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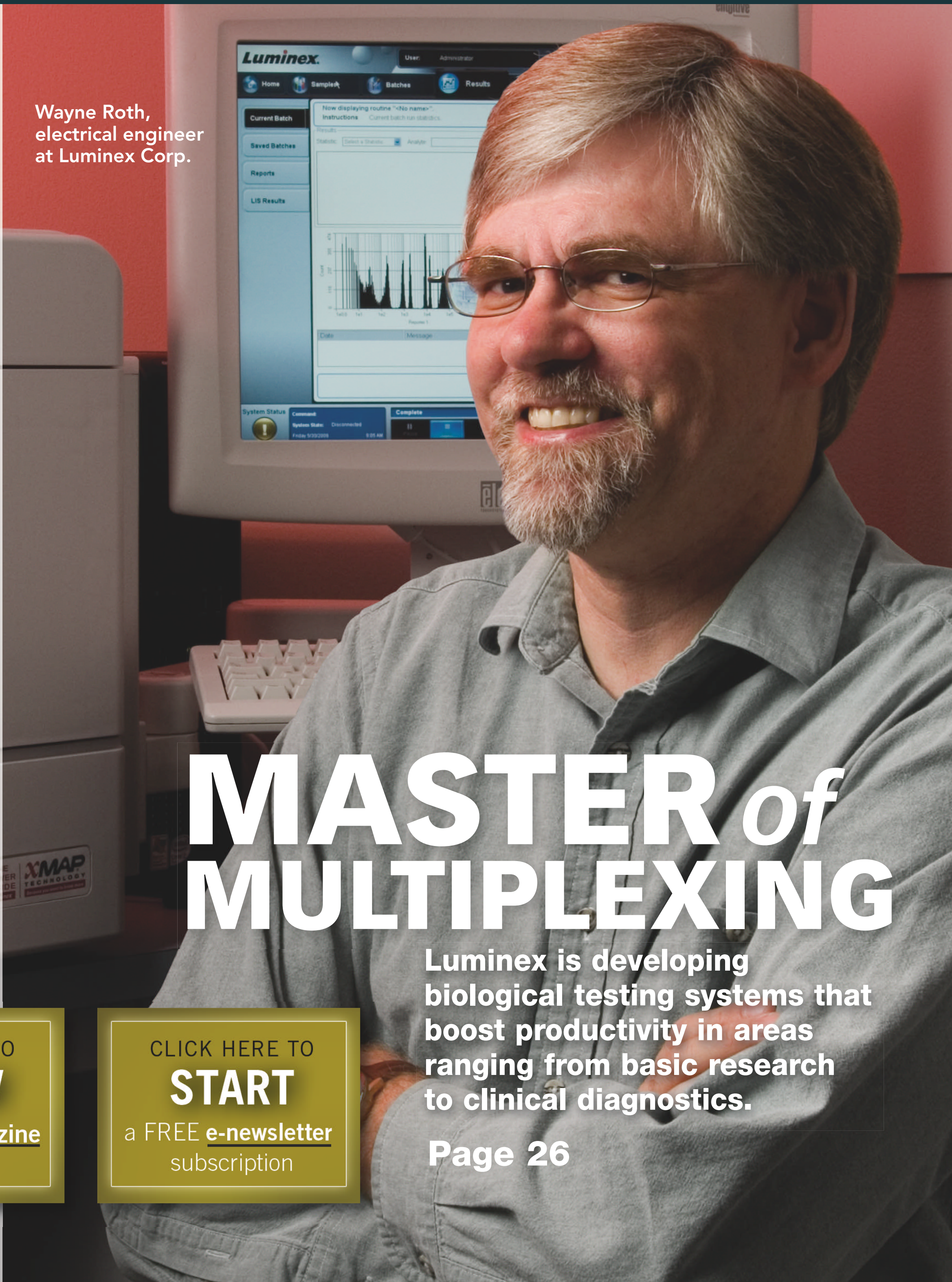

Wayne Roth, electrical engineer at Luminex Corp.

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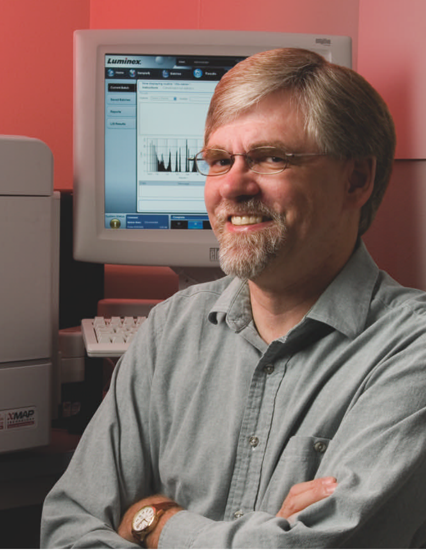

COVER BY: DAN BRYANT

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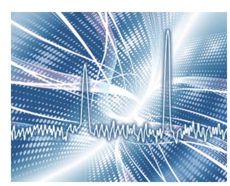

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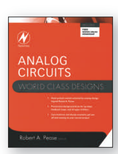

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Read the results of *T&MW*'s 2008 Salary Survey to find out whether your salary and benefits are competitive with the rest of the industry. In analyzing the survey results, contributing editor Lawrence D. Maloney noted, "While many Americans are being buffeted by inflation and job worries, test engineers by and large remain firmly in control of their fate, enjoying rising salaries and strong demands for their services." Do you agree?

www.tmworld.com/salary_2008

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RICK NELSON
EDITOR IN CHIEF

Language skills key in global economy

Having recently returned from an international trip, I was struck by the reaction to presidential candidate Barack Obama's comments that American parents should encourage their children to study foreign languages. According to ABC News, Obama's comments "…prompted outrage from some…groups who argued his remarks were an endorsement of the idea that Americans should be forced to learn Spanish. "As the blogger Digby (www.digbysblog.blogspot.com) put it, "Have we really dumbed ourselves down so much in this country that presidential candidates have to apologize for saying that children should learn things?"

"Companies want to employ people fluent in their customers' languages."

Most of the reaction misses the mark completely. No one advocates forcing Americans to learn Spanish. And consider this from Rasmussen Reports: "A national telephone survey conducted last month by Rasmussen Reports found that US voters overwhelmingly disagree with the presumptive Democratic presidential nominee." The poll found that 83% of Americans place a higher priority on encouraging immigrants to speak English as their primary language while 13% say it is more important for Americans to learn other languages.

But here is what Obama said: "We should be emphasizing foreign languages in our schools from an early age." Nowhere did he say that it's less important that immigrants learn English. In fact, I expect he would agree, as I do, with the 83%—I think it's more important for immigrants to learn English that it is for Americans to learn another language. But that's not to say it's unimportant that Americans make the effort.

Americans—including frequent travelers—often point out that English speakers needn't learn other languages because people in other countries speak English. That's true to a point, and English tends to be the international language of business. Further, it's unlikely in this era of globalization that a language barrier would stand in the way of a sale. I had to go back to the period between the world wars to find an example where language differences did hinder a transaction; the May 5, 1920, *New York Times* article "Refuses to Conduct Business in French" quotes a Hamburg functionary replying, in German, to a French official: "I can express only profound astonishment that you presumed to write to me in French…I cannot tolerate the fact that…you did not address in German your requests and solicitations."

Such an attitude is unlikely to be given voice today. But it is true that most companies find it advantageous to employ people fluent in the languages their customers speak. And colleges advise students that mastering a foreign language is an important step in preparing for business careers. The University of Pittsburgh, for instance, offers foreign-language courses geared toward undergraduate business students.

It's not just businesses that value language proficiency. The US House Armed Services Oversight and Investigations subcommittee heard last month that military personnel need more language skills—and that those skills are best learned in elementary school.

There may be reasons why it's not practical to initiate widespread foreign-language education in elementary schools—not least of which might be a lack of competent teachers. But the concept is one that candidates and voters of all parties should be able to support—for the benefit of business and the security of the country. T&MW

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Test & Measurement World

EDITORIAL STAFF

Editor in Chief: Rick Nelson
rnelson@tmworld.com
ATE & EDA, Inspection, Failure Analysis, Wireless Test, Software, Environmental Test

Managing Editor: Deborah M. Sargent
dsargent@tmworld.com

Senior Technical Editor: Martin Rowe
mrowe@tmworld.com
Instruments, Telecom Test, Fiber-Optics, EMC Test, Data-Analysis Software

Assistant Managing Editor: Naomi Eigner Price
neprice@tmworld.com

Contributing Technical Editors:
Bradley J. Thompson, brad@tmworld.com
Steve Scheiber, sscheiber@aol.com
Richard A. Quinnell, richquinnell@att.net
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Reed Business Information-US, A Division of Reed Elsevier Inc.
CEO: Tad Smith
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HOW TO CONTACT T&MW

EDITORIAL:
225 Wyman St.
Waltham, MA 02451

Phone: 781-734-8423
Fax: 781-734-8070
E-mail: tmw@reedbusiness.com
Web: www.tmworld.com

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CIRCULATION:
Jeff Rovner
303-265-6266
jrovner@reedbusiness.com

LIST RENTAL:
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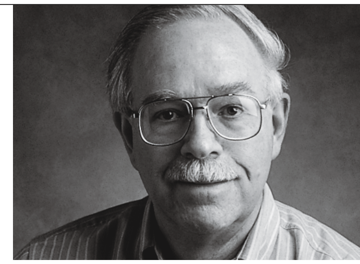


BRAD THOMPSON
CONTRIBUTING TECHNICAL EDITOR
brad@tmworld.com

Get unsmart

"Is Google Making Us Stupid?" That's the provocative title of an article by Nicholas Carr that appears in the July/August 2008 issue of *The Atlantic Monthly*. It's also somewhat misleading, because Carr's investigation focuses mostly on the complex interactions between our brains and the media we regularly use.

Carr contrasts the differences between reading printed matter and reading information on a display. To use either medium, you depend on complex mental processes that get altered by your interaction with the media—think of it as neural programming, or reprogramming if you spent your formative years as a reader and are now by choice or necessity a Web head.

Reprogramming our brains for Web interaction has side effects. Specifically, our attention spans become shorter, reducing our ability to concentrate on a topic and to think critically about a topic. Our information-intake rates change, too. Instead of immersing ourselves in a topic and proceeding at a slow pace, we expect to get the information we need by drinking from the Internet's fire-hose-like data stream as it whooshes past.

Test-equipment designers face a couple of challenges as a result of these Web side effects. First, if no one takes the time to read it, does a well-written and extensive printed manual add value to an instrument? Technical writers accustomed to spreading a topic over several pages will require mental reprogramming to present complex descriptions in brief paragraphs.

Second, printed instruction manuals may disappear altogether and reappear as online manuals accessible via the Web, or as extensive help functions built into the instruments. Given the choice, I favor built-in help pages because a Web connection may not always be available.

Perhaps the advent of true artificial intelligence will produce instruments that become so "smart" that they require very little human intervention to perform a complex series of tests. Imagine your reaction when a verbal command to your AgiTronix Wizard-Scope 9000 ("Herbert") evokes the following reply: "I'm sorry, Dave. I cannot perform that series of measurements. It would adversely affect end-of-quarter shipments and endanger profitability."

Now, where did you put that module-extraction tool? T&MW

DEPARTMENT OF CORRECTIONS

In my "Test Voices" column for *Test & Measurement World*'s June 2008 issue, I mistakenly and indirectly attributed the creation of CP/M to Microsoft instead of Digital Research. Shucks, I knew that. My thanks go to the readers who took the time to correct me, and my apologies go to anyone whose corrections I failed to acknowledge due to e-mail problems.

DEPARTMENT OF ONLINE LITERATURE

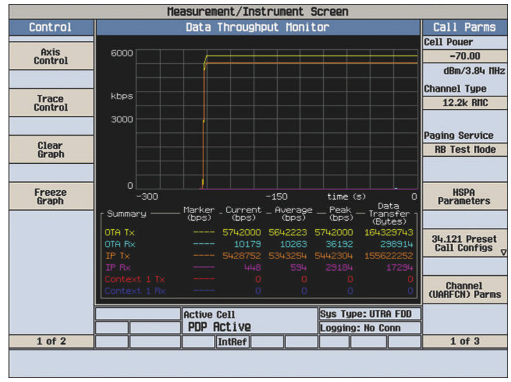
You can read "Is Google Making Us Stupid?" in *The Atlantic Monthly*'s July/August 2008 printed form at your public library or (heaven forfend) online at:
www.theatlantic.com/doc/200807/google

You can often track down the manufacturer of an obscure component simply by dropping the part number or manufacturer's name into the Google search engine, but often a specialized Web site provides better information without Google's clutter of gray-market advertisers offering the component for sale. For example, visit:
www.sherlab.com

If you need an inexpensive voltage-transfer standard, a wind-gust measurement instrument, or are curious about resistor thermal noise, check out Geller Laboratories' offerings:
gellerlabs.com/index.html

While researching quartz-crystal motional parameters for a filter design, I stumbled across Jack Smith's Clifton Laboratories Web site and a relevant application note that extensively discusses various crystal measurement methods and results. Digging further, I noted a diverse collection of practical advice for measuring heat-sink performance, carbon-composition resistor stability, and ferrite-core characteristics:
www.cliftonlaboratories.com

Agilent adds HSUPA test capability



Agilent Technologies has announced a 5.7-Mbps HSUPA test capability for its W-CDMA/HSPA Test and Lab Application software packages, which run on the company's 8960/E5515C wireless communications test set. The E1963A W-CDMA/HSPA Test Application supports Radio Bearer and Frequency Division Duplex test modes and applicable 3GPP TS 34.121 HSUPA RF measurements. The E6703E W-CDMA/HSPA Lab Application features all the capabilities of Test Application and adds support for packet-switched (PS) data connectivity for HSDPA mobile devices.

HSUPA (High-Speed Uplink Packet Access) is a 3G mobile telephony protocol in the HSPA family with uplink speeds up to 5.7 Mbps. It is designed to extend and improve the performance of UMTS protocols by reducing latency and increasing uplink throughput.

The 8960 test set can be used for wireless device development, manufacture, and repair of all major 2G, 2.5G, 3G, and 3.5G wireless technologies. The new 5.7-Mbps HSUPA test capability for the E1963A Test Application and E6703E Lab Application will be commercially available in the fourth quarter.

Base prices: W-CDMA/HSPA Test Application—$14,800; HSDPA and HSUPA test-mode options—$10,400 each; and W-CDMA/HSPA Lab Application (including all Test Application features and HSUPA and HSDPA test-mode options)—$46,000. www.agilent.com.

Editors' CHOICE

Spectrum analyzer catches live frequencies

Although Tektronix calls the SA2600 spectrum analyzer a handheld instrument, the term "armheld" is more appropriate. Despite offering battery operation and a carrying strap, the instrument's 13x10x4.8-in. dimensions and its 12-lb weight make it a little bulky for the average engineer to hold in a single hand. Nevertheless, the SA2600 can still be transported easily and can handle a variety of RF technologies.

The analyzer is designed for field use in areas such as cell towers and WiFi or WiMAX hotspots. Running Windows CE, the SA2600 uses the company's DPX technology to let you see frequencies that appear only once in a while. It includes GPS mapping so you can document the location of a particular frequency: Just load your maps into memory and you can mark locations with measurement details.

Because it's a real-time spectrum analyzer that captures a signal and converts it to the frequency domain, the SA2600 updates itself 500X faster than a swept-tuned spectrum analyzer. It can perform 48,000 measurements/s and catches frequency-hopping signals such as Bluetooth. It can capture signal-hopping pulses of durations as short as 125 μs with 100% probability. The SA2600 operates on frequencies from 10 kHz to 6.2 GHz with 20-MHz real-time bandwidth and –153-dBm displayed average noise level.

Price: $22,900. *Tektronix, www.tek.com.*

Lockheed Martin builds radar test facility

On July 11, Lockheed Martin broke ground a $15 million, 9600-ft^2 radar test structure at its Radar Systems facility in Syracuse, NY. The 80-ft-tall structure will house equipment that will be used to design, analyze, characterize, and test advanced radar systems, such as digital phased array systems. Users will be able to automate a precision antenna measurement process from setup through analysis.

The Medium Extended Air Defense System (MEADS) is expected to be an early user of the new facility. MEADS is a mobile air and missile defense system designed to replace Patriot systems in the US and Germany and to replace Nike Hercules systems in Italy. Lockheed Martin's Syracuse facility is developing the new MEADS surveillance radar. www.lockheedmartin.com.

PXI manufacturers plan seminar series

Geotest, KineticSystems, and Pickering Interfaces have teamed up to create the "No Compromise Test Solutions Conference," a seminar designed to dem-

Editors' CHOICE

Keithley adds WiMAX testing to RF instruments

Built on a DSP-based software-defined radio (SDR) architecture, the Model 2820 RF vector signal analyzer and Model 2920 RF vector signal generator from Keithley Instruments enable users to test WiMAX in any frequency band between 400 MHz and 4 GHz. The SDR architecture allows the instruments to be easily upgraded to accommodate new wireless and cellular standards, and they can perform 802.16e mobile WiMAX Wave 2 testing with up to 4x4 multiple-input, multiple-output channels.

