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JULY/AUGUST 2012
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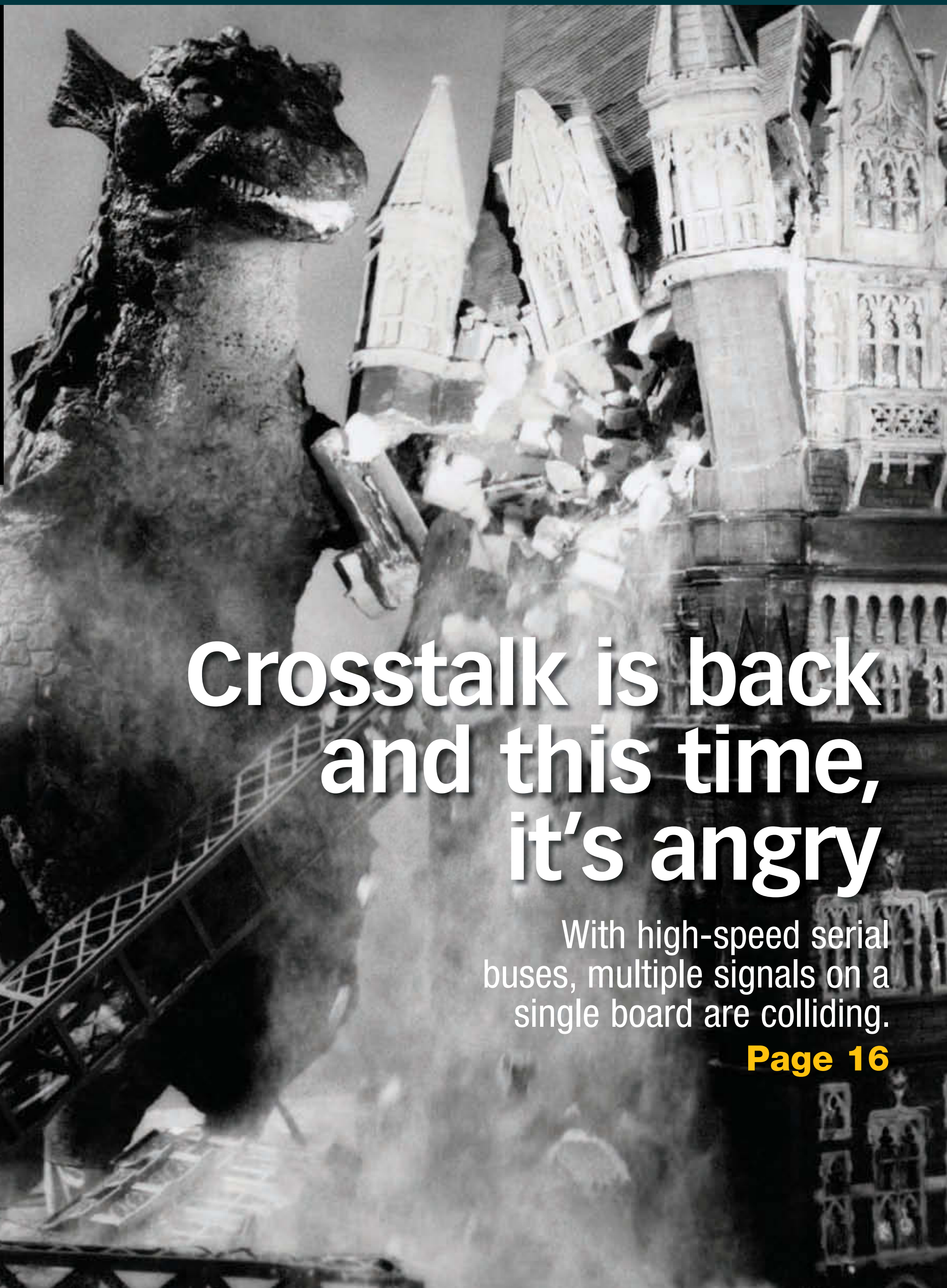
THE MAGAZINE FOR QUALITY IN ELECTRONICS



Crosstalk is back and this time, it's angry

With high-speed serial buses, multiple signals on a single board are colliding.

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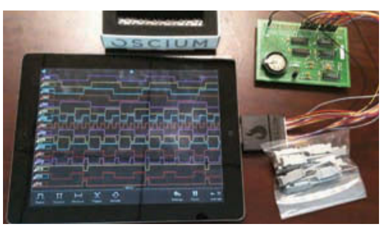

MARKET TRENDS

VIEWPOINT

Cover: In a scene from the 1961 British film *Gorgo*, a Godzilla-like creature destroys a London building.

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Do you remember your first scope?

Senior Editor Janine Love invites you to share your fond (and not so fond) memories of your first oscilloscope.

www.tmworld.com/4390232

Demonstrating enclosure resonance

There are times when an increase in harmonic content can't completely be explained by circuit or PC board design. If you've already done a good EMC design and are still getting radiated emission problems, then perhaps resonances in the product enclosure are, in effect, amplifying the internal harmonics. Kenneth Wyatt explains.

www.tmworld.com/4390124

DLL-based clock recovery cranks up net bandwidths

To meet the bandwidth demands, ever more robust clock recovery schemes are necessary. But, 25% over-head is too high. Enter DLLs (delay locked loops), whose reduced power, size, and complexity combine with simpler transfer functions and improved stability enable clock-recovery circuits to remain locked after dozens of identical bits.

www.tmworld.com/4378176

Explain this

Senior Technical Editor Martin Rowe needs you to explain something to a non-engineer: how Internet Protocol phones work.

www.tmworld.com/4390254

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Gone digital

By the time you receive this, *Test & Measurement World* will have gone all digital: this is the last print magazine. Now we editors can focus all our energy on just one format, delivering news, technical information, and commentary in real time.

With this change comes a new TMWorld.com, which launched earlier this month. This new site enables us to exchange information in an environment custom-made for engineers involved in test. We look forward to bringing you more technical content as well as engage in timely, relevant discussions about your latest test challenges and discoveries.

This new site enables us to exchange information in an environment custom-made for test engineers.

With this redesign, we've also changed how we organize content on TMWorld.com. The site has five Test Centers:

• **Design and Prototyping:** Here, you'll find articles covering design-for-test, simulation, and PCB layout.

• **Characterization:** We'll cover signal analysis, signal integrity, data acquisition and analysis, EMC test, and topics on general-purpose measurements. We also cover programming techniques and test circuits.

• **Manufacturing:** Articles on boundary scan, yield, throughput, statistical-process control, system integration, programming, inspection, IC test (analog, digital, and mixed-signal), board test, machine vision, wafer-level testing, and relevant case studies go here.

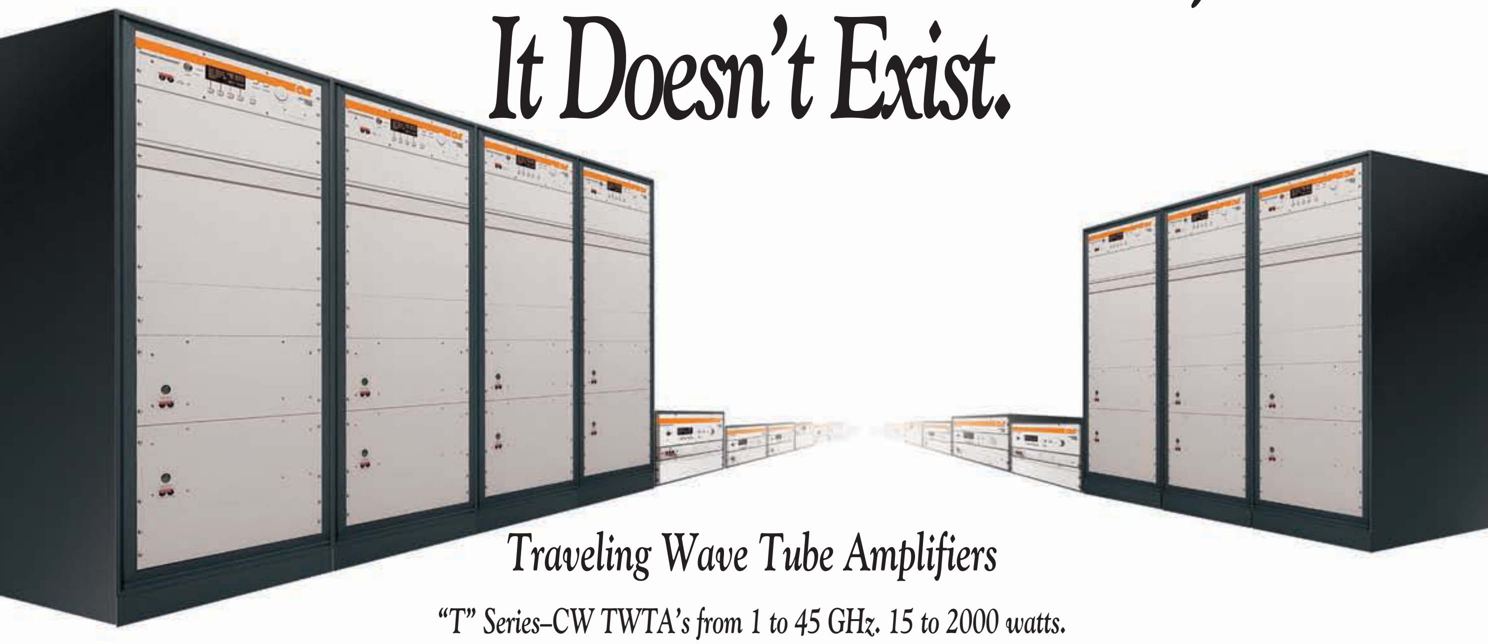
• **Field Service:** Here you'll find information on the latest portable and handheld test tools, plus measurement tips and techniques to get production lines up and running quickly. Furthermore, all electrical measurement equipment needs calibration. The Field Service Test Center also includes calibration and equipment management.

• **Failure Analysis:** Look here for articles on diagnosing failures, particularly in ICs.

