UBM Electronics

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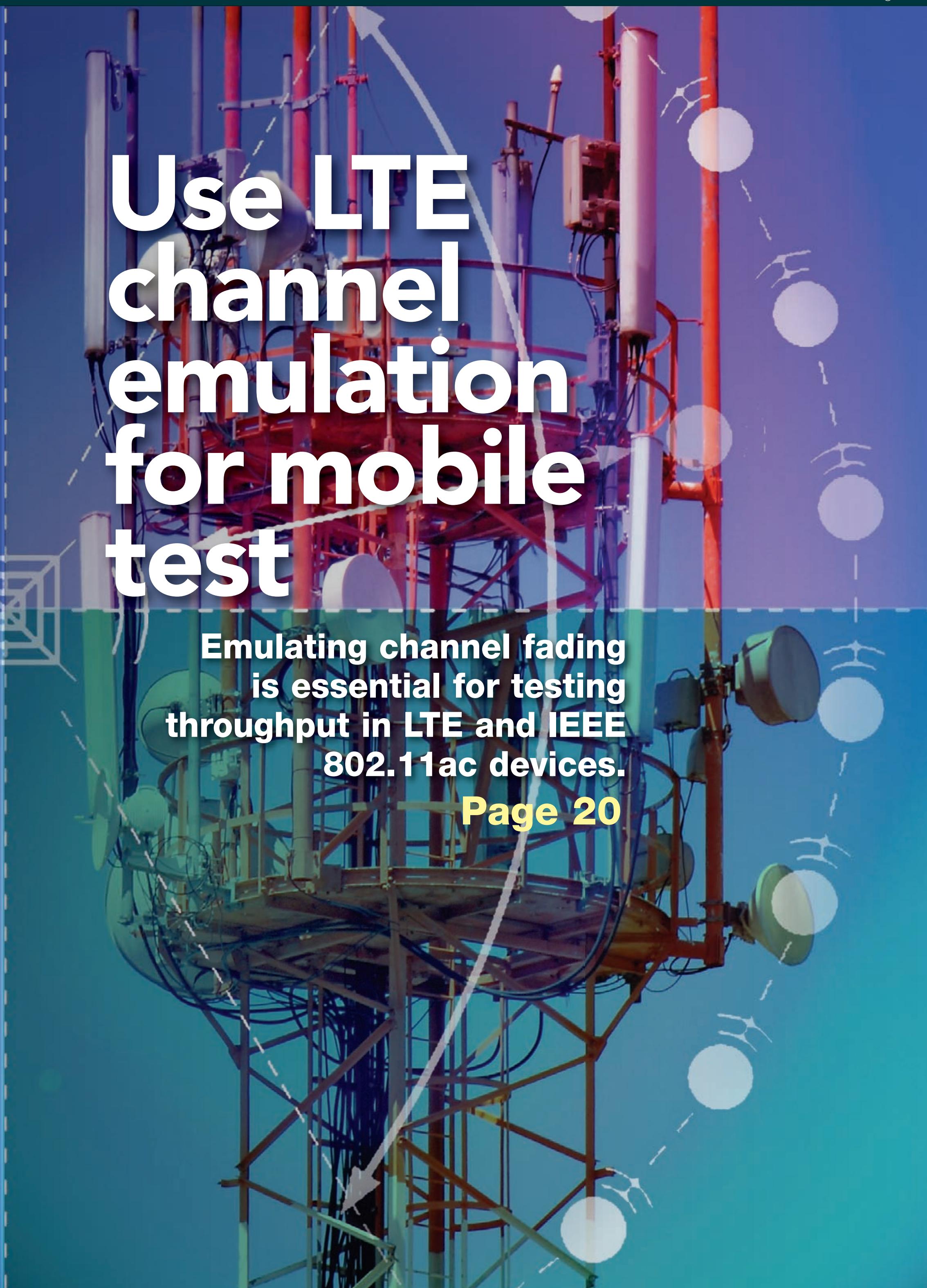
Test & Measurement World

THE MAGAZINE FOR QUALITY IN ELECTRONICS



Use LTE channel emulation for mobile test

Emulating channel fading is essential for testing throughput in LTE and IEEE 802.11ac devices.

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Hello faster update rates. Goodbye status quo.

Oscilloscopes Redefined—Starting at $1,230*

	Agilent 2000X (MSO/DSO)	Comparable Leading Competitor's Model	Agilent 3000X (MSO/DSO)	Comparable Leading Competitor's Model	Agilent 7000B (MSO/DSO)	Comparable Leading Competitor's Model
Bandwidth (MHz)	70-200	50-200	100-500	100-200	100-1 GHz	350-1 GHz
Max. update rate	50,000	200**	1,000,000	5,000	100,000	50,000
Screen size	8.5 in.	5.7 in.	8.5 in.	7 in.	12.1 in.	10.4 in.
Fully upgradable	Yes	No	Yes	No	MSO only	No
Function generator	Yes	No	Yes	No	No	No

Data References: Refer to Agilent pub 5989-7885EN for update rate measurements. Data for competitive scopes from publications 3GW-25645-1, 3GW-22048-1, and 3GW-20156-10.
*All prices are in USD and subject to change **Not specified. Measured at 200 waveforms/sec.

