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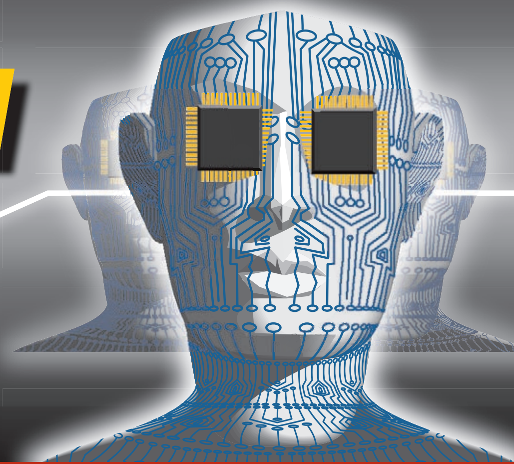
Test & MEASUREMENT WORLD

THE MAGAZINE FOR QUALITY IN ELECTRONICS



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Moving a lab is a monumental task

When moving their cal lab, engineers at Northrop Grumman had to plan new facilities and recalibrate equipment.

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Comments shared by readers at www.tmworld.com:

In response to "What's your favorite test instrument?" in Martin Rowe's "Rowe's and Columns" blog, Opcom said:

"The analog, CRT-based oscilloscope. I use two Tektronix 7904s. Let's face it, digital ones update sloppily and nothing is as good looking as an electrostatic deflection CRT. Digital scopes are useful for many things but the trace on a CRT can be interpreted in more ways than the digitized LCD image."

William Ketel added:

"For many years my favored instrument was a Radio Shack 30,000 ohms per volt multimeter. Not only was it able to do all kinds of continuity, and 'sort of continuity' checks with its low ohms scale, but the very low voltage 0.6 volts full scale range was good for evaluating small voltage drops in connections and connectors."

Add your comments:

bit.ly/uDOny7

Jitter and timing in the presence of crosstalk

Testing high-speed serial data streams for evidence of jitter is critical in order to achieve a good bit-error rate. Chris Loberg of Tektronix explains how oscilloscopes, jitter-analysis software, and bit-error-rate testers all play a role in decomposing jitter into its components. Read the article and post your comments:

bit.ly/v8qwyB

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BILL SCHWEBER
EDITOR, PLANET ANALOG

The quest for ever-better primary standards is a fascinating story

I just finished reading *World in the Balance: The Historic Quest for an Absolute System of Measurement* by Robert Crease; it's a history of measurement systems and metrology, especially metric. What a pleasure to slow down, lie back, and read about those challenges, and how we got to where we are now.

I suspect most people will not be interested in such historical material, but we should be: How do we know that the 5½-digit DVM reading is correct? What does "correct" even mean? What about those femtosecond readings, or even the long-baseline time bases for experiments? We need primary standards, of course, and we need a way to describe them (such as the metric system). Given how casually we now measure with extraordinary accuracy, precision, and repeatability—well, it hasn't been an easy path.

> **Can you imagine having to compare your secondary meter rod to the primary one with its "scratch marks"?**

Even if you are not interested in the historical aspects, you'll find the last part of the book very interesting, as it details the quest for a reproducible mass standard. As most of you know, the kilogram is the only primary standard that is still represented by a tangible physical artifact rather than a reproducible standard. And apparently, the primary kilogram is losing weight, for various possible reasons—or maybe the "copies" are gaining? (And before we used wavelengths of light to define the meter, we used the primary meter stick as the standard—can you imagine the basic challenges of comparing your secondary meter rod to the primary one with its "scratch marks"?)

For mass, researchers are looking for a standard that has accuracy and reproducibility in the range of 1 part in 10^8. The techniques being investigated, but that have so far fallen short, are an ultrapure mass of silicon measured via a relationship to Avogadro's number and a watt force-balance electromechanical scheme. Both are very, very good, but not good enough—there are all sorts of second- and third-order sources of error to worry about at these levels of performance.

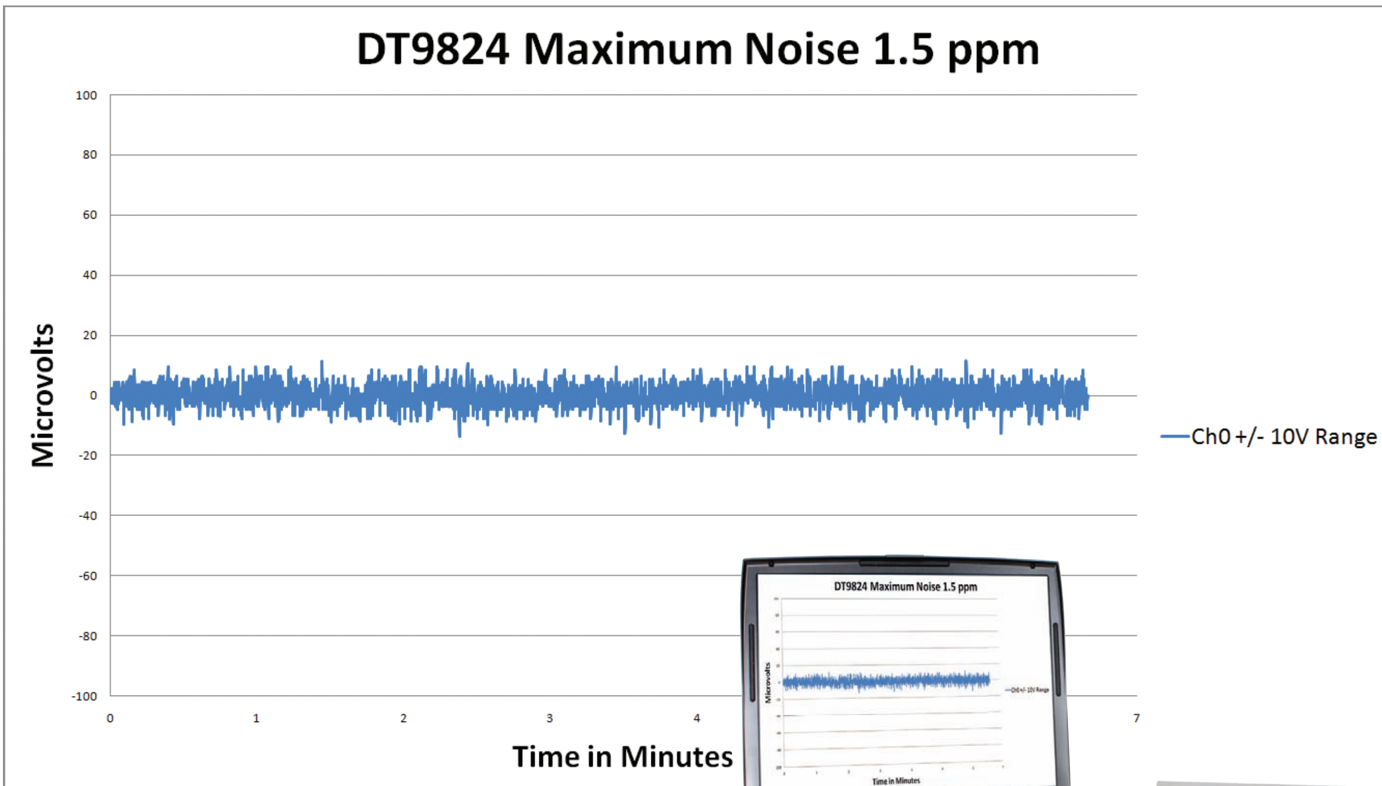
The book also discusses the types of meetings that the international societies hold in order to decide and plan next steps—it's a real subculture, of course. And at these levels of precision, some of the questions and issues are the equivalent of "how many angels can dance on the head of a pin?" so to speak—they are in the philosophical "what does this really mean, anyway?" realm, as well as "just" scientific.

There's also a great quote in the book from an MIT science dean, c. 1940: "No single tool has contributed more to the progress of modern physics than the diffraction grating"—and the book explains the critical role of the grating in metrology standards development.

This book is much, much better than *Longitude* by Dava Sobel (about the quest for the highly accurate clock in the 1700s, needed for seafaring navigation), which received much praise but which I did not like: Sobel used 1000+ words of description when a single figure or drawing would have been much better—that's what I call the *New Yorker* school of writing! T&MW

Guest contributor **Bill Schweber** *is the editor of "Planet Analog" (www.planetanalog.com), one of the Designline sections on the Website of* EE Times, *a sister publication of* Test & Measurement World.

Precision And Stability At A Great Price... The Absolute Gold Standard of USB Data Acquisition



DT9824 noise performance shows a maximum of ±15µV of noise at Gain of 1 and sampling rate of 10Hz.

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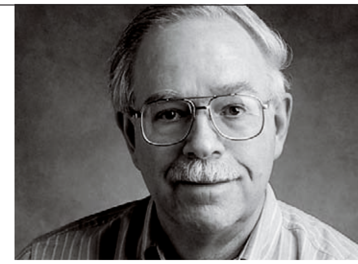
Serious measurement requires the best.

BRAD THOMPSON
CONTRIBUTING TECHNICAL EDITOR
brad@tmworld.com



Further adventures with the U1733C

While "U1733C" might make a good name for a submarine or possibly a robot, in this instance the name refers to Agilent Technologies' U1733C, a handheld multifunction digital meter capable of measuring resistance, capacitance, inductance, and impedance at certain selected frequencies. What else can it do?

I stumbled across one application by accident. On a whim, I connected the U1733C to a malfunctioning audio amplifier, figuring that I'd measure the amplifier's input impedance. Delivering approximately 0.7 V RMS at 1 kHz, the U1733C produced a sine wave that allowed me to scope my way to a shorted transistor. For a lower-level signal, I connected the U1733C to a stepdown transformer (using one of a Signal Transformer LP-12-200's dual 115-VAC primary windings) and measured 53 mV RMS on one of the transformer's 6.3-V secondaries.

On a lighter note, the U1733C's 100-Hz and 120-Hz (actually specified as 120.481-Hz) frequency settings are useful for demonstrating linear full-wave rectified power-supply hum to neophyte engineers who grew up with switched-mode power supplies. Hearing that mellow hum emanating from an older-vintage receiver or audio amplifier should immediately direct one's attention to the power supply's filter capacitors, followed by capacitance measurements with the U1733C.

Another application surfaced when I needed to sort out a multiwire cable terminated in a connector. I set the U1733C to 1 kHz and attached it to a pair of wires and probed the connector's pins with a Murata PKB5-3B0 piezoelectric sounder element. The piezo element delivered adequate volume for use in a quiet setting.

In general, I found the U1733C convenient and relatively easy to use. I didn't test the U1733C's optional tweezer leads (for surface-mount parts) and infrared data-transfer link and data-acquisition software.

To improve the U1733C as it is, I'd extend its standard clip leads by an inch or two and include a printed copy of the user's manual. If I were to redesign the instrument, I'd use a dot-matrix LCD display to eliminate the need for emulating alphabetic characters using only seven segments per character, which is so 1970s. But then it wouldn't be a U1733C. T&MW

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

FUN WITH THE U1733C

Here's my recipe for relaxation: Start with one cold winter evening. Fire up the workshop's wood stove. Brew a fresh pot of coffee, tune in some good music on the shop radio, and sit down with a collection of salvaged unmarked toroids and a U1733C. Measure inductance and Q, and mark appropriately. It doesn't get much better than this (see photo).

FREE SOFTWARE

If you're casting about for a version of, say, BASIC to resurrect the source code of an antique data-acquisition program, The Free Country offers a wide selection of free programming languages and utilities for solving various PC-related problems:

www.thefreecountry.com

PHYSICS DEFINITIONS AND CALCULATIONS

For a concise array of definitions and applied math, visit:

hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

MEASURING—AND COPING WITH— HARMONICS ON AC POWER LINES

Given the widespread use of switched-mode and uninterruptible power supplies and green-energy power converters, engineers involved with power-grid management are increasingly concerned about power waveforms that depart from sine waves. To explore the topic, go to:

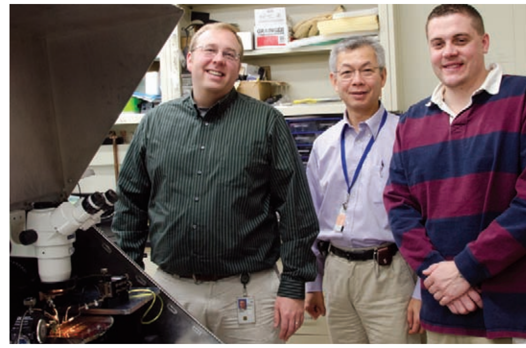
www.reo.co.uk/files/mains_harmonics_book.pdf

MORE ABOUT THE U1733C

To learn more about Agilent's U173xC family of handheld LCR meters, visit:

cp.literature.agilent.com/litweb/pdf/5990-7693EN.pdf

NIST tool aids "circuit-aware" reliability testing



Jason Campbell, Charles Cheung, and Jason Ryan researched the circuit-aware reliability test methodology.

Researchers in the PML (Physical Measurement Laboratory) at NIST (National Institute of Standards and Technology) have devised a data-transformation methodology that could ease the reliability qualification of semiconductors. NIST says the research addresses the problems that arise when rigid reliability criteria are applied to semiconductors without accounting for a product's end use.

Led by Charles Cheung, the research team has developed a methodology to transform transistor-level reliability data into data that reflect how an electronic circuit will degrade in its intended application. This information would let a manufacturer know that a particular circuit will last two years in a high-performance application or 20 years in a low-performance one. Products with less-stringent reliability needs could be manufactured and sold, even when a technology is not ready for use in demanding applications.

To develop the methodology, the researchers observed how transistors degrade over time under certain stress conditions. They input the degradation data into a simulation tool that reveals how a circuit as a whole responds to the degradation of each of its components. The test circuit can be programmed to reflect the operation of most common circuit elements, and the simulation tool outputs the parameters that are most important to the operation of the circuit (such as timing delay). Thus, engineers can determine how a circuit will behave over the life of a product so they can optimize its performance and reliability. www.nist.gov.