The Model 2820 RF vector signal analyzer is optimized for automated testing of wireless devices in both R&D and production. According to Keithley, the analyzer's measurement speeds are up to three times faster in production test than competitive instruments, while taking up half the space and costing half as much. Together, the Models 2820 and 2920 reduce the test time for RF devices, as they provide built-in list mode features for performing simultaneous measurement of components, transmitters, and receivers. Working in conjunction with the instruments is SignalMeister Version 2.0 waveform creation software, which allows users to create the entire range of signals in accordance with WiMAX and WLAN wireless connectivity standards and 3GPP and 3GPP2 cellular standards.

Base prices: Model 2820 at 4 GHz—$25,000; Model 2920 at 4 GHz—$23,000. SignalMeister can be downloaded at no charge from Keithley's Web site; specific software licenses start at $2500. *Keithley Instruments, www.keithley.com.*

onstrate the benefits of using products from multiple vendors when building test platforms. The seminar will be held at several locations across the US.

Presentations will focus on a particular aspect of test (such as data acquisition, digital, software, signal conditioning, and signal switching), and presenters will explain how products from different vendors can be integrated into a test system. The seminars will focus on PXI-based test platforms, but other platforms will be discussed as well.

"Designing a test system can be a complex undertaking, especially if you're considering multiple test platforms such as PXI and LXI," said Loofie Gutterman, president of Geotest. "With so many vendors to choose from, selecting the ones best suited to your application can be a daunting task. The 'No Compromise' seminar can help customers make more informed choices." www.geotestinc.com.

CALENDAR

Autotestcon, September 8–11, Salt Lake City, UT. Sponsored by the IEEE. www.autotestcon.com.

International Test Conference, October 26–31, Santa Clara, CA. Sponsored by the IEEE. www.itctestweek.org.

Electronica, November 11–14, Munich, Germany. Produced by Messe München. www.electronica.de

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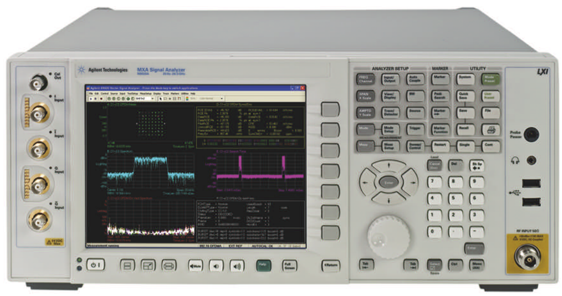
> > > MTT-S International Microwave Symposium, June 15–20, Atlanta, GA, IEEE, www.ims2008.org.



The N9020A MXA signal analyzer supports two-channel, analog baseband analysis.

Courtesy of Agilent Technologies.

At the **Rohde & Schwarz** booth, **NMDG** demonstrated an approach to nonlinear device analysis with its NM300 extension kit. The kit is a hardware and software combination that enables R&S ZVA and ZVT vector network analyzers to characterize the harmonic behavior of active devices in the time and frequency domains.

Agilent Technologies demonstrated a new nonlinear vector network analyzer (NVNA) capability for its PNA-X microwave network analyzer. Requiring minimal external hardware, the Agilent NVNA software effectively converts a four-port PNA-X into a high-performance nonlinear analyzer that measures nonlinear parameters that Agilent calls X parameters.

The company also presented a series of new analysis capabilities for its PSA high-performance spectrum analyzer and midrange MXA signal analyzer, including the addition of up to 80-MHz analysis bandwidth to the millimeter-wave PSA spectrum analyzer and two-channel, analog baseband analysis for the N9020A MXA signal analyzer.

Keithley Instruments announced a set of signal creation and analysis tools—based on the company's Model 2820 RF vector signal analyzers and Model 2920 RF vector signal generators—that extend its RF test capabilities to support 802.16e mobile WiMAX Wave 2 testing with up to 4x4 multiple-input, multiple-output (MIMO) channels (see p. 13).

Keithley also introduced version 2.0 of its SignalMeister waveform creation software, which features a new object-oriented graphical user interface (GUI) that uses a click-and-drag objects-based approach that allows RF engineers to intuitively create waveforms; the GUI is optimized for MIMO signals and enables the creation of signals in accordance with WiMAX and WLAN wireless connectivity standards and 3GPP and 3GPP2 cellular standards.

Aeroflex introduced its 3020C PXI modular digital RF signal generator, a 1-MHz to 3-GHz instrument that supports applications in the HF, VHF, and UHF bands. The instrument offers a modulation bandwidth of 90 MHz to support broadband communications standards or multicarrier test applications, and it delivers RF output power of –120 dBm to +6 dBm. In combination with the recently introduced 3030C wideband RF digitizer, the instrument supports RF component and transceiver testing.

Anritsu announced the MT8860C WLAN test set, which combines the capabilities of a power meter, spectrum analyzer, and vector signal generator to perform radio-layer measurements on WLAN chip sets. A network mode uses standard LAN protocol messaging to perform transmitter and receiver measurements on a device under test without the need for test-control software from the device manufacturer. Anritsu also introduced new phase-noise software for its MS271xB microwave analyzers, and it debuted PowerMAX software, which provides for enhanced visualization and control of the company's ML2490A power meters via Ethernet.

W.L. Gore & Associates introduced an online builder tool for configuring Gore Ultra High Density (UHD) interconnects that can be used in bench test systems and automated test equipment. The UHD cables operate to 15 GHz and support 10-Gbps data rates. UHD cable assemblies can be configured as single lines or ganged into two-, four-, or eight-position housings; a 10-ps relative time match is standard for all ganged UHD assemblies.

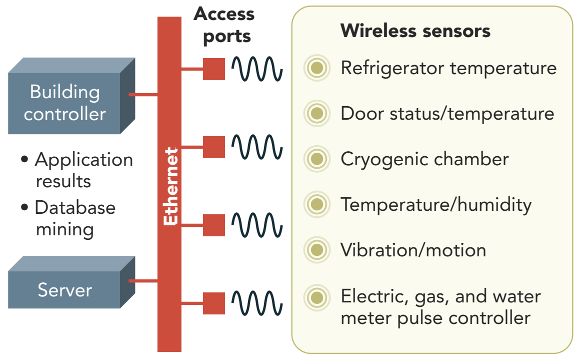
Wireless Telecom Group's Boonton Electronics division introduced its 4540 RF power-meter series, which are more compact and offer lower prices than the company's flagship 4500B meter. The 4540 instruments capture, analyze, and display RF signals in time and statistical domains. A statistical complementary cumulative distribution function mode can collect up to 4 Gsamples of data to support the analysis of CDMA, OFDM, and other signals. T&MW

MARTIN ROWE
SENIOR TECHNICAL EDITOR
m.rowe@tmworld.com

A wireless mess

Wireless sensor networks have found their way into a myriad of applications from grape vineyards to factories to office buildings. Because no single wireless technology currently fits all situations, numerous radios and protocols have appeared, muddying the waters for engineers who need to develop these networks. Standards-based technologies including WiFi, ZigBee, WiMAX, and Bluetooth, plus a host of proprietary protocols, are all in use today.

You might think that engineers would opt for a well-defined standard technology such as WiFi rather than turn to a proprietary method. "WiFi ICs and systems are practically commodities because they're easy to implement," said Dan Piroli, senior VP at Point Six Wireless. "Proprietary technologies are more difficult to deploy, and WiFi-based sensor networks work within a building's infrastructure." He also noted that IEEE 802.11b/g-based networks can use Internet Protocol.



Wireless sensor networks can record measurements in locations without AC power. Courtesy of Point Six Wireless.

While Piroli may be right about WiFi being a near commodity, it may not be the best technology at locations where AC power isn't readily available. Farms, vineyards, groves, and environmental monitoring sites, for example, often lack AC power.

"WiFi is a high-power user," said Robert Robinson, VP of wireless sales and marketing at Crossbow Technology. The client (sensor) and host (hub) need constant contact, and WiFi nodes need constant power, making them less than ideal for battery-powered operations. "We would like to use WiFi," said Robinson, "but it won't work in areas without AC power. We don't fully implement the current ZigBee description because it calls for powered routers."

"Battery-powered WiFi networks aren't as efficient as battery-powered IEEE 802.15.4 networks running ZigBee," observed Joel Young, CTO of Digi. ZigBee may be an improvement over WiFi, but it's not a panacea. Because ZigBee is a low-speed bus, its nodes use less power than high-speed WiFi, and ZigBee nodes have a sleep mode. But ZigBee isn't a full mesh network: Its wireless hubs still need AC power.

As a result of the deficiencies of WiFi and ZigBee, companies such as Crossbow and Digi have developed their own wireless protocols and the hardware to run them. Crossbow's wireless network runs over an IEEE 802.15.4 physical layer, the same as ZigBee, but it's designed to let all nodes go to sleep when not in use. The nodes, therefore, can run for years on a single battery.

Recognizing the power problem in WiFi networks, companies such as GainSpan and G2 Microsystems have begun developing low-power WiFi-compatible ICs. These devices should run for years in sensor networks and other applications such as asset tracking. The **figure** shows a WiFi-based wireless network.

If ultra-low-power WiFi nodes work as promised, they will solve some of the issues regarding a lack of AC power—as long as the signal can reliably reach a powered access point. That should make WiFi a strong competitor to ZigBee, but it won't solve the problem in large unpowered areas such as agricultural fields. They need low-power, battery-powered hubs that can "sleep" when not in use. They also must let the nodes form their own mesh network to pass data to and from the host without a network hub. T&MW

Handbook on infrared imaging

FLIR Systems has released *The Ultimate Infrared Handbook for R&D Professionals.* The 40-page book provides an overview of infrared (IR) thermography, IR detectors, how to best use an IR camera, and how to use filters. www.infraredresearchcameras.com/infrared_handbook.

White paper explains DTV timing

Symmetricom's white paper, "Single Frequency Networks Require Robust Time and Frequency Synchronization," explains the role that timing sources play in single-frequency networks (SFNs) that use multiple transmitters for digital TV (DTV) signals. By referencing a common timing source, the transmitters are able to achieve synchronization and distribute the digital video and audio signals of a program to a receiver at exactly the right time. www.symmttm.com/pdf/db/SingleFreqNtwrk.pdf.

Test digital video

"BER and Subjective Evaluation for DVB-T/H Receiver Test," from Agilent Technologies, explains how to use the company's Signal Studio software in conjunction with vector signal generators, bit-error-rate (BER) measurements, and video clips to evaluate digital broadcast video. cp.literature.agilent.com/litweb/pdf/5989-8446EN.pdf

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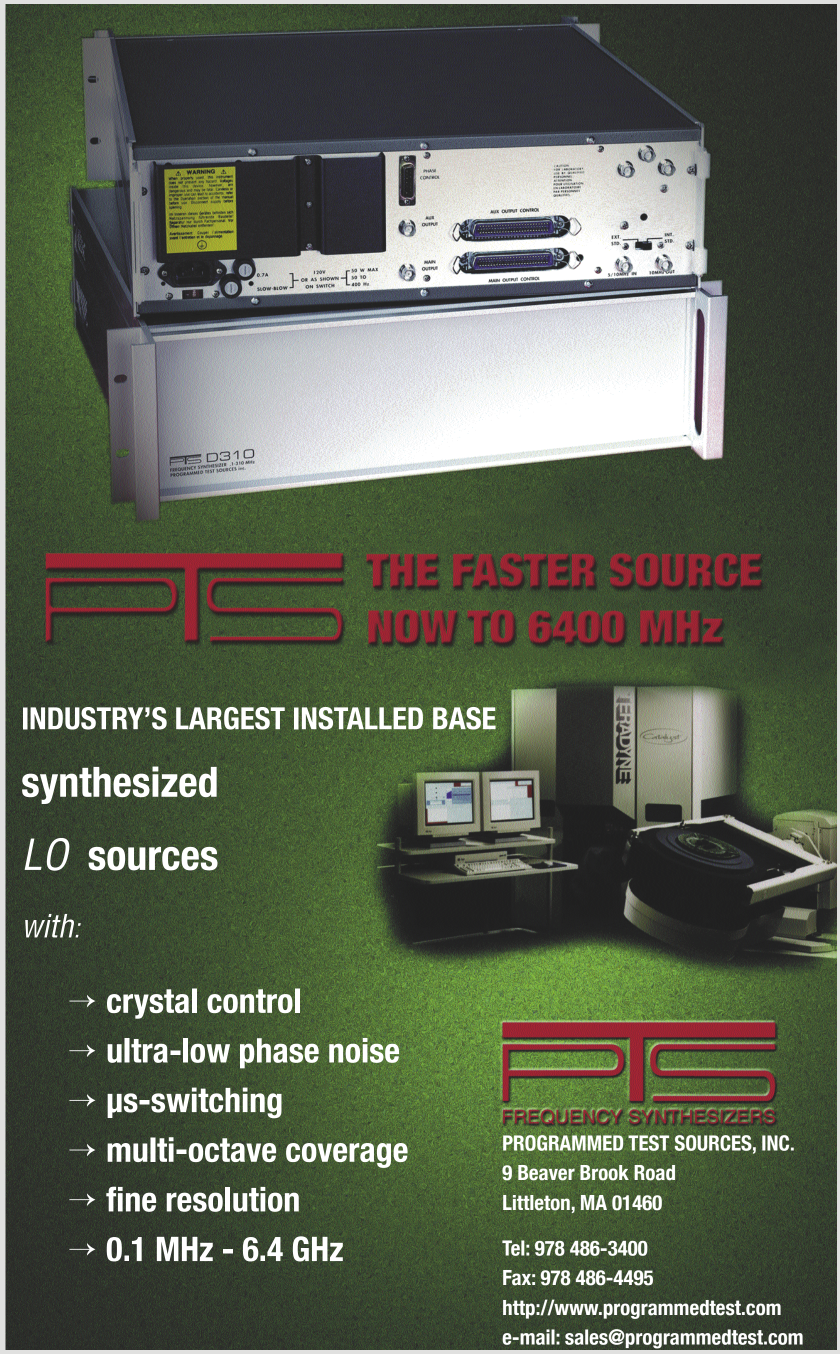

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JUAN ROSALES
TEST & MEASUREMENT RESEARCH ANALYST
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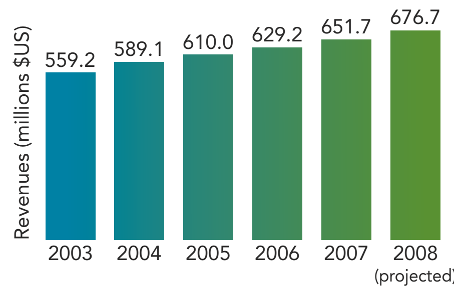
Need for EMC testing benefits spectrum-analyzer market

Electromagnetic compliance (EMC) remains a hot topic among regulatory groups and manufacturers. With the continued integration of electronics in consumer devices, there will be a significant increase in the number of possible electromagnetic sources present in any given environment. EMC testing, therefore, is necessary to guarantee the safe and effective operation of such products.

To combat the risks associated with electromagnetic interference (EMI), product manufacturers are adopting spectrum analyzers as reliable tools for EMC testing. Typically lightweight and feature-rich, spectrum analyzers can be used in conjunction with antennas, line impedance stabilization networks (LISNs), and near-field probes to find EMI radiation sources. The use of spectrum analyzers often saves time and money for engineers who do not wish to travel to an EMC lab for their compliance tests. Spectrum analyzers that can handle an 18-GHz frequency range are well suited for examining satellite communications systems' operations, testing communications equipment, and fulfilling wireless system commissioning and troubleshooting.

The communications industry is perhaps the most important area of growth for spectrum analyzers, as this sector continues to witness the deployment of new wireless networks and standards that must be tested for EMI. As technologies such as WiMAX, 3G wireless, and WCDMA continue to evolve, they are expected to contribute a significant proportion of revenues to the overall spectrum-analyzer market. Although spectrum analyzers have been known for their somewhat hefty price tag in the past, the introduction of lower-cost testers has made such devices more affordable and desirable to many end users. This is largely attributed to vendors who have moved toward the development of less-expensive handheld devices. With their small footprints and portable nature, such products allow for utility both in the field and on the bench. Despite the increased use of handheld devices, spectrum-analyzer vendors must realize that their revenues may be hindered by the availability of previously used systems currently in the market, which are prime options for R&D engineers who wish to minimize operating costs.



World spectrum-analyzer market revenues from 2003 to 2008.

Even with used systems available, the mature spectrum-analyzer market will continue to experience modest growth, given its importance in EMC testing. The **figure** depicts market revenues from 2003 to 2007 and expected revenues for 2008. With a high degree of market competition and price sensitivity, vendors must understand the importance of developing products with enough features and capabilities to satisfy the testing needs of end users. T&MW

Semiconductor equipment book-to-bill

North American-based manufacturers of semiconductor equipment posted $1.03 billion in orders in June 2008 (three-month average basis) and a book-to-bill ratio of 0.85, compared with 0.79 in May and 0.82 in April. "With a half year of data at hand, bookings for the North American equipment manufacturers are down 27% compared to the same period one year ago," said Daniel Tracy, senior director of Industry Research and Statistics at SEMI, adding, "The industry awaits more clarity in the overall economic condition before increasing capital spending." www.semi.org.