Think of each Test Center as a community where you and fellow engineers can discuss projects, workarounds, and test techniques. All content on the new TMWorld.com is free and available without registering. If you're inspired to comment, a quick-start registration can get you started, but we suggest that you eventually set up a profile where peers can find you. You can then follow specific articles or people and upload your own articles (we'll vet them and guide you in making them better). So, say one of our bloggers covers an area of interest, you can follow that blogger (or any registered user). Or, if you think you can do better, send in your own blog!

My favorite reason for registering is the personal library, the digital equivalent of tearing out pages. You can save any article to your library for future reference.

We'll work to keep a constant flow of content, but we need your help and guidance. If you have an article idea or you'd like to blog on a topic, let us know. If have images of a recent test rig you set up, send them in. Perhaps you have a measurement or programming technique to share. The new TMWorld.com is the forum for sharing it. We'll help you connect you with like-minded engineers who can help you get your design tested and out to market. Contact me at martin.rowe@ubm.com for Design and Prototyping, Characterization, and Field Service. Contact Janine Love at janine.love@ubm.com for Manufacturing and Failure Analysis. If you've never contributed before, now is the time. If you have contributed before, we welcome your new content ideas. In the meantime, see you online at *www.tmworld.com* T&MW



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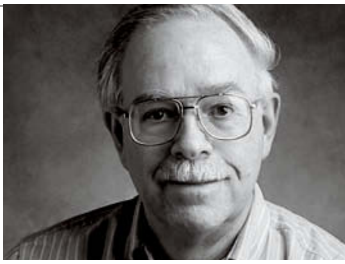
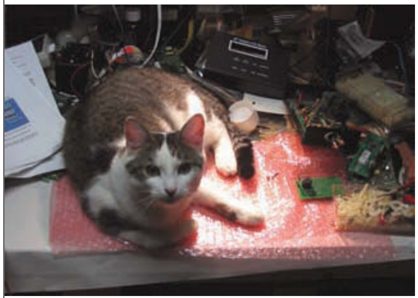


Cluttered Bench Syndrome

Without looking, can you recall the color of your workbench's top surface? No? You're likely suffering from Cluttered Bench Syndrome (CBS), an insidious syndrome that's endemic to any electronics work environment regardless of size. I could serve as the CBS poster child; in no particular order, here's what's currently cluttering my bench:

- Test equipment: oscilloscope and probes; spectrum analyzer; digital multimeters (handheld and bench); power supply; semiconductor tester; component impedance bridge; test leads.
- Hardware: assorted screws and nuts in various thread pitches; washers; unused cable ties.



- Tools: side cutters (three types); scissors; needle nose pliers (two types); hemostats (three sizes); battery-powered drills (two); wire strippers (two styles); desoldering tool; soldering iron; SMT hot-air rework station; stereo dissecting microscope; magnifier with halo lighting fixture; assorted screwdriver bits.
- Wire: miscellaneous cutoffs in assorted gauges (lengths too short to respool, too long to discard and thus awaiting future reuse).
- Sleeving: miscellaneous cutoffs (see wire, above).
- Solder & solder flux: three partially used spools (different gauges, all of non-RoHS compliant tin/lead composition); two flavors of flux.
- Components: unused (leftovers awaiting restocking in cabinets); used (leads long enough for reuse); defective (removed from equipment, awaiting failure analysis).
- Coffee cups: one (ceramic, used, sludged).
- Breadboards: audio-filter prototype; software-defined radio.
- Work in process: 1930s-vintage table radio; smoked power supply.
- Paper: schematics; data-sheet printouts; random scribbles.

A few simple steps can go a long way toward reducing workbench clutter and thus saving time and money. An interrupt-driven environment routinely pushes housekeeping chores to the bottom of the priority stack, so schedule a mandatory Friday-afternoon bench cleanup. If you must leave an instrument in a partially disassembled state, minimize orphaned parts by returning fasteners to their places. Create—and label—temporary storage containers for work-in-progress, and include a brief up-to-date status memo. Tag items awaiting parts with their expected delivery dates.

And do keep the cat off your workbench.

(Note: The price for the Valon Technology Model 5007 was originally misstated as $29 in the June 2012 column. The correct price is $295.) T&MW

To read past Test Voices columns, go to *www.tmworld.com/4376430*.

CATS ON WORKBENCHES

Cats love to get attention by occupying workspaces, but an electronics workbench is no place for your lab's feline mascot. Flakes of solder and bits of insulation get trapped in a cat's fur and paws and ingested when Kitty cleans herself with her tongue. Heavy metals and wire fragments aren't good for a cat's digestive system.

The same considerations apply to humans who snack at the workbench, so discard that dropped doughnut and the coffee with the half-submerged resistor. Better yet, don't eat at your bench!

FAMOUSLY-CLUTTERED SPACES

Jim Williams' bench: http://bit.ly/MiR2KA
Bob Pease's office: http://bit.ly/P1ddUr

TOOLS FOR DECLUTTERING

Sorting through the contents of stray hardware in a coffee can be slow and tedious. As an alternative, consider the under-$5.00 Easy Sorter Funnel Tray—pour in mixed hardware, pick out what you need, and pour the rest back into the can: http://bit.ly/S74xM9

Multidrawer small-parts cabinets such as those made by Akro-Mills offer convenient storage for frequently-used static-resistant components: www.akro-mils.com

Brother International Corporation offers an inexpensive range of labeling systems that can help you identify work-in-progress and storage containers: www.brother-usa.com/

Tossed casually onto a benchtop, test leads have a penchant for tying themselves in knots. Use available wall space and cable hangers such "The Claw" by Middle Atlantic Products to sort and suspend expensive and fragile test leads: www.middleatlantic.com

Teseq increases presence in RF amplifier market

Teseq announced its intentions to acquire New York-based Instruments for Industry (IFI), a designer and manufacturer of solid-state and TWT (traveling wave tube) amplifiers, to broaden its product line in the RF amplifier market. By combining the competencies of IFI and the recently acquired Milmega with its own EMC emission and immunity test expertise, Teseq will be able to offer customers systems for a variety of applications, including commercial, industrial, automotive, military, defense, and communications.

Johannes Schmid, president of Teseq, said, "Because IFI is a US-based manufacturer, we have an immediate increase in the services we can offer this growing customer base. With the future acquisition of IFI, Teseq will expand its product range from 9 kHz up to 40 GHz and up to 10 kW. IFI brings the latest in GaN and LDMOS Class AB solid-state technology and the knowledge to manufacture TWT amplifiers, as well as its excellent relationships within the defense and military markets, to Teseq."
Teseq, www.teseq.com

LeCroy to be acquired

LeCroy announced on May 30 that Teledyne Technologies will acquire the oscilloscope maker for a cash payment of approximately $291 million. According to a press release, LeCroy will operate as a Teledyne subsidiary, keeping the LeCroy name. The acquisition will make Teledyne's microwave technology available to LeCroy engineers. The company had already announced an intent to produce the world's first 100-GHz real-time oscilloscope.

"We believe Teledyne can help us accelerate our high-end oscilloscope programs to deliver real-time bandwidth well beyond 100GHz by utilizing Teledyne's leading InP technology," said LeCroy President, Chief Executive Officer and Director Thomas Reslewic in the press release. "Furthermore, through a combination of Teledyne's microwave and mixed signal design capabilities with LeCroy's signal processing expertise, as well as our respective market channels, we envision growing our markets and adding new products such as signal generators and multi-function instruments."

The acquisition of LeCroy leaves Agilent Technologies as the only independently owned competitor among the top three oscilloscope manufacturers

WiGig-enabled devices put to the test at plugfest

Members of the Wireless Gigabit Alliance (WiGig) tested the interoperability of devices using the multi-gigabit wireless WiGig technology under real-world conditions at WiGig Plugfest in June, moving the technology closer to commercialization. This second plugfest establishes the basis for future interoperability of different products and signals the imminent transition of 60-GHz WiGig networking into actual products realized on the market.

The WiGig Plugfest follows the publication in 2011 of three Protocol Adaptation Layer specifications: the WiGig Display Extension, the WiGig Serial Extension, and the WiGig Bus Extension. WiGig members are now testing their WiGig-based products to ensure interoperability within the ecosystem and to provide end users with a guarantee of reliable solutions at product launch next year.
WiGig Alliance, www.wigig.org

Editors' CHOICE

QualiSystems' TestShell framework is IPv6-ready

TestShell, a software framework from QualiSystems for lab management, device provisioning, and test automation, allows engineers to configure, deploy, and execute a test plan to address IPv6 (Internet Protocol version 6) performance issues. Used in the networking and storage environment to manage and drive large-scale testing labs, TestShell makes it possible to build complex test plans that are adjusted and executed from a central framework through its automated testing environment.

IPv6 testing involves multiple devices that need to be integrated into a setup and then managed and shared. In addition to simplifying test setup and resource sharing, TestShell can be extended to provide life-cycle management of the test lab. Switches, servers, generators, and other devices in the testing environment can be scheduled and managed through a simple user interface.

Eitan Lavie, QualiSystems' VP of product management and marketing, said "We responded to our customers' needs by providing a testing framework that simplifies and upgrades the crucial validation process of new IPv6 products before releasing them to the market and brings higher confidence to the process."

Prices for the TestShell enterprise software start at $30,000 for small startup testing labs.

QualiSystem, www.qualisystems.com/site/content/t2.asp?Sid=73&Pid=500.

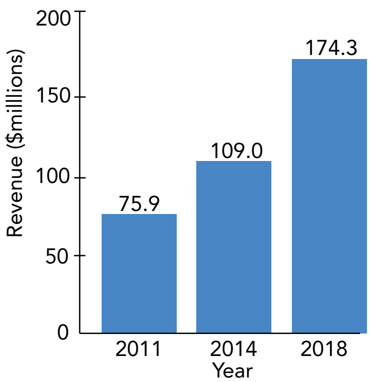
Demand grows in Latin America for general-purpose test equipment

By Mariano Kimbara, Senior Research Analyst, Measurement & Instrumentation, Frost & Sullivan

The total Latin American general purpose test equipment market generated $75.9 million in revenue in 2011 and the compound annual growth rate (CAGR) is estimated at 12.6 percent for the forecast period 2012–2018. The continuous upgrade and migration from 2G and 3G to 4G technologies is driving market demand. The deployment of 3G is ongoing in the region, increasing the demand for spectrum and network analyzers and similar equipment. LTE has already been deployed in Brazil, Colombia, Uruguay, and Puerto Rico. A number of 4G trials and deployments that are expected to generate growth for this market going forward will begin in 2012. This will create a "wireless decade" over the next 10 years. Other factors expected to drive market growth include the increasing electronics manufacturing and outsourcing activities in the region, government spending on infrastructure, and growing opportunities in the education funding research area and defense sector for some countries.