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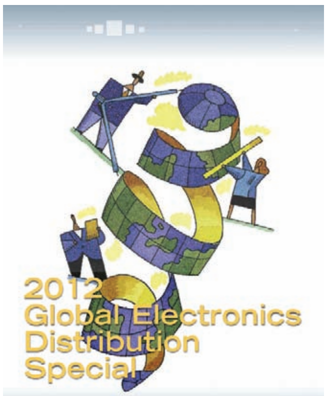

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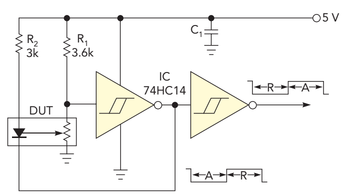

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Check out these exclusive features on the *Test & Measurement World* Website:

What's your *least* favorite test instrument?

Join the conversation! On p. 15 of this issue, Martin Rowe relates some of the comments he received when he asked engineers to name their favorite test instruments. Now, he'd like to know what instruments you've purchased or rented but wish you hadn't:

bit.ly/AdO9rt

Putting the 'e' in 10BaseTe MAU

The UNH-IOL is currently developing a test suite and test system for 10BaseTe MAU conformance. Due to the similarities between 10BaseT and 10BaseTe, the lab's staff decided to integrate both tests onto the same test board and use a similar software package. This allows them to simplify testing, which saves time.

In the "Testing the Limits" blog, Collin Huston explains that unique features in 10BaseT make it easy for the lab to integrate the two standards. First, 10BaseT already implements energy-efficient idle signaling by transmitting link test pulses spaced 16 ms apart, as opposed to a constant-link idle signal as seen in Fast or Gigabit Ethernet. Second, a 10BaseTe device can link with a 10BaseT device and remain in 10BaseTe mode, as long as the minimum cabling requirements, such as category 5, are met. Read about the lab's work and then add your comments:

bit.ly/yMXICg

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Check out the *Test & Measurement World* Website for a roundup of recently released or updated software products that can aid you in your test, measurement, and inspection applications:

www.tmworld.com/1202_software

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MARTIN ROWE
SENIOR TECHNICAL EDITOR

Engineering and music

In 2009, Glen Watkins of ETS-Lindgren organized a live music session at the IEEE EMC Symposium in Austin, TX. EMC engineers moved that session to the EMC Symposiums in Ft. Lauderdale in 2010 and Long Beach in 2011, and will move it to the Pittsburgh site 2012. Three members of "The EMC Society Band" recently shared their musical experiences.

Mike Violette is the president of Washington Labs. He started playing guitar at age 10 or 11. "I always wanted to be in the music business and be a rock star," he said, "but my father told me to have something to fall back on." So, Violette studied engineering.

His engineering background helped him understand audio and harmonics.

Violette's engineering background helps him understand music. "There's a strong connection between music, audio, and sound. There's certainly a technical part to music, in understanding chord progressions and key signatures. Sound pressure levels and harmonics—things that you run into in a lab—are part of music, but music definitely sits in a different part of your brain."

Drummer and EMC consultant Kenneth Wyatt is always tapping out a song, whether it's on the drums or with his thumbs on a steering wheel. "Music has always been a favorite pastime." He started playing clarinet in elementary school, switched to trumpet, then to drums, which he started playing at religious services. "One day, the music pastor told me I was playing in three days, so I had to learn quickly." Wyatt then took lessons and continued playing for about five years before being "consumed" by engineering.

Jeff Silberberg is the leader of the band, for which he has played guitar, bass, keyboards, and soprano sax. An EMC engineer with the US Food and Drug Administration, Silberberg drove his own stage equipment—at his own expense and without air conditioning—from Maryland to Florida for the EMC Symposium in July 2010. He expects to drive to Pittsburgh in August 2012.

Silberberg started with clarinet in the fourth grade. When he was in the sixth grade, a friend convinced him to play clarinet in the school talent show, and he's been performing ever since. He then learned to play the ukelele and later convinced his mother to buy him an acoustic guitar.

Silberberg started a rock band in high school. "I started playing folk songs like Peter, Paul, and Mary, but when Bob Dylan went electric, so did I." His band played teen dances and played on the local UHF TV station. He kept playing through college, going home on weekends to practice.

He sold his guitar after getting married, but he missed music too much and bought another one, joining a band for which he played rhythm guitar. When the lead guitarist left just before the band's audition for its first wedding gig, Silberberg had to learn all the lead parts in a week. Learning keyboard and sax grew out of necessity. Playing Top 40 songs at weddings means you have to sound like the record. When a song called for a keyboard, he learned enough to play the song. The same applied to his learning the sax.

Silberberg considered studying music in college but decided that he could not only make a living as an electrical engineer, he could also learn how the boxes he used for music actually worked. His engineering background helped him understand audio and harmonics. "There's a definite connection between math, engineering, and music," he noted. T&MW

Share your music-related stories in the online version of this article at www.tmworld.com/EMC_Band.

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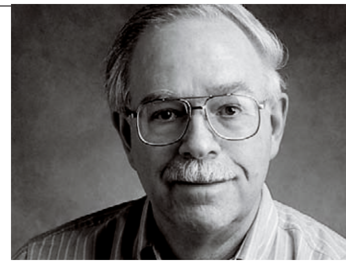


Old dog, newer trick

Although mostly obsolete, the vacuum tube still has its adherents among audiophiles, test-instrument collectors, amateur-radio fans, and those curious about the physics of active devices. Given that a family of characteristic curves is worth a thousand data points, being able to view a device's behavior enhances a small laboratory's capability.