PCB book-to-bill

For rigid printed-circuit boards (PCBs) and flexible circuits combined, industry shipments in May 2008 increased 5.1% from May 2007, and orders booked decreased 4.2% from May 2007. Year to date, combined industry shipments are up 6.2% and bookings are up 7.5%. Compared to the previous month, combined industry shipments for May 2008 are down 0.7% and bookings are down 5.2%. The combined (rigid and flex) industry book-to-bill ratio in May 2008 fell to 0.96 from 1.01 in April. www.ipc.org.

Cellular subscription growth

Fueled by rapid growth in China, India, and Africa, worldwide cellular subscriptions continued to expand rapidly in 2007, reports In-Stat. Due to some areas approaching saturation and a relatively slow world economy, subscription growth in 2008 is expected to be much less, the market-research firm says. Recent research found that the number of worldwide cellular subscriptions in 2007 grew by 667.6 million over 2006; 2008 subscription growth is forecast to be only 382.5 million over 2007. By 2012, yearly growth in subscribers is expected to decrease to only 163 million per year, roughly twice the population increase projected for that year. www.in-stat.com.

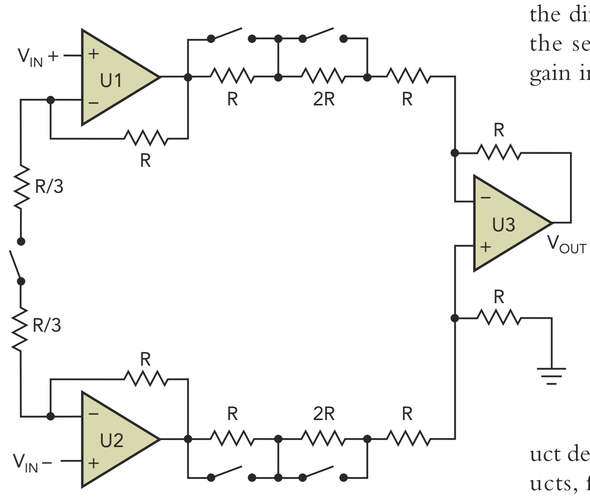
ATE

Optimize a digitizer's analog signal path

Mixed-signal ICs used in cellphones, DVD players, HDTVs, and set-top boxes require analog signal measurements during production. Therefore, the automated test equipment (ATE) systems used to test such products need amplifiers that provide a combination of high bandwidth and accuracy when digitizing signals.

Amplifiers in the analog signal path play a key role in providing gain, differential inputs, and high input impedance while maintaining bandwidths of several hundred megahertz. The signal channel requires gain settings from 0.25 to 4, which adjusts the input signal to match the analog-to-digital converter's input voltage range (4 V_{p-p} to 250 mV_{p-p}).

A differential input amplifier typically consists of three current-feedback operational amplifiers surrounded by gain-setting resistors and relays. The amplifiers, configured to provide a differential input, feed into a third amplifier that provides high common-mode rejection for the signal path (**figure**).



A differential, adjustable-gain amplifier consists of three op amps.

To maintain bandwidth, the amplifier circuits distribute the gain over the circuit's two stages. U1 and U2 make up the differential-input stage, while U3 is the second stage. By minimizing the gain in any stage, the circuit minimizes variations in closed-loop bandwidth. The circuit maintains its bandwidth because the feedback resistors across each amplifier remain unchanged as gain changes.

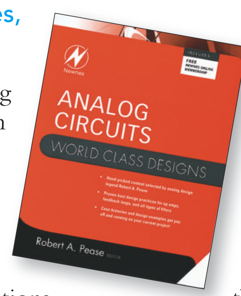
To learn the details of the amplifier-circuit topology, you can download the paper "Selecting Op Amps for High-Speed ATE Digitizers" by Maurizio Gavardoni, product definer for Maxim Integrated Products, from the online version of this article (www.tmworld.com/2008_08).

Martin Rowe, Senior Technical Editor

BOOK REVIEW

Don't monkey around with analog circuits

Analog Circuits: World Class Designs, Robert A. Pease, ed., Newnes, www.newnespress.com, 2008. 472 pages. $39.95.



Engineers engaged in the test or data-acquisition function frequently need to design some analog circuits. I prefer that you get your analog-design tips from sibling publication *EDN* (which I also edit), but self-interest aside, you can't go wrong having *Analog Circuits: World Class Designs* on your bookshelf. Editor Bob Pease, staff scientist at National Semiconductor, presents his own work (for example, a chapter titled "What's all this error-budget stuff, anyhow?") as well as the work of seven contributors.

The book provides good background material on topics like feedback control and stability, and it presents the basics of op-amp topologies and data conversion. You'll find many op-amp, filter, and data-conversion circuits you can adapt to your own needs.

But what I find most interesting in this book are the chapters in which the authors shed light on how they solve design problems. In chapter 2, for example, Phil Perkins of LTX notes that he combines circuit analysis using the traditional loop and node equations with an analysis-by-inspection technique he learned at MIT. He continues applying the technique for building V-I cards that can force current or voltage into a test load.

In addition, Richard S. Burwen, one of the founders of Analog Devices, describes how he designs circuits without filling notebook pages with calculations and without screen after screen of computer simulations. "Probably, I am the last circuit designer in the world to acquire a computer," he writes. In contrast, Bonnie Baker of Texas Instruments presents a chapter on solving analog problems in the digital domain.

My favorite chapter, though, is "The Zoo Circuit," by Jim Williams of Linear Technology, in which the author recounts how a monkey frolicking on parallel bars helped him design a low-power CMOS voltage-to-frequency converter. I guess the lesson is that a good engineer accepts help wherever he or she can find it.

Rick Nelson, Editor in Chief

Disclosure: The editor and writers are frequent contributors to *EDN*, its competitors, or both. The book publisher is owned by *Test & Measurement World*'s parent company.

Sync sine waves over three decades

This sine-wave generator can synchronize a sine-wave output through three decades of frequency, while maintaining low total harmonic distortion and constant amplitude.

By Alfredo H. Saab and Tina Alikahi, Maxim Integrated Products

The test and calibration of audio-frequency circuits and systems often require a sine wave with an accurate amplitude and frequency and a low total harmonic distortion (THD). Some test applications require that a signal generator have the ability to accurately synchronize the output with an external timing signal.

Simple sine-wave generators can offer varying degrees of performance, but you'll find it difficult to maintain a low THD with constant amplitude if the sine-wave output must remain locked to a synchronization signal over an extended range of frequencies. The circuit in **Figure 1** uses three ICs to generate a low-THD, constant-amplitude sine-wave output synchronized to an external square wave or pulse input signal that spans a three-decade range from 20 Hz to 20 kHz.

The synchronizer IC (74HC4046) is a phase-locked loop (PLL) with one voltage-controlled oscillator (VCO) and three phase/frequency detectors. The best phase/frequency detector to use for maintaining a low THD with constant amplitude is one with a frequency-capture range equal to the VCO frequency range (the maximum frequency minus the minimum frequency). In this case, it is the phase-comparator 2 (PHC 2 out) output.

A 74HC4060 general-purpose binary frequency divider generates at its Q6 output the 74HC4046's VCO output divided by 64. This divided VCO output feeds back to the 74HC4046's phase/frequency comparator input (Comp In). When the VCO is phase locked, it synchronizes the pulse input (Sig In) to the divided VCO output. Components C1 and R1 set the VCO's frequency range from the minimum to the maximum level of the VCO's input-voltage range.

The MAX297 switched-capacitor low-pass filter that follows the PLL has a cutoff frequency (from analog signal input to analog output) equal to 1/50th of the frequency at its clock input. Any signal with a ratio to the clock frequency lower than 50 is heavily attenuated (Ref. 1). That clock signal is, in this case, the VCO output.

The analog input is the same 74HC4060 Q6 output square wave used for the PLL feedback. Because the clock and signal inputs always have a frequency ratio of 64, the fundamental sine wave of the input signal always falls within the filter bandpass, appearing at the output. No other harmonic com-

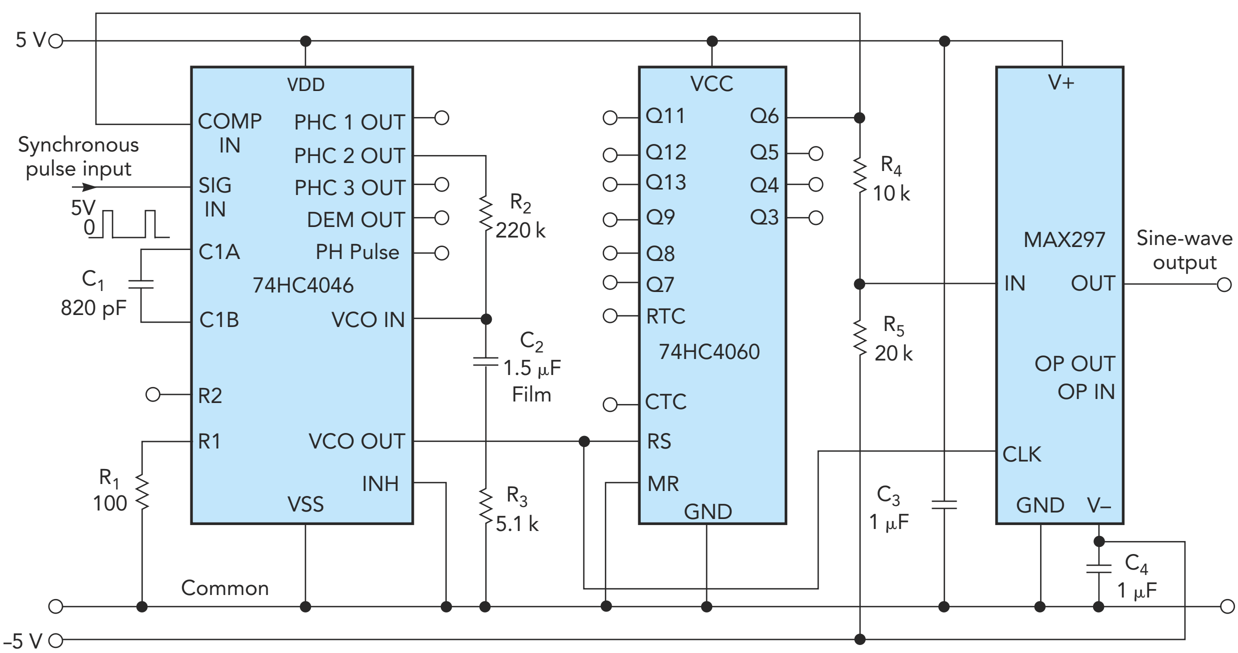


Figure 1. This three-IC sine-wave generator, which covers three frequency decades and provides low distortion, can be synchronized with an external signal.

ponent of the input square wave will fall within this bandpass, because the ratio of the clock frequency to frequency is always less than 50.

The fact that the filter's analog input signal is a 50% duty cycle square wave helps in this application because such a square wave contains only odd harmonics of the fundamental. The lowest-frequency harmonic is then the third, which is well within the filter's deep-attenuation range (frequency to clock ratio is 21.33 for the 3rd harmonic).

THD and amplitude vs. frequency for circuit in Figure 1

Frequency (Hz)	THD (%)	Amplitude (VRMS)
20	2.775	1.470
50	2.650	1.472
100	2.525	1.472
200	2.250	1.473
500	1.002	1.473
1000	0.186	1.473
2000	0.260	1.472
5000	0.330	1.473
10000	0.405	1.473
20000	0.022	1.472

You can frequency-modulate the synchronization signal, but that task forces a compromise between the synchronization-tracking speed (or maximum modulation frequency and depth) and the frequency-locking range. The PLL's low-pass filter components—R2, R3, and C2—set that range. Modulation speed is limited for the values in the figure because those values are optimized for an extended-frequency locking range. T&MW

REFERENCE

1. "MAX293/MAX294/MAX297 8th-Order, Lowpass, Elliptic, Switched-Capacitor Filters," Rev. 1, Maxim, October 2005. datasheets.maxim-ic.com/en/ds/MAX293-MAX297.pdf.

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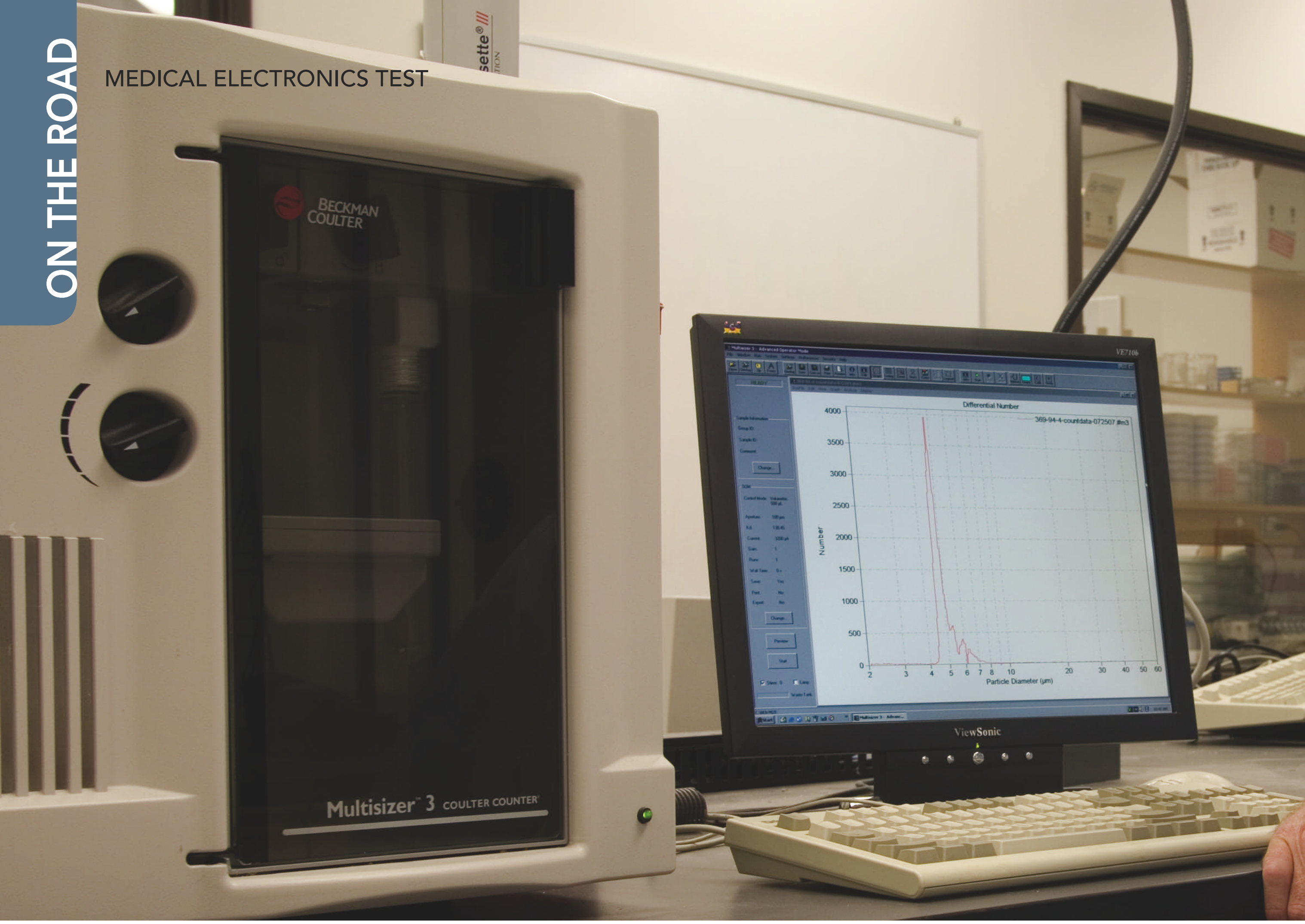


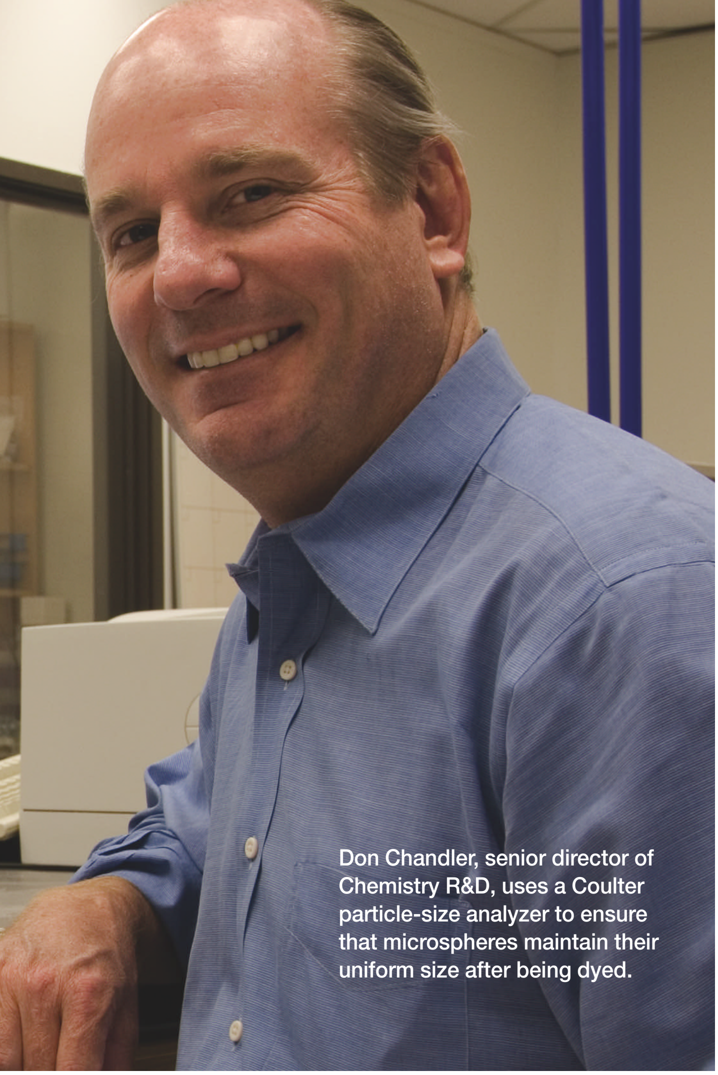
MASTER *of* multiplexing

Luminex is developing biological testing systems that boost productivity in areas ranging from basic research to clinical diagnostics.