UNH-IOL accounts for FR4 effects on test jigs

The UNH-IOL (University of New Hampshire InterOperability Laboratory) designs and builds its own test jigs to connect test equipment with devices under test. The staff makes its test jigs out of FR4 material, and for a jig used with data communications products, they must compensate for the fact that FR4 can introduce loss on technologies that operate near or above 1 GHz.

For 1000BaseT PMA (physical media attachment) testing (IEEE 802.3 Clause 40), the UNH-IOL uses a test jig that converts an Ethernet jack to SMA connectors in order to test a 1000BaseT transmitter on an oscilloscope. To correlate the measurements of this signaling to those of implementers and other labs, the UNH-IOL staff had to characterize the loss of the 1000BaseT PMA test jig. They found the loss by measuring the differential insertion loss using a network analyzer, and despite the short length of trace used and a jig design created with good engineering practices, the loss was over 0.5 dB. This amount of loss could cause miscommunication between engineers at two different laboratories and could slow attempts to correct the underlying issues.

In this example, the UNH-IOL found that the differential insertion loss was between 300 kHz and 200 MHz. The staff now applies this loss during the post-processing of measurements to eliminate the effects of the jig. www.iol.unh.edu

Tek unveils handheld oscilloscope family

Editors' CHOICE

With a weight of 4.8 lb, 7 hr of battery life, and four isolated channels, the THS3000 handheld oscilloscopes from Tektronix are built for use in demanding conditions. The oscilloscopes have a 10,000-point record length and are available with either a 100-MHz bandwidth and a 2.5-Gsamples/s sample rate or a 200-MHz bandwidth and a 5-Gsamples/s sample rate.

The four channels are isolated from the chassis ground as well as from each other. The external USB inputs for data storage, instrument setups, and PC communication are also isolated, so users can safely make floating measurements for voltages up to 300 VRMS CAT III (when using the included 10X probes) or 1000 VRMS CAT II (with optional probes). The instrument has 600 VRMS CAT III rated inputs (BNC to earth ground) for safe high-voltage measurements.

With 21 automated measurements, the THS3000 includes an FFT function that provides insights into to the frequency spectrum of a signal, revealing signal interference, cross-talk, or switching noise. For initial setup or for situations where connection points constantly change, the THS3000 series has autoset and autorange features that automatically set up the trigger system and adjust vertical and horizontal oscilloscope settings.

Base price: $3950. *Tektronix, www.tek.com.*

CALENDAR

DesignCon 2012, January 30–February 2, Santa Clara. *UBM Electronics, www.designcon.techinsightsevents.com.*

IPC APEX, February 28–March 1, San Diego. *IPC, www.ipcapex-expo.org.*

Measurement Science Conference, March 19–23, Anaheim. *Measurement Science Conference, www.msc-conf.com.*

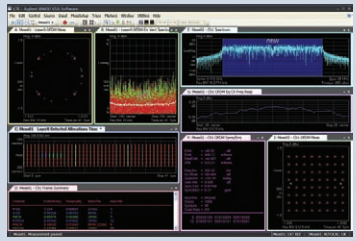
International Microwave Symposium, June 17–22, Montreal. *IEEE, www.ims2012.mtt.org.*

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

Editors' CHOICE

Agilent adds multimeasurement capability to 89600 VSA software

Agilent Technologies has added a multimeasurement capability to its 89600 VSA (vector signal analysis) software that provides the power of multiple signal analyzers through a single user interface, permitting the simultaneous signal analysis of multiple carriers and signal formats for more efficient wireless testing. Since all measurements reside in the test instrument's memory, any or all of them can be called on for immediate and coordinated execution.



In addition, measurements can be performed sequentially when signals are spaced too far apart to be captured in a single acquisition. With results displayed on one screen, you can use trace overlays and user-defined equations to perform in-depth comparisons. The 89600 VSA software is compatible with more than 30 Agilent signal analyzers, oscilloscopes, and logic analyzers.

Price: A typical configuration of the software costs $10,713. *Agilent Technologies, www.agilent.com.*

MARTIN ROWE
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Measurements keep pumpkins sailing

On Thanksgiving Day, the chances are pretty good that you watched football on television. But there was another televised competition you could have watched instead: *Punkin Chunkin* (punkinchunkin.com) on The Discovery Channel.

The 2011 Punkin Chunkin competition ran from November 2 to 4 and was broadcast a few weeks later. The point behind "punkin chunkin" is for competitors to build a machine that can hurl pumpkins. During the competition, the pumpkins, which weigh between 8 and 10 lb, fly through the air propelled by air cannons, torsion catapults, centrifugal-force machines, and other mechanisms. The air cannons hurl pumpkins more than 4000 ft., while other machines tend to hurl at shorter distances. Torsion catapults, for example, typically send pumpkins sailing between 1000 and 3000 ft.

FIGURE 1. **Torsion catapults use twisted rope to apply force to a swinging arm that hurls an object.** Courtesy of John Camping, Team ETHOS.

John Camping is a member of Team ETHOS (Experimental Torsion Hybrid Onager System) from Beavercreek, OH, which came in third among six competitors in the torsion division. A torsion catapult is based on a classical Greek design that uses rope wrapped around two posts (**Figure 1**). The throwing arm goes inside the loop created by the rope. The lever pulls back, twisting the loop. When the lever is released, the ropes try to straighten, and the energy stored in the ropes forces the arm forward, which hurls the pumpkin.

FIGURE 2. **A USB data-acquisition system monitors the force on the vertical posts.** Courtesy of Measurement Computing.

A few years ago, the tension on the vertical posts caused some damage and the team had to rebuild the machine. At that time, Camping integrated a data-acquisition system from Measurement Computing (**Figure 2**) into the machine to monitor the tension that the ropes apply to the two posts. He wrote an application note that explains how the catapult works and how the data-acquisition module helps it (Ref. 1).

Team members, called "chunkers," take the annual competition quite seriously. They spend the year between competitions designing new machines or modifying existing machines. Camping explained that he programmed the data-acquisition system and machined some of the parts himself. A local machine shop donated time to fabricate the more complex parts. He estimated that donated shop time is worth between $15,000 and $20,000. Much of the material for the machine was also donated, and Camping estimates that the total cost runs between $70,000 and $80,000. Air cannons may cost as much as $150,000 because they need compressors and are more complex than other chunking machines.

While chunkers continuously modify and redesign their machines, they're learning that the pumpkin itself can affect the distance it flies. Camping explained that the size, weight, and distribution of mass in a pumpkin can affect distance, depending on the type of machine used to hurl it.

Although Team ETHOS didn't win in its division, its machine didn't "pie:" Each pumpkin sailed away as opposed to breaking up at the machine. T&MW

REFERENCE

Camping, John, "Building a USB DAQ System for a Championship Pumpkin Catapult," Measurement Computing, www.mccdaq.com/appnotes/an116.aspx.

To read past Tech Trends columns, go to www.tmworld.com/techtrends.


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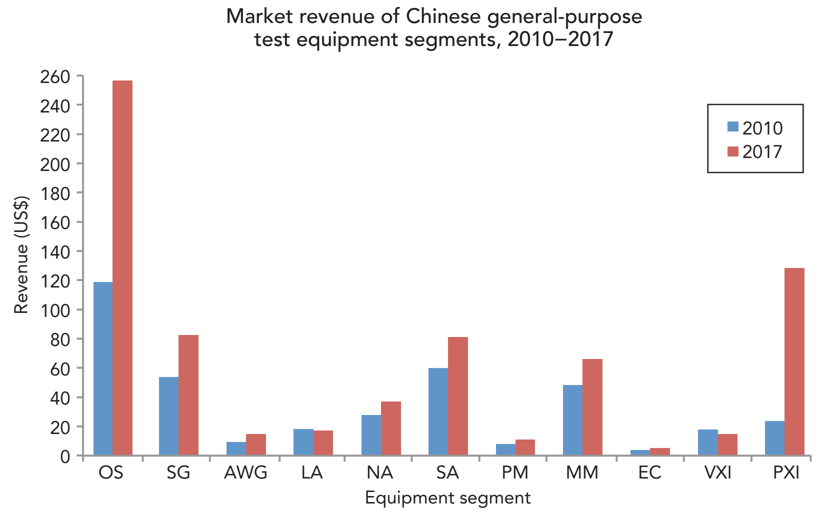
Chinese test market promises strong growth

The slowdown of the global economy adversely impacted the Chinese general-purpose test equipment market in 2009. Compared with other regions, however, the Chinese market recovered more rapidly. The total market generated revenue of $389.0 million in 2010, an increase of 20.5% over 2009. Market revenue is expected to reach $713.5 million in 2017, with an expected CAGR (compound annual growth rate) of 9.1% from 2010 to 2017.

The Chinese general-purpose test market is dominated by traditional instruments whose market share was 89.3% in 2010. The traditional instruments market as a whole is mature and the growth is expected to be moderate during the forecast period, though certain segments such as high-end digital oscilloscopes are expected to witness above-average growth. One exception is the logic analyzer segment, which is expected to have a negative CAGR during the forecast period (**figure**).



The traditional instruments market is segmented into oscilloscopes (OS), signal generators (SG), arbitrary waveform generators (AWG), logic analyzers (LA), network analyzers (NA), spectrum analyzers (SA), power meters (PM), digital multimeters (MM), and electronic counters (EC). VXI and PXI modular instruments round out the market. Source: Frost & Sullivan.

The growth of the telecom industry will be a significant driver for market growth during the forecast period. During its 12th Five-Year Plan period (2011–2015), China plans to invest around 1 trillion yuan ($150 billion) in mobile telecommunications. According to the plan, 500,000 3G base stations will be built, and China will also accelerate the development of 4G by conducting experiments on its own TD-LTE technology and putting it into commercial use if possible. The rapid deployment of 3G and 4G technologies in China is expected to be a growth booster for test equipment such as spectrum analyzers.

Other key market drivers include the sustaining demand from the aerospace and defense industries, the expansion of electronic devices, and the R&D globalization in China. Additionally, high-end customers are concerned with equipment features such as bandwidth, frequency, and accuracy. The need for better performance will also drive market growth.

Chinese customers in the industrial manufacturing and communication segments desire increased functionality and more features in test equipment, yet at a lower price. Consequently, the vendors of traditional test equipment are offering lower prices while keeping the performance at higher levels. The vendors are also developing integrated instruments that have multiple functions, enhanced speed, and advanced accuracy.

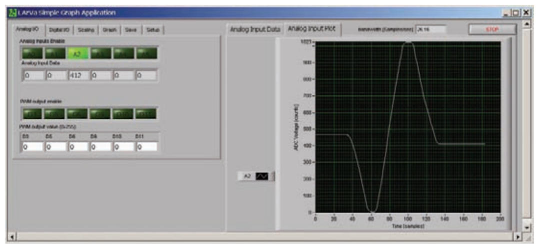
Modular instruments are also playing a role in the Chinese general-purpose test equipment market. The VXI instrumentation standard is experiencing a declining market trend. The VXI test equipment market accounted for $18 million in 2010. The revenue is expected to decrease at a CAGR of –2.9% from 2010 to 2017, and reach $14.7 million by 2017. In contrast, PXI has a double-digit growth trend in China. In 2010, the market revenue accounted for $23.7 million. This market is expected to grow at a 27.2% CAGR from 2010 to 2017, and reach $128 million by 2017.

Key factors expected to drive PXI market growth include its capacity, flexibility, and ease of use, as well as the support from leading test instrument vendors and customer focus on the price-performance ratio. Compared with traditional stand-alone instruments, PXI-based systems offer more flexibility, so the end users can customize the test equipment, although customer familiarity with traditional box instruments is likely to impede the application of PXI-based instruments.

Frost & Sullivan reports that the market share of VXI-based instrumentation is likely to continue to gradually decline during the forecast period, while PXI-based instrumentation is expected to witness medium-to-high growth in China. Continuous developments in wireless applications are increasing the need for PXI instrumentation in the communications industry. Meanwhile, the aerospace and defense industry is also anticipated to generate sustained demand. T&MW

DATA ACQUISITION

Build a DAQ system for about $30



Free LabView drivers let you use the Arduino hardware as a data-acquisition system.

Arduino is an open-source hardware microcontroller with its own development environment. The latest board, the Arduino Uno, costs less than $30 from a variety of vendors (Ref. 1). Hobbyists have developed most of the Arduino applications to date, but things may be changing. With six 12-bit ADCs, 14 DIO (digital input/output) pins (six of which can perform PWM [pulse-width modulation] output), simple serial communications over USB, and a low price tag, Arduino has begun showing up in professional applications.

Angstrom Designs has released a free driver that turns the Arduino into data-acquisition hardware. The LArVa (LabView Arduino) driver features automatic firmware uploading, onboard data averaging, and variable communication rates. In addition, it also accesses the Arduino ADCs, PWM, and DIO pins. The **figure** shows the LabView user interface, and the online version of this article includes an image of the LabView graphical code: www.tmworld.com/2011_12.

The free LArVa sample Simple Graph Application installer includes the driver, the LabView source code, an executable file, and support files (Ref. 2). You can use the LabView source code as a starting point for all sorts of projects, including data acquisition, temperature monitoring and control, and PWM motion control. To get users started, Angstrom Designs has also provided application notes on voltage and temperature data acquisition (Ref. 3).

With a 16-MHz, 8-bit Atmel microcontroller at its core, Arduino isn't right for high-end test and measurement applications. With solid features and an affordable price, however, it meets the needs of many projects, and it may mark the introduction of open-source hardware into professional test and measurement.

Casey Hare, Angstrom Designs

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1. Arduino Uno: www.arduino.cc/en/Main/ArduinoBoardUno; Vendors: www.arduino.cc/en/Main/Buy.
2. "Simple Graph Application using LArVa," Angstrom Designs. www.angstromdesigns.com/larva/download.
3. "Application Notes," Angstrom Designs. www.angstromdesigns.com/larva/application-notes.

HIGH-SPEED SIGNALS

DesignCon panel to discuss high-speed measurements

Characterizing high-speed serial devices and transmission channels gets harder every day. Data rates of 30 Gbps need clock signals reaching 15 GHz, so you need expensive test equipment to characterize these signals. Furthermore, no single instrument can provide all the information needed to characterize a device or a transmission channel. An oscilloscope and a BERT (bit-error-rate tester) aren't enough anymore. Today, you also need microwave equipment such as VNAs (vector network analyzers).

