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April 2007
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Test & Measurement World

THE MAGAZINE FOR QUALITY IN ELECTRONICS

Chandra Shekhar Pandey, consulting engineer at Juniper Networks.

"TRIPLE PLAY" IS SO YESTERDAY

Engineers at Juniper Networks use their heavily equipped test lab to simulate a multiplay network, where video is the driving force.

Page 26

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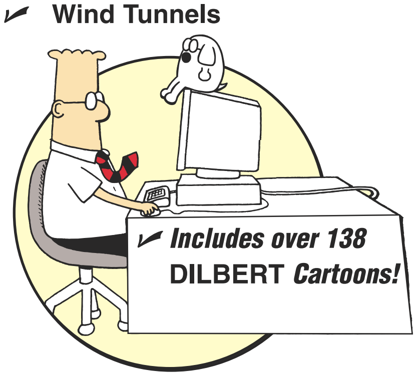

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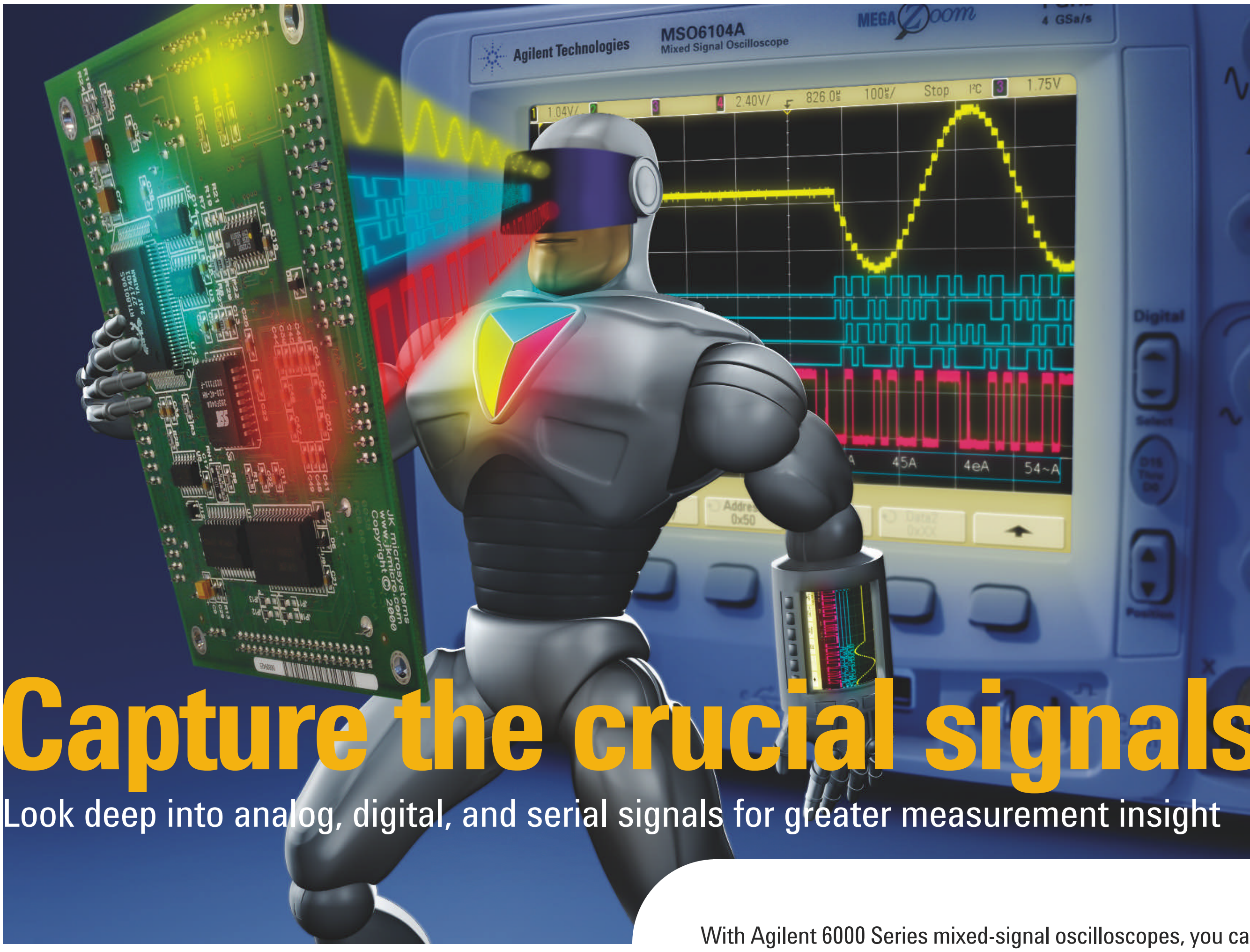

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Test & MEASUREMENT WORLD®

CONTENTS

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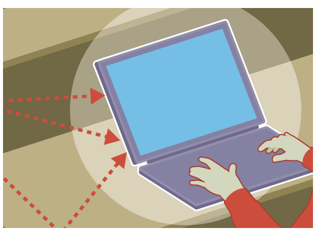

Wireless test / Page 35

FEATURES

DEPARTMENTS

TECH TRENDS

MARKET TRENDS

TEST DIGEST

TEST REPORT SUPPLEMENT

ONLINE

www.tmworld.com

Check out these exclusive features on the *Test & Measurement World* Web site:

Accreditation brings unforeseen benefits

Audio Precision recently received ISO/IEC 17025:2005 accreditation from the American Association of Laboratory Accreditation (A2LA). Attaining accreditation took several years and thousands of work hours, but now the company can prove measurement traceability to national standards. Although the process was tedious, it led to engineering changes that improved the company's products. In this exclusive interview, company chairman Bruce Hofer described the changes his company implemented and discussed how he persuaded the management team of the importance of accreditation.

www.tmworld.com/accreditation_ap

Music man strikes again

Senior technical editor Martin Rowe has now written and recorded his third song in praise of engineers. He got the inspiration for his latest ode while walking the floors of the 2006 EMC Symposium. When someone said, "We check designs early for EMI," Martin knew he had found his lyrics. Listen to "Check Designs for EMI Early" on the *T&MW* Web site. And while you're there, listen to "The Measurement Blues" and "The Lab in the Corner," too.

www.tmworld.com/emi_song

Blog commentaries and links

Taking the measure

Rick Nelson, Chief Editor

- JTAG port delivers thermal information
- Crime and technology
- ASICs: rumor of death exaggerated

www.tmworld.com/blogs

From the archives

- **High Speeds and Fine Precision Knock PCB Traces off Pedestal**

The ideal conductor is history. If you don't believe it, your designs could be toast. From DC to the gigahertz frequency ranges, PCB trace resistance and reactance can degrade product performance. Taking care to measure trace impedances accurately can help you determine why a circuit fails to perform optimally. For more, read this article from our January 2000 issue.

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Reed Electronics Group

Instrumentation 2.0's "data bus"

In your automated instrument system, do you want a "data bus" or a "results bus"? My initial thought was, take the "results bus." But a "results bus" locks you into the answer your test-equipment vendor thinks you want; the "data bus" lets you derive the answer best suited to your application.

The "data bus" is a component of what Eric Starkloff, National Instruments' director of product marketing, describes as Instrumentation 2.0, which is tailored to the test of such products as the Apple iPhone. In a discussion with editors at *Test & Measurement World*'s offices, Starkloff described why such products need a new approach. He quoted *Time* magazine's iPhone description: "Suddenly, the interface isn't fixed and rigid, it's fluid and molten. Software replaces hardware."

RICK NELSON, CHIEF EDITOR

To test such products, a software-centric Instrumentation 2.0 system supports user-defined measurements, custom user interfaces, modular hardware, PC connectivity, and real-time data transfer (over a "data bus"), said Starkloff. In contrast, Instrumentation 1.0 employs fixed hardware, a fixed user interface, and connectivity to a "results bus" that carries vendor-defined measurement information.

Instrumentation 2.0 benefits from high-bandwidth buses like PXI Express.

The development of Instrumentation 2.0 paces the emergence of the Department of Defense's synthetic-instrumentation architecture, which the market-research firm Frost & Sullivan defines as a subset of the virtual-instrumentation approach that National Instruments has long championed. Instrumentation 2.0 relies upon technologies such as high-performance data converters and high-bandwidth buses like PXI Express.

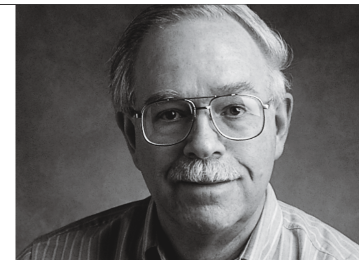
In a spirited discussion with Starkloff, editors questioned whether even PXI Express is fast enough to enable Instrumentation 2.0's "data bus." Starkloff said that Instrumentation 2.0's processing power could be distributed; the key is that it be software-based and user-accessible.

We will never achieve the infinite speed and resolution data converters and infinite-bandwidth buses that an ideal virtual instrument demands, but it's clear that today's technology is sufficient for practical Instrumentation 2.0 implementations. T&MW

In a related matter, *Test & Measurement World* is pleased to introduce a bimonthly Market Trends column. In the first installment (p. 20), Mark Holler, a research analyst with the Frost & Sullivan North American Industrial Automation & Electronics Practice, comments on synthetic instrumentation's prospects in nonmilitary applications. Since joining Frost & Sullivan in July 2006, Holler has completed research on synthetic instrumentation and wireless-network test equipment. He has a degree in economics and finance from the University of Texas at Dallas.

Post your comments at www.tmworld.com/blog.

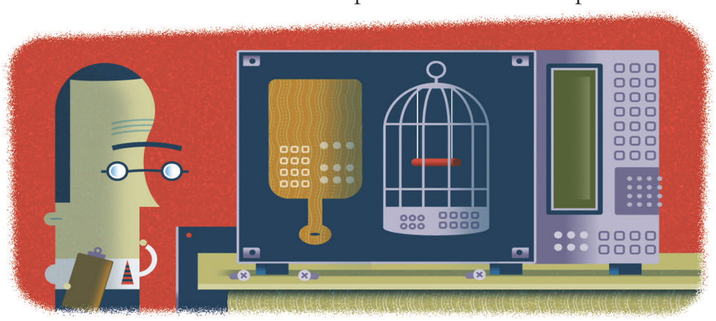
BRAD THOMPSON
CONTRIBUTING TECHNICAL EDITOR
brad@tmworld.com



Bird cage + paddle board = kludge

While troubleshooting a piece of equipment, I encountered a bird cage and a paddle board. The "bird cage" consisted of a 24-pin DIP wire-wrap socket, most of whose pins plugged into an IC socket, which in turn plugged into a socket on a circuit board. A few of the pins on the wire-wrap socket had been trimmed short and replaced with resistors soldered in series with the contacts of the lower socket. Leads from a couple of capacitors stretched from pin to pin.

A few lengths of wires snaked down the side of the bird cage to join a matchbook-sized paddle board that sported a pair of ICs and a few passive components. A blob of hot-melt glue secured the paddle board to the main board. Time and financial pressures no doubt inspired the add-



DANIEL GUIDERA

on circuits, which the designer presumably fixed on the board's next spin cycle. Fortunately, the equipment failure didn't involve this kludge.

The "kludge" enjoys a long and somewhat checkered history as a fix for a design flaw, or as a rapid implementation of a customer-requested feature. During World War II, the vacuum-tube industry diverted most of its production capacity to the war effort, forcing domestic radio repair techs to scramble for replacement tubes. Replacing and rewiring a tube socket to accommodate an available tube posed problems, and JFD Manufacturing devised the Sockette to adapt an available tube to fit a hard-to-find tube's socket.

Nowadays, IC manufacturers render older or slow-selling DIP ICs obsolete by cranking out new products at a dismaying rate. If you're faced with replacing an obsolete IC, use any Web browser to search for the part number. Be aware that counterfeit and rebranded devices exist, so choose sellers with care. You can also use modern versions of the Sockette. For example, e-PBoard Design, Interconnect Systems, and Aries Electronics offer custom and off-the-shelf products that convert almost any component's footprint to another.

Whether you test other peoples' equipment or build your own test fixtures and accessories, sooner or later you'll get a chance to practice—and appreciate—the fine art of kludgery. While necessity may give birth to the occasional invention, more often it delivers kludges. T&MW

FOR MORE INFORMATION

Originally designed for short-range high-frequency communications in military aircraft, and popularly known to radio amateurs of the 1950s as "Command Sets," receivers in the SCR-274 and ARC-5 series used 12-V tubes originally designed for consumer products (e.g., the 12SK7, 12SR7, and 12SR7). For a history of the Command Sets and their test equipment, go to: www.shlrc.mq.edu.au/~robinson/museum/command.html.

On the home front, a hard-pressed radio service tech might have used a type 24A Sockette to substitute a functionally equivalent Loktal-based 14A7 for an unavailable 12SK7. To view a listing of then-available Sockettes, go to: www.surplustuff.com/chart1.gif.

In the post-World War II vacuum-tube era, the Vector Socket Turret foreshadowed today's paddle board. Manufactured by Vector Electronics & Technology (which would later manufacture Vectorbord to meet the needs of discrete semiconductor users for a prototyping medium), the turret socket allowed users to retrofit an existing socket with additional components. You can still purchase a few types from antique-electronic suppliers. Scroll down the following Web page to view examples of Vector's turret sockets: www.vacuumtubesinc.com/socketsnos.html.

To view Vector's present-day offerings of extender cards, test accessories, and other products, go to: www.vectorelect.com.

Interconnect Systems (www.isipkg.com/adapters.htm) offers custom adapters for obsolescent devices, while e-PBoard Design (www.epboard.com) features a broad range of DIP-to-SOIC and other economically priced device adaptors, as does Aries Electronics' Correct-A-Chip family of products (www.arieselec.com).

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50 Ohm Dbl Shield Coax RG223/U				
1 Ft. to 10 Ft.	P01D23S02S18	$24	$23	$21
SMA Right Angle to SMA Right Angle				
50 Ohm Coax RG58C/U				
1 Ft. to 10 Ft.	P01D58S17S17	$27	$25	$23
50 Ohm Dbl Shield Coax RG142B/U				
1 Ft. to 10 Ft.	P01D42S18S18	$29	$27	$25
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50 Ohm Dbl Shield Coax RG223/U				
1 Ft. to 10 Ft.	P01D23N03N03	$20	$19	$18
50 Ohm Dbl Shielded Coax RG214/U				
1 Ft. to 10 Ft.	P01D14N04N04	$23	$22	$21
50 Ohm Dbl Shield Coax RG142B/U				
1 Ft. to 10 Ft.	P01D42N03N03	$22	$20	$19
50 Ohm Coax RG213/U				
1 Ft. to 10 Ft.	P01D13N01N01	$21	$20	$19
50 Ohm Dbl Shielded Coax RG400/U				
1 Ft. to 10 Ft.	P01D40N03N03	$22	$21	$20

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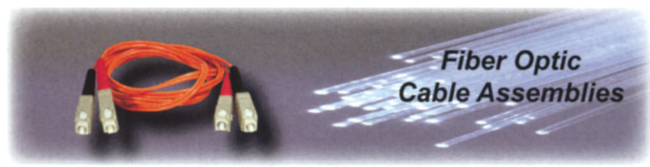
50 Ohm Dbl Shield Coax RG142B/U				
1 Ft. to 10 Ft.	P01D42T05T05	$17	$16	$15
50 Ohm Dbl Shield Coax RG223/U				
1 Ft. to 10 Ft.	P01D23T05T05	$16	$15	$14



Length	Model	1-9
Type: ST - ST Duplex		**Multi-Mode**
1 Meter	X031	$11.49
2 Meter	X032	$15.49
3 Meter	X033	$16.49
4 Meter	X034	$17.99
5 Meter	X035	$18.99
Type: SC - SC Duplex		**Multi-Mode**
1 Meter	X071	$16.49
2 Meter	X072	$20.49
3 Meter	X073	$21.99
4 Meter	X074	$22.49
5 Meter	X075	$24.49
Type: FC - FC Duplex		**Multi-Mode**
1 Meter	X151	$35.99
2 Meter	X152	$37.99
3 Meter	X153	$39.90
5 Meter	X155	$40.99
Type: LC - LC Duplex		**Multi-Mode**
1 Meter	X191	$37.49
2 Meter	X192	$39.99
3 Meter	X193	$40.99
4 Meter	X194	$41.49
5 Meter	X195	$41.99
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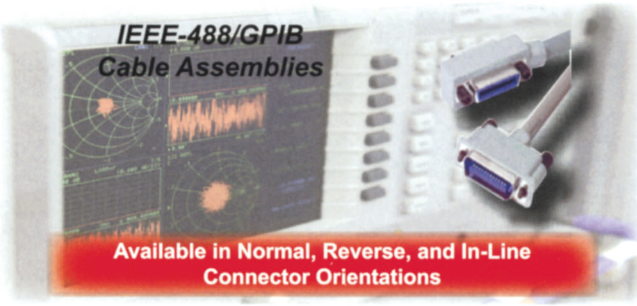

Model #	Length	1-9
Connector Orientation: Normal / Normal		
IENN-0	0.5 Meter	**$53**
IENN-1	1 Meter	**$56**
IENN-2	2 Meter	**$62**
IENN-3	3 Meter	**$67**
IENN-4	4 Meter	**$73**
IENN-5	5 Meter	**$78**
IENN-6	6 Meter	**$84**
IENN-8	8 Meter	**$95**
Connector Orientation: Reverse / Reverse		
IERR-0	0.5 Meter	**$52**
IERR-1	1 Meter	**$55**
IERR-2	2 Meter	**$60**
IERR-3	3 Meter	**$65**
IERR-4	4 Meter	**$70**
IERR-5	5 Meter	**$75**
IERR-6	6 Meter	**$80**
IERR-8	8 Meter	**$91**
Connector Orientation: Inline / Inline		
IEII-0	0.5 Meter	**$38**
IEII-1	1 Meter	**$40**
IEII-2	2 Meter	**$45**
IEII-3	3 Meter	**$50**
IEII-4	4 Meter	**$56**
IEII-5	5 Meter	**$61**
IEII-10	10 Meter	**$86**
Connector Orientation: Normal / Inline		
IENI-0	0.5 Meter	**$47**
IENI-1	1 Meter	**$50**
IENI-2	2 Meter	**$55**
IENI-3	3 Meter	**$61**
IENI-4	4 Meter	**$67**
IENI-5	5 Meter	**$72**
IENI-10	10 Meter	**$99**
Connector Orientation: Reverse / Inline		
IERI-02	0.2 Meter	**$49**
IERI-05	0.5 Meter	**$50**
IERI-1	1 Meter	**$53**
Connector Orientation: Normal / Reverse		
IENR-03	0.3 Meter	**$52**
IENR-05	0.5 Meter	**$53**
IENR-1	1 Meter	**$56**

Model #	Length	1-9
Type-A Male to Type-A Male		
UBN-3003	3 Ft	**$8**
UBN-3006	6 Ft	**$9**
UBN-3010	10 Ft	**$10**
UBN-3015	15 Ft	**$12**
Type-A Male to Type-B Male		
UBN-3103	3 Ft	**$7**
UBN-3106	6 Ft	**$8**
UBN-3110	10 Ft	**$9**
UBN-3115	15 Ft	**$11**
Type-A Male to Type-A Female		
UBN-3203	3 Ft	**$8**
UBN-3206	6 Ft	**$9**
UBN-3210	10 Ft	**$10**
UBN-3215	15 Ft	**$11**

