

Challenge 4 – What about multiple OSs?

One of the advantages of languages such as Java and C/C++ is that they support numerous OSs, including Windows, Linux, Unix, and Solaris. In theory, .NET is even more powerful because it has the potential of supporting multiple OSs in addition to supporting multiple languages such as Visual Basic .NET and C#. This is possible because the design of the CLR is publicly documented. Using this information, there is an open-source project called Mono underway, with a goal of creating the .NET Framework for Linux. Unfortunately, today, .NET is still primarily for Windows.

Since .NET focuses on computers running Windows, your applications cannot benefit from the strict determinism guaranteed by a real-time OS or the open-source code provided by Linux. The managed environment and the garbage collection prevent the .NET Framework from being deterministic. This might be a major limitation for control applications that require precision motion. Other industries, such as defense, are very specific about OS choice. In cases where an OS such as Solaris is required, you must remove .NET from the list of possible development platforms.

Conquering the Four Challenges

Despite the pitfalls introduced by .NET, you can still be successful using this new technology. National Instruments has specialized in measurement and automation for more than 28 years and offers a variety of development and driver software to help you overcome the aforementioned challenges.

National Instruments Measurement Studio – ni.com/mstudio

Challenges Conquered: • 1

To account for the fact that Visual Studio .NET is designed as a general-purpose development environment, NI Measurement Studio supplements Visual Studio .NET with functionality specific to test and control. Without Measurement Studio, simply acquiring measurement data, performing an FFT, and displaying the results on a graph would require writing your own .NET class libraries and controls from scratch.

Measurement Studio provides a complete suite of native .NET scientific user interface controls such as graphs, knobs, gauges, thermometers, and more. All of these controls are designed to be fully extensible so you can use them as a base class to define your own custom controls. For engineering analysis, Measurement Studio includes libraries for curve fitting, frequency domain analysis, filtering, windowing, signal generation, and more. Finally, Measurement Studio includes code generating assistants to help you interactively program data acquisition tasks and instrument control operations. With Measurement Studio, you can take advantage of all the features that .NET offers, plus measurement-specific controls, libraries, and assistants. And because Measurement Studio is an add-on toolkit for Visual Studio, it fits in seamlessly with your current .NET controls and C# and Visual Basic .NET source code.

National Instruments LabVIEW – ni.com/labview

Challenges Conquered: • 1 • 2 • 4

NI LabVIEW is a fully functional graphical programming environment with which you can quickly create virtual instruments with intuitive graphical code. This graphical approach to programming has revolutionized the way test and control applications are developed and deployed since its introduction in 1986. With function blocks such as FFTs, wires to connect these blocks, and programming structures such as loops,

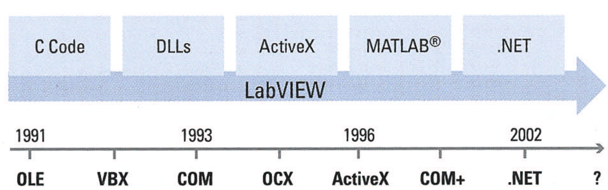

Figure 8. LabVIEW Calls Third-Party Party Technology

you can create complete applications without ever typing a line of text code. Over time, as other technology such as OLE evolved into ActiveX, then into .NET, LabVIEW has continued to provide a stable programming platform based on graphical code.

Every time a new technology is introduced, LabVIEW shields you from rewriting your applications from scratch or struggling to incorporate old technologies with new technologies. Instead, LabVIEW provides a common code base from which you can still incorporate other technologies, including .NET assemblies, ActiveX, DLLs, C code, and The MathWorks, Inc. MATLAB® script (*see Figure 8*). Specifically for .NET, you can use LabVIEW to instantiate .NET classes, invoke methods, and set and get properties. *Figure 9* shows LabVIEW source code that is invoking a .NET assembly to access the current CPU utilization and display the results on a waveform chart.

In terms of OS support, LabVIEW offers full support for Windows, Macintosh, Linux, and Solaris. LabVIEW even can execute deterministically on real-time targets. To exchange code between OSs, simply exchange virtual instrument (.vi) files and compile to machine code locally.

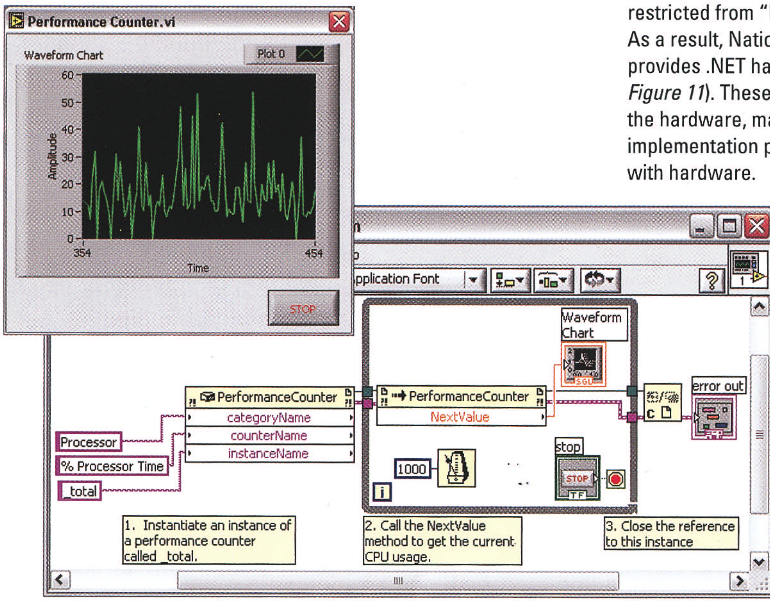

Figure 9. Performance Monitoring with LabVIEW and .NET

NI TestStand – ni.com/teststand

Challenges Conquered:
• 1 • 2

NI TestStand is a ready-to-run test management environment for automating and sequencing your test and validation systems. With NI TestStand, you can sequence test modules created in a variety of languages and technologies, including .NET assemblies, LabVIEW VIs, DLLs, ActiveX components, and HT Basic code. For .NET, NI TestStand includes a fully-functional .NET adapter with which you can call .NET methods and get and set properties, as well as debug .NET source code directly from NI TestStand. With a single NI TestStand project, you can easily sequence old test modules created in C along with new test routines created using the latest .NET technology. To configure a test step in NI TestStand, simply point and click to the location of your module as shown in *Figure 10*.

National Instruments Device Drivers – ni.com/downloads

Challenges Conquered:
• 3

As mentioned earlier, you cannot create device drivers in .NET because the CLR is restricted from "kernel mode" of the OS. As a result, National Instruments provides .NET hardware APIs for many of its hardware drivers (*see Figure 11*). These .NET APIs provide an object-oriented interface to the hardware, managed exception handling, and event handlers. This implementation provides a natural .NET programming experience with hardware.

Successful .NET Use

.NET is a new technology that offers many benefits for test and control applications, but also presents challenges. You can successfully overcome these challenges, but you must first understand them and then use the right tools. National Instruments tools such as Measurement Studio, LabVIEW, NI TestStand, and NI drivers make the migration to .NET easier and your application more powerful.

.NET Hardware APIs:

- **NI-DAQmx** for data acquisition devices
- **NI-VISA** for GPIB, serial, Ethernet, USB, and VXI instrument control
- **NI-488.2** for GPIB instrument control
- **Modular instrument .NET wrappers** for digitizers, arbitrary waveform generators, DMMs, high-speed digital, and switches
- **Machine vision .NET wrappers** to acquire and analyze images

Figure 11. .NET-Supported Hardware APIs

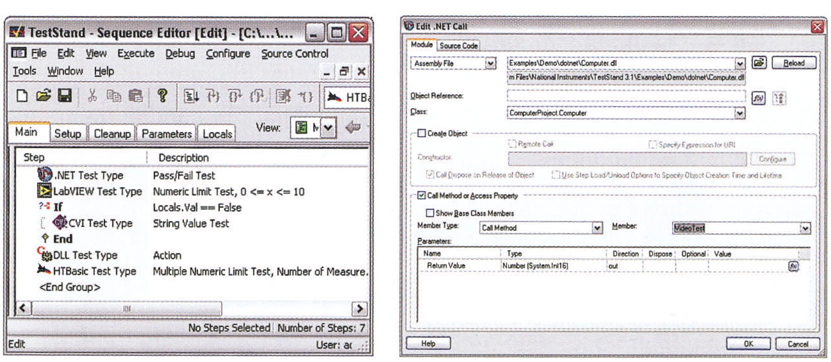

Figure 10. NI TestStand Manages .NET and Other Test Languages

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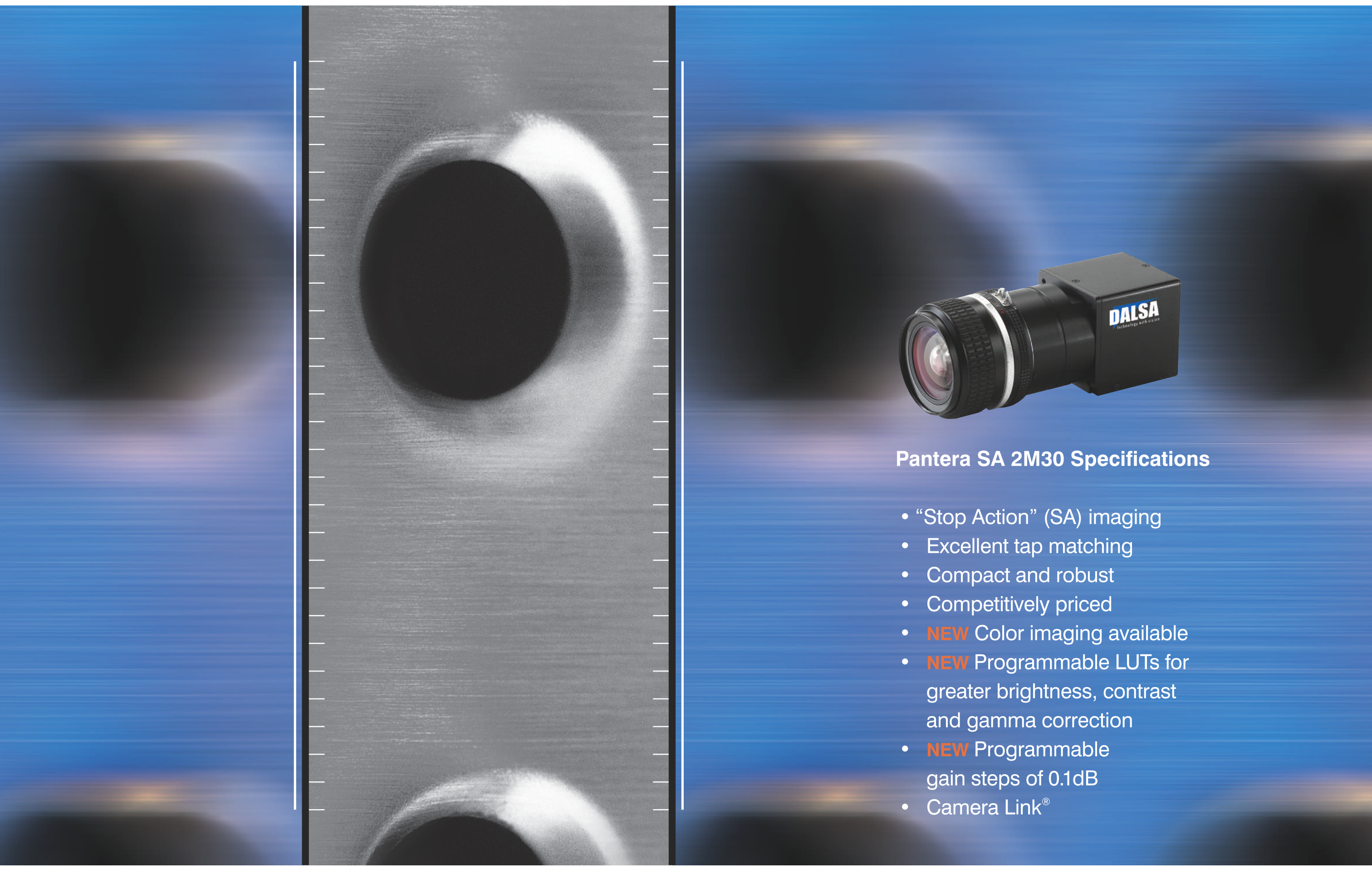

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MODULAR INSTRUMENTS

Spin, look, and measure

DEVICE UNDER TEST

Dimmer controls for automotive dashboards. Each control consists of a knob with an embedded light bulb. The knob attaches to a potentiometer. A 2-cm x 3-cm area in the center of the knob illuminates for night use.

THE CHALLENGE

Develop a test system that performs a visual inspection of each knob, measures torque and electrical resistance and current, and measures light intensity of the backlit area in the center of the knob. The system must turn the knob and keep track of its position over a 200° arc.

THE TOOLS

- Galil Motion Control: motion-control card (PCI bus). www.galilmotion.
- Kistler: torque transducer and amplifier. www.kistler.com.
- Kollmorgen: motor. www.danahermotion.com
- National Instruments: PCI bus data-acquisition and frame-grabber cards, graphical programming language, and vision software. www.ni.com.
- Pentax: camera lens. www.pentax.com
- Renishaw: motor-position encoder. www.renishaw.com
- Sony: industrial camera. www.sony.com

PROJECT DESCRIPTION

When a manufacturer of automotive dashboard controls needed an automated manufacturing and test system, the company hired Meikle Automation (Kitchener, ON, www.meikleautomation.com) to develop and deliver it. The system consists of a manufacturing portion run by a programmable-logic controller (PLC) and a test portion controlled by a PC. The test portion uses a camera, a frame grabber, and vision software to capture and analyze multiple images of the control under test. A 2-cm x 3-cm area in the center of the knob lets light from a bulb pass through to indicate function to a driver. Data-acquisition and motion cards measure the torque, resistance, and angle of each control.

The system starts in calibration mode where it monitors the control's torque through 200° of rotation. "We calibrate out the torque induced by the mechanical components of the system," said software team leader Dean Mills. "The encoder gives us enough pulses to produce a relatively constant velocity because it removes any jitter from the motor."

An analog-input channel in the data-acquisition card digitizes the torque sensor's signal, which the software continuously monitors. When the control reaches the end of its arc, torque rapidly increases. The system halts the motor and reads the encoder's value, thus finding the position of the control's minimum electrical resistance. The system then rotates the control clockwise until it detects the other end of the arc. From those two points, the system knows how many steps it needs to traverse the range (the system tests several models of control, which have varying numbers of steps).

