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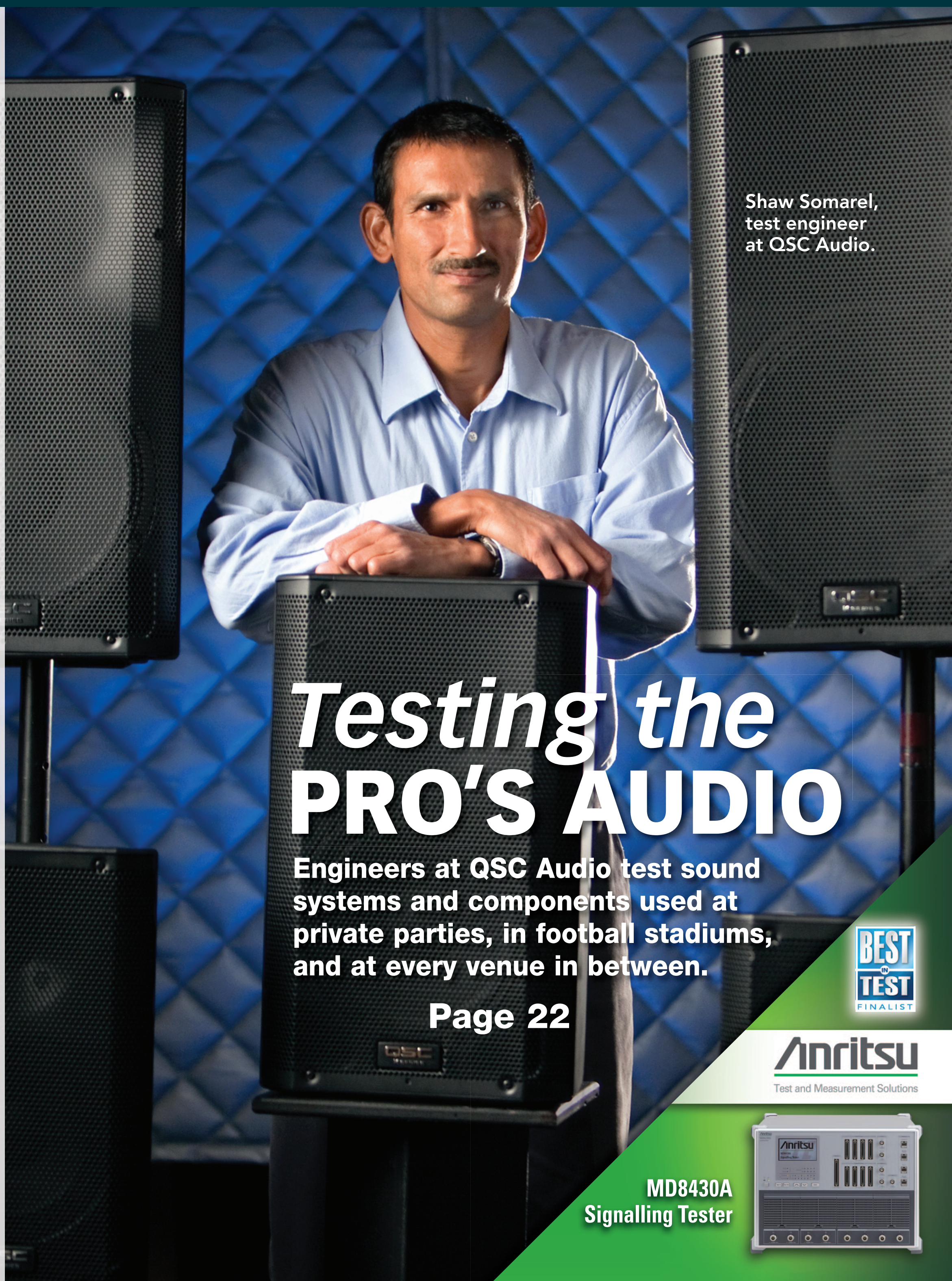
Test & Measurement World

THE MAGAZINE FOR QUALITY IN ELECTRONICS



Shaw Somarel, test engineer at QSC Audio.

Testing the PRO'S AUDIO

Engineers at QSC Audio test sound systems and components used at private parties, in football stadiums, and at every venue in between.

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The Bigger Picture!

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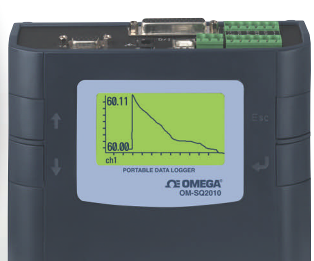

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COVER BY: STEVE LABADESSA

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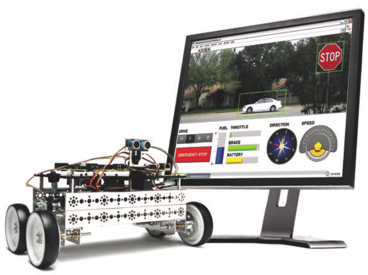

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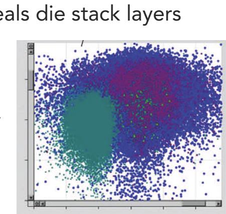

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Check out these exclusive features on the *Test & Measurement World* Web site:

Engineering a competitive test strategy (guest commentary)

In part three of a series on ways to improve your test strategy, Richard McDonell of National Instruments explains why test engineers should participate in the design phase of a new product introduction.

www.tmworld.com/ni_teststrategy

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RICK NELSON
EDITOR IN CHIEF

How many devices?

When I travel, I drag along a lot of electronic devices and peripherals: laptop, cellphone, cellphone headset, noise-canceling headphones, voice recorder, digital camera, MP3 player, laptop charger, cellphone charger, power inverter (12 VDC to 120 VAC), USB cable, iPod cable, and maybe something else that I've forgotten. What I'd like to do is condense all this into a single WiFi, Bluetooth, and 3G- or 4G-enabled cellphone-sized device. And I'm not talking about *The Onion* parody of a new device (Ref. 1): one whose functionality is unclear, but it's more expensive than the old device, available in blue, offers fewer buttons to push, less frustration, and a new wire to connect it to less-portable devices.

Let consumers choose the functions they want and need.

I am definitely interested in the functionality: I want this device to run Windows 7, be able to complete cellphone calls anywhere in the world, and match dedicated digital cameras and MP3 players in graphical and audio quality. And I'd like it to be able to connect to a full-sized keyboard and monitor when they are available.

Perhaps a much-anticipated tablet PC expected to be announced soon will meet some of my expectations. Perhaps, but I have my doubts. Functional convergence always seems to involve compromise. Nevertheless, I'd accept some compromise in exchange for a lightened load.

One company with the technology to support convergence from a connectivity standpoint is Broadcom, and while researching an upcoming *EDN* article on wireless devices, I asked Craig Ochikubo, VP and GM of wireless personal area networking at Broadcom's wireless connectivity group, about the prospects of a converged device. He commented that in a world of billions of handsets, millions of laptops, and countless other consumer electronics devices, it's unrealistic to expect that a single device could make everyone happy. He said, however, that there is room for innovation in developing devices that appeal to specific groups of consumers, based on factors such as age.

The difficulty of pleasing many people with one device is emphasized in a recent article in *The Economist* (Ref. 2). Technologies may be global in nature, the article says, but what people worldwide expect from their cellphones varies widely, imposing a Tower of Babel syndrome on the cellphone industry. The article suggests that culture and lifestyle differences among countries affect what cellphone features people want (Americans put up with poor reception to avoid the hassle of switching carriers, but Finns demand good reception on remote roads and in tunnels).

Nevertheless, there is some hope for convergence. *The Economist* article quotes James Katz, a professor of communications at Rutgers, as saying, "Regardless of culture, when people interact with personal communications technologies, they tend to standardize infrastructure and gravitate towards consistent tastes and universal features."

I'm not expecting a single killer device to emerge, but I am hoping that manufacturers build lots of devices with varied combinations of features that let consumers choose the functions they want and need. T&MW

REFERENCES

1. "New Device Desirable, Old Device Undesirable," *The Onion*, December 3, 2009. www.theonion.com/content/news/new_device_desirable_old_device.
2. "Mobile-phone culture: the Apparatgeist calls," *The Economist*, January 2, 2010. p. 56.

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PCB12500 System Set-up Shown: A Controller and Five Remote Generator Heads

Remote Head on 3 Foot Cable

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  - 2^7, 2^10, 2^15, 2^23, 2^31
  - Inverted / Non-Inverted
  - Fixed Patterns: 1010, 1100
- Adjustable output amplitude (0V to 2V)
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- 2 Tap de-emphasis (0 to 20db)

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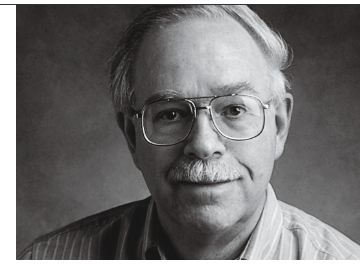
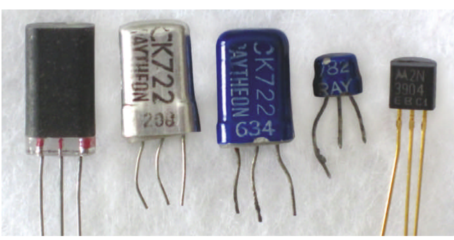


Your first transistor

For many budding electronics practitioners, the CK722 marked the transition from vacuum-tube technology to transistors. Introduced in 1953 by Raytheon Semiconductor Products, the CK722 sold for $7.60 (that's approximately $60.50 in today's dollars). A couple of years later, the CK722's list price had fallen to $1.00 ($8.00 in today's dollars). I purchased my first transistor and financed it from a week's earnings from my paper-delivery route.

Using components scrounged from my collection of junked radios, I painstakingly assembled my first transistorized project—a single-stage audio amplifier to boost the output of a crystal detector AM-band radio. The amplifier didn't work. I unsoldered the CK722 and checked its junctions with my only test instrument—a cheap Japanese multimeter from Lafayette Radio.



From left to right: samples of all three CK722 packages—black epoxy, silver metal, and the classic blue-enameled package—plus a CK782 hearing-aid transistor, which is about the same size as the CK722's "inner transistor." A 2N3904 is included for comparison.

I switched the meter to its continuity test mode, which featured a relay-style buzzer. And that's when I killed my first CK722. The buzzer delivered humongous inductive-kickback voltage spikes to the CK722's delicate junctions, which either short-circuited or opened (I don't remember which).

Temporarily defeated but not discouraged, I purchased a second CK722. That one lasted through two projects before one of its leads broke off flush with the bottom of the transistor's blue-enameled case.

Curious as to what was inside, I used sidecutters to peel away the CK722's case and discovered a smaller transistor! By carefully soldering extensions onto the inner transistor's stubby leads, I resurrected it for another project or two before I again destroyed it.

Years later, I learned that Raytheon experienced a relatively high reject rate for the PNP germanium transistors offered to hearing-aid manufacturers. Repackaged in larger cases, the rejects became CK722s.

And the CK722 wasn't much of a transistor. A combination of low current gain, high noise figure, high leakage currents, and a frequency response that struggled to get out of the audio range made it somewhat unpredictable and disappointing to use.

Today, the 2N3904, a garden-variety NPN silicon transistor whose specifications run rings around those of the CK722, costs only a few cents. But who among us will remember purchasing our first 2N3904? T&MW

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

TRANSISTORY

Visit the CK722-specific online museum, which includes a two-CK722 dual-LED blinker circuit:

www.ck722.com

Make the Semiconductor Museum your starting point for an exploration of early transistor history:

semiconductormuseum.com/Museum_Index.htm

A 1934 EE graduate of MIT, Norman B. Krim worked for Raytheon in a variety of positions, including directing the development and marketing of the CK722 transistor. To learn more about the engineer who gave us the CK722, read:

semiconductormuseum.com/HistoricProfiles/Krim_Profile_Index.htm

For a history of Raytheon and additional insights on the company's evolution from tube manufacturer to diversified corporation, go to:

sites.google.com/site/transistorhistory/Home/us-semiconductor-manufacturers/raytheon-part-one-2

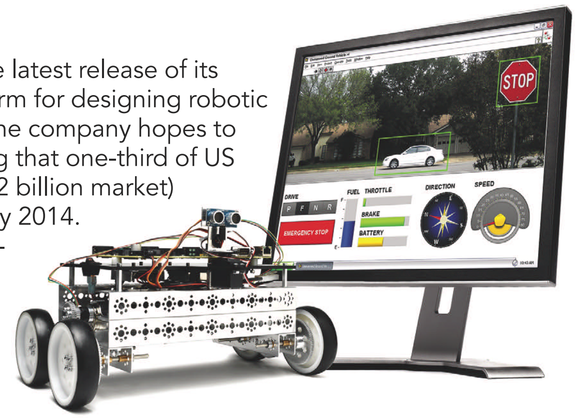
Yahoo.com hosts 2N1150_Down, a newsgroup dedicated to early solid-state devices:

tech.groups.yahoo.com/group/2N1150_Down

Frederick Picariello (aka Freddy "Boom Boom" Cannon) recorded "Transistor Sister," an early 1960s rock-and-roll anthem featuring what's arguably the only reference to an electronic component in popular music. In this song, "transistor" refers to the entire radio receiver—that's much like referring to an automobile engine as a "piston," but we'll take what we can find:

www.mp3lyrics.org/f/freddy-cannon/transistor-sister

NI pursues robot revolution



National Instruments is supporting the "robot revolution" with the latest release of its LabView Robotics software, which provides a development platform for designing robotic and autonomous control systems. With LabView Robotics 2009, the company hopes to capitalize on what it sees as a burgeoning market for robots, citing that one-third of US military vehicles must be autonomous by 2015 (representing a $52 billion market) and that the educational robotics market will reach $1.96 billion by 2014.

The company positions LabView as a tool for meeting the challenges that it says currently limit our use of robots in day-to-day lives; such challenges span software design (involving modeling, simulation, and algorithm design), embedded system design (involving analog and digital I/O, protocols, motion control, concurrency, and determinism), and connectivity (dealing with actuators, sensors, and motors). LabView Robotics 2009 ties together LabView Real-Time, LabView FPGA, NI Vision, LabView Control Design and Simulation, LabView SoftMotion, LabView Statechart, LabView Mathscript RT, and LabView PID Toolkit. It adds robotics IP for sensing, connectivity, protocols, path planning, obstacle avoidance, and steering.

Target hardware platforms include NI CompactRIO, NI Single-Board RIO, and a new LabView Robotics starter kit. NI said it is collaborating with companies including Cogmation Robotics (on system simulation), Energid (kinematics), Hokuyo (LIDAR sensors), iRobot (hardware integration), Microsoft (system simulation), MobileRobots (hardware integration), Maxon Motor (smart-motor connectivity), Pitsco Education (OEM and academic starter kits), Skilligent (vision software), TORC (the JAUS protocol), and Velodyne (LIDAR sensors) to add capabilities. www.ni.com.

Chip sales on the rise?

In what may be a hopeful sign for the test industry, the SIA (Semiconductor Industry Association) reports that worldwide sales of semiconductors rose to $22.6 billion in November 2009, a 3.7% increase over the $21.8 billion of sales in October (monthly sales numbers represent a three-month moving average). The organization also found that sales were 8.5% higher than the $20.9 billion in sales in November 2008. This increase came at the end of a year in which sales for the first 11 months declined 13.2% compared to the same period in 2008.

"For the first time in 2009, worldwide semiconductor sales in November were in positive territory compared to one year ago," said SIA president George Scalise in a prepared statement. "2009 ended with sales of many IT and consumer products faring better than earlier projections. Sales of personal computers continue to strengthen in line with recent projections and appear to signal the beginning of recovery of demand from the business sector. The release of the Windows 7 operating system in October has been a positive factor. Unit sales of handsets should come in roughly even with 2008 levels. In the consumer space, there have been a few bright spots including LCD TVs, which saw an increase of 25 to 30% in units in 2009." www.sia-online.org.