CAT 5E and CAT 6 Patch Cables

Model #	Length	1-9
Category 5e Type		
C5S-0101	1 Ft	**$1.59**
C5S-0103	3 Ft	**$1.99**
C5S-0105	5 Ft	**$2.39**
C5S-0107	7 Ft	**$2.79**
C5S-0110	10 Ft	**$3.39**
C5S-0115	15 Ft	**$4.29**
C5S-0125	25 Ft	**$6.59**
C5S-0150	50 Ft	**$11.79**
Category 6 Type		
C6S-0101	1 Ft	**$5.99**
C6S-0103	3 Ft	**$6.99**
C6S-0105	5 Ft	**$7.99**
C6S-0107	7 Ft	**$8.99**
C6S-0110	10 Ft	**$10.99**
C6S-0115	15 Ft	**$12.99**
C6S-0125	25 Ft	**$17.99**
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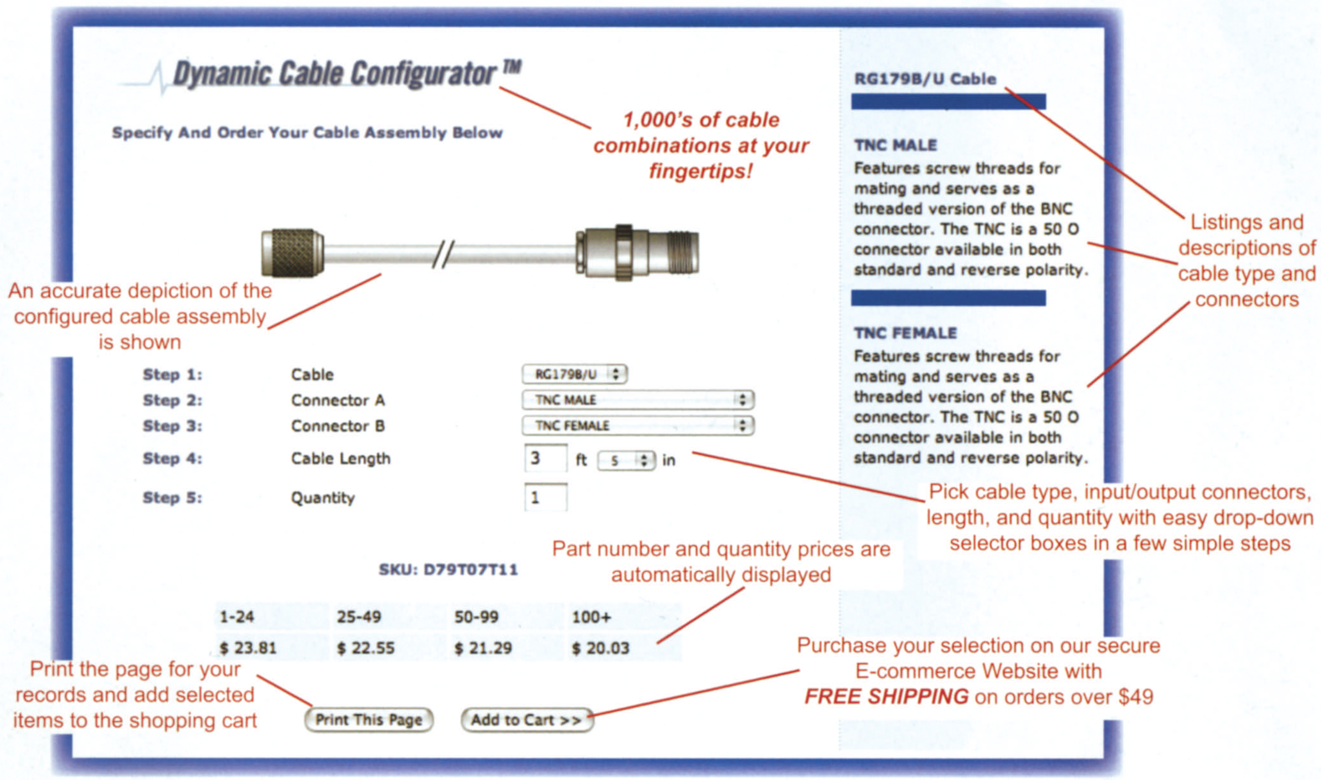

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10+ $6.99

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10+ $17.49

BNC/M to RCA/F
AB26

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10+ $5.99

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Network analyzers test in differential mode up to 40 GHz

Rohde & Schwarz has introduced an option that adds a true differential measurement mode to the R&S ZVA and R&S ZVT network analyzers. The new option is aimed at precisely characterizing the nonlinear, balanced RF components that developers increasingly are designing into wireless communications equipment. The option supports fully corrected measurements using true differential signals up to 40 GHz.

In the new true differential measurement approach, two network-analyzer internal generators generate signals of identical amplitude having 0° and 180° phase offset (with phase deviation less than 1°). The network analyzer resets the amplitude and phase relation at each test point to take into account fluctuations caused by DUT input reflections. An instrument equipped with the option delivers measured differential wave quantities and mixed-mode S-parameters fully corrected of system errors.

The new option can be integrated into the instruments by means of a software update and requires no additional hardware for calibration or measurement. Users can switch quickly between the virtual differential approach traditionally used and the new true differential mode. For direct comparison of measurement results, the two methods can be applied simultaneously. www.rohde-schwarz.com.

Mosaid to sell memory test assets to Teradyne

Mosaid Technologies has agreed to sell certain assets of its System Division's automatic test equipment (ATE) business to Teradyne for $20 million. The sale was anticipated to close April 30.

The Systems Division develops memory ATE for semiconductors. Teradyne is purchasing the assets and intellectual property (IP) associated with a Mosaid tester platform and will also receive a license to certain IP associated with current ATE product lines.

"For years, we have set the standard for excellence in engineering memory test equipment, with the Mosaid name being synonymous with high-quality memory test systems," said George Cwynar, president and CEO of Mosaid. "However, challenging business conditions within this market—coupled with our strategic emphasis on intellectual property—led to this divestiture, which marks the end of an era for Mosaid." www.mosaid.com.

Ceremony pays tribute to award winners

During a ceremony held February 21 in Los Angeles, CA, *Test & Measurement World* announced the recipients of our annual industry awards. The winners were also profiled in our March issue (www.tmworld.com/2007_03).

Publisher Russ Pratt began the proceedings by announcing that John Gmitter, lead test engineer at Harris RF Communications, had been selected the 2007 Test Engineer of the Year by a vote of *T&MW*'s readers. Gmitter manages a team charged with developing test stations that support his company's high-volume manufacturing of tactical communications equipment; as part of his award, he designated Monroe Community College to

Viscom debuts AOI/AXI system

Editors' CHOICE

The X7056 parallel optical and x-ray inspection system combines 3-D automatic x-ray inspection (AXI) with parallel top and bottom automatic optical inspection (AOI). The optical inspection rate is 4 in.^{2}/s; the AXI rate is 1 in.^{2}/s.

The heart of the X7056's x-ray technology is a high-performance microfocus x-ray tube, developed and produced by Viscom, that ensures a resolution of 15 µm per pixel. The company's iterative Easy3D software helps to resolve and analyze features despite complicated overlaps on printed-circuit boards (PCBs) populated on both sides.

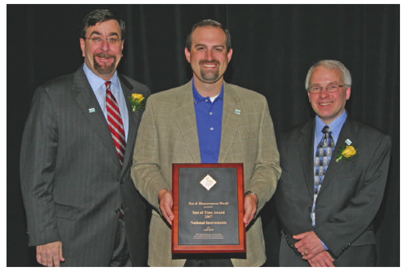
The X7056 employs 6-Mpixel sensor technology and can be equipped with AOI cameras for simultaneous inspection of the top and bottom of a PCB. Simultaneous inspection and double-track loading result in rapid inspection and minimal handling times, according to Viscom.

The modular X7056 can be used as a combination AOI/AXI or pure AXI system. Additional features include rapid program generation with Viscom EasyPro software and the full scope of Viscom inspection algorithms. The X7056 is hardware- and software-compatible with all Viscom AOI systems. An optional Viscom Process Control (VPC) software module controls process monitoring and optimization with various filter functions.

Base price: $350,000. *Viscom, www.viscom.com.*

receive a $30,000 engineering grant, courtesy of award sponsors Agilent Technologies, Keithley Instruments, and National Instruments.

Chief editor Rick Nelson next honored the manufacturers of the 12 products that had won 2007 Best in Test



Richard McDonell (center) accepts the Test of Time Award from Publisher Russ Pratt (left) and Rick Nelson.

awards, and he announced that our readers had selected the Agilent Infiniium 80000B series oscilloscope as the Test Product of the Year. Nelson presented the award plaque to Jun Chie, marketing manager, and Mike Karin, R&S manager of the company's oscilloscope business unit.

CALENDAR

International Microwave Symposium, June 3–8, Honolulu, HI. Sponsored by IEEE Microwave Theory and Techniques Society (MTT-S). www.ims2007.org.

Sensors Expo, June 11–13, Rosemont, IL. Sponsored by Questex Media Group. www.sensorsexpo.com.

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

Nelson then presented the Test of Time award, which recognizes a product that continues to provide state-of-the-art performance at least five years after its introduction. For 2007, our editors chose National Instruments' LabView software. Richard McDonell, group manager, PXI and Instrument Control, accepted the award for his company. www.tmworld.com/awards.

Editors' CHOICE

AWGs go mixed signal

Engineers who must test systems that have both analog and digital signals can take advantage of the AWG5000 from Tektronix, an arbitrary waveform generator (AWG) that offers either four analog outputs or two analog outputs with an optional 28 digital outputs.

The analog outputs let you create distorted signals for testing systems under repeatable simulated real-world conditions. For example, you can generate analog outputs to test I/Q modulators in RF transmitters, such as those used in wireless LANs. You can generate the signals by capturing a signal with an oscilloscope and replaying it. You can also use PC software to develop the signals and then load them into the AWG, or else run the software inside the AWG using a mouse and keyboard. In addition, you can create signals with software such as Matlab or Excel.

Each model has two digital-marker channels for each analog output. You can use the marker channels to trigger analog-to-digital converters such as those in RF/IF transmitters or to trigger instruments such as oscilloscopes.

Four models are available: two 2-channel models and two 4-channel models, with variable sample rates up to 600 Msamples/s and 1.2 Gsamples/s. The two-channel models also have an option for 28 digital I/O channels that let you, for example, test digital-to-analog converters using a digital representation of a noisy signal.

Prices: $25,000 to $45,000. *Tektronix, www.tektronix.com.*

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Exhibitors address PCB design, test, and inspection

> > > APEX, February 20–22, Los Angeles, CA, IPC Association Connecting Electronics Industries. www.goapex.org.

Agilent Technologies debuted its Medalist i3070 in-circuit test (ICT) system, which according to the company employs advanced algorithms to increase analog test throughput by 50%, compared with legacy 3070 systems. The i3070 systems include Agilent's VTEP v2.0 vectorless test technology (see p. 68). **CheckSum** introduced its Analyst fcs ICT system, which accommodates bed-of-nails test fixtures built for Agilent 3X7X-series ICT systems. CheckSum also debuted its Analyst ems+ft system, which combines ICT and functional test, and announced an order for multiple CheckSum systems that integrate boundary-scan tools from **Corelis**.

Elektrobit exhibited a range of JOT Automation test equipment, including two mobile terminal test boxes (the J409-41 and J409-54) and a new panel-flash stand-alone fixture. The J409-41 combines RF shielding with one-hand open/close operation, quick adapter change, and minimal maintenance. The J409-54 is an RF-shielded mobile terminal test handler designed for board-level testing and mobile-terminal final test. The semi-automatic unit can interface with a vision test system and button test actuators.

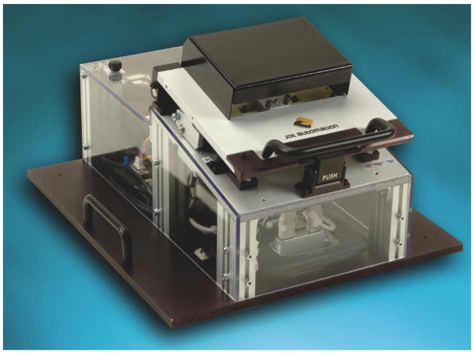
Distributor **Aegis Electronic Group** presented new **Sony** smart cameras, including the XCI-V3, which is equipped with a VGA (640x480-pixel) progressive-scan CCD, and the XCI-SX1, which incorporates an SXGA (1280x1024-pixel) progressive-scan CCD. Both cameras include an AMD Geode GX533 processor with either a built-in Linux or a Windows XPE operating system.

Viscom introduced its X7056 parallel optical and x-ray inspection system (see p. 13), which combines 3-D automatic x-ray inspection (AXI) with parallel top and bottom optical inspection. **BPM Microsystems** showcased its 4710 automated programming system, which is designed specifically for high-density devices that exhibit long programming times. The 4710 can rapidly program flash devices while offering the versatility to program microcontrollers, FPGAs, PLDs, and other device types.

Acculogic introduced an ICT system, a flying-prober enhancement, boundary-scan (JTAG), CAD-processing, and test-control software. **Digitaltest** highlighted automated in-circuit, flying-probe, and functional test systems. The company shared a booth with **The Test Connection**, which demonstrated an integrated in-circuit and functional tester that employed a PXI system.

Sunstone Circuits, a specialist in prototype and high-mix, low-volume PCB design and production, introduced what the company describes as its ECOsystem, "a strategic vision to consolidate and improve the PCB prototyping process for designers from concept-to-delivery through the integration of four discrete segments of PCB prototyping."

Texmac announced that it now offers testing and programming services based on Takaya APT Series flying-probe test systems. The services are available to users of Takaya systems and to electronics manufacturers who need fixtureless test performed on a contract basis.



The new JOT Automation panel-flash stand-alone fixture employs a simple manual open-nest configuration for board flashing that can house several nests.

Courtesy of Elektrobit.

Aegis Industrial Software, a vendor of manufacturing information-management systems, showcased the Version 7 evolution of its NPI (new product introduction) and MES (manufacturing execution system) software system. The software facilitates the collection and analysis of test and inspection data. **VJ Electronix** introduced its Vertex Series-A x-ray inspection system. The company reports that the new system employs a flexible design that allows it to be customized to any inspection task, that it allows for faster load/unload product exchange, and that it includes a closed-loop control system to ensure reproducible results.

Eunil H.A. Americas highlighted its SPOIS PCB optical inspection system. The system employs MVTec's Halcon software. **RMD Instruments** introduced its LeadTracer-RoHS XRF (x-ray fluorescence) system, which is designed specifically for the electronic industry to provide portable screening capability to help meet RoHS directives. **CyberOptics** chose APEX for the US debut of its Flex Ultra HR optical inspection (AOI) platform. The company also introduced a new user interface. T&MW

See the online version of this article at www.tmworld.com/2007_04 for links to vendors and to our complete APEX coverage.

MARTIN ROWE
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Digital video drives network changes

TV is driving the wireline communications business. An ever-increasing demand for bandwidth to the home is forcing more fiber into the ground and is leading to network upgrades not seen since the dot-com bust. The impact of digital video is only expected to grow and take test equipment along with it.

"Broadband video is one driving force behind deployment of the state-of-the-art fiber needed to carry the high-capacity signal," stated the Telecommunications Industry Association in January (Ref. 1).

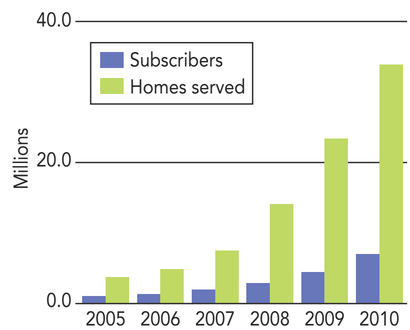
Market studies back up the TIA comment. According to In-Stat, the number of subscribers who received their TV from telcos was 700,000 in 2006 and will jump to 6.5 million in 2010 (see **chart**). In-Stat also predicts that the number of homes served (potential subscribers) will increase from 4.4 million in 2006 to 33.5 million in 2010.

The Information Gatekeepers Group has also published a survey that predicts that the number of IPTV subscribers will increase from less than 2 million in 2006 to nearly 13 million in 2010 and that about 44 million homes will be potential IPTV subscribers, up from about 13 million in 2006 (Ref. 2).

Don't, though, assume that all telco-delivered video is IPTV. The IGI Group report may give realistic numbers, but it carries on the common misconception that all telcos use IP to deliver broadcast TV.

"IPTV means any video delivered over Internet Protocol," said Michelle Abraham, telecom-market analyst for In-Stat. "When you watch a video on a Web site, you're watching IPTV." Abraham prefers the term "telco TV," referring to subscription TV delivered by telcos.

Unlike AT&T and other providers, Verizon, for example, doesn't use IP as the transport protocol for broadcast TV programs. Verizon uses IP for video-on-demand only. The company uses quadrature amplitude modulation (QAM) to deliver broadcast TV over fiber, much as cable operators use QAM over copper. Verizon, for the most part, isn't an IPTV provider.



North American homes with potential telco-TV service (homes served) will grow dramatically by 2010, with a proportionate increase in actual subscribers.

Source: In-Stat, www.instat.com.

Ethernet tester adds IPTV

Exfo has added IPTV monitoring software to its FTB-8510B Ethernet Packet Blazer test module. The software adds media delivery index (MDI) ratings for video-quality measurements. It also measures clock-reference jitter, stream rate metrics, bandwidth utilization, and IP metrics on up to 255 MPEG media streams. www.exfo.com.

Network Tester adds MPEG-4

Anritsu has added optional MPEG-4 capability to its CMA5000 optical network test system, which can test from the physical later to the transport layer (layers 1 to 4) of an optical network. It can test GigE, DWDM, SONET, and other networks and has a built-in OTDR for physical-layer tests. www.us.anritsu.com.

Test for HDCP compliance

Quantum Data has released a High-Bandwidth Digital Content Protection (HDCP) compliance test option for its Model 882 video test instrument. The 882-series can emulate High-Definition Multimedia Interface (HDMI) HDCP sources, sinks, or repeaters and performs HDCP compliance tests. www.quantumdata.com.

Regardless of the delivery technology, digital video requires test equipment. Manufacturers with products from routers to set-top boxes need tools to analyze their video. The three product announcements in the box on this page reflect the growing demand for test equipment. Field testers for optical access networks are introduced on a regular basis. Video analyzers that measure picture quality are also on the rise. Protocol analyzers, once used only for transport protocols, now include MPEG stream analysis and video-quality measurements. T&MW

REFERENCE

1. "TIA Report: Broadband Demand Drives Highest Telecom Industry Growth Since 2000," Telecommunications Industry Association, January 25, 2007. www.tiaonline.org.

2. "IPTV: The Telco's New Light Sword," Information Gatekeepers Group, June 2005. www.igigroup.com.

MARK HOLLER
RESEARCH ANALYST, FROST & SULLIVAN
www. frost.com

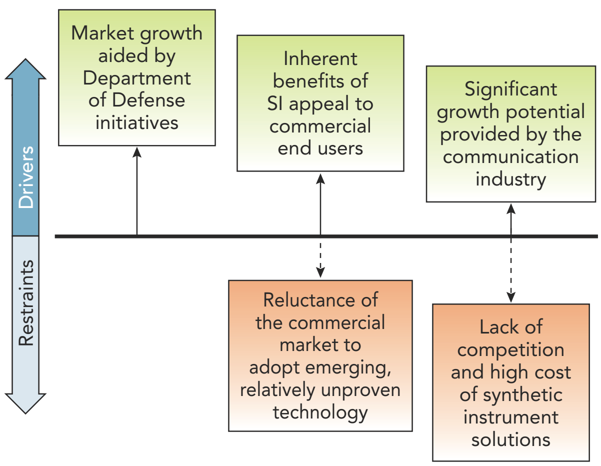
What factors are affecting growth in the SI market?

Synthetic instrumentation (SI) has been a prominent buzzword in the test and measurement industry over the last few years, and with good reason. The aerospace and defense (A&D) industry continues to be the largest driver for growth in the market, but SI contains inherent benefits that make it extremely attractive to commercial industries as well:

- the ability to emulate multiple traditional instruments using a common set of hardware,
- rapid reconfigurability,
- the ability to integrate multiple form factors and technologies within one system,
- a reduced footprint,
- the elimination of redundant hardware, and
- reduced obsolescence by allowing users to replace or add individual components.

The communication industry also provides significant growth potential for the SI market. The proliferation of wireless technology has created and increased the demand for testing equipment. As SI technology becomes more affordable and as awareness within the commercial sector increases, SI technology has tremendous potential within the communications industry.

Nevertheless, the market penetration for SI systems remains very low and has been confined almost exclusively to the A&D industry. There are a couple of reasons why.



Synthetic instrumentation will become attractive to commercial and communications users as the technology matures and competition lowers costs.

First, a lack of competition within the market and the corresponding high cost of SI systems serve to restrain growth. Only a few complete solution providers and system integrators compete in the market, and these participants are focusing on high-performance RF and microwave solutions that cost between $100,000 and $700,000. As interest in SI increases, more competitors are likely to enter the market and drive down the costs. As technology improves, less costly and lower-performance systems will become available.

In addition, most companies take a wait-and-see approach to new technologies. Traditional modular and card-cage test systems have a proven record of precision and performance, while SI systems are still viewed as "pie-in-the-sky" technology by many market participants. As SI technology becomes more mature, commercial users will be more willing to use SI systems in their operations.