BY LAWRENCE D. MALONEY, CONTRIBUTING EDITOR

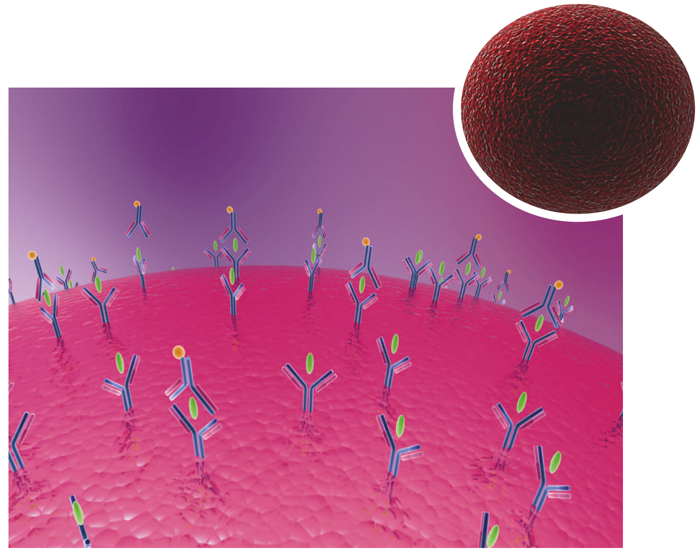
A German biotech center wanted to strengthen its capabilities in food safety and plant pathogen detection. The Mayo Clinic was looking for a collaborator to develop new genetic testing services for identifying blood disorders. A clinical laboratory needed a more efficient tool for screening potential organ donors.

The solution for these applications—and for a growing number of other life sciences testing challenges—is bioassay



Don Chandler, senior director of Chemistry R&D, uses a Coulter particle-size analyzer to ensure that microspheres maintain their uniform size after being dyed.

DAN BRYANT



The Luminex multiplexing system features color-coded beads, called microspheres (inset), that can be coated with a reagent specific to a particular bioassay, allowing the capture and detection of specific analytes. Courtesy of Luminex.

analysis equipment produced by Luminex Corp. Through its network of some 50 research and clinical diagnostic partners around the world, Luminex has installed more than 5000 of its flow cytometry-based instruments since its first system went on the market in 1997. In addition, the company's diagnostics arm, called Luminex Molecular Diagnostics, develops its own bioassays, such as a panel approved earlier this year by the FDA for diagnosing respiratory diseases (see "Payoffs from multiplexing," p. 28).

While there's no shortage of competitors pursuing the multibillion-dollar bioassay market, the 13-year-old Texas firm has distinguished itself by developing instruments that substantially increase the throughput of test results, a major concern for customers such as high-volume clinical labs and pharmaceutical companies competing to bring new drugs to market. The company's success is evident in its $75 million in sales in 2007, an increase of 42% over the previous year.

Using a multiplexing approach, the company's latest analyzer—the FlexMAP 3D—can simultaneously test for up to 500 analytes in a single sample, five times as many as the most advanced Luminex system now on the market. FlexMAP 3D is now being readied for FDA 510(k) clearance (the process through which the FDA approves medical devices for market), with a commercial launch anticipated for early 2009.

"In a clinical environment," said John Carrano, PhD, VP of R&D at Luminex, "physicians want to look at several different factors in diagnosing patients, and our technology allows them to examine many biological targets or analytes simultaneously, rapidly, and accurately. Likewise, in life sciences research and drug discovery, the ability to survey many different targets at once substantially improves the efficiencies of research."

Delivering those benefits requires a design and test effort that embraces a multitude of technologies in a high-performance flow cytometry instrument: fluidics, microspheres, optics, electronics, mechanics, and software.

Inside xMAP technology

The Luminex stable of analyzers, including the Luminex 200 now on the market and the upcoming FlexMAP 3D, are based on the company's patented xMAP technology. While competitive flow cytometers combine different sizes and color intensities to identify microspheres used in the systems, the xMAP technology relies on microspheres with a uniform 5.6-micron diameter and uses a proprietary dying process to color-code these fluorescent beads into 100 distinct sets. Each bead set can be coated with a reagent designed for a particular bioassay, allowing the analyzer to detect specific analytes when the beads are mixed with a biological sample.

During a typical bioassay, a syringe-pump within the analyzer controls the uptake of sample fluid containing beads from a microtiter plate to the base of a cuvette—a clear, thin tube. The sample then passes through the cuvette surrounded by fast moving sheath fluid that accelerates and separates the beads. A red 635-nm laser focuses on the cuvette and excites the fluorescent dye mixture in each microsphere, while a 532-nm green laser excites a fluorophore reporter tag bound to the surface of the microsphere. Photodiode detectors measure the fluorescent signals generated from the dyes within the microspheres, and a photomultiplier tube detects the fluorescence emitted by the reporter molecules on the bead's surface.

High-speed digital signal processors (DSPs), together with system software, classify each microsphere based on its spectral address. Assay results, which typically measure a sample's fluorescent intensity, are transformed mathematically to depict analyte concentration and are displayed on the system's workstation screen.

With the xMAP technology, researchers and clinical technicians using the Luminex 200 can interrogate thousands of microspheres per second, resulting in an analysis of up to 100 different reactions in a single sample well in just seconds. FlexMAP 3D will ramp up that capability per well to 500 and reduce the measurement time.

Customers have expressed appreciation for the throughput potential of xMAP. "We're anxious to explore ways to adapt Luminex technology for our business," said Neal Apple, VP of the Food Safety and Laboratory Service Network of Tyson Foods, which recently signed a collaborative agreement with Luminex. "We believe it will give us the flexibility to gather more testing data faster and develop and validate rapid testing options not currently available commercially."

It begins with the beads

The engineers faced with the task of testing the Luminex system must target the individual subsystems, as well as the overall performance of the entire system. It all starts with the tiny polystyrene microspheres, or beads, that form the basic building blocks of the Luminex systems.

"The special thing about these beads is that they are identical, with only a 1% variation in the diameter," explained Don Chandler, PhD, senior director of Chemistry R&D. "This requires an ele-

Payoffs from multiplexing

Besides expanding its instrument line, Luminex is also expanding its capabilities in developing bioassays. Early this year, the FDA cleared a new Luminex test, called the xTAG Respiratory Viral Panel (RVP), that can identify 12 viruses and subtypes—including strains of influenza, respiratory syncytial virus (RSV), and adenovirus—from just one swab sample from a patient.

The multiplexing capabilities of Luminex instruments are an important step in the goal of achieving "personalized medicine," noted Jeremy Bridge-Cook, VP of Luminex Molecular Diagnostics.

Jeremy Bridge-Cook, PhD, VP of Luminex Molecular Diagnostics, said this multiplexing capability in the xTAG RVP test not only saves time and cuts costs, compared to performing a series of tests on patients, but also substantially increases the chances of pinpointing a diagnosis. "Too often, with previous methods, you don't find out what is causing a respiratory infection," noted Bridge-Cook. "In many cases, one test is performed, and if it's negative, the conclusion is: 'We don't know what it is.'"

Patient samples are placed in wells on microtiter plates within the Luminex multiplexing instrument, where the sample and bead mixture is excited by lasers. The system's software indicates if a virus is present. Courtesy of Luminex.

Why the urgency for fast, accurate diagnosis? The Centers for Disease Control state that viral infections represent the seventh leading cause of death in the US, with associated annual healthcare costs of $10 billion. In just one of many examples in recent years, inadequate screening led to the deaths of nine infants from respiratory illness in a neonatal intensive care unit before the virus was stopped, as reported in an article in the *Pediatric Infectious Disease Journal* by Natasha Halasa, a Vanderbilt University Medical Center physician.

"Because the symptoms of respiratory disease overlap tremendously, it can be very difficult to determine whether an illness is caused by a virus, and if so, which specific virus," said Christine Ginocchio, director of Microbiology/Virology and Molecular Diagnostics at North Shore-LIJ Health Systems Laboratory in Lake Success, NY. "The xTAG RVP provides results on a broad range of viral pathogens, which will assist in the diagnosis of respiratory infections and help physicians recommend the appropriate treatment quickly. The test also tells us what types of viruses are circulating in our communities, which can assist physicians and public officials in preventing outbreaks."

The xTAG RVP panel is one of more than 40 tests cleared by the FDA for use with Luminex multiplexing instrumentation, most of which have been developed by Luminex partners. In all, more than 245 different assays run on Luminex xMAP technology.

Moving forward, Bridge-Cook sees multiplexing as a valuable tool in "personalized medicine," where the ability to understand more about a patient at a molecular level can lead to more effective treatment. "You can't personalize medicine unless you know more about the patient," he said, "and our technology essentially allows you to ask multiple questions about a patient's sample simultaneously."—*Lawrence D. Maloney*

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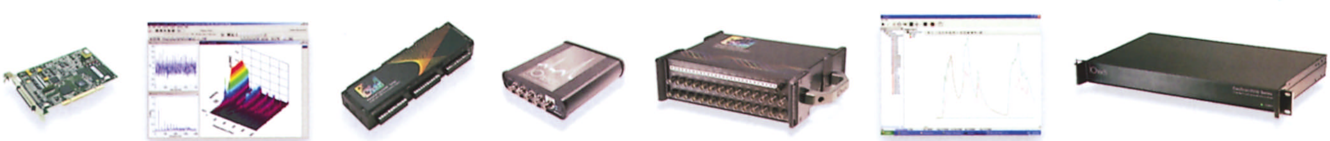

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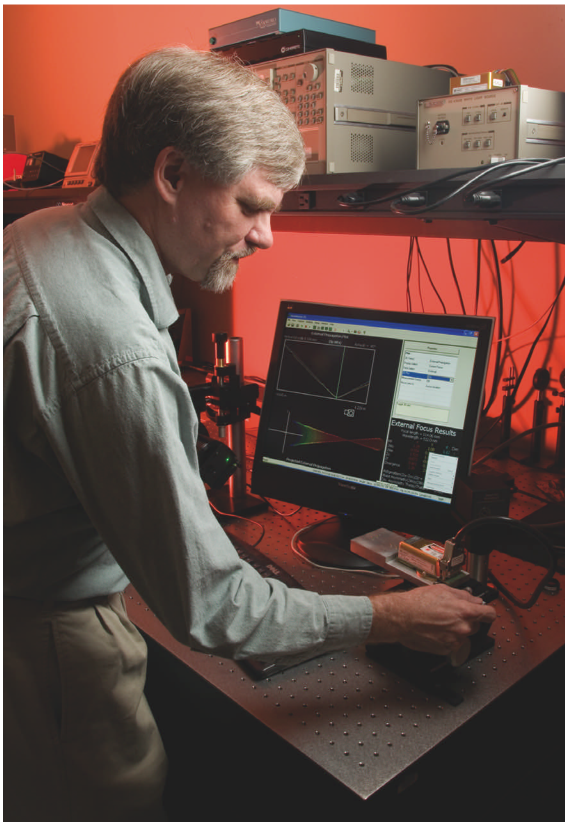
gant technique in manufacturing, and is critical to our technology because when we dye these beads, they need to absorb the same amount of dye to yield a reproducible signature every time."

To ensure uniformity in size and surface characteristics, Luminex evaluates every batch of untreated beads it produces with electron microscopes. After the beads are dyed, test staff employ Coulter particle-size analyzers to ensure that the dyes did not alter the uniform size of beads. The instrument accomplishes this by meas–uring impedance changes when a particle passes between two electrodes.

In addition, the Luminex system itself is used to evaluate the potential assay performance of beads as well as dye uniformity and accuracy. "Every lot of beads is tested on the analyzer to make sure the targeting is accurate," said Chandler. "In the Luminex 200, for example, there are 100 targets per each sample well, and we need to make sure that we are targeting the center of each of these 100 regions."



DAN BRYANT

In developing the FlexMAP 3D instrument, the biggest challenge for electrical engineer Wayne Roth's team was matching the system's optics to the microsphere dyes. A prime tool in optics design: the Coherent ModeMaster beam analyzer, which helps calibrate the laser so it focuses on a precise spot size on a bead.

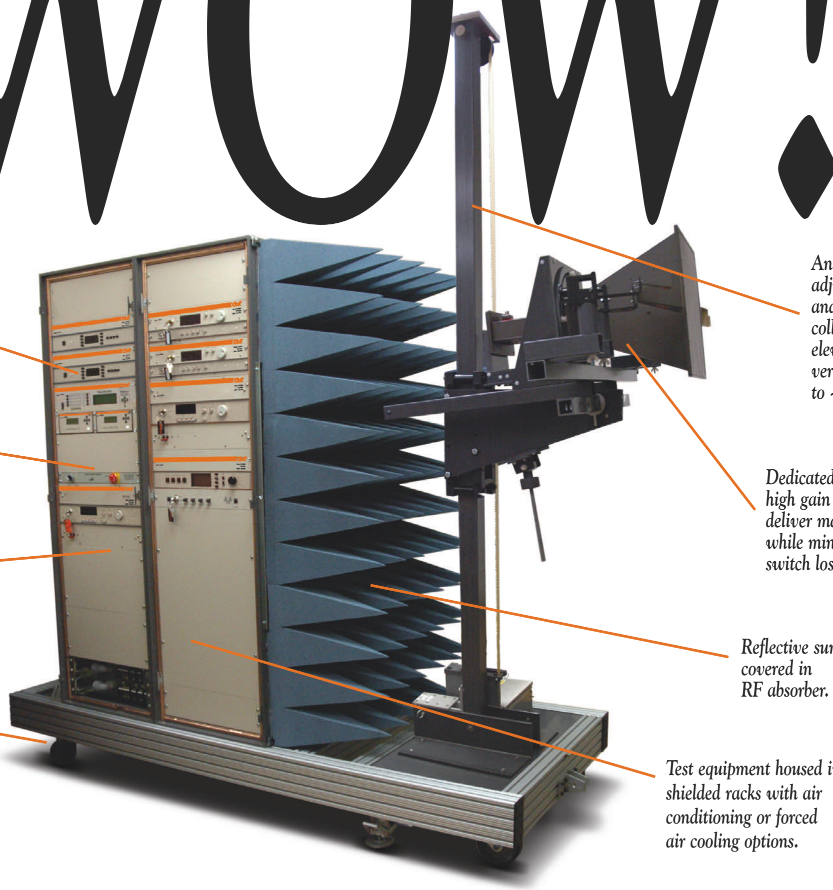
What QC looks for in such tests is a tight grouping of fluorescent signatures from the microspheres in a given region. In the Luminex 200, this appears as a two-dimensional grid or "bead map." For example, one internal dye in a bead might have a fluorescent intensity of 1000, while the second dye might have an intensity of 500. This results in a dot at the coordinates (1000, 500) on the bead map. Every time a bead comes through the analyzer, another dot is recorded. A third fluorescent signature is simultaneously measured—this one associated with reporter molecules on the surface of the microsphere.

The development of the FlexMAP 3D system posed new test challenges for the Luminex team. To facilitate the increased multiplexing associated with the new instrument, each bead incorporates a third internal dye as well as the reporter dye. This third dye, which creates a "third dimension" in the classification bead map, is what allows the instrument to analyze up to 500 targets.

"We had to find an additional dye that we could excite using the same two lasers as before," recalled Chandler. "There is a lot of crosstalk between dyes, which absorb, emit, and share energy between each other. As you add more dyes, the interactions are a significant factor in choosing the final dye set."