Trig-Tek is now part of EADS North America

EADS North America Test and Services announced the acquisition of Trig-Tek, a provider of precision, dynamic test

Adlink introduces PoE frame grabber

Editors' CHOICE

Adlink Technology has announced the release of the GIE62+ PoE (Power over Ethernet) frame grabber, which provides two independent GigE (Gigabit Ethernet) ports for multiple GigE Vision device connections with data transfer rates up to 1 Gbps. By supporting the LACP (Link Aggregation Control Protocol), the two GigE ports can be configured as a LAG (Link Aggregation Group) and provide a sustained maximum data rate of 2 Gbps.

The GIE62+ is the company's latest addition to its "power over cable" series of frame grabbers, supporting PoCL (Power over Camera Link), IEEE 1394b (FireWire 800), and now PoE. "Power over cable" enables single cable connections between cameras and frame grabbers to provide both data and power.

The frame grabber includes two isolated TTL digital inputs, two outputs, and two programmable trigger pulse inputs to connect to external devices such as position sensors and strobe lighting. The GIE62+ also provides automatic detection of being a powered device within the system to ensure reliable connections between other PoE and non-PoE cameras and frame-grabber cards.

Base price: $279. *Adlink Technology, www.adlinktech.com.*

and measurement instruments for the US aerospace and defense markets.

"Trig-Tek is an excellent acquisition and a good fit for our engineer-to-engineer culture," said Jim Mulato, president of EADS North America Test and Services. "Its complementary product line will enable us to provide even more complete, tailored test solutions to our military, semiconductor, and engine test customers." Lyle Wells, president and owner of Trig-Tek, will remain in a consulting role. www.eads-nadefense.com.

IOtech, Measurement Computing to combine

IOtech and Measurement Computing, subsidiaries of National Instruments, will integrate their product lines during 2010 and become combined under the Measurement Computing name. The companies began sharing resources in 2007 but kept their operations independent until now.

IOtech's data-acquisition products will be manufactured at the Measurement Computing facility in Norton, MA. The product lines include the USB PersonalDaq, Ethernet-based data recorders, PCI cards, and stand-alone dataloggers. IOtech's vibration-analyzer product line will move to NI headquarters in Austin, TX. www.mccdaq.com.

CALENDAR

OFCNFOEC, March 21–25, San Diego, CA. *Optical Society of America. www.ofcnfoec.org.*

Measurement Science Conference, March 22–26, Pasadena, CA. *Measurement Science Conference. www.msc-conf.com.*

APEX, April 6–9, Las Vegas, NV. *IPC. www.goipcshows.org.*

SAE World Congress, April 13–15, Detroit, MI. *SAE International. www.sae.org.*

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

Editors' CHOICE

DAQ systems offer PC control

The DS206 and DS207 data-acquisition systems from Dynamic Signals provide 16-bit analog inputs in several configurations, channel counts, and sampling rates. The USB-controlled DS206 provides six analog inputs, two analog outputs, and 16 digital (TTL-level) I/O channels. It can simultaneously sample on all six inputs at 50 ksamples/s.

The DS207 has two versions: DS207-100 and DS207-250. Both connect to a PC through a StarFabric connection. The DS207-100 is available with 32, 64, or 128 analog inputs with an aggregate sampling rate of 100 ksamples/s. You can cascade two units to get up to 256 channels. The analog inputs have programmable gain and scan rates and have optional low-pass filters to prevent aliasing. The DS207-250 has eight analog inputs (expandable to 16) and simultaneously samples all channels at 250 ksamples/s. It includes signal conditioning for bridge completion and has programmable gain, excitation, and calibration.

All models come with daView software that lets you configure all channels and plot data through a graphical interface.

Prices: DS206—$800; DS207-100—$50/channel; DS207-250—$650/channel. *Dynamic Signals, www.dynamicsignals.com.*

MARTIN ROWE
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Windows 7's eventual windfall

A recent discussion on a LabView user group revealed that engineers are starting to use Windows 7 for controlling instruments. Many automated measurement systems, however, will continue to run Windows XP or perhaps an older version of Windows for as long as the systems are useful. Other systems may get Windows 7, but not until the system computer needs to be replaced. The exceptions might be systems with Vista computers, which are likely to get Windows 7 upgrades.

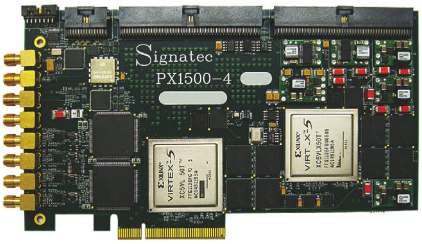
If you upgrade to Windows 7 with a new PC, you'll likely find more differences in the computer than just those that Windows imposes, especially if you use PC-plug-in instrument cards. For example, you may find that you no longer have enough PCI slots. Instead, you may find PCIe (PCI Express) slots. That could force you to buy new instrument cards, which might improve throughput.

If you replace your PCI cards with PCIe cards, you'll have to consider moving to the 64-bit version or staying with 32 bits. In high-speed or high-channel-count applications where you might collect lots of data, you can benefit from a 64-bit operating system, because it breaks the 4-Gbyte memory ceiling.

But Sean Sullivan, director of engineering at Data Translation, said, "Running 32-bit applications on Win64 might actually be slower than running them on a 32-bit version because all calls go through the WOW64 [Windows on Windows 64-bit] layer. The best scenario is to run 64-bit applications with your 64-bit drivers, but it is going to take some time before applications are available in 64-bit versions."

In addition, moving to the 64-bit Windows 7 might put your 32-bit applications at risk. Armando Valim, LabView product manager at National Instruments, noted that older 32-bit applications may not work on Windows 7 due to compatibility issues.

Several companies have announced support for 64-bit Windows 7. National Instruments currently supports 64 bits for many of its products. (You can check the company's Website for information about a specific product, www.ni.com.) On December 15, Agilent Technologies announced 64-bit driver support for its Acqiris line of digitizer cards. Other companies with 64-bit drivers for instrumentation cards include Adlink, Measurement Computing, and ZTec Instruments.



PCIe cards such as this digitizer may replace PCI cards in new Windows 7 computers. Courtesy of Signatec.

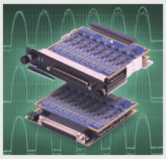
Valim explained that NI has a team of engineers running benchmark tests on Windows 7 to compare it to Vista and XP. He said that with Windows 7, you should see a slight improvement (up to 10%) in multicore applications and that Microsoft has improved its USB support by up to 20%.

If you're thinking about using a Windows 7-based notebook computer, you should be aware of changes in power management. Valim pointed out that Windows 7 is more aggressive with its power management than previous Windows products. "Windows 7 goes into power-save mode too quickly for many measurement applications," he said. "You may need to change the power-management settings to keep the measurements coming." T&MW

Site offers introduction to EMC

Wim Vogel of Modern Applied Technology Engineering has developed a short Powerpoint presentation that provides an introduction to EMC (electromagnetic compliance). Vogel explains typical reasons for EMC problems, how to detect them, and how to solve them by adding components or ground connections. www.mate.nl/wvogel/indexEnglish.html.

Boards simulate strain-gage output



United Electronic Industries has released two DNx-AO-358 simulated strain-gage output boards for use with the company's PowerDNA cubes and PowerDNR RACKtangle and HalfRACK chassis. Both boards provide eight channels of simulated strain-gage output based on signals from real variable resistor bridges. The boards support both DC and AC excitation (DC to 25-kHz range) with a system bandwidth of 250 kHz, minimum. The output update rate is 0 to 5 kHz. Each board also includes an onboard ADC that monitors excitation voltage to an accuracy of ±10 mV. www.ueidaq.com.

Chips to increase bandwidth

Agilent Technologies' InP (indium phosphide) semiconductor process will increase bandwidth in an upcoming line of oscilloscopes. Analog bandwidth will start at 16 GHz. According to the company, that bandwidth is achievable without signal processing. www.agilent.com.

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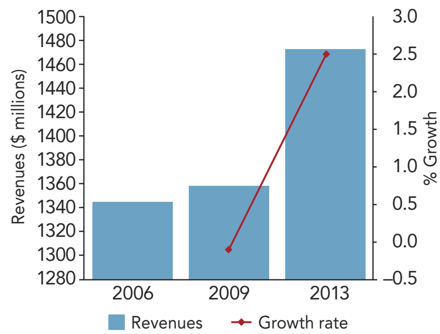
RF testing market should expand in 2010

On the RF technology testing front, a fresh approach to testing is necessary due to the rapid development and growth of new communication technologies such as LTE. Moreover, the convergence of technologies, while enabling the integration of more applications, has also increased opportunities as well as challenges for vendors of RF test equipment. In 2010, the need to develop and test handsets to meet the extreme performance requirements of LTE networks will accelerate due to increased deployments of these networks.

RF test solutions have to handle increased data rates, higher spectral efficiency, and low latency as well as provide scalable channel widths. MIMO (multiple-input, multiple-output) technology is expected to generate opportunities for the test vendors in this market. Another noticeable trend in RF testing equipment is the integration of more test capabilities into a single, one-box system that simplifies test processes.

In 2009, many test and measurement companies announced cost reduction and restructuring actions in response to the global economic conditions. In addition, semiconductor manufacturers showed a reluctance to invest in capital equipment, with focus shifting to test solutions that are able to keep costs low, such as multisite testing, which has been in existence for some time. With the highly integrated SOC (system on chip) market facing competition from SIP (system in package), there has been a growth of products that are built with multiple technologies, adding more complexity to the testing process. This has resulted in end users demanding improved RF testing capabilities without any additional cost implications.



Total revenues for the RF test equipment market, which includes spectrum analyzers, signal generators, network analyzers, and power meters, should increase by 2013.

The test process has increasingly become more complex. The test and measurement industry is forced to address the concerns of chip manufacturers and decrease the cost of ownership of test systems. Another noticeable trend in 2010 will be the higher adoption rate of software instrumentation, which significantly improves the efficiency of test and measurement systems. These trends will lead to the development of faster and more flexible automated test systems while reducing the cost of test overall.

Among the different end-user segments, there has been an increase in the application of RF-based devices in automobiles recently—such as SDR (software defined radio), which enables the delivery of some of the most popular consumer features including AM/FM radio, digital radio, MP3 playback, and navigation by using common configurable and scalable hardware via software. This augurs well for the RF test equipment market, as ATE (automated test equipment) is likely to be in demand. Higher throughput in RF measurements, with parallel RF source and measurement capabilities that can address this requirement, is likely to drive the demand in this market in 2010. T&MW

To read past "Market Trends" columns, go to www.tmworld.com/markettrends.

Hit outlook "reset" button and be ready for IC boom in 2010

Borrowing a term from General Electric CEO Jeff Immelt, market-research firm IC Insights is advocating the idea of a "reset economy" and is suggesting the IC industry may be in for a market "boom" in 2010.

Immelt's belief is that businesses, governments, and consumers will operate very differently in the post-crisis economy, and that corporations will need to adjust their practices and views to the new environment. According to IC Insights, this "reset" philosophy can be applied to the worldwide IC industry outlook.

"In only 12 months, the IC industry endured the most volatile quarterly swings in its history," Bill McClean, president of the research company, said. "While Q4 2008 and Q1 2009 set records for dramatic sequential quarterly IC unit shipment declines, Q2 2009 and Q3 2009 set records for the fastest-ever sequential quarterly growth for IC units! After such a period, it is probably best to step back and take a fresh look at the IC industry as it stands today and assess what can be expected for 2010."

And what is a possibility for 2010 is massive market growth, the company said. Among the "reset" IC industry points IC Insights made was that the Americas region was the only major region to see growth in its IC market in 2009, thanks in large part to the memory market. Capital spending for memory devices is forecast to more than double in 2010, IC Insights said, further warning, however, that the expected increase may not be enough to avert memory shortages and significant price increases in 2010.

Suzanne Deffree, Managing Editor, News, EDN

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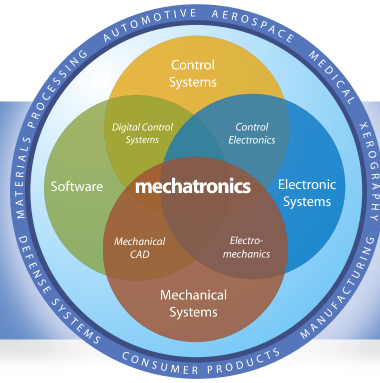
MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS, AND SOFTWARE IN DESIGN



What's your point of view?

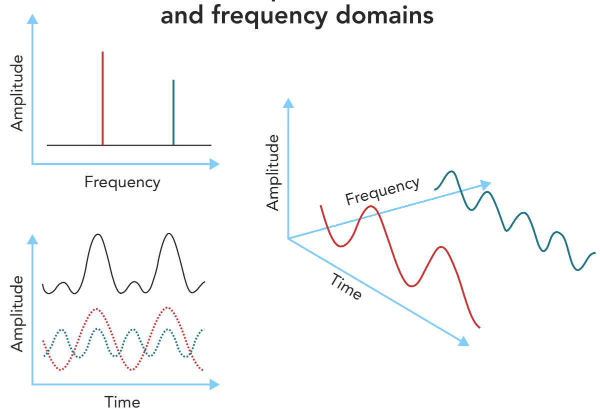
Time, frequency, and modal domains offer complementary views, insight.

Each of us is a critical-thinking problem solver. We have to be, as society's problems are mounting, getting harder, broader, deeper, and multidisciplinary. As basic engineering skills—analysis, hardware, and software—have become commodities worldwide, America's competitive advantage comes from being immediate, innovative, integrative, and conceptual. Our innovation must be local; you can't import it, you create it! It is a way of thinking, communicating, and doing. It differentiates us from other engineers around the world.

As multidisciplinary teams are formed to solve these problems, usually with a core group comprising mechanical, electronic, computer, and controls engineers together with problem-specific experts in, for example, combustion, chemistry, structures, materials, anatomy, and physiology, insight and communication are of utmost importance. We have all witnessed how engineers from different backgrounds describe the same concepts using different language and different points of view, which often can lead to confusion and, ultimately, design errors. Being able to describe concepts with clarity and insight in a variety of ways is essential for the mechatronics engineer as the multidisciplinary team leader.

The two domains, time and frequency, represent different perspectives. They are interchangeable, complementary points of view—that is, no information is lost in changing from one domain to another—and together lead to better understanding and insight.

Relationship between time and frequency domains



Time and frequency domains together give insight and enhance communication.

Most signals and processes involve both fast and slow components happening at the same time. In the time, or temporal, domain, we measure how long something takes, whereas in the frequency, or spectral, domain, we measure how fast or slow it is. No one domain always offers the best answer, so the ability to easily change domains is quite valuable and aids in communicating with other team members.

A third domain, the modal domain, is particularly valuable in analyzing the behavior of mechanical structures. It breaks down complicated structural vibration problems into simple vibration modes. Unique insight into the use of the modal domain in mechatronic system design has been provided in the work of Dr. Adrian Rankers, manager of mechatronics technologies at Philips Applied Technologies.

The time domain is a record of the response of a dynamic system as indicated by some measured parameter, as a function of time. More than 100 years ago, Jean Baptiste Fourier showed that any real-world signal can be broken down into a sum of sine waves, and this combination of sine waves is unique. By picking the amplitudes, frequencies, and phases of these sine waves, one can generate a waveform identical to the desired signal. To show how the time and frequency domains are the same, the **figure** shows three axes: time, amplitude, and frequency. The time and amplitude axes are familiar from the time domain. The third axis, frequency, allows us to visually separate the sine waves that add to give us the complex waveform. Note that phase information is not represented here.

If we can predict the response of a system to a sine wave input—that is, the frequency response—then we can predict the response of the system to any real-world signal once we know the frequency spectrum of that signal. The system's frequency-response curves are really a complete description of the system's dynamic behavior.

Engineers who can bridge gaps among disciplines and articulate complementary points of view clearly and insightfully will certainly have a competitive advantage. T&MW

Kevin C Craig, PhD, is the Robert C. Greenheck chair in engineering design and a professor of mechanical engineering, College of Engineering, Marquette University.

For more mechatronic news, visit: mechatronicszone.com.