So, what does the future hold for SI systems? SI has the potential to replace traditional automated test equipment (ATE) for many end users. If all participants that build ATE systems use this concept, then the estimated potential is approximately $500 million. This clearly indicates that the SI market portends tremendous opportunities for growth. But this growth depends on the vendors' ability to deliver a cost-effective, proven solution, and to successfully market this solution to commercial end users. Once this is achieved, the SI market will finally be able to reach its full potential. T&MW

PCB book-to-bill

The North American rigid printed-circuit board (PCB) industry book-to-bill ratio for January continued below parity at 0.91, while the flexible-circuit book-to-bill ratio edged up to 0.93, according to IPC. Rigid PCB shipments were down 3.5% and bookings were down 19.2% in January 2007 from January 2006. Flexible circuit shipments in January 2007 were up 14.3% and bookings were down 10.6%. www.ipc.org.

Virtual VoIP in China

With China's telecom market having relatively high long-distance rates, VoIP has gained fast market recognition, reports In-Stat. The number of broadband VoIP subscribers served by telecom carriers is expected to expand to 9.53 million by the end of 2011, up from 720,000 in 2006, the market-research firm says. www.in-stat.com.

Semiconductor equipment book-to-bill

North American-based manufacturers of semiconductor equipment posted $1.71 billion in orders in January 2007 (three-month average basis) and a book-to-bill ratio of 1.06, according to SEMI. The three-month average of worldwide bookings in January 2007 was $1.71 billion. The bookings figure is about 14% higher than the final December 2006 level and about 39% above the January 2006 level. www.semi.org.

The WiMAX Boom: It's Not All Magic

Along with the compelling advantages of WiMAX, system operators and equipment vendors must be prepared to tackle some new technical challenges.

WiMAX (Worldwide Interoperability for Microwave Access) is rapidly changing the landscape for wireless broadband access, both for consumers and businesses alike.

Designed around the IEEE 802.16 standard, WiMAX networks seem destined to spread rapidly over the next few years, especially as a delivery vehicle for broadband. Based on modern transmission capabilities, such as Orthogonal Frequency-Division Multiplexing/Orthogonal Frequency Division Multiple Access (OFDM/OFDMA), WiMAX has as its key objective providing reliable access to high-speed Internet applications. Its future outlook grows even brighter with the widespread trend toward mobile applications.

The R&S SMJ100A Vector Signal Generator (shown here), combined with the compact R&S FSL Spectrum Analyzer, is a cost-efficient production measurement solution for WiMAX applications.

But WiMAX isn't just another network. As engineers schooled in earlier technologies tackle this emerging standard, they will face many different system requirements, especially in terms of RF requirements and architectures. For example, to ensure stable functionality, manufacturers of WiMAX equipment will require reliable measurement solutions capable of handling all the different dimensions that the technology presents.

Benefits and Challenges

WiMAX can provide fixed, nomadic, portable and mobile wireless broadband without direct line-of-sight. With a connection radius of three to ten kilometers, it also boasts a capacity of up to 40 Mbps per channel. That adds up to superior communications power – enough to provide hundreds of businesses with T-1 type capacity and thousands of residences with DSL speed connectivity.

However, the 802.16 WiMAX standard differs from the more familiar 802.11 a/g standard in several ways. Although both are built on OFDM, rather than a fixed bandwidth and small number of subcarriers, WiMAX features variable bandwidths ranging from 1 to 28 MHz, with 128, 256, 512, 1024 and 2048 subcarriers. What's more, WiMAX allows transmissions to be confined to a subset of the available carriers – but using the same amount of power – which effectively allows for longer range.

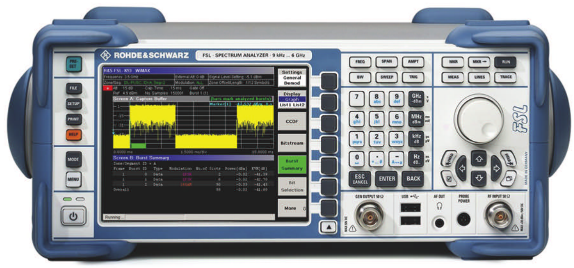
As WiMAX evolves into devices inside buildings, it will be necessary to make up for the power loss incurred when transmitting the signal outside buildings. Because customer-provided equipment is typically limited in power, concentrating the power over fewer subcarriers in the uplink can balance the power in the uplink and downlink, and enable greater range.

Having more subcarriers also means that they are spaced more closely. And that requires tighter control of phase noise and timing jitter, as well as provision of higher-performance synthesizers. You also need to give consideration to the guard interval, a time delay that occurs before each packet is transmitted. In WiMAX, even the guard interval varies.

Another change is in error vector magnitude (EVM). Under the 802.11 standard, the magnitude is pegged at -25 dB, yielding a 10% packet error rate. WiMAX, by contrast, aims for a 1% error rate with an EVM of -31 dB. Similarly, the new network gets increased performance by imposing an even stricter limit on receiver noise.

Things get more complex in other

dimensions, too. While 802.11 relied only on time division duplexing (TDD), WiMAX 802.16 supports TDD, frequency division duplexing (FDD) and half-duplex FDD (H-FDD).



The R&S FSL Spectrum Analyzer allows you to perform measurements on WiMAX signals in accordance with the OFDM/OFDMA method, even without an additional PC.

Tools to Help You Cope

For engineers and others who must develop, manufacture or implement WiMAX components and applications, it is critical to have the right tools to meet these new demands. For example, you need to have the ability to analyze characteristics of these high-frequency signals, a task that is beyond the means of conventional spectrum analyzers. Generating WiMAX reference signals can also pose challenges.

Modern spectrum analyzers would seem to have the ability to measure parameters such as bandwidth, spurious emissions, and power in adjacent channels. However, to be successful with WiMAX, the resolution bandwidth of a spectrum analyzer must be greater than the bandwidth of the RF signal. In other words, it needs to exceed 28 MHz in the mode with the greatest bandwidth in order to measure the burst power directly in the time domain. The spectrum analyzer also must be able to successfully demodulate the signal. So the demodulation or IQ bandwidth must exceed 28 MHz as well. In short, at the start of a measurement, you not only need to set standard parameters, such as the frequency and recording length, but also the bandwidth and the length of the guard interval.

The signal generation capabilities of your equipment must be able to handle similar kinds of complexity. For instance, to produce test signals for ODFM receiver tests according to the WiMAX standard, it helps to predefine different scenarios, such as 64 bursts with user-defined power and payload for both downlink and uplink. Likewise, your equipment should be able to time the position of each uplink burst in a frame that can be varied. This allows you to simulate mobile stations operating at a variety of distances. And, for automatic testing, equipment operators will want to generate test signals by remote control.

A Suite of Solutions

To address all these new WiMAX concerns, Rohde & Schwarz, an independent group of companies specializing in electronics, offers a full range of highly capable devices. In fact, the WiMAX Forum has selected Rohde & Schwarz as radio conformance test tester (RCTT) developer for mobile WiMAX.

Rohde & Schwarz is well prepared to help engineer customers reap the benefits of WiMAX. The company has built a strong reputation as a leading supplier of solutions for test and measurement, broadcasting, radio monitoring and radio location, as well as mission-critical radio communications. Established more than 70 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. ●

WiMAX Spoken Here!

Rohde & Schwarz offers packages for signal generation and spectrum analysis that cover all the production requirements for WiMAX.

For example, the company's R&S SMJ100A Vector Signal Generator, combined with the compact R&S FSL Spectrum Analyzer, is a cost-efficient production measurement solution for WiMAX applications. Internal options allow you to perform tests in accordance with the IEEE 802.16-2004 and IEEE 802.16e-2005 standards.

By using the Digital Standard WiMAX R&S SMJ-K49 option, you can generate signals on the physical layer for both mobile and stationary applications. For signal analysis, the R&S FSL-K93 allows you to perform measurements on WiMAX signals in accordance with the OFDM/OFDMA method, even without an additional PC. You can also get remote control via LAN and GPIB. The measurement of modulation quality and all RF parameters, such as adjacent-channel power or spectrum masks, makes the R&S FSL unique in its price class. Its high measurement speed also reduces test time in production.

In addition, you can control these new functions remotely via LAN or GPIB. And the short setting times with which frequencies and waveforms are changed mean very fast throughput time. The R&S SMJ Vector Signal Generator also offers standard-compliant signals for receiver tests and high signal quality when performing amplifier tests.

For More Information

Engineers can get a complete overview of WiMax technology by visiting: http://www.wimax.rohde-schwarz.com.

Among other useful links:
Learn about WiMAX measurements, MIMO systems, the WiMAX standards and WiMAX power amplifier testing at: http://www.rohde-schwarz.com/appnotes-forkeyword/wimax.htm

View the Rohde & Schwarz WiMAX Brochure and WiMAX System Overview Poster at: http://www.rohde-schwarz.com/www/dev_center.nsf/html/wimax_downloads

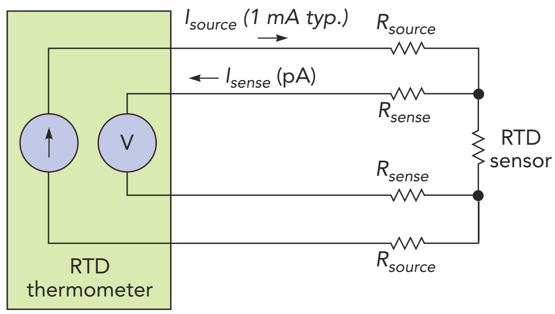
TEMPERATURE MEASUREMENT

Select your temperature sensor

Temperature is the most common physical measurement in electronics. Today's sensors—thermocouples, RTDs, and thermistors—serve different purposes and are based on different technologies.

Thermocouples, for example, are small, easy to use, require just two wires, and cover a wide temperature range. They do, however, require linearization and a reference sensor.

RTDs are more linear and more accurate than thermocouples, but they often require three or four wires (**figure**) and are subject to self-heating. Thermistors are the most sensitive to temperature changes but have the smallest temperature range.



Four-wire RTDs use two wires for sensor excitation and two for measurements. Using four wires removes voltage drops in the sensor wires caused by excitation current and lead resistance.

Dale Cigoy, senior applications engineer at Keithley Instruments, has written a paper that covers the technologies and applications of these temperature sensors. "How to select the right temperature sensor" explains how each sensor works, describes error sources, and helps you select the right kind of sensor for an application. Cigoy also discusses the pros and cons of each sensor and explains how to avoid common mistakes when connecting temperature sensors.

You can download a copy of Cigoy's paper from the online version of this article (www.tmworld.com/2007_04), where you will also find links to more information about temperature measurement, including a spreadsheet for calculating thermistor resistance versus temperature.

Martin Rowe, Senior Technical Editor

MACHINE VISION

North American MV markets to grow at slower rate

The North American machine-vision markets will grow in most segments this year, pacing the US and Canadian economies, according to Paul Kellett, director of market analysis for the Automated Imaging Association. Kellett expects machine-vision sales volumes for most product categories to grow in 2007, but at decreasing rates, as the US gross domestic product (GDP) growth slows from 3.4% in 2006 to 2.7% in 2007, and as the Canadian GDP growth dips to 3% in 2007 from 3.1% in 2006.

Kellett, who surveys the North American machine-vision market annually, presented preliminary 2006 results and 2007 forecasts on February 1 during the annual business conference of the Automated Imaging Association (AIA) in Orlando, FL. Among the highlights, Kellett expects machine-vision component revenues to increase from \$204.7 million in 2006 to \$218.6 million in 2007.

As indicated in the **table**, he expects growth in optics, cameras, imaging boards (including frame grabbers and vision-processing boards), and software. The weak spot, he says, is lighting, which is facing price pressure as a result of the emergence of low-cost LEDs.

Note that the "cameras" entry in the table does not include smart cameras, which Kellett classifies as "integrated equipment" instead of as "components." For smart cameras (including sensors and embedded vision processors), Kellett expects revenues in 2007 to grow 10.5% (vs. 15.2% in 2006) to \$126.2 million.

As for application-specific machine-vision systems, he expects revenues to reach \$1249.3 million in 2007, representing 2.8% growth (compared to 3% in 2006). The declining growth rates for 2007, he said, result from a slowing of the ongoing economic expansion.

The complete study tracks revenues and unit shipments, reporting results from 2001 and providing forecasts through 2011. The full market report is available from the AIA's Web site, www.machinevisiononline.org.

Rick Nelson, Chief Editor

North American machine-vision components results and forecasts

	2006 revenue ($ millions)	2006 growth (%)	2007 revenue ($ millions)	2007 growth (%)
Optics	31.6	2.1	32.2	2.0
Lighting	29.3	–7.0	28.1	–4.0
Cameras*	92.4	16.8	105.4	14.0
Imaging boards**	30.4	–10.8	31.4	3.2
Software	21.0	2.8	21.5	2.3
Total components	204.7	9.5	218.6	6.8

*not including smart cameras, which the study lists separately.
**including frame grabbers and vision-processing boards.

Source: Automated Imaging Association

INSTRUMENTS

Turn the light on

DEVICE UNDER TEST
High-power light-emitting diodes (LEDs) used in lighting signs, warning lights, decorative lights, and as color backlights for cell phones and laptop computers. Colors include red, blue, yellow, green, and white. Wavelengths range from 470 nm for blue to 636 nm for red.

THE CHALLENGE
Measure light intensity and color in prototype lots of several hundred pieces as part of engineering evaluations. Look for uniformity in intensity and color that results from manufacturing processes. Change measurement techniques to accommodate high-power devices. Perform statistical analysis on parts to determine variations in device output.

THE TOOLS
- Instek: power supply. www.instek.com.
- Labsphere: LED integrating sphere. www.labsphere.com.
- Photo Research: spectroradiometer. www.photoresearch.com.
- Wei Min Industrial: LED tester. www.weimin.com.tw.

PROJECT DESCRIPTION

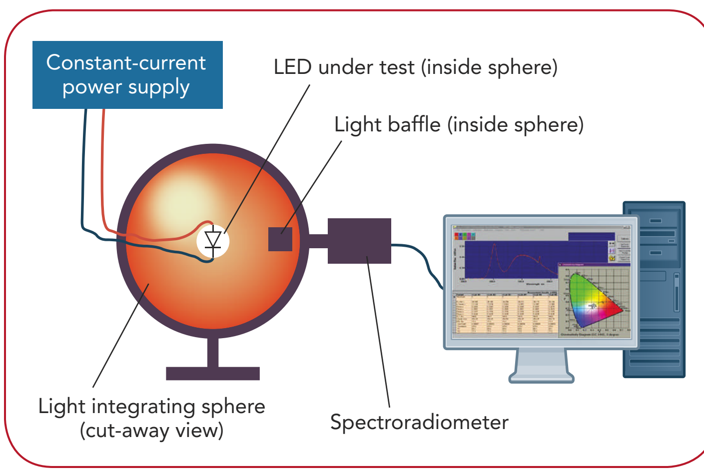
Once just bright enough for use as indicator lights, LEDs now illuminate cell phone and laptop screens and have applications in signs as well. "High-power LEDs have thrust LED manufacturers into light sources," said Harold V. Anagnos, founder and technology consultant at Lumex (Palatine, IL; www.lumex.com). Anagnos predicts that high-power LEDs will become mainstream in applications such as vehicle headlights and room lighting. "In 20 years, the panels used in suspended ceilings will contain LEDs."

Each high-power LED design requires lab measurements for numerous parameters; the most important are dominant wavelength, peak wavelength, luminous flux, and chromaticity (color quality). Because of the higher power, engineers must use different measurement techniques than they use for indicator LEDs. High-power LEDs can easily overload a spectroradiometer—a problem that engineers don't have when testing LEDs used as indicator lights.

To solve the problem, the Lumex engineers use a 4-in. diameter integrating sphere whose interior reflects 98% of a source's light. The metal sphere not only blocks outside light from interfering with measurements, but also lets only a small portion of an LED's light exit through its aperture and reach the spectroradiometer. That reduces the amount of light that reaches the instrument, which eliminates the problem of flooding it with too much light.

The LED under test sits at the geometric center of the sphere (**figure**). On one side sits the spectroradiometer sensor with a baffle that has the same reflectivity as the inside of the sphere. Prior to using the sphere, the engineers had to run the high-power LEDs at low forward current (I_F) to avoid flooding the spectroradiometer's sensor.

Using analytical software supplied with the spectroradiometer, the engineers can calculate the mean and standard deviation of color and intensity parameters for a fixed input current from which they can characterize the LED. They also use an LED tester to make electrical measurements such as forward voltage (V_F), reverse breakdown voltage (V_Z), leakage current (I_R), difference of V_F value between two I_F levels (V_{DF}), and transient V_F deviation (V_{FD}).



Engineers test high-power LEDs mounted inside a sphere that reduces the amount of light that reaches a spectroradiometer.

LESSONS LEARNED

Because high-power LEDs are often used to light areas, uniformity in color and intensity are more important than they are for indicator lights. "Color measurements are particularly important for yellow and green because our eyes can sense less than 1 nm differences in color wavelength," said Anagnos. He concluded, "The customer will check for uniformity visually rather than by making measurements."

Martin Rowe, Senior Technical Editor

FOR MORE INFORMATION

Basics of Spectral Measurement, JETI Technische Instrumente, May 2005. www.jeti.com/down/basics/basics.pdf.

"A Guide to Integrating Sphere Theory and Applications," Labsphere. www.labsphere.com.

Eric Jenkins leads a team of engineers that evaluate data forwarding and encapsulations in software.

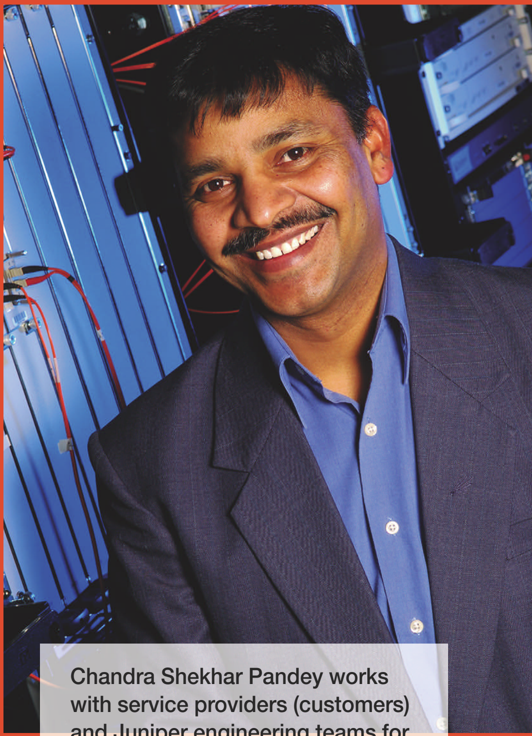
"TRIPLE PLAY"

Engineers at Juniper Networks use their heavily equipped test lab to simulate a multiplay network, where video is the driving force.

WESTFORD, MA—"Triple play," the voice, data, and video bundle that communications service providers promote, is already yesterday's news at Juniper Networks. Juniper engineers now refer to "multiplay," which adds services such as online gaming to the list of what providers can deliver.

Regardless of how many "plays" service providers offer, video is the most demanding service that Internet Protocol (IP) based networks must deliver. As IP video (TV and games) is deployed, service providers need to test their network configurations. That's where Juniper Networks' Westford lab plays a vital role. The lab consists of several test beds, one of which is an entire IPTV network containing everything from video sources to TV screens. Consulting engineer Chandra Shekhar Pandey administers this network, called the IPTV and Multiplay Center of Excellence.

Communications providers (Juniper's customers) come to the lab to learn how to configure their networks to deploy IPTV. They rely on Pandey to help with network architecture, configuration, and deployment, because his network contains the entire video chain. Pandey also works



Chandra Shekhar Pandey works with service providers (customers) and Juniper engineering teams for design and validation in the IPTV and Multiplay Center of Excellence.

MARK WILSON

IS SO YESTERDAY

MARTIN ROWE, SENIOR TECHNICAL EDITOR

with Juniper's engineering teams who need access to the test bed in order to gain a better understanding of the user experience.

Customers of multiplay providers expect a user experience that is at least as good as that provided by cable operators. Cable systems broadcast all channels simultaneously to a customer's set-top box (STB), and when the customer tunes to a desired channel, a program is immediately displayed.

In contrast, most IPTV networks send only the channels to a residential gateway or STB to which a customer has subscribed, and they send just one channel at a time. When selecting a channel, the user essentially sends a command to the network, which responds by transmitting the requested channel. Thus, it's challenging for IPTV providers to give customers a channel-surfing experience that emulates cable.