Vacuum-tube curve tracers are expensive. Demand by audiophiles has pushed asking prices for Tektronix's 1956-vintage Model 570 well over $1000, making this rare instrument unaffordable for casual experimenters. An alternative, the Model 575 transistor curve tracer, typically sells for under $400 but requires accessories to display vacuum-tube characteristics.

A recent series of messages in Yahoo's TekScopes forum inspired me to explore what's needed to plot tube curves within the limitations imposed by the Model 575's transistor-specific capabilities. These include a lack of tube sockets, the absence of heater (or filament) and screen-grid power supplies, limited base (or grid) voltage-step size, and a 200-V maximum collector (or plate) voltage supply.

Tektronix addressed the latter shortcoming via its factory-upgraded Type 575 Model 122C and also offered the 122C upgrade kit, which is likely unobtainable nowadays. For testing many small-signal tubes, most users can live with the 575's 200-V limit. An external amplifier module can boost the grid-voltage steps by a factor of 10, and an inexpensive multivoltage switched-mode universal power supply can warm a tube's heater.

Traditional tube testers solve the tube-socket problem by providing one of every commonly used socket type and a matrix of switches to connect a DUT's (device under test's) socket pins to the tester's circuitry. Since my requirements involve either an extensive exploration of a single tube's characteristics or the testing of a batch of identical tubes, I opted for a simpler approach (see photo). A small printed-circuit board provides an interface between the 575, external power supplies, and a 12-pin connector for the tube socket. Two plugs and jumper wires connect the DUT's pins to the curve tracer, enabling my old Model 575 to plot vacuum-tube curves—a newer trick for an older dog! T&MW

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

MAKING CONNECTIONS

To bridge the gap between the 575 and a vacuum-tube DUT that requires from four to 12 connections, the interface panel provides connectors for external filament (or heater) and screen-grid power supplies. Two groups of flying leads connect to the 575's emitter, base, and collector binding posts. The DUT socket mounts separately and connects to the interface panel. If needed, ferrite beads on the DUT's grid and plate wires help suppress parasitic oscillations. The remaining sockets accommodate a pair of plugs serving as a removable "patch panel" for configuring the DUT socket's pinout to the interface.

A small universal power supply intended for digital cameras delivers a switch-selectable DC output of from 3 to 7 V at up to 2.1 A to the DUT's filament or heater. If required, an adjustable regulated DC power supply provides screen voltage.

BOOST THE OUTPUT

A 575's base/grid step generator's limited output benefits from an external amplifier. This Linear Technology application note describes a suitable high-voltage amplifier featuring either transistors or a vacuum-tube output stage:

cds.linear.com/docs/Application%20Note/an18f.pdf

USING A TEK 576 OR 577

Daniel Schoo offers an introduction to tube curve tracing and shows how to use these later-model semiconductor curve tracers to display tube curves:

bit.ly/w2hroZ

REFERENCE BOOK

This book provides a definitive introduction to curve tracers, tube testers, and other vintage instruments:

Douglas, Alan, *Tube Testers and Classic Electronic Test Gear,* Sonoran Publishing, 2000. 166 pages.

Oscilloscope hits 60-GHz bandwidth on 10 channels simultaneously

LeCroy has announced the LabMaster 10 Zi-A (LM10Zi-A), a physically large modular DSO (digital storage oscilloscope) system that acquires 80 Gsamples/s per channel and can deliver 36-GHz bandwidth on four to 20 channels. Thanks to its frequency-domain-based DBI (digital-bandwidth-interleaving) technology, the instrument can acquire 160 Gsamples/s per active channel and can deliver 60-GHz real-time bandwidth on two to 10 channels.

An LM10Zi-A system comprises a display/control module and from one to five acquisition modules. The LM10Zi-A series includes five models of acquisition modules, two of which support DBI.

The company adopted the modular approach for several reasons. For example, few probes have bandwidths greater than approximately 30 GHz. This lack often necessitates the use of pairs of channels as differential inputs for capturing signals that contain significant energy at and above 30 GHz. So, in applications that require simultaneous acquisition and display of multiple wideband signals, oscilloscopes that provide more than 30-GHz bandwidth on just two channels often prove to be inadequate. According to Ken Johnson, LeCroy's marketing director for high-performance scopes, the lifetime in the market of a scope that offers 30 GHz on only two channels would be too short to justify its development cost. Johnson said that LeCroy's modular architecture yields products with greater expected market lifetimes, because over a period of five years or more, LeCroy customers will be able to repeatedly upgrade their modular scope systems without discarding any of the older components. Prices for complete working systems begin at $252,900. www.lecroy.com.—*Dan Strassberg,* EDN

IEEE plans mobile video standards

During the 2012 CES show in January, the IEEE announced plans to develop three standards that will cover mobile video communications: IEEE P1907.1 ("Standard for Network-Adaptive Quality of Experience [QoE] Management Scheme for Real-Time Mobile Video Communications"), IEEE P2200 ("Standard Protocol for Stream Management in Media Client Devices"), and IEEE P3333 ("Standard for the Quality Assessment of Three Dimensional [3D] Displays, 3D Contents and 3D Devices based on Human Factors"),

"Mobile video is a phenomenally promising technology space, with the potential to transform and enable whole new applications and business models. But in order for that chain of events to be set in motion, significant challenges must be addressed in the areas of quality, user experience, and cost of delivery, among others," said Judith Gorman, managing director, IEEE Standards Association.