BOOK REVIEW

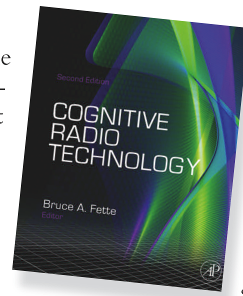
Cognitive radio targets convergence

Cognitive Radio Technology, 2nd ed., by Bruce A. Fette (editor). Elsevier Academic Press (elsevierdirect.com), 2009. 828 pages. $80.

Cognitive radio stands poised to revolutionize the way we acquire information wirelessly. As Bruce A. Fette puts it in *Cognitive Radio Technology*, "A cognitive radio (CR) is the convergence of many pagers, PDAs, cell phones, and array of other single-purpose gadgets we use today." In the process of helping users with this convergence of functionality, CR will help wireless networks by performing spectrum management and optimization tasks to minimize spectral congestion. In addition to dealing with external conditions such as available spectrum and interference, a CR can adapt to internal characteristics, such as low battery and component failure.

As described in the book, CR will build on SDR (software-defined-radio) technology, in which parameters like carrier frequency, modulation, voice and video coding, error correction, and network access are controlled by software.

The book looks forward to the expansion of SDR into spectrum-aware CR with respect to governmental and technological issues. The book presents this example that ties the two together: The US, Japan, and Europe have different spectral and EIRP (effective isotropic radiated power) rules for radios operating in 2.4-GHz and 5-GHz unlicensed bands. That presents radio manufacturers with unattractive options: They can make three models (one for each region), they can make one model with a switch to select in what region each unit will be sold, or they can build an overly constrained version that meets the requirements of all three regions. As a better alternative, a CR will determine which region it finds itself in and make adjustments for optimum performance in that region.



Cognitive Radio Technology doesn't have much to say about the necessary test-and-measurement instrumentation, but the "Cognitive Radio Performance Analysis" chapter explains how CR deals with static devices as well as other CRs in its environment. It presents traditional engineering analysis techniques as well as game theory as applied to CR, presenting a version of the prisoners' dilemma in which two CRs attempt to maximize their own throughput.

The final chapter suggests that the most significant challenges to CR deployment lie at the boundary between the technical community and the regulatory community. *Cognitive Radio Technology* is a useful reference to have on hand as the issues get sorted out.

Rick Nelson, Editor in Chief

SOFTWARE TOOLS

Model-based design aids medical device test

Engineers can save themselves a lot of effort by carefully evaluating their designs in software before building hardware. Model-based design can be of significant value in helping isolate domain experts, such as medical-device or aerospace engineers, from the need to understand low-level hardware and software details.

Brett Murphy, manager of technical marketing at The MathWorks, recently made the case for early verification (Ref. 1). He said that aerospace and automotive members of the company's customer-advisory boards cite verification and validation as top priorities. Errors most often emerge at a project's specification stage, and fewer errors manifest themselves during design, implementation, and test. But engineers frequently don't detect the errors until the test stage.

One MathWorks customer that has employed model-based design is the Cleveland FES Center at Case Western Reserve University, which develops technology that can restore movement to individuals with neuromuscular disabilities. Robert Kirsch, PhD, a professor of biomedical engineering at Case Western Reserve and associate director of technology at the Cleveland FES Center, said that adopting model-based design reduced the development time of FES (functional electrical stimulation) devices and enabled researchers to build customized prototypes for patients many times faster than they could before.

Traditionally, Kirsch said, the organization has relied on a group of software engineers who wrote low-level assembly and C code to implement algorithms, safety features, and system checks specified by the systems-integration team. A successful implementation, he said, would take several iterations and would constitute a bottleneck, but model-based design tools allow programming to occur at a higher, block-diagram level, allowing engineers and clinicians to modify an FES controller application and immediately test the results.

See the online version of this article for more information on the FES and model-based design, www.tmworld.com/2010_02.

Rick Nelson, Editor in Chief

REFERENCE

1. Nelson, Rick, "Model-based design and early verification aid designers," *EDN*, December 15, 2009. p. 22. www.edn.com/article/CA6711858.htm.

Test ideas

Measurement tips from readers

Sort thyristors with a test circuit

Use this circuit to sort for latch current and hold current.

By Chee Hua How, TDK Malaysia

Thyristors conduct current from their anode to cathode (I_{AK}) when they receive a gate pulse of sufficient current and duration. They will continue to conduct if I_{AK} reaches the latching current (I_L) level even after the gate pulse ends. The device should remain on as long as I_{AK} exceeds the device's hold current (I_H). If I_{AK} falls below a minimum I_H level, the thyristor should turn off.

Thyristor data sheets will specify typical values for I_L and I_H, but you may need to sort thyristors based on the difference between I_L and I_H—not their individual values—to ensure that the thyristor will properly control a circuit. If you ignore the variation of these two parameters, the thyristor may cause a product failure should it fail to properly turn on or off. Thus, you may need to set limits that guarantee proper circuit operation.

The circuit in **Figure 1** lets you set values for $I_{L(MAX)}$ and $I_{H(MIN)}$ that will ensure proper product operation. $I_{L(MAX)}$ and $I_{H(MIN)}$ are two extreme properties that never coexist in a single device. You can then use LEDs to indicate the thyristor's pass or fail condition. **Table 1** describes the four possible test results.

The settings in Figure 1 are for screening a TSN10A80 thyristor to fulfill requirements of $I_L \leq 20$ mA and $I_H \geq 6$ mA. The circuit uses a 20-mA current source formed by U1 and Q3. This current can then travel through the LED1 branch, through the LED2 branch, or through the series RC circuit

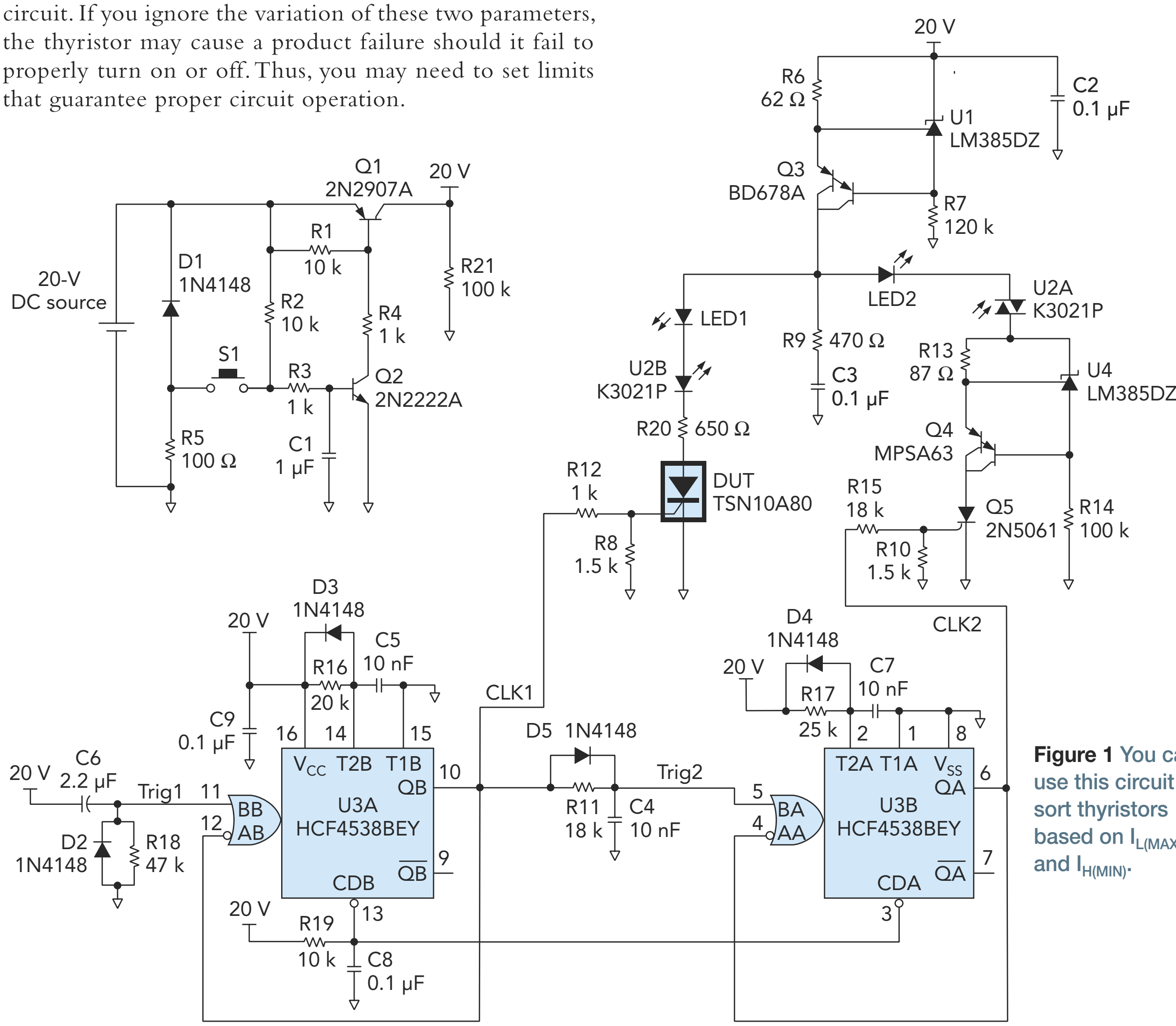


Figure 1 You can use this circuit to sort thyristors based on $I_{L(MAX)}$ and $I_{H(MIN)}$.

(R9 and C3). A dual monostable device, U3, sets two clock pulses (CLK1, CLK2) that trigger either the DUT or Q5, provided the pulses are of sufficient length to guarantee that the respective devices turn fully on and off.

Start a test by pressing switch S1, which forces Q2 off and thus forces Q1 off. That momentarily removes V_{CC} (20 V) from the circuit (**Figure 2**). Following a short delay t_{DLY1}, the first firing signal, CLK1, goes to the DUT (device under test) to turn it on. The DUT will conduct the entire 20 mA from U1, which will illuminate LED1. Q4 and Q5 will not conduct because CLK2 is low.

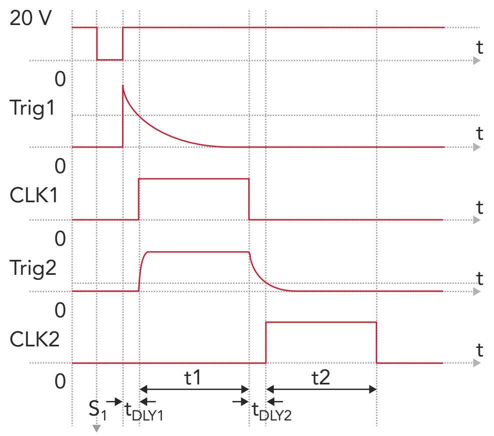


Figure 2 A timing diagram shows the relationships between the CLK1 and CLK2, which trigger the DUT and the circuit's two main branches.

After period t_1, U3A will remove the gate pulse CLK1 from the DUT. A blanking time of t_{DLY2} will follow. The RC network R11 and C4 set the blanking time, which is the period in which the DUT should latch in its conducting state. If the DUT fails to latch, it won't conduct current and LED1 will extinguish (condition 1 of Table 1).

If the DUT latches, I_{AK} will be 20 mA and U2B will turn on, sending a trigger pulse to its triac side, U2A. After t_{DLY2} elapses, U3B will initiate CLK2 and Q5 will conduct for period t_2. Q5 should then latch in its "on" condition. When Q5 activates, the U4-Q4-U2A network will divert 14 mA from the DUT branch. If the remaining current (6 mA in this example) of DUT current is below the DUT's holding level, LED1 will extinguish and LED2 will remain on (condition 3 of Table 1). If not, the DUT has failed to turn off and both LEDS will remain on (condition 4 of Table 1).

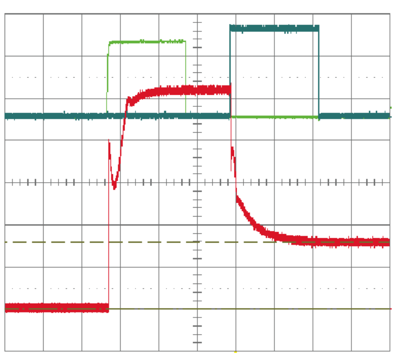


Figure 3 A DUT failed to shut off because its current dropped from 20 mA to 6 mA.

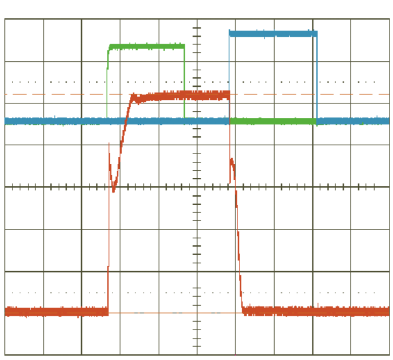


Figure 4 A DUT passed when it properly shut off, dropping its current to 0 mA.

Table 1. Test result state diagram

Condition	LED1	LED2	Result
1	Off	Off	DUT fails to latch
2	On	Off	Invalid; tester problem
3	Off	On	Pass
4	On	On	DUT fails to turn off

The values shown in Figure 1 are based on measurements for the TSN10A80 thyristor. To use this circuit with another thyristor, you will need to adjust the duration of t_{DLY1}, Δt_1, t_{DLY2}, and Δt_2 by changing the values of R18•C6, R16•C5, R11•C4, and R17•C7, respectively, to change time constants. Proper timing of t_1, t_{DLY2}, and t_2 will ensure that the current flowing into the DUT reaches steady state before the firing signals (CLK1 and CLK2) time out.

Proper timing also prevents excessive overshoot or undershoot current. The CLK1 and CLK2 pulse durations in **Figures 3** and **4** show 105 µs and 120 µs, respectively (100 µs/div). The tall waveform in Figure 3 shows a failed DUT, while Figure 4 shows a passed device. In both cases, the DUT successfully latched (tall trace). In Figure 3, I_{DUT} dropped to 6 mA after CLK2 activated, diverting 14 mA through Q4 and Q5, but the DUT remained on. In Figure 4, I_{DUT} dropped to 0 mA, indicating that the DUT had shut off. Thus, the device tested in Figure 3 had a value of $I_{H(MIN)} \leq 6$ mA, but in Figure 4, $I_{H(MIN)} > 6$ mA. T&MW

Testing the pro's audio

Engineers at QSC Audio test sound systems and components used at private parties, in football stadiums, and at every venue in between.

BY MARTIN ROWE, SENIOR TECHNICAL EDITOR

Costa Mesa, CA—You may have not heard of QSC Audio, but you've heard its sound. Amplifiers, digital audio processors, and loudspeakers from the company provide sound at private parties, movie theaters, conventions, concerts, and sporting events. QSC products bring the sound to venues such as the Sydney Opera House in Australia and the football stadium at the University of Alabama.

At QSC's headquarters in Costa Mesa, engineers develop and evaluate the company's products. They also provide test-engineering support for the company's production line, where amplifiers and digital audio processors undergo many tests that you might expect to see only during development. The loudspeakers and the transducers inside those products also go through a series of tests in the company's sound labs.

Test engineer Shaw Somarel supports production test of amplifiers and digital audio processors. He develops and maintains automated test stations that perform more than 100 measurements on each amplifier or digital audio processor. The test stations, like the rest of the line, must support many of the company's electronic products.

The production line is a high-mix, medium-volume, build-to-order line. An amplifier, for example, starts as a bare PCB (printed-circuit board). A bar code identifies the board for parts placement, test, final assembly, and packing. Eric Andersen, QSC's VP of manufacturing, ex-

Test engineer Shaw Somarel develops production testers for QSC Audio's amplifiers and digital audio processors.

STEVE LABADESSA

plained that the line supports 84 different amplifier models without needing a setup for each board. All materials for all models are available at all times at the point of use. The networked assembly system downloads placement programs from a database as needed based on the bar codes.

When an amplifier board enters the production line, solder paste is silkscreened onto the PCB's pads. A pick-and-place machine then assembles the surface-mount components on the board at about 10 parts/s. Next, through-hole machines add axial and radial leaded parts. Assemblers then manually add large capacitors and inductors, which are often needed in high-power amplifiers (QSC's most powerful amplifiers produce 4000 W/channel on each of two channels).