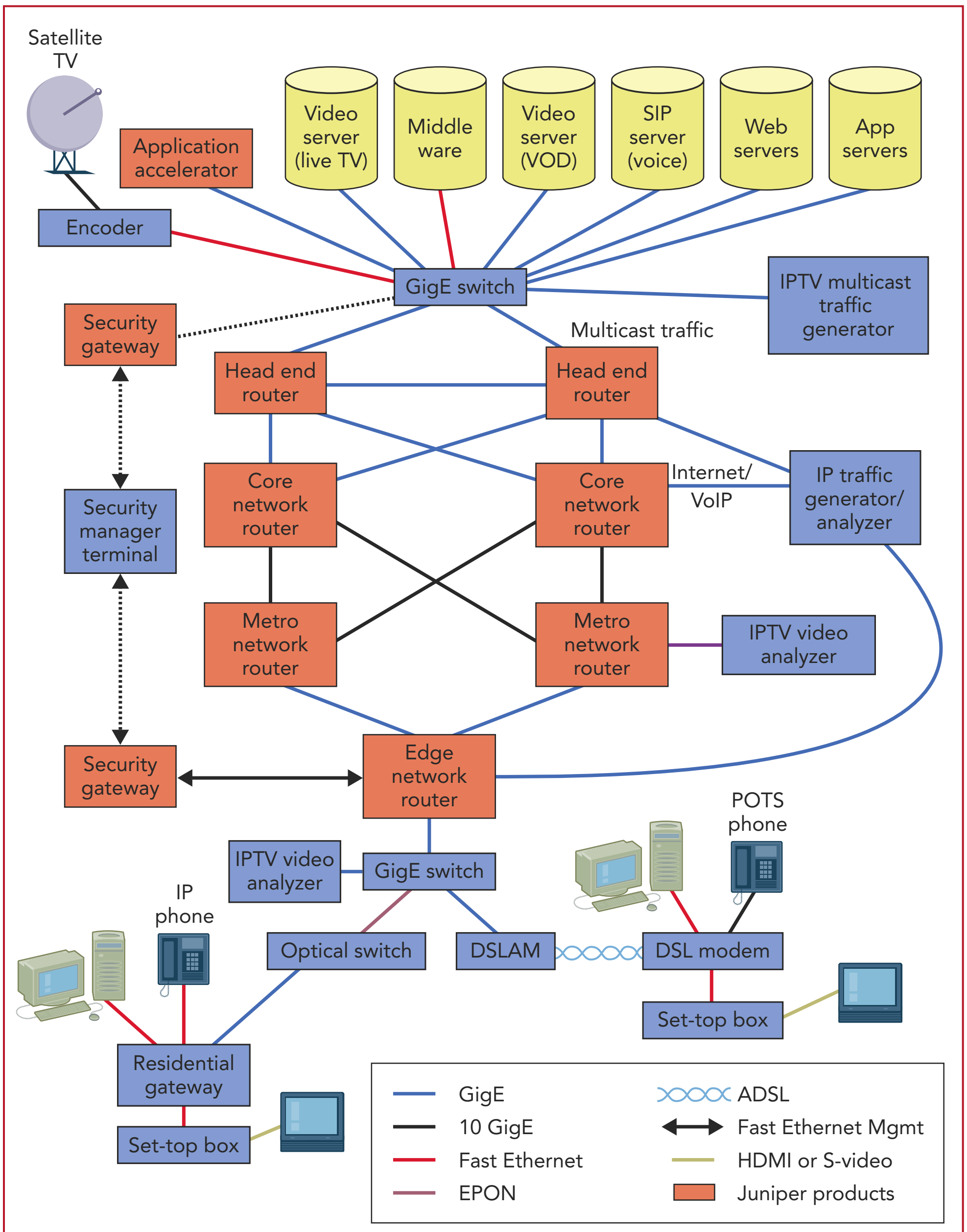


FIGURE 1. Juniper's IPTV and Multiplay Center of Excellence network represents a complete service-provider's network, from video sources to TV screens.

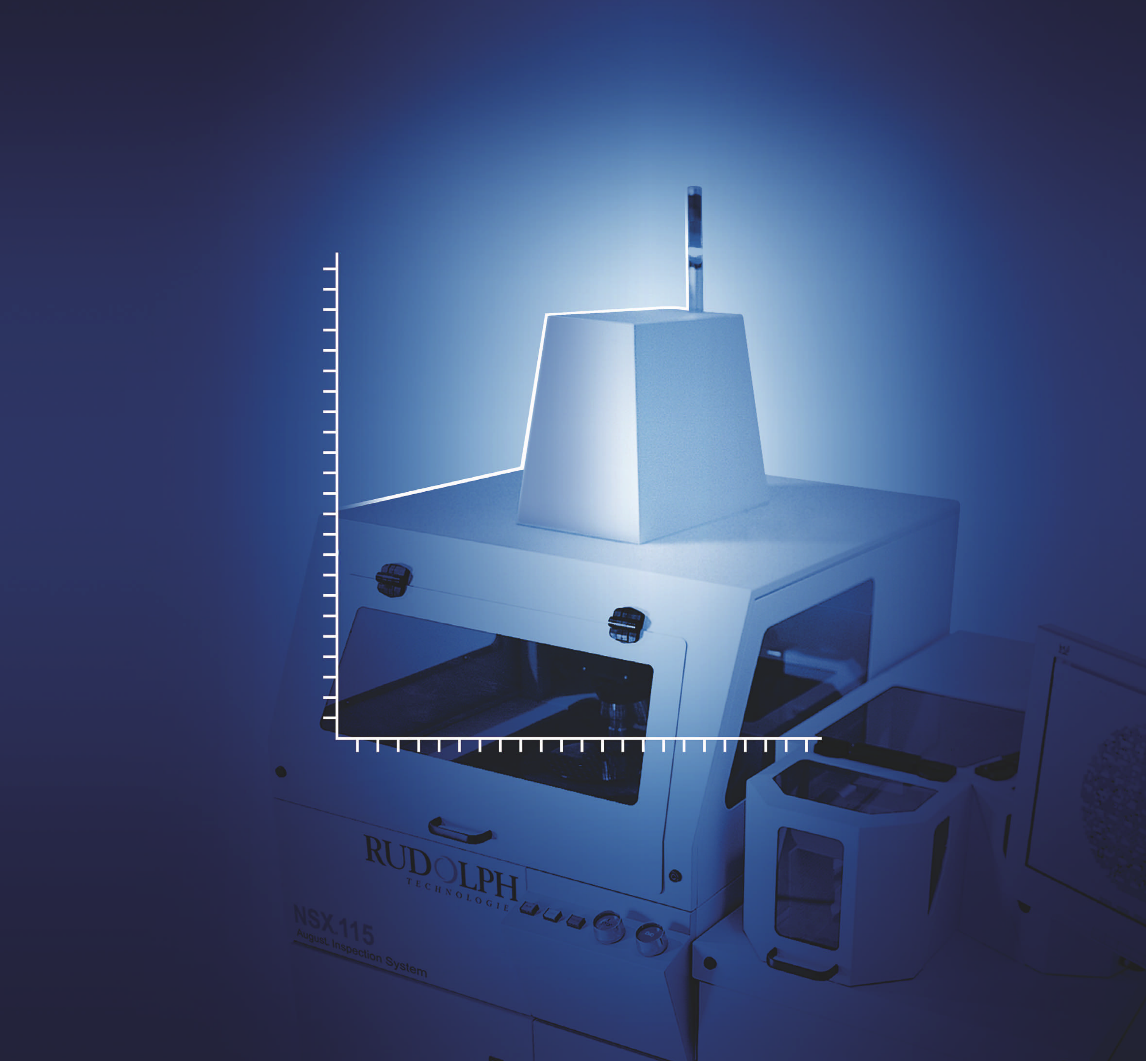
In addition, whenever an IPTV provider adds a new customer, the additional load on the network must not cause degradation of service to previous subscribers. Provider networks must also deliver uninterrupted services even when under denial-of-service attack or other security threats.

Inside the test network

As Eric Jenkins, system test manager of the company's Interface Group, observed, "Chandra's lab is a representation of the real world." Juniper's Center of Excellence contains the company's core routers, metro routers, security appliances, and edge routers, as well as network elements from other manufacturers, such as DSLAMs, fiber-to-the premises (FTTP) equipment, DSL modems, residential gateways, middleware, and video servers (**Figure 1**). The center also shares lab space with other test beds used to verify new and updated products.

Pandey and his team can reconfigure the test network to emulate how a service provider plans to deliver its services. "Some customers want to see just a portion of a network, while others want to see a network from satellite to set-top box," said Gary Southwell, director of the IPTV and Multiplay Solutions group. "As a result, Juniper engineers have become experts in all aspects of IPTV networks."

When they evaluate their systems at the Center of Excellence, service providers can focus on all or part of the network. For example, they may concentrate on testing a Juniper core-network router or edge router only. Or, they may concentrate on the overall service delivery. They also look to the cen-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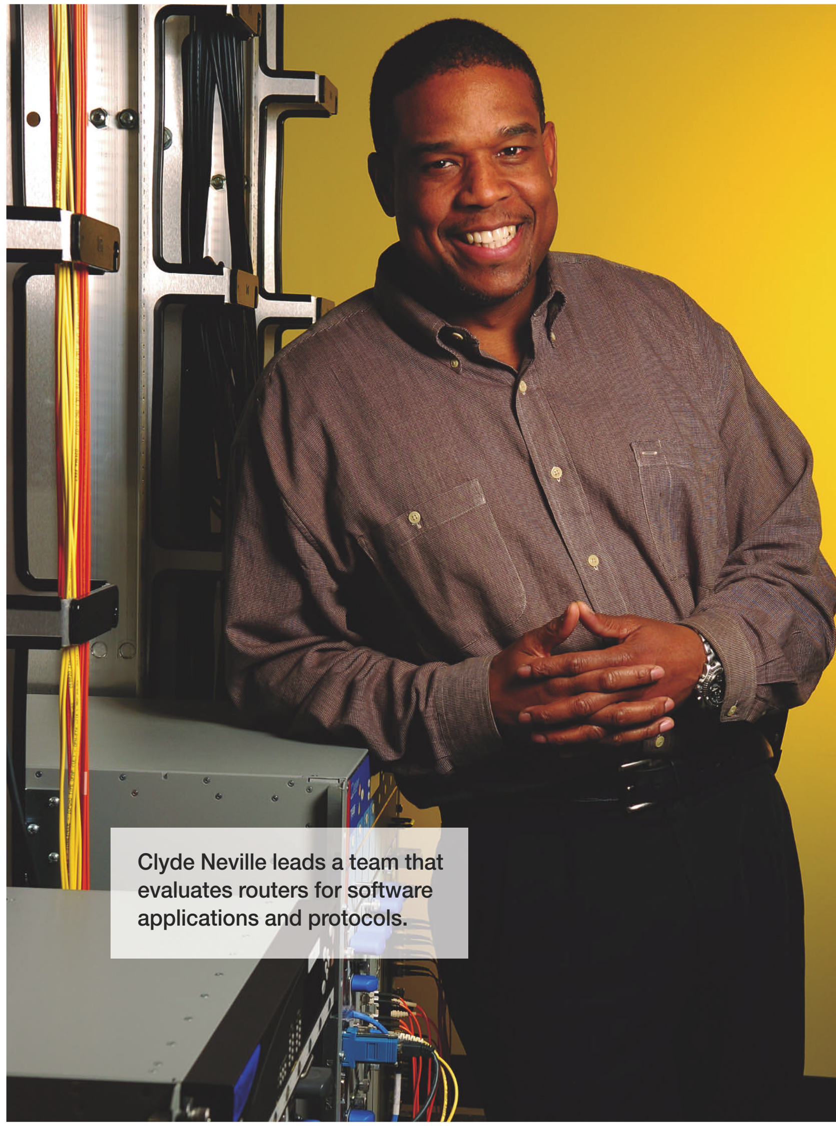
ter's staff for advice on how to design and configure their network to deliver next-generation services.

The Center of Excellence network also consists of live video sources such as a satellite receiver and a video server. The live feed goes to an encoder that encapsulates the feed into MPEG-2 and H.264 (MPEG-4 Part 10) over IP for transport. The network also contains video-on-demand (VoD) servers and "middleware" servers that contain software applications that run over the network. A session-initiation protocol (SIP) server adds voice calls to the network. A Juniper application accelerator accelerates HTTP (Web services) on the network.

Redundant Juniper video-provider edge routers focus the data into Gigabit Ethernet (GigE) streams that feed a redundant pair of Juniper core routers. The routers, in turn, transport 10-GigE streams to a pair of metro routers.

The redundant routers and links let engineers test the network should one router or interconnecting link fail. Service providers often place redundant routers in cities hundreds of miles apart so that if a natural disaster destroys on of the routers, customers won't lose service.



Clyde Neville leads a team that evaluates routers for software applications and protocols.

MARK WILSON

At the edge router

Metro routers send IP packets to a Juniper edge router, which contains subscriber information such as the services to which the customer has subscribed. A GigE switch in front of the edge router can aggregate lightly loaded DSLAMs or FTTP equipment, or uplinks can directly connect to the edge router. Dual links to edge routers provide link-level redundancy.

The edge router makes subscriber services available to subscribers' TVs, computers, and IP or POTS phones through DSL or Ethernet passive optical network (EPON) connections. Finally, the network contains two security gateways that Pandey uses during simulated network attacks.

Pandey's network also contains test equipment that generates and monitors IPTV traffic. Several Agilent Technologies multi-services testers generate traffic equivalent to 500 channels (some are audio only), and the testers simulate the equivalent loads of thousands of subscribers. They also monitor bandwidth usage and can tell engineers when the network is reaching overload and needs more capacity.

The center's engineers can monitor video quality with remote video over IP monitoring systems from IneoQuest. The monitoring systems provide a score called a media delivery index that represents video quality. The IPTV multicast traffic generators are located at the head end's GigE switch.

The monitors let Pandey compare video quality and packet loss across the core, metro, and edge routers. The systems communicate with network-monitoring software from Hewlett-Packard. Data from the IPTV monitors help the monitoring software decide if a service provider is delivering the subscribed level of service.

The Westford lab also contains test beds that engineers use to stress routers beyond their design specifications. Engineers such as Chris Fernandes test routers and line cards for basic functionality. "IPTV, VoIP, and gaming are layered on top of data services," said Jenkins of the company's Interface Group. "There must be no degradation of service, even if a router is handling thousands of subscribers. Subscribers expect the same experience they're used to even though the delivery mechanism has changed."

During a test, Pandey and others will force an active router to fail. They observe forwarded traffic to check how the remaining network elements perform. "The network must recover from this failure by rerouting traffic within 300 ms, or it will affect the user's experience," said Pandey.

Feedback provider

The Center of Excellence does more than simply let Juniper's customers configure and test proposed deployments. It also provides Pandey with valuable in-

formation that he feeds to the engineering team for product enhancements and new product ideas.

When design engineers incorporate new features into a design, they hand the new product to the engineers in Jenkins' group. These 11 engineers test the forwarding and encapsulation functionality of new designs—two essential functions of IP routers. They also run regression tests on new software to verify that it remains compatible with older revisions.

One important test covers channel-changing time. Juniper engineers use a "channel zapping" tool to initiate and

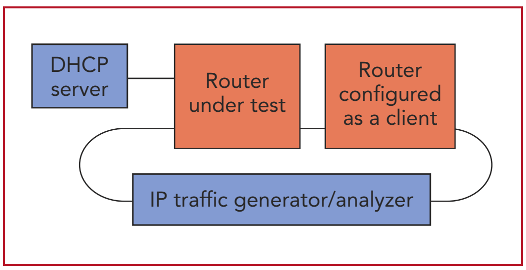


FIGURE 2. **Engineers test routers for performance while carrying applications encapsulated in Ethernet packets.**

time stamp channel changes. Because IP networks carry MPEG-encoded video streams, which periodically send I-frames followed by partial (B/P) frames, a change in channel doesn't appear on the subscriber's TV screen until it receives a full frame, called an I-frame.

When Juniper engineers began measuring channel change time, they used timing software on the Agilent multiservices testers. Now, the time stamping takes place in hardware. "We sometimes have to work closely with test-equipment manufacturers to get the test equipment designed right to meet the scalability and functionality we and our customers need," said Pandey.

Protocols, protocols

After engineers in Jenkins' group test data forwarding and encapsulations, they hand products to a group headed by software quality assurance (SQA) manager Clyde Neville. This group consists of eight engineers in Westford and six in India who perform functional, system, scaling, negative, interoperability, and call-setup performance tests.

Neville's group focuses on protocol testing at layers 2 (Ethernet), 3 (IP), and 7 (application). They focus their efforts on performance and interoperability of Juniper's core and edge routers that contain 10-Gbps line cards that support 16,000 connections (subscribers). A fully loaded router chassis supports 96,000 connections.

For interoperability tests, the lab contains a test bed with routers from Cisco Systems, Foundry Networks, Nortel Networks, and Unisphere Networks (Unisphere became part of Juniper in 2002, which is how Juniper entered the edge-router market). At the time of my visit, Neville's group was focusing on interoperability testing for a new revision of Juniper's JUNOS operating system for multiservice and core routers and its JUNOSe for broadband services routers or edge routers.

A typical interoperability test setup consists of two routers and a client generator made by Spirent Communications. "Customers want to make sure that a protocol they develop for another router will also work on a Juniper router," commented Neville.

Neville's group is responsible for proving that if any part of a router fails, the router will keep the data flowing. "We yank a line card out of a running router to verify that the system keeps running," he explained. "We also perform boundary testing. That is, if a router is rated to handle 96,000 connections, we'll exceed that number to ensure that the router won't crash."

In the lab, Neville and his group of engineers run performance tests of routers and new software revisions. They use a Spirent protocol tester to measure parameters such as number of lost packets should something fail (**Figure 2**). The test gives them data on how long the router under test takes to recover from a failure.

When engineers in Neville's group don't need the full test bed, they use a test bed that performed interoperability tests before they obtained the protocol tester. The test bed consists of a router set up to run as a client for the router under test. Windows and Linux-based servers provide content for the router. The test bed also contains a Dynamic Host Control Protocol (DHCP) server that lets engineers test routers using DHCP-v4 and DHCP-v6 protocols.

Neville's group also runs scaling and integration tests on every release to verify current functionality doesn't negatively affect any product. Using a test bed that's a duplicate of one that Jenkins' group uses, Neville's group runs a series of automated scripts to test routers. Juniper has another identical test bed in India.

Regression tests typically run 24 hours a day. "We have over 100,000 scripts for running regression tests," Neville explained. "The number of scripts we use grows with each software release. To test all of Juniper's products, we have hundreds of thousands of scripts."

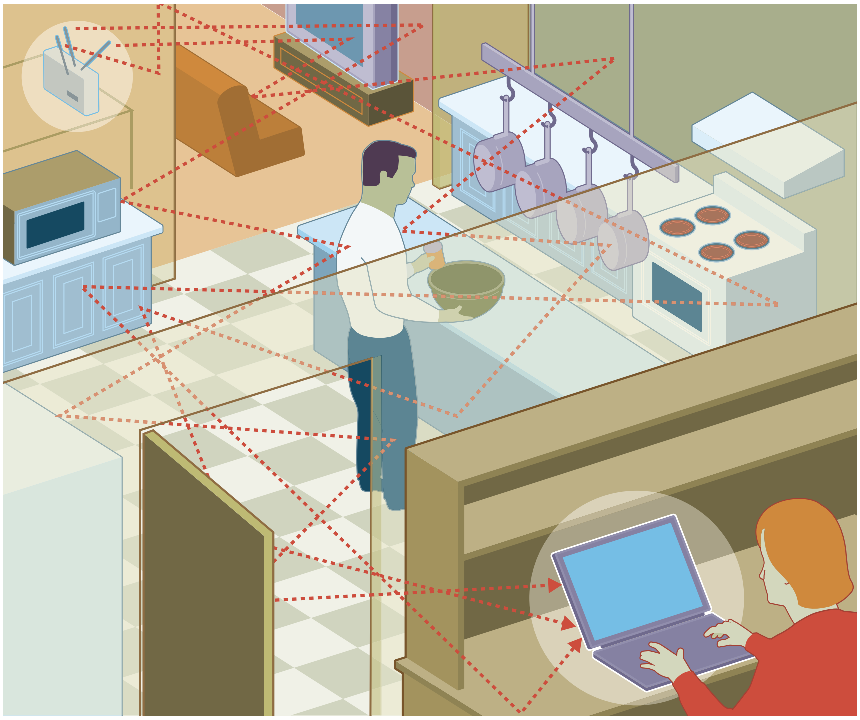
Working with test vendors

Throughout my visit, I heard Juniper engineers talk about working with test-equipment manufacturers to get complete test tools. Today, test equipment can simulate more than 500 channels of content and can monitor transmissions for protocol violations. Video-quality testers can produce scores the engineers can use to rate video quality.