High-bandwidth signals lose integrity as they pass through cables, PCB (printed-circuit-board) traces, and test fixtures. A VNA can produce S-parameters that you can use in an oscilloscope to de-embed signal losses from your measurements. De-embedding removes signal losses, which provides a waveform display that better represents signal at the point of interest. But a VNA can cost $250,000 or more.

In "The Future of Measurements" session at DesignCon 2012, a panel of engineers will discuss how they work with and around their test equipment and how they use a combination of equipment to get data that no single instrument can provide. The members of the panel are:

- Daniel Chow, principal signal integrity engineer at Altera;
- Samuel Stephens, member of the technical staff at AMD;
- Reginald Conley, director of hardware applications at PLX Technology;
- Bryan Casper, principal engineer with Intel's Circuit Research Lab; and
- Andrew Baldman, senior technical staff member at the University of New Hampshire InterOperability Laboratory.

At this session, which I will moderate, the panelists will discuss how engineers use equipment such as lower-cost time-domain reflectometers instead of VNAs to obtain S-parameters. They will also explain the problems with using commercial software that is integrated into test equipment to analyze jitter. Each manufacturer uses a different algorithm, which can produce different results even when measuring the same signal on different equipment. Some engineers, therefore, use an oscilloscope as a digitizer and write their own signal-analysis software, yet other engineers even question an oscilloscope's ability to adequately digitize a signal, citing limited sample rates and high noise floors.

The session, Session 13-TP7, will take place in Santa Clara, CA, on Tuesday, January 31 at 3:45 pm. You can find more information about this and other DesignCon sessions at www.designcon.com.

Martin Rowe, Senior Technical Editor

Scripts automate source-measure units

By programming an SMU with internal scripts, you can free the system controllers to focus on higher-level test functions.

By Andrew Street, NXP Semiconductors

SMUs (source-measure units), often used to characterize semiconductor devices, can supply constant voltage or constant current to circuits and devices. At NXP's design center in Billerica, MA, we use SMUs to characterize ICs in the early stages of development, particularly if a DUT (device under test) doesn't have an on-chip current source or if the design engineer needs to manipulate the device's operating points. SMUs let us accurately set both the stimulus level and compliance limit.

Most SMUs have a high-resolution, high-accuracy DMM (digital multimeter) that can measure the parameter that the SMU is sourcing. We often use such SMUs as the power supplies in our automated characterization systems rather than using separate power supplies with switching units to connect the DMM to the power supply.

To characterize semiconductor devices, you must source voltage or current and measure the device's response to various stimuli. While that may seem simple, each test can involve many steps. We could run manual tests using an SMU's front panel, but automating the steps saves considerable time.

In our lab, we use Keithley 2600 series SMUs that run internal scripts written in a Lua-based language (Ref. 1). This language, in addition to supporting the usual branching and conditional software constructs, supports mathematical operations and string processing. The SMU's host-processor memory can accommodate scripts with at least 50,000 lines of code, and it can manage memory buffers that hold from 50,000 to 100,000 data points.

Because the SMU can run scripts, we can download test code from the system controller into the SMU and execute the script within the SMU. Once a test or series of tests has run, the SMU sends the test results to the system controller.

Running a script in the SMU saves significant I/O overhead and test time. Scripts internal to the SMU let us perform DC tests on discrete devices, and we can extend this approach to the development and characterization stages of an IC. We have implemented scripts that increase power-supply outputs to check for ESD (electrostatic discharge) protection integrity, that run fault diagnostics, and that run internal function tests. Further, we can also run the test code from the instrument front panel, thereby extending its functionality. Two simple examples illustrate how to use test scripts.

Measure current stabilization

During a test, an analog IC such as an RF gain block warms, which can result in measurement instabilities. Because production test times are less than 1 s, we need to understand the device's thermal time constants because they play a role in testing.

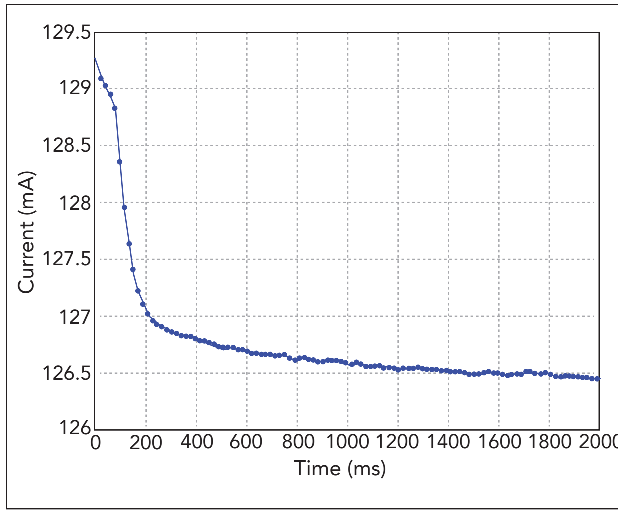

Fig. 1 An RF block's current consumption drops for the first 200 ms after turn on.

The **program listing** in the online version of this article (www.tmworld.com/2011_12) contains script code that sets the SMU's output voltage to Vstart and measures the current consumption Nmeas times at Tsamp intervals and then sets the output voltage to Vstop. Because the SMU time stamps each measurement using its high-resolution timer, we are able to plot current consumption versus time. Once the system controller downloads the script code to the SMU, the system controller simply calls the function monI() with the necessary arguments. When the SMU returns a '1' (similar to an *opc in SCPI), the controller reads the data in the SMU's memory buffer.

Figure 1 shows current versus time from an RF gain block. The actual sample period is the sum of Tsamp and the measurement integration time, which is set by the number of power line cycles (nplc) and the internal processing of the unit. When nplc = 1 (for good noise rejection) and Tsamp = 0, the actual sample period is about 17.6 ms in a 60-Hz system. The measured jitter on the sampling has a standard deviation of about 75 µs.

An implementation using a separate power supply and DMM would require the system controller to command a power supply to turn on at the desired voltage and then trigger a DMM to collect a number of readings, assuming the DMM were capable of capturing a number of measurement samples with a single trigger. A hardware trigger would initiate the data capture. Another alternative to using an SMU would be to use an oscilloscope to sample the voltage across a current-monitoring resistor, but that would require access to the necessary test points.

Curve tracing

As part of an IC evaluation, we measure I-V characteristics between certain pins on an IC. That lets us verify the correct operation of circuit elements such as ESD structures. I-V signatures are often useful during ESD testing because they provide an early indication of a failure. The Keithley SMUs come with a number of factory-installed curve-trace scripts that we often modify to meet our needs.

The program listing in the online article also illustrates a simple script that sweeps the voltage and measures the current. The input arguments to the function are the SMU unit, the start and stop voltages, the source-current limit, the measurement dwell time, and the number of sweep points, respectively. In this case, the function checks the current configuration of the SMU and ensures it's configured as a voltage source prior to performing the sweep.

Note that the buffer for the results is created using another user-written function, genBuffer(smu), that also resides in the SMU memory. The voltage range is set to accommodate the larger of Vstart and Vstop and illustrates the use of the math library. Once the sweep is complete, the original settings are restored and the function returns a logic 1 to the system. **Figure 2** shows the results of the I-V measurement on a diode-based structure.

These examples show how we automate measurements using scripts that run in an SMU. Scripts let the SMU handle its own operational details, which frees the system controller to focus on higher-level functions such as test-system configuration, test management, data analysis, and operator interfaces. T&MW

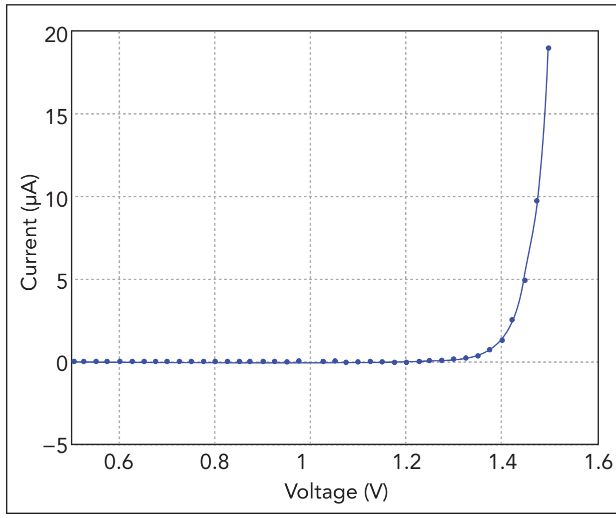

Fig. 2 A curve trace shows that a diode-based structure's forward current increases rapidly when the forward voltage reaches a threshold of about 1.4 V in this instance.

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FOR FURTHER READING

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Andrew Street *is a test and product engineer with NXP Semiconductors, a maker of RF amplifiers, mixers, up/downconverters, and other components.*

Moving a lab is a monumental task

To move their calibration lab to a new location less than 2 miles away, engineers at Northrop Grumman had to plan facilities, work with contractors, and recalibrate test equipment.

BY MARTIN ROWE, SENIOR TECHNICAL EDITOR

BALTIMORE, MD—If you've ever moved to a new home after first renovating it or if you've moved a lab, a production line, or an entire company, then you know that such endeavors require a tremendous amount of work, both before and after the move. You also know that no matter how well you plan the new location's design and construction, there will be last-minute changes and unexpected problems. That's what engineers at Northrop Grumman's calibration lab went through when they moved the electrical and physical calibration labs to a new location. Although the move distance was short (1.7 miles), the amount of work involved was long.

In early 2010, the calibration lab staff, including chief metrologist Bernie McDermott and lab manager Gary Jennings, learned that Northrop Grumman's Electronic Systems sector was expanding its manufacturing capacity and needed to turn the floor space occupied by the calibration lab into manufacturing space. Management considered outsourcing all calibration, but after a six-month study showed the company would realize a cost savings by keeping the calibration functions in house, they decided to move the lab, a decision that also saved many jobs.

Even before management chose to retain the lab, the staff began planning the new facility. If they had waited for the final decision, they might not have had enough time to build the facility and also pack the lab.

The new facility, known as "Friendship Square," was previously a warehouse and thus had no interior walls. The lab occupies a quarter of the building, with a museum of electronic equipment and other functions occupying the rest. Working with an architect, Jennings and McDermott developed floor plans as well as plans for electrical requirements, plumbing, parking, and transportation. Because the lab was leaving the main Northrop Grumman facility where most of its customers resided, Jennings and Terry O'Brien, manager of metrology engineering and calibration services, also had to devise a system for transporting test equipment needing calibration between the main buildings and Friendship Square, as well as between the lab and other Northrop Grumman locations in Maryland and Virginia.

Electrical needs

The company moved the electrical and physical calibration labs, but the dimensional calibration lab stayed in place. Why? Because of the tight temperature controls required for a dimensional lab. Moving the dimensional lab would have tripled the

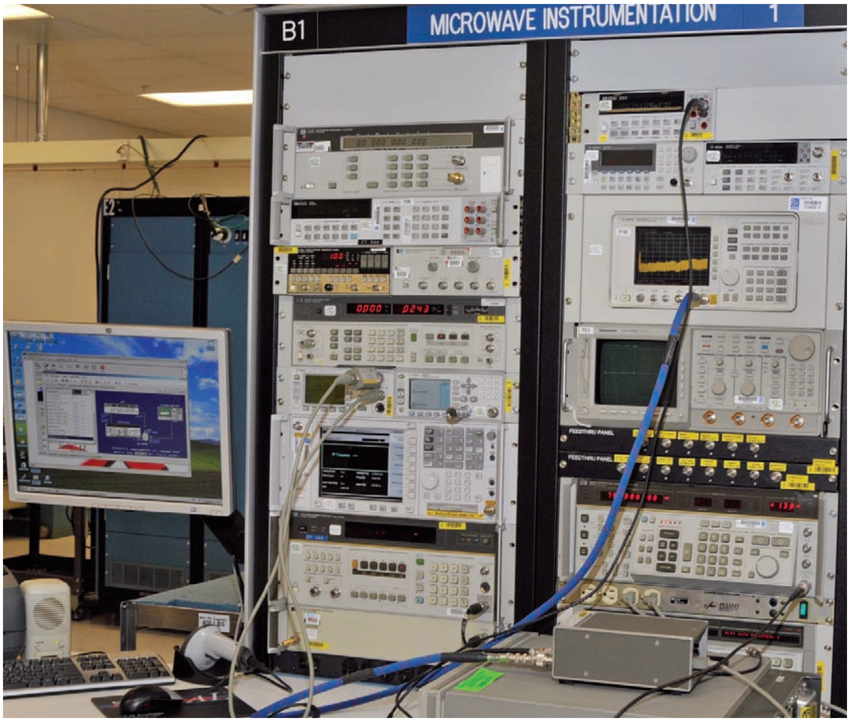


FIGURE 1. **The calibration lab at Northrop Grumman has automated stations for calibrating oscilloscopes, digital multimeters, power sensors, spectrum analyzers, microwave instrumentation, and other test equipment.** Courtesy of Northrop Grumman.

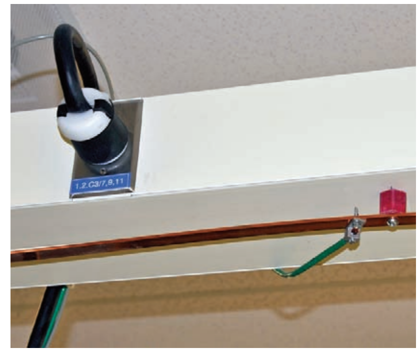


FIGURE 2. **Ground bars, located under electrical wiring conduits, provide access to earth ground that is located deep under the lab. The grounding system has lowered power-line noise in the new lab.** Courtesy of Northrop Grumman.

HVAC cost at the new location. Even with that, planning and moving the two labs cost several million dollars plus construction costs.