An important trend in the region is the increase in outsourcing operations. The leading telecommunication operators in the region, such as América Móvil and Telefónica, have launched strategies to outsource part of their maintenance activities, generating contracts and opportunities for test equipment vendors.

The oscilloscopes market held the largest market share in 2011, followed by spectrum analyzers, network analyzers, and multimeters.



Note: All figures are rounded. The base year is 2011
Source: Frost & Sullivan analysis

Latin America General Purpose Test Equipment Market: Revenue, 2011, 2014 and 2018
CAGR: 12.6%

The oscilloscope segment is the fastest growing segment in the Latin American general-purpose test-equipment market.

From an end-user perspective, the communications segment held the largest market share in terms of revenue, followed by the aerospace & defense and education segments. There are increasing opportunities in the cellular operators, government, and broadcast end-user segments.

Brazil continued to hold the largest market share in the Latin American general-purpose test-equipment market in 2011, followed by Mexico and Argentina. Beyond Brazil and Mexico, countries such as Colombia, Chile, Venezuela, and Peru are expected to boost market revenue growth. Leading test-equipment vendors are focusing on these countries by establishing operation centers and sales offices locally.

Some of the leading companies apply price increases twice a year; however, the price increases are very conservative.

"The challenge is to consolidate our position in the Latin American market that is increasingly focused on price; however, price is not everything in the value proposition," said Diego Parra, Anritsu's Latin America sales director. "Our sales cycle begins by educating the client on our value proposition. The market has begun to require more specialized technical support."

From a technological perspective, there is an emerging need for modular and integrated test equipment. "Local test equipment is required to have a greater number of test instruments within a single box. More and more, manufacturers of traditional box instrumentation are migrating or starting to increase modular instruments in their product portfolio and it is definitely having an impact in Latin America," said Gustavo Valdes, National Instruments' strategic marketing manager for Latin America.

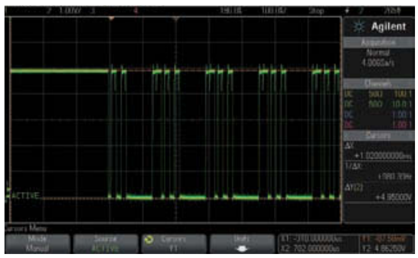
Overall, economics are improving in the region and most of the local governments are willing to invest in education, which is anticipated to generate sustained demand for general-purpose test equipment. The Latin American region is keen on catching up with new technology, which augurs well for test and measurement companies.

INSTRUMENTATION

Active probes are worth the extra cost

In an article on the "Test & Measurement Designline" portion of the EE Times Website, Jae-Yong Chang, product manager and planner for Agilent Technologies' oscilloscope product line in the Oscilloscope Products Division, provides guidance on the optimal probe to use for different applications. He points out that most low-to-mid-range oscilloscopes come with one high-impedance passive probe per channel. But what about active probes? Chang notes that active probes are more expensive, but they offer better performance that may make a difference in applications that require high-bandwidth, high-signal fidelity performance.

a) The amplitude of the signal measured with the 100:1 resistor divider probe is decreased to 1.65 V due to the resistive loading of the low-impedance probe.



b) The output measured with an active probe with 1-MΩ input impedance makes the amplitude measurement correctly.

The article explains the issues with "probe loading," or when the probe becomes a part of the circuit, introduces loading, and changes the measurement. Chang provides a graph that compares the input impedance of a general-purpose passive probe with 10-MΩ resistance and 4-pF capacitance with that of an active probe with 1-MΩ resistance and 1-pF capacitance as they are used across increasing frequencies. He notes that although the 10:1 passive probe comes with higher input impedance at low frequency ranges, the input-loading characteristics of the active probe are usually better at high frequencies because of the probe's lower input capacitance.

Next, Chang outlines the benefits of differential active probes as well as high-voltage differential probes. He explains how they work and that they provide better signal integrity due to very low impedance grounding and higher input impedance. Giving equal time, he drills down into detail on the Z0 passive probe (also known as a 50-Ω passive probe). Chang explains that if you select a Z0 probe as a low-cost alternative to a higher-priced active probe, you should be careful with the resistive loading effect, because it may alter the measured amplitude of the signal as well as the bias point.

Finally, Chang steps through a detailed comparison of a measurement taken with a 100:1 resistor divider probe and a measurement taken with an active probe with 1-MΩ input impedance (see figure). You can link to his article, "Active probes: why they are worth buying," from the online version of this article at www.tmworld.com/4389717.

Janine Love, Senior Editor

WIRELESS TEST

Testing E911

In the event of an emergency, we have been trained since childhood in the US to dial 911 from the closest available phone, which back when almost every household had plain-old-telephone service, enabled the emergency operator to look up the exact location of the phone line used to originate the call and coordinate a response. Today, with the majority of 911 calls originating from mobile devices, pinpointing the exact location of callers is not so simple.

More than 10 years ago, the FCC introduced its E911 Phase II location requirements for US wireless network operators and mobile devices. E911 (enhanced 911) requires that caller location be provided to public-safety answering points with 50-m accuracy for 67% of calls and with 100-m accuracy for 95% of calls (see figure). The FCC is also investigating ways to further improve the performance of locating 911 callers who use mobile devices.

A typical E911 call from a mobile phone can pinpoint the caller's location to within 50 m, translating to about 27 houses in this type of neighborhood.

All of this is spurred by a basic problem: Despite all the technology, location accuracy is often just not good enough when calls are placed from mobile phones; in some cases, usable location information is impossible to obtain, especially when calls are made from indoors. Today, more than 70% of 911 calls originate from mobile devices, and more than 60% of 911 calls originate indoors.

Industry bodies such as 3GPP and 3GPP2 have developed compliance standards for mobile devices to help ensure the FCC's location accuracy requirements are achieved. Since these standards are global, they are often a requirement in other markets as well. For 2G and 3G devices that use CDMA, GSM, or WCDMA technology, the requirements are well established. The recent push to launch LTE, or 4G, networks, however, is shaking things up.

With LTE migration well underway in North America, wireless service providers are working to upgrade the technologies that enable caller-location identification in order to deploy E911 capabilities. Designers need to understand how the different positioning technologies (or combinations of technologies) play into the requirement to support E911 on LTE networks in North America and must also understand the implications for testing the complex positioning scenarios that can result.

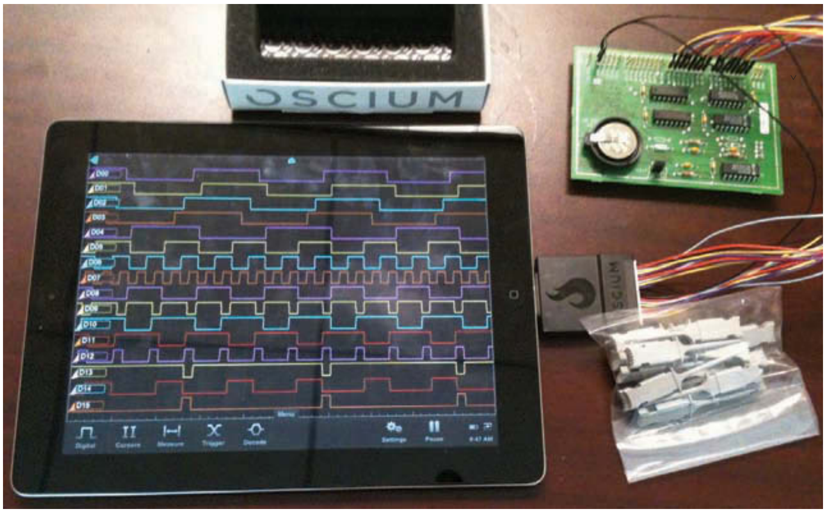
No current positioning technology is capable of providing the FCC's required accuracy level by itself, so a combination of technologies will likely be needed. Current LTE standards support three handset-based positioning technologies: ECID, A-GNSS, and Downlink OTDOA. LTE deployments also employ two location protocols: LTE Positioning Protocol and Secure User Plane Location Version 2.0.

In the online version of this article, we discuss the FCC's standards and how they translate into location protocols, and we also explain how engineers can test E911 in LTE networks: www.tmworld.com/4390391.

Brock Butler and Susan Ahimovic, Spirent

PRODUCT TRYOUT

iOS logic analyzer shows the bits



Oscium, the company that developed the iOS-based iMSO-104 oscilloscope and WiPry WiFi spectrum analyzer/power meter, has now developed the LogiScope, a 16-channel logic analyzer for the iPad, iPhone, and iPod Touch. I tried the $389 LogiScope on an iPad 2 rather than on an iPhone because of the iPad's larger screen. Viewing 16 traces on the iPhone's screen is, well, challenging.

As the figure shows, the LogiScope comes with two wiring harnesses, each holding eight color-coded input wires and a ground wire. The leads connect to standard-sized pins. The instrument also comes with a bag of 16 clip leads. I used 16 channels of a 24-channel logic demo board as a signal source.

After downloading the free app from Apple's App Store, I connected the LogiScope. The iPad immediately found the instrument and signals appeared. Navigating the menus is easy and is similar to the way you navigate the menus on Oscium's other products. Each trace on the screen is color-coded to match the color of the wire. Using your finger, you can move any trace up or down the display.

The "Digital" menu lets you turn on any channel and give each a name. The "Cursor" menu lets you enable cursors for measuring time between events or the frequency of a signal. Using the "Measure" menu, you can measure duty cycle, pulse width, and frequency.

The LogiScope also provides a two-level trigger. Virtual logic gates add combinational logic for building a trigger. The virtual gates let you set up AND, NAND, OR, NOR, XOR, or XNOR conditions to trigger an acquisition. Trigger conditions include rising or falling edges, levels, or pulse width.