"Test equipment is coming into its own," noted Pandey. "We've worked with test-equipment makers to get the features we need." Juniper VP of engineering Chris Vaughn pointed out that Juniper's test-equipment needs are constantly outstripping the capabilities of commercial test equipment.

Jenkins echoed that sentiment, noting that "not many test vendors can support 44 ports on one line card. Test equipment is trailing our needs to support 96,000 interfaces [subscribers] on one router."

The testing that takes place at Juniper Networks gives service providers confidence that the networks they develop and deploy will deliver data, voice, video, and games at a quality level that subscribers expect. Testing will only increase in importance as service providers add HDTV to their offerings. HDTV's higher bandwidth will further stress networks, but users won't tolerate any degradation in service. T&MW



DANIEL GUIDERA

Equipment meeting the complex 600-Mbps multiple-input, multiple-output WLAN standard will require sophisticated channel-emulation test strategies.

Testing 802.11n

FANNY MLINARSKY, OCTOSCOPE

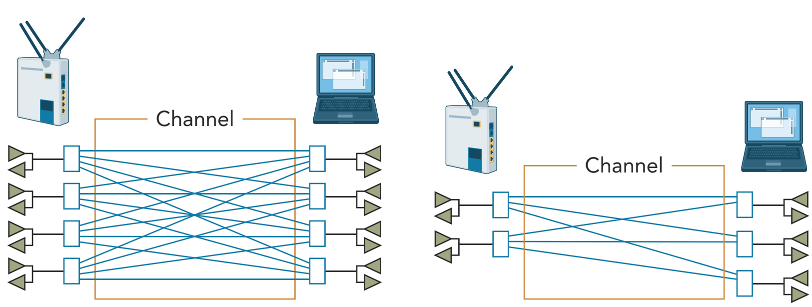
Wireless LAN (WLAN) throughput advancements introduced by the emerging IEEE 802.11n standard come at the price of unprecedented technological complexity. This creates an immediate need for sophisticated test systems that can help manufacturers and service providers bring robust, well-tested products to market. Although the final standard will not be published until mid-2009, draft 2.0 is now mature enough that companies such as Intel, Broadcom, Atheros, Marvell, and Qualcomm have already released 802.11n chipsets that will require only software changes in order to comply with the final standard.

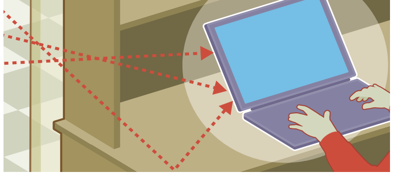
IEEE 802.11n will be able to reach data rates of 600 Mbps, and it guarantees a minimum of 100 Mbps of throughput (see "Throughput and packets," p. 42). Throughput is not just a function of data rate and can be adversely affected by protocol overhead and retransmissions caused by poor signal integrity.

Throughput measurements for legacy 802.11a,b,g networks often take place over the air link where overhead counts toward throughput, but 802.11n specifies throughput at the MAC SAP (Media Access Control Service Access Point) interface, where the metric more meaningfully reflects true data throughput. A throughput of 100-Mbps at the MAC SAP interface for 802.11n represents a fourfold increase over the throughput of legacy WLAN technology.

Prestandard 802.11n solutions claim data rates in the 300-Mbps range—the level at which access points (APs) need Gigabit Ethernet connections to the infrastructure to keep up with the air link. IEEE 802.11n owes its high throughput to the latest advancement in wireless transmission—MIMO (multiple input, multiple output).

FIGURE 1. 802.11n specifies MIMO operation with up to four transmitters and four receivers. Some products feature two transmitters and three receivers, and some have three transmitters and three receivers with other combinations possible.





How does MIMO work?

MIMO is a true innovation in the area of wireless data transmission. It turns the long-time enemy of airborne signals—multipath—into a friend. Multipath is a common phenomenon in wireless channels, where the signal reflects from walls, furniture, and people. Reflections add together in the air, causing the signal at the receiver to be a distorted version of the original. While 802.11a,b,g radios work to overcome the effects of multipath, 802.11n MIMO radios actually take advantage of multiple paths to increase throughput by sending several data streams simultaneously. This requires multiple transmitters and receivers in the radio.

Table 1. Prestandard implementations and manufacturers' claims

Prestandard chipset	Claimed throughput* (Mbps)	Number of transmitters, receivers, spatial streams, and antennas supported (*NxM*: *N* transmitters, *M* receivers)
Atheros AR5008-2NG	150–180	3x3, 2 streams**
Broadcom Intensi-fi	180–200	2x2, 2 streams
Intel 4965AGN		2x3, 2 streams
Marvell TopDog		2x3, 2 streams
Qualcomm/Airgo AGN400	170–175	2x3, 2 streams

**These throughput figures are reported by the manufacturers, and the measurement methodology may not be available. For reliable throughput metrics and comparison, the measurements should be performed by an independent party using a controlled test environment specified in the IEEE 802.11T test specification.*

***The Atheros chipset has more transmitters than streams to implement cyclic shift diversity (CSD), a signal-shaping technique incorporated into the 802.11n specification. CSD spreads the spatial streams across multiple antennas by transmitting the same signal with different cyclic shifts.*

An *N*x*M* MIMO system has *N* transmitters and *M* receivers (**Figure 1**). Signals from each transmitter reach each receiver via a different path in the channel. MIMO works best if these paths are spatially distinct and each is capable of carrying its own data stream. If the radios are within line of sight of each other, MIMO can deteriorate into the traditional single-stream transmission, SISO (single input, single output).

The 802.11n standard incorporates two MIMO techniques: spatial multiplexing and beamforming. Spatial multiplexing divides data into multiple streams and sends them simultaneously over multiple paths in the channel. These streams are recombined in the receiver to get the original data.

Beamforming is a technique that uses several directional antenna elements to spatially shape the emitted electromagnetic wave to beam the energy into the receiver over some optimum path. Beamforming requires the transmitting and receiving stations to perform channel sounding to optimize the shape and direction of the beam.

Beamforming can be used in conjunction with spatial multiplexing or by itself when only a single path is available between the radios. Beamforming at the transmitter can be augmented with Maximum Ratio Combining (MRC) at the receiver—a technique that phase-aligns and adds signals received by multiple antennas to optimize signal integrity.

Most existing prestandard 802.11n chipsets support two spatial streams but can use more than two transmitters and receivers to shape and transport these streams. Multiple antennas or antenna elements can also be used for beamforming or for diversity. (Diversity is a technique of using two or more antennas for reception of the signal. Some diversity algorithms select the best signal from multiple antennas, and some algorithms may combine the signals.) **Table 1** summarizes how the prestandard solutions work.

Table 2. Legacy 802.11 physical-layer data-rate adaptation and frequency band

	Supported data rates (Mbps)	Frequency band (GHz)
802.11b (DSSS)	1, 2, 5.5, 11	2.4
802.11a (OFDM)	6, 9, 12, 18, 24, 36, 48, 54	5.8
802.11g (combination of 11b and 11a)	1, 2, 6, 9, 12, 18, 24, 36, 48, 54	2.4

Physical layer signaling for 802.11n vs. legacy

In the earlier versions of 802.11, rate adaptation seemed complex compared to single-rate Ethernet, but now it seems simple compared to 802.11n. Legacy 802.11a,b,g devices can automatically and dynamically adapt data rate based on channel conditions—the better the channel, the higher the rate. Legacy radios transmit a single data stream using either direct-sequence spread-spectrum (DSSS) or orthogonal-frequency-division multiplexing (OFDM) modulation. Data rates are automatically selected by the legacy networks (**Table 2**).

The complexity of 802.11n rate adaptation has given birth to the concept of Modulation Coding Scheme (MCS). MCS includes variables such as the number of spatial streams, modulation, and the data rate on each stream. Radios establishing and maintaining a link must automatically negotiate the optimum MCS based on channel conditions and then continuously adjust the selection of MCS as conditions change due to interference, motion, fading, and other events.

There are 77 MCSs specified in the current IEEE P802.11n draft (January 2007), with eight of them being mandatory for 802.11n compliance. **Table 3** shows an example of how MCSs are specified. The highest data rate of 600 Mbps is achievable with MCS 31 using 64-QAM modulation in a 40-MHz channel, four spatial streams, and operating with a short guard interval (GI) of 400 ns.

MIMO channel models

MIMO throughput, number of spatial streams, selection of MCSs, and beamforming techniques are highly dependent on the physical channel. To help develop and test MIMO products, the IEEE 802.11n group defined six MIMO channel models—A through F (**Table 4**). Model A is a test mode. Model B represents a typical small office environment.

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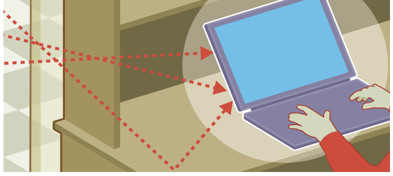

Model F represents a large metropolitan environment.

Radio signals reflecting from buildings, walls, furniture, and other conductive surfaces travel in *clusters*—multiple reflections of the same signal arriving at the receiver at different times and with different amplitudes, but from the same general direction. The number of clusters represents the number of independent propagation paths. The MIMO channel models include Doppler shifts, which are amplitude fluctuations of signals caused by moving objects, such as people and cars. The Doppler shifts are modeled assuming reflectors are moving at 1.2 km/h.

Measuring range performance through a channel emulator

Throughput and range performance of 802.11n devices can be measured using a channel emulator (**Figure 2**) that implements IEEE 802.11n models. The Azimuth Systems' ACE is one such product. Channel emulation must be bidirectional to support the channel-sounding techniques used in beamforming. The transmitter may derive channel information from the ACK frames sent by the receiver or by the sounding matrix computed and reported by the receiver.

The channel emulator should offer a 4x4 configuration, since 802.11n supports up to four spatial streams. A typical channel emulator downconverts the inbound RF signal to a lower IF frequency, digitizes the signal, and mathematically applies the IEEE 802.11n models to the signal using digital signal processing (DSP), thus emulating the channel effects. The computationally distorted IF signal is then upconverted and presented to the station at the opposite port of the emulator

Backward-compatible MIMO devices can operate in three modes: legacy (802.11a,b,g), mixed-mode (802.11n and 802.11a,b,g), or greenfield (802.11n only). The highest throughput is achieved in greenfield mode when only the 802.11n devices are present on the network. A single legacy station on a MIMO network can significantly slow down the total network throughput. When measuring throughput, the operating mode will make a difference in the results and should be taken into account.

Table 4. Key parameters in the IEEE 802.11n models A–F

	IEEE 802.11n models A	B	C	D	E	F
Average wall distance (m)	5	5	5	10	20	30
RMS delay spread (ns)	0	15	30	50	100	150
Maximum delay (ns)	0	80	200	390	730	1050
Number of taps	1	9	14	18	18	18
Number of clusters	N/A	2	2	3	4	6

Note: Delay spread and number of clusters increase as the modeled physical space gets bigger.

Source: "TGn Channel Models," Vinko Erceg, et al., IEEE 802.11 document 11-03/0940r4. users.ece.utexas.edu/~forenza/11-03-0940-04-000n-tgn-channel-models.doc.

Table 3. MCSs that are mandatory in the current IEEE P802.11n draft.

MCS Index	Modulation	R	$N_{BPSC(iSS)}$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 800 ns GI*	400 ns GI
0	BPSK	1/2	1	108	6	108	54	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	135.0	150.0

**Guard Interval (GI) is the time delay used by the receiver to let the reflections in the channel settle before sampling data bits.*

Legend

N_{SS}	Number of spatial streams
R	Code rate
N_{BPSC}	Number of coded bits per single carrier
$N_{BPSC(iSS)}$	Number of coded bits per single carrier for each spatial stream, iSS
N_{SD}	Number of data subcarriers
N_{SP}	Number of pilot subcarriers
N_{CBPS}	Number of coded bits per symbol
N_{DBPS}	Number of data bits per symbol
N_{ES}	Number of FEC encoders
N_{TBPS}	Number of total bits per subcarrier

Note: These are rate-dependent parameters for mandatory 20-MHz, N_{SS} =1 MCS, N_{ES} = 1. The draft goes on to specify 77 different MCSs for 20- and 40-MHz channels.

802.11n considerations for handsets

For handsets, the biggest concern is battery life. To that end, 802.11n has introduced a power-save protocol called PSMP (power save multi-poll) that enables the station to go to sleep when not transmitting or receiving. This mode is particularly valuable for VoIP devices because voice traffic has a cyclical pattern and is composed of short frames, less than 100 µs, with long periods of silence, on the order of 20 to 30 ms, depending on the codec. This traffic pattern results in a low duty cycle of radio on/off, and if the station can sleep during the off cycle, battery life can be significantly extended.

PSMP enables handsets to wake up periodically to exchange packets with the AP, powering up the radio only when necessary. PSMP is a sophisticated protocol that requires the AP to keep track of sleeping stations and to save their data for periodic delivery during the wake/sleep cycle. 802.11n also improves power efficiency through higher data rates that minimize radio ON time.

Channel frequency selection and management

The planned 802.11n networks use the conventional unlicensed bands at 2.4 GHz and 5 GHz, but while 802.11a,b,g

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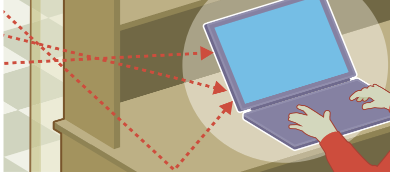


networks occupy 20-MHz channels, 802.11n networks can use 20- or 40-MHz channels. A 40-MHz channel consists of two adjacent 20-MHz channels—primary and secondary.

Since only 70 MHz is available in the 2.4-GHz band that is already crowded with 802.11b,g networks, 40-MHz operation of 802.11n can disrupt existing networks. The issue of 40-MHz operation in the 2.4-GHz band has been a contentious one at the IEEE, and the 802.11 working group addressed it at its January 2007 meeting by introducing new coexistence protocols.

Coexistence includes methodology for detecting WLAN activity in the band, for sharing the secondary channel with adjacent Basic Service Sets (BSS is analogous to a cell in the cellular networks and consists of the AP and its associated stations), and for switching channels when necessary to avoid interference. Coexistence protocols are complex protocols requiring coordinated periodic scanning of all available channels, and the 802.11 working group may still have concerns about them—concerns that might delay the standard. Coexistence is less of a concern in the 5-GHz band where more spectrum is available. Nevertheless, the new coexistence protocols will apply to all bands of operation.

The 802.11n standard will also use the 3.65-GHz to 3.70-GHz contention-based band recently made available by the FCC and now being standardized by the IEEE

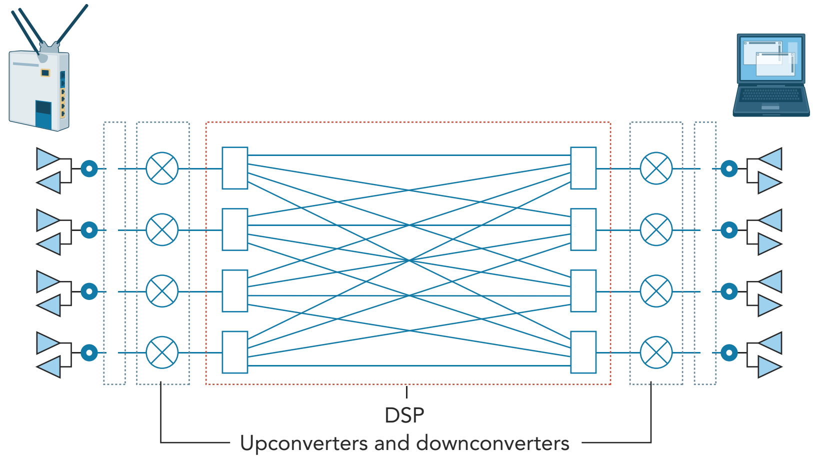
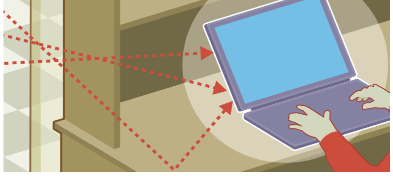


FIGURE 2. This block diagram illustrates a MIMO channel emulator. In a 4x4 emulator, 16 paths (N^2) are modeled with the coupling from each transmitter to each receiver.



802.11y task group. This specification is expected to be published in April 2008.

Test considerations for 802.11n

As new MIMO devices arrive on the market, the industry must ensure their reliability and interoperability before they can be deployed on a wide scale. Since the biggest promise of 802.11n is increased throughput and range, the first test priority is to measure a product's throughput vs. range. This test should be performed following the conducted environment methodology specified in the IEEE 802.11T test specification and using a MIMO channel emulator, since throughput depends on a radio's ability to handle multipath signals.

Additional test solutions are needed to verify the many new specifications in the PHY and MAC layers. Partly due to technical requirements and partly because too many cooks share the kitchen (about 100 people actively work on the standard), 802.11n is vastly more complicated than 802.11a or 802.11g, and it includes changes to both the MAC and the PHY layers.

With an increased variety of platforms now supporting WiFi and looking to upgrade to MIMO, the IEEE 802.11 committee had to address multiple contending requirements. For example, the requirement for higher throughput may in some cases be in conflict with the requirement for power conservation and backward compatibility. With so many different requirements, the emerging standard now has many options for basic operation such as beamforming, MCS selection, greenfield mode, and coexistence. The MIMO industry needs sophisticated test solutions that will ensure successful deployments and happy users. T&MW

Throughput and packets

Throughput is a function of packet size—the longer the packets, the higher the throughput. The shorter the packets, the more effect packet headers and interpacket gaps have on throughput.

The industry likes to specify throughput using the maximum packet size, and 802.11n has increased the maximum packet size through aggregation techniques in order to achieve the increase in throughput over legacy networks. IEEE 802.11n's 100-Mbps minimum throughput is specified using the maximum packet size.

Fanny Mlinarsky *is president and principal consultant at octoScope, a consulting company focusing on wireless and RF product design and advocacy. In 2001, she founded Azimuth Systems and served as the company's chief technology officer for five years. Before founding Azimuth, she managed the Agilent Handheld Cable Testers and Network Troubleshooting Tools business unit. fm@octoscope.com.*

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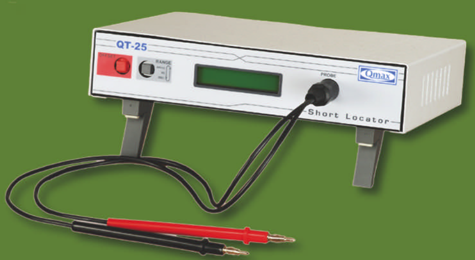

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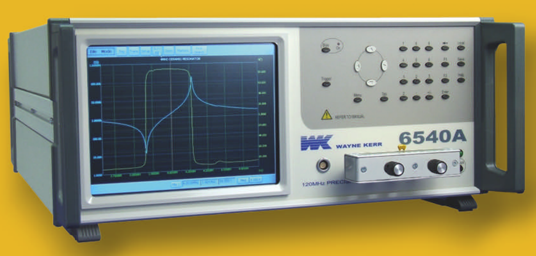

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Courtesy of Edmund Optics.

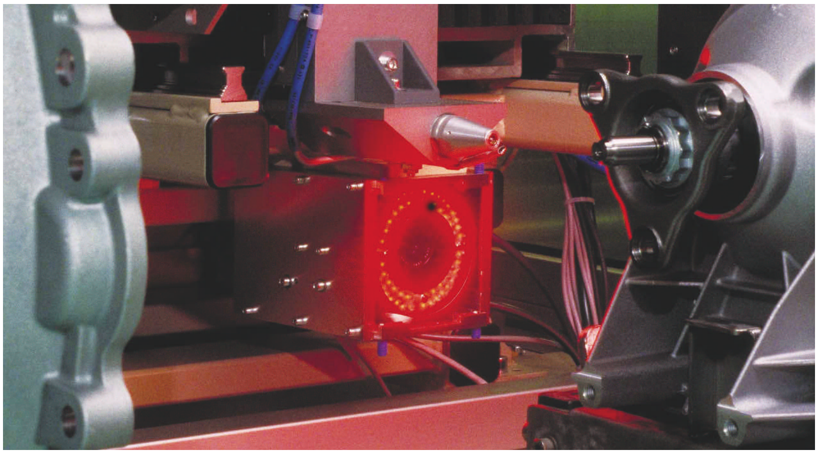
System integrators and vendors of vision systems can help you define the requirements for an inspection system.