Once a board has its surface-mount components, it goes through a reflow oven. "We design our boards so that they can all use a single reflow heat profile," said Andersen. A wave-solder machine solders the through-hole parts to the board. During wave solder, fixtures hold the components in place to minimize flexing and lead stress. Following wave solder, assemblers add heat sinks to the power transistors. Assemblers then install a fully populated board into a chassis, which is then ready for test.

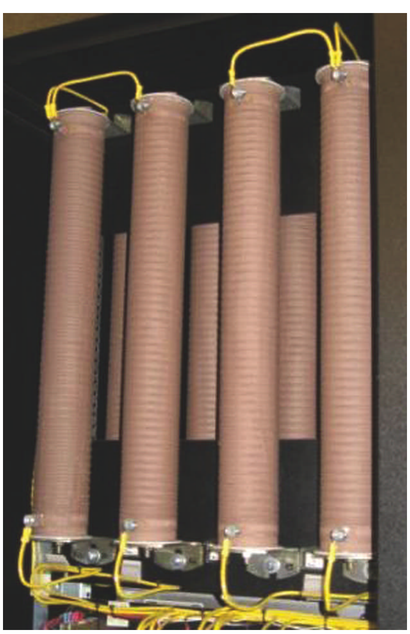
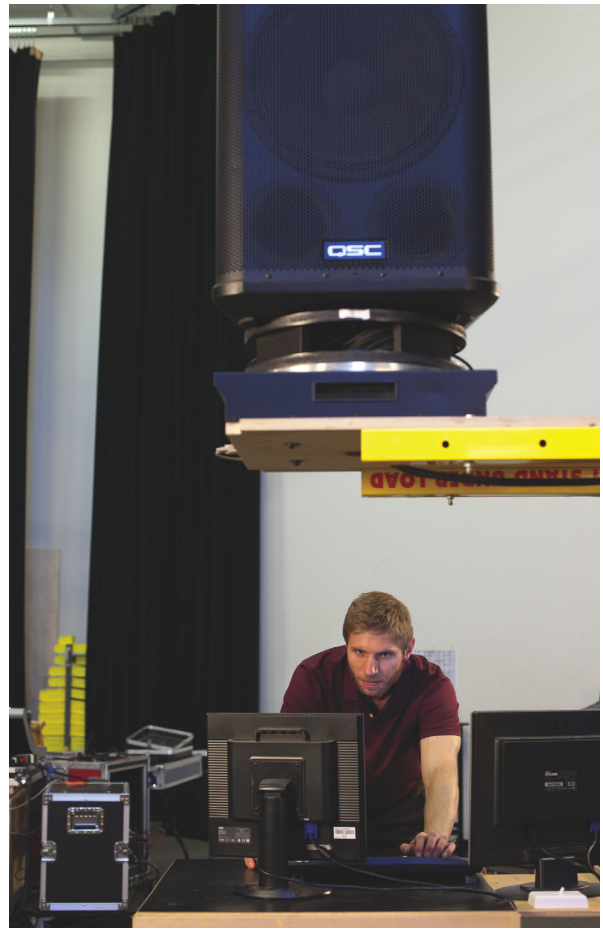


FIGURE 1. A production test rack holds banks of power resistors for amplifier testing.

The first test an amplifier undergoes is a thermal test, which verifies that the amplifier's thermal-shutdown circuits work. A fixture shorts the amplifier's outputs while a container around the chassis restricts airflow. The amplifier heats until it reaches a set temperature point that activates the thermal-shutdown circuit, which mutes the amplifier's outputs. As it cools below the set temperature point, the amplifier will recover and resume operating.



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Loudspeaker engineer John Brodie evaluates speakers by placing them on a lift and measuring their response to audio signals.

Automated test

After the thermal test, the amplifier is ready for final test. There, an automated test station downloads the amplifier's test procedure from a server on the company's network. Somarel wrote the test station's control software in Visual Basic .NET. He stores the test parameters in Excel spreadsheets.

An amplifier test station consists of a PC, a PLC (programmable logic controller), a Variac, a Fluke DMM (digital multimeter), a Fluke oscilloscope, an Audio Precision audio analyzer, and switch modules. The test station also contains power resistors capable of handling an amplifier's power output. **Figure 1** shows the power resistors mounted in the test rack. The PLC controls contactors for configuration of the load resistors and AC mains power. It also controls relays that perform audio signal routing to the amplifier under test. The load resistors connect to the amplifier's output through a custom speaker-cable assembly.

Dissipating power as high as 4000 W requires several power resistors wired in parallel. **Figure 2** shows how the power resistors form 8-Ω, 4-Ω, and 2-Ω loads used for testing both linear and switching (class D) amplifiers.

Each final test consists of more than 100 measurements such as frequency response, rated output power, THD (total harmonic distortion), SNR (signal-to-noise ratio), CMRR (common-mode rejection ratio), output signal phase, and output short-circuit current. The audio analyzer makes all the output signal measurements. It uses a proprietary communications bus that talks to a PCI card in the computer. The DMM (connected through GPIB) measures the AC mains voltage, the current supplying the amplifier, and the amplifier's output current under load. During each test, the PC, which controls the Variac through an RS-232 connection, regulates the Variac's output to the rated line voltage of the amplifier under test.

The test station has a 100-MHz analog oscilloscope that's not under computer control. Technicians use it to adjust the bias spikes at an amplifier's frequency crossover points. "We can probably use a digital oscilloscope," said Somarel, "but analog oscilloscopes typically give a more detailed trace display."

Somarel is developing a new amplifier test station for amplifiers that won't need an oscilloscope. He plans to replace the current Audio Precision System One audio analyzer with an APx585 model that has an oscilloscope integrated into its application software. The new analyzer has eight channels as opposed to two channels, which will reduce test time because the analyzer will be able to test all of an amplifier's channels at once (QSC Audio's amplifiers have as many as eight channels). Somarel expects at least a 50% reduction in test time with the new test station.

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Luis Esparza tests transducers for loudspeakers by analyzing audio response and by measuring movement with a laser vibrometer.

Somarel has already integrated the eight-channel audio analyzer into test stations for QSC's digital-audio products. One of the digital products, called Q-Sys, can control an entire audio system over Ethernet. Each Q-Sys controller can route digitized audio in a 512x512 matrix among amplifiers and audio sources such as microphones.

QSC's digital-audio products send digitized 24-bit audio using CobraNet, an audio protocol that runs over 100-Mbps Ethernet. QSC's engineers modified one of the company's current digital products that converts the CobraNet audio into an AES (Audio Engineering Society) digital stream so that the audio analyzer can process the digital audio.

"The CobraNet audio stream is demuxed and converted into an I^2S digital stream for digital signal processing," said Somarel. "The stream is then routed to a digital transceiver, which converts I^2S to an AES audio stream. Only two channels of the CobraNet audio stream are processed at a time, because the Audio Precision APx585 can only read two channels of AES audio signal."

Speakers make the sound

No sound system is complete without speakers, and QSC Audio manufactures a wide range of them in Costa Mesa. Most of the speaker testing takes place in two labs: the 4-pi lab and the 2-pi lab. In these labs, engineers evaluate complete speakers and transducers.

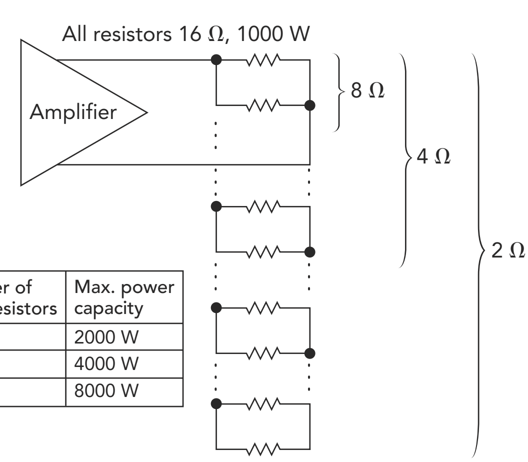
In the 4-pi lab, loudspeaker engineer John Brodie tests complete speakers and their cabinets' internal waveguides. The room is large enough for Brodie to measure a speaker's first response—the sound that reaches your ear directly from the speaker, before reflections. In the 4-pi lab, first-response audio reaches two microphones about 15 ms before reflected sound.

Each of the two microphones hangs from the ceiling at a 90° angle to each other. The speaker under test sits on a turntable that sits on a commercial lift. The lift raises the speaker to the level of the microphones. Lasers on the wall let Brodie align the speaker under test with the microphones.

To test a speaker, Brodie excites it with an amplified log-swept-sine or multitone signal. The microphones connect to a test system. "We use a system called SoundCheck by Listen Inc. SoundCheck uses a 24-bit PC sound card as a digitizer, digitizing sound from the microphones through preamps."

Brodie noted that the test system requires some setup time. It has a library of steps that define the sound card, the test site calibration data, and the speaker impedance. The library lets the test system perform math such as FFTs (fast Fourier transforms) on captured audio and generate the stimulus signals.

Brodie demonstrated the system with a QSC model



Number of 16-Ω resistors	Max. power capacity
2 (8 Ω)	2000 W
4 (4 Ω)	4000 W
8 (2 Ω)	8000 W

FIGURE 2. Banks of power resistors produce loads of 8 Ω, 4 Ω, and 2 Ω on each of two channels.

HPR 122 amplified speaker. He used a log-sine stimulus tone. (You can hear that tone at the online version of this article at www.tmworld.com/2010_02.) The SoundCheck system then performed an FFT on the first-response audio, analyzing it for frequency response, power, and distortion.

As part of a speaker evaluation, Brodie needs to measure a speaker's maximum power and frequency. He tests a speaker with up to 100 Vrms across its terminals, then steps down to –12 dB from that point. He then calculates relative change in level to find the amount of compression. "If a speaker port tube is too small," he said, "you get wind turbulence and have to redesign it."

Brodie also uses the response from the two microphones to characterize the speaker's projection profile. "A speaker's waveguide design may be for 90° dispersion pattern. If it comes out 80° or 100°, we will redesign the waveguide." To get the dispersion pattern, Brodie uses the turntable to rotate the speaker in 5° increments.

The audio analyzer software needs site calibration data so it can mathematically eliminate reflections and other effects from measured sound. To get calibration data, Brodie took a speaker outside and played it loud enough to get measurements without reflections (hopefully without bothering the neighbors). He then used that baseline measurement and subtracted reflections as part of the calibration.

Testing transducers

If you look up at one of the walls in the 4-pi lab, you'll see a set of wood panels where the center panel holds a transducer. Behind the panels, Luis Esparza evaluates transducers in the 2-pi lab. The 2-pi lab is located high above the floor of the 4-pi lab to minimize reflections.

STEVE LABADESSA

QSC's production test stations use audio analyzers from Audio Precision that make over 100 measurements.

Figure 3 illustrates the setup Esparza uses to measure the dispersion pattern of a transducer. A microphone, supported by ½-in. copper pipe assembly, can pivot 90° around the transducer at a 1-m distance. From inside the 2-pi lab, Esparza moves the pipe, changing the angle of the microphone relative to the transducer under test. He moves the microphone in 5° increments and records a transducer's off-axis response. Esparza uses a PC-based audio analyzer called Clio from Audiomatica. It consists of a signal-conditioning box that connects to a 24-bit PCI sound card. He uses the card to produce stepped-sine sweeps and MLS (medium-length sequence) measurements that measure a transducer's transfer function.

Figure 4 shows a plot that Esparza produced on a transducer's transfer function. The graph has several plots, each of a different color where each color represents frequency response with the microphone at a different angle relative to the transducer. In this test, Esparza made measurements from 0° to 45° from center in 15° increments.

Esparza uses such plots to find a transducer's directivity response, from which he determines where a speaker's crossover network should cross from its low-frequency transducer (woofer) to its high-frequency transducer (tweeter). In the example illustrated in Figure 4, Esparza would set the crossover frequency at about 2 kHz.

Esparza also makes plane-wave measurements where he measures the response of compression drivers. (Compression drivers are efficient transducers that produce high-frequency sound waves.) Normally, a compression driver is designed to emit sound as a plane wave. To make these measurements, Esparza attaches a compression driver to a waveguide tube that channels all of the sound to a microphone (**Figure 5**). He can measure the plane wave directly from the transducer without dispersion affecting the measurement using a swept-sine or MLS signal. "We get phase and magnitude measurements at the same time, and we can measure distortion

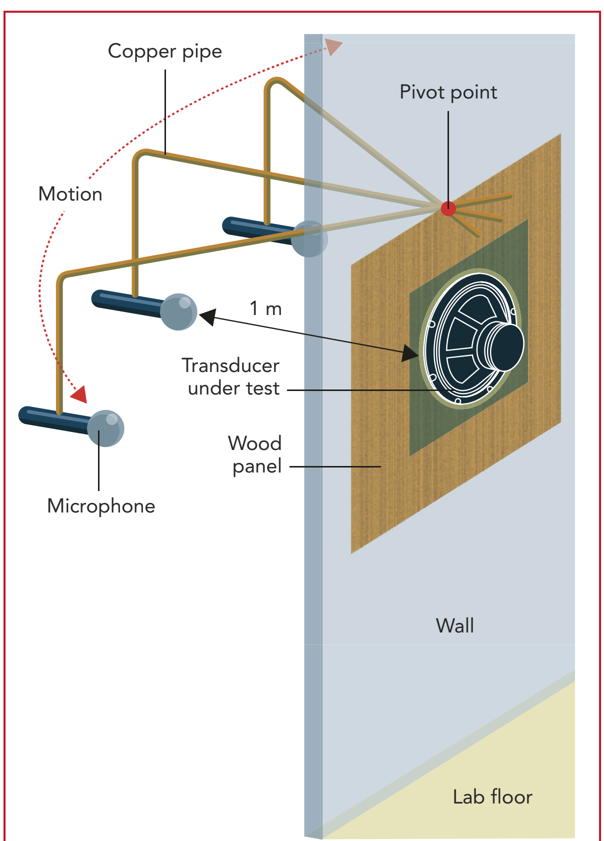


FIGURE 3. A copper pipe assembly lets engineers move a microphone in a 1-m arc around a transducer under test.

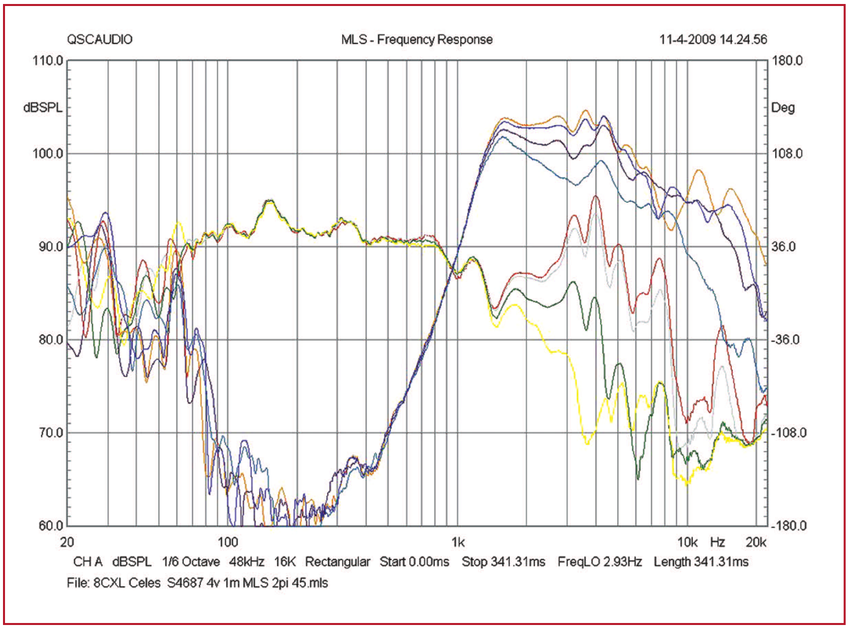


FIGURE 4. A frequency-response plot taken with a microphone at several angles lets engineers set a transducer's crossover point, around 2 kHz in this case.

and power compression using the same test fixture," he said.