Overall, the LogiScope is a handy tool for troubleshooting logic circuits. To read my complete product tryout of the LogiScope, go to the online version of this article at www.tmworld.com/4389719. To read my tryout of the earlier-released WiPry spectrum analyzer, go to "Product tryout: iOS spectrum analyzer/power meter lights up WiFi" at www.tmworld.com/4378083.

Martin Rowe, Senior Technical Editor

Crosstalk problems are back

Crosstalk, a problem associated with parallel buses, is now an issue with high-speed serial buses, where multiple signals on a single board can interfere with each other.

BY RANSOM STEPHENS, CONTRIBUTING TECHNICAL EDITOR

The inexorable demand for electronic systems with increasing bandwidth and decreasing size puts more high-speed channels in ever-closer proximity. Technologies such as 40-Gbps and 100-Gbps Ethernet employ up to 10 channels at 10 Gbps each or four channels at 25 Gbps. When so many high-speed serial lanes reside in a single system, they're bound to interfere with each other.

Serial buses such as Ethernet, Fibre Channel, and PCI Express capitalize on the robust nature of serial technology, with its interference-canceling differential signaling and jitter-canceling embedded clocking. To achieve incrementally greater data rates, the emerging technologies employ multiple serial lanes that operate in parallel. With each additional lane, a bus scales to a higher data rate (Ref. 1). Unfortunately, every channel is both an aggressor and a victim. Differential signaling can only partially cancel crosstalk at these high data rates. After a decade spent developing serial data technologies and dealing with jitter, closed-eye diagrams, and pre-emphasis and de-emphasis, and then having equalization save the day, engineers have realized that crosstalk has come back to haunt them.

Marty Miller, chief scientist at LeCroy, put it like this: "When we started switching from parallel to serial interconnects, crosstalk stopped being a big concern, but now we're moving to serial channels in parallel. We have systems with dozens of SerDes on one chip operating at 50 times the data rate [of parallel buses]. We're looking at a crosstalk nightmare."

What is crosstalk, anyway?

Crosstalk is the electromagnetic interference of multiple signals that occurs when radiation from an aggressor channel is picked up by a victim channel. Maxwell's equations describe electromagnetic radiation only when electric and magnetic fields change. Crosstalk is generated during logic transitions. With rise and fall times of 20–30 ps at 10 Gbps or 5–10 ps at 25 Gbps, the emerging high-rate standards have rapidly changing electric fields that can couple from one lane to another. The faster the change, the louder the crosstalk.

High-speed serial systems use differential signaling to beat back all types of EMI (electromagnetic interference). Differential pairs consist of two conductors. One carries the signal, and the other carries the inverse of the signal, or its complement. If the conductors are arbitrarily close together and are of precisely the same length, then they carry identical EMI. The receiver takes the difference of the pair, canceling the interference and reinforcing the differential signals. This is called common-mode rejection, because signals common to both elements of the pair are rejected.

Unfortunately, real differential pairs have non-zero separation, are not exactly the same length, and suffer other asymmetries such as impedance variations at contact points and variations in trace widths, thickness, and roughness. These imperfections limit common-mode rejection.

Engineers developing multilane serial links anticipated crosstalk's return, but that's not the whole story. Pavel Zivny, domain expert on high-speed serial data with Tektronix, said, "Intersignal crosstalk was expected, but there's another source of crosstalk that we didn't anticipate. As the transmitters on a SerDes chip draw current from the power plane, they generate power-supply variations that have different properties." Current draw in one device can cause variations in the power delivered to an adjacent device, a condition known as "chip crosstalk."

Intersignal crosstalk, appears as sporadic jolts on the victim whenever an aggressor makes a logic transition. This interference lasts for the duration of that transition, whereas chip crosstalk has a longer duration.

Crosstalk is exacerbated by pre-emphasis and de-emphasis, which enable high-speed serial data receivers to reach a low BER (bit-error rate), even when signals are so degraded their eye diagrams are closed. At the transmitter, pre-emphasis enhances the high-frequency content of signals, which fends off the low-pass nature of the transmission lane's frequency response. Unfortunately, that high-frequency content generates the most crosstalk.

It's worse at the receiver. As Miller said, "Two of the three standard equalization techniques, CTLE (continuous-time linear equalization) and FFE (feed-forward equalization), amplify crosstalk noise. The third technique, DFE (decision-feedback equalization), is the only one that doesn't make it worse, but nothing we have now makes it better."

Another complication arises in systems with parallel buses. Because the channels in parallel buses are frequency locked, they have fixed-phase relationships. With fixed-phase relationships, the time position of intersignal crosstalk in the eye diagram is also fixed. If crosstalk jolts occur at the crossing point in an eye diagram, they have a smaller impact on the BER than if the crosstalk jolts are offset by half a bit period and occur in the center of the eye at the victim.

Figure 1 shows an eye diagram with no crosstalk jolts. In **Figure 2a**, the crosstalk jolts appear at the crossings, and in **Figure 2b**, the jolts appear at the eye opening's widest point. In many systems that use multiple serial lanes, including 40/100 GbE (Gigabit Ethernet), each lane operates at the same nominal frequency, but the lanes aren't locked. Because each channel operates on a clock recovered from the data, the relative phases are free to float. **Figure 3** shows how unlocked, or "asynchronous," crosstalk smears the traces and is deceptively similar to the effect of random noise and jitter.

Oscilloscopes analyze crosstalk

If you're in complete control of a serial-data link's individual lanes, you have the luxury of performing systematic, straightforward crosstalk analyses. Assume that you have a 100-Gbps link made from ten 10-Gbps lanes. Start by analyzing lane 1. Turn off lanes 2 through 9 and check the waveform and eye diagram of lane 1. Then, turn on a lane adjacent to 1. Any degradation you see is caused by crosstalk. Next, turn on each lane, and you can gauge the trouble. This is a simple diagnostic recipe for finding lanes that are more troublesome than others.

If the lanes are frequency locked, you should be able to isolate the problem. If they're not locked, the degradation will look like a mix of random jitter and noise. In the unlocked case, it's better to examine the waveform, bit by bit, comparing the aggressor waveform to the victim waveform.

Unfortunately, these techniques won't help you estimate the eye closure corresponding to a given BER, which is what

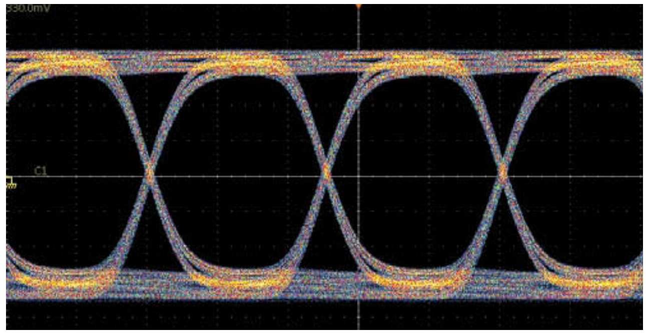


FIGURE 1. An eye diagram that has no crosstalk will have no impairments. Courtesy of Tektronix.

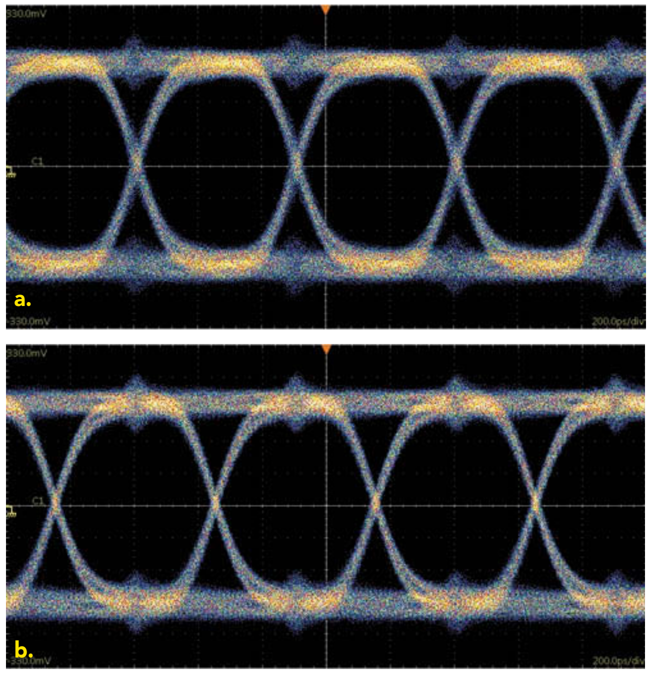


FIGURE 2. These eye diagrams display the effects of different victim-aggressor phase relationships. a) The aggressor and victim are in phase, and the crosstalk impairment is at the crossing point. b) The aggressor and victim are half a bit out of phase, and the crosstalk impairment is at the center of the eye.

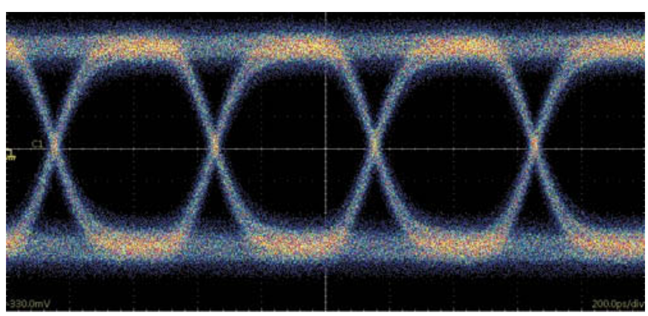


FIGURE 3. When the aggressor and victim are asynchronous, crosstalk noise varies across the victim's eye diagram.

Photos courtesy of Tektronix.

compliance testing requires, usually down to a BER of 10^{-12}. Plus, you're not likely to have that much control of individual channels. Rob Sleigh, product marketing engineer for sampling scopes in Agilent Technologies' Digital Test Division, said, "At these speeds, the connectors and ICs have much smaller geometries and we should expect crosstalk from various sources. Additionally, 100 Gigabit Ethernet gearboxes switch between 4x25 Gbps and 10x10 Gbps, and since you can't shut off individual lanes, it makes crosstalk isolation even more challenging."