In the physical calibration lab, engineers and technicians calibrate equipment for measuring temperature, humidity, vibration, and flow. The electrical lab handles equipment such as oscilloscopes, multimeters, spectrum analyzers, power sensors, and signal sources used to test electronic systems. "Most of our test equipment is used for RF measurements," said Jennings. **Figure 1** shows a typical calibration station in the electrical lab, this one for microwave instrumentation.

The new facility needed single-phase and three-phase AC mains power, both 120 V and 240 V. It required data wiring for the networked calibration stations, and it also needed timing signals. "We needed many different styles of receptacles because our equipment operates throughout the world," said McDermott. Thus, he had to specify which type of power receptacles the lab needed and where to locate them.

When specifying the power wiring, McDermott had to contend with grounding. The new lab has bonded grounds, which reduce power-line noise compared to the lab's previous location. Three rods go into the ground under the labs, one in the physical lab and two in the electrical lab. To be effective and to meet building requirements, the ground rods have to go deep enough to reach "virgin soil" that hasn't been touched in at least 100 years. Jennings estimated that the electrodes are 25 ft underground, and he said they had to be installed before the concrete floor was poured. Braided copper wires come up to make ground points in the labs. To make the grounding accessible to the calibration stations, the electrical lab has copper ground rails just below the electrical conduits that run over the calibration stations. **Figure 2** shows one of the rails.

The electrical wiring drop locations were based on plans for calibration-station locations. At first, the floor locations were based on the layout in the old lab, but that changed to improve work flow. Each calibration station has a three-phase power drop with GFIs (ground-fault interrupters). One power phase goes to the station's controller PC, one powers the calibration instruments, and one powers the equipment under test. "Breaking up power into phases reduces the amount of current per phase," noted McDermott. "It also provides isolation, and the solid grounding minimizes power-line noise." To accommodate the three phases and the calibration stations, the lab has a wall of circuit-breaker panels.

McDermott changed the electrical lab floor plan after the move because the electrical layout was designed before the space plan. The locations of calibration stations weren't optimal. In the previous location, the calibration lab was located along a long hall and was included in plant tours. Thus, the space layout was designed to give visitors a good view of the electrical lab through a window. At Friendship Square, there are fewer tours, so McDermott was free to optimize the floor layout for best work flow.

In addition to power and data wiring, the electrical lab has coax cable for a time-base signal used to synchronize station clocks and provide timing of calibrations. "The communication people ran the coax, but we had to connect it and distribute it to the calibration stations," said McDermott. "Each station has its own distribution." Not only did lab personnel have to distribute the clock signals, but they had to do it up to a week after the move because the wiring wasn't completed in time. Lab personnel had to attach BNC connectors to coax cables that electricians ran because electricians typically won't perform this function.

HVAC is an important aspect of any building, but it is especially important in a calibration lab, where temperature and humidity can affect calibration results. Moving to Friendship Square made the engineers more aware of the HVAC system. In the old facility, the calibration labs were embedded deep within large buildings, virtually unaffected by outside weather changes. In the smaller Friendship Square building, two of the lab's walls are outer walls, a setup that makes the lab more susceptible to weather changes. The lab needs to maintain temperature to within ±3.3°C.

Because the building had been a warehouse, its HVAC system was sorely inadequate to house a calibration lab. Installing adequate HVAC equipment on the roof required structural improvements that reinforced the roof's I-beams.

The installed HVAC system was oversized for the calibration lab alone. At the time of the move, there were large unoccupied areas that are now in use. "The oversized HVAC system was short cycling when we moved in," said McDermott. "Once the rest of the building was occupied, the HVAC system became more stable."

In the former location, the electrical lab had room-wide temperature and humidity sensors, which is typical of calibration labs. In addition to monitoring temperature and humidity for the whole lab, engineers equipped each calibration station's equipment rack with temperature/humidity dataloggers from Veriteq Instruments. If either parameter is out of tolerance, the station will shut down. The dataloggers also free technicians from manually entering temperature and humidity data into calibration records.

The lab also has room temperature and humidity sensors because of the location along outer walls. McDermott noted that the HVAC system has improved dramatically in the year since the move. "We're still getting some variation in temperature and humidity here, but it's improving."

No infrastructure

Because the calibration lab would no longer reside in the main Baltimore facility, the staff needed to think about infrastructure that they previously had taken for granted. For example, they had to find a way to transport test equipment to and from the lab, as they could no longer simply roll it down the hall. Test equipment now needs to be transported to and from the main buildings as well as between the lab and other Northrop Grumman locations.

The staff set up a truck schedule for moving test equipment among 12 locations. Internal customers at the main facility have a place where they can leave equipment for transport to the lab, which occurs twice a day. Some bring equipment to and from the lab by car. Because test equipment now travels by vehicle, rather than staying indoors, it's subjected to outside environmental conditions. Thus, equipment must reach a stable temperature before calibration.

The staff also needed a loading dock at the new facility. Prior to renovation, the building had a ramp that lead to a loading dock, but the ramp was removed to accommodate new walls. The lab now has a hydraulic lift that lets truck drivers move test equipment in and out of the facility.

Other delivery issues arose. For example, the lab used to use the main facility's shipping and receiving department, but now uses another Northrop Grumman facility known as Troy Hill for shipping and receiving. This has actually worked out better because the main facility's shipping people were used to dealing with large items such as radar equipment and would sometimes lose track of small items such as temperature probes. Another transportation issue that the lab staff had taken for granted was payroll, which now has to be delivered to Friendship Square.

Before finally moving the lab, the company also had to schedule time to show employees how to reach the new facility. Although the lab was moving just 1.7 miles, some people didn't know where it was. The company rented buses to bring the technicians and other support staff to see Friendship Square.

Moving day

As the scheduled moving day approached, lab staff and employees began packing. But the Friendship Square building wasn't quite ready, and the contractor responsible for reconfiguring the old lab space began working before the lab had moved out. "They started putting plastic over our equipment to begin renovations on the old location, and we had to work around that," said McDermott.

Other logistical problems arose. For example, the company had hired a logistics contractor to handle the move, and the contractor marked each item as to its location. Of course, the electrical work wasn't ready and the flooring was still being installed as the equipment arrived. The movers were forced to leave the calibration stations on the opposite side of the new building from the loading

Chief metrologist Bernie McDermott was responsible for moving the electrical calibration lab and specifying the lab's floor layout and wiring. Courtesy of Northrop Grumman.

Technician Jerry Oppel calibrates spectrum analyzers on either of two automated stations.

Courtesy of Northrop Grumman.

Calibration lab manager Gary Jennings negotiated with contractors and government agencies to get the lab to its new location.

Courtesy of Northrop Grumman.

dock. Lab personnel had to move the stations around the building to get everything in.

Finding a moving company wasn't easy, either. Jennings explained that they interviewed about a dozen companies, but most didn't have enough insurance to handle the job. A calibration station can have a million dollars worth of equipment, and with several moving stations, the value of the Northrop Grumman equipment exceeded many movers' liability insurance. In the end, only a few companies bid on the job.

The lab was shut down for four days—Thursday to Monday—and the move took place over a weekend. Once moved in, the lab's staff had to not only install the calibration stations but also had to verify that the stations performed as they did before the move. That meant having everything calibrated and proving to an accreditation body that the equipment functioned properly. Because the move was planned well in advance, the staff sent some primary standards such as resistors and temperature probes to NIST for calibration prior to the move. When the calibrations were complete, the standards were shipped to Friendship Square. In other instances, the lab's instruments were shipped to manufacturers or to an outside calibration lab for calibration over the move date. For some equipment, the staff purchased duplicates to minimize down time.

"We had to requalify the lab," said McDermott. "A2LA [American Association of Laboratory Accreditation] required objective evidence that our equipment was functioning at a known state for specific measurements. We also had to show that the new lab had environmental stability, but that takes time. I wanted two weeks of stable temperature and humidity to show A2LA. We also had some intermediate checks of our equipment. For example, we had to calibrate some equipment such as VNAs [vector network analyzers]. We checked power sensors against our primary standards. Some equipment required new calibration, but for some, we could just check key points to verify uncertainty."

The move also forced the lab's internal customers to plan their calibrations. Well in advance of the move, the lab staff notified customers who had calibrations due during the move to send in their equipment prior to the move so as not to use equipment with expired calibration dates.

As with any renovation and move, unexpected problems occur. Some were small, some were large, and some were just plain unusual. Typical unexpected issues included things like doors that opened into halls. The doors that the contractor installed were solid, which created a safety hazard because someone opening a door couldn't see someone coming down the hall. To fix the problem, the contractor installed windows in the doors. On a larger scale, some walls were moved several times to accommodate equipment.

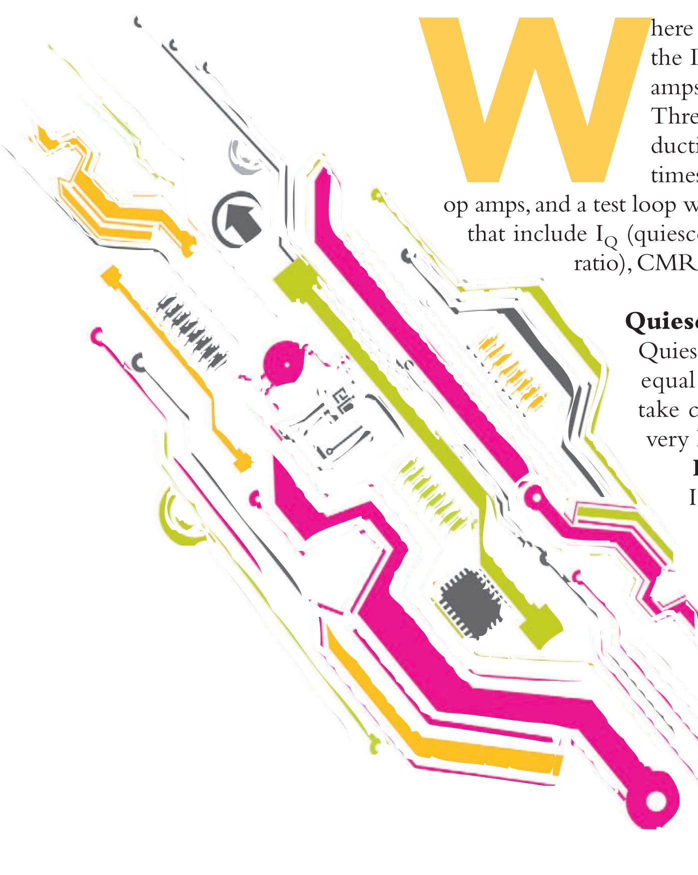
The most unusual problem occurred when plumbers uncovered a human skeleton while digging in the ground to install new pipes. Apparently, the building was built over a former grave site. That brought all construction to a halt until the state evaluated the situation.

Moving also provided opportunities for the engineers to evaluate procedures and identify opportunities for improvement. For example, Jennings defines the turnaround time of a calibration as the time from when equipment leaves the customer's facility to the time it returns. "In the old facility, we'd just put calibrated equipment on a shelf and let the customer retrieve it. Now, we have to take transport time into account." McDermott still sees the lab environment as a place that needs improvement. "We were the benefactor of being inside a large facility, and now we have to be more aware of lab conditions," he said. T&MW

Circuits test key op amp parameters

Measure quiescent current, offset voltage, DC gain, and rejection ratios with a few test circuits.

BY DAVID R. BAUM AND DARYL HISER, TEXAS INSTRUMENTS



Where engineers once needed only a single circuit to thoroughly test all the DC characteristics of an operational amplifier (Ref. 1), today's op amps have far better specs that require several circuit configurations. Three test-circuit topologies are commonly used for bench and production testing of DC parameters in op amps: a self-test loop (sometimes called a false-summing junction test loop), a test loop with two op amps, and a test loop with three op amps. You can use these circuits to test DC parameters that include I_Q (quiescent current), V_{OS} (offset voltage), PSRR (power-supply rejection ratio), CMRR (common-mode rejection ratio), and A_{OL} (DC open-loop gain).

Quiescent current

Quiescent current is the current a device draws with its output current equal to zero. Although an I_Q test may seem rather simple, you must take care to ensure good results, especially when dealing with either very high or very low I_Q parts.

Figure 1 shows the three practical circuits that you can use to test I_Q and the other parameters. When performing a test with these circuits, be sure to consider any load currents, such as feedback current in the test loop. The feedback resistor RF can put a load on the part that can affect the I_Q measurement.