The 2-pi lab also has a laser vibrometer that Esparza uses to measure the physical vibration of a transducer or speaker cabinet. The laser scans across the surface of the speaker cone or cabinet wall. "We want to see how the cone moves," he said. "We once had a frequency response issue at 3 kHz on a 6-in. cone. The outer edge of the cone moved more than the inner edge of the cone. Because of that measurement, we had the compression-driver manufacturer change its geometry, which corrected its frequency response."

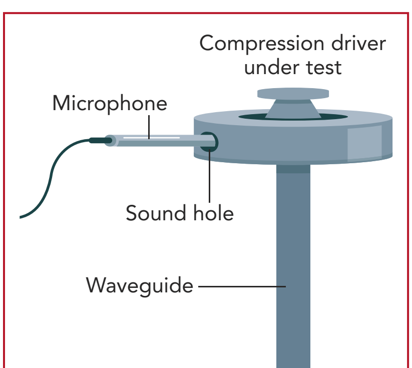


FIGURE 5. A waveguide channels all the sound from a transducer in one direction for a measurement.

Esparza also uses the vibrometer when testing a cabinet. He provides measurement data for cabinet designers to improve cabinet construction and optimize the locations of braces.

The 2-pi lab also has a transducer distortion analyzer manufactured by Klippel (see photo of Luis Esparza on p. 25). The Klippel analyzer is a laser-based instrument that calculates a transducer's nonlinear behavior by measuring the physical motion as a function of input current, which lets Esparza find how much of the input energy comes out of the transducer. The system measures nonlinearity of a transducer's cone assembly, magnet, and structure.

After performing measurements in the 2-pi and 4-pi labs, QSC's engineers can decide if a speaker is ready for reliability testing. That's where Chris Davies, manager of the Loudspeaker Systems Group, takes over.

Engineers in Davies' group test a speaker's or transducer's reliability by running it at its full rated power or higher in order to find out how much power it can handle. But running speakers at full power is rather loud and requires an insulated room to keep the sound from annoying QSC's neighbors.

QSC's reliability lab consists of two steel walk-in containers located behind the building. One holds a double-insulated chamber in which speakers and transducers under test operate at full power or higher for in excess of 100 hr. The second container holds the control equipment: CD players, a QSControl.net networked audio system with I/O and amplifiers, and an Agilent Technologies data-acquisition system. All equipment runs under software written in National Instruments LabView. Patch panels let Davies connect the amplifiers to the speaker under test in the adjacent container.

Davies uses the custom software to select an input source (a CD player or any of a variety of noise signals) and digitally route its output to the appropriate amplifiers. During a test, the data-acquisition system monitors voltage and current at the speaker under test and notifies the design team of any failures. The data-acquisition system measures current by measuring the voltage across a shunt resistor.

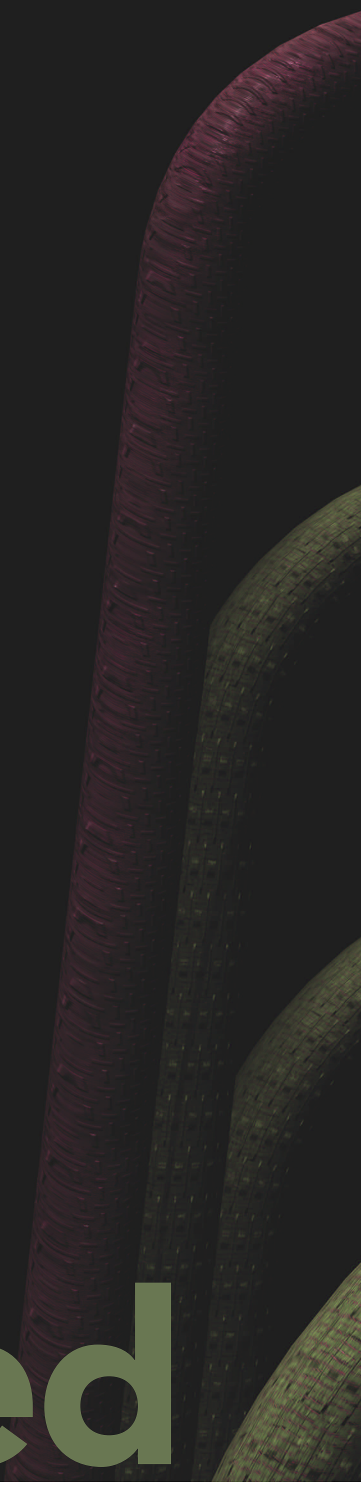
A test can run for as little as 2 hr or for more than 100 hr. After a 2-hr test, the system will give the speaker a rest and start again. Power levels start low and then ramp up. "We expect failures because we drive the speakers beyond the design limits, looking to see when they break," said Davies.

QSC Audio's engineers test audio products in the lab and in production to ensure that listeners get the most from musicians, DJs, movies, conventions, and concerts, and then musicians and DJs put the products to the real test on stage. At permanent installations such as theaters, convention centers, and stadiums, everyone can hear the results of those efforts. T&MW

ON THE WEB

Read the online version of this article to learn about Pat Quilter (founder of QSC Audio) and his collection of vintage audio equipment, which includes a record player from 1910 that has an external horn amplifier and a record player that plays cylinders developed by Thomas Edison.

www.tmworld.com/2010_02.



BY RICK NELSON, EDITOR IN CHIEF

When you're designing complex devices and systems for communications, semiconductor test, and other sophisticated applications, you often need to make measurements with instruments that can talk to each other. You might, for instance, need to synchronize a signal source and an analyzer to evaluate a prototype, or you may need to make automated measurements to collect voluminous characterization data.

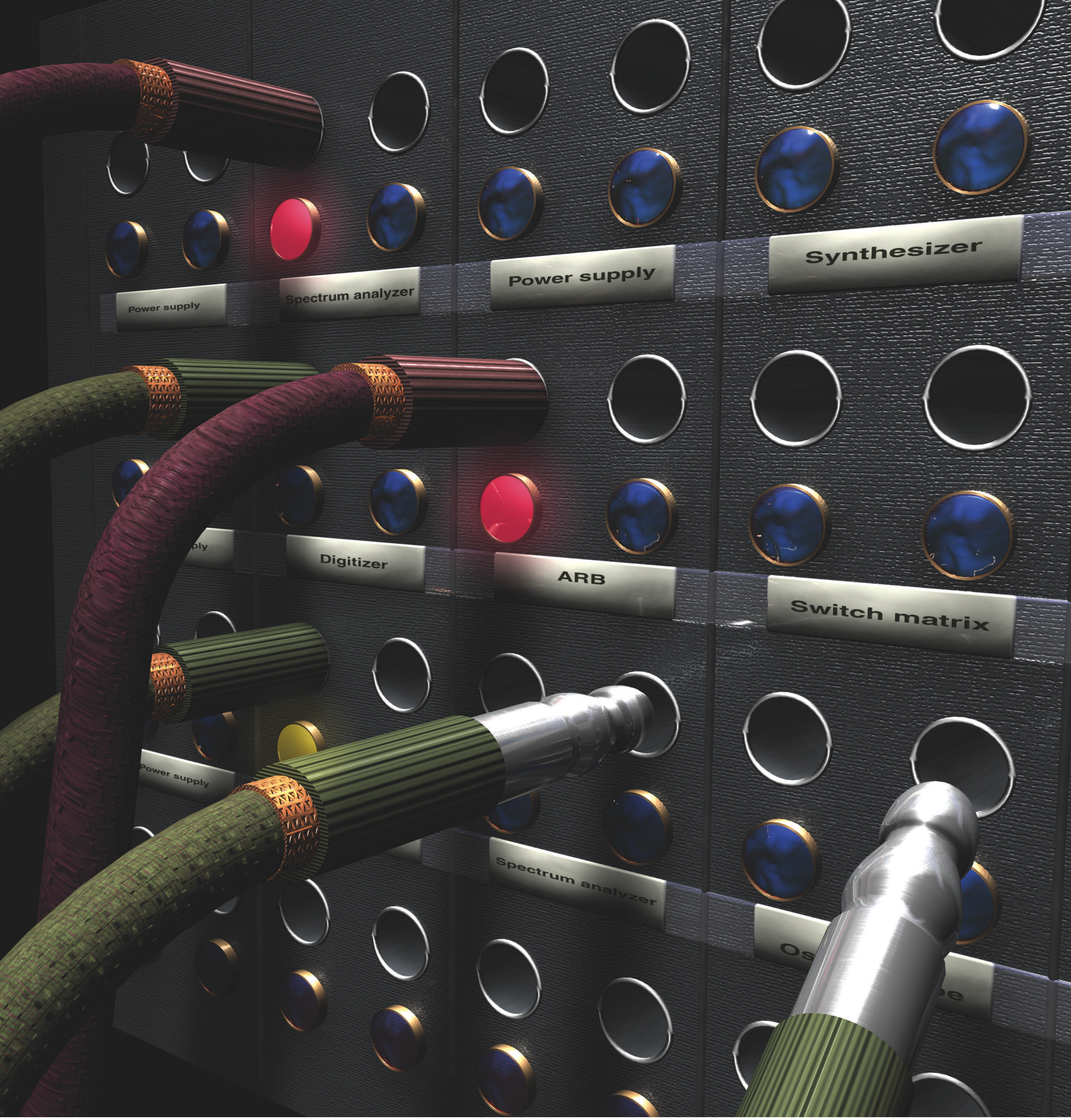
Instruments have long been able to communicate with controllers and with each other to serve such applications. That capability dates back to the late '60s, to the invention of the HP-IB (Hewlett-Packard interface bus), which was codified as the IEEE 488 standard and took the vendor-neutral name of GPIB (general-purpose interface bus). And instruments have long been available with general-purpose computer-centric interfaces ranging from RS-232 to USB. But those interfaces have limitations. GPIB cables are bulky and expensive, and data rates are limited. USB cables are ubiquitous and cheap, but the interface has no instrument-specific features and limits you to communications with a few instruments near a single computer.

The LXI and PXI standards are overcoming these limitations, and their respective proponents, which the LXI Consortium and PXI Systems Alliance represent, have been touting each standard's features and benefits for data acquisition, communications test, semiconductor characterization, and other applications. You can use instruments conforming to either standard alone or in hybrid systems to bring automated test capability to your laboratory.

Yet another standard, AXIe (AdvancedTCA Extensions for Instrumentation and Test), affords a way to tie LXI and PCI Express instruments together (Ref. 1). Promulgated by Aeroflex, Agilent Technologies, and Test Evolution, AXIe builds on the AdvancedTCA (Advanced Telecom Computing Architecture) computer bus to serve general-purpose and semiconductor-test applications, although it is so new that no test products employing an AXIe interface have been released.

Connected INSTRUMENTS

LXI and PXI systems serve applications including communications test and semiconductor characterization.



As evidence that there is no single correct instrument-system architecture for every application, several vendors are supporting or are at least investigating LXI and PXI standards (**Table 1**). But if you are working in the microwave range, you'll need an LXI system or a hybrid system with LXI microwave instruments, because most PXI instruments cannot support the necessary bandwidth. Phase Matrix offers the 26.5-GHz PXI-1420 downconverter, and Pickering Interfaces offers PXI microwave switches, but general-purpose PXI RF signal sources and receivers, offered by Aeroflex and National Instruments, top out at 6 and 6.6 GHz, respectively.

Rather than looking to boost bandwidth, makers of PXI RF modules have been targeting support for emerging technologies. Aeroflex, for example, recently announced new LTE measurement capabilities for its PXI systems. In contrast, just about any type of instrument you can buy for the bench is probably available in an LXI-compliant version. For example, Rohde & Schwarz has introduced its R&S ZVA67, a 10-MHz to 67-GHz vector network analyzer. The instrument complies with LXI Class C.

In addition, LXI can prove to be the technology of choice if you require some form of remote access or if you must cover long distances. For example, if you need to conduct tests on a radar range in which your source and receiver are hundreds of meters apart, an LXI system can easily accomplish measurements that would otherwise be impractical (Ref. 2).

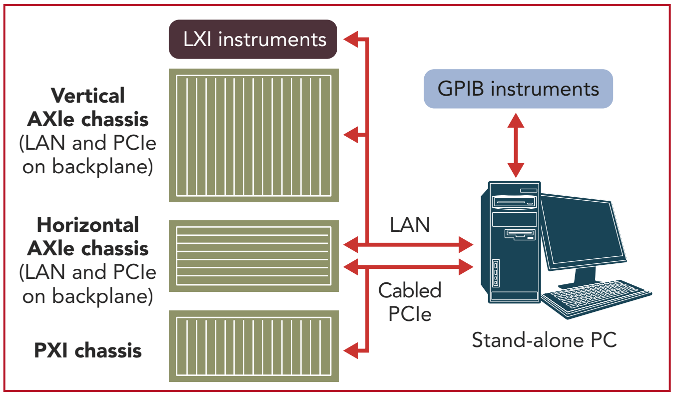
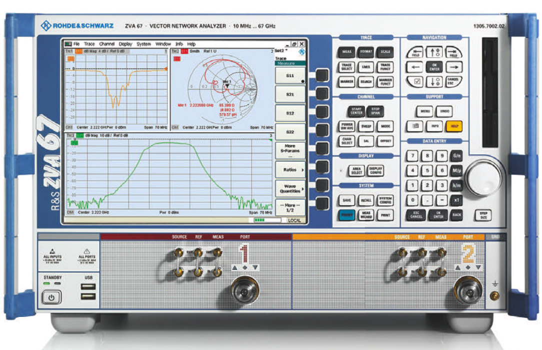


FIGURE 1. The AXIe standard uses backplane and cabled PCIe or LAN cards to connect instruments.

On the other hand, PXI affords a way to easily configure an instrument system without dealing with LAN issues and without involving your IT department. PXI inherently provides clock synchronization among instruments in a backplane—an ability available on LXI Class A and B instruments but not on the more common—particularly in the RF and microwave range—Class C versions. Further, PXI systems can stream data at high rates for off-instrument storage and analysis.



LXI instruments extend well into the microwave region. One example is the Rohde & Schwarz R&S ZVA67, a 10-MHz to 67-GHz vector network analyzer that is LXI Class C-compliant. The instrument features a 110-dB dynamic range at 67 GHz and can serve in R&D as well as production applications. Courtesy of Rhode & Schwarz.

Making the case for LXI

"Today, 1211 products are certified as LXI-compliant, approximately a 50% increase from 12 months ago," said Agilent Technologies' Von Campbell, who serves as the LXI Consortium's president, speaking last fall at Autotestcon 2009 (September 14–17, Anaheim, CA). Over the same period, he said, the number of instrument families available with LXI connectivity increased from 64 to 140, with 24 member companies having LXI-compliant products. He noted that LXI products cover every major product category for building a high-performance test system, with no holes or gaps in instrument capability (Ref. 3).

Joining Campbell at the Autotestcon LXI presentation were Rob Purser, manager for test and measurement products for Matlab and Simulink at The MathWorks; Bob Stasonis, sales and marketing manager at Pickering Interfaces; Chris Van Woerkom, senior marketing engineer at Agilent Technologies; and Tom Sarfi, VP of business development at VTI Instruments.

Purser noted that LXI "leverages the telecom wave" to reduce interconnect costs and ensure long-term stability for a test system. Ethernet, he said, has a 30-year history of evolution and maintains compatibility. Most LXI implementations don't require special hardware, although Purser cautioned against buying the cheapest Ethernet cables for your instrument system. He said LXI complements current technologies, allowing you to use LXI with your GPIB, PXI, or VXI system.

Despite the capabilities of Ethernet, Purser said, Ethernet alone is not enough. If you use Ethernet alone—and many instruments do have Ethernet interfaces—you'll need a way to configure hundreds of LAN options, to discover instruments, to connect test and measurement software to instruments, and to coordinate measurement activities. LXI, he added, provides a default LAN configuration to handle the details you would otherwise have to deal with when connecting your instruments to a LAN. To show how easy it can be to set up an LXI system, Purser at The MathWorks' Autotestcon booth demonstrated a communications-channel test setup comprising Agilent and Tektronix instruments operating in conjunction with a PC running MathWorks' Matlab software.