IEEE P1907.1 will define an end-to-end QoE management scheme for real-time video-communications systems; the goal is to ensure that the quality of video on mobile devices does not lag behind that of traditional broadcast mediums.

IEEE P2200 will enable more efficient downloading and streaming of content through the standardization of time-shifted caching; the standard is intended to both improve user experience and relieve congestion on wireless networks.

Finally, IEEE P3333 is designed to establish methods of quality assessment of 3-D displays, content, and devices based on human factors such as photosensitive seizures, motion sickness, and visual fatigue. www.ieee.org.

Editors' CHOICE

Stanford touts ultrahigh resolution of RF signal generators

The SG380 series of RF signal generators from Stanford Research Systems employs a synthesis technique, called rational approximation frequency synthesis, to generate RF and microwave signals with ultrahigh frequency resolution of 1 μHz. The SG380 signal generators also offer versatile modulation capabilities (AM, FM, phase modulation, pulse modulation, and sweeps) at what Stanford says is a fraction of the cost of competing designs.

Three standard models produce sine waves from DC to 2.025 GHz (SG382), 4.05 GHz (SG384), and 6.075 GHz (SG386; pictured). An optional frequency doubler extends the frequency range of the SG384 and SG386 to 8.10 GHz. Other options include low-jitter differential clock outputs, an external I/Q modulation input, and a rubidium time base.

All three models provide low phase noise, specified at −116 dBc/Hz at 1 GHz (20-kHz offset); full-octave frequency sweeps; OCXO time base; and standard RS-232, GPIB, and Ethernet interfaces. Each unit has two front-panel outputs—one BNC and one N-type—with overlapping frequency ranges.

Base price: $3900. *Stanford Research Systems, www.thinksrs.com.*

CALENDAR

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.*

Design West, March 26–29, San Jose. *UBM Electronics, www.ubmdesign.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

Guzik AXIe digitizer runs to 13 GHz

Guzik's ADC 6000 series of AXIe modules bring high-speed signal capture to the AXIe bus. A one-channel model has a maximum bandwidth of 13 GHz with a sampling rate to 40 Gsamples/s; other models have bandwidths of 4 GHz, 6.5 GHz, and 8 GHz with samples rates of 10 Gsamples/s and 20 Gsamples/s. In addition, the ADC 6000 modules have deep memory, ranging from 2 Gbytes to 16 Gbytes for the four-channel model and 8 Gbytes to 64 Gbytes for the one-channel model. Modules can be interleaved to double the sample rate.

To transfer signals to a host computer for processing, the modules use a four-lane cabled PCI Express Gen 4 link, which delivers 1.6 Gbytes/s of sustained transfer rate (the host needs a PCIe bridge card). The modules need not send all the data to a host computer, though, because they can process data with their onboard FPGA.

The ADC 6000 modules have a digital hardware trigger capability that lets you define trigger conditions, and they also have external triggers and clocks for synchronizing signal acquisition to external equipment and for system integration. Software support includes a development kit for custom applications.

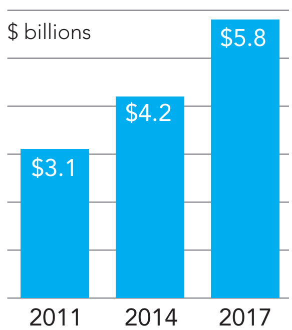
Guzik, www.guzik.com.

Market Trends:

Smart devices create opportunities for test vendors

The rapid changes that are taking place in wireless communications are driving growth in the wireless test equipment market. With the growing number of subscribers, smartphones, data services, mobile banking, and social-networking applications, there is a need for increased functionality in test and measurement tools.

The wireless test equipment market consists of signal generators, spectrum analyzers, network analyzers, and telecom and datacom test equipment. The global wireless test equipment market generated revenues of $3.1 billion in 2011 and is expected to exceed $5.8 billion in 2017 with a CAGR (compound annual growth rate) of 11.0% from 2011 to 2017. Numerous factors are contributing to the growth.



Revenue forecast for the global wireless test equipment market.
Source: Frost & Sullivan.

As LTE technology moves toward deployment, it brings new challenges, including higher data rates. The volume of mobile data traffic is increasing as a result of high-speed networks; an increased penetration of next-generation mobile phones (especially smartphones) and connected devices (laptops, netbooks, notebooks, and tablets); and higher-bandwidth-consuming applications and services.

In 2009, the penetration rate of active 3G (and 3.5G) users in North America was 12%, and it is expected to exceed 35% in 2015. Consequently, the demand for 3G-compatible test equipment is expected to increase. Likewise, the demand for QoS (quality of service) and QoE (quality of experience) analysis is increasing as growing mobile data usage creates more traffic on the network.

Smart devices are changing the mix of traffic from mostly voice to integrated voice, video, and data, thus creating a demand for products that can test a network's performance and capacity along with how well it handles integrated transmissions. Another market driver is the need to support mobility across technologies, from LTE to 3G, and back to 2G.