How Tektronix addressed the problem

Perhaps the most annoying problem with crosstalk is that jitter-analysis software frequently mistakes crosstalk for RJ (random jitter). Since RJ contributes disproportionately to the estimate of total jitter defined at a given BER, crosstalk can appear as a far more egregious problem than it really is.

In Zivny's view, "The main problem is to accurately predict total jitter and eye opening while providing a quantitative measure of the crosstalk problem." Tektronix accomplished these goals by implementing an approach that Zivny conceived.

In the early 2000s, manufacturers of test and measurement equipment were in a heated battle to determine the most accurate jitter-analysis technique (Refs. 2 and 3). At the time, measurements taken with different equipment often varied by more than 100%. One of the approaches that brought the problem under control was to use a spectral technique for measuring RJ. With this technique, engineers look at the spectrum of the timing of logic transitions; periodic components show up as spikes that can be removed.

Figure 4 shows the effect that crosstalk has on the spectrum of uncorrelated jitter. Note the higher noise level and additional spikes in **Figure 4b** that are missing from **Figure 4a.** The RMS value of the remaining smooth continuum is then identified with RJ. RJ is assumed to follow a Gaussian distribution, and the amount of eye closure at a given BER can be estimated using the dual-Dirac model (Ref. 4). Crosstalk shows up in that continuum and, thus, the spectral techniques mistake crosstalk for RJ and overestimate eye closure, sometimes by more than an order of magnitude.

Zivny's idea was to first isolate RJ and crosstalk from the spikes of sinusoidal and periodic jitter in the spectrum. Because this data set doesn't contain any elements that are correlated to the data, like intersymbol interference, it's called uncorrelated jitter. The data is then transformed back into the time domain where the cumulative distribution function is used to isolate unbounded Gaussian RJ. The remaining bounded jitter is labeled NP-BUJ (nonperiodic bounded uncorrelated jitter). Whatever crosstalk that exists in the jitter distribution is isolated in NP-BUJ.

There is no a priori reason to believe that NP-BUJ is exclusively crosstalk. Engineers have a good idea of what's going on in their systems, so it's not much of a stretch to equate NP-BUJ with the horizontal eye-closure caused by crosstalk. This analysis is also performed in the vertical direction where noise plays the voltage equivalent role of jitter to get NP-BUN (nonperiodic bounded uncorrelated noise) (Ref. 5). Whether or not NP-BUJ and NP-BUN are exclusively caused by crosstalk doesn't affect the eye closure estimates at given BERs.

LeCroy extracts crosstalk residuals

At LeCroy, Marty Miller's approach is quite different. Miller said, "My belief is that the most important aspect an oscilloscope brings to the table is noise analysis and, to first order, crosstalk is signal-to-noise degradation—radiative effects with variations and fluctuations that you can see on a scope." Miller's approach is to automate a detailed examination of the victim waveform.

The approach starts with the test patterns. "It's important in any crosstalk analysis," Miller said, "that the patterns transmitted on the aggressors not only be distinct from the victim test pattern but have a different length." If the aggressor pattern is the same length as the victim pattern, crosstalk will appear to be correlated to the data. If the aggressor pattern is precisely the same pattern as the victim pattern, not only will the crosstalk be correlated, but the crosstalk and the signal can exhibit constructive and destructive interference, or beats.

Miller likes a short test pattern on the victim and long patterns on aggressors. This makes it possible to fully evaluate

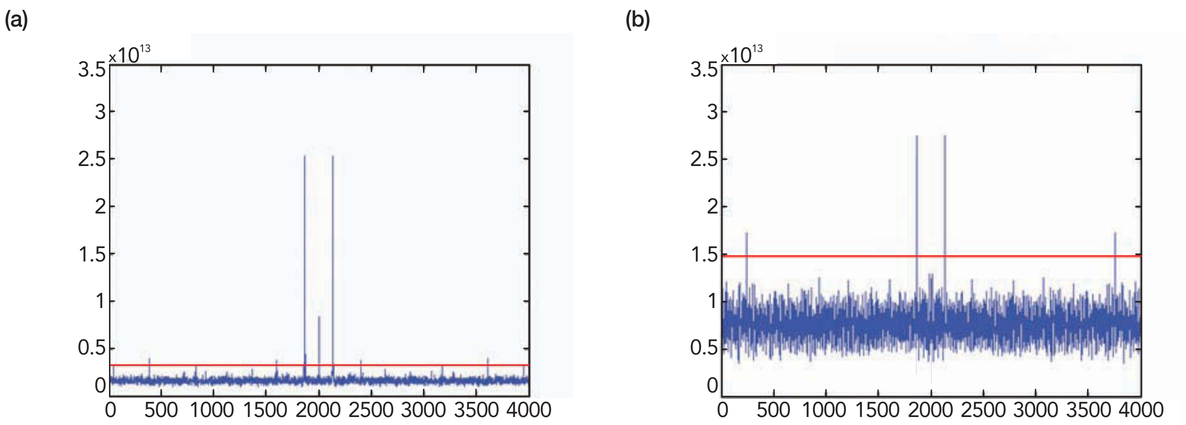


FIGURE 4. A spectral plot of RJ and PJ shows that crosstalk adds noise and spectral peaks that are missing in (a) and present in (b).

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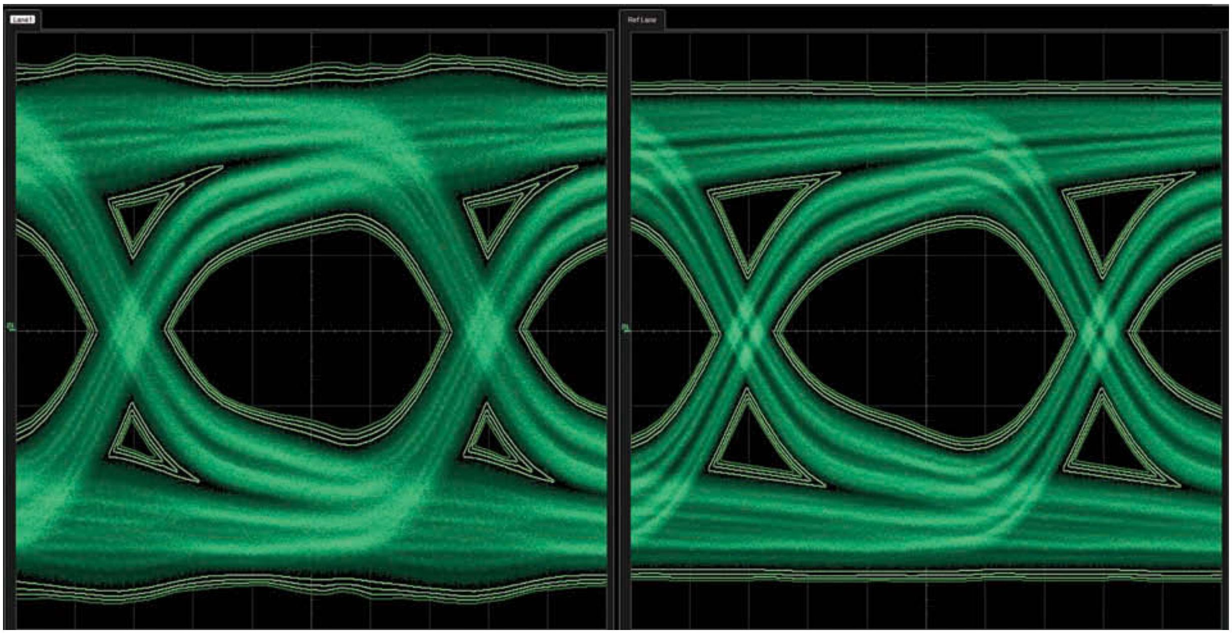

Photo courtesy of of LeCroy.

FIGURE 5. A signal-centric contour plot contains a superposition of the trajectories of all symbols in a test pattern, including all sources of noise and lines of equal BER, here at 10–6, 10–9, 10–12, and 10–15, with crosstalk (left) and without crosstalk (right).

each bit in the victim pattern subject to a representative sample of crosstalk impairments.

The next step involves evaluating the shape, or trajectory, of each symbol in the victim test pattern. By comparing each repetition of a symbol, Miller's technique separates the crosstalk impairment into a waveform of its own that he calls crosstalk residuals. The residuals are what you would see on the victim lane if you could turn off the victim signal and look at the crosstalk alone on that lane. The process is independent of any phase relationships between the victim and aggressors, so it doesn't matter whether or not the victims and aggressors are frequency locked.

The final result is a novel construct Miller calls a "signal-centric contour plot" (**Figure 5**). This plot is a combination of the trajectories of every symbol in the test pattern with all the jitter and noise as well as the actual crosstalk distribution portrayed as a fluid cumulative distribution function from which the probability of a deviation from the mean waveform can be calculated. It's like a generalized BER-contour plot and provides eye-closure estimates to any BER, with crosstalk properly included in the calculation.

Agilent opens the catalog

Agilent applications engineer Stephen Didde commented that, "The error detector of a BERT [bit-error-rate tester] has 100% data capture. It's the only test equipment that actually measures eye opening at very low BER. No matter what signal impairments there may be, crosstalk from different lanes, power-supply interference, or other unknown problems, the BERT measurement can be trusted."

In addition, Agilent is bringing more of its test equipment to home in on the problem. Sleigh said, "You shouldn't rely on one instrument to identify and determine root causes for crosstalk. In addition to time-domain waveform analysis using an oscilloscope, other tools such as vector network analyzers and simulation tools such as ADS [Agilent's Advanced Design System software] can provide insight into crosstalk issues early in the design process."

Mike Resso, signal integrity measurement specialist in Agilent's Component Test Division, added, "Crosstalk is ultimately a problem of common-to-differential mode conversion. The differential S-parameters of a victim lane indicate how susceptible it will be to electromagnetic radiation within the board, regardless of its source. In fact, not only can the magnitude of crosstalk be determined, but the position where crosstalk is picked up by the lane can be located" (Ref. 6).

Performing a complete calculation of crosstalk would require a scattering matrix with two elements for every trace, four for each differential pair of traces. A 10x10-Gbps differential system would require a 40x40 scattering matrix, which would require 1600 S-parameter measurements. No system is yet capable of making these measurements at that scale in an automated fashion. Resso said that Agilent engineers can measure six complete channels, a 24x24 scattering matrix that can account for a victim and up to five neighboring aggressors. He added, "The calibration takes about 15 minutes as well as the measurement, and the resulting file is 37 megabytes. To do more than 24 ports is definitely feasible, but we would need to think about managing the huge data sets."