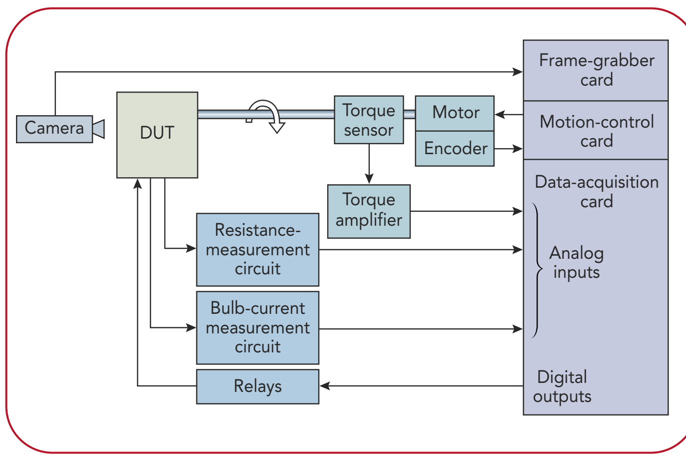
Throughout the rotation, the system continuously monitors torque, resistance, and angle. The system decides if the part passes or fails based on the torque reading being between a minimum and maximum range throughout the curve, the potentiometer resistance linearity compared to a master resistance curve, and the minimum and maximum resistance at the extreme ends of travel. In addition, the overall angle of rotation must fall within a minimum and maximum range.

RESULTS

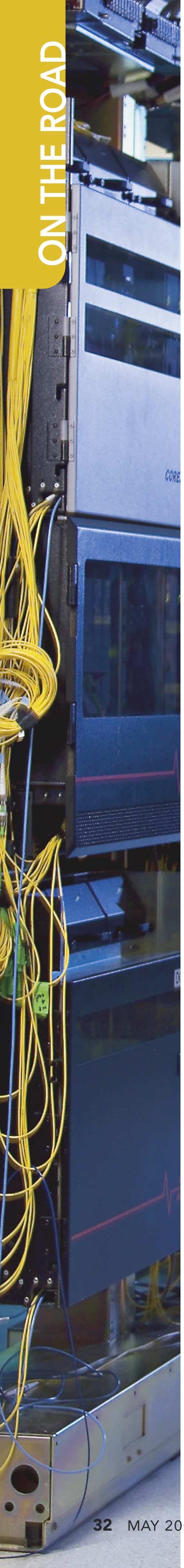
The PC-based system turns the DUT at 60°/s, and it tests a part in 4.5 s to 5 s. The previous system, which used a PLC for testing and for manufacturing, turned the DUT at 20°/s. The new system, in operation for over 18 months, uses a PC for its test portion, which is far better suited for the testing tasks. The PC also performs the visual inspection in parallel with the electrical measurements, something the old test system couldn't do with a PLC. "With the PC, we can take images without waiting for other events to conclude," said Mills. "The previous system performed one measurement at a time."

"The hardware works very well, with torque measurements accurate to within 0.001 N-m. Our software lets us tie data acquisition, digital I/O, instrument I/O, and interfacing with a programmable-logic controller that drives the assembly line," said software engineer Ben Zimmer. "The system has run 10 hours a day for over 18 months, testing a new part every 10 seconds."

Martin Rowe, Senior Technical Editor



An automated system performs a visual inspection and measures electrical parameters of automotive dimmer controls.



BUILT *for the* LONG HAUL

MARTIN ROWE, SENIOR TECHNICAL EDITOR

LINTHICUM, MD—Whenever you place a long-distance call or use the Internet, you likely use a Ciena CoreStream optical transmission system without knowing it. Major telecom carriers throughout the world rely on CoreStream systems to carry voice, data, and video between metro networks in different cities. Part of that reliability comes from the intense testing that Ciena engineers perform during design verification at the component, subsystem, system, and network level.

Ciena takes an unusual approach to product development, as some of the people who define the technical details of new products and upgrades also perform design-validation tests. Greg Bartolomei, director of systems validation, and James Allard, senior director of systems and verification, are two key people at the beginning and ending of a product's development cycle. Allard works closely with Ciena's customers and with marketing to obtain feedback to define a new product or feature upgrade. After marketing develops a functional feature specification, Allard's systems-engineering team transforms it into an engineering requirements and specifications document.

When Ciena begins work on a new design, Allard assigns a systems engineer to follow the product throughout its development. Allard says the engineer lives in the engineering labs and is the "one neck to grab" when other engineers need a resource or if something goes wrong. "The process not only ensures quality," said Allard, "but it ensures that we developed the product we set out to design."

After Allard's systems-engineering team writes a product's engineering specs, the specs are passed on to digital hardware engineers, software engineers, a power-supply specialist, and mechanical, reliability, network, and automation engineers who all contribute their expertise to the product's design. Because the heart of a long-haul transport system is its optics, engineers in the optics lab, electronics lab, lightwave systems lab, and systems-validation lab test the optics at the component, board, system, and network levels to verify that a product will meet Ciena's specifications. At the end of the development phase, Bartolomei and others validate the final engineering product design, and then Allard's group has the final say on whether a product is ready for production, based on tests from Bartolomei's group. The entire process can take up to four months.

It starts with optics

Photonics director Jean-Luc Archambault manages eight engineers in the components lab who evaluate optical products for new designs. Upon receiving engineering specs, engineers including senior principal engineer Dr. Doyle Nichols test optical receivers, transmitters, amplifiers, and passive components such as splitters. (For a complete

ROBERT BURKE

TESTS ENSURE THAT CIENA'S CORESTREAM OPTICAL TRANSPORT SYSTEMS COMMUNICATE RELIABLY BETWEEN CITIES.

Director of systems validation Greg Bartolomei and his team perform system-level tests on Ciena's new products to verify that they meet engineering specifications.

list, see "Products tested in Ciena's components lab" in the online version of this article at www.tmworld.com/archives.)

Ciena tests optical components to verify that they meet manufacturers' specifications and that they will perform properly in the company's equipment. "We compare our measurements against those of the manufacturers" noted Archambault, "If we see large discrepancies between our measurements and manufacturers' specs, we must resolve them. Often, we require component makers to add tests to their products."

The components lab has four test benches for active components, two each for evaluations at 10 Gbps and two for slower speeds (1 Gbps and 2.5 Gbps). On the day of my visit, Nichols tested an optical receiver at 10 Gbps. He often tests components at the slower speeds when they will connect to a tributary line.

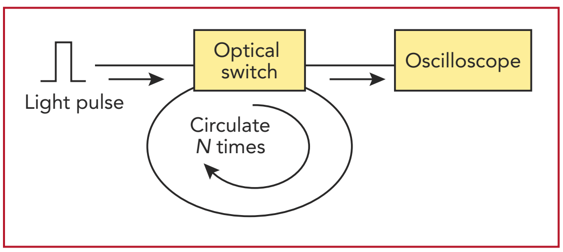


FIGURE 1. An optical switch routes a light pulse around a loop to simulate the effects of the pulse going through a chain of amplifiers.

To test a component, Nichols uses a test mounting board roughly 2 ft x 3 ft in size, on which he mounts the device under test (DUT), fiber-optic cables, attenuators, splitters, and connectors. Nichols knows the characteristics of all components other than the DUT, which ensures that no unforeseen variables will alter his measurements.

Nichols routes the receiver's electrical output to a clock-recovery circuit, which extracts embedded clocks from data streams. He runs the receiver's recovered clock and data stream into a bit-error-rate tester (BERT), an optical spectrum analyzer (OSA), and a digital communications analyzer (DCA). With these instruments, Nichols performs tests such as BER versus optical power and BER versus optical signal-to-noise ratio (OSNR). A receiver evaluation usually takes one or two days in the optics lab. (For details on how Nichols performs BER versus OSNR tests, see "Bits battle noise," Ref. 1.)

Optical signals must pass through dozens of amplifiers as they travel the long distances between cities. Ciena engineers typically perform more than 100 measurements when they qualify an amplifier. "Testing is an *N*th-dimensional problem," said Archambault. "You can spend as much time testing as you want." While Ciena purchases most of the amplifiers it uses, Archambault said the company gets heavily involved in an amplifier's design. "Sometimes, we come up with our own preliminary designs and show them to our suppliers," he noted.

James Allard, senior director of systems and verification, leads the group that writes engineering specs; his group also has the final say on when a design is ready for production.

Homegrown testers

Amplifiers add noise to optical signals. To simulate a light pulse traveling through amplifiers, Archambault's engineers built a recirculating fiber-optic loop that contains one or more amplifiers (**Figure 1**). The switch forces the pulse through the loop many times. The loop simulates light passing through an amplifier or small chain of amplifiers each time around, letting the engineers conduct long-distance testing with relatively few amplifiers. A digital delay generator regulates the time the light runs around the loop. When the time expires, the switch lets the light pulse exit the loop. Engineers can test the effects of a pulse passing through 30 amplifiers by passing light 15 times through a loop that contains two amplifiers.

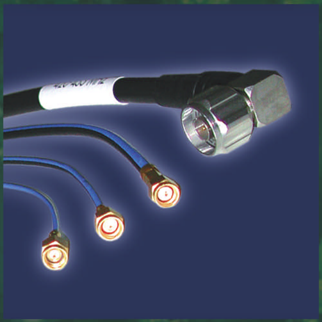
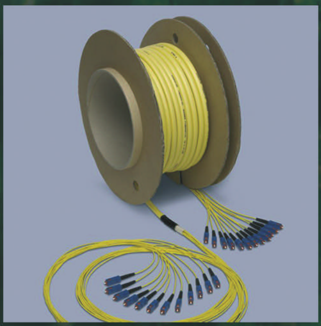
The recirculating loop is but one homegrown tester in the components lab. Ciena engineers also built an automated test system that measures how well an amplifier boosts optical 1's and 0's. Other tests the system performs include gain level, gain flatness, and gain accuracy. The engineers use a comb laser source to generate more than 2000 optical signals of different wavelengths across a 38-nm wavelength band. Using an OSA, they can take measurements at each wavelength. *(continued)*

The CoreStream system

Ciena's CoreStream optical transmission system uses dense-wavelength division multiplexing (DWDM) to deliver up to 2 Tbps of data in the C band. DWDM puts data from different sources on their own wavelengths of light and then multiplexes them on a single optical fiber for transmission over long distances. CoreStream contains optical terminals, amplifiers, and add/drop multiplexers connected through a chassis backplane. Optical terminals interface the system to OC-12 (1 Gbps), OC-48 (2.5 Gbps), and OC-192 (10Gbps) optical data streams where the system multiplexes the lower-speed tributaries into the OC-192 streams.

The system supports synchronous optical network/synchronous digital hierarchy (SONET/SDH), asynchronous transfer mode (ATM), and Internet Protocol (IP). It can send and receive data at 10^{-15} BER. Ciena also provides LightWorks ON-Center, a management software application that telecom service providers can use to manage their networks.—*Martin Rowe*

A CoreStream optical transmission system is scalable to meet the needs of communications carriers. Courtesy of Ciena.

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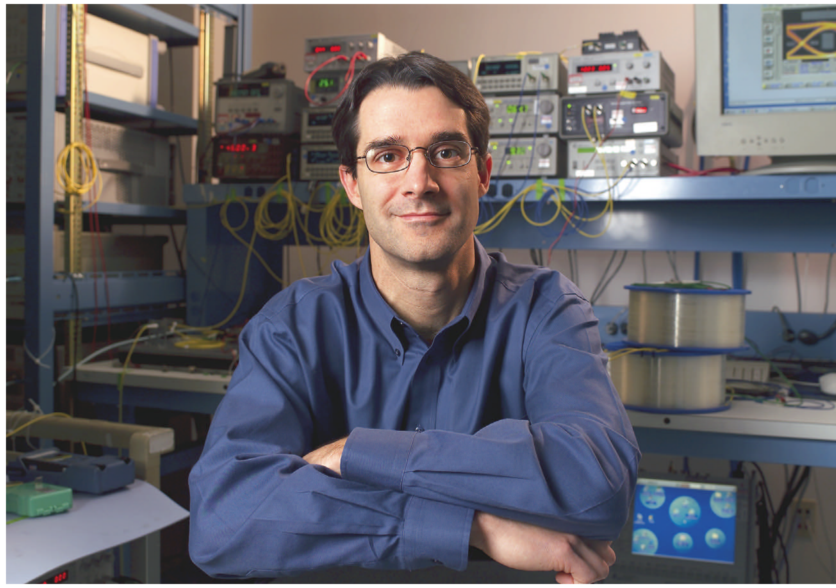
Archambault's team also test dispersion-compensating fibers (DCFs), which compensate for dispersion of light as it travels through a fiber-optic cable. The engineers measure loss and dispersion as a function of wavelength, and they perform multipath interference measurements. Backscattering will occur in a DCF that isn't properly designed.

Besides performing bench-level performance tests, the engineers also test components for reliability by placing them in thermal chambers. Archambault pointed out that a component will undergo a thermal stress at 75°C, 90% relative humidity for about three weeks. Components also undergo temperature cycling from –40°C to 85°C.

Operational tests take place at temperatures from 0°C to 65°C. During these tests, an engineer drives a component with a pattern generator and measures BER. The engineer also looks at a component's eye diagram with a sampling oscilloscope to measure how a device's output changes with temperature. An optical switch, controlled by a PC, lets engineers run thermal tests on up to 18 devices at once.



ROBERT BURKE

Jean-Luc Archambault manages the components lab, where engineers evaluate active and passive optical components.

Add the electronics

Engineers in the electronics lab design the hardware and software that will integrate with the optical components evaluated in the components lab. Headed by senior director Cecil Smith, the lab employs 25 engineers who develop products and write test software. "To develop one board," noted Smith, "we may use an RF analog engineer, one or two digital designers, a mechanical engineer, a power specialist, and a PCB designer. Automation engineers write test code that automates engineering tests and production tests. Our people are very good at what they do, and we can often use a circuit design in more than one application."

Hardware and software development takes place simultaneously. Hardware engineers manually test the first iteration of a product such as a line card by testing the card's physical-layer functions. **Figure 2** shows the test equipment on a typical engineer's bench. Engineers use the equipment to measure parameters such as signal power, jitter, and BER.

To perform these tests, engineers built a test bed that includes a CoreStream backplane. It also provides access to optical and electrical data streams that the card needs. Engineers start by looking at waveforms from the backplane and from the line card's electrical interfaces to its optical components. The test bed connects to a PC that exercises and calibrates the card. (Calibration involves setting the card's optical power levels and wavelengths.)

For time-domain measurements, Smith's engineers use DCAs to observe eye diagrams of transport signals in electrical form on the card and in optical form as the signals enter and exit a card's line interfaces. They look for reflections and check for correct waveform shapes, and they use logic analyzers to investigate data patterns. They then adjust drive levels, extinction ratios, or impedances to get the best jitter performance.

The engineers also measure a card's optical output power and make BER measurements on both transmitted and received data streams. To make the optical BER measurements, they use SONET test sets that transport payloads of pseudorandom bit sequences encapsulated in SONET frames. The frames start as OC-3 (155 Mbps) and OC-12 (622 Mbps) streams multiplexed up to OC-192 (10 Gbps) streams. They also add noise to the signals so they can measure a card's ability to accurately transport data under less than ideal conditions.