A key tool here was fluorescent spectrometry, which helped the R&D staff eliminate dyes whose energy transfer was not compatible with the design. "Some dyes that would seem to be ideal based on wavelength weren't very efficient in energy absorption and

WOW!



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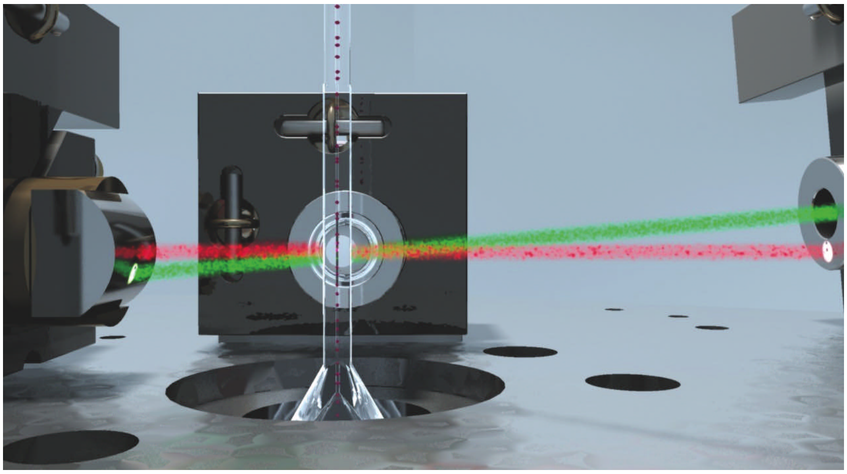


In a typical bioassay, a sample passes through a cuvette surrounded by fast moving sheath fluid that accelerates and separates the microspheres. A red laser excites the fluorescent dye mixture in each microsphere, while a green laser excites a fluorophore reporter tag bound to the surface of the microsphere. Courtesy of Luminex.

emitting, so they were ruled out," noted Chandler.

Engineers in the company's QC department also use spectrometers to inspect new dyes in manufacturing, and they employ spectrophotometers (for both Fourier-transform infrared spectroscopy and ultraviolet-visible spectroscopy) to assess beads and reagents used in the bead manufacturing process. In addition, they turn to high-pressure liquid chromatography to test dye purity.

Testing the hardware

At Luminex, the development of bead chemistry goes hand in hand with the design of the system hardware that analyzes the beads. "Moving from 100 beadsets to 500 for the FlexMAP 3D required a lot of back and forth between the instrument and chemistry teams," said Chandler. "We had to make sure that the hardware engineers could capture the light from the dyes we were proposing."

Electrical engineer Wayne Roth, who served as chief engineer for both the Luminex 200 and the FlexMAP 3D system, agreed that the biggest challenge for his hardware team was matching the system's optics to the microsphere dyes. "We have multiple dyes inside the beads," he said, "so we implemented a clever design of the optical filters in the optical path between the microsphere and the detector so you can tell the dyes apart."

The Luminex systems feature an open architecture suitable for many applications, noted John Carrano, VP of R&D.

To address this optics design, the hardware engineers needed spectrophotometers to measure the spectra of the dyes and to precisely measure the blocking performance and edges of the optical filters. "Besides picking the right spectra to transmit to your detector, almost more important is what wavelengths you want to block from the detector," explained Roth.

Equally crucial are the tests on the system's lasers. Engineers in R&D and QC use Coherent ModeMaster beam analyzers to measure the M^2 rating, or beam quality factor, of lasers that the company buys from suppliers. The same instrument also helps the engineers calibrate the laser so it focuses on the precise spot size on a bead that is targeted for illumination.

Other test challenges stem from changes in FlexMAP 3D's design. For example, the R&D team developed a patented air-pressure-driven fluid-delivery system that compensates for variations in fluid viscosity. To ensure that beads move at the required constant speed through the cuvette, the engineers installed a variable electronic pressure regulator and microprocessor, which automatically measure the sheath temperature and adjust the air pressure to compensate for viscosity change.

In developing that design, the engineers put the entire instrument in an environmental chamber, changing temperature and measuring flow rates. "This helped us create the pressure profile we need to apply across the temperature range the system is exposed to," said Roth.

During the environmental test, the rate of fluid flow through the cuvette was measured in real time, using a digital oscilloscope connected to the red and green photodetectors. The time that a bead takes to transmit between the two separated laser spots is measured in microseconds.

In fact, said Roth, digital oscilloscopes are "probably the most important tool we have in this company as far as testing." Scopes come into play in applications ranging from adjusting analyzer optics to measuring the voltage that detectors produce upon capturing the reflected light from the microspheres.

For example, oscilloscopes assist engineers in achieving optimal alignment of the laser beams, which is important for ensuring consistent results during assays. Said Roth: "We hook up the oscilloscope to the optical detectors and adjust the lasers and lenses to get the consistency we need from one bead pulse to the next, as seen on the oscilloscope screen."

From software to system

Beyond their arsenal of bench instruments, Luminex engineers also rely on a long menu of software packages to develop and test the company's multiplexing instruments. Among the many examples cited by Roth:

- Microsoft Excel is used extensively for calculations, including the timing sequence of a new dual-syringe system that will boost throughput in the FlexMAP 3D system. In this design, one syringe aspirates the sample out of a well in the microtiter plate, while the other syringe dispenses another sample of microspheres through the cuvette.
- MathCAD was called on for numerous tasks, such as modeling the egg-shaped regions that distinguish one bead set from another. This was an essential step for setting up the classification algorithms for the bead sets.

To a large extent, the Luminex multiplexing instrument itself serves as the most important tester. In demo batches, Luminex engineers use the analyzer and its software to test parameters such as classification efficiency and how well each bead is read by the instrument. Courtesy of Luminex.

- PSPICE design software helps electrical engineers simulate filters for the system's analog electronics, while mechanical engineers turn to SolidWorks 3D CAD to model hardware assemblies and the analyzer's enclosure.
- COSMOSFloWorks computational fluid dynamic software models fluid movement, while COSMOS finite-element analysis software provides thermal analysis of components such as the stainless-steel optics plate on which the lasers rest.
- LabView plays a role in many applications, including the design of a software-based accelerated life test for valves in the fluid-delivery system.
- Homegrown test applications, programmed in C++ and C#, test assemblies such as the positioning system responsible for moving the microtiter plate that contains the bioassay samples. The FlexMAP 3D system will handle both 96-well and 384-well plates, meaning that there could

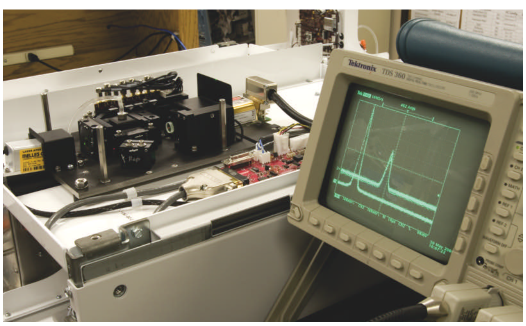
be 384 different patient samples in one well plate for in vitro diagnostics.

- Microsoft Visual Studio Test Edition, Bugzilla, and homegrown software emulators test the system firmware that runs embedded microprocessors, field-programmable gate arrays, and DSPs.

In many ways, however, the Luminex analyzers themselves may well be the most important test instruments in the Luminex arsenal. "It is very important that we do systems integrated testing for such an interdisciplinary instrument that serves such a diverse user base," said R&D VP Carrano.

To perform this integrated testing, the Luminex team had to develop the key performance metrics and then set up a design of experiments on the machine to test those metrics and gather statistics to prove reproducible results. Among the key parameters that the system measures:

- throughput, or the amount of time it takes the system to read a 96-well plate, using a 100-plex-per-well standard;


DAN BRYANT

Digital oscilloscopes come into play in applications ranging from adjusting optics to measuring the voltage that detectors produce upon capturing the reflected light from the microspheres.

- dynamic range, including the system's ability to detect light in multiple light paths with different signals;
- coefficient of variance, a measure of the instrument's precision;
- classification efficiency, or how well each bead is read by the instrument; and
- assay performance, typically involving known assays with readily recognizable signals.

One measurement that addresses many of these parameters is the dose response curve, which analyzes signals from the reporter dye (Phycoerythrin) coating on beads of the same mixture from an entire microtiter plate. "That kind of test allows you to look at limits of detection, dynamic range, classification efficiency, a certain level of multiplexing, and throughput," said Carrano. "This is an example of a design of experiments that gives you a solid feel for the true functioning of the instrument."

Getting ready for market

Luminex is now setting up its manufacturing line and QC system for the new FlexMAP 3D, according to Oliver Meek, the Luminex VP for Quality Assurance and Regulatory Affairs. Working with R&D, QC engineers developed the battery of tests to be used in manufacturing test and will rely on many of the same procedures and instruments that R&D used in developing the instrument. This includes 100% testing of all major subassemblies. Assembled units also will undergo additional tests, including hipot.

Upon completion of verification and validation studies, Luminex will then release beta units this year to key partners for field tests of assays as part of the FDA 510(k) clearance process. "In addition to the new instrument itself, we also have to repeat testing for assays already cleared by the FDA on the new FlexMAP 3D system," explained Meek.

While the Luminex 200 will continue to be a workhorse, the company expects FlexMAP 3D to open up even more opportunities, ranging from high-volume clinical diagnostic labs that serve doctors and hospitals to tissue typing for transplants and the emerging field of molecular diagnostics. "The FlexMAP 3D is important to the research community," said Steven Binder, director of Technology Development for Bio-Rad Laboratories' Clinical Diagnostics Group. "The new design, supporting 500 targets, moves Luminex into a larger space regarding protein discovery."

R&D VP Carrano points to the company's open architecture as a key Luminex advantage. "Different users, whether they come from in vitro diagnostics, drug discovery, food safety, or genetic research, can use our platform without any changes. And that puts us in a very good position for continued success." T&MW

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CHECK ESD SIMULATORS FIRST

BY KENNETH WYATT, WYATT TECHNICAL SERVICES

When you are designing products for compliance with electromagnetic compatibility (EMC) standards, testing circuits for immunity to electrostatic discharge (ESD) is a must. Standards such as IEC 61000-4-2 and ANSI C63.16, which specify how to set up and perform these ESD tests (Refs. 1, 2), require that you use an ESD simulator to produce test pulses.

The standards also specify the shape and timing of the current pulse you must inject into your equipment under test (EUT), so before running an immunity test, you must verify that your ESD simulator produces a current pulse with the proper shape and rise time. You can verify a simulator's performance by using a calibrated ESD target and a high-bandwidth oscilloscope.

The ESD waveform

ESD generated from a person touching an enclosure or a cable can disrupt the circuits in electronic systems. A typical human-body ESD event creates a high-current discharge into any metallic object as a person's finger approaches it. The resulting current pulse may amount to several amperes at a very high leading edge with a rise time of less than 1 ns (**Figure 1**).

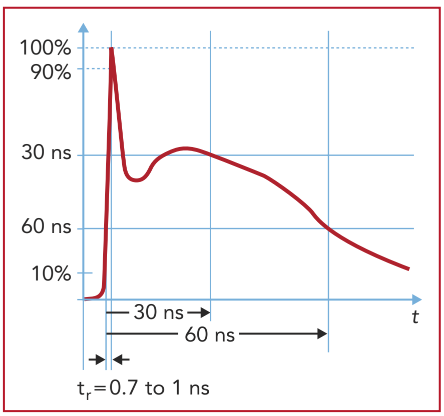

FIGURE 1. The current from an ESD event has a rise time of less than 1 ns.

You can model the human body with a simple series RC network (**Figure 2**). As the electric charge builds, the capacitor charges to several thousand volts. When the switch is flipped, this charge discharges rapidly into the EUT. Several manufacturers offer simulators that reproduce current waveforms very close to this human-body model. The wave shape these simulators must generate is specified in IEC 61000-4-2.

IEC 61000-4-2 requires that you verify the ESD simulator's tip voltage before testing your EUT. It also requires that you verify several characteristics of the resulting current waveform, such as current peak, current reading at 30 ns, and current reading at 60 ns.

You must measure the simulator's tip voltage with an electrometer or gigohm meter (Ref. 3). I've found that for precompliance tests, you can use a simple high-impedance, high-voltage resistive voltage divider (a resistive divider of 100 MΩ in series with 1 MΩ) and a digital voltmeter. Make sure the resistors can withstand up to 25 kV. *(continued)*

Before performing ESD immunity tests, you must verify the output of your ESD simulator with a calibrated ESD target.

Use a shunt

To check an ESD simulator's output, you must measure the waveform of the resulting current across a low-impedance, high-frequency resistive shunt connected to ground. This shunt, or ESD target, emulates a discharge into a large metallic object such as an equipment enclosure.

The IEC and ANSI standards currently specify a shunt impedance of less than 2.1 Ω, but that will change in future revisions. To help engineers more accurately verify ESD simulator performance, draft standards now specify a higher-bandwidth, lower-impedance calibrated ESD target. The new target has an impedance of about 1 Ω. Today, the IEC and ANSI standards specify a 1-GHz bandwidth target. The draft standards specify a 4-GHz target. (The online version of this article includes photos of the two types of targets, www.tmworld.com/2008_08.)

When setting up your test, you must mount the target in the center of a 1.2-m^2 ground plane. ANSI C63.16 target specifications include a reflection coefficient of less than 0.1 (equivalent VSWR of less than 1.22) and an insertion loss of less than 0.3 dB up to 4 GHz.

To complete the test setup, you'll need cables, attenuators, and an oscilloscope. Use good-quality low-loss cables between the target, the attenuators, and the oscilloscope. Keep the total cable length less than 1 m so you comply with the IEC and ANSI standards. ANSI C63.16 requires a double-shielded cable that prevents signal leakage from affecting your measurement. It also recommends RG-400/U cable, but RG-214/U—although twice the diameter—has half the loss and seems to work well. You can also use any gigahertz-bandwidth coax cable.

IEC 61000-4-2 also specifies that you place the oscilloscope inside a Faraday cage to shield it from ESD-induced radiated emissions. During the time the standard was developed (early 1990s), many engineers made these measurements with analog oscilloscopes. The standard specified a shield to prevent distortion in the displayed waveform on an analog oscilloscope. The shield also minimized false triggering caused by fields emitted from the discharge.

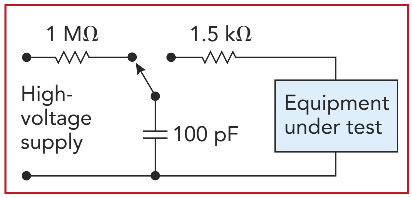

FIGURE 2. An RC network simulates an ESD event from a person's finger.

Today, most high-speed digital oscilloscopes have well-shielded input circuits, so the Faraday cage may not be required in practice. I've found simply mounting the ESD target in the center of a 1.2- m^2 sheet of aluminum prevents unwanted triggers in well-shielded oscilloscopes.

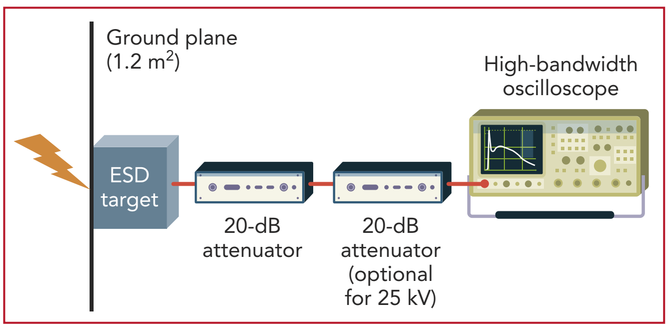

FIGURE 3. Attenuators between an ESD target and an oscilloscope protect the instrument's input amplifiers.

You'll need attenuators to protect your oscilloscope's input preamplifiers (**Figure 3**) because the ESD target can produce voltages greater than 50 V. A 20-dB attenuator is convenient because it represents a 10X attenuation and you can simply multiply the measured voltages by 10 to find the actual voltage across the shunt, then calculate the resulting current. Your attenuator must be capable of handling up to 50-V spikes, and its bandwidth must accurately pass frequencies up to 6 GHz.

Approach with care

When executing your tests using air discharge, try to approach the target with the ESD simulator from a 90° angle and at a constant speed. You'll maximize repeatability, but you can expect to see a lot of variation in wave shape. For contact-discharge tests, place the tip directly on the target prior to discharging the simulator.

The target-attenuator-cable chain will produce some loss of signal amplitude. Variations in loss from one test setup to another must be ±0.3 dB from DC to 1 GHz and ±0.8 dB from 1 GHz to 4 GHz. **Table 1** shows that system-accuracy variations of less than 1 dB can greatly affect measurement accuracy.