In July, Agilent is releasing extensions on its EZJit jitter-measurement software. With that release, Agilent will provide amplitude-analysis and jitter-analysis algorithms that distinguish crosstalk from RJ and random noise. According to Agilent, these enhancements will improve total-jitter estimates in the presence of crosstalk.

Can crosstalk be corrected?

When high-speed serial buses reached 5 Gbps, it seemed impossible to accommodate BERs of 10^{-12} and lower without replacing standard printed-circuit-board materials with expensive new media that are less sensitive to intersymbol interference. But engineering innovation rose to the task, leading to the development of different equalization schemes that let receivers identify logic levels at the desired BERs in highly impaired signals whose eye diagrams are completely closed.

Will some sort of signal compensation technique save the day? Zivny said, "I've heard techniques discussed going back to telegraph days: echo cancelation and hybrid circuits." Sleigh added, "Once we've developed techniques to identify crosstalk, we'll have the understanding we need to create techniques for solving the problem. Right now, we're working on identification."

"Only compensation applied at the transmitter is likely to help, because that's where we know what's coming," Miller said. He concluded, "We'll be discussing crosstalk analysis for the next 15 years much the way we've been discussing jitter analysis for the last 15." T&MW

REFERENCES

1. Derickson, D., and M. Müller, eds., Digital Communications Test and Measurement, Chapter 2, Prentice-Hall, 2008.
2. Stephens, R., and B. Fetz, et al., "Comparison of Different Jitter Analysis Techniques With a Precision Jitter Transmitter," DesignCon 2005, bit.ly/JqQJYa.
3. Chow, D., and R. Stephens, "Methodology for Jitter Measurement Correlation and Consistency," Proceedings from DesignCon 2005.
4. Stephens, R., "Jitter Analysis: The dual-Dirac Model, RJ/DJ, and Q-Scale," Agilent Technologies White Paper, 5989-3206EN, 2004. bit.ly/L8CxG6.
5. Agoston, M., and P. Zivny, "Accurate Analytical Model of Bounded Uncorrelated Jitter and Noise Improves the Accuracy of Crosstalk Impaired Link Evaluation: Theory, Validation, Practical Results," Proceedings from DesignCon 2012.
6. Resso, M., and E. Bogatin, Signal Integrity Characterization Techniques, International Engineering Consortium, 2009.

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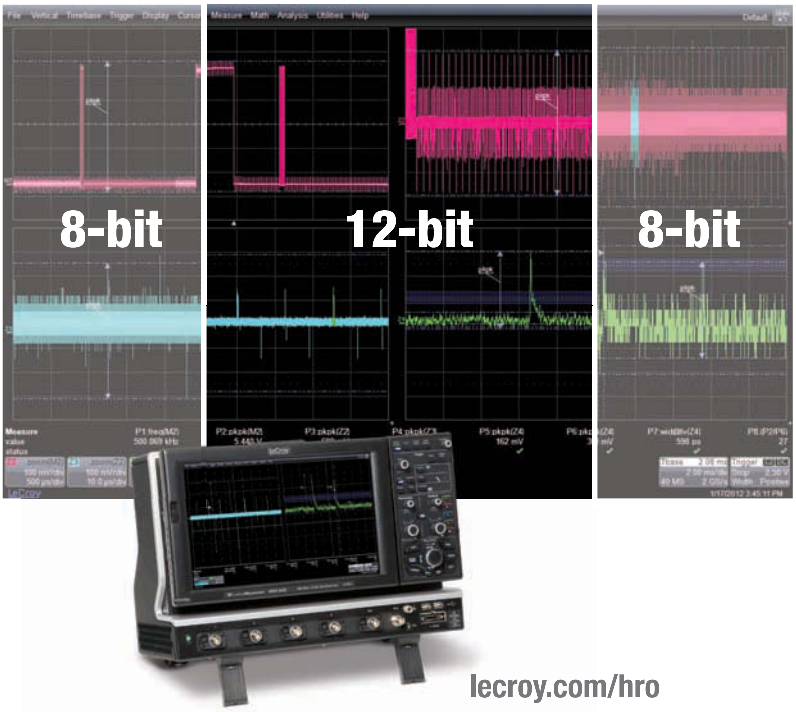

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Beyond the Limits

Precompliance testing for radiated emissions

Some basic tools can help you identify trouble spots in your lab.

BY KENNETH WYATT, WYATT TECHNICAL SERVICES

Many engineers bring their products to the test lab having no idea if it will comply with EMI/EMC standards. Building a precompliance test lab is expensive, but you can still isolate radiated emissions with magnetic-field "sniffer" probes on enclosures and current probes on wires and cables.

Engineers at smaller companies often can't afford a full-time compliance engineer. Thus, it's often difficult to predict whether a product will pass radiated emissions testing prior to taking the product to a test lab. You can spend a lot of time and money preparing a product, only to have it fail, which will require you to spend even more time and money on a redesign and a second round of testing. Ideally, performing some precompliance tests in your own lab will increase your confidence that a product will pass its compliance tests on the first try.

An engineer named Jeremy recently sent me several questions about how to prepare for qualification testing. Jeremy's situation is probably similar to that of many engineers. After having been laid off from a large firm where he worked on product design and development, he now works for a much smaller company where he wears multiple hats and has responsibility for EMC (electromagnetic compatibility)—yet he has little equipment available for solving problems. Jeremy is learning the hard way about EMC. He takes products to an EMC lab for testing, only to have them fail. He thinks he has found a solution to a problem but is unable to perform any compliance tests himself; he has to take the design to a test lab, pay $600 to $1600, and then potentially fail the testing again.

I think we've all "been there and done that!" My heart goes out to engineers in this situation, but the situation isn't hopeless. There are easy ways to perform precompliance tests in your own lab. It's an important and cost-effective set of skills to learn. You'll end up saving your company considerable time and money if you can perform some simple tests on the bench at your own facility.

Below, I have listed Jeremy's questions (edited to fit this space) along with my answers. I'm sure many engineers who are new to the EMC field will identify with Jeremy's concerns and can learn from his situation.

FIGURE 1. Loop probes can help you locate and identify radiated emissions.

Making near-field measurements

Question: When making near-field measurements with a small loop probe (**Figure 1**), I don't know whether everything I see with the near-field probe is actually a problem. I want to change as little as possible, because at a small company, it really hurts to scrap materials because of a change to a design.

Assume that with a small near-field probe, I see some amplitude of emission at a chassis seam that is 16-in. long, I see the same amplitude of emission from an air slot that is 2-in. long, and I see the same emission level over the entire length of a 6-ft-long load cable. My gut feeling is that the 6-ft-long cable is radiating from a larger area and therefore must be radiating more power, but I'm not so sure about the 2-in. air slot and the

16-in. chassis seam.

I need a way to better understand near-field measurements from chassis seams or around connectors and how they relate to the far-field amplitude. I've had some people tell me to fix every leak I see, but this can be expensive and a waste of money. I've read articles that say near-field measurements may or may not be related to the far field, and that sometimes problems seen in the far field aren't seen in the near field and vice versa.

Answer: Correlating near-field with far-field measurements is a common area of concern. Before correlating the measurements, engineers need to be sure they understand the physics of the situation.

Consider a "point source" (electrically small) radiating E-field dipole antenna (Hertzian dipole). In the near field, the radiating electromagnetic waves will be spherical, and they will gradually become planar (plane waves) in the far field. As you move away from this radiating point source, the E-field (measured in volts/meter) drops off with distance.

In the near field, the equations for the electromagnetic (electric and magnetic) fields are complex and include factors of $1/r^2$ and $1/r^3$. In other words, the field strength tends to drop off quickly. In the far field, the measured E-field drops off by a factor of 1/r, where r is the distance away from the point source radiating antenna. Because this conversion from spherical to planar waves is gradual, it's difficult to definitively say where the exact transition point is, but most EMC engineers assume the point is at: distance = wavelength/(2★π), or about 1/6 of a wavelength.

If you were to plot the wave impedance (Zω = E/H, E-field and H-field plots) versus frequency for a dipole antenna, you would find that in the near field, the E-field is high (over 5 kΩ) and the H-field is minimal (about 20 Ω). If the emission source has a high current and low voltage (E/H < 377), the near field is predominantly magnetic (H-field). If the source has a low current and high voltage (E/H > 377), the near field is predominantly electric (E-field). As you move out to the far field, the E-field and H-field wave impedances converge to approximately 377 Ω in free space. Henry Ott has a plot of this, along with a good explanation, in his latest book, *Electromagnetic Compatibility Engineering* (Ref. 1).

So, what does this mean when measuring near-field emissions on a product? You'll need to recognize that the near-field to far-field correlation is very complex and not a one-to-one relationship. You'll also need to consider wavelength as you measure circuit traces, cables, seams, and apertures. Jeremy is right with his guess that the 6-ft. cable will tend to be more of a radiation risk than the 2-in. slot. The rule of thumb of 1/20 of a wavelength is good to keep in mind. Think of the seams, gaps, traces, holes, and cables as antennas. Small, or electrically short (that is, less than 1/20 of a wavelength), antennas are inefficient radiators. As the electrical length approaches 1/4 or, especially, 1/2 wavelength, the antenna becomes an efficient radiator and can cause trouble.

When I'm measuring enclosure seams, for example, I identify the dominant harmonics and use a marking pen to record the length of the particular seam, as well as the frequencies of concern. If the seam is electrically short, then it's probably not the dominant emission source. If I'm measuring common-mode currents on a cable, I identify the dominant harmonics and, because most cables are electrically long, I can be relatively sure emissions on that cable will be a problem. The nice thing about a current probe is that you can maximize their readings by sliding it back and forth along the cable, then fixing it in place, before you begin troubleshooting.