If a card requires design changes, its second iteration usually goes to

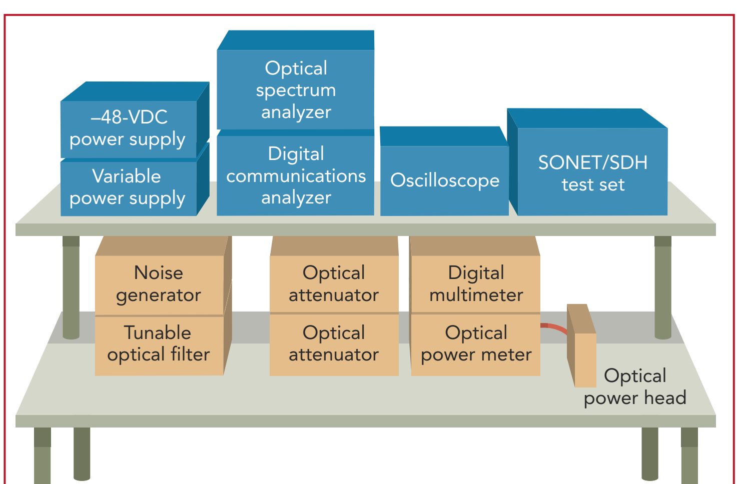


FIGURE 2. Engineers' benches in the electronics lab contain optical and electrical test equipment.

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the automation group, where engineers run the card through a series of automated tests. "We have an extensive set of I/O libraries that we use to bring up new cards," said Smith. Automation engineers use those libraries to write test code in LabView, and they often reuse the code in production test systems.

As software engineers complete software modules, testing moves from checking the hardware to checking that the hardware and software work together. For example, a line card must report errors if SONET frames fail to arrive at their destination. The software must also fill a payload frame when errors occur.

When engineers are convinced that a card and its embedded software meet specifications, they perform environmental tests. "Some countries don't have good environmental controls," said Smith. "Transport systems could reside in central offices that, although heated, could receive a blast of cold air if someone opens the door in the winter, so we test our cards for thermal shock." A typical test subjects a card to a temperature change of 40°C in one minute.

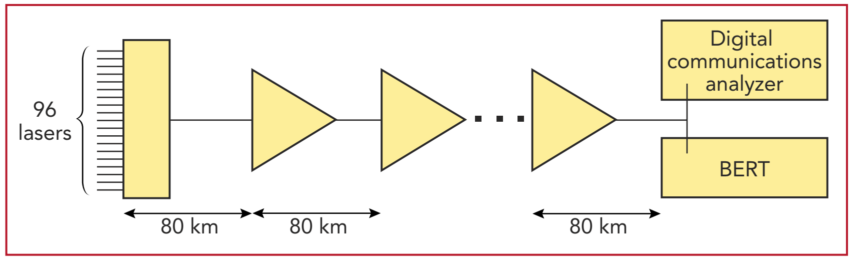


FIGURE 3. In the LWS lab, engineers test the effects of amplifiers in an optical network.

On to the systems

When a card passes its tests in the electronics lab, it's ready to run in a system and communicate over a simulated network. In the lightwave systems (LWS) lab, Dr. B. Sridhar tests cards and systems under simulated real-world conditions. He uses racks of test and network equipment, 30,000 km of fiber, and dozens of optical amplifiers to emulate networks in the field. "People characterize communications systems in terms of distance and capacity," said Sridhar. "We test line cards and systems to see how they perform under different conditions." Sridhar also uses the lab's network to test purchased optical amplifiers by looking at the signals they produce and by running BER tests.

From his network measurements, Sridhar can evaluate new products and can recommend to customers how they should configure new networks for optimal performance. Ciena has developed a network-design software tool that customers use to configure their networks with amplifiers and fibers. The tool is based on Sridhar's work at characterizing networks in the LWS lab.

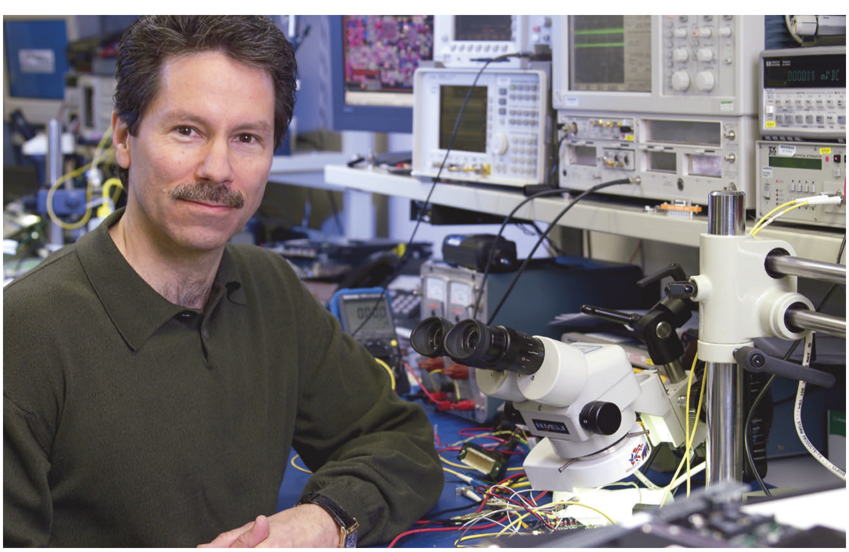
On the day of my visit, Sridhar tested a 93-channel system configured with 1600-km of fiber and 20 erbium-doped fiber amplifiers (EDFAs) spaced 80 km apart (**Figure 3**). Typical long-haul networks have amplifiers every 80 to 120 km. A CoreStream system can accommodate up to 192 channels, each on a unique wavelength, in a 10-Gbps link. A single EDFA can amplify all 192 wavelengths, eliminating the need for an individual amplifier for each channel. The test network needs two EDFAs, one for each transmission direction.

The LWS lab's network also consists of patch panels that let engineers choose fiber types. A 1x16 optical switch lets Sridhar measure the noise produced by optical amplifiers along a fiber-optic link. Because each amplifier adds noise, the total noise in a network is proportional to the number of amplifiers and the amount of gain each one provides. In a network that must maintain a 20-dB signal-to-noise ratio, even 0.1 dB to 0.2 dB of noise from each amplifier can be enough to reduce performance.

Sridhar tests each transport system or line card with different vintages of fiber because each produces different amounts of dispersion in the optical signal. He then adds dispersion-compensation fiber to compensate for the network's dispersion, as Ciena's customers will do. "Once we design a transport system," said Sridhar, "we test it with different fiber types to ensure that it will work in the real world."

To perform his tests, Sridhar uses a tunable filter that selects each wavelength. He looks at each channel's optical power with an OSA. Although an OSA indicates a wavelength's power, it provides no information about the signal's integrity. Therefore, Sridhar uses a DCA to view a signal's shape and jitter in the time domain.

Because communications service providers demand that their networks operate at 10^{-12} BER or lower, Sridhar designs networks to run at 10^{-16} BER, which lets him attain a good margin of



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Senior director Cecil Smith manages 25 electrical, software, and automation engineers who develop products and test software in the electronics lab.

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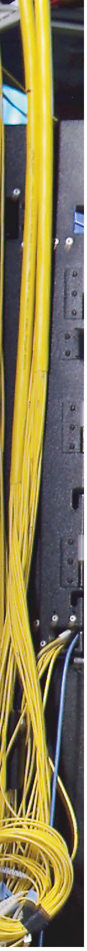

error. "We're trying to figure out how far we can go between amplifiers," noted Sridhar. "We look for the optimum configuration for each customer. More channels results in shorter distances because channels close in wavelength will more likely interfere with each other as distance increases."

Full circle

After a new product passes tests in the components lab, electronics lab, and LWS lab, it goes to the systems-validation lab for final approval. Bartolomei and Allard, who wrote the product's engineering specs, now test the product to verify that it meets or exceeds the system requirements and specifications.

Allard and his engineering team test new products under conditions that simulate a customer's existing network, bringing hardware, its embedded software, and system software together for the first time. In this lab, engineers verify that a product or product upgrade will work with the network-management software that Ciena's customers use. Ciena provides network operators with network-management software, but so do third-party developers. Some operators develop their own management software, and Ciena uses that software in the systems-validation lab to verify that products are ready for production.

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Product upgrades must also pass tests in the systems-validation lab. "Customers don't need a new box to get the latest features," said Allard, "They can add the latest features to existing equipment in the field." Bartolomei and Allard verify all product upgrades because they have at least one of every Ciena product built over the last 10 years. Thus, they can emulate any customer's network in the lab.

As part of systems validation, Bartolomei and Allard configure optical switches controlled through a LabView program that simulates real-world hazards such as broken fiber-optic cables. When a simulated break occurs, they check that the system properly recovers from the break. They also check a system's physical layer to make sure it's compatible with the customer's network. "It's a luxury to be able to simulate so many customer networks," said Bartolomei, to which Allard added "we can quickly mimic a customer's network from the management software layer to the physical layer."

When Allard's group approves a product or upgrade, it goes to production. The systems that test production units were developed by automation engineers in the electronics lab, which completes the circle of light. T&MW

REFERENCES

1. Rowe, Martin, "Bits battle noise," *Test & Measurement World*, March 2005. p. 59. www.tmworld.com/archives.

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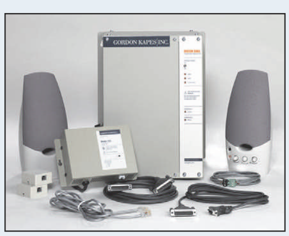

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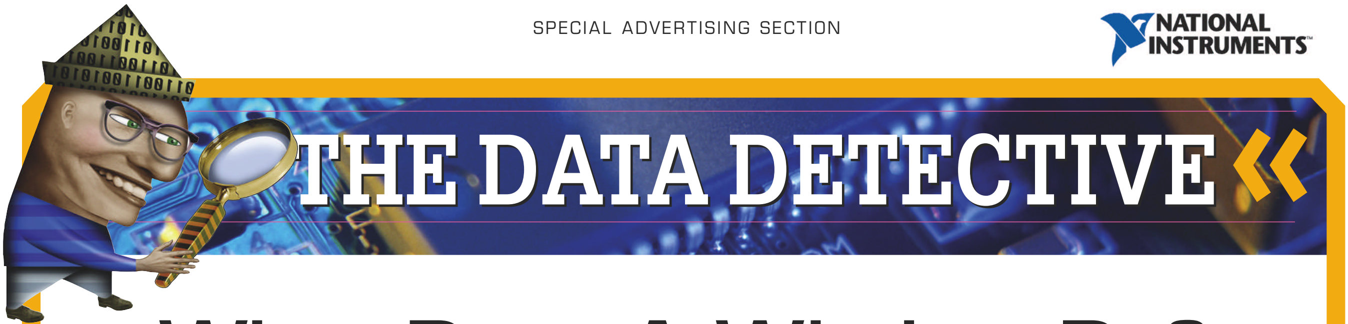
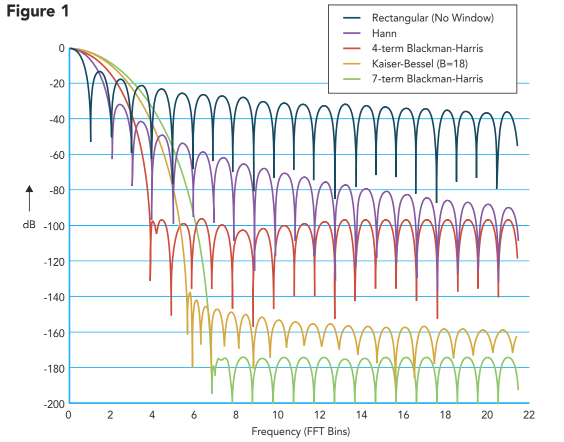


What Does A Window Do?

Instead of a pure Fourier transform, engineers and researchers must settle for the discrete Fourier transform (DFT), which operates on sampled data. That data may come from a digital oscilloscope, a data-acquisition system, or another instrument. Because the DFT operates on discrete points taken over a finite sampling period, its results are not perfect. Apply a DFT—usually implemented as a fast Fourier transform (FFT) algorithm—to a sampled sine wave, for example, and the power-vs.-frequency plot shows "leakage" of energy into frequency bins where you know it doesn't exist. In this example, the leakage appears as side lobes close to the frequency of the sine wave.

You cannot remove all leakage from the results of an FFT because acquiring samples for a finite period causes the FFT to spread the results across many frequencies. You can, however, apply window functions to the sampled data to reduce leakage. Simply by sampling a signal you have already applied a rectangular window to it. Think of the sampling process: An instrument opens a window on the data and during its sampling period, it acquires and multiplies each sample by 1.

Figure 1



The abrupt "opening" and "closing" of the rectangular window—inherent in measuring instruments—results in discontinuities that cause problems. To see what happens, duplicate the sampled data and tape together several samples end-to-end. The abrupt transition from one group of samples to the next becomes obvious. Windowing functions eliminate or reduce the abrupt transitions and thus increase the sensitivity of FFT results.

Luckily, you do not have to come up with your own window functions; mathematicians have developed many that suit particular needs. The equations for windows exist in many references, and commercial software, such as LabVIEW, includes window functions as part of the FFT data-analysis tools. Common FFT window functions include the Hanning (Hann), Hamming, Blackman-Harris, and Kaiser-Bessel. Time-domain plots of the window functions shows curves that start and end at 0 and reach 1.0 at the median point. A frequency-domain plot shows the roll-off and ripple for each window type (Figure 1).

The Hanning window works well in most of cases because it offers good frequency resolution and reduces spectral leakage. When you don't know the nature of a signal, start with the Hanning window. The following general rules serve as guides for applying a window to a set of data:

- When a signal contains strong interference at "distant" frequencies, choose a window with a high side-lobe roll-off rate.
- When a signal includes strong interference near the frequency of interest, select a window function with low maximum side-lobe levels.

The Missing Window

A recent shipment of high-quality oscillators to Fred's company included several modules that did not pass a test of incoming devices. A test engineer provided only a no-go/go report, so Fred has spent time in the lab looking at electrical characteristics of the failed oscillators. Now he has taken his measurements into the frequency domain to look carefully at the oscillators' outputs.

Like Fred, can you apply frequency-domain tools to look for possible problems in the oscillators' output signals? Get clues and test out your data-analysis detective skills at **http://rbi.ims.ca/4391-500**.

- When you must resolve two or more signals near in frequency, choose a smoothing window with a narrow main lobe.
- When amplitude accuracy of a single frequency component is more important than its exact location in a frequency bin, choose a window with a wide main lobe.
- When a signal's spectrum appears flat, or broadband, use the uniform window, or no window.

Keep in mind that applying a window may reduce frequency resolution. To overcome this reduction, increase the sampling rate and proportionately increase the acquisition time.

For Further Reading

"Windowing: Optimizing FFTs Using Window Functions," www.ni.com.

Lyons, Richard G., "Understanding Digital Signal Processing," 2nd ed., Prentice-Hall, Upper Saddle River, NJ. 2004.