Figure 4 shows the current waveform from an "older style" ESD target, represented as a voltage on the oscilloscope screen. The target transfer function is approximately 1 V/A when connected to a 50-Ω load. When subjected to an ESD pulse of 8 kV, the target will output about 30 V, but most oscilloscopes have an input voltage limit of 10 V. This is where the attenuator comes into play. When you run the signal through a 20-dB attenuator, the oscilloscope will display 3 V. When measuring ESD discharges as high as 25 kV, you'll need an additional 20-dB attenuator, which will provide an additional 10X reduction in signal level.

Choosing an oscilloscope

When choosing an oscilloscope, look carefully at an instrument's bandwidth, rise time, and noise. To accurately measure the signal without sampling errors, an oscilloscope must have sufficient bandwidth. For a Gaussian-response oscilloscope, you may need a sample rate up to six times the oscilloscope's bandwidth, although four times the bandwidth is more typical.

With a digital oscilloscope, you must also pay attention to sample rate. A digital oscilloscope has a more flat response over its usable bandwidth, and it has a sharp roll-off above its 3-dB frequency.

Table 1. System accuracy variation causes a percentage measurement error.

Accuracy variation (dB)	Percentage
0.1	1.16
0.3	3.51
0.5	5.93
0.7	8.39
0.9	10.92

Thus, you need a sample rate of 2.5X the oscilloscope's bandwidth to avoid alias errors.

In order for an oscilloscope to accurately display an ESD pulse's rise time, it must have sufficient bandwidth and rise time. The rules for determining whether a scope's specifications are adequate differ for analog and digital models (Ref. 4).

For analog oscilloscopes, the generally accepted rise time and bandwidth rules were:

- Bandwidth = 0.35/(rise time), or rise time = 0.35/bandwidth.
- The oscilloscope must have less than one third the rise time of the incoming signal in order to measure the rise time with an error of 5% or less.

For digital oscilloscopes, use the following calculations:

- Bandwidth ~0.43/(rise time)
- The oscilloscope's rise time only needs to be ~0.7 times the rise time of the signal in order to measure rise time with an accuracy of a few percent.

The flatter frequency response of digital oscilloscopes enables them to produce less attenuation at frequencies below the –3-dB point than analog oscilloscopes do. Thus, digital oscilloscopes produce more accurate measurements. Secondly, the steeper roll-off of digital oscilloscopes helps reduce aliasing errors.

Typically, a human-body ESD pulse can have a rise time of less than 200 ps. The bandwidth required to accurately display this would be approximately 0.43/(200 ps), or 2.15 GHz. Some ESD simulators can produce rise times of 50 ps and thus require an oscilloscope bandwidth of 8.6 GHz.

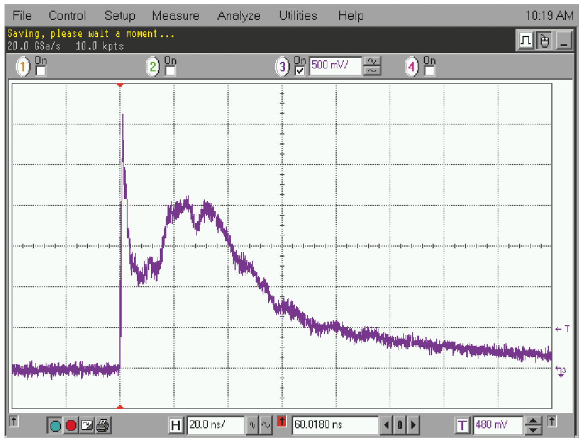

FIGURE 4. An ESD contact discharge, when run through a 20-dB attenuator, peaks at 3 V, but is actually 30 V.

Table 2. True rise time versus observed rise time as a function of oscilloscope bandwidth.

Pulse rise time (ps)	Oscilloscope bandwidth (GHz)	Oscilloscope rise time (ps)	Observed rise time (ps)	Difference (ps)	Error (%)
700	1	350	783	83	11.8
700	1.5	233	738	38	5.4
700	2	175	722	22	3.1
700	3	177	710	10	1.4
700	4	88	705	5	0.8
700	6	58	702	2	0.3

The IEC and ANSI standards place more stringent requirements on measurement repeatability than they do on the rise time. To capture ESD, you must set your oscilloscope to "single-shot" mode. If the oscilloscope returns a range of different answers for repeated rise-time measurements, then you can't depend on it to accurately measure the rise time on any one occasion—even if the average of many measurements is highly accurate. A major factor in single-shot repeatability is low internal noise, so compare noise specifications when you evaluate oscilloscopes for ESD testing.

The higher an oscilloscope's bandwidth, the more accurately it will capture the ESD pulse's rising edge. **Table 2** shows that an oscilloscope's rise time directly affects the measured rise time of an ESD pulse. For a pulse with a rise time of 700 ps, you need an oscilloscope with at least 4-GHz bandwidth to get less than 1% error. You must add this error to any system errors when you measure rise time.

To measure an ESD pulse, set the oscilloscope to single-shot mode and use a positive-edge trigger. Set the trigger level just above zero. You may need a minor trigger-level adjustment to capture the entire waveform. Set the vertical sensitivity to either 0.5 V/div or 1 V/div and set the time base to 20 ns/div. Assuming the measured signal is a triangle (for simplicity in calculations), a measured rise time of 800 ps will require a 10-Gsamples/s sample rate, which equates to 100 ps/sample, or eight samples on a rising edge, enough to accurately represent it.

Be sure to perform and document your verification test prior to any precompliance or compliance test to prove proper simulator operation. Then, once you complete verification tests, you can perform investigative or qualification testing, knowing that your ESD simulator is working properly. T&MW

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Kenneth Wyatt *holds degrees in biology and electronic engineering. He worked as a senior EMC engineer for Hewlett-Packard and Agilent Technologies for 21 years. He has written articles and presented conference papers on RF amplifier design, RF network analysis software, EMC design, and harmonic comb generators for predicting shielding effectiveness. He is a senior member of IEEE and a long-time member of the IEEE EMC Society where he serves as photographer. He is also a member of the dB Society and is a licensed amateur radio operator. ken@emc-seminars.com.*


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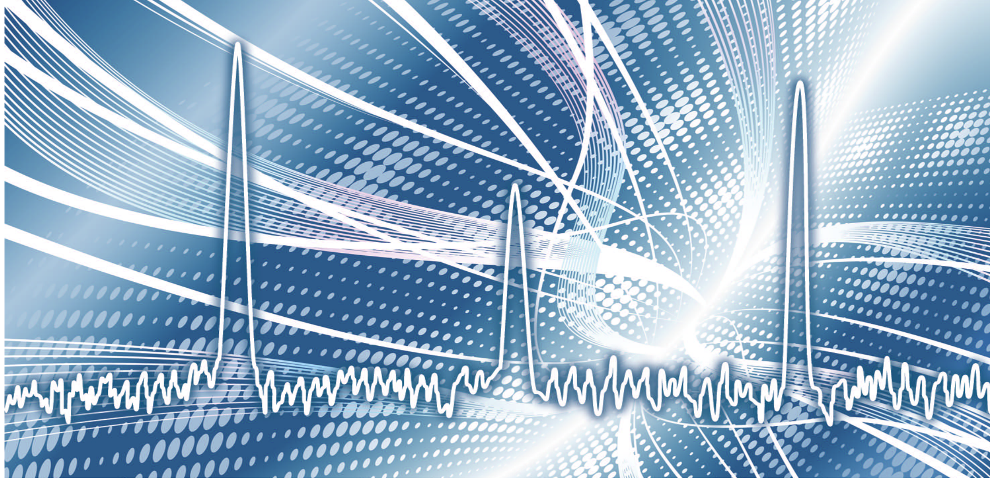

DYNAMIC RANGE UNRAVELED

BY SATISH DHANASEKARAN AND DARRIN RUSSELL, AGILENT TECHNOLOGIES

CHARACTERISTICS SUCH AS NOISE AND DISTORTION INTERACT TO AFFECT THE DYNAMIC RANGE OF A SPECTRUM ANALYZER.

To provide the increased bandwidth and data-transmission rates necessary for wireless data, voice, music, and video applications, engineers must contend with higher-order modulation schemes that place stringent demands on spectrum analyzers, particularly on their dynamic range. Defined as the difference between the highest and lowest power signals that a spectrum analyzer can simultaneously measure, an instrument's dynamic range impacts measurements such as adjacent channel response and spurious response.

A spectrum analyzer's distortion and noise floor directly affect its dynamic range. Understanding the measurements you need to make for a given application can help you evaluate whether an analyzer's dynamic range is adequate and may prevent you from buying a more expensive analyzer than you need.

Dynamic range plays a vital role in measurements on wireless transmitters (**Figure 1**). Air-interface standards and regulatory bodies such as the FCC specify the performance requirements for transmitters and provide guidelines for spectral purity that cover spectral emissions and adjacent-channel power ratio (ACPR).

Table 1 gives an example of transmitter specifications at the block outputs in Figure 1. Typically, the signal at the output of the digital-to-analog converter (DAC) has the tightest spectral performance requirements.

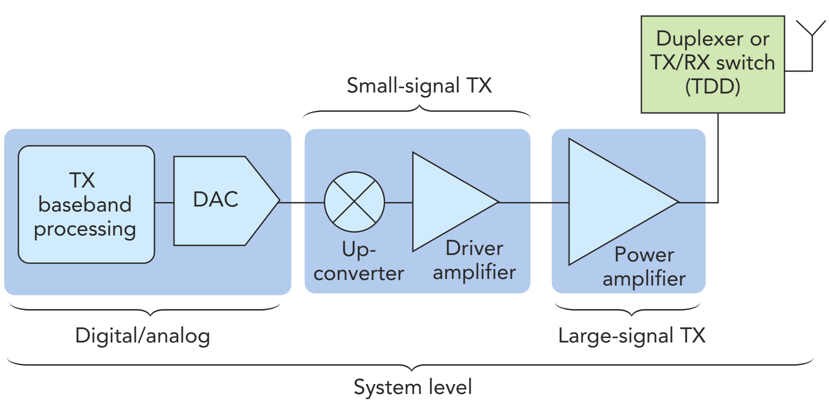

FIGURE 1. An RF transmitter's function blocks have different performance specifications.

Spectrum-analyzer specifications that affect dynamic range include third-order intercept (TOI), second-order harmonic intercept (SHI), and displayed average noise level (DANL). The dynamic-range chart (**Figure 2**) shows these parameters versus a spectrum analyzer's mixer levels. As the mixer level increases, DANL decreases toward the instrument's phase-noise level, which is the same point where TOI emerges above the phase noise.

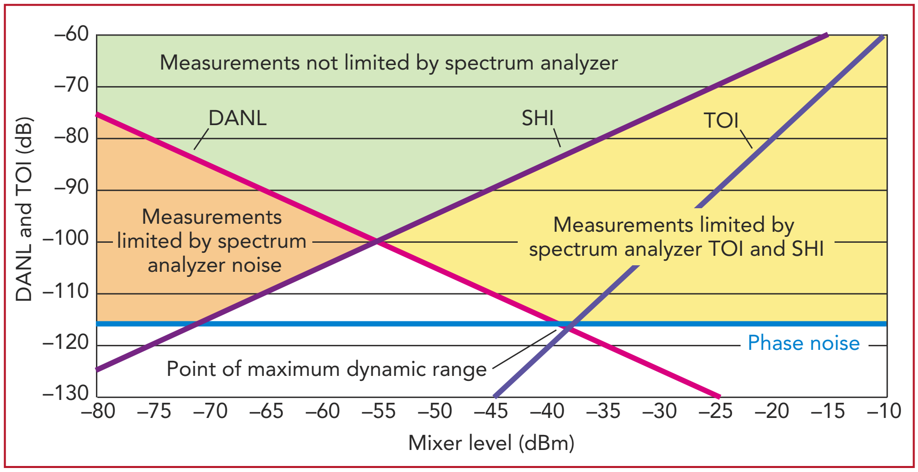

FIGURE 2. DANL, SHI, TOI, and noise limit a spectrum analyzer's dynamic range.

The SHI and TOI of a spectrum analyzer's mixer (**Figure 3**) greatly affect the instrument's distortion. The mixer input level (in decibels referred to 1 mW, or dBm) is the difference between the input signal applied to the analyzer and the RF input attenuation level (also in dBm).

For measurements at RF and microwave frequencies, the third-order and fifth-order intermodulation products of active components such as mixers and amplifiers dominate the instrument's ACPR measurements. For an ACPR measurement to reflect the true performance of the transmitter under test, the analyzer's distortion must be significantly lower than that of the transmitter. If the spectrum analyzer's distortion level is 18 dB below that of the device under test, the measurement uncertainty will be less than 1 dB (Ref. 1).

The TOI slope in Figure 2 shows that for every 1 dB that you reduce the mixer's input signal level, you reduce the TOI distortion products by 2 dB. You can achieve even lower levels at the mixer's input by increasing the analyzer's input-signal attenuation. Increasing the attenuation, however, directly impacts the noise floor and reduces the dynamic range. Optimal attenuator settings, therefore, involve a tradeoff between TOI and noise-floor performance.

Table 1. Performance specifications at internal blocks of a transmitter

Specification	Digital/analog output	Small-signal transmitter output	Power amplifier output	System output
Power level (dBm at 10-MHz bandwidth)	–10	20	34	33
7-MHz offset	–71	–68	–61	–58
25-MHz offset	–83	–80	–73	–70

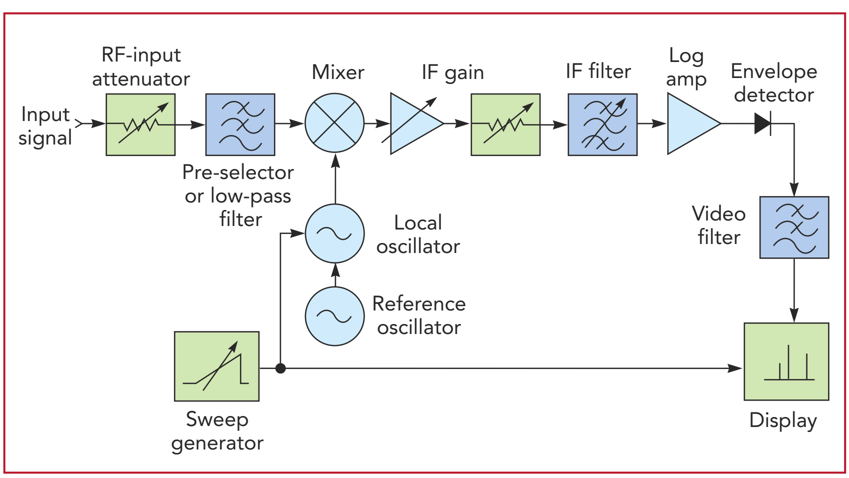

FIGURE 3. Active components such as mixers add harmonic distortion to a received signal.

Two tones

You can use two-tone analysis as a starting point to better understand a spectrum analyzer's performance, because you can represent wide-bandwidth signals as a summation of tones (**Figure 4**). Third-order intermodulation products drop in amplitude to the instrument's noise floor from the center of the carrier to the edge of the adjacent channel.

Although lower in amplitude, fifth-order distortion products don't reach the noise floor until twice the main channel's bandwidth (alternate channel). Even harmonics fall outside the area of interest and thus don't appear in Figure 4.

DANL—a measure of a spectrum analyzer's sensitivity—also affects dynamic range and is typically specified at 0-dB input attenuation and normalized to a 1-Hz resolution bandwidth (dBm/Hz). Spectrum-analyzer noise forces an increase in DANL as the mixer level drops in response to greater attenuation of the signal in front of the mixer.

Using Figure 2, you can find the optimal mixer input level and, with it, the level of input attenuation. The intersection of the TOI and noise-floor lines provides the optimal mixer input level for maximizing dynamic range at about –38 dBm. Figure

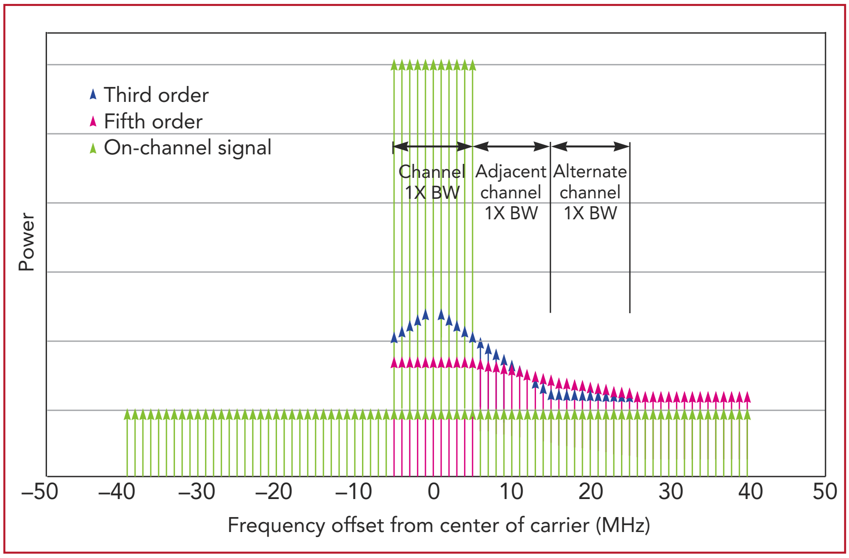

FIGURE 4. Third-order and fifth-order distortion decreases as the frequency offset from the carrier increases.