To show you an example of these circuits, we used them to test a TI OPA369 op amp. The maximum quiescent current for this part is 1 μA per channel. The maximum input offset voltage is 750 μV. The two-op-amp-loop circuit in Figure 1 puts a voltage of 750.75 mV on the output of the DUT (device under test). That input voltage puts 15 μA through R_F. This current comes from the power supplies, and it will add error to any measurement. Therefore, you

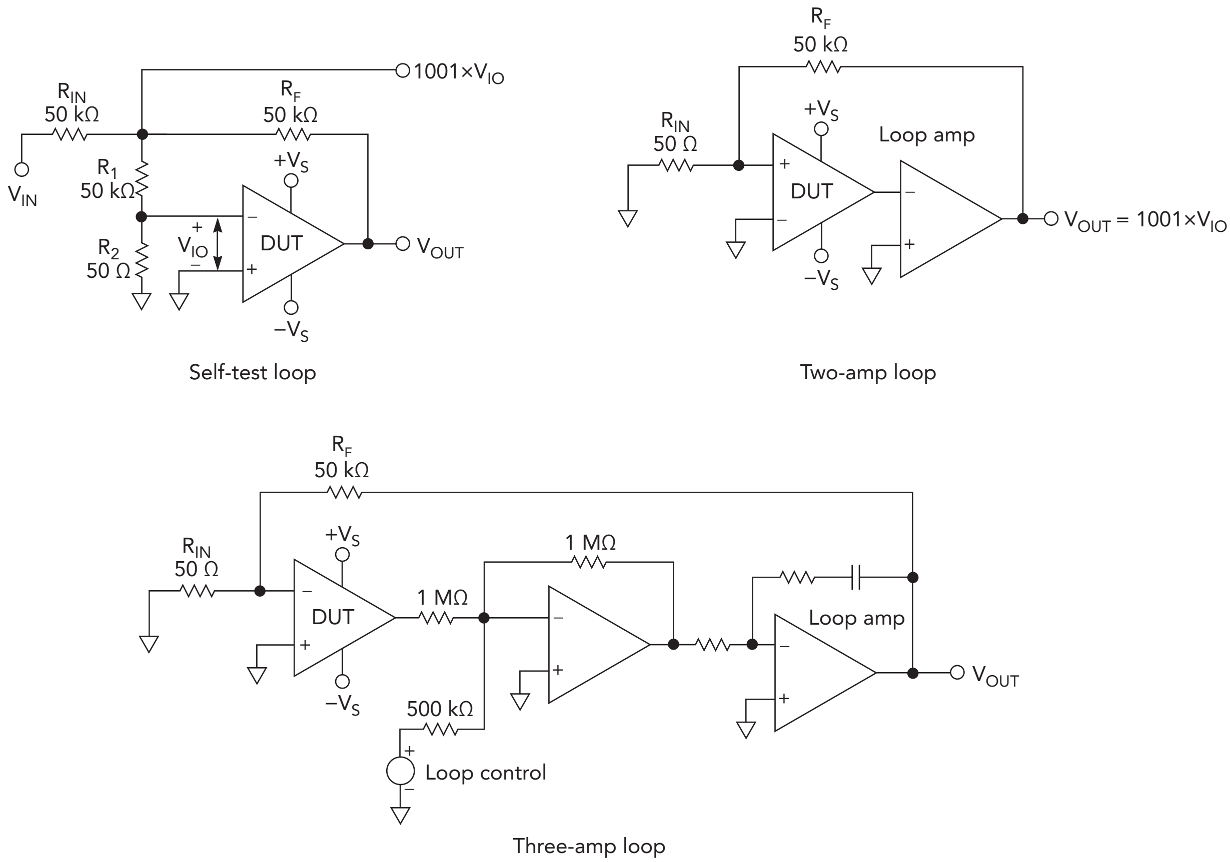


FIGURE 1. These three circuits let you measure quiescent current, I_Q.

must take steps to ensure that the output current is truly zero before making the I_Q measurement.

The self-test circuit isn't the most efficient circuit for measuring very low quiescent currents because of the feedback current that the output must provide. In this implementation, you must adjust the output to the gained-up offset voltage V_{OS}—not always an easy task—or switch out the 50-Ω resistor to eliminate feedback current. The two-op-amp loop accomplishes the zero output requirement by adding another amplifier. If you choose a low-input-bias current loop amp, the output current should cause an insignificant error.

The three-op-amp loop also lets you measure I_Q, but the 1-MΩ resistor at the DUT's output can become an issue: It's always a parasitic load, regardless of which parameter you're measuring. If you're measuring output load current, then this resistor represents an additional load.

You must also consider the resistor noise, which is 85 µVp-p from 0.1 Hz to 10 kHz for the 1-MΩ resistor. Using a 100-kΩ resistor would reduce the noise to 27 µVp-p. So, you can drop the resistor value to reduce noise, but then the parasitic resistor loading on the output of the DUT will be more significant.

Voltage offset

The V_{OS} test is fundamental to the measurement of most other op-amp DC specifications. Therefore, pay careful attention when setting up the test circuit, because poor choices in the configuration of this test can compromise the other DC measurements.

V_{OS} is defined in different ways. One source calls it "the differential DC input voltage required to provide zero output voltage with no input signal or source resistance" (Ref. 2), while another defines it as "the differential DC input voltage require to provide zero output voltage, with no other input signal and zero resistance in either input terminal path to ground" (Ref. 3). Another definition, "the differential DC input voltage required to provide zero voltage at the output of an operational amplifier when the input bias current is zero" is an ideal theoretical method for testing the input offset voltage, but it isn't practical because no op amp has zero input-bias current.

These definitions suggest that you should connect a low-output, high-accuracy, fine-resolution variable voltage source to the input of the op amp and adjust the input voltage until the output voltage is zero. Then, the input offset voltage would simply be the inverse of the input voltage applied.

There are two serious problems with this method. When testing op amps with very high open-loop gain, you must make sure that the voltage source's resolution is less than 1 µV to guarantee any degree of repeatability. You must also use an iterative approach to drive the output to zero. Noise in the system, coupling into the voltage source and op amp, will make it nearly impossible to measure and control the op amp in a high-speed automated test environment.

Given the problems with the ideal method, the usual method of choice in bench test environments is to put the DUT in an inverting gain configuration (**Figure 2**). This method has an advantage in that the DUT is stable and no additional compensation is usually required.

(continued)

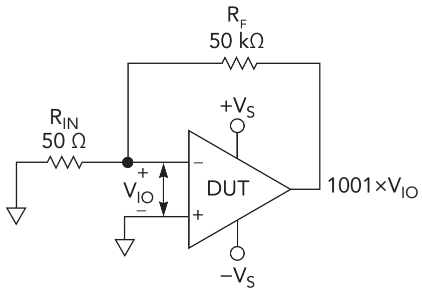


FIGURE 2. Use this circuit to measure offset voltage, V_{OS}.

Test circuits may also include a 50-Ω resistor between the noninverting input and ground for input-bias current cancellation. But with very-low-input-bias current op amps, the only real contribution of this resistor is additional noise. For a 100-pA part, the additional error without this resistor is only 0.005 µV. The cancelation works only if the bias currents are equal in direction and in magnitude.

The circuit in Figure 2 is a simplification of the self-test summing-junction method in Figure 1, but without resistors R_1 and R_2. This circuit is also inherently stable for most op amps, a trait that generally outweighs the potential disadvantages and makes it the preferred test circuit.

The disadvantages of using the test circuit in Figure 2 present themselves if you use it to test other parameters such as I_Q and A_{OL}. This circuit, left undriven, results in a V_{OS} error equal to:

$$(V_{OS} \times \text{closed-loop gain}) \times A_{OL} \text{ in V/V}$$

This error may be insignificant, or it may be reduced by driving V_{OUT} to 0.0V by applying the appropriate V_{IN}.

The equation used to compensate for the error at the output can be adjusted with this calculation:

$$V_{OUT} = (2 \times A_{SJ} + A_{CL} - A_{SJ}) \times V_{OUT}\text{ (ideal)}$$

where A_{SJ} is the summing-junction gain and A_{CL} is the closed-loop gain.

Often, an additional amplifier is used in the test loop, as shown in the two-op-amp loop in Figure 1. This configuration comes closest to meeting the definition for V_{OS}.

The DUT's output is held within the V_{OS} of the loop amplifier to ground. You can null out the offset of the loop amplifier if it has a V_{OS} adjustment, or you can control the noninverting input to eliminate the offset. In this way, you can drive the output of the DUT to zero.

The voltage measured at V_{OUT} is 1001 × V_{OS}. Unless a load is attached to the DUT's output, the output must only supply the input-bias current of the loop amplifier. This is an important consideration for low I_Q parts when you are measuring quiescent current. In the previous two circuits, the DUT must supply the feedback current into R_F.

By connecting the noninverting input of the loop amplifier to a programmable voltage source, you can measure other op amp performance such as A_{OL}, output swing, and CMRR. As the loop-control voltage is varied, the output of the DUT attempts to match the control voltage.

Of course, the two-op-amp loop does have some disadvantages:

- It is more complex than the self-test circuit;
- It requires loop compensation, because the circuit isn't inherently stable; and
- The output of the DUT can be controlled only over the loop amplifier's common-mode range.

The circuit will oscillate if the loop isn't properly compensated. You can stabilize the loop by placing an appropriate capacitor in parallel with R_F or by placing an appropriate RC combination across the loop amplifier.

A variation on the two-op-amp-loop test method is the three-op-amp loop, which uses current steering to control the DUT's output voltage. The compensation for this loop is set by the RC combination across the second loop amplifier. As in the two-op-amp circuit, the offset voltage of the DUT is measured at V_{OUT}, and V_{OUT} is 1001 times the offset voltage. This topology solves the DUT output swing limitation of the previous circuit. If greater output swings are required, you can use a smaller resistor in series with the loop-control voltage.

The three-amplifier loop also has some drawbacks:

- It is more complex than the other circuits;
- It requires loop compensation because, like the two-op-amp loop, it is not inherently stable; and
- The output of the DUT always has a minimum 1-MΩ load.

Power-supply rejection ratio

PSRR is the ratio of the absolute value of the change in power-supply voltages divided by an op amp's change in the input-offset voltage. Simply put, it's the op amp's ability to reject changes in the power-supply voltages over a specified range. Because you need the offset voltage to make this measurement, you can use the techniques already developed for measuring V_{OS}.

Any of the three test loops in Figure 1 will work for PSRR measurements if you set the power supplies, $+V_S$ and $-V_S$, to the minimum supply voltage for the DUT and measure 1001 × V_{OS}. Next, set the power supplies to the DUT's maximum voltage and measure 1001 × V_{OS} again. These two equations show how to calculate PSRR:

$$\text{PSRR} = \frac{\Delta V_{SUPPLY}}{\Delta V_{OS}}$$

$$\text{PSRR(db)} = 20 \times \log\left(\frac{\Delta V_{SUPPLY}}{\Delta V_{OS}}\right)$$

Some op amps require additional considerations when you use this method. These op amps have a low enough operating voltage that the midpoint of the power supplies (zero common-mode voltage) exceeds the maximum common-mode voltage allowed

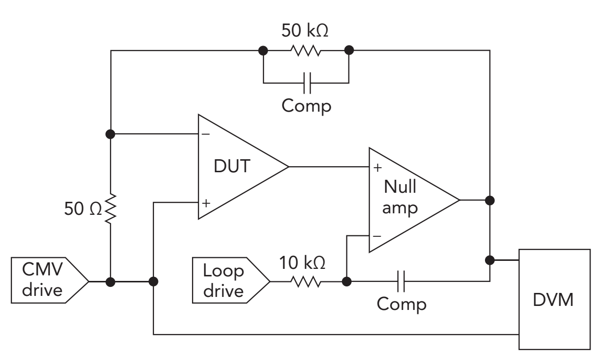


FIGURE 3. This two-op-amp loop lets you measure an op amp's CMRR.

for the op amp in a low-power-supply configuration. Some rail-to-rail input devices have multiple input stages and operate well in this condition, but they will transition to a different input stage and introduce an error in the PSRR calculation.

In both types of amplifiers, a fixed common-mode voltage can prevent either the common-mode saturation or input stage transition. Keeping a constant common-mode voltage for both measurements of the PSRR test will result in an error that cancels during the calculation of PSRR. The actual common-mode voltage needed for these devices will vary depending on the topology of the amplifier's input stage.

Common-mode rejection ratio

CMRR is the ratio of the differential voltage gain to the common-mode voltage gain. That is, it's the op amp's ability to reject common-mode voltages over a specified range. Because you need the offset voltage to make this measurement, you can use techniques already developed for measuring V_{OS} to measure CMRR.

For this test procedure, change the input common-mode voltage and measure the change in the op amp's V_{OS}. The most direct and obvious way to do this is by applying a common-mode voltage to the DUT's noninverting input. This method requires that the measurement system be referenced to the applied common-mode voltage. **Figure 3** shows the test setup for the two-op-amp loop.

You may want to make all measurements with respect to ground. To do that, tie the noninverting input to ground and move the power supplies in a tracking fashion, positively or negatively, to apply effective common-mode voltages to the amplifier. The output must be driven to the midpoint of the supplies to eliminate any A_{OL} errors that corrupt the CMRR measurement. These equations show how to calculate CMRR:

$$\text{CMRR} = \frac{\Delta V_{INPUT}}{\Delta V_{OS}}$$

$$\text{CMRR(db)} = 20 \times \log\left(\frac{\Delta V_{INPUT}}{\Delta V_{OS}}\right)$$

DC open-loop gain

A_{OL} is the ratio of the output voltage to the differential input voltage. The measurement involves measuring the input offset voltage at several points and calculating A_{OL}.

The procedure for measuring A_{OL} requires some knowledge of the op amp's output behavior. Ideally, an op amp could swing all the way to both power supply rails. This is not usually the case. A_{OL} will be specified at some distance from the rails at a given load.

Assume that the output can swing from V_{OUT} (positive) to V_{OUT} (negative). If you drive the output to V_{OUT} (positive), the voltage on the input of the DUT will be $V_{OS} + V_{IN}$ (positive). The extra voltage V_{IN} (positive) is required to drive the output to V_{OUT} (positive).

Conversely, if you drive the output to V_{OUT} (negative), the voltage on the input of the DUT will change to be $V_{OS} + V_{IN}$ (negative). You need to measure that change on the input to achieve the desired full-scale output.

The method for measuring A_{OL} using the circuit in Figure 1 is:

1. Connect the appropriate load to the DUT.

2. Force V_{IN} to set V_{OUT} (positive) to the product data sheet specification for positive swing.

3. Measure V(1), which is: 1001 × (V_{OS} + V_{IN} (positive)):

$$V_{IN}(\text{pos}) = \left(\frac{V(1)}{1001}\right) - V_{OS}$$

4. Then, force V_{IN} to set V_{OUT} (negative) to the product data sheet specification for negative swing.

5. Measure V(2), which is: 1001 × (V_{OS} + V_{IN} (negative)):

$$V_{IN}(\text{neg}) = \left(\frac{V(2)}{1001}\right) - V_{OS}$$

6. Calculate:

$$A_{OL} = 20 \times \log\left(\frac{V_{OUT}(\text{pos}) - V_{OUT}(\text{neg})}{V_{IN}(\text{pos}) - V_{IN}(\text{neg})}\right)$$

7. Substitute the values measured for V_{IN} (positive) and V_{IN} (negative):

$$A_{OL} = 20 \times \log\left(\frac{V_{OUT}(\text{pos}) - V_{OUT}(\text{neg})}{\left(\frac{V(1)}{1001} - V_{OS}\right) - \left(\frac{V(2)}{1001} - V_{OS}\right)}\right)$$

8. Note that V_{OS} drops out of the equation:

$$A_{OL} = 20 \times \log\left(\frac{V_{OUT}(\text{pos}) - V_{OUT}(\text{neg})}{\frac{V(1)}{1001} - \frac{V(2)}{1001}}\right)$$

Designing and testing op amps also requires you to perform input bias-current testing, a topic we will cover in future articles on www.tmworld.com. We'll provide a test circuit that you can use to combine the self-test circuit and two-op-amp loop to take advantage of both test methods. Another article will cover compensation issues, because the two-op-amp loop will oscillate if not properly compensated. T&MW

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Measurements optimize battery run time

Hidden sources of power drain require you to make more than just run-time measurements in order to optimize battery performance for mobile devices.