SPECIFYING a vision system

JON TITUS, CONTRIBUTING TECHNICAL EDITOR

Your boss has given you a new assignment: Design a vision system to inspect a product that will soon go into production. You might decide on a "jump-start" approach and quickly gather information about cameras, lights, and other hardware. That route may lead to a dead end.

Vision systems can be configured in various ways, and image data can be processed by a PC, a programmable logic controller (PLC), a smart camera, or a vision system itself (**Figure 1**). In addition to choosing a camera and lens with the necessary resolution, you also need to light your setup properly and select an interface for transferring image data. The best path to choosing the right components begins with an evaluation of your product and your production line.



A vision system's camera and lights must fit within existing space on a production line. In this instance, the system supplies a ring light around the camera to provide uniform direct illumination. Courtesy of Cognex.

"Before engineers consider specific vision products, they must have clear and unambiguous written specifications that describe what they want a vision system to do," said John Agapakis, head of product management for the Siemens Vision Center of Competence. "Some engineers ask us about vision equipment, but they have not yet examined a defective part. So, they don't know what a failed product would look like or what steps in their process might cause failures. Without that information, it becomes difficult to successfully assemble a vision system."

If a vision system must make basic gauging measurements or determine the presence or absence of components, engineers can quickly agree on what dimensions or characteristics distinguish a pass or a fail condition. "But when vision systems must find small defects, engineers require a database of accurate images that show good, bad, and marginal products," explained Steve Cruickshank, principal product marketing manager for PC vision products at Cognex. "From an inspection standpoint, that's half the battle—getting an agreement about what good or bad products look like and what defects make a product bad. If engineers plan to identify marginal defects, they must specify which of these 'defects' they can accept and which ones they must reject."

"Most of the time, people start with a few sample images, but the more images they can provide, the better they can identify problem products," said Cruickshank. "We ask a customer's engineers to review the images and visually separate the good products from the bad. Before we can assist customers, we need a fixed set of test images."

Agapakis of Siemens noted that images provide a good start. Often, though, vision-equipment vendors and vision-system integrators must work closely with human inspectors to quantify their knowledge. That type of information, gained from years of experience, can prove critical for distinguishing good, bad, and marginal products.

Take a test drive

Most vendors of vision equipment can perform feasibility studies that help engineers determine whether they can inspect for each characteristic or defect they specify. These studies usually involve sending a vendor samples of good, bad, and marginal products. Depending on the vision products or systems a vendor offers, the report from a study may recommend specific camera types, light sources, controllers, mounting configurations, and so on. Vendors also may loan equipment to engineers so they can perform tests in their own lab or on their production line.

System integrators can help companies that lack the capability to test cameras, lights, and lenses under realistic conditions. Vision-equipment vendors usually work with several system integrators that may have had experience with a product similar to the type you want to inspect or that may have worked with companies in a related industry.

"The cost for an integrator's study can run from $5000 to $15,000," said Greg Hollows, vision integration partners coordinator at Edmund Optics. "That's a lot to spend, particularly if the results show you cannot achieve the results you expect. But you must ask yourself, 'Should I pay for a complete feasibility study, or should I buy vision equipment that may not fit on my production line or that may not work?'" Even if initial tests by an integrator fail, the integrator's experience may let it suggest alternative approaches.

ON THE WEB

The online version of this article contains links to additional sources of information about choosing cameras, lenses, light sources, and vision software. **www.tmworld.com/2007_04.**

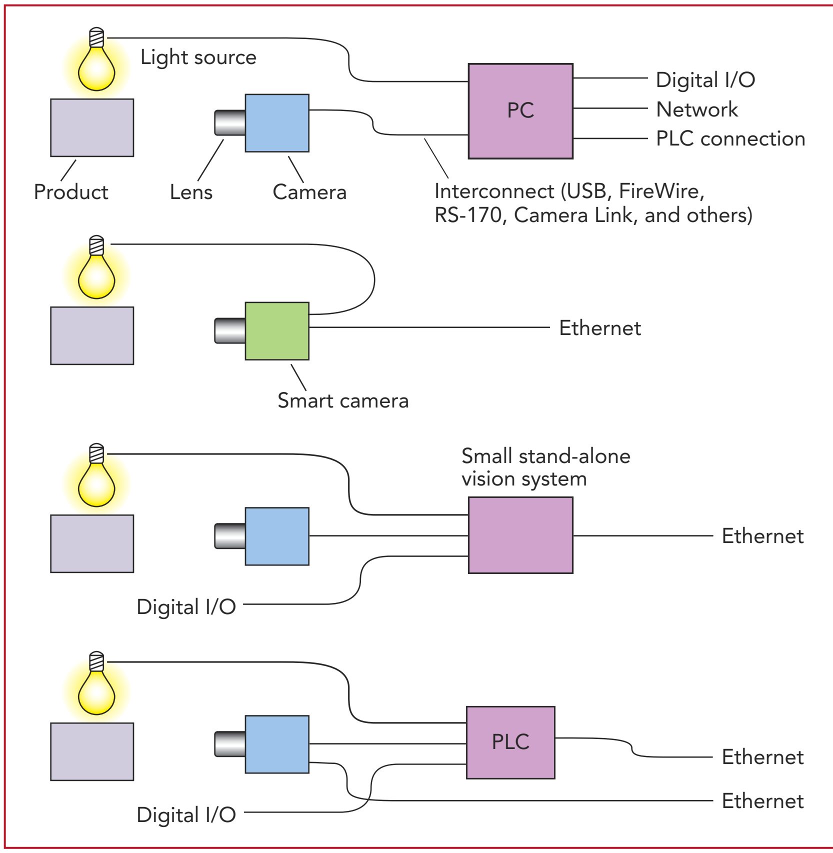


FIGURE 1. Engineers can put together vision systems in a variety of ways, four of which appear here in simplified form. A complete system may combine these approaches to inspect products at several points along a manufacturing line.

Hollows recommends engineers start vision-system planning concurrent with the design of production equipment. "I get calls from people who want to put a vision system on an existing production line or in production machinery well along in design. In some cases, the machinery has only small openings or constrained mounting arrangements that make it difficult or impossible to include a camera, lens, and lights."

Inspection of a PCB, for example, may require special lights that illuminate a PCB from several angles and require considerable space. "Engineers must leave space in their production machinery to accommodate vision components," said Hollows. "You just can't add them as an afterthought."

According to Cruickshank at Cognex, one customer defined an inspection task that required a camera mounted a significant distance from products undergoing inspection. The new vision system detected failures that operators could not trace to a specific defect, so they needed to find the cause of the false rejects. "They looked at the images and saw during the inspections someone had put their hand between the camera and the products. No matter how good the vision system, software tools can't perform an inspection if someone blocks a part."

Round up image specs

As engineers evaluate the requirements of their vision system, they must consider the type of camera and lens an application demands. "Often engineers want to purchase a camera right away," said Matt Slaughter, vision product engineer at National Instruments. "But camera selection should come later in the development process. Your system requirements should determine the type of camera you choose, not the other way around."

To start, camera and lens choices depend on the field of view and resolution. Field of view simply describes the dimensions of the areas you need to inspect.

Charge-coupled device (CCD) sensors used in area cameras usually have a 4:3 aspect ratio—the ratio of the sensor's horizontal to vertical dimension. Thus, engineers must determine how well an image of their product will "fit" in the camera's sensor. In some cases, say for a long narrow product or a cylindrical product, several area cameras or a line camera will provide better images. A line camera builds up an image one line at a time as an object moves by it or rotates in front of it.

Resolution defines how well you can see the smallest objects in an image. Say you have a PCB on which you must inspect 0402 (0.04x0.02-in.) surface-mount components. Your camera should capture at least two or three pixels along the smallest edge to create enough information for your vision software. (Some imaging experts would argue for sub-pixel techniques that extract edge information from a number of nearby pixels, but I'll stick to basic concepts here.)

So, assume you need three pixels along a 0.02-in. component edge, or 150 pixels/in. Thus, if you must examine 0402 components across a 6x6-in. PCB, you will need a camera with at least a 900x900-pixel CCD sensor—well within the capabilities of an SXGA-resolution camera with a 1240x1024-pixel sensor. But if you have a larger PCB, say 12x18 in., you may need to use several area cameras, a higher-resolution megapixel area camera, or a motion system that moves the large PCB across one camera's field of view. If you plan to examine the quality of solder joints rather than just locate component edges, you will need much higher resolution to bring out joint details.

How fast do you need data?

"Some people may need one image every few seconds, while others may need to inspect 100 to 1000 images per second," said NI's Slaughter. The total amount of image data, obtained by multiplying the number of pixels per image by the number of images per second, determines a minimum bandwidth." (Keep in mind one pixel "creates" from 8 to 12 bits of monochrome information or 24 bits or more of color information.)

Bandwidth requirements determine the interface your system will use to transfer image information to a computer; options include RS-170, USB, FireWire, Camera Link, Ethernet, and Gigabit Ethernet (GigE). If bandwidth requirements exceed the capability of an interface or of a host PC, consider using smart cameras or vision sensors that can perform analysis and metrology functions prior to sending image information to a host computer. Also, you could give some inspection tasks to a small vision PLC that will manage cameras, process images, and report results to a larger computer.

FIGURE 2. A ring light attached to a camera illuminates the bottom of a bottle so an inspection system can check for cracks or other defects. Courtesy of Advanced Illumination.

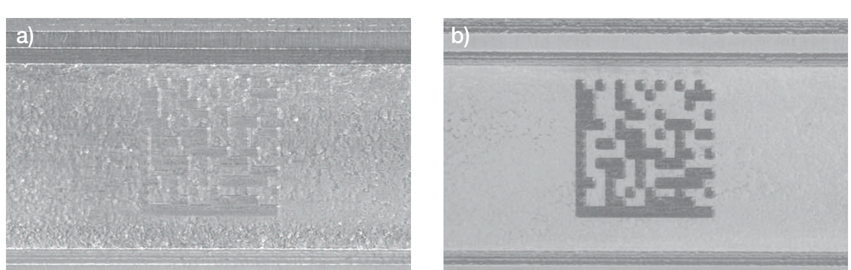
When engineers evaluate a camera interface, they must balance the cost of the cables against performance requirements. Although Camera Link cables offer a high bandwidth—5.44 Gbps—they are expensive and span only about a 10-m distance. (Fiber-optic links can extend the distance: A 100-ft link costs about $1800.) In contrast, a camera that operates over a GigE connection can use standard Cat-5e or Cat-6 cable that costs under $0.20/ft, and a GigE connection can run at least 100 ft.

"Due to the nature of GigE communications, remote triggering presents a synchronization problem," noted Slaughter. "So, engineers might decide to trigger and synchronize a remote camera via the camera cables. Typically, though, a remote GigE camera would rely on a small nearby proximity sensor to sense an object and trigger the camera and the lights." It proves almost impossible to synchronize a network of GigE cameras over a nondeterministic GigE network.

Lights accompany cameras

Like cameras and their interfaces, light sources require thorough evaluation, too. Mike Romano, laboratory manager at Advanced Illumination, commented that engineers must run feasibility studies on lights just as they do for cameras and lenses. "It's a huge oversight to design lights into a vision system without ensuring they work for the camera you expect to use and the product you must inspect," he said. "Suppose you have purchased a red-LED light source and you plan to inspect red printing on a label. The spectral response of a CCD camera may not let it detect the red characters. You don't want to discover that at the last minute." And improper lighting can decrease contrast so much that engineers can't extract useful information from an image.

Most companies that supply lights for vision systems offer engineers evaluation or demo units—and advice. "If engineers tells us they want to examine PCBs for missing components, based on our experience we can suggest several types of suitable lights," said Romano. "Or the



a) A Data Matrix symbol formed on a textured surface appears as a gray blur when illuminated with a ring light. b) The same symbol produced a high-contrast image when illuminated with a diffuse on-axis light. Courtesy of Siemens Energy & Automation.

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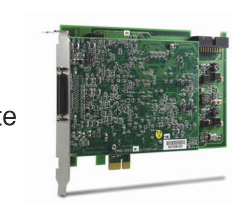

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engineers can send us good, bad, and marginal PCBs so we can make a preliminary evaluation, report our findings, and send back test images. The engineers can run the images through their software to ensure it finds what they want—characters, components, colors, and so on." To start the test process, engineers fill out a questionnaire on the Advanced Illumination Web site and send it to the company along with sample products.

Local conditions also affect light choices. "Some engineers use infrared [IR] illumination in places where bright or flashing lights might bother people," said Romano. But IR light has a drawback: It can diminish color contrast to the point that a monochrome camera "sees" red and green or red and yellow as the same color.

Some applications may require two or more sets of lights so a vision system can acquire several images of a product for different purposes. Diffuse lighting, for example, would light a product from many angles to produce a shadow-free image and reveal defects on angled or curved sides. Coaxial illumination would light a product from above to highlight front surfaces. Backlights provide high-contrast product outlines for gauging applications. And a ring light (**Figure 2**) produces uniform shadow-free illumination from all angles around a camera. This type of light source also can illuminate objects in wells or holes in a product.

Don't forget ambient conditions

Ambient light may play an unexpected role in inspections. Cruickshank of Cognex explained, "In one application, sunlight from a skylight interfered with the inspections as the sun moved throughout the day and the inspection system tried to deal with the effect of changing light conditions." Engineers can establish a constant light intensity, perhaps in an enclosure, to overcome problems with changing ambient light.

Some applications require engineers to reproduce a vision system for use on several production lines. They can work out any problems or bugs on one line and then transfer their knowledge and experience to the others. "Engineers must ensure their system is robust and not fragile," remarked Cruickshank. "You don't want a system to 'just work' on the first production and then fail on the next line, even though you bought the same camera, the same lens, and so on. Subtle differences can cause a duplicate system to fail."

Cruickshank recommends engineers slightly vary the lighting, defocus the camera, move the camera, change exposure time, and so on to determine if and how the changes affect performance. Use good engineering techniques to ensure your system doesn't operate on the "edge" of equipment tolerances. In the end, engineers may have to adjust their inspection priorities. He explained, "You want a vision system that reliably performs a few tasks all the time rather than a system that works half the time and tries to do too much." T&MW

MACHINE-VISION & INSPECTION

TEST REPORT

QFN devices require x-ray inspection

Steve Scheiber, Contributing Technical Editor

Quad-flat-pack no-lead devices (QFNs) attach to boards in different ways from conventional quad flat-packs (QFPs). Manufacturers have to inspect boards with QFNs differently as well. I asked Jeremy Jessen, technical marketing engineer at Agilent Technologies in Loveland, CO, to discuss the impact of no-lead devices. During our discussion, Jessen explained that QFNs not only offer space savings, but they also demonstrate superior electrical and thermal characteristics.

Q: How do QFNs make contact with boards?

A: By soldering an exposed metallic pad beneath the package body to the printed-circuit board instead of using leads around the device perimeter.

Q: How do QFN failure mechanisms compare with those of QFPs?

A: QFPs are leaded devices, where the leads are soldered to the land pattern on the board. Most QFP failures occur at the leads—such as insufficient solder or lifted leads. Sometimes the solder wicks up to the top of the lead during reflow, causing a short.

Because QFNs have no leads, there are no leads to fail, although a pad might still contain insufficient solder. Excess solder on the pad might cause the device to tilt. In that case, one side would show very strong joint formations, while the other side shows nothing but opens.

Q: How do people inspect the boards in each case?

A: Boards with typical leaded devices can use either optical or x-ray inspection. Non-leaded devices like QFNs have limited to no line of sight, so they require x-ray inspection.

Inspection of leaded devices is fairly simple. Leaded-device solder fillets are fairly uniform and include a heel, a center, and a toe. The heel sits relatively high on the board. The solder drops down at the center, then rises again (although not as much) for the toe. The inspection step compares these relative heights. A higher-than-normal center could denote a lifted lead. A joint's wicking characteristics determine whether it is wide enough, so measuring length alone will verify sufficient solder volume.

QFN solder joints don't all look the same. Depending on the type of pad on the QFN, a joint might form a large toe outside the perimeter of the package, while other types form a joint beneath the package. The heel, center, and toe may be the same height, forming a solder plateau.

Jeremy Jessen
Technical Marketing Engineer
Agilent Technologies
Courtesy of Agilent Technologies

Inspection systems measure the length and height of each component of the joint, but they also measure the width of each section by looking across the joint at gray levels per pixel in the x-ray image. Too narrow a center might mean an open. Comparing the measurement results to an "average" ideal (with appropriate tolerances) decides pass or fail.

Q: How has the switch to lead-free solder affected failure characteristics?

A: In the examples we have seen, wicking behavior generally didn't change much. Open joints are not as flat as with leaded solder, showing more of a peak. We do experience a significant increase in the number and volume of voids in the solder. If the voids represent no more than about 10% of the total solder volume, we don't call it a fault, but we would fail a joint with 20% voids. Some x-ray systems can misinterpret the information from the voids, calculating solder heights too low and inappropriately failing some good joints as open. We compensate for the voids to reduce that effect. □

INSIDE THIS REPORT

EDITOR'S NOTE

Inspection continues to grow

Steve Scheiber, Technical Editor

No one can argue that the demographic of "test" strategies has continued to change for three decades. Test—once treated as the poor relation in a manufacturing operation—has taken on critical significance as a way to improve product quality and (to the surprise of many managers) reduce costs.

More recently, inspection has emerged as a legitimate component of most test strategies. When first implemented, inspection and "pure" test often resided in different parts of an organization, with inspection part of the manufacturing group. Conflicts arose. If test took over inspection duties, inspection staff members would lose their jobs.

Those concerns have receded. Today, inspection plays an increasingly critical role in the overall process. Certainly interest in the subject has exploded in recent years. *Test & Measurement World* initiated this test report as a semi-annual event. A few years ago we increased its frequency to quarterly. With this issue, we have officially gone bimonthly.

The principles of inspection haven't changed since the job was performed by humans wielding magnifying lenses and microscopes. Some optical and x-ray systems still require constant human oversight. Some players in the industry have changed or merged, some of the early adopters remain, and new participants constantly add their own expertise to the mix. □

Contact Steve Scheiber at sscheiber@aol.com.

HIGHLIGHTS

New version of Camera Link on tap

The Automated Imaging Association (AIA), which maintains the Camera Link standard, reports that the Camera Link committee has approved two annexes to the standard. Annex D adds electrical descriptions, allowing manufactures to create cables optimized for varying combinations of length, diameter, and flexibility. It also defines a connector that permits Camera Link to be integrated into miniature and remote-head cameras.

Annex E provides an optional feature for powering and controlling the camera using a single cable similar to USB and FireWire. Called Power over Camera Link (PoCL), this capability eliminates the need for a separate power cable while providing full backward compatibility for systems that do not use PoCL.

Both annexes are part of Camera Link 1.2, which the AIA expects to release later this year as version 2.0. Winn Hardin, an AIA contributing editor, has posted a full explanation of the new annexes on the AIA Web site. www.machinevisiononline.org.

Apparatus portends faster STMs

A nanoscale apparatus developed by JILA (a joint venture of the National Institute of Standards and Technology [NIST] and the University of Colorado at Boulder) offers the potential for a 500-fold increase in the speed of scanning tunneling microscopes (STM) and may make it possible for scientists to watch atoms vibrate in high definition in real time. The device measures the "wiggling" of the beam by measuring the space between the beam and an electrically conducting point just a single atom wide, based on the speed of electrons "tunneling" across the gap.

NIST says that other methods may be more precise at measuring very fast motions of ultra-small devices, but the new technique can minimize unwanted random electronic "noise" as well as measure the random shaking of the beam caused by back-action or recoil. The beam's undulations were measured with tens to hundreds of times greater precision than a typical STM result. This level of sensitivity is possible because the atomic point contact acts as an amplifier for the otherwise imperceptible factors, and the gold beam is tiny and floppy enough (100 nm thick, 5.6 mm long, and 220 nm wide) to respond to single electrons. www.nist.gov.

CALENDAR

- **International Robots & Vision Show**
  June 12–15, Chicago, IL
  Automated Imaging Association and Robotic Industries Association. www.machinevisiononline.org.

Dalsa extends GigE camera family

Dalsa has expanded its Genie family of GigE Vision-compliant digital cameras with three models in the compact Genie HM Series. The Genie-HM640, HM1024, and HM1400 capture image data at speeds to 295 frames/s in VGA resolution or 60 frames/s at 1400x1024-pixel resolution.