Olga Yashkova, Program Manager, Test & Measurement Practice, Frost & Sullivan

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Readers speak out about their favorite instruments

Ask any musician about his or her favorite instrument, and you'll get a mix of old and new, but mostly old. The same goes for engineers. Several engineers voiced their opinions about their favorite test instruments on my "Rowe's and Columns" blog (Ref. 1).

The question "What's your favorite test instrument?" drew responses for oscilloscopes, multimeters, signal/spectrum analyzers, a logic analyzer, and a few other instruments. As you might expect, engineers mostly mentioned old, obsolete equipment as favorites, with some claiming that nothing built today is as good. Several engineers, including former *EDN* editor Paul Rako, picked an analog oscilloscope as the favorite. "For a single choice, I would have to say my Tek 3465B 400MHz analog scope" Rako wrote. Several engineers commented that they like HP analog oscilloscopes such as the Models 180 and 1740.

Reader BobL also prefers analog oscilloscopes. He's managed to keep two Tektronix 7904 analog oscilloscopes running in his lab. "Transients are sometimes impossible to see with a digital scope, but analog display is great." An engineer using the name Opcom also has two Tektronix 7904s.

Many engineers still like analog oscilloscopes, such as the HP Model 185, built in the 1960s. Courtesy of Agilent Technologies.

"Lets face it," Opcom wrote, "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."

Based on the comments, I conclude that there is a whole group of engineers who still prefer analog oscilloscopes no matter how much digital oscilloscopes have advanced. Dave McGuire even had a message for the oscilloscope makers when he wrote that his favorites are "My Tek 2465A and 7904A oscilloscopes. Yes I have some fancy digitizing scopes (the Tek 222 is very handy on the road!) but nothing beats an analog scope for fast transients...analog and digital scopes are completely different instruments. Are you listening, Tektronix and Agilent?"

Of course, not everyone engineer's favorite instrument is an old analog oscilloscope. Some engineers actually like modern digital oscilloscopes. David Danielson commented that he likes his LeCroy Waverunner 44Xi, which is still available as the 44Xi-A. Another reader favored the Tektronix TDS2042C.

Handheld instruments also made a showing. Several people pointed to handheld multimeters as their favorite instrument. William Ketel commented that his favorite 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." Ketel also likes his Fluke 77 handheld multimeter. The Model 77 series IV is still available.

Newer digital oscilloscopes such as the Tektronix TDS2024C also have fans. Courtesy of Tektronix.

Ketel is not the only engineer who likes a Fluke handheld multimeter. One engineer said he likes his Fluke 87, which is still available as the Fluke 87 V.

A few bench digital multimeters made the list, too: the Keithley 197, Fluke 8060A, and HP 34401A. The 34401A is still available with the Agilent Technologies name.

While most respondents commented on general-purpose test equipment, some mentioned specialized products. An engineer named Buzz said, "When analyzing QAM I like the Sunrise Telecom AT2500rqv, and for 8VSB I use a Rohde & Schwarz FSH3 with a DVM-400 Digital Video Measurement System. A Triveni MT-40 supplements the DVM-400."

What's you favorite instrument? What instrument have you bought that you wish you hadn't? Leave a comment on my blog post at tinyurl.com/6vhaovd. T&MW

REFERENCE

1. Rowe, Martin, "What's your favorite test instrument?" Rowe's and Columns blog, *Test & Measurement World,* December 6, 2011. tinyurl.com/6vhaovd.

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

TEST IDEA

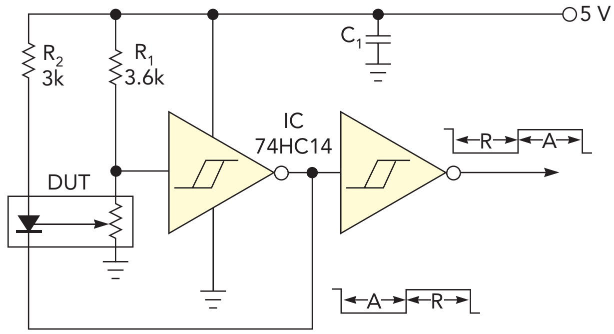
Circuit measures optocoupler's response time

Here is a simple circuit you can use to measure the attack and release times of photoresistor-type optocouplers that often find use in audio compressors or volume-control circuits (**figure**).

The design uses an oscillating Schmitt trigger with the optocoupler DUT (device under test) in the feedback loop. The photoresistor and resistor R_1 form a voltage divider that controls the input of the Schmitt trigger. The optocoupler's LED connects to the trigger output. You can measure the duration of the output pulses with an oscilloscope or a digital meter. The duration of the negative output pulses is equal to the switching on-time, or attack time. The duration of the positive pulses is equal to the switching off-time, or release time.

The attack and release times depend on the value of R_1; you can observe both by varying the value of R_1. With the component values in the figure, the durations of the output pulses are a 0.15-ms attack time and a 2.7-ms release time.

During oscillation, the resistance of the photoresistor sweeps in from R_{P1} to R_{P2}. The circuit sweeps these photoresistor values according to R_1, the power-supply voltage, and the Schmitt-trigger thresholds, as the following equations show: $R_{P1} = R_1 \times V_{T2}/(V_{CC} - V_{T2})$ and $R_{P2} = R_1 \times V_{T1}/(V_{CC} - V_{T1})$, where V_{T1} is the positive-going threshold voltage and V_{T2} is the negative-going threshold voltage of the Schmitt trigger.