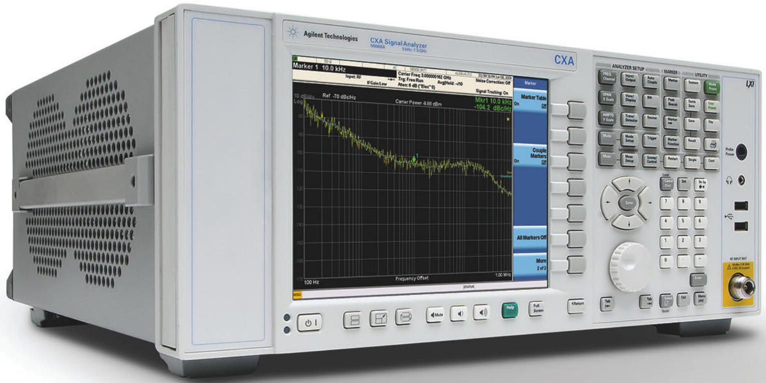
Van Woerkom of Agilent elaborated on LXI's capabilities, noting that it provides a consistent set of LAN communication services for test systems, supports LAN discovery for instruments, defines a standard Web page for instruments, specifies IVI (Interchangeable Virtual Instrument) drivers, requires interoperability testing for compliant products, and offers extensions for triggering and synchronization.

Dealing with your IT department

If you've ever dealt with your IT department, you might believe that LAN connectivity is a bug and not a feature. Speaking during the Autotestcon presentation, Stasonis of Pickering Interfaces commented on how to avoid pitfalls when connecting instruments to a corporate network and offered advice on dealing with firewalls and your IT department, which, he said, is understandably concerned with uptime and security issues.

If you must communicate with instruments across a campus or around the world, or if you want to provide remote access to the instruments in your lab, IT involvement is essential. According to Stasonis, you'll need to identify the number of IP addresses you need, define a network topology that minimizes latency and simplifies discovery, and describe your anticipated network traffic with respect to bandwidth and the services and protocols you'll be using. In addition, he said, you will want to determine where you archive test results and how to han-

"I need to achieve profit goals and control costs."



Fast, lean and ready to adapt.

Pressure to control costs is increasing. But so is pressure to deliver faster. Agilent's new CXA signal analyzer helps you do both, whether for product development or manufacturing testing. It's the quickest analyzer in its price class. One-button channel power, ACP, OBW and SEM* measurements speed design and test results for greater yield. And it's one of the new future-ready test tools in the Agilent X-Series spanning instruments, measurements and software. That's flexibility to run lean today and upgrade as needed. Spec Agilent, and expect more.

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Agilent Technologies

dle system updates—of virus protection, for example.

If the requirements for your automated test system are modest, you might get by with a configuration that won't upset your IT department, said Van Woerkom. He described a system with a PC, a router, and LXI-compatible instruments configured in an isolated subnet. You can let your router configure your instruments using the DHCP (Dynamic Host Configuration Protocol), although manually assigning IP addresses and aliases can avoid problems associated with address reassignment and can simplify programming. "Programs like a fixed address," he said.

To conclude the Autotestcon presentation, Sarfi of VTI Instruments outlined the instrument characteristics of Classes C, B, and A. Class C is the basic configuration, ensuring interoperability with other LXI Class C instruments. Most LXI-compliant RF and microwave instruments fall into Class C, although VTI makes Class A-compliant microwave switches.

Class B instruments implement the IEEE 1588 standard to provide synchronization among instruments, each of which includes its own clock operating at a slightly different rate from its neighbors. Class B systems include one timekeeping master and several slaves, using time stamps to keep clock deltas in the tens of nanoseconds, Sarfi said. He concluded by describing Class A instruments, which include an eight-lane M-LVDS (multipoint-low-voltage-differential-signaling) bus to support precise asynchronous handshaking at hardware speeds, with errors limited to propagation delays.

Table 1. Key members of the LXI Consortium and PXI Systems Alliance

Company	LXI	PXI
Adlink Technology, www.adlinktech.com		•
Aeroflex, www.aeroflex.com	•	•
Agilent Technologies, www.agilent.com	•	•
Alfautomazione, www.alfautomazione.it		•
Ametek Programmable Power, www.elgar.com	•	
Averna, www.averna.com		•
BAE Systems, www.baesystems.com		•
Brüel & Kjaer, www.bksv.com	•	
C&H Technologies, www.chtech.com	•	A
Chroma ATE, www.chroma.com.tw		•
EADS North America, www.eads-nadefense.com	•	A
Geotest—Marvin Test Systems, www.geotestinc.com		•
Gigatronics, www.gigatronics.com	•	•
Goepel Electronic, www.goepel.com	•	•
Keithley Instruments, www.keithley.com	•	A
LeCroy, www.lecroy.com	I	•
MAC Panel, www.macpanel.com		•
The MathWorks, www.mathworks.com	•	
National Instruments, www.ni.com	•	•
One Stop Systems, www.onestopsystems.com		•
Pacific MindWorks, www.pacificmindworks.com	•	
Phase Matrix, www.phasematrix.com		A
Pickering Interfaces, www.pickeringtest.com	•	•
Rohde & Schwarz, www.rohde-schwarz.com	•	A
TDK-Lambda Americas, us.tdk-lambda.com	•	
Tektronix, www.tektronix.com	•	O
Teradyne, www.teradyne.com	I	•
Virginia Panel, www.vpc.com		•
VTI Instruments, www.vtiinstruments.com	•	
ZTec Instruments, www.ztec-inc.com	•	•

This table includes companies mentioned in this article as well as companies that were listed as strategic, participating, or advisory members of the LXI Consortium (www.lxistandard.org) or sponsor or executive members of the PXI Systems Alliance (www.pxisa.org) as of January 2010. It does not include informational or associate members of the respective organizations unless noted.

Notes:
A = associate member of the PXI Systems Alliance
I = informational member of the LXI Consortium
O = Tektronix is working with National Instruments to develop a PXI oscilloscope that will incorporate Tektronix technology and be marketed by National Instruments.

From bench to PXI

If you plug all your instruments into one backplane, you have no need for IEEE 1588 synchronization or a separate hardware bus. "Suppose you want to synchronize two digitizers," said David Hall, RF and communications product marketing engineer at National Instruments. "In the old oscilloscope approach, you connect some cables on the back. With the PXI approach, you just say 'use PXI trigger line 1,' and that's all there is to it. From a timing and synchronization point of view, there are some inherent advantages to all the modules having access to a common digital bus."

Hall elaborated on PXI's benefits for communications system design, particularly for measurements involving MIMO radios. With traditional instrumentation, he said, "the way you would make those measurements is you would buy two vector signal analyzers and connect cables on the back end and hope that the LOs [local oscillators] are synchronized. In the PXI approach, the modules are inherently synchronized simply because you put them in the same chassis."

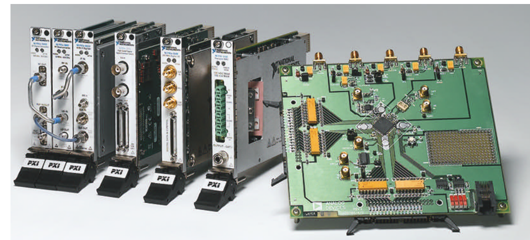
Hall cited another example of how PXI can be used in communications system design. He explained how some attendees at ION GNSS 2009, the Institute of Navigation's Global Navigation Satellite System meeting (September 22–25, Savannah, GA), needed to build better GPS receivers. As part of their efforts, Hall said, they were taking PXI systems into the field and acquiring raw satellite signals from the air. The PXI backplane is both a command bus and a data bus, and PXI Express can stream acquired I/Q samples in real time "until you fill up a hard drive," Hall explained. You can then use the stored samples to exercise and optimize prototype receivers.

In addition to communications test, NI is targeting semiconductor characterization with a series of instruments introduced last November at Productronica (November 10–13, Munich, Germany). Scott Savage, NI's market development manager for semiconductor test, touted the success that NI customers have had in using LabView and PXI hardware for semiconductor validation and characterization. He specifically cited the efforts of ON Semiconductor, of ST-Ericsson in conjunction with Mesulog and Saphir, and of researchers at the University of Applied Science working in cooperation with Austriamicrosystems as evidence to support the applicability of NI's approach to semiconductor test applications (Ref. 4).

A matter of taste

If you use bench instruments in an application that both LXI and PXI can serve, your choice of platform when moving to automation may center on your experience, your comfort level, and your age. Hall at NI said that he learned to use an oscilloscope in college, and the

point was for the instrument to provide him with diagnostic information that would enable him to make decisions. With the proliferation of PCs into test applications, it becomes important to get measurement information into a PC and use the PC to control the instruments and assist in decision-making. Although LXI and GPIB permit automation of bench instruments, "that wasn't the primary-use case" for which the instruments were originally developed, he said.



National Instruments recently introduced a suite of 10 PXI products that expand the capabilities of PXI for mixed-signal semiconductor test. The suite includes four HSDIO (high-speed digital I/O) instruments, two digital switches, two enhanced RF instruments, an SMU (source-measure unit), and specialized digital-vector file-importing software.
Courtesy of National Instruments.

Hall acknowledged that users like the feel of knobs and buttons and that users approaching instrument automation for the first time can find the idea of programming scary. He studied computer engineering in college and still finds the task of programming an instrument in C somewhat difficult. The graphical LabView language, he said, simplifies the task, and the company provides many sample programs to help new users get started.

Christopher Ziomek, president of ZTec Instruments, which makes digitizers in formats including PXI and LXI, said his inclination as an engineer would be to grab a Tektronix scope if he wanted to make a measurement in a lab. He noted some practical considerations. For example, if you want to make measurements while power-cycling a PXI scope under test, you'd need two PXI chassis: one for the scope under test and one for the test equipment. "I'm more comfortable with something that has knobs," he said, even though ZTec has developed its ZScope software, which mimics a traditional oscilloscope's front panel on a computer screen.

ZTec's younger engineers are more comfortable with the modular format, Ziomek added, and are happy running ZScope on tablet PCs. Modular instruments can also enhance productivity. Given PXI or LXI instruments and a computer interface, engineers are more likely to automate a measurement that they would otherwise manually repeat many times if restricted to a traditional bench instrument.

Ultimately, there will be room for a variety of instrument formats, a fact that vendors will take advantage of. Tektronix, for example, maker of the traditional engineering scope that Ziomek favors for lab work, said at NIWeek 2009 (August 4–6, Austin, TX) that it was teaming up with National Instruments to develop a 10-Gsamples/s, 3-GHz PXI digitizer. Craig Overhage, chief technology officer of Tektronix, said that the company had been looking at how to bring its high-bandwidth, high-sampling-rate oscilloscope technology to customers who prefer a modular-instrument architecture. Overhage said he sees different use cases for PXI scopes and traditional scopes, and he doesn't expect the introduction of the new PXI scope, which NI will market, to affect sales of the company's popular traditional instruments. T&MW

REFERENCES

1. Rowe, Martin, "Technical standard for test instrumentation announced," *Test & Measurement World,* November 11, 2009. www.tmworld.com/2009_axie.
2. Nelson, Rick, "LXI speeds gigahertz measurements," *Test & Measurement World*, November 2007, p. 49. www.tmworld.com/2007_11.
3. The Autotestcon session is available as a Webcast on the *Test & Measurement World* Website: "How to Create Advanced ATE Systems with LXI: Building on the Industry's Best Practices." www.tmworld.com/autotestcon2009_lxi.
4. The National Instruments Website includes papers that describe how several companies have used NI's PXI products for semiconductor test. www.ni.com/automatedtest/semiconductor.

A version of this article appeared in the November 12 issue of EDN.

Modules simplify 10-Gbps optical tests

Yokogawa has introduced a transceiver interface module and a signal generator module for its AQ2200 series optical-test-system mainframe. The modules streamline testing of 10-Gbps XFP, SFP+, and XENPAK optical transceivers.

The AQ2200-642 transceiver I/F module (shown in photo) combines an optical multimeter, a power supply, and a signal controller for an optical-module evaluation board. The power supply has one adjustable range and four fixed ranges that cover popular voltages used in optical modules. The AQ2200-651 signal generator module provides five channels of RF clock outputs at frequencies from 155 MHz to 180 MHz and 620 MHz to 720 MHz.

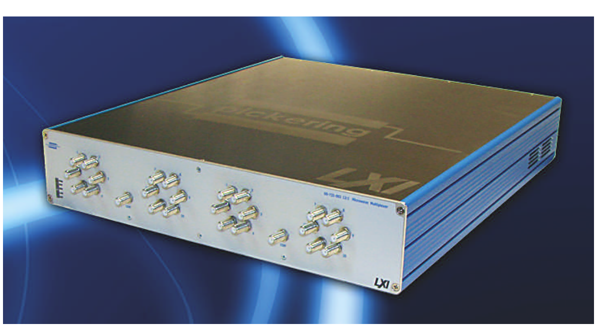
Prices: AQ2200-642—$8000; AQ2200-651—$9500. *Yokogawa, tmi.yokogawa.com.*

RF multiplexer switches 12 channels

The Model 60-722 LXI RF multiplexer from Pickering Interfaces is available with one or two banks of 12:1 ports. The 2U-high instrument switches signals at frequencies up to 1 GHz at 75-Ω impedance. It can handle a maximum voltage of 100 V at current up to 1 A. On resistance is less than 200 mΩ with an off resistance of greater than 10^{10} Ω.

You can control the multiplexer through its Ethernet port, which is LXI Class C-compliant. Software support includes a browser interface and a soft front panel. Driver support includes C, Microsoft .NET, IVI, and SOAP. You can use the drivers with LabView, Visual Studio, Vee, and Matlab.

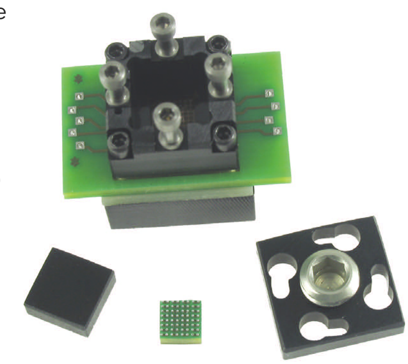
Base price: $9500. *Pickering Interfaces, www.pickeringtest.com.*



BGA transceiver socket operates at up to 10 GHz

Used for prototyping and testing 0.5-mm pitch, 51-pin wafer-level BGA devices, the SG-BGA-7154 socket from Ironwood Electronics operates at bandwidths of up to 10 GHz with less than 1 dB of insertion loss. It accommodates a package size of 4x4x0.8 mm and supports all currently used UMTS bands, including the different regional frequency requirements of Europe, Asia, North America, and Japan.

You can mount the SG-BGA-7154 on the target PCB (printed-circuit board) with no soldering. The socket connects all pins with 10-GHz bandwidth on all connections. Contact resistance is typically 20 mΩ per I/O. The socket's small footprint allows inductors, resistors, and decoupling capacitors to be placed very close to the DUT (device under test) for impedance tuning.



This ZIF (zero insertion force) socket is constructed with gold-plated wires embedded within the elastomer, which serves as the interconnect material between the DUT and the PCB. The elastomer is suitable for applications operating at temperatures ranging from –35°C to +100°C. Pin self-inductance is 0.15 nH, and mutual inductance is 0.025 nH. Capacitance to ground is 0.001 pF. Current capacity is 2 A/pin.

Price: $294 for one; reduced pricing is available for higher quantities. *Ironwood Electronics, www.ironwoodelectronics.com.*

Platform enables high-capacity network testing

Network equipment manufacturers and network service providers can stress-test their networks using real-world network traffic in a lab environment with EXFO's MCM Gigabit Ethernet interface series of test modules. According to the company, the interface series, which works with EXFO test platforms, delivers four times more capacity per port than competitive products for developing and deploying VoIP and IMS (IP multimedia subsystem) networks.