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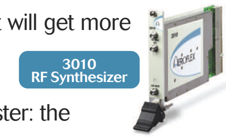

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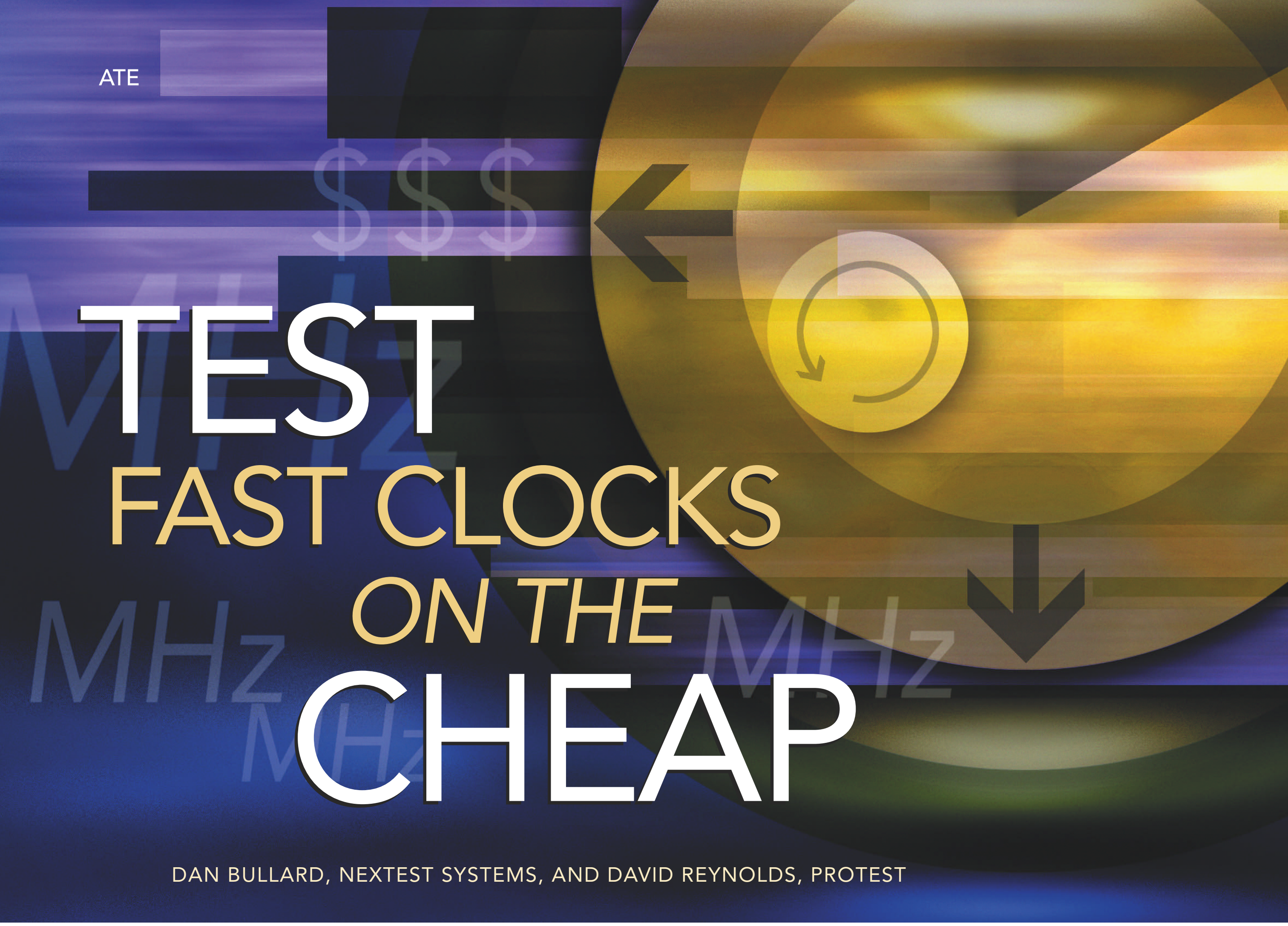

TEST FAST CLOCKS ON THE CHEAP

DAN BULLARD, NEXTEST SYSTEMS, AND DAVID REYNOLDS, PROTEST

When you need to measure the frequency of a high-speed clock, you probably look for an expensive rack-mounted box to do it. Not so fast. Instead, try using the digital-capture capability on your cheap digital tester, along with a few DSP library functions. Here's how to do it.

Nyquist was just an alias

Sampling theory, most people believe, says that you must take samples at more than two times the highest frequency of interest, so if you want to capture a 160-MHz clock (for example), you must capture at greater than 320 MHz. This is not really what Nyquist said, however. You need to obey this rule only if you want to avoid aliasing. (And by the way, telecommunications pioneer Harry Nyquist's name is itself an alias. His family name was Jonsson, but Harry's father, Lars, changed it, because another Lars Jonsson lived just down the road, and mail delivery became a real problem.)

If you capture a 160-MHz clock with a 33.333-MHz sampler, such as the Nextest Maverick's digital capture instrument (DCI), the clock signal will indeed exhibit aliasing—that is, it will look like another, lower frequency. This could be a problem if you don't expect this to happen, but if you do, you can use aliasing to your advantage.

A 160-MHz clock will alias back to 6.666 MHz. (160 MHz is just 6.666 MHz below 33.333 MHz times five, or 166.666 MHz.) **Figure 1a** shows the various bands created in the frequency domain by sampling at sampling frequency f_S equals 33.3333333 MHz. At the far right of Figure 1a is the band of 133 MHz (4x33 MHz) to 166 MHz (5x33 MHz). An instrument like the DCI doesn't allow you to actually see signals in these bands, but they do exist, and the proof of that is the alias that falls back into the Nyquist band, denoted here in yellow, running from DC to 16.666 MHz ($f_S/2$).

Since 160 MHz falls just 6.666 MHz below 166.666 MHz, it will alias back through the various bands (which you also can't directly observe), denoted as dashed

You can use an inexpensive digital tester to measure frequencies into the hundreds of megahertz.

red arrows. Eventually, an alias that you can see, 6.666 MHz, will appear in the Nyquist band. The reason the alias fell 6.666 MHz above DC is that it came from the upper half of the band, above 4.5 times the sampling frequency, so it folds back, appearing in reverse like an image in a mirror. The phase is reversed too, although for this purpose, that's not really important.

Now that you can see 6.666 MHz in the Nyquist band, does this mean that you are capturing 160 MHz? Not exactly. If you do see 6.666 MHz in the Nyquist band, it could indicate 160 MHz, or it could indicate any one of the other frequencies listed across the top of Figure 1a (26.6, 39.9, 60, 73.3, 93.3, 106.6, 126.6, or 139.9 MHz). Concrete proof that 6.666 MHz in the Nyquist band came from capturing 160 MHz has to come by sampling again at a different sampling frequency.

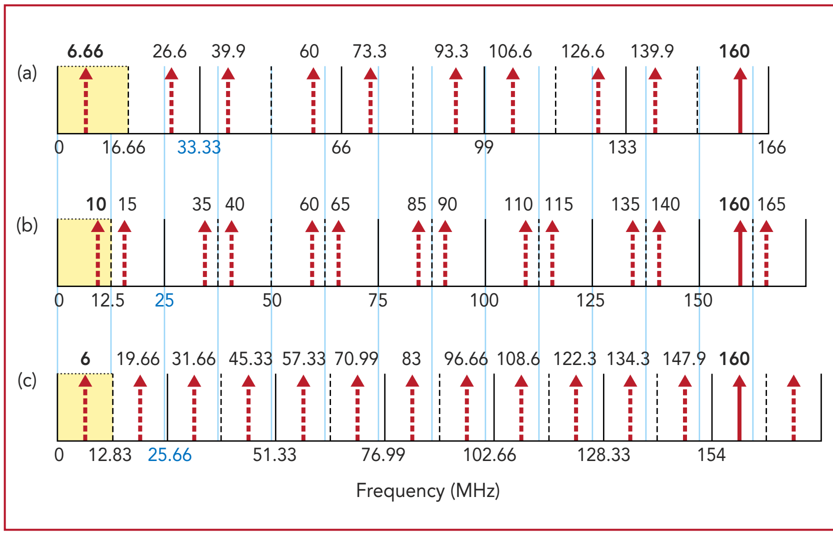

FIGURE 1. **Sampling a 160-MHz signal at (a) 33 MHz and (b) 25 MHz leads to ambiguities that (c) an orthogonal sampling rate, such as 25.66 MHz, removes.**

Which alias is which?

If you sample the 160-MHz clock again with a sampling frequency that is different from the original 33.333 MHz, the aliases will fall in different places. If you see an alias fall in a place that also suggests that you captured 160 MHz, then it's pretty likely that you captured 160 MHz in both instances and you can rule out the possibility that any of the other frequencies was captured. The new sampling frequency can't be closely related to the original, however; otherwise they will have common factors that will cancel and arrive at lower frequencies than the 160 MHz. For example, if you sampled 160 MHz again with a sampling frequency of 25 MHz (the inverse of 40 ns) the true answer won't be so obvious (**Figure 1b**).

Sampling at 25 MHz means that 160 MHz shows up 10 MHz above 150 MHz (6 times 25 MHz), so it will alias down to be 10 MHz above DC back in the Nyquist band. The bad news is that because 33.333 MHz (the inverse of 30 ns) and 25 MHz (the inverse of 40 ns) share a common factor of 1/(10 ns), or 100 MHz, they end up with common alias products.

Comparing Figure 1a and Figure 1b, you can see the problem. Note that 60 MHz appears in both lists of alias frequencies (the numbers across the top). This means that if you see something appearing at 6.666 MHz when sampling at 33 MHz, and you see something appearing at 10 MHz when sampling at 25 MHz, the captured signal could be 160 MHz, but it could also be 60 MHz. Now, if you are pretty sure that you aren't going to see 60 MHz, this could be fine. But how many test escapes are you willing to explain to your customer when the clock on the device turns out to be defective?

Let's get orthogonal

For the second sampling that will confirm the actual captured signal, you need a sample frequency that will not be related in any way to the original sample frequency; that is, it should have no common factors. One way to achieve this is to use a PLL to offset the system clock so you can get away from the standard system-clock-period resolution.

In the Nextest Maverick, you can use the APG PLL for this purpose. You must pick a frequency that has few if any common factors with the 33.333-MHz sample rate. For this example, we picked what looked like a fairly obscure system clock rate of 77 MHz (the inverse of 12.987013 ns), for a period of 38.961039 ns (three times the system clock period). This gives a sampling frequency of 25.666666 MHz. Unfortunately, you can't switch in the PLL on the fly, so you'll have to do one capture, reset all the timing, and then do another capture, but since the capture time is pretty fast (about 1 ms for 1-kHz resolution), it doesn't add much to the test time.

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Using this sampling frequency, the alias diagram should now look like Figure 1c, where 160 MHz falls exactly 6 MHz above 154 MHz (25.66 MHz times 6), so the alias ends up at 6.0 MHz in the Nyquist band. Note that the list of alias frequencies (across the top), are wholly different from the list generated by sampling at 33.333 MHz. This is crucial in making this technique work. You can confirm this yourself by once again looking at Figure 1a. There are no frequencies that appear in both alias lists (the top row of numbers) except the right answer, 160 MHz.

Remember, you'll need two different timing setups, two different patterns, and two different functional bursts. It's no good trying to switch timing sets on the fly, because most testers do not support switching time bases on the fly.

You'll need to set up your capture instrument to capture a single pin (the clock pin); the instrument will collect a sequence of 1's and 0's that represent the clock pin's transitions. Obviously, the comparator voltages need to be set to the 50% point of the clock, and an active load may be applied if the pin needs termination.

Once the functional test process has completed the capture, extract the digital

data to move it into a waveform. Next, subtract 0.5 from the waveform, that way, a captured "1" represents a voltage of 0.5, and a captured "0" represents a voltage of –0.5. (We'll explain the reason for this later, under "Resolution and Nyquist issues.")

Be sure the waveform X scale is set to the actual sample rate of the capture, or you will never get the right answer. Some testers do this for you automatically; others cannot because the capture instrument is not intended for time based waveform capture.

Just what frequency is it?

Now that you have two waveforms captured at two different sample frequencies, how can you measure the frequency of the clock signals they hold? While it is tempting to count the number of transitions in the waveform and then divide by the UTP (unit test period), this method just won't work.

The waveform may contain a small number of "runt transitions"—extra edges that occur close to the comparator threshold induced by noise. These extra transitions will cause this technique to overestimate the clock frequency, causing false readings.

One technique for turning time-domain data into frequency-domain—the FFT—data also provides very high noise immunity. The FFT will treat the runt transitions as noise so they won't interfere with your measurements.

All you have to do is perform an FFT, convert to magnitude (ignoring the phase), and look for the highest amplitude

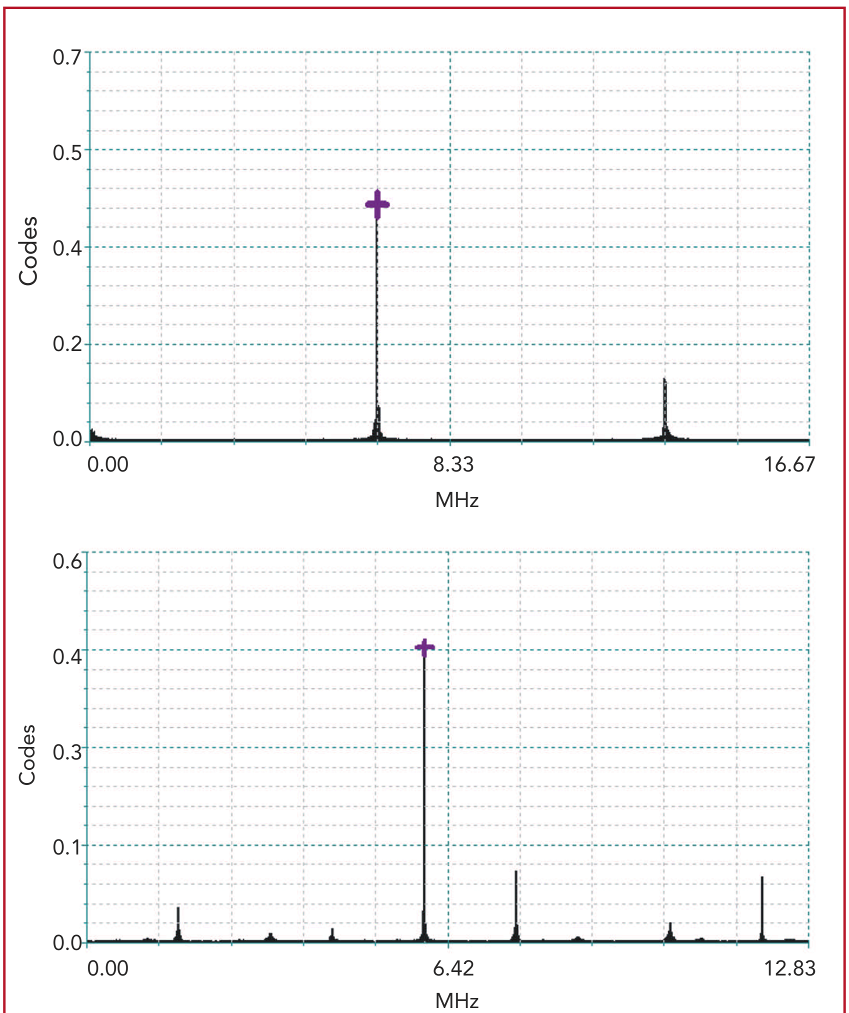
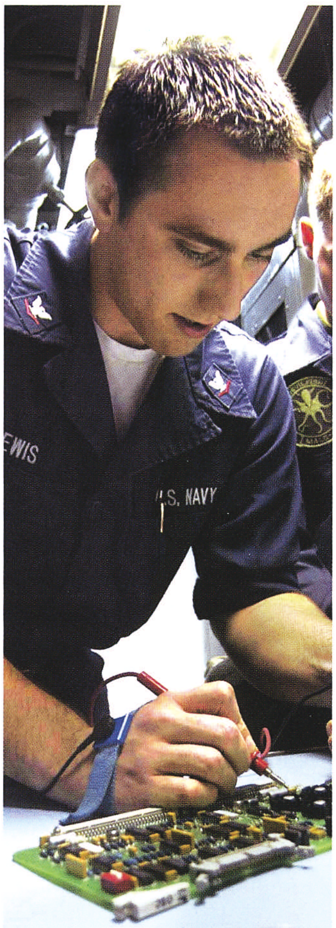
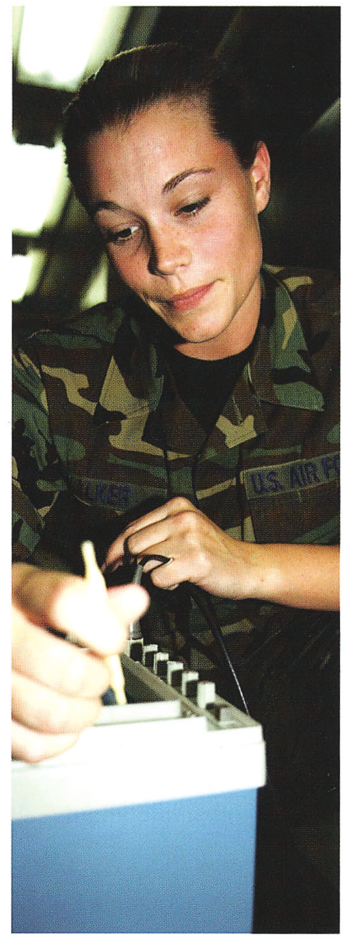


FIGURE 2. Nextest's Mixed Signal Wavetool shows the frequency-domain version of a 160-MHz clock captured (a) at 33.333 MHz and (b) at 25.666 MHz.