BY ED BROREIN, AGILENT TECHNOLOGIES

If you need to simply validate the battery run time in a mobile device, you can treat the device as a black box and either directly measure its run time or else measure the current drain for a prescribed period and then extrapolate the run time based on the battery's amp-hour capacity. If you want to optimize the battery run time, however, you must gain a deeper insight into the device's power consumption. You'll need to test and characterize the device's subcircuits and battery, both independently and in combination.

To characterize a device, you can capture long-term battery-current-drain data at high sample rates and over a wide dynamic range. Then, with a detailed characterization and analysis of the device's battery-current-drain profile, you can make informed tradeoffs for optimizing run time.

There are several ways to measure power consumption. First, you could measure current consumption with an oscilloscope and current probes, although this isn't the best option. Oscilloscopes provide high-speed waveform digitization, but their limited dynamic range, 8-bit resolution, and relatively high noise floor add uncertainty to measurements.

Another option is to use a high-sampling-speed, high-resolution, data-acquisition system and a precision current shunt. The better resolution of a data-acquisition system (typically 12 bits or 16 bits) provides better accuracy and wider dynamic measurement range than a current probe and oscilloscope. With this method, though, you must keep the maximum tolerable current-shunt peak-voltage drop small so it does not unduly affect the mobile device. Keeping the

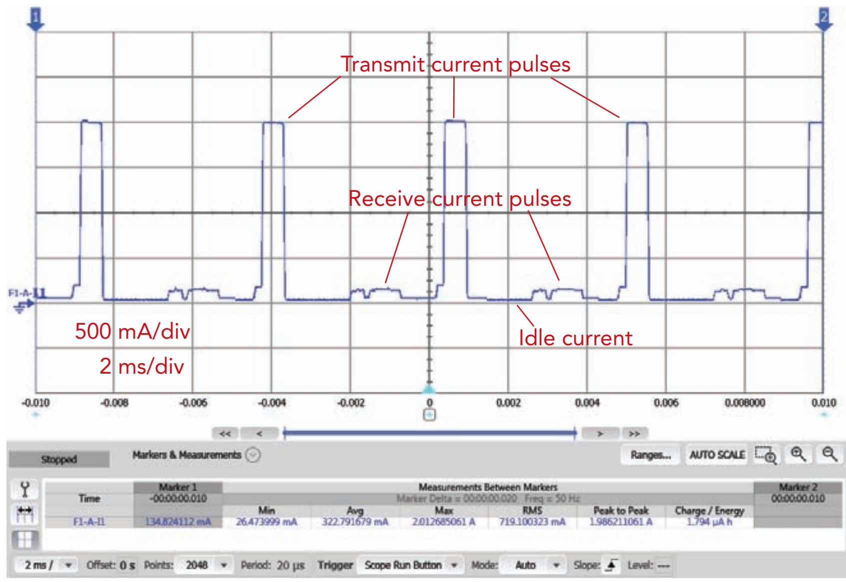

FIGURE 1. A wireless device's current draw has large pulses during transmit operations and smaller pulses during receive times.

shunt voltage drop sufficiently small limits the measurement's dynamic range and low-signal-level accuracy

A better method involves using a DC source that incorporates a high-speed digitizer with a wide dynamic range. With a DC source, you can accurately characterize a mobile device's current drain while eliminating the voltage-drop issues associated with using external shunt resistors.

Figure 1 shows the current-drain profile of a GSM/GPRS smart phone during a call. The plot shows the idle current-base-level value, the duration of the idle period, the current-drain values, and the durations of activities. Detailed current-drain profiles such as this let you see how the different modes of operation affect the run time of a mobile wireless device's battery.

While mobile phones and other mobile devices have high-power active modes, they often spend the majority of their time in standby or another power-savings mode. Other wireless devices, like sensors, may have only power-savings operating modes. Because devices spend such long periods in power-savings modes, these modes—which seemingly consume a negligible amount of power—can consume a major portion, or even all, of a battery's capacity. Evaluating these power-savings operating modes is a top priority for optimizing battery run time. The nature of current drain during power-savings operation, which spans several decades of amplitude, makes these modes challenging to measure.

During power-savings operating modes, wireless devices spend most of their time in a low-power sleep state. Periodically, a device wakes up and briefly enters a higher-power active state, often to transmit to and maintain contact with a base station. The resulting current drain is pulsed and has the following characteristics:

- a long period of typically tenths to tens of seconds (even minutes or greater for wireless sensors, depending on their function),
- an extremely low duty cycle of tenths of a percent to a few percent, and
- an extremely high crest factor on the order of a few hundred or higher.

The sleep state and the pulsed active-state currents are often both significant portions of the overall average, so these extremes, and everything in between, must be measured accurately.

Consider this example of a power-savings operation in which a wireless temperature transmitter has a pulsed current drain with the following characteristics (**Figure 2**):

- a period of 4 s (5 divisions at 0.8 s/div),
- a duty cycle of 0.17%, and
- average currents of approximately 21.8 mA peak and 53.7 µA for a crest factor of 400.

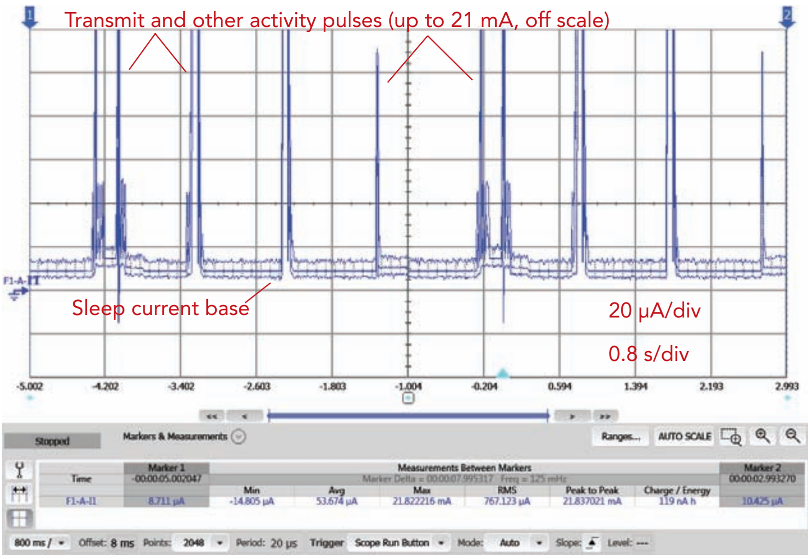

FIGURE 2. This profile of a wireless temperature transmitter's current drain shows the difference between sleep current and transmit current.

The wireless temperature transmitter is an example of a very-low-power device. While these characteristics are quite substantial, they are even far more dramatic for cellular-based devices, certain medical devices, and other battery-powered devices drawing peaks of hundreds of milliamps to amps, but having sleep currents of tens to hundreds of microamps.

Optimizing a device's battery run time requires you to do much more than simply measure the run time. Capturing and analyzing detailed long-term battery-current-drain profiles provides the insight you need about the inner workings of a device in order to optimize its battery run time. The current draw of a wireless device has a wide dynamic range between power-saving and operating modes. Thus, making the current measurements is particularly challenging. T&MW

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CT adds depth to x-ray inspection

By Ann R. Thryft, Contributing Technical Editor

Traditional x-ray cameras are often used in nondestructive electronics testing, such as during PCB (printed-circuit board) inspection, or in quality assurance when engineers need to gather quantitative data for specification drawings. CT (computed tomography) imaging takes the technology a step further, as it provides multiple x-ray images of an object captured at different angles, thereby increasing the available data, said Thorsten Achterkirchen, VP and GM for Teledyne Dalsa's Rad-icon Imaging division.

Q: How does CT imaging improve on traditional x-ray imaging?

A: Traditional x-ray cameras take a single projection view of an object, while CT x-ray cameras take as many as 100 or 200 images, each of which is a slightly different projection. Using sophisticated software algorithms, these can be reassembled into a three-dimensional model of the part, allowing the inspection of complex manufactured shapes, such as PCBs.

INSIDE THIS REPORT

For many industrial CT applications, including electronics inspection, you need to acquire a lot of images in a short period of time, and you must have high sensitivity since each image only uses a small dose of radiation. But each image must also contain a signal-to-noise ratio that's high enough so the software can analyze the images for defects. Therefore, CT imaging provides a huge leap forward in capturing defects compared with traditional single-shot x-ray imaging.

Q: What are some difficulties in adapting CT imaging to inspection?

A: In electronics inspection, when you need to check every high-value part that comes through, you need very high throughput. Historically, this type of CT x-ray application has been hampered by lower processing power, causing lower throughput. Another limitation has been frame rate, or how quickly you can acquire all of those images. Next, many traditional x-ray detectors take a long time to process images.

The latest generation in digital x-ray imaging technology leverages CMOS sensors. These offer a much higher-performing active element and better sensitivity. They also provide much better sensitivity, which enables the detection of features at very low image "noise" levels.

Q: What improvements have you made to your CMOS CT sensors ?

A: The Shad-o-Box product family started out with the 1024, a 2-in. by 2-in. camera running at 1 to 2 fps.

Thorsten Achterkirchen
VP and GM
Teledyne Rad-icon Imaging

Over the years, our customers have asked for products with larger active areas and higher frame rates to be able to do real-time inspection and CT imaging of larger objects. Therefore, in June 2011, Rad-icon released the Shad-o-Box 1280 HS to address these requirements.

In this new camera, the CMOS sensor's frame rate is 30 fps, which is faster than the previous generation sensor by nearly an order of magnitude. This is, therefore, our first truly real-time product, since 30 fps is the acquisition speed needed for use in electronics production lines. The camera also has 1.6-Mpixel resolution at that frame rate. We've almost completely eliminated image artifacts.

Q: What are other feature improvements?

A: The 1280 HS has 14-bit digital image quality and a real-time GigE interface. The camera's active area is 5 in. by 5 in., and pixel size is 100 microns, making it the ideal image size and resolution for PCB inspection, as well as for dimensional verification and failure analysis. □

EDITOR'S NOTE

Mixing analog and digital hardware

By Ann R. Thryft
Contributing Technical Editor

On what many consider the trailing edge of machine-vision technology, analog cameras, frame grabbers, and vision systems are still alive and well in several electronics inspection applications (p. 40). Although most cameras with analog outputs don't cost much, some are high-ticket items that qualify as valuable capital equipment. These are often cameras with very high-end NIR (near-infrared) and SWIR (short-wave IR) sensors that are used, for instance, in thermal inspection of solar panels or high-value circuit boards.

The maximum speed of analog cameras' data output is slower than that of digital cameras—by roughly two orders of magnitude compared to Camera Link base—and engineers and integrators building vision systems often must figure out how to retain and incorporate the cameras into a vision system being upgraded to digital equipment or to a digital, packet-based network such as GigE Vision.

Mixing analog and digital cameras in one network can be a challenge, so frame-grabber makers and other hardware vendors have taken steps to make this somewhat easier with specialized drivers and hardware. A heterogeneous system also provides benefits aside from retaining costly legacy equipment, such as flexibility in camera deployment for capturing data simultaneously from different angles or from different objects. □

Contact Ann R. Thryft at athryft@earthlink.net.

HIGHLIGHTS

Inline x-ray system goes 3-D

MatriX Technologies has expanded its automated x-ray inspection line with the addition of the X3 series, which features 3-D reconstruction software that generates slice images for dedicated 3-D solder-joint analysis. The X3 system combines selective 3-D analysis for critical areas with a high-speed transmission x-ray.

The software uses an algebraic reconstruction technique that generates detailed, high-resolution images with only a few projections. This 3-D inspection is particularly useful for analyzing double-sided boards with high packing density. The generated slice images allow a separate 3-D analysis for each side of the board. www.m-xt.com.

CCD camera runs 19 fps at 6 Mpixels

Outfitted with a Sony ICX694 EXview HAD CCD sensor, the Prosilica GX2750 from Allied Vision Technologies combines high sensitivity and near-IR response with low-noise imaging and improved antiblooming. The camera delivers 19 fps at a full resolution of 2750x2200 pixels and comes in both monochrome and color versions.

The camera has two Gigabit Ethernet ports configured as a link aggregation group to provide a sustained maximum data rate of 240 Mbtyes/s. It features flexible binning, region-of-interest readout, a global shutter, asynchronous external trigger and sync I/O, recorder and multiframe acquisition modes, three-axis motorized lens control, and a video-type auto-iris. www.alliedvisiontec.com.

Basler debuts Racer linescan cameras

Compact and easy to integrate, the Racer family of linescan cameras from Basler offers both Gigabit Ethernet and Camera Link interfaces. The monochrome cameras employ CMOS sensors capable of achieving line rates of up to 48 kHz over Gigabit Ethernet and up to 80 kHz over Camera Link.

Basler will start production with models offering resolutions of 2k and 4k pixels. Options for resolutions of 6k, 8k, and 12k pixels are expected to follow. The company also offers a free driver and software-development kit. www.baslerweb.com.

Altatech enters LED inspection market

Altatech Semiconductor recently introduced the AltaSight LEDMax system, which is designed to detect, classify, and characterize defects on wafers used in manufacturing LEDs. The system detects process-induced defects, including those that can result during metal-organic chemical vapor deposition of epitaxial layers, patterning processes, and final inspection. Altatech reports that the noncontact system generates images of surface imperfections with resolution down to 1 micron and has a depth-of-focus capability approaching 500 microns.