The Genie HM cameras have a high-speed sensor and can transmit data over standard Cat-5e and Cat-6 cables to distances of up to 100 m. The cameras are supported by Dalsa's Sapera Essential machine-vision software that bundles image acquisition and control with image-processing tools. When a camera is connected to the system, the Genie Framework software facilitates application integration and setup by identifying the camera and communicating with the Sapera Essential environment. www.dalsa.com.

POWER READER

DataMan 100 — the world's smallest high-performance ID reader

Cognex introduces the remarkable DataMan™ 100 ID reader for identifying items marked with 1D or 2D codes. This powerful fixed-mount reader delivers outstanding code reading performance. Plus it's fast, simple, and smaller than a flip phone.

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COGNEX

Infrared inspection benefits from image subtraction

Steve Scheiber, Contributing Technical Editor

Most inspection techniques examine electronic devices and printed-circuit boards (PCBs) while they are in an unpowered state. Infrared inspection takes a different approach, requiring that circuits emit heat, which means the device or board must be operating at some level.

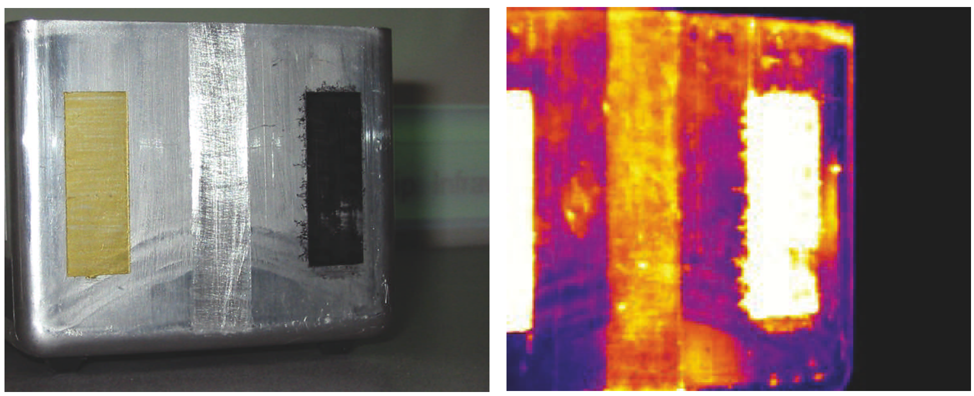
Infrared inspection can provide information about the board operation that an automated optical inspection (AOI) system can't see. Insufficient solder, for example, increases circuit resistance at the solder joint and therefore raises the temperature sufficiently to be detected by an infrared camera.

Also, a faulty circuit will exhibit a different temperature profile from a good one. Comparing the circuit's behavior with the corresponding behavior of a known-good equivalent (either a real one or a simulation) reveals whether the circuit should pass or fail.

Like many theories, however, this one makes several assumptions. Most significantly, it assumes that the way in which a circuit emits infrared radiation is both known and predictable. The validity of that assumption depends on the materials and techniques used in the circuit's construction.

Of particular concern is the efficiency with which the circuit emits infrared radiation (emissivity) when compared with a theoretical "black body." The left side of the **figure** shows an object made of several materials and with varying degrees of surface roughness. The right side of the figure shows a corresponding IR image made while holding that object at a constant temperature. The differences in emitted radiation result from variations in emissivity.

PCBs consist of a substrate and numerous individual components made of a variety of semiconductor materials exhibiting a range of emissivity values from reflective to flat black. How, then, can you measure temperature gradients accurately and reliably in this non-homogeneous environment? Ideally, you would need to know the actual emissivity at every point on the board.



The object on the left includes several materials and varying degrees of surface roughness. The infrared image of the object clearly shows differences in emissivity. Courtesy of Flir Systems.

Increase system accuracy

Chris Bainter, scientific segment engineer for Flir Systems, explained how manufacturers address this problem. "Some manufacturers literally paint the board black during board development to increase the accuracy of the results, but that approach would prove unacceptable during routine production," said Bainter. "Other companies construct a 'black box,' putting the infrared camera and the board under inspection inside it. Aside from the need to compensate for the heat generated by the camera in that enclosed space, the approach is expensive and time-consuming."

Another technique uses "image subtraction," in which the infrared inspection system software creates a thermal baseline representing an ideal temperature profile, subtracting that ideal from the inspection results. Since the emissivity of a particular point on the board is unlikely to change much from one (allegedly identical) board to the next, the subtraction operation renders the differences largely irrelevant. Bainter noted, "Subtraction can occur directly in the camera as well as in turnkey or custom-developed software. In this situation, the software can adjust the measurement results to compensate for varying emissivities across the board."

Like all test and inspection techniques, infrared inspection is not a panacea. Implementing it requires paying attention to both its principles and its limitations, as well as to the equipment available to make it work. □

FOR FURTHER INFORMATION

For an introduction to infrared inspection, see "Characteristics and use of infrared detectors," a 43-page pdf on the Hamamatsu Photonics Web site. sales.hamamatsu.com/assets/applications/SSD/Characteristics_and_use_of_infrared_detectors.pdf

Needed: New Thinking For Wireless/RF Testing

As the worlds of SoC and SiP converge, engineers require equipment with the flexibility to handle both architectures.

For years, engineers who test semiconductors have wrestled with the separate challenges posed by SoC (System on a Chip) and SiP (System in a Package). But increasingly those two sectors are coming together, creating a new, more challenging era that requires fresh approaches to testing.

This convergence stems in large part from the growth in multi-device SiP technology, which is permitting more and more applications to be integrated. Thus, denser SiPs are now showing up in the same application with highly integrated SoCs. Even a casual glance at industry trends, particularly in the consumer market, reveals the growth of crossover products that combine multiple technologies.

As a result of these developments, companies require faster RF multi-site testing at an ever lower cost. It is also prompting engineers to look for testers that can be quickly and easily reconfigured to address both SiP and SoC architectures. Yet available testers simply don't have the flexibility to address both architectures. Result: Independent device manufacturers (IDMs) and sub-contract manufacturers (SCMs) are being forced to live with ever more complex testing setups and, consequently, a reduction in overall equipment utilization.

Unless the industry can solve this new dual-testing challenge, chipmakers will face ever higher investments in testing, declining utilization of testers and steady increases in the cost of ownership (COO).

$$\text{COO} = \frac{\text{ATE Cost (CapEx + OpEx)}}{\underset{>90\%}{\text{Yield}} \times \underset{>80\%}{\text{Utilization}} \times \underset{2x,\ 4x,\ 8x\ +\ \text{(multi-site)}}{\text{Throughput}}}$$

Figure 1: RF multi-site testing can easily double or quadruple throughput. This immediately lowers your cost of ownership by 50% or 75% respectively.

Answers to the SoC-SiP Test Dilemma

Getting a grip on this problem requires an understanding of the dynamics and drivers of testing. Because the tester is the ultimate focus of the testing process, it is often assumed, incorrectly, that it is the dominant contributor to the test cell's overall COO. However, it is rarely that simple. In fact, three key elements contribute to a test cell's COO -- the tester, the handler and the equipment integration. In this case, integration includes the method of docking, design and construction of the performance board, test program generation, and the overall meshing of all these elements into the production environment.

Vendors often specialize in only one of these three areas due to the overall complexity of the test problem. For example, companies tend to be experts either in the complex mechanical components of the handler or in the custom software and signal integrity challenges of the tester. But those intent on solving their COO challenge must understand the interrelationship among these three vital areas, and be able to sort out the most critical elements.

Advantest's new T2000LS OPEN-STAR®-compliant test solution is designed with compact, modular features that companies need to effectively test high-functionality SoC consumer devices.

There are several avenues to reducing cost of ownership in this new SoC-SiP environment. Among the major steps:

- Develop system level testing, either bit error rate (BER) or error vector magnitude (EVM) to replace parametric testing (IP3, noise figure, IQ imbalances).
- Develop a dual-insertion test strategy.
- Improve the indexing time and multi-site efficiencies of the handler.
- Develop scalable, flexible docking/load board technologies.
- Optimize test programs.

- Develop RF multi-site testing capabilities to improve throughput.

Impact of Multi-site RF Testing

Although all these steps can contribute to reduced COO, the factor with the greatest potential impact and the one that is most critical to wireless/RF testing is development of RF multi-site testing. Enhanced capability here can provide tremendous "bang for the buck," dramatically lowering the COO.

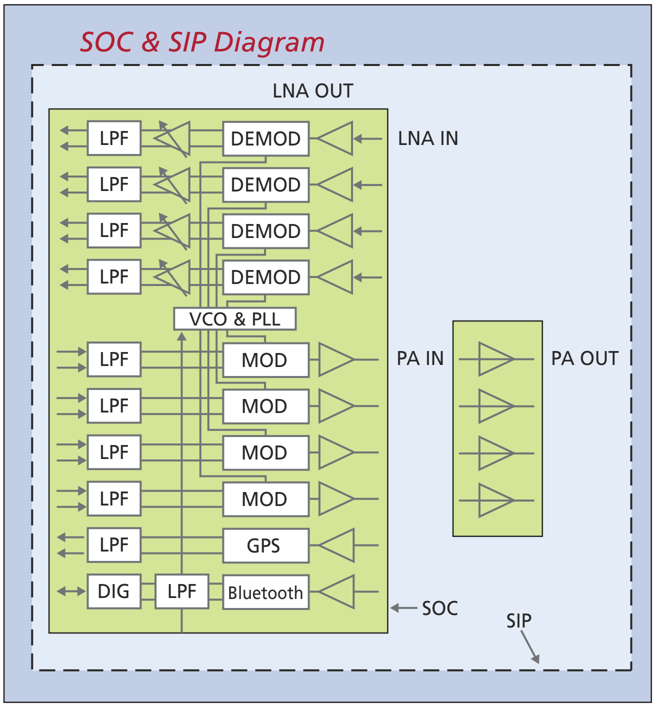
It's a matter of simple math. Given that all other factors are equal, effectively increasing the number of devices under test (DUT) by implementing RF multi-site testing can easily double or quadruple throughput. This immediately lowers your COO by 50% or 75% respectively (see figure 1 for a simplified COO equation). While it is possible to improve COO by improving yield or utilization, the gains are incremental compared to multi-site throughput.

Of course, such tremendous benefits are easier to envision than to achieve. RF multi-site testing is a complex proposition. It isn't just a matter of enabling a second, third or fourth site on the tester. High frequency signals complicate the handler and docking tasks needed to ensure signal integrity. Highly skilled RF engineers are usually needed to design the performance board, and previous manufacturing experience in building these items is critical to ensure success. Furthermore, site-to-site correlation issues could plague inexperienced board designers, test engineers and product engineers, which could have an adverse effect on yields.

In short, if not handled correctly, these challenges and risks can negate the potential benefits of RF multi-site testing, adding thousands of dollars in costs and slowing a production release cycle by months.

Still, the magnitude of the potential benefits of RF multi-site testing in reducing COO is too great to ignore. So, given the potential for greater than 50% savings on COO, ATE purchasers are going to look to ATE suppliers to overcome the challenges of multi-site RF testing when they deliver next generation RF/wireless testers.

Although it's a tall order, it seems like the time is finally right for test vendors to do just that. Harnessing their experience in related areas, there is no reason why not. Most of all, solving this problem is crucial to the advancement of the industry. And that's a fact that can't be ignored. ■



Engineers need testers that can be quickly and easily reconfigured to address either SoC or SiP architectures– or both. In this example, the SoC is a multiple input/multiple output GPS device, plus Bluetooth transceiver. The SiPs are the external PAs (power amplifiers) and the LNA path (low noise amplifier).

RF Multi-site Testing: The Next Wave

To preserve profitability, manufacturers need to trim their test costs. While RF multi-site testing once seemed practically impossible, experience with single function devices such as power amps shows the potential to master the problem.

Companies need RF multi-site capabilities for complex functions that might include Bluetooth, GPS, and other multi-frequency radio. Clearly, this approach will demand tremendous digital intelligence, as well as unprecedented adherence to a large number of signal parameters and variables.

To meet these industry requirements, developers of next generation test equipment will need to offer systems with multiple receivers so that testing of different capabilities does not have to be conducted serially.

This report is by Keith Schaub, an RF product engineer at Advantest America and the author of Production Testing of RF and System-on-a-Chip Devices for Wireless Communications.

FOR MORE INFORMATION

Advantest Corporation is a world leader in automatic test equipment for the semiconductor industry, and a leading producer of electronic and optoelectronic instruments and systems. Engineers can learn more about its comprehensive line of testers, handlers and mechanical/electrical interfaces by visiting: http://www.advantest.co.jp/products/ate/en-index.shtml

Calculate the costs of adding inspection to a test strategy

Steve Scheiber, Contributing Technical Editor

Choosing an inspection system to incorporate into a manufacturing line is primarily an engineering decision—you need to find a system with the capabilities that match your needs. Adding an inspection system to an apparently already effective test strategy, however, often represents more of an economic decision than an engineering one.

The reluctance of managers to add inspection equipment generally comes down to cost. To convince them to make the purchase, you must demonstrate that the expenditure will quickly pay for itself. Although preparing an economic justification may seem like a daunting task, making a few reasonable assumptions can simplify it considerably. The following discussion outlines the basic principles and offers a simplified example. Real-world analysis will require somewhat more rigor.

Consider a company making complex microprocessor-based boards in relatively high mix in a single manufacturing facility. The existing strategy consists of in-circuit test, functional test, system assembly, and system test. In the hope of finding more faults earlier—before defective products undergo expensive testing steps—you are considering adding an automated optical inspection (AOI) system prior to in-circuit test. How can you justify the purchase to management?

Consider the real costs

Any economic-justification model consists of three classes of costs:

- **Fixed costs.** Fixed costs occur only once in the model. They include the price of the inspection system, any site preparation (such as concrete platforms or installation of power conduits), and initial training costs. For simplicity, you can lump any items that come with the machine—spares kits, for example—with the purchase price.
- **Recurring costs.** These costs occur periodically, but not constantly. For example, maintenance costs fall into the recurring-cost category, as does the cost of spares to replace any parts consumed during equipment repair and any unanticipated downtime. Fixture and programming costs usually fall into this category. But with an AOI system, fixtures are primarily platforms that hold boards of various sizes, so their purchase can be considered a one-time cost, and in this case, I suggest bundling them with the system purchase price under "fixed costs." Because AOI system programs generally come from CAD files or by learning from known-good boards, you can assume either that the programming cost is small enough to ignore or that any programming cost at AOI is offset by savings at functional test.
- **Ongoing costs.** These costs are essentially continuous. Labor charges are calculated in cost per hour, but you can also state them as cost per half hour, cost per day, and so on. Board troubleshooting and repair at each step falls into this category, as does board scrap.

Ignore the irrelevant costs

In creating an economic justification that compares alternatives, you need to include only costs (and benefits) that change significantly depending on your final action. In adding inspection, the goal is to find more faults and find them sooner (and less expensively). You can assume that adding inspection will not change the boards' fault spectra or the failure rates out of manufacturing and that no failure caught by the existing strategy will escape the new arrangement. Also, because you should assume that any repairable boards are sent back through the system, the only products that result from the new process are good boards and scrap.

In essence, the existing process appears as a "black box" fed by manufacturing or by the new inspection

GENERAL ASSUMPTIONS

- The existing facility will accommodate the extra step.
- The cost of evaluating alternatives does not change regardless of what you decide and can be ignored.
- The fault spectrum from manufacturing remains constant.
- No fault that the test process found before adding inspection escapes the new version.
- The output from system test contains only good boards and scrap.

COST ASSUMPTIONS

- Facility costs–including rent or mortgage, property taxes, and security costs—do not change.
- Spares kits and site-prep costs can be lumped with the equipment price.
- The labor costs of the existing process remain constant. The only variation comes from operating the extra equipment.
- Recurring training can be grouped with the initial training and considered part of the aggregate "training costs."
- You can assume no significant change in the secondary damage caused by board repair.
- The scrap generated by board repair does not change because the fault spectrum does not change.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Calculate the costs • from page 59

step and generating output that ships to customers. Most costs from the existing process remain constant.

You can also ignore any costs associated with your analysis that do not depend on whether you add the inspection system. Evaluating your process with and without inspection is not free, nor is comparing costs and features of available inspection equipment, but you spend that money regardless of how you proceed.

In analyzing costs that *could* matter, you must separate likely effects from less likely ones that only complicate the model. For example, if adding an inspection step doesn't require building or moving to a new factory, then the aggregate facility (fixed) cost doesn't change. Your company may allocate such costs as mortgage, property taxes, and building security to each process based on the amount of floor space it occupies, but that breakdown is merely an accounting convenience. At the end of the day, the entire factory can neither expand nor contract in response to adding or removing process steps, so the overall cost remains constant.

Adding a piece of capital equipment like an AOI system will undoubtedly increase the facility's energy consumption, and therefore the overall utility cost for the entire factory. That cost tends to be small compared with other associated costs, and in many cases you can ignore it. If you expect the effect to be significant, however, include only the anticipated additional cost in your analysis. Baseline energy use does not change.

Similarly, include only the additional labor costs that the extra step requires. Labor costs for the existing process remain constant, and are therefore irrelevant for this purpose. The cost of devices consumed during board repair doesn't change because the fault spectrum doesn't change, and you can ignore that as well.

The **box** on p. 59 summarizes the general and cost-related assumptions, while **Table 1** (p. 62) presents the primary costs that remain.

Running the numbers

To see how adding an inspection system could save your company money over time, consider the following example. Suppose a manufacturer ships 100,000 boards per year with a manufacturing cost of $600. The existing process produces 1% or 1000 scrap boards per year worth $600,000 and therefore requires building 101,000 boards altogether. (These numbers are rounded for simplicity; a 1% scrap would actually require the manufacture of 101,010 boards to yield 100,000 good boards.)

Actual yield from in-circuit test (the actual number of good boards) before adding inspection is 94.4%, which means the tester is passing 5656 bad boards (including the 1000 that will be scrapped). Functional test yields 99.4% of the 100,000 boards that will actually be shipped, therefore excluding the scrap. This means that 4056 boards are repaired at functional test, and 600 bad

TABLE 1. COSTS TO CONSIDER WHEN EVALUATING AOI

Fixed	Occur once in this scenario	● Inspection system cost ● Cost of money (i.e., interest on loan to purchase equipment) ● Training costs
Recurring	Periodic, but not continuous	● Maintenance ● Spares ● Downtime
Ongoing	Continuous ("analog")	● Labor (of extra step only—include salaries and benefits) ● Additional utilities (if significant) ● Board scrap ● Cost of repair at ICT ● Cost of repair at functional test ● Cost of repair at system test

TABLE 2. COSTS PER YEAR WITH AND WITHOUT AOI

	Without AOI	With AOI
System cost (three-year life)		**$150,000**
Extra operators (per year)		$83,200
Training (per year)		$5,000
Maintenance and spares (10% of purchase price per year)		$15,000
Downtime (2% of purchase price per year)		$3,000
Added operating cost (excluding capital) per year		**$106,200**
Board scrap (at a value of $600 each)	$600,000	$300,000
Repair cost at AOI/ICT ($15/repair)	Baseline	1638 extra boards: $24,570
Repair cost at functional board test ($25/repair)	4056 boards: $101,400	2918 boards: $72,950
Repair cost at system test ($75/repair)	600 boards: $45,000	100 boards: $7500
Total repair and scrap cost without AOI	**$746,400**	
Total repair and scrap cost with AOI including additional operating costs		**$511,220**
Annual savings		$235,180
After taxes (35% tax rate)		$152,867
Depreciation savings (35% of $30,000)		$10,500
Total annual savings		**$163,367**

Calculate the costs • from page 61

boards will move on to system test, where they will get repaired.

Assume that you are planning to add an inspection system to a line with an anticipated three-year life. The AOI system costs $150,000 (including lumped costs). The addition of two operators at $20/hr (including benefits) adds another $83,200 per year. Training operators to use the system costs $15,000, which is allocated at $5000 per year. You could estimate annual maintenance and spares at 10% of the system purchase price (a common cost for a maintenance contract), or $15,000, and estimate extra downtime at 2% per year, or $3000. Thus, inspection will add $106,200 per year to the production cost, not counting the capital outlay itself.

Suppose the new strategy reduces scrap by half, to 500 boards, saving $300,000 per year, and therefore requires only 100,500 board starts to ship 100,000 boards. A 96.5% yield out of in-circuit test sends 3518 bad boards to functional test, compared to 5656 without inspection, which means that an additional 1638 are getting repaired at the AOI/ICT stage. A 99.9% yield of the shippable 100,000 boards at functional test (again, excluding the scrap) sends only 100 boards to be repaired at system test.