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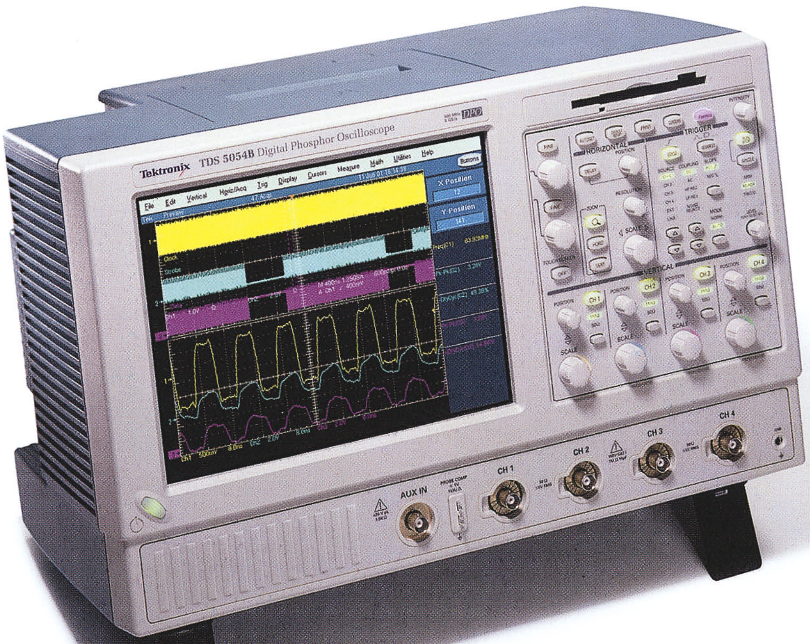

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Table 1. List of candidate frequencies

33 MHz	6.66	26.6	39.9	60	73.3	93.3	106.6	126.6	139.9	160			
25.66 MHz	6	19.6	31.6	45.3	57.3	70.9	83	96.6	108.6	122.3	134.3	147.9	160

signal. Since the data in the waveform is a square wave, there will be other components too (mostly odd harmonics), but by looking for the maximum value in the magnitude spectrum, you can find the location of the highest amplitude signal that has to be the fundamental of the clock that you captured.

Figure 2 shows the frequency-domain version of a 160-MHz clock captured first at 33.333 MHz and then at 25.666 MHz. The resolution of the frequency data in an FFT depends on two factors, the sample rate and the number of samples. The formula for the Fourier frequency is $f_F = f_S/N$. The example here has two sampling frequencies, so you have two resolutions:

33.333 MHz/32768 = 1017.25 Hz

and

25.666 MHz/32768 = 783.28 Hz

Your number of samples should be a compromise between test time and resolution. But being able to measure a 160-MHz clock with better than 1-kHz resolution is pretty good (approximately 6 ppm), especially given the fact that you can do this on a 33-MHz base-rate tester. The accuracy is half the resolution. If you want better, you'll pay for it, because the FFT time goes up pretty fast from here.

You could get 24.5-Hz resolution if you capture a million (2^{20}) samples, but an FFT on 1 million samples will bring even a dual Xeon computer to its knees for several seconds. Remember also that FFTs are most efficient when they operate on a power-of-two number of samples. Also note that this is one place a slower tester has an advantage—sampling slower gives you better resolution!

Stop at the intersection

Once you've measured the two alias frequencies, search the list of frequencies that the signal could be and see if you find an intersection. You'll need to write some code to look at the aliased frequencies to try to figure out where they intersect.

The best way to do this is to build a table having two rows containing the candidate frequencies for each of the sample rates. Search the rows for an intersection, or a match between the two lists (**Table 1**).

Because this example used two sampling frequencies that were orthogonal—that is, without common factors—there is no chance for overlap until you get above the gigahertz range. This is not likely to be a problem because the pin comparators on most cheap testers just don't have the bandwidth to go into the gigahertz range.

Once you have a match, you can infer that 6.666 MHz captured at 33.333 MHz and 6.0 MHz captured at 25.666 MHz are actually aliases of a 160-MHz clock. If it's not exactly 160-MHz, that will be apparent too, because the aliases will have drifted the same amount relative to their sampling frequencies, and will show up as 159.5 MHz or 160.2 MHz or whatever. In other words, this is not just a solution for a 160-MHz clock; this is a solution for just about any frequency you can capture with a digital pin comparator.

Resolution and Nyquist issues

You generally have to allow a little leeway when you look for matches in the two tables. This is done in case the frequency has drifted between the two captures, and to allow for the noncoherent nature of the capture. You have to avoid giving too much slop, however, because of a potential problem that could happen near the Nyquist and DC frequencies.

If the clock you are measuring gets very near a boundary, it's difficult to tell which side of the boundary the alias actually belongs to. For example, if you capture a 133.0-MHz clock with a 33.333-MHz sample clock, you'll see an alias appear at 333.333 kHz in the Nyquist band (333.333 Hz below 4 times 33.333 MHz). But that alias could

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also mean that you actually got a clock at 133.666 MHz (333.333 Hz above 4 times 33.333 MHz). If you allow for too much slop, you could pick the wrong number.

There are certain frequencies that are harder to measure than others, specifically K times one of the sample frequencies (where K is an integer). If the frequency you are measuring is exactly the same as one of the sample frequencies, most if not all of the samples will fall on either all high or all low. If they fall on all high, that's fine, the FFT will reflect that by putting a high value in the DC bin, and the software will find an intersection between DC and an alias of the frequency sampled at the other sample rate.

If, however, you failed to subtract 0.5 from your captured waveforms as we mentioned previously and you capture all lows, there will be no amplitude in the DC bin to detect. By subtracting 0.5 from the captured waveforms, you assigned a value of +0.5 to a solid high, and –0.5 to a solid low just in case the measured frequency falls into the DC bin due to aliasing. The polarity of the voltage doesn't matter to the FFT; it sees a magnitude of 0.5 either way.

You don't need to bolt an expensive box onto your cheap digital tester to measure a high frequency, even if it is far faster than your little digital tester can run. Just use the flexibility that's built into most testers to sample twice and beat Nyquist at his own game. T&MW

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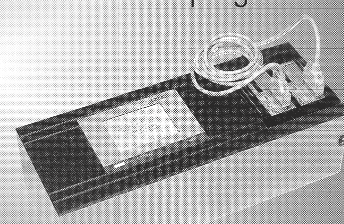

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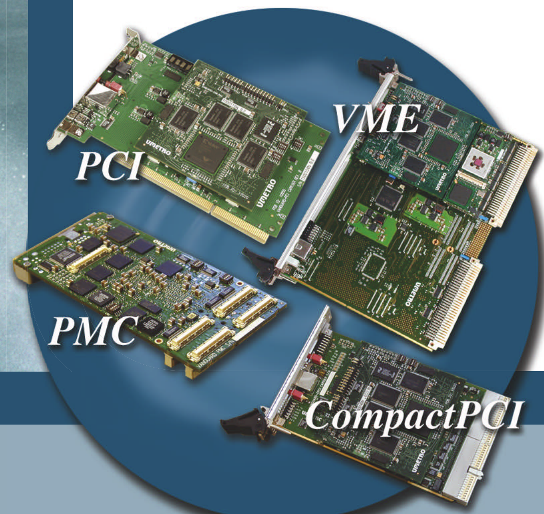

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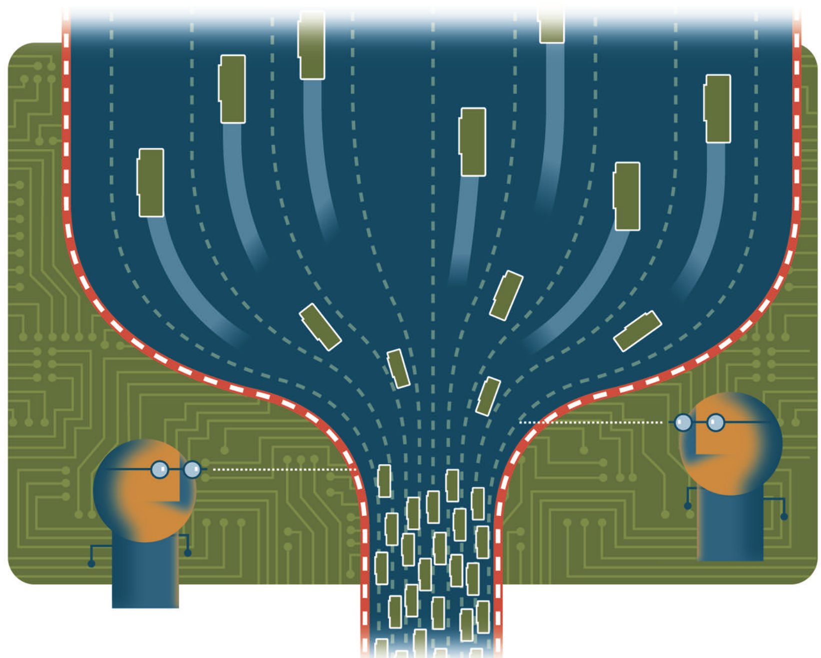


DANIEL GUIDERA

CONCURRENT TEST

DR. GRANT BOCTOR, DIGITALTEST

It is with regret that we announce that Dr. Grant Boctor, president of Digitaltest, passed away in late March. He died of a sudden heart attack while traveling in Egypt.

Dr. Boctor founded Digitaltest 25 years ago and has pioneered many printed-circuit-board test techniques, including the concurrent-test approach described in this article, which his staff submitted to us in February.

Before his death, preparations for Digitaltest's 25th anniversary celebrations were underway at the company's Stutensee-Blankenloch, Germany, headquarters.

Overwhelmingly, electronic manufacturers are seeking solutions to the end-of-line test bottlenecks that appear on high-volume product lines, where assembly beat rates are now faster than test rates. In addition, manufacturing engineering teams require techniques that can maintain test coverage and not increase the unit cost of test.

Until recently, the only viable solution required replicating the test platforms to gain more capacity to deal with the higher volume demand. But that approach requires more floor space, a higher capital budget, more operators, and longer maintenance times. New solutions using concurrent-test techniques promise to unblock the test bottleneck by using test-platform resources to test multiple units simultaneously.

Higher production rates

The gains in production-line assembly rates have come largely from product designs that use highly integrated components, which combine more functionality into smaller footprints and allow products to shrink in size, as seen in the portable electronic devices we carry. Instead of building individual small boards that go into such products, it is more effective to build large, multi-image boards and later separate them into individual units. This situation arises because of the desire to optimize the balance of load/unload time with machine build time. On consumer and automotive product SMT assembly lines, it is common to see boards with image multiples of two to eight units. On very small units, such as radio key locks, you might find 48 or more units for each board assembled.

Manufacturers may also find it more cost-effective to assemble many odd-shaped units in one easily transported multiple-image board, than to assemble them individually, as individual complex shapes would present a difficulty in automated transfer between machines. Examples include automobile steering-column sensor boards, which have a shape similar to that of a crescent moon (**Figure 1**). Six to eight such units can be built on one rectangular board at a line beat rate of around 120 boards per hour. Units then go to end-of-line test at this rate, multiplied by the number of units per board, or one unit at test every 7.5 s for a four-image board. This would immediately present a problem at test, as the normal allowance for unit load/unload alone is 5 to 6 s.

Smaller footprints, more functions

The adoption of smaller component technologies has lead to a reduction in the available space for probe-access test pads at production test. Active components also include more functionality per component, so the number of connections per device has increased, leading to higher connection densities. Because the higher density connections have contact pads much smaller than that required for test probe access, many sections of SMT boards are no longer fully accessible by probe-contact test methods such as in-circuit test (ICT). To make up for the drop in ICT fault coverage, manufacturers have turned to functional test techniques, such as BIST, boundary scan, and in-system-programming (ISP), in addition to conventional performance and compliance test techniques.

Products with multiple functions—such as mobile phones with cameras or pocket PCs that incorporate Bluetooth wireless communication and GPS navigation—further complicate the test process. The same-sized product, produced at the same line beat rate, now has multiple test demands. And tests of such devices must do more than ensure product quality; in many cases, they also must ensure the product complies with standards covering electromagnetic emissions.

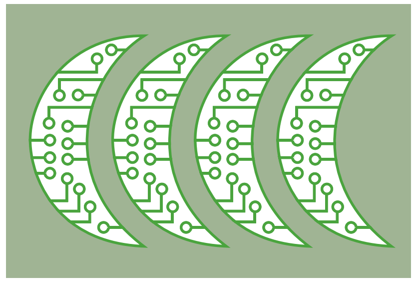


FIGURE 1. Steering-column sensors, having shapes similar to that of a crescent moon, would present significant handling problems, but multiple images can be assembled in a single rectangular board.

How, then, do you develop a test that can handle higher line production rates, multiple image boards, and increased product functionality—without creating a major end-of-line bottleneck? As Eliyahu M. Goldratt has pointed out in several books (Ref. 1, for example), normal test asset costs range from 10% to 25% of the capital cost of the complete assembly line. If traditional thinking is applied to solve the test bottleneck by deploying multiple replicas of the existing test setup, then test costs will rise as a percentage of total line costs—an obviously undesirable situation.

Recent advances in test architecture and test-management software have made concurrent test a feasible alternative. In concurrent test, a flexible, non-multiplexed test system with integrated functional test resources completes the test on multiple units simultaneously. Allowing the load/unload time to be shared by up to four units, and then completing the basic electrical test on all units simultaneously, the per-unit test time is dramatically reduced. Only when the more expensive functional test resources are needed to complete the test sequence are these used serially, thus ensuring only the lower cost resources need be replicated per unit under test.