You can determine an optocoupler's rise and fall times by incorporating a photoresistor in the feedback loop of an oscillator circuit.

In the case of the 74HC14 logic family, you can determine the thresholds from the data sheet and your power-supply voltage, according to the following equations, which yield typical values: $V_{T1} = 0.53 \times V_{CC}$ and $V_{T2} = 0.31 \times V_{CC}$.

Using 5 V as a power-supply voltage and solving the following equations, you can determine the photoresistor range: $R_{P1} = 0.45 \times V_{R1}$ and $R_{P2} = 1.13 \times V_{R1}$.

This approach lets you pick a value for R_1 so that the photoresistor range is suitable for your device. You can also vary the value of resistor R_2 to observe the LED-current-to-attack-time characteristic of the DUT but not affect the release time. Note that R_2 limits the current through the LED; if its value is too large, oscillation will not occur.

Using this circuit allows you to match custom optocouplers comprising green, superbright LEDs and an MPY7P photoresistor.

Peter Demchenko, Vilnius, Lithuania

This article first appeared as a "Design Idea" in the September 8, 2011, issue of *EDN*.

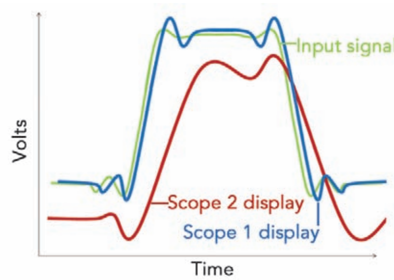
RESOURCE

Designlines' top test articles of 2011

Test & Measurement World is part of UBM Electronics, which also publishes *EE Times*. The *EE Times* Website includes several mini-Websites, called "Designlines," that are dedicated to various disciplines within electrical engineering. Below, I have summarized some of the most popular articles on the "Test & Measurement Designline" during 2011:

• *Oscilloscopes and ENOB*
One quality metric for an oscilloscope with a bandwidth in the gigahertz range is the ENOB (effective number of bits) of the scope's ADC. Joel Woodward and Brig Asay of Agilent Technologies discuss the importance of ENOB and how effective it is at predicting a scope's measurement accuracy (**figure**). www.eetimes.com/4216991.

• *Perfect timing: performing clock division with jitter and phase noise measurements*
As clock speeds and communication channels run at ever-higher frequencies, accurate jitter and phase-noise measurements become more important, even as they become more difficult to manage. Howell Mitchell of Silicon Labs describes pointers for situations where clock signals have been divided down from higher-frequency VCOs (voltage-controlled oscillators). www.eetimes.com/4219306.



While ENOB provides one basis for scope evaluation, ENOB computations don't include the effect of magnitude or phase flatness. Scopes 1 and 2 have the same ENOB, but scope 2 has offset and phase distortion errors that limit its ability to correctly display the input signal.

• *A measurement approach for IQ offset and imbalance of LTE mobile devices*
Imperfect analog front ends of mobile devices cause transmit signals to be non-ideal. Typically, the signal processing for IQ components is likewise affected. Christian Kuhn of Rohde & Schwarz explains that an estimation of the IQ offset must take into account the special structure of the physical layer of LTE. www.eetimes.com/4229667.

• *Hunting noise sources in wireless embedded systems*
When integrating a radio chip or module into a typical embedded system, designers must track down and eliminate noise and spurious signals. Darren McCarthy of Tektronix describes tips and techniques for hunting noise sources using a mixed-domain oscilloscope. www.eetimes.com/4227229.

• *Jitter and timing analysis in the presence of crosstalk*
Testing serial data streams for jitter is critical for long-term stability and for achieving a good BER (bit-error rate) in a design. Chris Loberg of Tektronix says to perform an effective analysis, you must select the right instruments and also have a good understanding of instrument noise, rise time, and factors such as 3rd, 4th, and 5th harmonic performance. www.eetimes.com/4233152.

• *DSOs: The banner specs tell only part of the story*
Dan Strassberg says an oscilloscope's performance in capturing anomalous waveforms depends on little-known and often poorly understood characteristics. You might discover that the headline specifications of a scope fail to reveal much of the information you need about the instrument's behavior. www.eetimes.com/4227286.

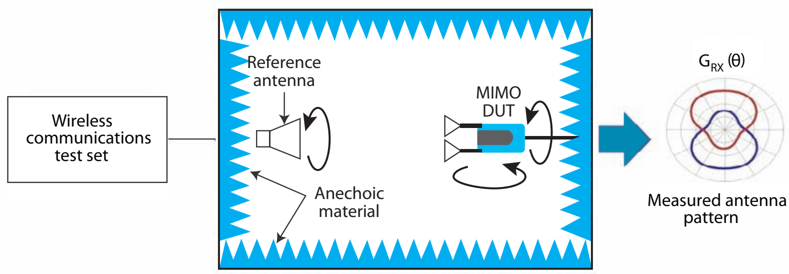
• *Vector network analyzers aid breast cancer screening research*
Bristol University spin-out Micrima is using high-speed vector network analyzers for the clinical trials of a revolutionary breast cancer screening technique. www.eetimes.com/4230300.