The one thing to be wary of, though, is that a 10-dB drop in near-field emissions does not usually equate to a 10-dB drop in far-field emissions. Remember, you're dealing with distance factors of $1/r^3$ and $1/r^2$ in the near field (tends to drop off quickly) versus 1/r factors as you move into the far field. You can be assured, however, that a significant drop in the near field will also help to some degree in the far field. If you find several potential seam leaks in your enclosure, do what Ott suggests and "kill it dead" by throwing everything you've got at the problem. Then, once you've achieved compliance, start removing fixes that aren't required.

Simulating a far field

Question: To simulate a far field, I've tried setting up a small digital TV antenna in my lab that is about 1 m away, but my ambient environment is too polluted. The 30-MHz to 60-MHz ambient is higher than my own emissions, so it doesn't really do any good.

Answer: Setting up a nearby antenna where you're troubleshooting is a great idea! I use that technique all the time, because it shows a truer picture of relative increases or decreases in field strength. Of course, if you could locate the antenna at 3 m or 10 m away, you'd be able to predict much more accurately whether the product would meet the required radiated emission limits. The problem is that all the other ambient signals from radio, TV, and mobile communications tend to interfere with observing the harmonic signals from a product. Hence, EMC labs use shielded measurement chambers for formal qualification testing.

I've set up temporary 3-m measurement sites in the basement of a building, which tends to help. I've also tried to orient a directional receive antenna at 90° to the strongest ambient, which tends to reduce the pickup. The only other solution is to try shielding the room you're working in with aluminum foil taped to the walls. I've also seen shielded tents that are used for temporary shield rooms.

Just a hint: Generally speaking, dominant emissions below 200–300 MHz are likely due to common-mode currents on cables; above that frequency, emissions are more likely due to slot, seam (differential-mode emissions), or sometimes cable emissions. In this specific case of 30 to 60 MHz harmonics, you could probably do most of your troubleshooting with a current probe, which tends to not be as sensitive to far-off ambient signals.

Current probes

Question: I need to make a current probe, but one thing that isn't clear to me is if just installing the probe can be enough to change the value of the common-mode current that is seen by a significant amount.

Answer: Current probes are a very valuable tool, and a do-it-yourself probe will work in a pinch (Ref. 2), but I'd highly recommend investing in a good commercial probe, such as the Fischer Custom Communications F-33-1 probe (see similar probes in **Figure 2**). This will serve you well.

Current probes do affect the common-mode cable currents to a minor degree. In fact, my colleague, Doug Smith (www.emcesd.com) has determined that at high frequencies, the cable currents can couple into the shielded case of the probe and be diverted along the outside of the probe-cable shield. This can be at least partly blocked with clip-on ferrite chokes. The important point, however, is to use the probe to monitor reductions in common-mode currents, which generally equate to reductions in measured radiated emissions.

Chassis design

Question: When designing a chassis, what are the allowable hole and slot sizes, and what is the attenuation of different sizes? I've read several sources that recommend keeping slots and holes to 1/20 of a wavelength of the maximum frequency of concern.

At my last company, we made high-power (1 kW to 10 kW) RF and DC power supplies, and we always used very small holes (about 0.1 in.) in the chassis for the air holes. It seems to me, though, that based on the 1/20 of a wavelength rule, I should be able to have a 2-in. slot for up to 300 MHz, but does this depend on how powerful the source is?

Answer: After the discussion of wavelength and what constitutes an efficient radiator, you now know that 1/20 of a wavelength is not efficient, and slots, seams, gaps, and traces where the dominant harmonic is 1/20 wavelength will not tend to be an issue. At the same time, when considering the shielding effectiveness of an enclosure, a seam measuring 1/20 wavelength, or less, should not be an issue. In fact, the general rule of thumb for shielding effectiveness of a slot is 1/20 wavelength provides about 20 dB of shielding effectiveness.

An array of slots (for example, for a ventilation port) will be less effective than small holes to some degree. There have been studies on the shielding effectiveness of slots versus holes, and these studies led to the development of the corresponding empirical equations for shielding effectiveness. This is why most ventilation ports are often a matrix of small holes, rather than an array of slots.

Jeremy is correct that for very-high-power RF sources, a chassis requires small holes for ventilation, and I'd suggest designing the enclosure for harmonics up to at least 1 GHz, which equates to approximately 1/2 in. maximum slot length. Again, Ott has handy charts in his book for determining the shielding properties of slots, holes, and seams.

FIGURE 2. Current probes measure common-mode currents that tend to cause cable radiation.

These are just a few hints that can help you prepare a design for formal EMC testing. To see further discussion of these points, see the online version of this article in "The EMC Blog" on www.tmworld.com/4376432. Plus, feel free to add your own questions to the discussion. T&MW

REFERENCES

1. Ott, Henry, *Electromagnetic Compatibility Engineering*, 2009. www.hottconsultants.com/EMCE_book_files/emce_book.html

2. Wyatt, Kenneth, "The HF Current Probe: Theory and Application" *Interference Technology*, March 20, 2012. www.interferencetechnology.com/the-hf-current-probe-theory-and-application.

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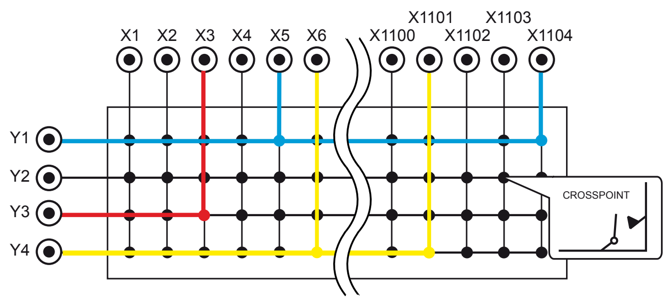

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USB 3.0 making headway into cameras

USB 3.0 doesn't just let you download movies or transfer files faster than previous versions, it also improves industrial camera speeds. The USB3 Vision standard will let cameras, computers, and software interoperate as well.

BY PAUL KOZIK, POINT GREY RESEARCH

USB 3.0, once known as Superspeed USB, offers considerable performance improvements over USB 2.0, answering the demand for a high-speed, high-bandwidth computer peripheral bus. Consumers who download large files such as movies and e-books can use USB 3.0 to provide the high bandwidth they need for fast data transfers. Engineers looking to rapidly transfer images from industrial cameras can also benefit from USB 3.0, and several manufacturers of industrial cameras have released entire product lines of USB 3.0-based cameras to meet this need.

Unlike consumers who download data to memory devices such as hard drives and flash drives, engineers need application software and a programming interface to transfer images from a machine-vision camera to a host computer. In response, the AIA (Automated Imaging Association) is developing the USB3 Vision camera interface standard, which will enable interoperability among a variety of imaging components. This standard, combined with the advanced capabilities that USB 3.0 offers, makes USB 3.0 a viable option for engineers who are developing machine-vision systems.

Best in class

Like other digital interfaces, USB 3.0 provides high data-transfer rates over a single cable, which simplifies its use and makes it cost-effective. In fact, USB 3.0-based vision systems are competitive with systems based on other interfaces. It can outperform many of them in terms of bandwidth and low CPU usage (see **Table 1**). USB 3.0 enables DMA (direct-memory access) data transfers, which allow images from the camera to pass directly to host memory without CPU interrupts. That greatly reduces CPU usage during data transfers and frees resources for image-processing applications.

USB 3.0 cables improve upon the half-duplex communication offered by USB 2.0 cables, where data flows in only one direction at a time. USB 3.0 cables add five wires for a total of nine wires in the connectors, and the cables use a dual-simplex interface that lets data flow in two directions at the same time. USB 3.0 cables are backward-compatible with USB 2.0, however, so users

FIGURE 1. A USB 3.0 cable adds five wires to the USB 2.0 interface. USB 3.0 uses both parts of the USB connector while USB 2.0 uses the left side only.

Table 1. Comparisons of digital interface standards used in vision systems.

	FireWire-b	Gigabit Ethernet	USB 2.0	USB 3.0	CAMERA LINK
Bandwidth	80 Mbyte/s	100 Mbyte/s	40 Mbyte/s	400 Mbyte/s	680 Mbyte/s (8-tap)
Cable length	10 m	100 m	5 m	5 m	10 m
Power + data over one cable	Yes (45 W)	Yes with Power over Ethernet (15 W)	Yes (2.5 W)	Yes (4.5 to 7.5 W)	Yes with Power over Camera Link (4 W)
Camera-control standard	IIDC	GigE Vision	N/A	USB3 Vision (in progress)	Camera Link
CPU usage	Low	Medium	High	Low	Medium

will be able to connect USB 2.0 peripherals to a USB 3.0-enabled computer, or connect USB 3.0 devices to a legacy computer. USB 3.0 Standard-A, Standard-B, and Micro-AB receptacles are also backward-compatible with USB 2.0. This relationship lets camera manufacturers focus on USB 3.0 technology while still supporting USB 2.0 customers. **Figure 1** shows a camera with USB 3.0 connector. USB 3.0 uses both sides of connector. USB 2.0 needs the left side only.

One of the most compelling features of the USB 3.0 interface for machine-vision cameras is its high bandwidth. Because USB 3.0 provides an effective bulk-transfer rate of approximately 400 Mbyte/s, which is 10 times faster than USB 2.0 and five times that of IEEE 1394b, camera manufacturers can build USB 3.0-based cameras that incorporate the fastest image sensors in low-cost packages. Previously, these sensors were limited to specialized high-speed cameras that offered onboard storage or that used complex interfaces to connect with expensive frame-grabber technology.

To demonstrate the capabilities that USB 3.0 offers to vision applications, we performed a streaming test with two of our Flea3 cameras (a 1920x1080 camera at 60 fps and a 1280x1024 camera at 125 fps) connected to a single PCIe card. The two cameras successfully generated a total of more than 280 Mbyte/s of image data.

In the past, camera vendors often used onboard solid-state or compact-flash storage and limited the user to burst capture behavior constrained by the capacity of the storage medium. USB 3.0 now lets camera vendors support image capture at high frame rates on a continuous basis, making it possible to use these cameras in applications that require 24/7 operation.