Implementing concurrent test

In one concurrent-test implementation (**Figure 2**), a single test platform contains four test heads interfacing to four units under test. Each test head has its own controller managing its test. All stimulus and measurement for each unit is managed with the four test controllers. A master controller manages the complete test cycle and allocates common resources needed to conduct the functional test. These can include test instruments, VXI, PXI, or serial-bus-standard instruments as used in automobile electronics.

As with conventional test systems, concurrent test-development software generates the test program to be loaded in each test head. If the units under test are identical, then the same software can be loaded into each test head. The software can generate the control program that will run on the master controller, and it includes tools that allow the user to determine where synchronization points are needed to execute the jump from the parallel test mode to the sequential test mode. The master controller manages the overall test system, starting and stopping the test sequence and compiling the data-log files needed for quality reporting and board routing.

Concurrent test lowers per unit test cost, but the calculation to determine the maximum load for a test process can be complex because, unlike assembly machine capacity, it is more than the addition of load/unload time plus process time. It must include factors for test repeats and test-failure diagnosis, and it must allow some capacity for returns test. Most engineers simplify the calculation by allowing a standard 25% factor for

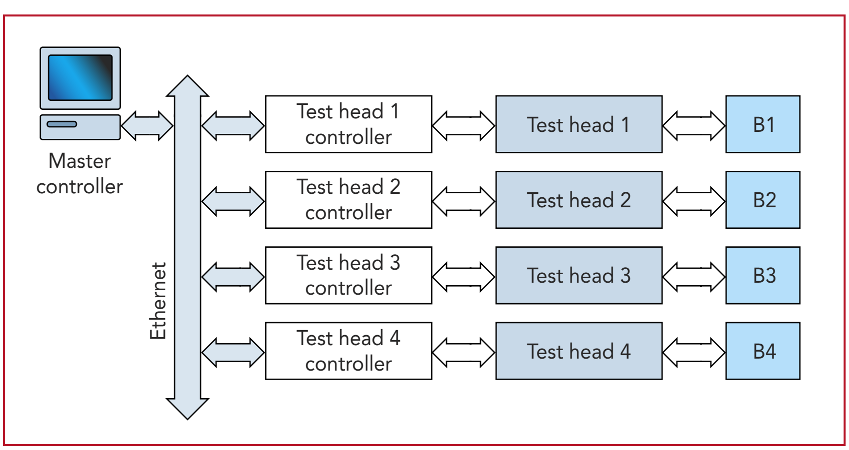
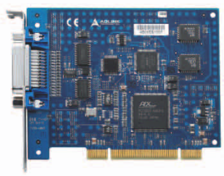


FIGURE 2. In this concurrent-test implementation, a single test platform contains four test heads interfacing to four units under test. Each test head has its own controller managing its test.



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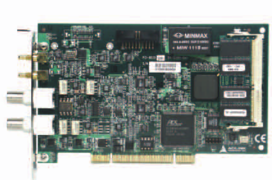

2-CH 65MS/s 14-Bit Digitizer with SDRAM

ADLINK's PCI-9820 and PXI-9820 are 2-CH 65 MS/s, high-resolution PXI digitizers with 512MB SODIMM SDRAM memory. They features flexible input configurations including programmable input ranges and user selectable input impedance. With lots of on-board acquisition memory, these digitizers are not limited by the PCI 132MB/s bandwidth and can record the waveform for a long period of time. The PCI-9820 and PXI-9820 are ideal for high-speed waveform capturing, software radio applications, and signal digitizing applications which require ample memory.

For more info, go to:
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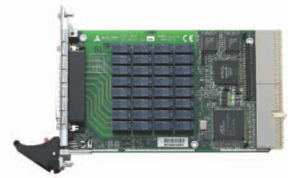

4x8 Two-Wire Matrix Module for Measurement and Automation

The PXI-7931 is matrix module with 32 cross-point two-wire relays (DPDT, 2 Form C), 220VDC/125VAC and switching capacity of up to 2A switching and 2A carrying. Using a termination board, users can choose between multiple configurations, (one 4x8, two 4x4, one 2x16, two 2x8 or four 2x4), and easily change the internal connection paths. It is PXI Rev. 2.1 and PICMG 2.1 R2.0 CompactPCI Hot Swap compliant and can be used in either PXI or CompactPCI systems. The PXI-7931 provides Direct-Update and Auto-Scan operation modes to accommodate various application requirements.

For more info, go to:
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- VGA Output supports 2048x1536 Resolution

PXIS-2506 Chassis
- 6-slot 3U PXI/CompactPCI Instrument Chassis with Power Module
- Accepts both 3U PXI and CompactPCI Modules
- One System Slot and Five PXI/CompactPCI Peripheral Slots
- Modular AC or DC 250W Power Supply

The **PXI Starter I** features:

PCI/PXI-8570 PCI-to-PXI/PXI-to-PXI Extension
- Direct PC control of PXI/CompactPCI Systems
- Up to 64-bit 66MHz PCI bus extension, 528MB/s peak
- Shielded Copper Cable up to 6 1/2 feet in length

PXIS-2630 Chassis
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these. The simple calculation of maximum allowable test time is

[(beat rate – (0.25 x beat rate)] – (load + unload time)

Thus, a 15-s unit production beat rate, with a 6-s load plus unload time can tolerate a maximum test time of only 5.25 s.

Once the single-unit test time exceeds this maximum allowance, additional capacity must be found. As previously mentioned, this would traditionally have required replica test systems. But these bring a high overhead of capital, floor-space, and operator time.

Concurrent test can significantly reduce this overhead. By loading/unloading four units and running all tests concurrently, the maximum test time allowed would become

[4 x 15 s – (0.25 x 4 x 15 s)] – (load + unload time) = 39 s.

In any real case, this maximum would be reduced by the serial tests that use common resources. So, the actual achievable maximum will need to be calculated for each application.

The cost-saving calculation is similar. Savings would be gained from requiring one test platform, one floor-space allotment, and one operator instead of four. Some cost for the concurrent test platform must be added, as that platform will have extra resources. But the cost is significantly lower than that required for four replica resources.

Results indicate that significant savings can be achieved using concurrent test systems at board-unit test. The additional benefits of lower demand on floor-space and support resources are equally valuable. T&MW

FOR MORE INFORMATION
* On board test, visit WWW.TMWORLD.COM/BOARD

REFERENCE

1. Goldratt, Eliyahu M., Critical Chain, North River Press, Great Barrington, MA, 1997.

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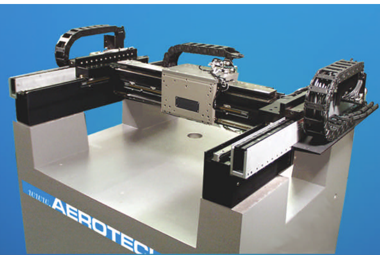
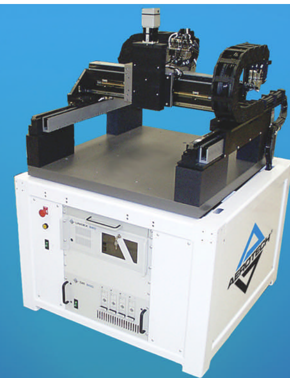


Customer

Top-five semiconductor and electronics metrology and inspection equipment manufacturer

Specifications

- Velocity to 3 m/s and acceleration to 5 g
- Dual Y-axis brushless linear servomotors
- Dual Y-axis linear encoders
- Optimized mechanical structure for high servo bandwidth
- Travel up to 1 m x 1 m

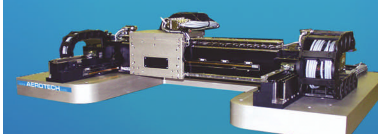


Customer

Largest independent disk drive manufacturer

Specifications

- Velocity to 3 m/s and acceleration to 3 g
- High-power brushless linear servomotors
- Optional machine base and risers with integral controller and drive chassis
- Travel up to 1 m x 1 m

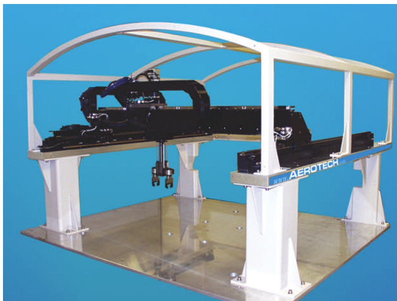


Customer

Number-one global semiconductor manufacturer

Specifications

- Extremely low profile with custom mounting plate
- Driven with brushless linear servomotors
- Noncontact linear encoder feedback
- Optimized cable management system for long life

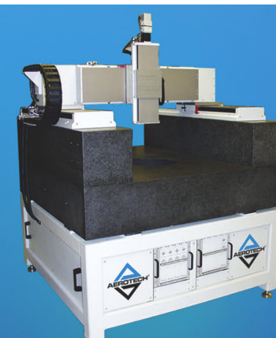


Customer

World-leading cell phone, pager, and semiconductor manufacturer

Specifications

- Driven with brushless linear servomotors
- Rugged design for 24/7/365 use
- Noncontact linear encoders
- Customizable Z and theta axes
- Travel up to 1.3 m x 1.5 m



Customer

Leading U.S. military/aerospace manufacturer

Specifications

- Large custom granite with through-hole and machine base with integral controller and drive chassis
- High-power X-axis brushless linear servomotor stage
- Ball-screw-driven Z-axis stage

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- LMA gantry options include dual independent X-axis mounting heads, customized mounting base, and risers

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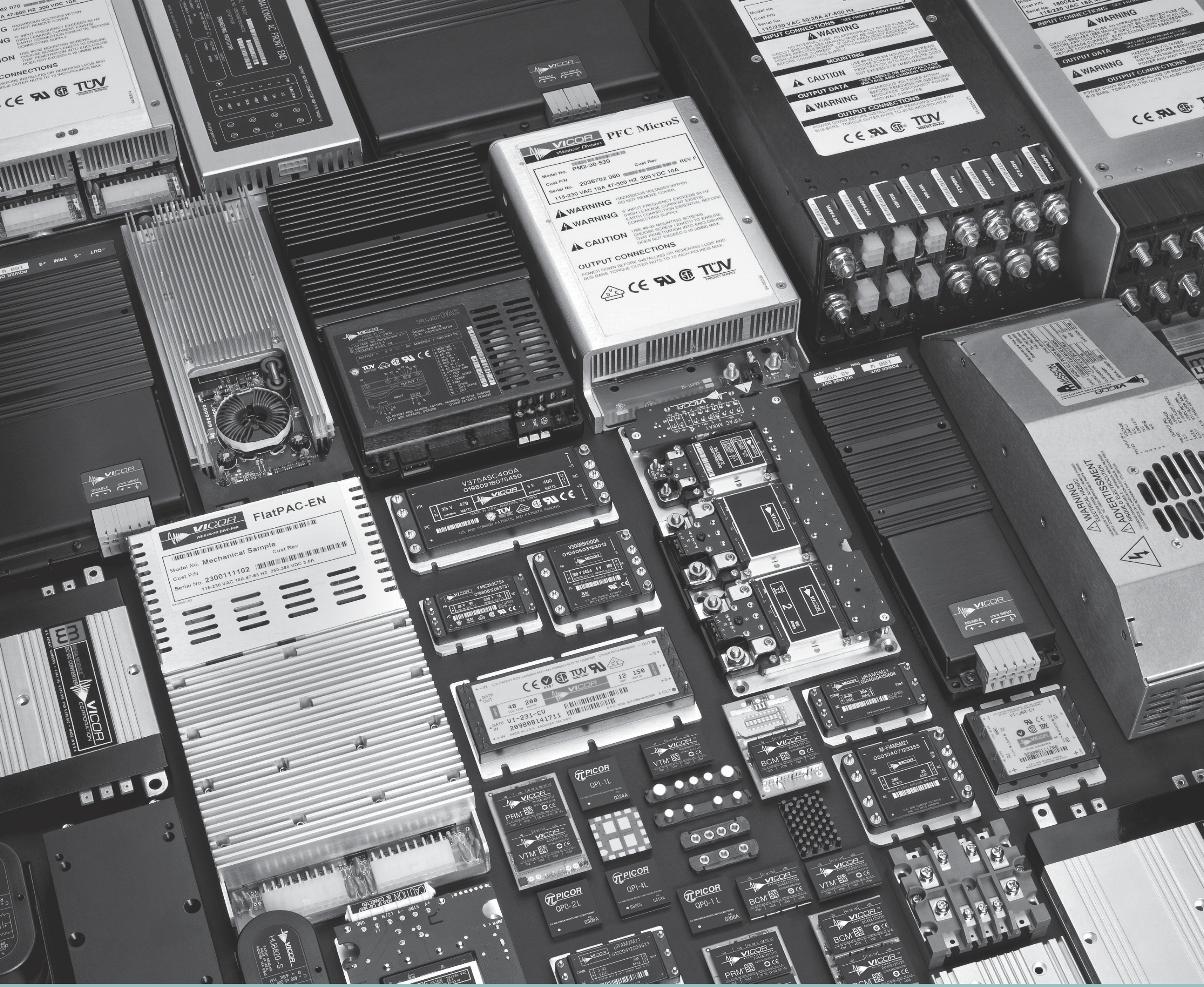

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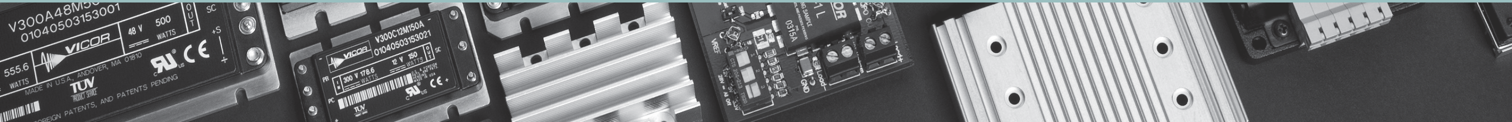


For more product information, visit the *T&MW* Web site: www.tmworld.com/webproducts

USB data-acquisition modules

Keithley Instruments is the latest to offer data-acquisition products for USB. The KUSB-3100 series consists of five modules. The Model KUSB-3100 and Model KUSB-3102 feature 12-bit resolution and sample rates of 40 ksamples/s and 100 ksamples/s, respectively. The

Models KUSB-3108 and KUSB-3116 provide 16-bit resolution and sample speeds of 50 ksamples/s and 500 ksamples/s, respectively.

Each module provides eight differential or 16 single-ended analog inputs, up to four analog outputs, 16 to 33 digital I/O lines, and up to five counter/timer inputs. The KUSB-3160 provides 96 digital I/O lines for monitoring or controlling switches, relays, and alarms. All modules come with Quickstart applications, visual programming tools and drivers, and support for LabView and TestPoint.

Prices: $349 to $2495. *Keithley Instruments, www.keithley.com.*

No-lead SMD removal kit

The Chip Quik lead-free surface-mount-device removal kit is designed to assist engineers and technicians conducting SMT rework. The Chip Quik removal method requires no expensive removal equipment, encouraging easy removal of QFPs, PLCCs, SOICs, and other SMD chip components at safe, low temperatures (less than 300°F) using a standard soldering iron.