A single module in the MCM Gigabit Ethernet interface series can emulate up to 256,000 VoIP/IMS subscribers and 64,000 voice/video streams, while performing quality analysis on every stream in real time. When interfaces in the series are used with the company's QualityAssurer 2U QA-604 platforms, the platform can support 512,000 emulated VoIP/IMS subscribers and 128,000 voice/video streams. When they are used with EXFO's InterWatch R14 platform, the platform can support 1.2 million emulated VoIP/IMS subscribers and 320,000 voice/video streams.

EXFO Electro-Optical Engineering, www.exfo.com.

Agilent introduces 12-GHz differential wafer probe tip

Agilent Technologies has introduced a 12-GHz differential wafer-probe tip that allows R&D and test engineers to use an oscilloscope to debug and test high-speed active ICs. The N2884A InfiniiMax differential fine-wire probe tip uses the company's ZIF probe-head technology, which Agilent says provides a flat frequency response over the entire 12-GHz bandwidth specification. The tip also reportedly eliminates the distortion and loading that affect probes with in-band resonance.

The N2884A measures a voltage versus an adjacent local ground or other node on the device under test. Agilent says the technique delivers better common-mode noise rejection and signal integrity than techniques that measure a voltage versus a ground distant from the probe point.

The N2884A package includes a probe arm and a set of five probe tips. The probe arm is compatible with the Wentworth Laboratories micropositioner.

Price: $1800. *Agilent Technologies, www.agilent.com.*

ZTec extends instrument software's OS support

ZTec Instruments has updated the software package that comes with its M-Class family of oscilloscopes and waveform generators to allow operation with Windows 7. This latest software release is included with all M-Class instruments on all available platforms: PCI, PXI, VXI, and LXI.

The standard instrument software furnishes drivers for common programming environments, such as C/C++, IVI-C, LabView, and COM, plus the company's ZWave or ZScope control software and ZFind Resource Manager. ZWave and ZScope provide interfaces that deliver the look and feel of a bench function generator and oscilloscope, respectively.

In addition, the updated software offers streamlined LXI instrument discovery. Users can now discover their instruments using the ZFind Resource Manager without any knowledge of the IP address. This enhancement is available under both Windows and Linux.

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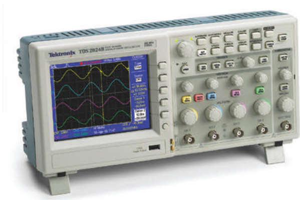

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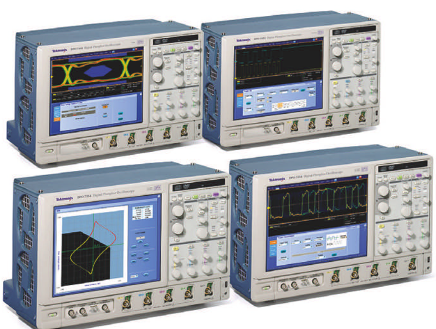

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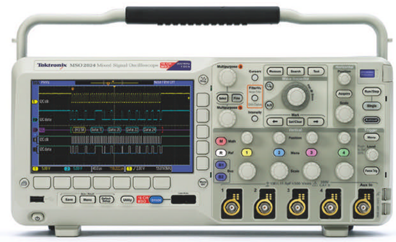

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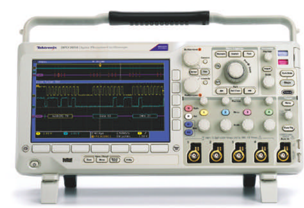

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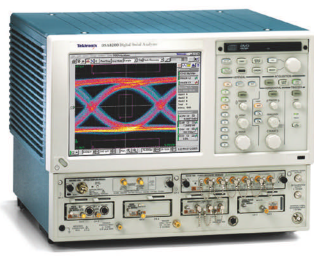

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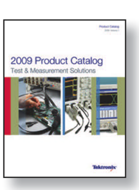

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Acoustic imaging reveals die stack layers

By Ann R. Thryft, Contributing Technical Editor

Acoustic microscope imaging is commonly used along with x-ray inspection during semiconductor production and failure analysis to reveal internal flaws such as cracks and voids. Until recently, however, acoustic microscopy was not good at finding and analyzing defects on specific layers of a stacked die assembly. Ray Thomas, manager of Sonoscan's SonoLab division, described new software algorithms that his company developed to improve the use of this imaging technique for nondestructive, offline examination of stacked die.

Q: What are the main challenges that engineers face when inspecting stacked die assemblies using acoustic microscopic imaging?

A: The process engineer needs to know where defects are located in a die stack, along with their size, extent, and type, such as a crack on the third die layer, or a delamination between the fifth and sixth layers. In a semiconductor package containing a single die, acoustic imaging technology propagates ultrasound into the package to make an image of its internal features, such as cracks, delaminations, or voids, which can then be inspected. While ultrasound penetrates solid materials, it is reflected by the interface of two different materials, such as mould compound and the die. These reflections produce an image of the interfaces.

The additional die layers and die attaches in a stacked die configuration create complexity. Reflections from the interfaces on each layer merge with the reflections from interfaces at other levels in the stack and can't be separated, creating a composite image that's difficult to interpret. Sorting out this mess is nontrivial, but it must be done to assess stack reliability.

Q: What other technologies can be used for stacked die inspection?

A: The alternatives are destructive physical analysis techniques. No other nondestructive evaluation method is used to separate out the layers so you know where defects are located. The fact that ultrasound can bounce off of the layers is a strength of that technology. The complication of reflections from so many layers merging together in an image is the difficulty.

Q: What advancements have you made in acoustic imaging and how do they help solve the inspection problem?

A: Our new proprietary software capability gives us a level of detail where you can see individual layers with some accuracy and assign defects to specific layers. What we're changing is the ability to correctly interpret the signals. There was a great deal to learn about how the reflections from multiple interfaces interact with each other. Also, not every part configuration is inspectable. For example, when die in the stack are roughly the same size, you tend to have better access throughout the stack's thickness, but when one die overhangs another, access becomes limited.

Materials also affect accuracy. For example, mould compound is a composite material so it scatters ultrasound. If we can inspect a stack of bare die that has not yet been overmoulded, we can use a higher frequency to get better accuracy between layers. Typically, we're looking for cracked die, or delaminations and voids between layers. But some of the other things we detect along the way include nonuniformities in the die-attach material, which may be caused by incomplete curing or incomplete mixing. □

Ray Thomas
SonoLab Manager
Sonoscan

INSIDE THIS REPORT

EDITOR'S NOTE

Recovery? Vision gives mixed signals

By Ann R. Thryft, Technical Editor

Although some pundits are talking about an economic recovery, reading the tea leaves for machine vision produces mixed results. Research firm Strategies Unlimited predicts that once the final numbers are in, worldwide image sensor shipments will have experienced an unprecedented 30% downturn during 2009, an indication of what happens in vision when the whole world stops buying products that must be manufactured and inspected. Although the firm forecasts a return to growth in 2010, this sharp decline occurs after more than a decade of continuous growth.

But machine vision is expanding into new areas. In photovoltaic crystalline-silicon solar manufacturing, the economic downturn has spurred competition among both wafer fabs and solar-cell manufacturers to produce higher-quality, more efficient products, instead of focusing mainly on getting volumes out the door (p. 42). Since solar-cell manufacturing hasn't depended much on automation, machine vision, or metrology and yield-management tools, there's room for expansion to help boost product quality. And more and better inspection will be needed for newer processes such as multilayer screen printing, while more intelligent use of data can help improve and refine processes. Meanwhile, the glut in solar panels is lifting and growth continues, which should mean more opportunities for machine-vision and inspection technologies. □

Contact Ann R. Thryft at ann@tmworld.com.

HIGHLIGHTS

Wafer-inspection system detects macro defects

Microelectronic device manufacturers can use the Iris wafer-inspection system from SemiProbe to detect flaws in the wafer circuit pattern as well as contamination or process damage. Depending on the choice of optics, the Iris inspection system is able to identify defects as small as 3 µm.

The system is suitable for examining optical components, double-sided devices, photovoltaics, MEMS, and other microelectronic devices. Iris can find visual defects such as probe marks, thru-silicon vias, bumps, incomplete etch, scratches, large-scale contamination, and passivation. Configurations are available for performing manual visual inspection or automated inspection.

Once a defect is identified, its failure code is noted on the wafer map. Wafer maps are fully exportable in a variety of formats for offline analysis or downstream processing. www.semiprobe.com.

Halcon Embedded runs on the Beagle Board

MVTec Software reports that it has taken initial performance measurements with its Halcon Embedded 9.0 machine-vision library running on the Beagle Board using Ångström Linux as the operating system. The Beagle Board single-board computer is based on the OMAP35x processor from Texas Instruments.

From the results of its tests, MVTec said that image-processing algorithms such as filtering or blob analysis can be performed on the Beagle Board running Halcon in milliseconds. The company added that subpixel-precise measurements are possible in less than 1 ms. www.halcon.com.

Market for image sensors dips in 2009, should rebound in 2010

By Ann R. Thryft, Contributing Technical Editor

Research firm Strategies Unlimited has predicted that once final figures for 2009 are available, the overall market for image sensors worldwide will show a decline for the first time since 1997, when the company began tracking this market. Although growth is expected to return in 2010, revenue will increase at a lower, single-digit rate compared to the double-digit revenue growth the market experienced over the last decade, said Tom Hausken, director of the firm's photonics and compound semiconductors research.

Unit shipments of the image sensors used in machine vision will generally follow the same curve, said Hausken. In 2008, shipments of machine-vision image sensors grew only 8% to 256,000 units compared to the 238,000 units that shipped in 2007. For 2009, Hausken expected a 30% drop from 2008 figures to 179,000 units. He predicted shipments of 188,000 units in 2010, an increase of only 5%.

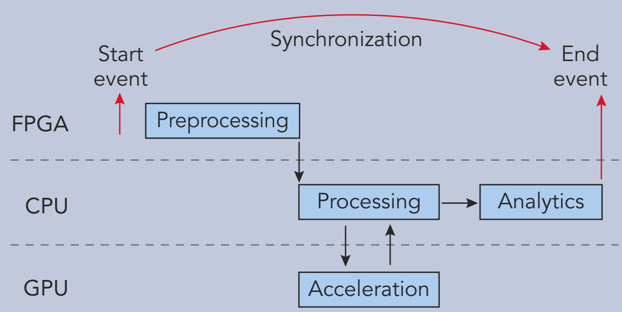
Hausken called the 30% drop in growth in 2009 "huge," and said it was due primarily to the global recession. Although the 30% decline last year is not as big a drop as, for example, the decline in shipments of semiconductor manufacturing systems, it's larger than the drop in cellphone shipments, which only took a 10% hit, said Hausken. "Going forward, we see about 5% to 11% growth over the next few years starting in 2010 in unit shipments of these sensors. Since machine vision is still expanding, this is a common growth rate for that business." □

High-performance computing speeds image data processing

By Ann R. Thryft, Contributing Technical Editor

The amount of image data generated in some machine-vision applications is growing rapidly as camera resolutions increase, panels and wafers get bigger, and the features to be inspected shrink even further. In semiconductor wafer and mask inspection, as well as in FPD (flat-panel display) inspection, the board-level or multi-board vision processors and blade servers traditionally used to process this data are running out of steam.

Some vendors of vision processors, such as Matrox Imaging, are creating systems that build upon HPC (high-performance computing) architectures to process the growing data that must be handled as it comes into the system via an external interface adapter and moves among multiple processors.



FPGAs, CPUs, and GPUs play different roles in the Matrox Supersight system, which tailors high-performance computing for image processing. Courtesy of Matrox Imaging.

Larger wafers mean more data

In semiconductor inspection, wafer sizes are moving from 150 mm to 300 and even 450 mm, while at the same time the features on the wafer that must be examined are shrinking, said Pierantonio Boriero, product line manager for Matrox Imaging. "3-D x-ray systems can generate 0.5 Tbytes to 9 Tbytes per scan," he said. "Compounding the challenge is the increase in dynamic range from 8 bits to 12 bits per pixel."

In the FPDs manufactured today, the substrate glass measures 2.16x2.4 m, so there are roughly 80 Tbytes of data to inspect per panel. In the near future, the imaging of larger panels, with substrate glass measuring 2.88x3.13 m, will result in about 140 Tbytes of data per panel.

"Not only is this an enormous volume of pixels to inspect, but throughput must remain high, since this is in-line processing equipment," said Boriero.

Traditional vision-processor boards were based on a DSP (digital signal processor) or a microprocessor and also included custom ASICs for the image processing, said Boriero. "With a single expansion board that performed all the necessary data-acquisition and processing functions, increasing the processing power was a problem because of the much higher power consumption and heat-dissipation levels," he said.

Blade server systems do offer greater computational power per processing node but suffer from limited I/O bandwidth between blades, commonly provided by Gigabit Ethernet and sometimes Infiniband. They also lack a spare slot for a frame grabber or other specialized I/O expansion board, resulting in inadequate external I/O expansion for getting data into and out of the whole system.

"We could have solved the problem by employing multiple host PCs with vision-processor boards, but that would exceed most production floor space requirements," Boriero explained. He added, "Once we got beyond what one board or one standard PC can do, we started thinking about multiple processors running concurrently, sharing data among them all via a switched-fabric backplane. That's when we looked at high-performance computing, which is a broad concept of how to make multiple computer systems work together."

The Matrox Supersight system, which consists of up to four system host boards in one box with a high-speed fabric interconnect, tailors HPC technology for image-processing applications. The rack-mounted system includes a PCIe (PCI Express) 2.0 backplane, quad-core Intel Xeon CPUs for image processing and analysis, FPGAs for image preprocessing, and GPUs (graphical processing units) for accelerated image processing.

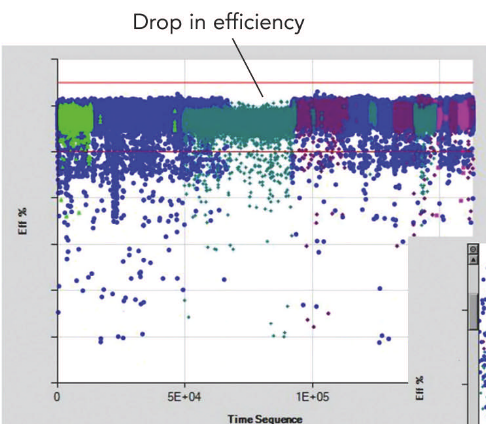
To maximize computing resources by increasing I/O throughput, Matrox chose PCIe x16 Gen 2, at 8 Gbytes/s bidirectional, to interconnect boards and nodes within the system, said Boriero. The PCIe switched-fabric backplane is packet-based, so it enables developers to segment the data and move it around more efficiently among the different processing elements. "Developers can create clusters, or little work groups made up of different technologies, each working on a portion of the data set," he said. The point-to-point, full-duplex nature of PCIe lets developers isolate bus traffic within the compute clusters, which helps optimize performance, especially as the number of processing elements increases. □

Inspection, metrology solar tools evolve

By Ann R. Thryft, Contributing Technical Editor

Although thin-film and crystalline-silicon PV (photovoltaic) solar wafers and cells share some similar defects, they require different manufacturing and inspection techniques. Crystalline-silicon solar cells are based on wafers, so software tools used for machine vision, inspection, metrology, and yield analysis of regular semiconductor wafers are being applied to high-volume manufacturing of silicon solar wafers and cells. Thin-film solar cells, on the other hand, are created with substrate materials such as glass or stainless steel, and thus require different inspection techniques.

The main differences between semiconductor and crystalline-silicon PV solar-cell manufacturing are volumes and cost, according to Mike Plisinski, VP and GM of Rudolph Technologies' Data Analysis and Review business unit. "A large, first-tier semi fab has about 100,000 wafer starts a month, versus a first-tier crystalline-silicon PV fab with about 500,000 starts a day," he said. In the semiconductor world, manufacturers depend on metrology and analysis data after most process steps. Unlike a high-value semiconductor wafer, "a PV cell or wafer is worth maybe a couple of dollars," said Plisinski. So, manufacturers do not need as much data after each step to ensure wafer quality.