• *Understanding the impact of digitizer noise on oscilloscope measurements*
Noise can make it difficult to make measurements on a signal in the millivolt range, such as in a radar transmission. Jit Lim of Tektronix explains how you can use ENOB testing to accurately evaluate the performance of digitizing systems. www.eetimes.com/4217597.

Colin Holland, Editor,
Test & Measurement Designlines

COMMUNICATIONS TEST

Tips for testing MIMO, LTE, and 802.11ac devices



In the first stage of the two-stage test method, a reference receiver and MIMO device operate in an anechoic chamber.

The cover story in this issue, "Test mobile devices by emulating the radio channel" (p. 20), features a technique for testing LTE and IEEE 802.11ac devices, both of which use MIMO (multiple input, multiple output) technology as the physical-layer wireless interface. MIMO increases data rates over previous single-stream wireless technologies by using multiple transmitters and receivers, setting up a multipath environment. The cover story focuses on beamforming, a technique for strengthening a signal by focusing a signal in a particular direction, and it mentions several models under consideration for simulating channel fading in the lab.

You can learn more about MIMO testing from two articles available in the "Designlines" section of the *EE Times* Website. "Test MIMO over-the-air with a two-stage method" by Allison Douglas (http://bit.ly/xFfeS7) in the "RF & Microwave Designline" explains how a reference antenna and MIMO device can be tested in an anechoic chamber for measuring the antenna pattern (**figure**). No chamber is needed at the second stage, where LTE protocols are applied to the transmission signals. Channel models such as those described in this issue's cover story are then applied to the signals for throughput measurements.

In "802.11ac Wireless LAN: what's new and the impact on design and test" in the "Test & Measurement Designlines" (http://bit.ly/xDI7mo), Mirin Lew discusses the design and test challenges of applying MIMO to the emerging IEEE 802.11ac standard, which is an evolution of the IEEE 802.11n standard. IEEE 802.11ac increases throughput by providing signal bandwidths of 80 MHz and 160 MHz as opposed to the 40 MHz found in 802.11n devices. Because 802.11ac devices will use 256 QAM (quadrature-amplitude modulation), error-vector magnitude measurements will be more critical than they were for devices designed for previous WiFi standards. The article explains how to make the measurements with a vector signal analyzer.

Martin Rowe, Senior Technical Editor

Use LTE channel emulation for mobile test

Emulating a radio channel's fading in the lab is essential for testing throughput in the multiple-antenna systems used in cellular LTE and IEEE 802.11ac devices.

BY JANNE KOLU, PETTERI HEINO, AND JUHA MÄÄTTÄ, ELEKTROBIT

As users of mobile devices demand more bandwidth for their apps, network carriers have begun implementing LTE (Long Term Evolution) technology into their networks. Part of the LTE infrastructure relies on MIMO (multiple input, multiple output) radio channels, which use several antennas to focus signals and boost performance. Because users of mobile devices are generally on the move, carriers and equipment manufacturers must test their networks and their devices by emulating the signal fading of an actual network's radio channel.

To test the performance of a cellular handset or chipset, manufacturers can measure BER (bit-error rate), BLER (block-error rate), and FER (frame-error rate) as a function of the signal-to-noise ratio. All of these measurements count the number of errors in a predefined amount of data. High error values mean that the mobile device doesn't adequately mitigate fading effects in the radio channel. Another typical performance measure is the data throughput vs. the signal-to-noise-ratio. This is typically measured in kilobits per second and defines how much data the system is able to correctly transmit in 1 s.

Performance tests require a communications tester and a radio-channel emulator (**Figure 1**) for the DUT (device under test). A communications tester establishes a link to a cellular device by emulating a base station, but its features include only a small subset of those in a real base station. For a throughput measurement, the communications tester sends a known data pattern to the DUT. With a direct cable connection from the tester to the device, the test setup can achieve its highest possible throughput.

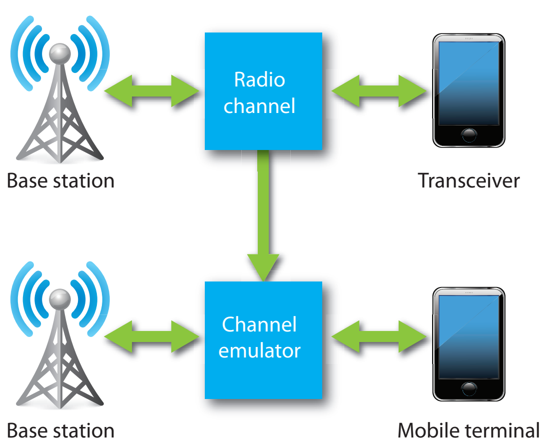


FIGURE 1. A radio-channel emulator creates a real-life radio environment in lab conditions.

A radio-channel emulator, placed between the tester and the DUT, will distort the signal, which causes a decrease in throughput. **Figure 2** shows a typical test setup for a device with multiple antennas.