An integrated review station performs real-time analysis of the gathered inspection data. It can stitch together images from different perspectives, generate 3-D renderings, and measure defect sizes. Results are stored in the system and can be exported in standard file formats.

The AltaSight LEDMax can be used in volume manufacturing, process development, or R&D applications. In addition to handling the full range of compound semiconductor wafers on which LEDs are produced today, AltaSight LEDMax can accommodate sapphire, silicon, silicon carbide, and other transparent surface substrates. AltaSight LEDMax can handle 4-in. to 8-in. wafers, and the company expects to release a field-upgradeable option for handling 2-in. substrates soon. www.altatech-sc.com.

Dark-field optics inspect thin-film solar

By Ann R. Thryft, Contributing Technical Editor

To drive down the cost per watt of PV (photovoltaic) solar panels, some industry observers say that substrate material must shift from silicon to glass, using thin-film technology. Dark Field Technologies, a supplier of glass and thin-film scanners, recently developed an inspection and metrology tool for thin-film PV deposited on glass, based on its NxtGen system technology, said CEO Timothy Potts.

Thin-film PV processes place three layers of coating on the glass substrate, Potts explained. After each layer is deposited, some is scribed away, forming lines that isolate the panel's conductive areas. Each of the scribes, known as P1, P2, and P3, is 40 to 50 microns wide. A scribe's width, pitch, and offsets must be precisely controlled, and coatings must be precisely and thoroughly removed, to maximize yield and produce panels with maximum conversion efficiencies.

"Our challenge was that no technology could do 100% on-line metrology and inspection of thin-film solar panels being coated and scribed, at real-time production line speeds of 100 to 150 feet per minute, and on glass, which is not perfectly flat and bounces during its transport on the conveyor," said Potts.

The first scribe, P1, creates hundreds of lines on the conductive oxide or molybdenum layer of coating. The panel's active layers are deposited during the second and third coatings. The P2 scribe, which is performed on the second layer, must be inspected to ensure it is complete, and also to ensure that offsets between P1 and P2 are within certain limits. For example, center-line to center-line distances can't vary by more than 2 to 5 microns. Typically, a third, metal coating is deposited. After the third scribe, P3, is applied, its width and offsets to P2 and P1 must be measured.

Dark Field tried building thin-film inspection systems with bright-field optics, said Potts. These systems used matrix cameras, which sample less than 0.05% of thin-film scribes, and provide only scribe width and offset data, not defects or residual coating information. But the system proved too slow for on-line production use. Images from a production line tend to go out of focus due to small changes in panel flatness or bounce, and autofocusing systems do not work at production speeds. "Instead, we came up with the idea of using dark-field laser optics and high-speed line-scan cameras for the inspection and metrology of on-line scribing," he said. "In an optical dark field, you see and image not the scratch but the scattering effect it has on rays of light. For the same resolution, you can provide several times the data you get in bright-field optics." This system became the NxtGen Scribe 100.

The Dark Field NxtGen Scribe 100 system inspects thin-film photovoltaic panels for scribe defects.

Courtesy of Dark Field Technologies.

To create the optics for the NxtGen Scribe 100, the company used Hi Resolution Macro Line Scan enlarging lenses from Schneider Optics and Piranha 2 linescan cameras from Teledyne Dalsa. "At high resolution, any kind of optical aberration has a multiplier effect," said Potts. "The Schneider lenses gave us the minimum optical aberration, since they are so precise across the entire field of view."

Potts and his team also looked for the right kind of lasers to solve the speckle problem, inherent in all lasers. "If you blow up a laser image, you see bright and dark spots in it," he said. "These give an unusable signal when you try to do high-resolution work with lasers and cameras to create enhanced images of the scribes. So, we had to develop proprietary solid-state lasers." Potts said the NxtGen Scribe 100 is the first production metrology and inspection system to combine cameras with lasers.

After generating enhanced images, the NxtGen Scribe 100 system uses high-speed signal-processing hardware from Matrox and uses software analysis for defect detection and measurement. "We had to develop the processing hardware and software needed to get very precise measurement accuracy," said Potts. "We had to write some clever algorithms to perform image processing at these high speeds."

The resulting system provides detailed information about each scribe, including width, pitch, offset, standard deviation, percentage missing, and spacing violations, and it measures the amount of remaining residual coating. The system is accurate within 2 microns, and a large depth of field ensures the system stays in focus on warped panels and even when the glass bounces, said Potts. □

Can analog and digital vision hardware coexist?

By Ann R. Thryft, Contributing Technical Editor

Vision systems that employ analog equipment make up a large proportion of the installed base, but engineers and integrators who build such systems are shifting to the use of digital hardware and digital interface standards. Some system designers are tasked with upgrading an existing system from analog to digital technology, while others need to integrate legacy analog vision hardware into newer digital systems.

Marc Damhaut, senior VP of product management at Euresys, a maker of frame grabbers, said his company sees existing applications migrating from analog to digital cameras. In 2011, however, analog-input frame-grabber cards still represent 50% of the company's sales of machine-vision frame grabbers, excluding video-surveillance cards.

The decision about whether to use analog or digital hardware usually boils down to pricing, compatibility, potential space constraints of the application, and the data resolution required to make pass or fail inspection decisions, said Donal Waide, director of business development for frame-grabber maker BitFlow. For example, large LCD panels may require vision systems with high resolution, compared to the lower resolutions that are acceptable for small semiconductor parts.

"The higher resolution would be in the form of a digital system, while analog is adequate for the lower resolutions," Waide said. He added that because analog cameras have lower resolution than digital models, there's less data coming in from an analog camera. "The maximum data throughput from analog cameras is PAL signaling, about 11 Mbytes/s," he said. "Yet the most basic digital cameras, Camera Link base, offer data rates of 255 Mbytes/s, so it's a significant return on your investment."

Vision systems built on analog interface standards have different network topologies from those built on digital standards like GigE and GigE Vision, said John Phillips, senior product manager for Pleora, a supplier of video networking hardware and software. Ethernet-based digital networked video systems may include GigE Vision cameras and real-time hardware video receivers and have point-to-multipoint, or even multipoint-to-multipoint, topologies.

"Analog camera topology is point-to-point and depends on simple camera-to-computer connectivity, which limits their utility in machine vision to systems where data is limited, or to those that perform limited, cursory inspection," Phillips said. "An example might be eight analog cameras that go into two frame grabbers in a single PC."

Another point-to-point topology is the digital, serial CoaXPress standard, said Phillips. "It's true that it also runs on coax cable, but upgrading a machine-vision system from analog cameras to higher-resolution CoaXPress cameras only resolves the cabling issue," he said. "Sure, you can reuse your cabling if you want to, but that doesn't put your video onto a network, and communications are still only point-to-point."

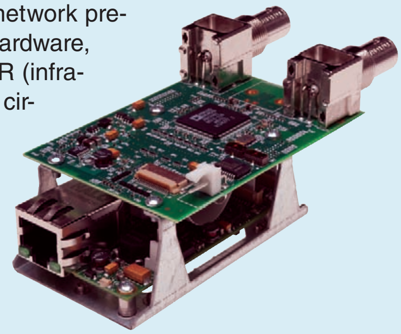
Machine-vision systems that require a point-to-multipoint topology include those that perform more in-depth inspection, said Phillips. Like the huge pieces of glass used for solar panels, products may be so wide, or of such high value, that you'll need many cameras to inspect them. "In this situation, a single PC may not be adequate to take in all those images, stitch them together into a single image, and analyze it for maybe five or six different kinds of defects, all in a reasonable amount of time," he said. By contrast, in a point-to-multipoint network, you can break up the workload among multiple PCs to process the data faster.

Some products can duplicate and redistribute an analog camera's signal to multiple endpoints, said Phillips. But adding an endpoint in an analog system—such as a monitor to display the signal from existing cameras—requires reconfiguring the cabling and adding a redistribution amplifier. Once you put that redistribution box in place, you can't dynamically change where the video is going without either swapping cables or replacing the box altogether. By contrast, adding or removing vision hardware in a GigE Vision system doesn't require you to reconfigure cabling.

If you want to do more complex 3-D inspection, you'll need all-digital vision systems, because higher-resolution digital cameras must be closely in sync, said Waide. "For example, a pixel point viewed from a high-resolution camera and compared to another camera with equally high resolution will result in the most accurate location of the pixel in 3-D," he said.

As the price of digital cameras drops, they become more practical for a wider range of applications, yet some limitations remain. For example, Camera Link digital cameras must be located within 10 m of the computer, said Waide. "While repeaters are an option, they are not preferred in inspection environments," he said. "The Camera Link cable is more expensive than coaxial, and depending on the camera, a second cable may be required. Analog's coax cables can traditionally be much longer, up to 100 m. A caveat, though, is the fact that, on coax, the signal can lose power over a certain distance, so you have to put in repeaters every 10 to 20 m for good data accuracy. Power loss also affects your ability to power the camera over the coaxial cable."

Analog and digital in a single network



The iPORT Analog-Pro IP engine outputs low-latency video from up to two analog cameras. Courtesy of Pleora Technologies.

Reusing analog cameras in a digital network preserves investments in costly legacy hardware, especially when those cameras use IR (infrared) to look for thermal anomalies on circuit boards, usually in the inspection of high-value, high-reliability electronics, said John Phillips, Pleora's senior product manager. Most new IR cameras have GigE Vision interface options, but older units are most likely analog.

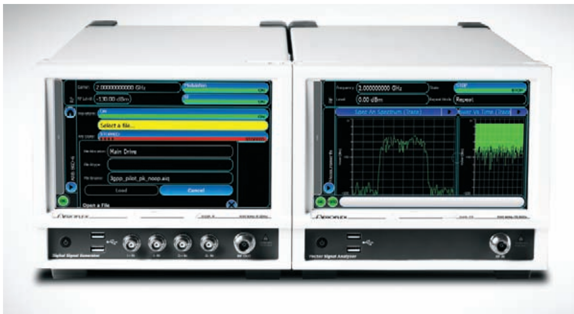
Pleora's iPORT Analog-Pro IP engine, developed specifically to connect analog cameras to digital networks, uses GigE Vision and GenICam for camera control and video transfer over a GigE link, said Phillips. "The idea for the Analog-Pro product and the problem it solves came out of the military market, where they often use cameras very similar to those that appear in inspection systems," he said. The ability to reuse high-value long-wave and short-wave IR cameras on military land vehicles when a system is upgraded is critical. It keeps cost down and reduces risk, since the cameras are prequalified to precise image quality and performance specifications. Rather than being connected to an analog frame grabber, two cameras can be connected to a single iPORT Analog-Pro. "It's true that there's still coax cabling between the cameras and the iPORT Analog-Pro, but you get rid of the much longer cabling between the camera and the vehicle's mission computer," he said.

Mixing analog and digital cameras lets you examine different objects simultaneously or examine the same object from different angles, said Donal Waide, BitFlow's director of business development. In PC-based digital vision systems, you can attach multiple cameras of different types to a single digital frame grabber. The company's Neon-CLD and Neon-CLQ Camera Link boards support simultaneous image capture from up to two or up to four Camera Link base cameras, respectively. Cameras can be PoCL (Power over Camera Link) and non-PoCL; they can have different resolutions, frame rates, and triggering modes; and you can synchronize some or all of them.

"If I also want to put an analog camera in the vision system, I simply plug in an analog frame grabber to one of the PC's slots," he said. "Since they can't communicate with each other, only with the PC, the analog and digital frame grabbers—and their attached cameras—form independent subsystems within the PC-based vision system."—*Ann R. Thryft*

Damhaut said that upgrading a system that uses an industrial analog camera and a Euresys Domino card to a system that uses a Camera Link camera and a Euresys Grablink card is straightforward, as far as Euresys' frame grabbers are concerned. This is because all of the company's machine-vision frame-grabber cards are compatible with the same MultiCam driver.

Some users have reported, however, that upgrading from analog cameras to GigE Vision cameras is more difficult than upgrading to Camera Link cameras. "The reason is that Camera Link is essentially a point-to-point protocol that does not introduce any delay when triggering the camera or transferring image data, [so] there is no latency when using Camera Link," he said. □



Signal generators and analyzers handle digital modulation

Aeroflex has expanded its S-Series line of RF test instruments with the introduction of two digital signal generators and two VSAs (vector signal analyzers). The SDG-3 (3 GHz) and SDG-6 (6 GHz) signal generators include an IQ modulator with a 300-MHz RF bandwidth that lets them generate QPSK, QAM, and pulse-modulated signals. Both instruments can produce signals with +13-dBm output power (+20-dBm optional), and both feature a two-channel AWG with a sample rate of up to 250 Msamples/s and signal memory up to 4 Gbytes. You can use the embedded IQCreator software to generate modulated carriers from the AWG signals.

With the SVA-6 (6 GHz) and SVA-13 (13 GHz) VSAs, you can directly input signals with peak signal power levels up +30 dBm. The maximum sensitivity of –148 dBm/Hz lets you distinguish low-level signals from noise when measuring a transmitter's spurious outputs. The VSAs can measure wireless signals for power, modulation quality, and signal spectrum. Both models have a noise floor of –138 dBc/Hz at 2 GHz with a 10-MHz offset. Frequency settling occurs in 250 µs at frequencies up to 6 GHz.

You can use the SDG and SVA instruments in a single test setup and synchronize them so they operate as a single source-and-measuring system. The instruments have a mechanical interlocking system that lets you attach them to each other on a bench or in a rack.

Base prices: signal generators—$18,000; VSAs—$22,000. *Aeroflex, www.aeroflex.com.*

Sunrise tester gains OTDR, fiber inspection

Sunrise Telecom now offers the RxT-4000 FOT (Fiber-Optics Toolkit) for its RxT Smart Productivity Test Platform, a handheld modular test set based on an open platform. The new module provides test and verification capabilities for operators deploying fiber-optic infrastructures.

The RxT-4000 FOT integrates an OTDR (optical time domain reflectometer) with up to four wavelengths (850, 1300, 1310, and 1550 nm) for testing single-mode and multimode fibers. It also provides a light source, optical power meter, visual fault locator, and loss test set.