Repairing each board after either inspection or in-circuit test costs $15, rising to $25 after functional test and $75 after system test. As **Table 2** shows, the inspection system, in theory, reduces aggregate annual test costs by more than $235,000.

Actual results are a bit less rosy. The savings is subject to income tax. Assuming a corporate 35% tax rate, the result is a still-considerable $152,000. The tax code also permits depreciating the equipment over five years (irrespective of the anticipated three-year life for the project), reducing the part of the benefit subject to tax by $30,000 per year and therefore adding 35% (the tax) of $30,000, or $10,500, to the after-tax benefits. So, the original $150,000 cost of the system would generate $163,367 of actual annual savings, a justifiable expense to any corporate manager, since the system would pay for itself in less than a year.

Other factors, such as the opportunity cost (the cost to borrow the money for the equipment or the "interest rate" it would earn on another project) and the cost of false failures would add to the analysis, but this calculation serves as a first approximation.

Knowing that you want to make a capital purchase will not generally convince your company comptroller to sign the check. A justification showing the bottom-line impact of the expenditure will likely elicit a more favorable reaction. □

FOR FURTHER INFORMATION

Scheiber, Steve, "Justifying inspection in a test strategy," Machine-Vision & Inspection Test Report, *Test & Measurement World,* November 2005. www.reed-electronics.com/tmworld/article/CA6277925.html.

PRODUCTS

Remote camera offers interchangeable heads

Toshiba's IK-TU51 remote-head digital color camera system works with interchangeable ⅓-in. and ½-in. image sensors. The IK-TU51 delivers up to 800 lines of resolution and provides real-time imaging with 10-bit digital signal processing and a 64-dB signal-to-noise ratio. Frame memory allows continuous video imaging in integration mode. The imager also offers a freeze-frame function and user-selectable triggering. It is available with an RS-232C interface, both LVDS digital and RGB analog outputs, and a C-mount lens flange. *Toshiba America, www.cameras.toshiba.com.*

Smart camera debuts

Vision Components has introduced its VC4472 smart camera, which includes a 1.125-in. CCD sensor with a 1600x1200-pixel resolution and a maximum frame rate of 10 fps (20 fps in binning mode). Incorporating a 1-GHz, 8000-MIPS Texas Instruments DSP, the VC4472 features an 8-bit color overlay that can operate in opaque or transparent mode. The standard unit includes an RS-232 and an Ethernet interface, an external trigger input that enables jitter-free image recording, and a high-speed encoder interface. In addition, the smart cameras come with 4-Mbyte flash EPROM and 64-Mbyte SDRAM. *Vision Components, www.vision-components.com.*

ID reader handles 1-D and 2-D codes

Smaller than a flip phone, the new DataMan 100 fixed-mount ID reader from Cognex reads codes ranging from printed bar codes to 2-D direct-marked codes. The reader uses IDQuick software, a Cognex decoding tool for fast reading of well-formed codes. All DataMan 100 readers offer integrated illumination, a beeper, adjustable optics, a built-in aimer, and a push-button trigger. The DataMan 100 can identify an expanding list of 1-D and 2-D codes, including UPC/EAN/JAN, Code 39, Code 128, Code 93, Interleaved 2 of 5, Data Matrix, QR Code, and microQR Code. *Cognex, www.cognex.com.*

High-res camera sports GigE interface

Based on a Kodak KAI-4021 progressive-scan CCD sensor, Prosilica's GE2040 vision camera runs 15 frames/s at 2048x2048 resolution over its Gigabit Ethernet interface. Monochrome and color models are available with either a C mount or F mount. The camera provides external trigger and sync, general-purpose I/O, region-of-interest readout, various binning modes, and direct RGB24 output. The camera works with Prosilica's software-development kit as well as with third-party software from Matrox and National Instruments. *Prosilica, www.prosilica.com.*

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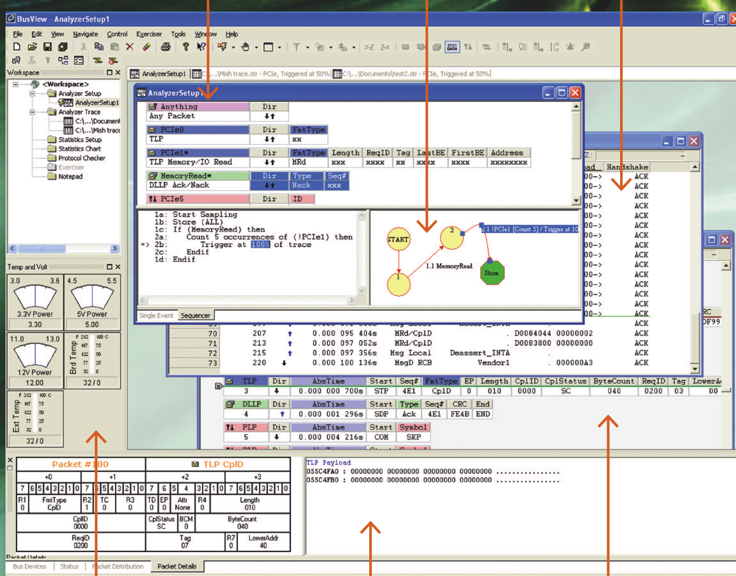

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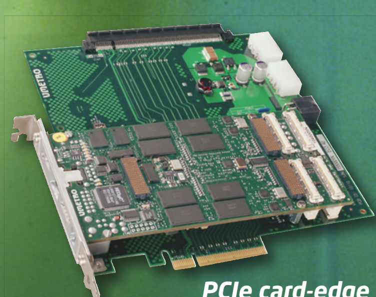

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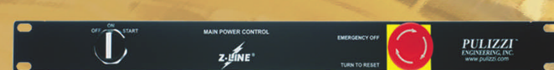

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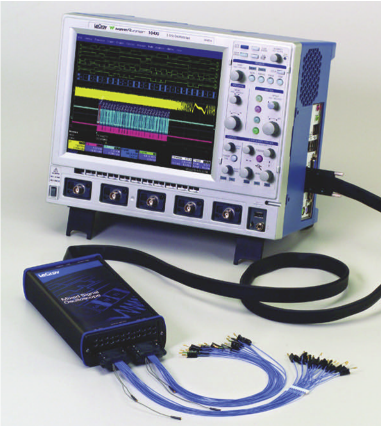
Oscilloscopes add 18 or 36 logic channels

LeCroy's WaveRunner Xi and WaveSurfer Xs oscilloscopes now have options that add 18 or 36 logic channels—two more channels than most mixed-signal scopes. The extra channels let you view an 8-bit or 16-bit bus, a clock, and a read or write strobe.



The MS-500 and MS-250 options add different speed and memory depth to new or existing scopes. The MS-500 ($3990 for 18 channels) works with digital signals up to 500 MHz (sample rate of 2 Gsamples/s) with 50 Mpoints of memory per channel. You can double the number of channels with the MSO-DLS-36 option ($990), which will interleave the channels to provide 250 Msamples/s, 1 GHz, and 25 Mpoints per channel. The MS-250 ($2990) adds 18 channels with 1-Gsamples/s sample rate, 250-MHz maximum signal speed, and 10 Mpoints of memory per channel.

You can trigger an acquisition on any analog or digital channel. Trigger types include edge, glitch, width, pattern, qualified, interval, or dropout. *LeCroy, www.lecroy.com.*

Combining functional and in-circuit test

CheckSum's Analyst ems+ft system combines in-circuit test (ICT) and functional test to target OEMs and contract manufacturers building power supplies, automotive electronics, medical electronics, industrial-control modules, and consumer products. The Analyst ems+ft enhances the low-cost advantages of the Analyst ems ICT platform with an integrated stimulus, measurement, and switching capability packaged in an integrated system.

At the heart of the functional side of the system is a second-generation, general-purpose, functional-test subsystem, which includes a true differential digital multimeter (DMM); a counter/timer; a function generator for sourcing DC, sine, and square waves; and digital I/O bits. The system supports standard GPIB (IEEE 488) and USB 2.0 interface buses. CheckSum's open architecture allows integration with functional-test software such as National Instruments' LabView and LabWindows/CVI as well as Microsoft's Visual Studio.

On the switching side is an ICT/high-voltage analog hybrid switch card, which provides 50 test points per card. Each test point is capable of handling up to 250 VAC (rms).

Base price: approximately $75,000 for an Analyst ems+ft equipped with 1000 ICT points, 200 in-circuit/high-voltage analog (hybrid) points, and modular GPIB power supplies. *CheckSum, www.checksum.com.*

Startup debuts two probe systems

Targeting known-good-die (KGD) applications, SemiProbe has announced two probe systems—the semiautomatic SA-8 and fully automatic FA-4—which allow testing of diced wafers on a stretch frame at production speeds. The company also announced the M-12 300-mm manual probe system. Both automated versions use high-speed pattern recognition to obtain the x, y, z, and theta position of all singulated die on the stretch frame prior to probing. The systems can scan more than 80,000 die positions in less then four minutes; probing begins after scan.

The M-12 300-mm manual system has a rapid-release feature that allows a user to quickly and easily navigate across a wafer with a single movement, re-engage a lead screw, and make fine adjustments using micrometer dials.

Base prices: SA-8—$55,000; FA-4—$138,000; and M-12—$65,000. *SemiProbe, www.semiprobe.com.*

Measure Foundry works with all test instruments

Measure Foundry 5, formerly DT Measure Foundry, has expanded its I/O capabilities beyond Data Translation hardware. The software uses VISA to send commands to instruments such as digital multimeters (DMMs), oscilloscopes, function generators, spectrum analyzers, RF generators, and power supplies. I/O buses include IEEE 488, USB, VXI, PXI, and LXI. You can write VISA scripts that send SCPI commands to any instrument and receive measurement results.

Once you build a VISA script, you can use a feature called Process Component to build applications. Scripts may contain conditional loops and branches,

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and you can develop multithreaded applications, with each thread running independently.

Measure Foundry 5 comes in two editions: Basic and Professional. Both let you develop a full range of applications. The Pro edition lets you compile your applications into stand-alone executables.

Base price: $1995. *Data Translation, www.measurefoundry.com.*

Detect PCB defects on power, ground pins

The Agilent Medalist VTEP v2.0 suite of vectorless test techniques includes a new network parameter measurement technology, which allows users to detect opens on power and ground pins on connectors. Targeting applications having PCI Express, DDR, and SATA connectors, the VTEP v2.0 technology maximizes signal integrity while limiting bit-error rate (BER) and radiated electromagnetic interference (EMI).

VTEP v2.0 preserves the original VTEP vectorless-test technology as well as iVTEP, which is targeted at ultra-small integrated circuit packages with minimal or no lead frames. VTEP v2.0 employs the same hardware as the original VTEP; therefore, no hardware upgrade is required.

Base price: free on all Agilent Medalist i3070 systems and to existing Agilent in-circuit test customers holding software-upgrade contracts. *Agilent Technologies, www.agilent.com/see/vtep.*

System tests gate charge and gate resistance

Integrated Technology has introduced the ITC59100 production test system for gate charge (Q_G) and internal gate resistance (R_G). The system automatically tests both Q_G and R_G according to programmed parameters, and it can report the values of R_{DS} ON and gate input capacitance.

The ITC59100 can test up to four separate devices in parallel with no multiplexing, at test times of less than 50 ms; it also can test any combination of N-channel and P-channel devices simultaneously.

Integrated Technology, www.inttechcorp.com.

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Transient generator brochure

AR's "RF/Microwave Instrumentation" brochure introduces the Models CI00250 (75 W, 10 kHz–250 MHz) and CI00400 (100 W, 10 kHz–400 MHz) conducted immunity testers and the TGAR automotive transient generator, which is available in 32- and 100-A versions. *AR Worldwide, www.ar-worldwide.com.*

Amplifier for PXI digitizers

A fast PXI instrumentation amplifier designed for PXI digitizers, the Model 4040A offers 100-V differential inputs with 70 dB of CMRR and bandwidth from DC to 50 MHz with programmable gain, attenuation, offset, and filters. *Tegam, www.tegam.com.*

VXS data recorders

Vortex M6000 high-speed data recording and playback systems use dual 4-Gbps or quad 2-Gbps Fibre Channel ports to achieve 720-Mbytes/s recording performance in a single 6U VME/VXS slot. *VMETRO, www.vmetro.com.*

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The V200 mixed-signal functional board tester includes a standard VHDL device library for in-circuit test and integrated boundary-scan test for high-pin-count FPGA/BGA/QFP devices. The tester also offers guided-probe backtracking. *Qmax Test Equipments, www.qmaxtest.com.*

Measurement and control handbook

Keithley's free 220-page handbook, "Understanding New Developments in Data Acquisition, Measurement, and Control," provides recommendations for designing test circuits, software programs, and common test and automation systems. *Keithley Instruments, www.keithley.com/at/450.*

2007 product catalogs

The new 2007 product catalogs from Adlink's three product segments—Test & Measurement, Automation, and Industrial Computing—are now available. Each catalog offers easy navigation, product showcases, and selection guides. *Adlink Technology, www.adlinktech.com.*

WiMax PXI solution

Aeroflex's wireless test capabilities aid in the production testing of consumer mobile devices and system components. Within a single software-definable PXI modular platform, the Aeroflex PXI 3000 Series supports WiMax OFDMA, 1xEVDO, and HSUPA. *Aeroflex Test Solutions, www.aeroflex.com.*

PXI-RF matrix

The DK-PXI-1001 represents the smallest and highest-performance 18-GHz 4x4 nonblocking switch matrix available for PXI. The matrix is ideal for engineers who need smaller, portable RF test systems. *Dow-Key Microwave, www.dowkey.com.*

Power-distribution management

Pulizzi manufactures power-distribution units for rack-mount electronic enclo-

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sures that provide circuit breaker protection, EMI/RFI filtering, spike/surge protection, remote power on/off, remote reboot, emergency power off (EPO), redundant power, and sequential power up/down. *Pulizzi Engineering, www.pulizzi.com.*

Harsh environmental imaging

Edmund's Harsh Environmental Optics (HEO) are precision lenses sealed inside water-resistant optical assemblies that excel in wash-down and wet surroundings. Offered in four focal lengths with two coating options, they are appropriate for visible or near-IR infinite conjugate imaging applications. *Edmund Optics, www.edmundoptics.com.*

Measurement and automation

The 2007 National Instruments "Measurement and Automation Catalog" features new product information, comparison charts, and key specifications. The free catalog, which contains more than 1000 products, is available for download on the company's Web site. *National Instruments, www.ni.com/printcatalog.*

2007 Innovation Award winner

The iSE environmental monitor provides Web-based surveillance of conditions in critical HVAC applications for computer server rooms, clean rooms, and labs, as well as critical cold-chain applications. All you need is a Web browser and an Ethernet network. *Omega Engineering, www.omega.com/iseries/ise.htm.*

Dynamic signal analyzers

The IOtech 600 Series follows in the tradition of the ZonicBook/618E and is intended for applications requiring lower channel counts. Now available, these compact USB 2.0 models are ideal for vibration and machine monitoring. *IOtech, www.iotech.com.*

USB data-acquisition solutions

SeaDAC modules connect to a computer's USB port and offer choices including reed and Form C relays, optically isolated inputs, TTL interface to industry-standard solid-state relay racks, and analog-to-digital and digital-to-analog conversion. *Sealevel Systems, www.sealevel.com.*

Electronic loads

The PLZ-4W Series of electronic loads (five models) offers the highest levels of reliability and safety. The instruments come with built-in three-range configuration for a wide dynamic range and high precision. Any sequence patterns can be stored in the built-in memory. *Kikusui America, www.kikusui.us.*

Inspection solution

Rudolph's NSX macro defect-inspection tool provides automated, 100% macro defect inspection with what the company claims is unmatched speed and flexibility. Defect data can be transferred to DMS Decision software for further analysis. *Rudolph Technologies, www.rudolphtech.com.*

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[An exclusive interview with a technical leader]

KEITH BARNES
CEO and President
Verigy
Cupertino, CA

Keith Barnes assumed responsibilities as president and CEO of Verigy in May 2006. Prior to taking this position, Barnes was chairman and CEO of Electroglas, a leading company in IC probe manufacturing, and before that, he was chairman and CEO of Integrated Measurement Systems (IMS), an Oregon-based company specializing in mixed-signal and memory-IC verification that was acquired by Credence Systems in 2001. Barnes is active in numerous industry associations, serves on the boards of Cascade Microtech and Clarity Visual Systems, and is a regent at the University of Portland.

Contributing editor Larry Maloney spoke with Keith Barnes about automated testing trends in a recent telephone interview.

Testing strategies for the long haul

Q: Now that the spinoff of Verigy from Agilent is complete, what are the chief challenges you face?

A: First, I want to compliment Agilent on the professional approach they took to the spinoff. Agilent made sure there was a transition team working throughout the process, so the spinoff went very well. We went public with the IPO on June 13, 2006, with final distribution of stock to shareholders on October 31.

It has been a huge effort to get to this point, including moving about 26 facilities, launching a new ERP [enterprise resource planning] system, and moving memory-systems manufacturing to Flextronics in Shanghai. Meanwhile, we had phenomenal revenue growth in 2006, and the ramp-up in activity made things even more challenging. This year, we hope to go through a stabilization period to make sure that all the systems we put in place are working correctly.

Q: What are Verigy's main markets for automated test equipment (ATE)?

A: We focus on testing complex systems on chip (SOCs) through our V93000 product line. We also target complex flash memory and stacked memory solutions with our V5000 product family. In the SOC division, we address several niches, including high-speed I/O, high-speed memory, and very complex mixed-signal SOCs. In memory test, we deal with NOR and NAND flash devices and stacked memory packages. The NAND flash area was new to us in 2006, and we enjoyed a significant expansion of our flash memory business as a result of these new products.

Q: What are some other factors that drove your revenues in 2006?

A: In SOC, we continued to make very good progress in establishing the top IDMs (integrated device manufacturers) as our customers. They tend to focus on very complex SOCs, processors, and the like. We also had good gains in the high-speed memory and in high-speed I/O areas.

Q: How will Verigy guard against the downward cycles that can plague the semiconductor test industry?

A: We put together a business model with three main elements. First is to make sure we innovate and produce new products profitably. Next, we focus on creating an excellent customer experience. The third element is a "focused operating model." We took a look at the lowest quarters in our business history and set a break-even level at the average of those low points. Conversely, when our industry is doing well and we're hitting the high-revenue points, we've devised a model that's designed to deliver best-in-class operating income of any company in the industry with a similar makeup to ours.

Q: How can ATE vendors help chip makers bring new products to market faster?

A: Our view of working with customers includes not just high-volume manufacturing (HVM) but also device verification and characterization. We work with customers early on when they're developing their devices and before they commit to manufacturing. That also helps us work through the prototyping phase on our product design so we are prepared for HVM as our customers commit to that.

Having the ability to work through all these stages helps us get customers to market sooner than is the case with vendors who are concerned only with high-volume manufacturing. Also, our single scalable test platform is usable from product development through manufacturing. So, for customers, there's no new software to learn, no new system to learn. And that speeds time to market and helps keep test costs in check. T&MW

Keith Barnes gives additional comments on curbing test costs, cooperating with EDA companies, and making decisions about ATE in the online version of this interview: www.tmworld.com/2007_04.

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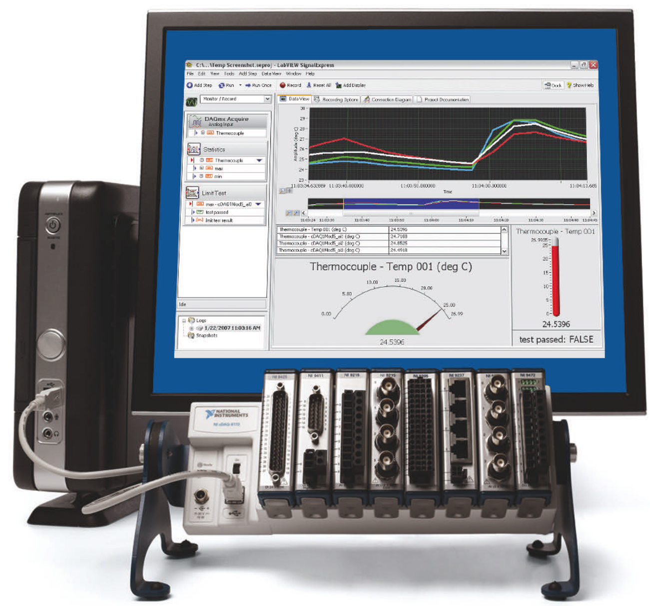

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