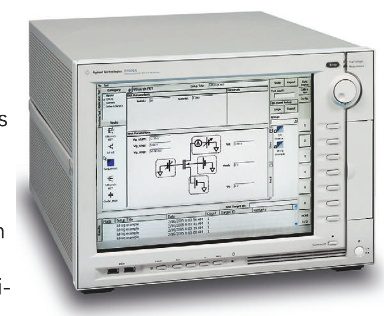
A user applies the kit's rework flux to all leads of the device to be removed and uses a standard soldering iron to melt the no-lead Chip Quik removal alloy. The flux and alloy react with the existing solder to create and maintain a molten state. Once this state is achieved, a user can remove the SMT device using precision tweezers or a vacuum pen, which are provided in the kit along with cleaning wipes, liquid flux remover, and swabs to assist users in cleaning the printed-circuit board.

Base price: $150 for a kit with sufficient materials to remove 12 to 15 SMDs. *Emulation Technology, www.1800adapter.com.*

Semiconductor device analyzer

The B1500A Windows-based self-contained, expandable parametric-characterization analyzer for semiconductors integrates capacitance versus voltage (CV) and current versus voltage (IV) measurements into a single instrument. Able to handle 65-nm lithographies and beyond, the modular instrument has a 10-slot configuration that supports high-resolution, medium-power, and high-power measurement units.

The instrument supports Agilent's new EasyExpert software, which provides a top-down approach to device characterization. EasyExpert software provides a library of device tests from which the user selects based on the measurement required. After the user makes a few selections, such as identifying the technology by classification and selecting the appropriate device type, the software selects the appropriate settings, makes the measurements, analyzes the data, and displays it graphically.



A 4.2-A ground unit is included with each B1500A mainframe. A multi-frequency capacitance measurement unit is also available, as is an atto-sense and switch unit (ASU), which provides measurement resolutions of 100 aA and 500 nV.

Base price: $45,000. Available: August 2005. *Agilent Technologies, www.agilent.com.*

Arbitrary waveform generators

Tabor Electronics has introduced two Wonderwave arbitrary waveform generators that create waveforms for simulating systems such as brakes and motor drives. The single-channel WW1281 produces waveforms at sample rates up to 1.2 Gsamples/s with 12-bit resolution. As a function generator, it creates sine waves and square waves at frequencies up to 400 MHz. It also can store waveforms up to 8 Msamples long (16 Msamples optional).

> > > > > > >

The dual-channel WW5062 creates waveforms at 50 Msamples/s/channel. It generates sine and square waves at frequencies up to 25 MHz with 14-bit resolution. Waveform memory is 512 ksamples with 1 Msample optional.

Both models come with ArbConnection 4.0 software, which lets you generate and edit waveforms on your PC. You can draw waveforms or create them using an equation editor and download them to either instrument through the Ethernet, USB, or IEEE 488 port.

Base prices: WW1281—$17,000; WW5062—$2,150. *Tabor Electronics,* www.taborelec.com.

Surface-mount test sockets

Dimensions Consulting has announced a new surface-mount BGA test socket for use with high-speed Serdes applications operating beyond 10 Gbps. In addition, the company announced a test socket for CSP and QFN devices. The socket for use with high-speed Serdes applications is based on a Pogo design with dual independent plungers to optimize force and deflection. In 1-mm pitch applications, each pin exhibits a rise time of less than 40 ps and an insertion loss of 2 dB at 40 GHz with an inductance of 0.6 nH.

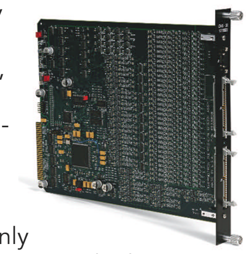
The pins employ a radius interface to printed-circuit boards to extend board life; a self-cleaning DUT plunger minimizes solder contamination. A version is also available for lead-free packages.

The new surface-mount test socket for CSP and QFN devices can be used for frequencies beyond 30 GHz. Available in pitches from 0.4 mm to 0.65 mm, it uses injection-molded lids and frames that are configurable per package; 3-mm Pogo-pin-style contacts connect a board and a DUT.

Base price: $550 per socket plus $6 per pin. *Dimensions Consulting,* www.dci-us.com.

Continuity monitoring system

Typically used with accelerated stress testing equipment, the Continuity Monitoring System (CMS) detects solder and connection faults due to cracks, degradation, misalignment, and oxidation. The CMS simultaneously monitors for discontinuities, while measuring and recording resistance for thousands of channels in parallel. Not only does the CMS accurately detect discontinuity events of intermittent solder joint and connection failures as short as 100 ns, but it also measures and logs resistance for trend analysis and validation of hard failures. Each CMS module has 32 channels, and each chassis accommodates up to 11 modules, or 352



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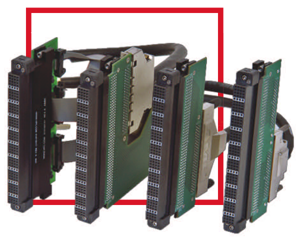

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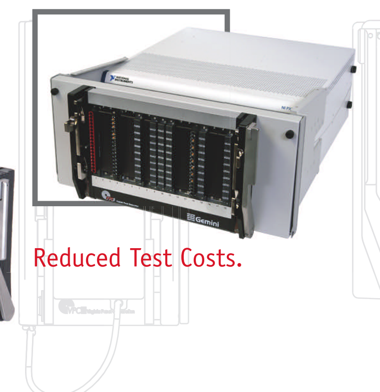

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channels. Multiple chassis can be rack-mounted for applications requiring higher channel counts. *Thermotron, www.thermotron.com/pts.*

PXI flexible-resolution digitizer

You can combine the NI PXI-5922 digitizer with LabView 7.1 to create any of a variety of instruments, such as an AC voltmeter, audio analyzer, frequency counter, spectrum analyzer, or I/Q modulation analyzer. The digitizer employs National Instrument's FlexII ADC, which samples anywhere from 15 Msamples/s at a resolution of 16 bits to 500 ksamples/s at a resolution of 24 bits. With its large dynamic range and low noise, the module can directly digitize low-level signals without the need for external signal conditioning, which in turn improves measurement accuracy and reliability. *National Instruments, www.ni.com.*

Field simulation tester

Offered with a variety of connector interfaces and fiber types, the Fiber Lab 3200 exactly simulates field applications in the development lab, manufacturing test area, central office, head end, hub site, or even at a trade show. This fiber management package houses individual spools of fiber that provide 1, 2, 4, or 8 dB of real fiber attenuation (or 1 to 25 km) in each of four individual attenuation areas. Each spool has both ends terminated on the front panel with SC/APC connectors or other connector options of your choice. The Fiber Lab 3200 eliminates fiber crimping and breakage and is suitable for the bench or for 19-in. rack-mounting. *M2 Optics, www.m2optics.com.*

(continued)

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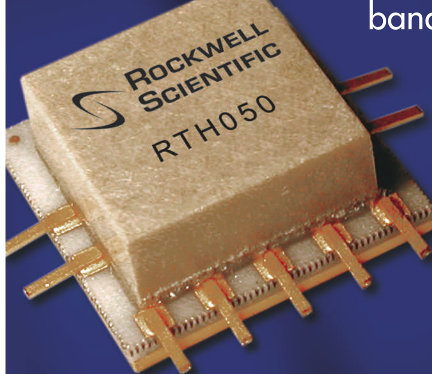

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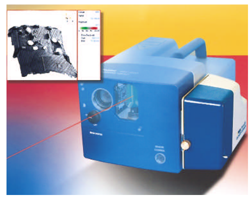
RSC1134

IP video test suite

Teamed with the HST-3000 handheld service tester, this IP video test suite provides set-top box emulation, including signaling for both broadcast video (IGMP) and Video-on-Demand (VoD) using RTSP; offers detailed analysis of the video transport stream, including PID discovery, packet loss, and jitter; and enables PCR jitter analysis. Test access includes both an Ethernet interface and an ADSL interface. The ADSL2+ option for the HST-3000 provides ATU-R emulation supporting ADSL1, ADSL2, and ADSL2+ in one module. *Acterna*, www.acterna.com.

Geometry scan unit

Used with the PSV-400 series of scanning vibrometers, the Geometry Scan Unit (GSU) combines a laser range finder with scan mirrors that position the vibrometer measurement beam to determine the 3-D geometry of test objects. After defining the measurement grid, but prior to measuring the test object's operational deflection shape, the GSU samples the grid and constructs a geometry file for the object. Within minutes, the 3-D geometry model of the structure can be plotted to a monitor giving a static baseline for observing the dynamic vibration of the object. *Polytec*, www.polytec.com.



Reverse debugging tool

To speed software development and improve software quality, Simics Hindsight allows reverse execution and debugging of arbitrary virtual systems on your desktop machine. With Simics Hindsight, you can step back just before the error and then run forward again to reproduce the

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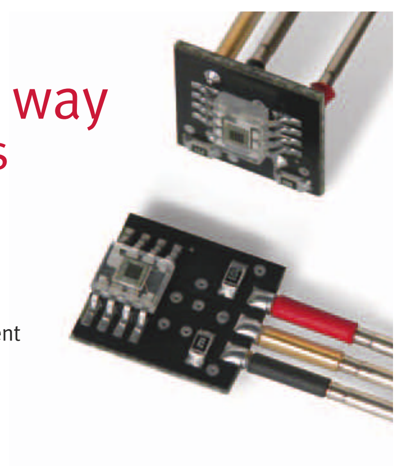

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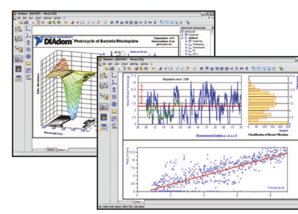

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error and look more closely at what occurs in detail without having to re-launch the program. Hindsight can even unboot an operating system, running the code backward until it reaches the initial hardware launch instruction after a hardware reset. Simics Hindsight is part of the Simics full-system simulation platform. *Virtutech, www.virtutech.com.*

Power dividers

Two-, three-, and four-way power dividers in the Dx-64FN series operate from 800 MHz to 2500 MHz, covering the cellular, PCS, and UMTS bands in a single unit. The Wilkinson style power dividers are intended for low-power applications where output isolation is preferable over lowest possible loss. The wide frequency range of the dividers allows them to be used with multiband antennas and leaky cable systems. *Microlab/FXR, www.microlab.fxr.com.*

Water baths

PolyScience stationary and shaking water baths are equipped with microprocessor-based PID controllers to maintain bath temperatures from ambient +5°C to +100°C with

±0.1°C accuracy and ±0.2°C uniformity. Models are available with single-chamber reservoirs in capacities of 2, 5, 10, 20, or 28 liters. The water baths provide a digital temperature readout, one-touch set-point recall, and three user-defined temperature preset buttons. *PolyScience, www.polyscience.com.*

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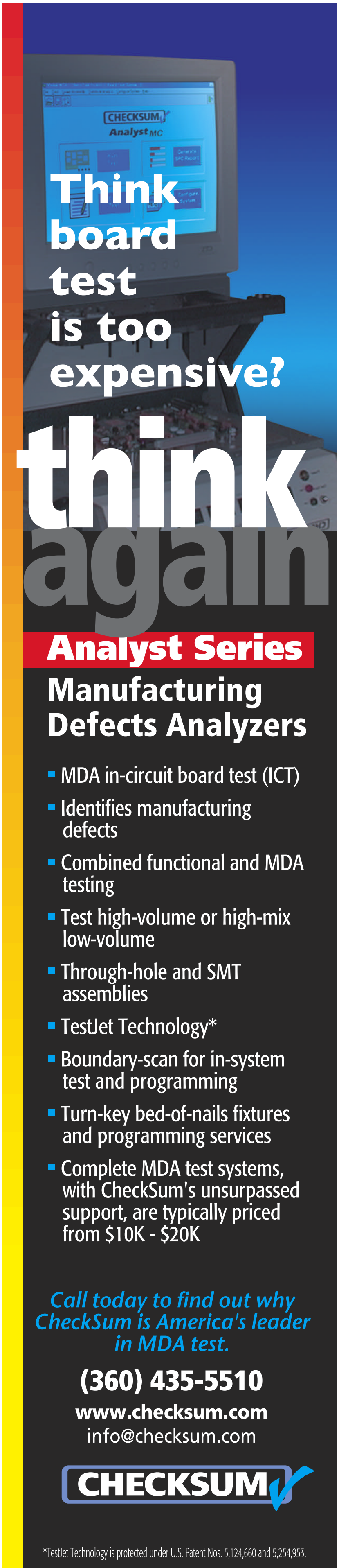

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- Internal or external trigger
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- PW_{IN} = PW_{OUT} mode
- Average and peak power overload protection

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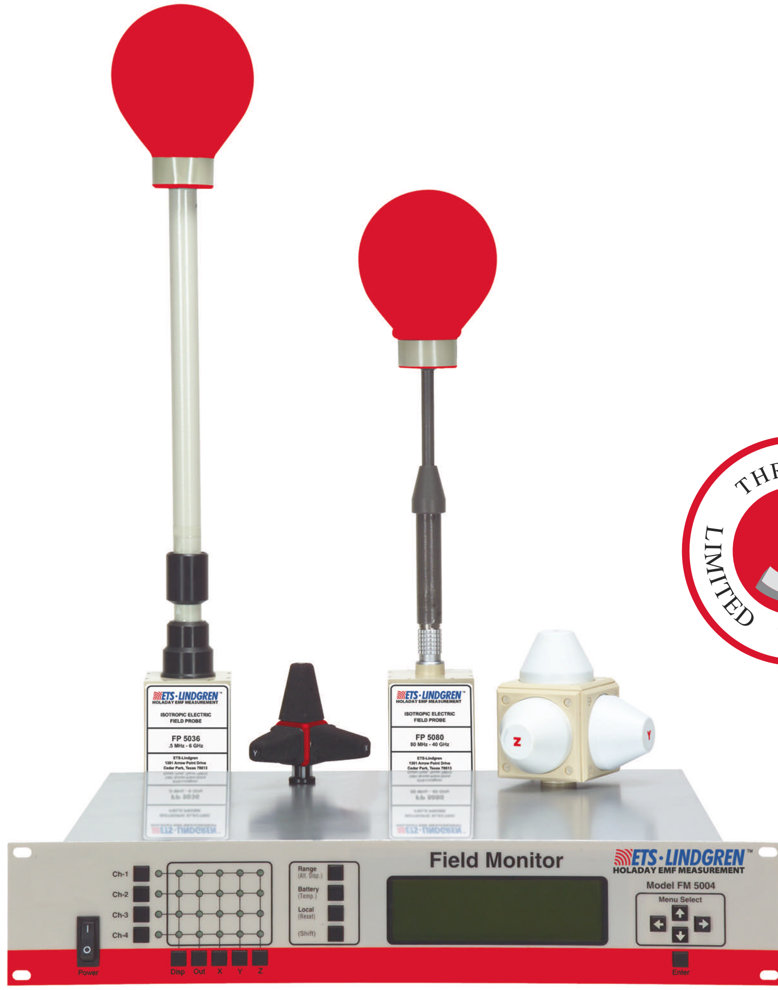

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Housed in a 1U 19-in. rack-mount chassis, the VSP12010 high-power, low-noise switching DC power supply generates up to 1.2 kW of power at an output voltage of 120 V. Precise output voltage control is achieved through manual tuning using front-panel 10-turn potentiometers and three-digit meters or remotely via an RS-232 serial port. Up to nine units can be cascaded to produce more than 10 kW of DC power. Price: $1725. *B&K Precision,* www.bkprecision.com.