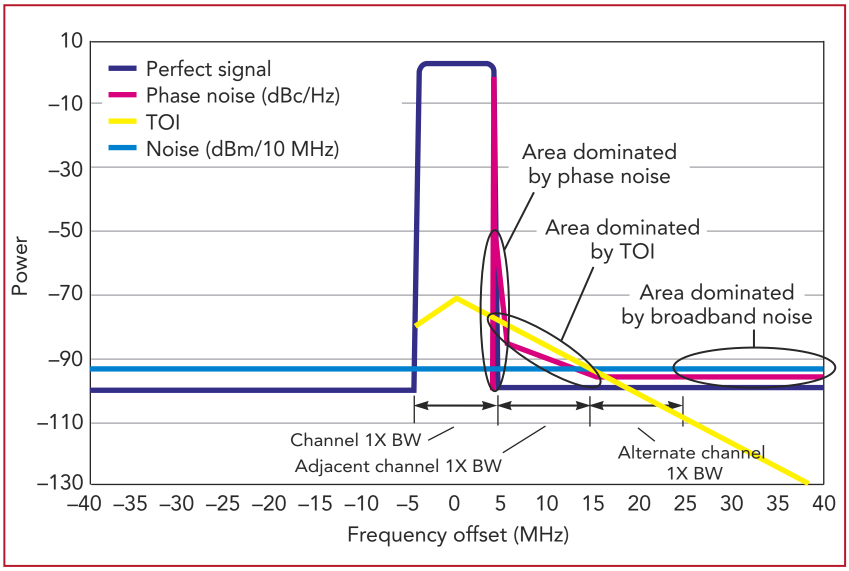

FIGURE 5. At offset frequencies from a channel, different parameters dominate dynamic range.

4 highlights this intersection and shows the areas where phase noise, TOI, and broadband noise dominate dynamic range.

To further improve dynamic range, some spectrum analyzers apply averaging and trace math to subtract the analyzer's noise from the measurement. Noise correction can provide up to a 10-dB improvement in noise-floor performance. Noise correction also lets you apply additional attenuation to drive the internal TOI of the analyzer down without increasing the noise floor (for TOI-limited measurements).

Problems with phase noise

The phase noise of an analyzer's local oscillator can also degrade noise-floor performance at offset frequencies close to the carrier. At offsets greater than 1 MHz from a carrier, the phase noise won't impact dynamic range.

As an example, assume you have a digitally modulated signal with a main channel bandwidth of 10 MHz (±5 MHz from the channel's center frequency) and that you need to measure the spectral emissions at an offset of 5.1 MHz in a 100-kHz integration bandwidth. The 5.1-MHz offset represents a 100-kHz offset from the edge of the main channel. At that offset, the analyzer's phase noise will now be a contributing factor (**Figure 5**). Thus, for measurements close to a channel's bandwidth, the analyzer's dynamic range is limited to 65 dB. At offsets further away (say greater than 1 MHz), the phase noise of the analyzer improves and does not represent a limitation for dynamic range.

Resolution bandwidth (RBW) also affects a spectrum analyzer's noise floor. When you increase resolution bandwidth, you increase the noise floor by (10*log(RBW2/RBW1)), but you shorten sweep time. So, you can trade off dynamic range for shorter measurement time.

SHI, TOI, DANL, and resolution bandwidth combine to form a spectrum analyzer's dynamic range. By optimizing the combination of these specifications, you'll find the optimum point of the instrument's dynamic range. T&MW

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Satish Dhanasekaran *has an MSEE from Florida State University and currently works as a wireless application specialist with Agilent Technologies. He has more than 8 years of experience in the RF/wireless industry.*

Darrin Russell, *a wireless application specialist with Agilent Technologies, has a BSEE from the University of Texas at Arlington. He has more than 10 years of experience in the RF/wireless industry.*

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Configure an optical test system

With the MAP-200 series from JDSU, you can configure a modular tester for passive or active optical components or systems. Designed for lab or factory use and available in a mainframe or portable chassis (version shown), the MAP-200 supports 16 modules that include power meters, amplifiers, attenuators, tunable filters, switches, polarization controllers, and optical sources.

The system can test 10-Gbps and 40-Gbps optical transmissions for parameters such as jitter, power, flatness, insertion loss, and stressed-receiver compliance. The optional user-interface panel includes a 10.4-in. LCD screen, control buttons, and a wheel. The MAP-200 works with a USB mouse and keyboard, and you can connect a computer monitor through its digital visual interface port.

The mainframe models can hold up to three or eight measurement modules, with the eight-slot mainframe available with front- or rear-facing orientation. All chassis models are LXI Class C compliant. Software support includes drivers for LabView and C/C++.

JDSU, www.jdsu.com/test.

LitePoint targets MIMO, WiMedia, and GPS

LitePoint recently launched three systems for testing to four wireless standards. The new IQnxnplus system offers multistream signal capabilities for WiFi and WiMAX MIMO development. IQultra, an ultrawideband (UWB) error-vector magnitude test system, covers both development and manufacturing testing of UWB devices. And the IQnav test system is aimed at high-volume manufacturing testing of embedded GPS-equipped devices.

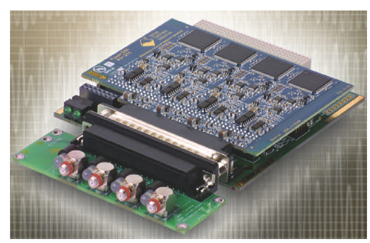
LitePoint IQnxnplus systems provide a modular approach for MIMO R&D testing. Each module contains its own vector signal analyzer (VSA) and vector signal generator (VSG). A synchronizer subsystem ensures that the modules work in lockstep. The systems can be configured from a 1x1 setup (for example, one module and a synchronizer subsystem) to a 4x4 setup (for example, four modules and a synchronizer subsystem). The modules support WiFi and WiMAX frequency ranges of 2.15 to 2.7 GHz, 3.3 to 3.8 GHz, and 4.9 to 6.0 GHz. The included graphical user interfaces—called IQsignal for WiFi and IQsignal for WiMAX—provide analysis and display capabilities for single, multistream, and beamforming adaptive-antenna functionality testing.

The IQultra WiMedia test system features a special-purpose VSA combined with an attenuator for UWB receive testing. The system can capture and analyze all WiMedia band groups (1 to 6) and time frequency codes (1 to 10). IQultra WiMedia test systems come in two versions: IQultra-300 for triple-band capture and IQultra-100 for single-band capture. Both support from 3.1 to 10.6 GHz and support multiband orthogonal frequency-division multiplexing (MB-OFDM) PHY layer specification version 1.2.

The multichannel IQnav for manufacturing test of GPS-equipped devices enables both carrier-to-noise ratio (CNR) measurements and location-fix tests to be performed in a single connection to the device under test. In addition, the IQnav offers synthetic power sweep capabilities where up to six CNR measurements are made simultaneously. Finally, the price of a six-channel IQnav compares with that of competitive single-channel testers, thus adding capabilities without affecting acquisition costs. IQnav is available in one- and six-channel models, both supporting L1 GPS frequencies (1575.42 MHz) over a power range of –60 to –145 dBm. The IQnav features specialized trigger capabilities that support testing of assisted GPS (A-GPS).

Prices: IQnxnplus—$55,000 to $129,000; IQultra WiMedia—$42,300 to $55,000; and IQnav—$9500 to $12,500. *LitePoint, www.litepoint.com.*

Get your four vibrations



United Electronic Industries has expanded its line of Ethernet-based data-acquisition systems with the introduction of the DNA-AI-211, an analog-input module that provides four isolated vibration sensor channels. Each channel has its own 24-bit analog-to-digital converter (ADC), so the board can sample all channels simultaneously. Each channel accepts signals from standard two-wire vibration sensors, and each can provide up to 8 mA of bias current for a sensor. An ADC, separate from the four 24-bit ADCs, monitors bias current for short or open circuits.

The 24-bit ADCs sample at rates up to 125 ksamples/s with a 109-dB signal-to-noise ratio. Analog and digital anti-aliasing filters have a 3-dB cutoff frequency of 49% of the sample rate, keeping the sampled signal under the Nyquist rate. The filters attenuate out-of-band frequencies by 100 dB.

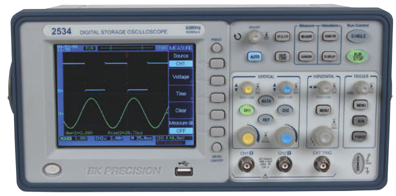
Price: $2000. *United Electronic Industries, www.ueidaq.com.*

> > > > > > >

60-MHz DSO delivers 400 Msamples/s

Outfitted with dual channels and analog-style knobs, the Model 2534 digital storage oscilloscope from B&K Precision lets you capture, save, and analyze waveforms and measurements using the supplied PC software. The scope provides a bandwidth of 60 MHz and a sampling rate of 400 Msample/s, and its advanced triggering, digital filtering, waveform recording, delayed sweep/zoom, mask testing, automatic measurements, and FFT functions create multiple options for circuit debugging.

The Auto button identifies the input signal and automatically sets



up the vertical, horizontal, and trigger controls to produce a usable display. You can automatically adjust the timebase to view the waveform area of interest by selecting the single cycle or multiple cycle option. Triggering capabilities include pulse width and line-selectable video trigger. In addition, you can save files to external memory complete with a time and date stamp.

Price: $799. *B&K Precision, www.bkprecision.com.*

PXI modules offer multiple resistor ranges

Pickering Interfaces introduced two PXI precision resistor modules: the Model 40-261 and the Model 40-297. The Model 40-261 is a two-channel module that offers two resistance ranges: 1.5 Ω to 2.9 kΩ and 10 Ω to 36 kΩ.

The Model 40-297 comprises a range of high-density resistor simulators that have broader resistance range and higher channel count, but lower resolution than the 40-261. Modules are available in three standard configurations: 1 Ω to 230 Ω, 2 Ω to 13.5 kΩ, and 3 Ω to 1.5 MΩ, providing 18, 9, and six channels, respectively.

Pickering Interfaces, www.pickeringtest.com.

Test sets handle frequency stability measurements

Pendulum Instruments has introduced two new time and frequency test sets: PicoTime and GPS PicoReference. PicoTime handles frequency stability measurements, while PicoReference is a combined frequency reference and measurement test set for frequency stability analysis.

PicoTime makes direct frequency measurements from 1 MHz to 30 MHz in comparison to an external 10-MHz frequency reference. It features 1-ps resolution and an easy-to-use software application for performance analysis.

Housed in a 1U rack-mount chassis, the GPS PicoReference test set comprises two modules: a measurement model and a GPS-disciplined Rubidium frequency reference with up to eight reference outputs. The measurement module provides a frequency testing range of 1 MHz to 30 MHz and 1-ps measurement resolution for clock characterization and calibration applications. The integrated software enables the GPS PicoReference to work with an external 10-MHz reference or through its built-in 10-MHz reference module.

Pendulum Instruments, www.pendulum-instruments.com.

DDS function generator boasts stability

Heading Protek's B8000FD series of dual-output DDS function generators is the Model B8040FD, an instrument that operates from 1 μHz to 40 MHz

with harmonic distortion of less than –54 dBc for sine waves; for square waves, the frequency range is up to 5 MHz, and it is 1 MHz for all other waveforms. The instrument also delivers 40-ppm long-term stability and 1-ppm short-term stability.

The B8040FD also generates square, pulse, triangle, ramp, exponential up, and exponential down waveforms, plus noise. It provides AM, FM, PM, FSK, ASK, and PSK modulation and bursts of up to 65,535 of all internal waveforms.

Base price: B8003FD—$387; B8010FD—$484; B8020FD—$599; B8040FD—$778. *Protek, www.protektest.com.*

Probe cards target memory, logic

SV Probe recently announced two new probe cards for semiconductor wafer test. Targeting NAND flash memory, the SureTouch single-touchdown memory probe card enables testing of all devices on a wafer with just one contact between the probe card and the wafer. It is positioned to address the demand for high parallelism testing, short manufacturing lead times, and lower cost of ownership for NAND flash memory. The MEMS-based LogicTouch, a fine-pitch vertical probe card, is designed for advanced mixed-signal and logic devices, such as microprocessors, digital signal processors, and system-on-chip ICs that require high parallelism testing and device adjacent pad pitch of 60 microns and below.

SV Probe, www.svprobe.com.

MACHINE-VISION&INSPECTION

TEST REPORT

Camera improvements boost flying prober inspection quality

By Ann R. Thryft, Contributing Technical Editor

The ability to perform optical inspection is a fairly recent addition to the feature set of flying probers, and newer camera technology is helping to boost that ability even further. Seica's GM David Sigillo commented on how the use of cameras in flying prober test has changed over the last three years and what those changes have meant for electrical in-circuit test.

Q: Why are cameras being integrated into flying probers?

A: Most basic flying probers now have one camera, integrated into the prober's test-head area and mounted on a mobile probe that flies over the circuit board to be tested. Since operators manually install the board inside the prober, the board's placement can vary slightly. The operator correlates the board's location inside the prober to the probe-head assemblies of the tester by moving the camera over the board's fiducial markers, of which a minimum of two are needed. The system does this correlation automatically, based on previously programmed fiducial marker locations.

INSIDE THIS REPORT

For example, if an installed board is not parallel to the rails in the tester, a slight angle offset occurs. Once the camera locates the markers, however, the prober computes the offset and feeds it back into the tester software that recalculates all the test-point locations or probing locations that the tester will target.

Q: Why do some probers have more than one camera?

A: Some prober models include numerous cameras, depending on whether they are single-sided or dual-sided probers. Cameras can be mounted so that they have access to one or both sides of the board. For example, Seica's new double-sided Pilot V8 flying prober has two CCD cameras, one on each side. The main need for the second camera is to visually inspect the board's components on the side opposite to the side being tested.

In electrical inspection, you may not have access to the board's signal net or can't perform an electrical test on a single component. If there's a known-good board from the customer, you can take a digital image of the component and its location and compare it to the image stored in memory for those components to which you have no electrical test access.

Q: What are some capabilities of newer cameras that are being integrated into flying probers?

A: In addition to detecting component presence, placement, skew, and orientation, newer cameras can also perform optical character recognition on characters etched on the board or components, such as part numbers or serial numbers. These same cameras can also digitize an image of the board, which allows operators to recall that image on an offline PC for off-tester engineering activity.

An additional improvement in flying prober cameras and image-acquisition software is the ability to capture multiple images of the board and its components. For example, components with the same electrical value from more than one vendor may look different, and the customer may want to use either one in production. Images captured by the cameras can be compared to a variety of images stored in the prober database, providing more flexibility in visual inspection acceptance criteria. □

David Sigillo
General Manager
Seica

EDITOR'S NOTE

Innovation despite economic woes

Rick Nelson, Editor in Chief

The machine-vision industry in North America is undergoing trying times, as contributing technical editor Ann Thryft reports on p. 52. She quotes Paul Kellett, the Automated Imaging Association's director of market analysis, as saying,

"In the short term, there will be some gnashing of teeth, but in the long term, prospects are bright."

Undoubtedly, some gnashing of teeth is going on, but so, too, is a wave of innovation. For example, Thryft reports on p. 49 about an enhancement that adds optical inspection to a flying probe system's electrical-test capability. On p. 54, she explains how computed tomography serves in printed-circuit-board failure analysis.

Innovative inspection products were also on display at last month's Semicon West show. Viscom, for example, highlighted flexibility, exhibiting its MX100IR desktop automatic wafer inspection system. Focusing on speed, Surface Imaging Systems introduced its NanoStation 300, which augments atomic force microscopy (AFM) with an optical inspection capability to rapidly identify regions of interest. As for emerging markets, KLA-Tencor, exhibiting at the co-located InterSolar North America show, highlighted its surface-metrology capabilities applicable to solar-power applications.

Our October "MV&I Test Report" will highlight additional products from Semicon West, but the snapshot presented here illustrates that innovation need not be stifled by an economic downturn. □

Contact Rick Nelson at rnelson@tmworld.com.

HIGHLIGHTS

JAI expands GigE Vision camera suite

JAI has added the BM-500GE (monochrome) and BB-500GE (raw Bayer color) 5-Mpixel cameras with a GigE Vision interface to the Basic tier of its C3 Camera Suite. The cameras are built around the Sony ICX625 ⅔-in. CCD sensor (2448x2050 pixels) and can operate at 15 fps.

A Sequence Trigger Mode allows the user to predefine on-the-fly changes to gain, shutter, and the region-of-interest (ROI) settings for a repeating sequence of up to 10 consecutive triggers. JAI says this capability is useful on production lines where items being inspected might require different settings for different regions of the object, or where different settings are needed to properly inspect for different types of defects within the same ROI. www.jai.com.