USB3 Vision promises plug-and-play

To aid developers of machine-vision systems that use the USB 3.0 interface, the AIA and providers of machine-vision cameras, software, and peripherals are developing the USB3 Vision standard to permit interoperability of cameras, accessories, and software from different manufacturers (Ref. 1). USB3 Vision is scheduled for release later this year, and components that comply with the standard will offer plug-and-play compatibility and will let developers interchange components with little or minimal effect on an overall system. The establishment of USB3 Vision ensures greater compatibility between cameras and host imaging libraries, a benefit that wasn't available to USB 2.0.

USB3 Vision will provide a framework for transmitting high-speed video and related control data.

Like the popular GigE Vision standard, which is also maintained by the AIA, USB3 Vision will provide a framework for transmitting high-speed video and related control data. Also like GigE Vision, USB3 Vision will make use of the GenICam programming interface (developed by the European Machine Vision Association) to capture camera attribute behavior. This will minimize the need to modify the host software to support a new camera model.

Developers who want to employ USB 3.0 should have no trouble finding affordable products for their systems. Peripheral devices for USB 3.0 are becoming readily available on the market, and chipsets used to enable the technology are priced very aggressively due to the high-volume market of hard-drive storage.

USB 3.0 is also currently supported by the majority of new laptop computers. By 2015, all PCs are expected to support it. In terms of operating systems, Windows 8 will provide native support, Intel has just announced its new 7-series chipset with native support, and the Linux community is actively developing a kernel driver to support USB 3.0 on Ubuntu and other Linux operating systems. T&MW

Reference *GigE Vision—True Plug and Play Connectivity, AIA, Ann Arbor, MI. www.visiononline.org/vision-standards-details.cfm.*

Paul Kozik *is the product manager at Point Grey, one of the founding members of the USB3 Vision committee. He has worked for a number of imaging companies in a variety of roles including applications engineering, sales, and technical support before transitioning to product management. Kozik manages all imaging products from initial concept to complete life cycle. He holds a bachelor of engineering science (BESc) degree from the University of Western Ontario.*

PRODUCTUPDATE

SPECIAL FOCUS: Time and power savers

Anritsu antenna analyzer touts long battery life

The Site Master S331L handheld cable and antenna analyzer from Anritsu delivers eight hours of continuous battery operation to allow field technicians to conduct a full day's testing on a single charge. Covering a frequency range of 2 MHz to 4 GHz, this one-port analyzer measures return loss, VSWR, cable loss, distance-to-fault return loss, and distance-to-fault VSWR.

Anritsu reports that the S331L has the highest RF immunity of any Site Master analyzer. A sweep speed of 1.5 ms per data point (typical) enables identification of intermittent problems in real time. The S331L also features a built-in power meter for testing RF power from 50 MHz to 4 GHz and built-in InstaCal module, which provides fast one-connection calibration. Power-saving functions, such as a sleep mode and automatic display brightness, can extend battery life beyond the continuous eight-hour rating.

The S331L has a backlit 7-in. TFT touch-screen display and can store more than 1000 files, including sweeps, setups, and screenshots. In addition, it comes with SweepMasters Direct, a trace-delivery service that allows users to capture, upload, and deliver traces. The compact analyzer weighs less than 4.4 lbs and is both dust- and splash-resistant. Price: $6750.
Anritsu, www.anritsu.com

NI offers LabView/AWR VSS cosimulation

To unify RF/microwave design and test, National Instruments announced connectivity between LabView system design software and AWR VSS (Visual System Simulator) software for communications system design. As the first major joint development between NI and AWR following NI's recent acquisition of AWR, the new connectivity helps engineers make better use of measurements in the design flow by executing LabView code directly from the AWR design environment.

Cosimulation within the AWR design environment is enabled through a LabVIEW element on the VSS diagram. The AWR design environment can now incorporate LabView signal-processing capabilities, including multirate digital signal processing, wireless standards, modulation, and fixed-point math. Engineers can integrate VHDL and LabView FPGA module code through NI FPGA-based hardware directly into VSS diagrams. In addition, new connectivity to both PXI and conventional RF instrumentation makes it easier to incorporate measurement data into simulations.

A whitepaper is available at *www.ni.com/white-paper/14072/en.*

GAO portable ADSL2+ tester multitasks

The Model A0010002, a portable ADSL2+ tester from GAO Comm, lets field technicians test the physical layer, network layer, and phone lines in accordance with ADSL, ADSL2+, and Re-ADSL (reach-extended) standards. It also functions as a digital multimeter and can even conduct tests while the operator browses previous test records.

Network layer tests include ping, IP config, route, and tracert. The compact tester (200×160×42 mm, weighing 900 g) performs line parameter

(continued)

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measurements, error detection, and modem simulation. DMM functions include the measurement of AC/DC voltage, loop resistance, insulation resistance, and capacitance. Additionally, the Model A0010002 allows Web-page browsing and online software updating. Outfitted with a color TFT LCD and touch screen, the unit stores 1000 test results and seven test configurations. It communicates with a computer via RJ45 and RS-232 ports for data exchange. A built-in rechargeable 7.2-V lithium battery offers a capacity of 4000 mAh to enable up to six hours of operation.
GAO Comm, www.gaocomm.com/

Seaward's micro-ohmmeter logs test results

A data-logging function on the Cropico DO7010 digital micro-ohmmeter from Seaward enables test sequences to be downloaded from a spreadsheet and test results to be uploaded back to the data records. Upgraded with additional memory storage and extra battery capacity, the DO7010 provides accurate four-wire measurement and operates for longer working periods between recharging.

The data-logging capability of the DO7010 allows measurements to be recorded remotely and either stored in internal memory or downloaded to a USB memory stick. An LCD graphic panel displays information on the measurement configuration. A measurement is triggered when the leads are applied to the device under test. An optional remote hand terminal allows control of the DO7010 at a distance of up to 15 meters.

The DO7010 offers four resistance-measurement ranges of 6 mΩ, 60 mΩ, 600 mΩ, and 6 Ω with resolution of 1 µΩ, 10 µΩ, 100 µΩ, and 1 mΩ, respectively. Accuracy on all four ranges is ±(0.1% reading +0.1% FS). The instrument is capable of measuring with a current of 1 A and 10 A on all except the highest range. It runs on rechargeable NiMh batteries, while smart battery technology extends the operating time of the instrument. Price: $3355.
Seaward, www.seaward-groupusa.com

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ADVERTISER INDEX

Remembering Dr. Roger Pollard: A life of innovation, collaboration, and leadership

This is a belated tribute to Dr. Roger Pollard, an esteemed collaborator and colleague who passed away last December at the age of 65—much too soon.

Dr. Roger Pollard absolutely loved development—of engineering and people. His long list of accomplishments spans both, and perhaps foremost are the 56 successful Ph.D. candidates he supervised during his time at the University of Leeds in the United Kingdom. Four of those Ph.Ds are current or retired members of technical staff at Hewlett-Packard or Agilent Technologies.

Roger's relationship with HP/Agilent began more than 30 years ago. Here's how he told the story in the January 2008 issue of *Agilent Measurement Journal*:

"My Agilent odyssey started in 1981 as a young faculty member at the University of Leeds looking to take a brief sabbatical—one different from the usual route of going to another university in another country to teach the same subjects to someone else's students. Some research background in network measurements made the HP (now Agilent) division in Santa Rosa, California seem the ideal place, so I penned a request to a conference contact. Three months later, a three-line message asked, 'Can you start next week?'"

Roger spent the next seven months as part of the team that developed the HP 8510A network analyzer, a landmark product that played a significant role in transforming the microwave industry. He returned to Leeds and settled back into academic life until he received a surprise query the next spring: "When can we expect you?"

And so it went for nearly three decades. Roger and his lovely wife, Anne, spent part of every summer in Santa Rosa. He contributed to projects, provided a fresh perspective and served as a confidant to many engineers and managers. His visits were eagerly anticipated by our R&D engineers—and the members of my team would often ask, "When will Roger be here? I need to run something by him."

Through such conversations Roger earned tremendous respect for his technical skills, and many considered him to be a true genius. Across the years, he was a key contributor to several HP/Agilent technical innovations:

- Multiple calibration techniques & algorithms
- The measurement of noise figure in a network analyzer
- Millimeter-wave component measurements and equipment
- On-wafer measurements
- Nonlinear vector network analysis
- Materials measurements
- Time-domain techniques

Those advances were a natural outgrowth of his personal research interests at the University of Leeds: microwave network measurements, calibration, and error correction, microwave and millimeter-wave circuits, large-signal and nonlinear device characterization, and terahertz technology. For many years, Leeds has performed some of the world's best research in the terahertz range.

Within the broader engineering community, Roger was a long-time volunteer for the IMS, MTTS, IEEE, and ARFTS. He served as IEEE vice president for technical activities, IEEE board of directors' secretary, and MTTS president. As chair of the TAB/PAB Products Committee, Roger provided the leadership for the creation of IEEE Xplore, now a world-class resource for technical information.

Above all, Roger will be best remembered for his leadership and people skills. When I asked his colleagues to describe their memories of Roger, here is what they had to say:

- **Leadership:** The ability to simplify complexity, to harmoniously blend strong-willed engineering talents, to motivate engineers to do better work, and to mentor engineers.
- **Infectious enthusiasm:** His sense of humor, a passion for people, the constant delivery of encouragement, and an ability to make the Smith chart exciting (no small feat, that).
- **Depth and curiosity:** A deep interest in subjects beyond engineering —politics, monetary policy, culture, language, and even construction methods.
- **Technical ability:** A genius-level intellect that was innovative but also practical and down-to-earth.

In March 2011, after Roger had retired as dean of engineering of Leeds, we were fortunate to bring him on as an official employee. We often joked that he was our longest-tenured summer intern because it took us 30 years to finally hire him. He told me it had been a dream of his to work for HP/Agilent after completing his academic career. He had it backwards: It was our dream to have him join us.

Personally, I thoroughly enjoyed my weekly one-on-one meetings with Roger. Our conversations were filled with technical discussions as well as his novel ideas, his advice, and a fair bit of humor. Going forward, I'll certainly miss the privilege of counting on his technical brilliance—but it's his leadership and people skills I'll miss the most. He made me a better leader, and made all of us better engineers.

Perhaps the best way to think about Roger—at least from an HP/Agilent perspective—is he didn't think outside the box. How could he? He never saw a box. T&MW

Henri Komrij is a senior R&D manager at Agilent Technologies.

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