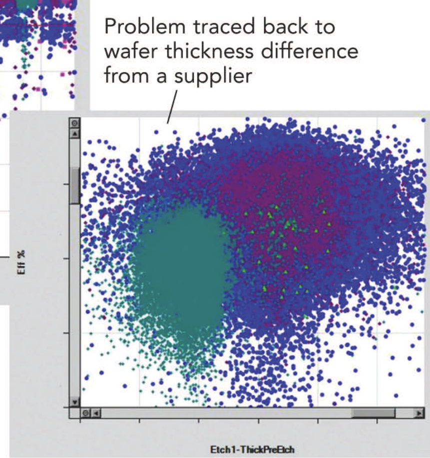


Fig. 1 Yield-analysis and process-management tools such as Rudolph's Discover Solar software can be used to trace a temporary drop in cell-manufacturing efficiency (colored green in the left image) to differences in wafer thickness from a particular supplier (colored green in the right image). Courtesy of Rudolph Technologies.

The current state of wafer-based solar-cell manufacturing resembles semiconductor wafer manufacturing in the early 1970s, said John Petry, manager of marketing for vision software at Cognex. At that time, traceability was first introduced and individual wafers were still handled by technicians. Similarly, in most solar-wafer production, people still handle wafers, geometries are coarser, and precise registration is not nearly as important.

But Petry said Cognex is seeing changes in crystalline-silicon solar-cell manufacturing, which is beginning to employ procedures used in today's 300-mm semiconductor wafer fabs, where wafers are tracked throughout production and handling is completely automated. Petry noted that solar-cell manufacturing techniques such as multilayer screen printing and thinner solder fingers on wafers need highly precise alignment, and thus must be automated.

The primary uses for machine vision in solar-wafer production are checking for edge chips and sorting and grading by color, said Petry, fairly simple applications for today's vision systems. "The other commonly requested test today is to detect non-penetrating microcracks," he said. "Unfortunately, no one's yet found an efficient in-line solution because the necessary imaging techniques—thermal sensors, for instance—are fairly slow. Given a good image, the visual inspection task isn't actually that hard." At present, manufacturers are solving the problem by handling the wafers more gently throughout production.

The need for machine vision in crystalline-silicon solar-wafer inspection is growing for a couple of reasons, said Petry. In the industry's early years, manufacturing processes were simple and fabs could sell wafers as fast as they made them, but since the recent downturn, fabs are competing more on quality.

"Manufacturing processes are becoming better understood, so fabs are better able to correlate wafer appearance to efficiency," he said. "Newer processes are also becoming more demanding, so you'll need more wafer inspection, for example, to confirm the alignment in a multilayer screen-printing step."

For simpler tasks such as wafer handling, said Petry, solar-cell manufacturers use vision software tools such as Cognex' VisionPro Solar Toolbox, which includes preconfigured tools for standard wafer alignment, edge and print inspection, and color checking. For key OEMs, Cog-

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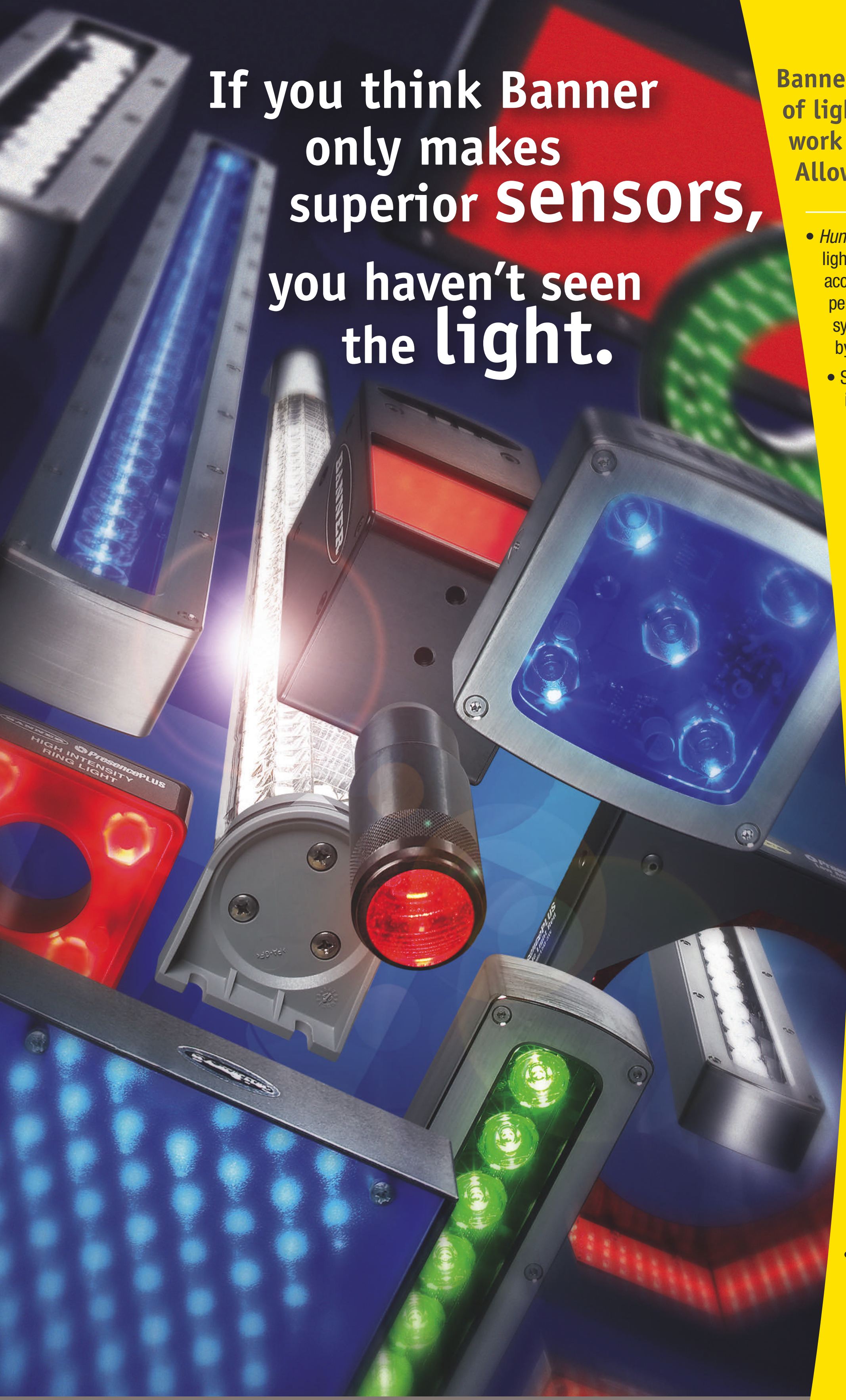

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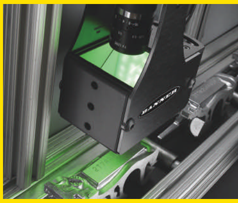

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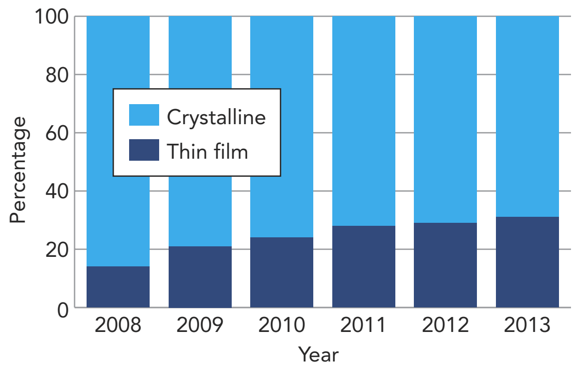
nex also produces custom solar-cell inspection tools. "For example, we have high-speed inspection software for screen-print registration that includes optical distortion correction for high-resolution linescan cameras," he said. (See "Machine vision in solar-cell fabrication," below.)

Cognex is working with wafer foundries on new algorithms to detect dislocations in polycrystalline wafers, since inconsistent crystal formation can lead to less efficient electrical conduction, said Petry. The company is also developing more complex pattern-recognition algorithms. "Foundries are just now beginning to understand the relationship between these pattern characterizations and wafer performance," he said. "But we expect that eventually these algorithms will also be useful for incoming inspection at some solar-cell fabs to ensure good-quality wafers from the foundry."



Source: iSuppli Corp., November 2009

Fig. 2 As measured by a percentage of total photovoltaic solar-panel watts, the proportion of solar cells based on thin-film technology is increasing and will double by 2013. Courtesy of iSuppli.

The need for solar metrology tools

Increased competition is driving manufacturers of both crystalline-silicon and thin-film PV solar cells to look for improvements through more intelligent use of data to make their lines more productive, said Rudolph's Plisinski. "In addition to differentiating on efficiency and in cost per watt, they are now trying to differentiate on product quality," he said. "With the long, 20- to 30-year warranties on PV panels, they need complete traceability."

Plisinski sees two types of yield- and quality-improvement issues in PV cell manufacturing: those at the factory-management level and those at the equipment level. Most manufacturers have not used data-management systems for monitoring factory-wide processes, due to limitations in existing software. At the equipment level, wafer breakage caused by manufacturing tools is still a big problem. Because of lack of traceability at the tool level, manufacturers can't put pressure on vendors to address the problem. "One use for Rudolph's Discover Solar fab-management software is to add that traceability," he said.

A big factor in PV cell efficiency is the quality of incoming materials, according to Plisinski. "You might have 10,000 samples in a batch, and some or all of that batch could be bad because of a material problem from one supplier," he said. That problem could cause a drop in overall PV cell efficiency that triggers process engineers to spend time looking for process or equipment problems. "Customers require systems that can identify these issues instantly and that allow manufacturers to trace these problems back to the supplier," Plisinski explained. (See **Fig. 1**).

The much larger volumes in silicon PV fabrication vs. semiconductor fabrication strains databases that were designed for fewer samples, and also strains data-collection and yield-management systems, said Plisinski, "so we had to design a yield-management system specifically for [the solar] industry." To create its Discover Solar fab-management system, Rudolph re-engineered its Dis-

Machine vision in solar-cell fabrication

Cognex says that machine-vision systems and software are now being used for these tasks in solar-cell fabrication:

Back-print registration inspection: Measuring the position, width, and distance between the bus bars and checking the continuity of finger lines.

Cell-defect detection: Inspecting cells for chips and cracks to ensure any defective cells are rejected prior to processing.

Cell-orientation detection: Monitoring solar cells to ensure correct upright orientation prior to the dopant application phase.

Color cell sorting: Inspecting and sorting solar cells by slight color variances and grading the cells based on inconsistencies in color.

Front-print registration inspection: Inspecting lines for contour breaks, continuity, and excess solder and ensuring that traces are parallel and correctly registered.

Laser edge isolation: Aligning cells and inspecting the edge groove cuts along the wafer edges to isolate the emitters from the back sides of the cells.

Robot guidance: Transmitting placement information for robot-guidance applications used throughout the solar-panel manufacturing process.

Screen-print alignment: Aligning solar cells for screen printing.

cover analysis and data-management software for IC manufacturing to accommodate those differences.

"First, we redesigned the underlying database structures so they could handle and display such huge volumes of samples quickly," he said. "Next, we modified the analysis engine. In PV solar manufacturing, there's not much metrology data available. Although thin-film panel manufacturers have some useful metrologies, a lot of analysis is still done by examining electrical test results and tool and sensor data. We needed domain-specific algorithms that would automate a process engineer's basic analysis to dramatically improve the time required to identify and resolve problems."

As PV manufacturers bring new technologies into pilot production and then strive to ramp quickly to high-volume production, they will continue to tighten process windows, said Plisinski. "We see customers looking to further improve line performance by using run-to-run control technologies to compensate for the variability of tools and materials over time," he said. "We also see PV manufacturers pushing process equipment vendors to make a greater amount of process data available to the factory to enable predictive metrology."

Thin-film technology grows

"While crystalline wafers constitute the vast bulk of solar-cell surface area manufactured today, many feel that the long-term trend is in thin-film, since they believe it will cost less and will be more flexible, both as a substrate and in the areas where it can be used," said Petry of Cognex. According to a recent report from market research firm iSuppli, the proportion of solar cells created with thin-film technology, as measured by a percentage of total solar panel watts, is growing quickly (**Fig. 2**).

PV solar-cell manufacturing can be divided into three generations, said Darin Cerny, marketing manager at Cognex. "The first involves processing of mono- or multicrystalline wafers," he said. "The second is thin-film deposition on glass or on a flexible substrate such as stainless steel." In thin-film solar-cell fabrication, inspection is currently being performed on incoming substrates and thin-film coatings.

Although the third generation is still in development, most third-generation materials will be polymer-based. "The goal is lower-cost yet higher-complexity materials that will produce even higher efficiencies than either first- or second-generation solar cells," Cerny said.

In wafer-based solar-cell fabrication, manufacturers have already learned much of what it is they want to measure, said Cerny. "But in thin-film solar, manufacturers are just starting to figure this out. They have some idea of what the defects are and what problems they cause. Now, they must concentrate on reliably and consistently finding these defects so that they can either adjust their processes to prevent them from occurring or decide whether to continue processing less-efficient material." □

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[An exclusive interview with a technical leader]

CHRISTOPHER A. BERONIO
Global Business Leader
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Landenberg, PA

Chris Beronio serves as the global business leader for microwave products in the Electronic Products Division of W.L. Gore & Associates. After joining Gore in 2000, Beronio held various engineering roles within high-performance digital interconnects before becoming a product manager for the flagship Microwave/RF Test Cable Assemblies product line. He earned a BSME from the US Naval Academy and an MBA from the University of Delaware.

Contributing editor Larry Maloney conducted a phone interview with Chris Beronio on cable assemblies for test applications and on the underlying technologies that are shaping future products.

Where reliability meets flexibility

Q: How has high-speed data transmission shaped the development of cable test assemblies at Gore?
A: Our customers really demand unique value from their suppliers and partners. They want faster test times and increased confidence in their test results, particularly when it comes to accuracy and repeatability. From our point of view, driving for the leading edge in frequency performance helps us create a rounded portfolio of products, including cable test assemblies and connectors designed for high data rates and frequencies up to 110 GHz. We really focus on using our material sets and product and market knowledge to provide phase and amplitude stable products to meet customer needs.

Q: What types of applications have you targeted for the 110-GHz test assemblies?
A: They're used primarily in R&D environments in such areas as passive millimeter-wave imaging, high-data-rate communications, intelligent vehicle systems, and wireless HDMI (high-definition multimedia interfaces).

Q: What would you consider to be your premier test assembly product?
A: The Gore VNA Microwave Test Assemblies, which we believe offer electrical engineers superior performance, durability, and repeatability. Key features include phase and amplitude stability under flexure, which means that you can hold your calibrations for a lot longer and focus more of your time on testing. The cables, which are compatible with OEM test equipment, also offer extremely high crush and torque resistance, as well as excellent flexibility without spring-back.

Q: What technical advances are driving improved performance in your cable products?
A: We don't believe in just putting together cables, connectors and other components; we want to understand the customer's end products and applications. That's why we have expanded our material choices and closely control the supply chain for our components.

We've used the economic downturn as an opportunity to listen closely to our customers' needs and to explore with engineers in our core technology group innovative ways to use expanded PTFE and our other fluoropolymers to take advantage of some of the new opportunities out there. Under development for 2010, for example, are products that offer both lighter weight and higher performance.

Q: For the 12th consecutive year in 2009, *Fortune* magazine named Gore one of the country's 100 best companies to work for. How does the company's culture contribute to product innovation?
A: Gore is one of only a handful of companies that has been included in that *Fortune* list since it was first introduced. The company culture values small teams and encourages collaborative problem solving and innovation. Since the company started in 1958, it has practiced a lattice style of management where associates work together, rather than the indirect communication that you often see in companies with a chain-of-command setup. We believe that we are all in the same boat and therefore share the same goals as a team. And we provide our associates with the freedom to organize around a project or opportunity and come up with innovative ways to service customers in many diverse markets, including electronics, consumer, industrial, medical, and fabrics. T&MW

Chris Beronio answers more questions about new products and technical support in the online version of this interview: www.tmworld.com/2010_02.

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