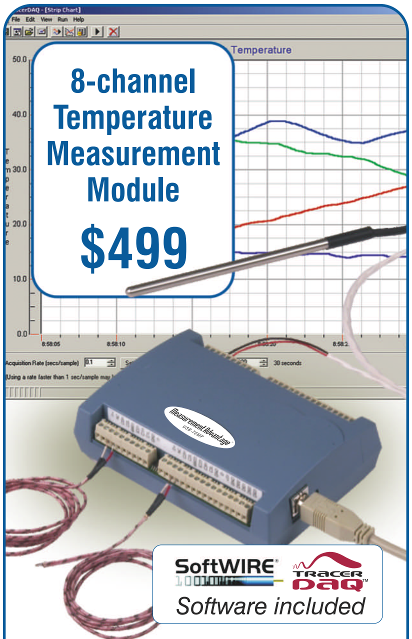
X-ray software

The quality|assurance 2005 software package is a full inspection environment that reduces the time it takes to program an automated x-ray inspection test, while improving the automated testing of area-array packages as well as QFP, MLF, and PTH packages. The software, which works with phoenix|x-ray's family of 2-D x-ray equipment, lets you import any CAD file to enable the x-ray machine to align and self-identify all package types. Program setup is fast since part types are saved to a common library and optimized inspection routines are aligned with the part geometry. *Phoenix|x-ray,* www.phoenix-xray.com.

3-GHz bypass switch

Targeting the wireless market, this 3-GHz bypass switch operates from 24 VDC to 32 VDC (28 VDC nominal at 300 mA typical at 20°C). The panel-mount switch, designated P/N 411FL-2308-2, employs a failsafe actuator and switches in 15 ms maximum. The panel side of the switch is equipped with N-type connectors, while internal system connections are through SMA connectors. VSWR is 1.10:1 from DC to 1 GHz, 1.15:1 from 1 GHz to 2 GHz, and 1.2:1 from 2 GHz to 3 GHz. *Dow-Key Microwave,* www.dowkey.com.

(continued)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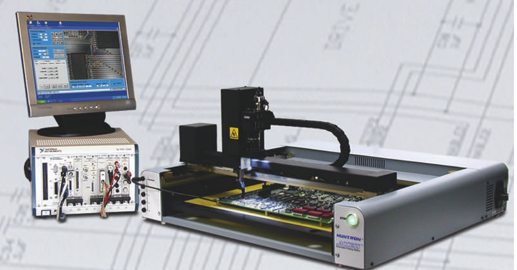

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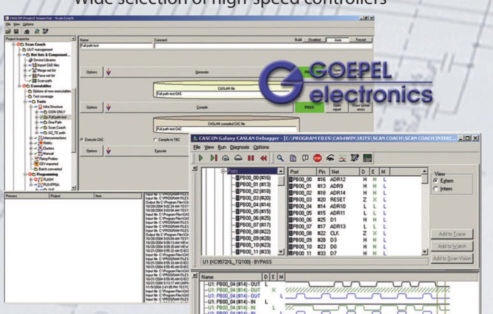

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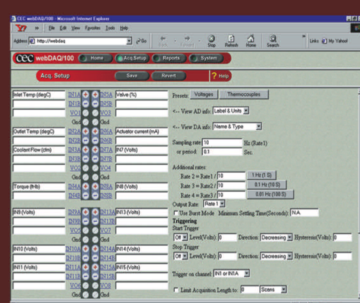

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Vision sensor

Highly detailed automated inspections are now possible at almost half the cost of comparable vision sensors with the PresencePLUS P4 GEO 1.3 vision sensor, according to the manufacturer. The sensor performs fixture-free inspections with 360°C rotation and 1.3-Mpixel resolution to capture minute details of multiple features at ranges from a few inches to several feet. *Banner Engineering,* www.bannerengineering.com.

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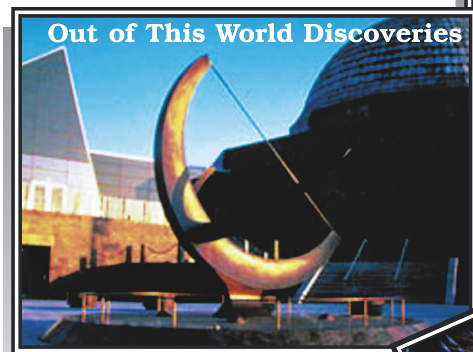

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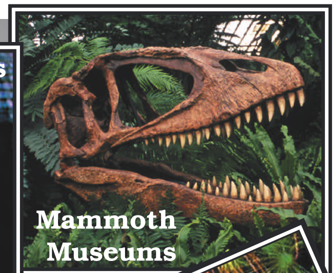

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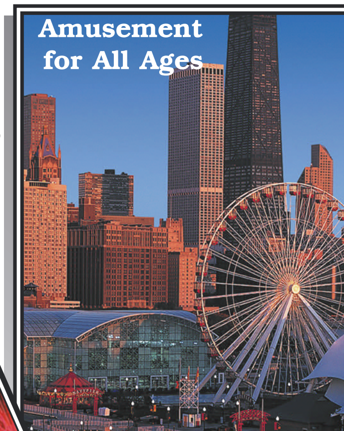

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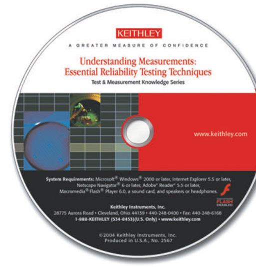

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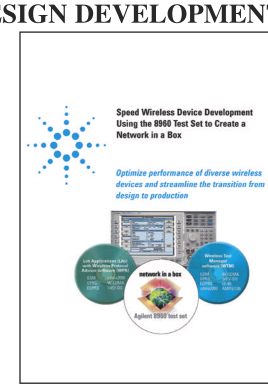

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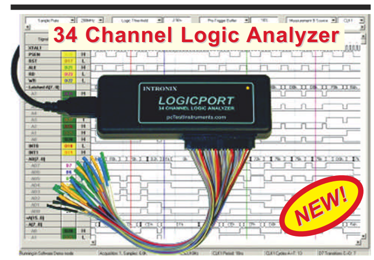

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BEN BAILEY
CEO
Measurement Computing Corp. (MCC)
Middleboro, MA

Ben Bailey has been involved in the test and measurement industry for more than 20 years. He graduated from Babson College, where he focused on quantitative methods and operations research, and went on to serve as the VP of sales at MetraByte. In 1989, he co-founded ComputerBoards (the company changed its name to Measurement Computing Corp. in 2000), and he eventually led the MCC team that developed the patented SoftWIRE graphical programming interface and served as founder and CEO of the company's SoftWIRE Technology subsidiary.

▸ *The online version of this article includes more Q&A with Ben Bailey on such topics as engineering challenges, Web issues, and product standards.*

www.tmworld.com/archives

Keeping costs in check always matters

Helping engineers obtain the measurements they need—at an affordable price—drives the strategy of Measurement Computing Corp. (MCC). Co-founder Ben Bailey described some of his firm's latest cost-saving moves in a recent interview with *Test & Measurement World*.

T&MW: How big a factor is cost control to engineers involved in test and measurement?

Bailey: We get our feedback from the marketplace. Whenever MCC makes a breakthrough in reducing the cost of a measurement, we increase our sales volume significantly. Our company is organized operationally—not technically—around cost control. The cost of a DAQ board is small compared to the costs of operating a company, marketing products, and paying engineers' salaries. So, we are always pushing the envelope to control those operational costs.

We also keep close watch on new ideas from manufacturers of analog-to-digital converters and other basic components. Controlling costs always matters, which is how we got to be number two in PC measurement, following National Instruments.

T&MW: Can you cite some MCC products that reflect this cost-control strategy?

Bailey: An important example is the 6000 series DAQ and PCI boards, which we positioned as functionally equivalent to NI products but costing 30% less. These included analog-to-digital boards, digital-to-analog boards, counter/timers, and digital I/O. The reception in the marketplace was astounding, which is proof that customers are greatly concerned about costs.

The exciting news this year has been our new Personal Measurement Devices. An alternative to PCI boards, these DAQ modules easily connect to the USB port of a desktop or laptop computer. About the size of a pack of cigarettes, the devices cut down on installation time and reduce costs, since they can be easily moved and shared within the engineering team. In short, here's a product selling for as little as $100 with all the capability of a $500 board that had to be installed in your PC. And they really lend themselves to field test and other portable applications.

T&MW: How about software innovations?

Bailey: Releasing our SoftWIRE graphical interface for Microsoft's Visual Studio.NET was very significant. There's a lot of interest among engineers in graphical programming, and SoftWIRE allows both nonprogrammers and occupational programmers to create powerful software applications without having to write any code.

SoftWIRE operates within Visual Studio and allows you to freely integrate C code, Basic code, and graphical programming diagrams. We also offer this software package at no charge, so its adoption has jumped dramatically.

T&MW: Looking ahead, what new directions do you see for PC-based test?

Bailey: The big advances are likely to be in software developments that make it less complex to connect sensors, acquire and use data, and give your data more context. For example, I may have the data I've gathered from my dynamometer, but what does this information mean in terms of the overall application?

I also think that test engineers will be gaining access to more and more specialized services through the Internet, such as information or software from engineers skilled in niche areas of measurement science. Engineers once employed by big companies are breaking away and selling such services to everyone via the Web. As a company, we will be looking for ways to help our customers tap into such services. T&MW

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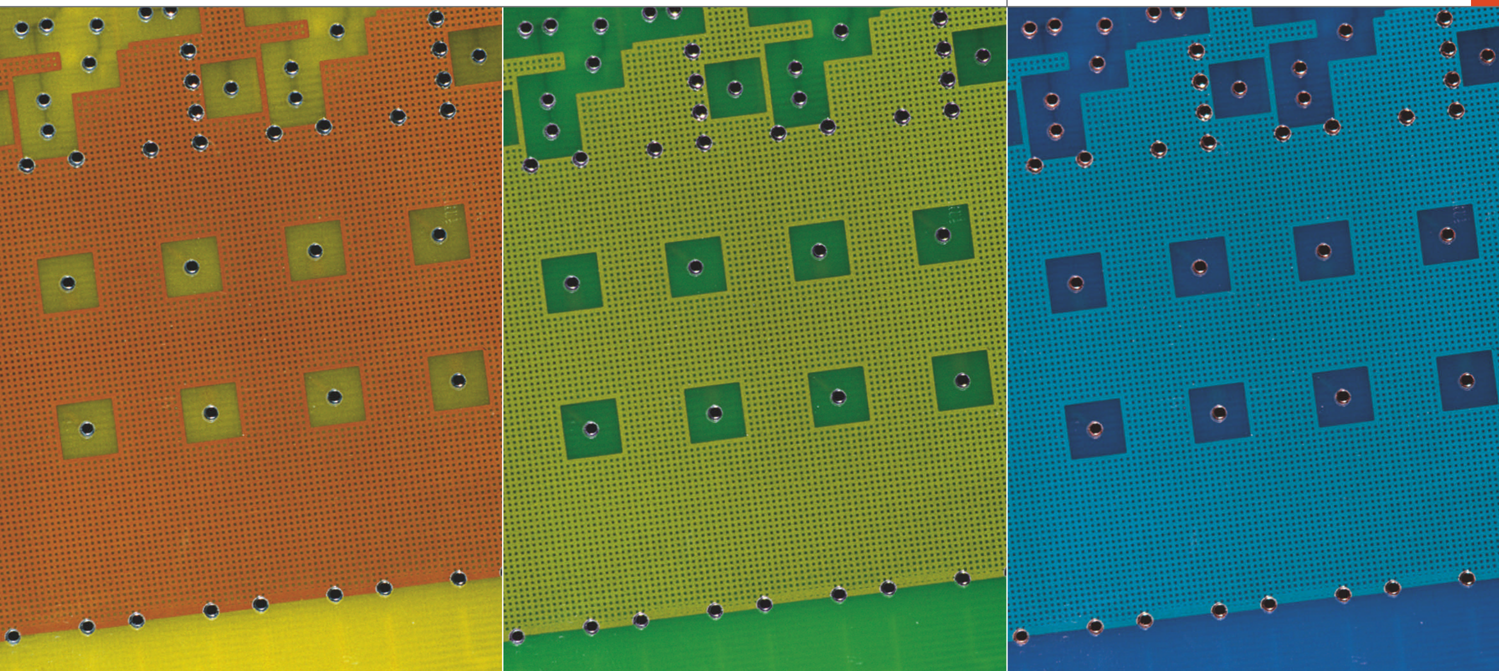

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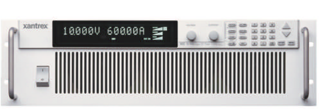

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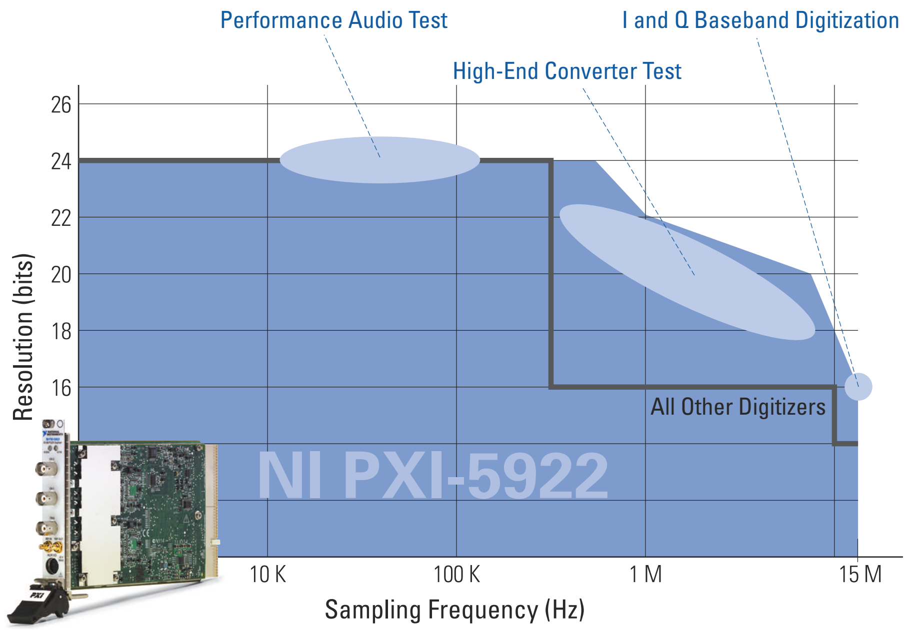

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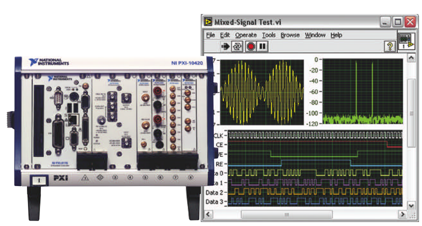

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