Paired with the battery-powered RxT test set, the FOT performs fiber-optic characterization that records event location and identity of the fiber under test. You can view and compare traces on the handheld tester's high-resolution color display, while a one-button auto-test mode simplifies testing.

RxT's productivity tools allow for remote access from any location through a Web browser. Using the company's realGate server, field-operation managers can optimize workflow and track assets remotely.

Sunrise Telecom, www.sunrisetelecom.com.

VibRunner acquires noise and vibration data

Accommodating 8 to 24 analog-input channels in a 1U-high mainframe, the VibRunner data-acquisition platform from m+p international can be used for noise and vibration analysis, vibration testing, and dynamic data measurement. It employs 24-bit sigma-delta ADCs with sampling rates of up to 102.4-kHz to allow alias-protected measurements in a frequency range up to 40 kHz and with more than 120 dB of spurious-free dynamic range.

VibRunner hardware teams with m+p's VibControl, SO Analyzer, and Coda software to meet a variety of testing needs. Multiple chassis can be synchronized via daisy-chaining for engine test cells where high data throughput is important and for satellite preflight testing requiring high channel counts. A single VibRunner houses up to three front-mounted modules in a stand-alone desktop instrument or 19-in. rack-mount system.

m+p international, www.mpihome.com.

Teseda software aids silicon failure analysis

Teseda has introduced three failure-analysis tools aimed at reducing root cause resolution and improving RMA (return material authorization) cycle time. The software tools work with Teseda's V550 and V520 silicon-debug and failure-analysis systems and Workbench silicon-debug environment.

At linewidths of 65 nm and below, scan-chain related issues amount to greater than 30% of overall scan failures. Teseda's Broken Chain Analyzer uses existing DFT-based tests to automatically analyze captured tester fail logs and detect all common causes of scan-chain failures, both hard and soft, down to the failing bit location.

The Diagnostic Manager NetXY maps device failures from logical to physical net location in a design to shorten determination of root cause. This latest release includes logic cone and physical scan-chain tracing to address EDA-vendor-independent failure diagnosis.

Automated screening tools included in the DC Field Triage Package target DC-related device failures. The toolset puts device-failure triage into the design and field-support centers, enabling timely and detailed responses to customers' quality concerns. Since first-level field screening is done in the field, factory failure-analysis tasks are offloaded by as much as 40%.

Base prices: Broken Chain Analyzer and Diagnostic Manager NetXY—$40,000 each; DC Field Triage Package—$23,000. *Teseda, www.teseda.com.*

PicoScope 2205 plugs into USB port

Pico Technology has combined a two-channel oscilloscope with a 16-channel logic analyzer in a compact, portable USB instrument. When used with the supplied PicoScope software, the PicoScope 2205 lets you view analog waveforms and digital data on a single PC or laptop screen.

With an analog bandwidth of 25 MHz, analog sampling rates of up to 200 Msamples/s, and a maximum digital input frequency of 100 MHz, the PicoScope 2205 is suitable for general-purpose analog and digital circuit design, testing, and troubleshooting. Since it is powered via the USB port, there is no AC adapter to carry—just plug it into your computer and run the software.

PicoScope software offers a range of signal-processing features, including spectrum analysis; automatic measurements; channel math; reference waveforms; multiple scope and spectrum views; I2C, UART, SPI, and CAN bus serial decoding; x-y mode; advanced triggering; mask-limit testing; and color-persistence display modes. Also included is a software-development kit that allows you to control the scope using your own software.

The oscilloscope's 16 digital inputs can be displayed individually or in arbitrary groups labeled with binary, decimal, or hexadecimal values. A separate logic threshold from −5 V to +5 V can be defined for each 8-bit input port. The digital trigger can be activated by any bit pattern combined with an optional transition on any input. In addition, you can combine analog and digital triggers using Boolean logic to enable complex mixed-signal triggering.

Base price: $576. *Pico Technology, www.picotech.com.*

Audio Precision extends HDMI option to APx525 analyzers

Audio Precision has added the HDMI+ARC test option to its APx525 family of two-channel and four-channel audio analyzers. The new configuration is aimed at designers and manufacturers of smartphones, tablet computers, and set-top boxes who require digital multichannel interfaces such as HDMI but need only a few analog audio channels.

The I/O option lets you measure HDMI audio quality and audio-format compatibility. All standard audio measurements are available, including level, SNR, distortion, phase, crosstalk, and group delay. It provides connections for source and sink devices, as well as auxiliary video input and monitor output.

The option also supports the ARC, as defined in the HDMI 1.4a standard, for testing ARC audio quality. In addition to full audio and metadata analysis, the APx525 analyzer can send and receive CEC (Consumer Electronics Control) commands to allow the observation and troubleshooting of ARC connection negotiations.

Audio Precision, www.ap.com.

Rohde & Schwarz oscilloscopes add FlexRay decoding

Rohde & Schwarz has added FlexRay protocol decoding to the RTO line of oscilloscopes. Like any communications protocol, FlexRay needs testing for errors. With the RTO-K4 option, the oscilloscope can display protocol content. Using hardware-based triggers, the instrument can trigger an acquisition based on specific protocol attributes, which lets it identify errors for system debugging. Test dialogs use graphics and links to other settings to let you set the instrument's configuration.

Protocol details in the measured waveform are color-coded, and protocol data is compiled in tables. The RTO line of oscilloscopes is available in bandwidths of 600 MHz, 1 GHz, and 2 GHz. All models come with either two or four channels, and they can process up to 1 million waveforms/s at sample rates up to 10 Gsamples/s.

Rohde & Schwarz, www.rohde-schwarz.com.

Test & MEASUREMENT WORLD

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VOL. 31, NO. 11

Subscription Policy: Test & Measurement World® (ISSN 0744-1657) is published monthly except January by UBM Electronics, 600 Community Dr., Manhasset, NY 11030-3825. Periodicals postage paid at Manhasset, NY, and additional mailing offices. SUBSCRIPTIONS: Free to qualified subscribers as defined on the subscription card. Rates for nonqualified subscriptions, including all issues: 1 yr. $150, 2 yrs. $250, 3 yrs. $300. Except for special issues where price changes are indicated, single copies are available for $10 (US orders) and $15 (foreign orders). Buyer's Guide issue is available for $35 (US orders) and $40 (foreign orders). For telephone inquiries regarding subscriptions, call 847-559-7597. E-mail: tmw@omeda.com. CHANGE OF ADDRESS: Notices should be sent promptly to P.O. Box 47461, Plymouth, MN 55447. Please provide old mailing labels as well as new address. Allow two months for change. NOTICE: Every precaution is taken to ensure accuracy of content; however, the publishers cannot accept responsibility for the correctness of the information supplied or advertised or for any opinion expressed herein. **POSTMASTER: Send address changes to Test & Measurement World, P.O. Box 47461, Plymouth, MN 55447. Canada Post: Publications Mail Agreement 40612608. Return undeliverable Canadian addresses to: BleuChip International, P.O. Box 25542, London, ON N6C 6B2.** Printed in U.S.A.

ADVERTISER INDEX

LINDA C. RAE
President
Keithley Instruments
Cleveland, OH

Linda Rae was named president of Keithley Instruments, a Danaher company, in 2010. She joined Keithley in 1995 in product marketing and then served as head of the Component Test Group as well as the company's Optoelectronics Group. She was later promoted to senior VP and GM. In 2005, she was named executive VP and COO. Rae earned a BSEE degree from the University of Florida and an MSEE and MBA from Case Western Reserve University.

Contributing editor Larry Maloney conducted a phone interview with Linda Rae on products that Keithley has developed to meet the test and measurement needs of emerging technologies.

Emerging technologies drive test advances

Q: How are the changing needs of test engineers affecting the kinds of products that Keithley is introducing?
A: One of the big changes we see is the need for wider dynamic range. This is driven by the growing interest in new power and energy efficiency in devices and materials. We see this trend at the semiconductor level and at the device and module level. As power requirements increase, the dynamic range of measurements that customers have to make is getting wider.

Engineers have to make measurements not only of high voltage and current but also low current and low voltages. If engineers want to use one equipment setup, it's becoming more challenging to get good leakage-current measurements or breakdown voltage measurements while also biasing at a very high power level or a very high current or voltage level. These requirements for dynamic range are influencing a lot of the products we are developing, and these new instruments must still deliver a high level of sensitivity, accuracy, and speed.

Q: What applications led the way in Keithley's business recovery in 2010 and 2011?
A: Certainly, we saw a lot of recovery in the semiconductor side, where there has been significant capital spending both for R&D and production test. Across many industries, we saw renewed spending on test for device characterization and production testing, as well as for general R&D. Our focus continues to be on the semiconductor industry and on the device side, where we sell a lot of our SMUs (source-measurement units) and semiconductor test systems. The underlying technology behind the applications we serve is continuing to evolve, and that creates more opportunities for future growth.

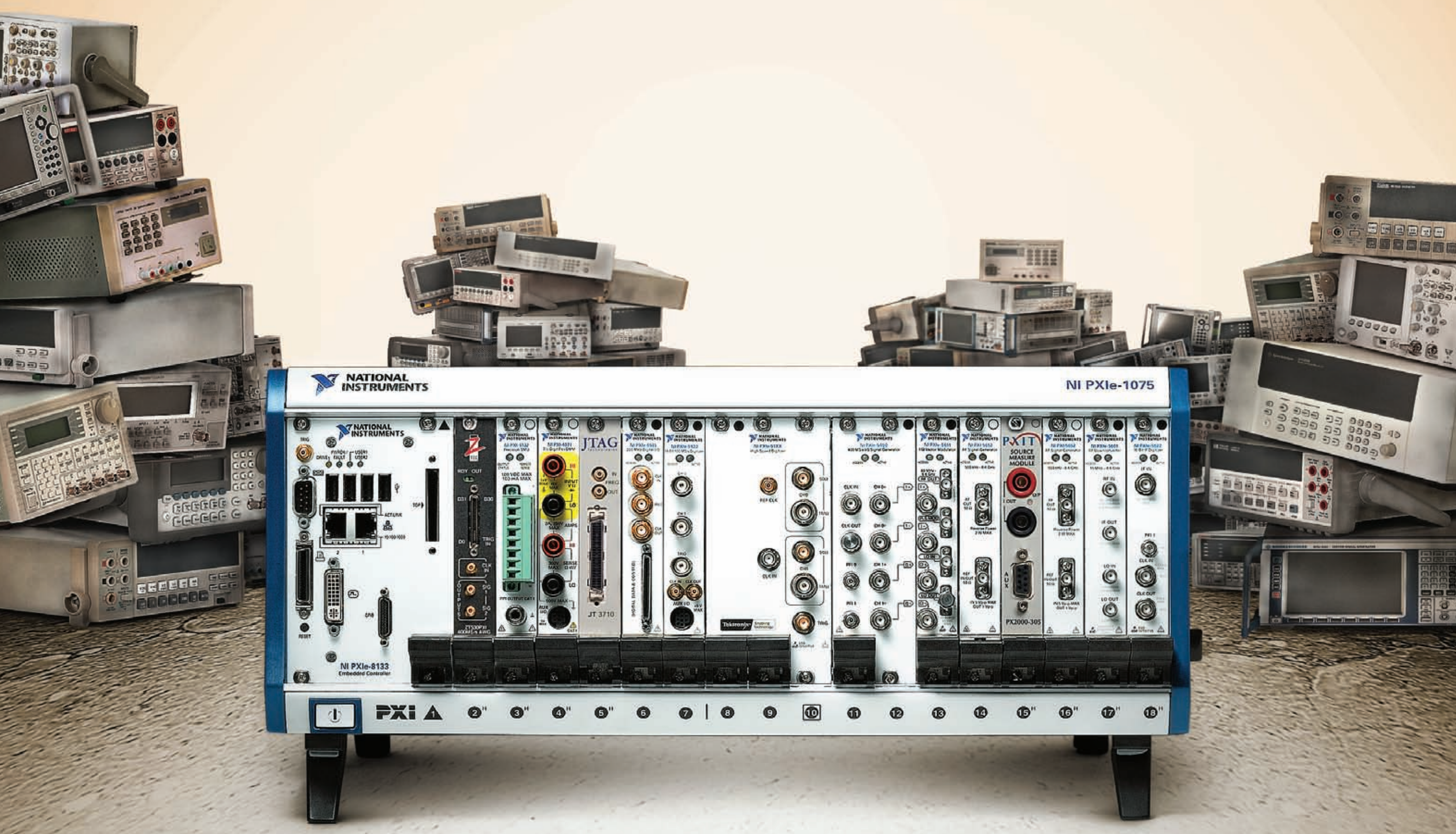
Q: What emerging technologies present some of the biggest challenges to test engineers?
A: In the semiconductor industry, there's the push to develop new materials that will help ensure the continued application of Moore's law, as researchers seek faster switching and operating speeds. Wider power requirements affect not only dynamic range, but also the way engineers make measurements. For example, we're focusing more on pulse test techniques that allow you to tightly limit the amount of time that you expose a material to energy in order to minimize self-heating effects that can influence measurements and damage a device. This is especially important in nanoscale devices. Other emerging technologies that present new challenges for test instruments include new types of nonvolatile memory, printable materials for electronic displays, and alternative lighting, such as high-brightness LEDs.

Q: How does Keithley benefit from its close relationship with the R&D community?
A: That relationship goes back 65 years, and it remains a key source of knowledge on technological changes and trends that will impact future measurement applications both at the R&D level and in production. In 2010, Drs. Andre Geim and Konstantin Novoselov won the Nobel Prize in Physics for their work on graphene, a single-atom-thick form of carbon with many potential applications in electronics, aerospace, and automotive. These scientists employed several Keithley instruments, including our Model 2400 SourceMeter and the Model 2182A Nanovoltmeter. This was the third instance of Keithley's involvement with Nobel Prize winners. Beyond Nobel laureates, if you look at the number of patents and scientific papers that specifically mention our SMUs, you'll find about 5000 references. T&MW

Linda Rae discusses more new test instruments aimed at leading-edge applications in the online version of this interview: www.tmworld.com/2011_12.

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

Move Your Automated Test Beyond the Box



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