FEI introduces high-resolution SEMs

With the release of its Magellan Family, FEI has introduced what it calls a new class of instruments: extreme high-resolution scanning electron microscopes (XHR SEMs). The Magellan XHR SEM allows engineers to see 3-D surface images at many different angles and at resolutions below 1 nm. The system images samples at very low beam energies, avoiding distortions caused by a beam penetrating into the material below.

The Magellan Family comes in two models: The Magellan 400 for scientific research and the Magellan 400L for semiconductor labs. The 400L, which allows manufacturers to see critical details on complex 3-D structures in 32-nm nodes and below, comes with a load-lock feature that speeds up throughput, and it includes a retractable solid-state backscatter electron detector. www.fei.com.

PPT Vision upgrades camera line

Available in both monochrome and color models, the upgraded Impact T3X intelligent cameras from PPT Vision offer pixel resolutions ranging from 640x480 to 1600x1200 as well as onboard image processing, real-time I/O, and 128 Mbytes of onboard memory. The Impact Vision Program Manager, which is part of the bundled software suite, offers more than 120 tools, including optical character recognition, blob analysis, circular pattern find, line find, and subpixel gauging. The cameras also offer discrete I/O, serial, Ethernet/IP, TCP/IP, HTTP, Modbus, and ActiveX communication protocols. www.pptvision.com.

Rudolph sells lead-scanner line

Rudolph Technologies reports that it has sold its lead-scanner assets, which the company acquired from RVSI Inspection in January, to BKM Technology Partners. The transfer of assets and inventory is expected to be completed during the third quarter of 2008. The lead scanners can be used to perform final inspection for semiconductor devices such as ball-grid arrays and quad flat packs.

"We are excited about adding the lead scanner to our semiconductor solutions portfolio," said Barton A. Katz, BKM partner. "BKM is committed to providing world-class support. Following a seamless transition of this business from Rudolph to our organization, we intend to deliver this same level of support for lead-scanner customers. BKM has previously supported the RVSI Lead Scanner product line in North America, so it makes sense to expand this expertise worldwide." www.bkmtechnologypartners.com; www.rudolphtech.com.

Machine-vision industry experiencing trying times

By Ann R. Thryft, Contributing Technical Editor

TABLE 1. 2007 WORLDWIDE MACHINE-VISION MARKETS (MILLIONS $US)					
Product	North America	Europe and Israel	Asia-Pacific	Rest of World	Total World
Components	$205.8	$223.0	$205.7	$49.1	$683.5
Smart cameras	$116.6	$126.3	$116.6	$27.8	$387.3
ASMV systems	$1,233.1	$1,335.9	$1,232.7	$293.9	$4,095.6
% of World	30.1%	32.6%	30.1%	7.2%	100.0%

Note: Numbers have been rounded

Source: Automated Imaging Association

A recent study from the Automated Imaging Association (AIA) reports that the machine-vision industry in North America is undergoing trying times, primarily due to the uncertain business cycle. "But this is not the first time the industry has faced such severe challenges," said Paul Kellett, director of market analysis at the AIA and author of the organization's 2008 *Machine Vision Markets* study (Ref. 1). "It has always come back and experienced a strong rebound."

Although the main driver of the North American machine-vision industry is the US economy, machine-vision companies not based in this geographic market sell into it, "and clearly their sales will be affected by what happens in the North American economies," said Kellett. "And demand for those products is falling off. It's harder to export to the US, since demand is down and the dollar is much weaker, so it's harder to compete with domestic machine-vision companies."

The machine-vision market is divided into three segments: components (such as optics, lighting, cameras, imaging boards, and third-party software) and two kinds of systems—smart cameras and application-specific machine-vision (ASMV) systems. In 2007, the study reports, sales volumes for machine-vision components in North America reached $205.8 million, sales of smart cameras reached $116.6 million, and sales of ASMVs reached $1.23 billion (**Table 1**). Together, these totaled just over $1.5 billion, an amount that is expected to grow to $2.1 billion by 2012.

The study also looks at sales of machine-vision products in Europe and Asia-Pacific (see "Machine vision in India and China poised for growth," below). Worldwide sales of machine-vision components in 2007 totaled $683.5 million, sales of smart cameras totaled $387.3 million, and sales of ASMV systems totaled $4.1 billion. By 2012, these totals are ex-

Machine vision in India and China poised for growth

The AIA's 2008 *Machine Vision Markets* study expects North American sales to rebound for two main reasons: because of the industry's past performance in recovering from troubled economic times and because of machine vision's essential role as an enabler of cost containment, production-quality control, and productivity.

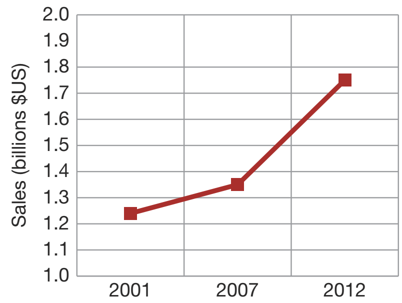
"In North America, there are both short-term and long-term demand drivers for machine-vision products," said Paul Kellett, AIA director of market analysis and author of the study. "The business cycle plays an important role in the short term, influencing the capital equipment budget of companies that purchase machine-vision products. But in the long term, demand will be a function of the fundamental value that only machine vision can bring in terms of efficiency, productivity, and quality."

As a key automation technology, machine vision is important to economic modernization in developing countries. To be competitive in the world market, a developing economy cannot indefinitely rely on cheap labor, said Kellett. At some point, it must modernize to achieve not only greater efficiency and productivity but also higher quality. That's where machine vision comes in. "The long-term demand for it will also be a function of the trend toward economic modernization in developing countries," said Kellett. Consequently, machine vision will become increasingly important in China and India.

Both component and OEM machine-vision markets are just beginning to emerge in India. But in China, large addressable markets have already appeared. In 2007 alone, nearly $178 million in total sales transactions were addressable by machine-vision companies. By 2012, this figure could grow to $431 million. While the actual penetration of these markets by machine-vision companies is not currently known, their large size suggests that even a low penetration rate could amount to significant sales.—*Ann R. Thryft* pected to grow to $928.9 million, $545.1 million, and $5.35 billion, respectively. European markets have the largest share of world sales at 32.6%, while North America and Asia-Pacific each have a 30.1% share.

Although the overall North American market has been growing since the post-2001 recovery began, sales growth in 2007 flattened. The study's forecasts assume an economic slowdown this year, but not a recession. According to the study's executive summary, "...we expect the slowdown experienced in 2007 to intensify in 2008." But if a recession occurs, then sales volumes will probably dip lower than those forecasted.

The growth rates of individual component, system, and software markets in 2007 varied, due to the different trends affecting them. For example, the average unit price of cameras has not declined at the same



In North America, sales of machine-vision systems, including smart cameras, are expected to rise to $1.75 billion by 2012.

Source: Automated Imaging Association.

rate as that of other components. Kellett explained that this is probably due to the trend toward digital images, which has increased digital camera sales at the expense of analog camera sales. "Within the digital slice, there are several major changes," he said, "including the increased need for higher resolution and faster speeds, and the consequent growth of high-bandwidth interfaces, specifically Camera Link and GigE." Color is also becoming important.

There are also major trends that affect most of these product markets. "The capabilities of all machine-vision products are expanding over time, but their prices are declining," said Kellett. At the same time, miniaturization and integration are increasing via electronic components.

For all of these reasons, "Machine-vision companies should focus on the long-term prospects of the industry," said Kellett. "In the short term, there will be some gnashing of teeth, but in the long term, prospects are bright." □

REFERENCE

1. *Machine Vision Markets: 2007 Results and Forecasts to 2012,* www.machinevisiononline.org/public/articles/index.cfm?cat=124.

CT brings clarity, precision to PCB inspection

By Ann R. Thryft, Contributing Technical Editor

Originating in medical and industrial applications, computed tomography (CT) has made inroads into printed-circuit-board (PCB) failure analysis. At first, the technology was used primarily in R&D laboratories, failure-analysis labs, and on new product production lines where operators need very high levels of resolution. More recently, CT has become necessary in mainstream production lines as 3-D stacking techniques and increases in board complexity have made it difficult for engineers to differentiate between layers in an x-ray. "You can see quite a lot with 2-D x-ray, but sometimes fine detail gets obscured by the layer above it," said Paul Walter, managing director for x-ray systems at Dage Precision Industries.

Production machines like the XD7500NT are beginning to take advantage of CT technology.

Courtesy of Dage Precision Industries.

Although systems with lower resolution have been standard in production environments, operators could see most of the faults on electronic devices as long as those systems included an angular view capability. More recently, production inspection machines have begun to take advantage of CT in addition to their x-ray analysis technology. "People are beginning to demand higher resolution and more technology on a wider range of machines," said Walter.

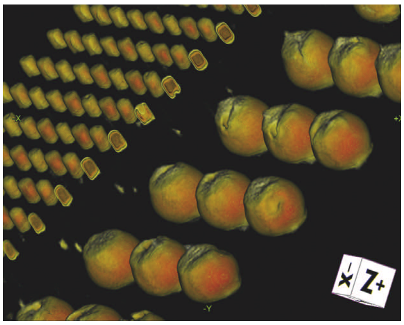
Whether CT is required on an electronics production line depends on PCB complexity and the type of faults that are found in production. For example, much of the demand for CT originated in the manufacture of extremely dense cellphone boards. The cameras in mobile phones are so complex that 2-D x-ray isn't capable of inspecting their faults.

By developing inspection systems that combine CT and x-ray capabilities, manufacturers are making it easier for their customers to uncover and evaluate faults in PCBs in a variety of environments. Dage itself offers two such systems—the Dage Precision XD7500NT and XD7600NT—that provide CT scan for 3-D modeling via optional modules. The company also offers new software called QuickView that speeds up the use of CT in both production and failure-analysis tools.

"Traditionally, to discover 3-D faults you might have created a microsection slice that would have been observed by a scanning electron microscope," said Walter. "But you have to make the slice in exactly the right position, and the method is both time-consuming and destructive. With CT, you can clear out the clutter above and below the fault and see it clearly."

Using CT, operators can create a 3-D model, place it on the viewer, and visually slice through faults like a virtual microsection. Dage's CT option for its x-ray systems allows the creation of volumetric slices through solder joints, fast reconstruction of CT images, and rapid creation of custom slices. Reconstruction resolution is up to 1024x1024x1024 volume pixels (or 1024^3 voxels).

A lot of fine-tuning was necessary for manufacturers to adapt CT hardware and software technology for electronics applications. Although the problems to be solved are basically the same as those in the medical and industrial arenas, CT technology is now being used with much smaller samples that require higher resolution. "For example, the size of faults in an aircraft engine turbine blade are on the order of 20 to 30 microns or more, versus the submicron accuracy range in electronics required for building 3-D images," said Walter.



CT imaging can help uncover faults on complex ICs, such as ball-grid arrays. Courtesy of Dage Precision Industries.

Despite the advantages CT offers for failure analysis in PCB inspection, the technology does have disadvantages. Higher-resolution inspections take longer because more images must be taken to create the CT model. And taking many images over a long period of time increases the chance that errors such as those caused by heat variances will occur. This is what prompted Dage to develop the QuickView software, which is based on an algorithm that speeds up image creation and processing.

"With QuickView, we tried to increase speed without sacrificing too much resolution by achieving a 3X to 4X speed improvement and retaining about 75% of resolution, compared to standard CT operation," said Walter. Operators can create many slices quickly, within less than 5 min each, while saving the slower, high-resolution slices that require 15 to 20 min each for the most critical areas. □

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225 Wyman St., Waltham, MA 02451
781-734-8423 Fax: 781-734-8070
Sales e-mail: tmwsales@reedbusiness.com
Editorial e-mail: tmw@reedbusiness.com
Web: www.tmworld.com

BUSINESS STAFF

Publisher: Russell E. Pratt
rpratt@reedbusiness.com
Assistant to the Publisher: Darlene Fisher
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Fast Pulse Test Solutions

Avtech's new 4 page **Web Guide & Short Form** catalog 17S outlines their large family of high-speed (40ps to 100 ns rise time), high-current (0.1 to 500 Amp) and high-voltage (2 to 3000 V) pulse generators, drivers and amplifiers for research lab and production testing applications.

Pulsed laser diode and discrete semiconductor device switching time applications are extensively highlighted along with ten other application areas. Numerous chassis photos, diagrams and output waveforms are included. **Catalog 17S is available online at www.avtechpulse.com/literature/cat17s.pdf.**

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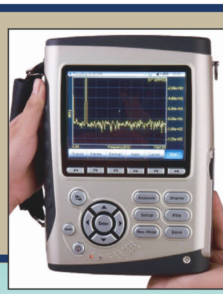

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ÉTIENNE GAGNON
VP, Product Management and Marketing
EXFO Electro-Optical Engineering
Quebec City, QC, Canada

Étienne Gagnon was appointed VP of product management and marketing at EXFO Electro-Optical Engineering in May 2003. In May 2007, he assumed responsibility for the company's telecom business units—optical, transport, datacom, and access. As such, he is responsible for EXFO's general marketing direction on both the product and communications levels. Gagnon is also responsible for the marketing communications of EXFO Service Assurance (formerly Brix Networks). He holds a bachelor's in mechanical engineering from the University of Montreal and a master's in European business from the École Nationale Supérieure des Télécommunications in France.

Contributing editor Larry Maloney conducted a phone interview with Gagnon on test solutions for telecom applications.

Test sets the tone for telecom quality

Q: How tough is it for engineers and technicians to meet the testing demands of rapidly evolving broadband services?

A: It's a very big challenge. The field is extremely fast moving, particularly in access technology, such as fiber to the home, fiber to the node, and triple-play services. Add to this the lack of uniform standards, interoperability issues among VDSL chipsets, and a shortage of skilled engineers and technicians to install and maintain networks.

Q: What is EXFO's niche within the global telecom industry?

A: Our job is to support network service providers, cable TV operators, and telecom system vendors as they cope with rapid growth. Early on, we focused on technology deployment in the field, particularly fiber-optic installation. But over the years we've broadened our mission to address telecom in general, including transport, datacom, and access. For all these applications, we provide easy-to-use test tools for the lab and the field. Our sweet spot continues to be engineers and technicians who install and maintain telecom networks, but we also support engineers at network equipment manufacturers.

Q: How will the acquisitions of Brix Networks and Navtel Communications expand EXFO's capabilities?

A: With its distributed, probe-based solutions, Brix Networks has proven experience in monitoring next-generation IP networks to ensure that voice, video, and data services are delivered with the quality of service (QoS) demanded by users. Navtel has specialized in testing emerging technologies, including next-generation IP networks that increasingly combine wireless and wireline systems. Its platforms perform several critical tests, such as capacity, performance, stress, and load testing, on switches, routers, and other devices from network equipment manufacturers. This acquisition will help EXFO expand into high-growth IMS (IP multimedia subsystem) and VoIP (voice over Internet Protocol) test markets.

Q: What were your most significant product introductions of the last year?

A: One very significant introduction is the AXS-200 platform for assessing the quality of service of IP-based voice, video, and data services. This platform provides troubleshooting capability that includes both the service itself and network hardware. If you talk to carriers, you'll find a tremendous need for this type of test solution, which helps to quickly resolve customer issues as they happen.

Another very successful product is the FTB-8130NG, a transport and datacom module for core networks and metro networks, especially ROADM (reconfigurable optical add-drop multiplexer) deployment. This one tester handles all the protocols in core networks, such as SONET, Datacom GigE, 10 GigE, and Fibre Channel. Finally, there's the FTB-5700, an easy-to-use platform for analyzing dispersion in fiber, which is a critical issue with deployment of higher transmission rates in networks.

Q: What are some future telecom advances that will drive new test solutions at EXFO?

A: Triple-play deployment is still in its early stages, and delivery of those services will come not only from wireline operators but from cable TV operators and even wireless operators as they go into the field with 4G technology. To support all this, we'll need to develop test solutions for very high transmission rates—40 Gig is just the beginning. Our future test modules also will need to service many different modulation formats, with 20 different modulation schemes already being pushed by vendors. T&MW

Étienne Gagnon answers more questions on telecom test, including challenges to industry growth, in the online version of this interview: www.tmworld.com/2008_08.

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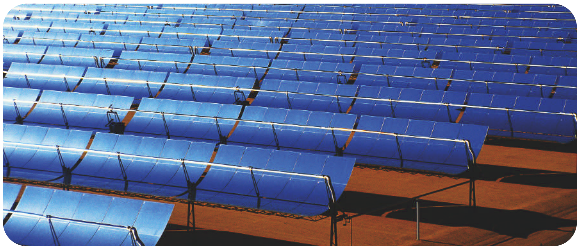

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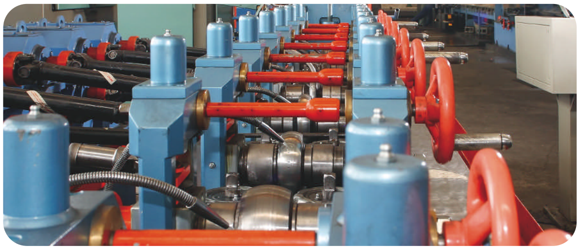

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