Typically, the main purpose of testing is to verify a product's compliance to a standard. Standard channel models are defined by the 3GPP LTE standard (Ref. 1). The standard also sets performance limits with a given model, ensuring a certain minimum performance for all LTE devices on the market. Most

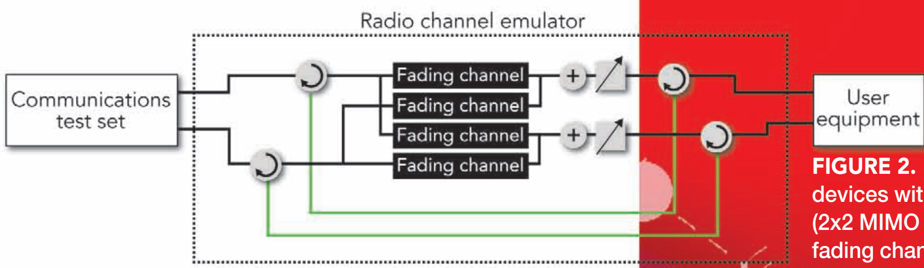


FIGURE 2. A typical test setup for devices with multiple antennas (2x2 MIMO downlink) shows four fading channels.

tests against the standard requirements are simply pass/fail measurements, so they do not measure the maximum performance of the device.

Performance testing in the lab provides a fully repeatable environment that allows manufacturers to debug problems in a design. After a design change, the performance can be checked against the same test conditions.

Beamforming and MIMO testing

Proper emulation of the radio channel and the spatial effects is crucial in the development and verification of multi-antenna systems. Performance testing of LTE devices requires beamforming, a technique that lets the tester change the actual antenna radiation pattern electrically, dynamically, and on a per-user basis.

Beamforming is a multi-antenna technique that uses the spatial dimension of the mobile radio channel. The beamforming technique is applicable to both the transmitting and the receiving side, but due to size and antenna spacing constraints, the use of beamformers is practically limited to base stations. **Figure 3** shows how a base station uses beamforming to extend its range.

Beamforming with multiple antennas has been used in radar and optical systems for decades. The basic idea of focusing an antenna beam is simple. Parallel antenna elements in the array are phased so that signals received or sent at a wanted direction experience constructive summing. Therefore, the combined signal power to that particular direction is maximized. This is the traditional form of beamforming, usually referred to as beamsteering.

Beamforming functionality has been an optional feature in telecommunication standards since the mid-1990s, but the lack of computing power forced system designers to select simpler approaches. Requirements for spectral efficiency and higher data throughput, along with improved digital-signal processing power, have made beamforming attractive for cellular systems. In current standards such as LTE and IEEE 802.11ac, beamforming is used adaptively. This means that optimal weights for each antenna stream are calculated based on given optimization criteria. That technique provides the best antenna characteristics against spatial radio propagation and interference conditions at each moment in time.

The test system needs a way to measure the radio channel's performance and adjust the antenna pattern. In TDD (time-division duplex) systems, the downlink-sounding procedure is used to find the weight of each portion of the transmitted signal. The test system simply measures uplink signals and predicts the optimal weights for the downlink. In FDD (frequency-division duplex) systems, user equipment must measure downlink sounding signals and report the results to the base station. *(continued)*

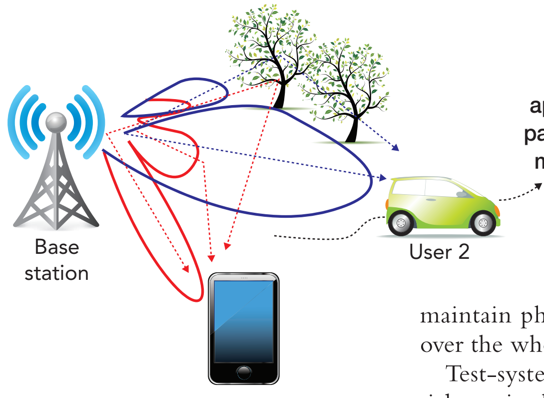


FIGURE 3. Beamforming applies weights to antenna patterns to direct the transmitter port toward the mobile device.

System designers must optimize the channel sounding so that the wideband spatial channel is measured accurately enough and yet efficiently without consuming too much valuable data payload capacity. The mobility of devices makes testing more difficult. Interference and reflections in multipath radio channels are continuously changing as UE (user equipment) and other objects move. The feedback latency of a closed-loop based channel estimation and weighting must be taken into account in system implementation. The beam adjustment must be shorter than the changing speed of spatial channel characteristics.

Developing a beamforming system for a stable environment is a fairly simple task, but developing a beamforming system that also works in a real radio environment, which is never constant, is much more challenging. The whole concept of beamforming relies on phased antenna arrays. Therefore, in the beamforming test setup, engineers must work to control and maintain phase accuracy and stability over the whole test system.

Test-system calibration is an essential step in the execution of laboratory tests. Because a beamforming test setup has multiple parallel radio channels, the relative amplitude levels need calibration to achieve balancing. A special element in beamformer testing is the phase calibration in addition to amplitude calibration. A beamforming test environment requires phase accuracy within a few degrees. It's important to compensate for effects from antenna RF cabling as well.

A typical setup for performing beamforming testing on TD-LTE equipment consists of an eight-antenna base station and two mobile devices, each having two antennas. Because downlink channel estimation is based on uplink measurements, the uplink channel also needs to be emulated. Thus, the full setup (**Figure 4**) has two 8x2 connections for the downlink emulation and two 1x8 connections for the uplink emulation (uplink is transmitted with one antenna per UE device).

Perhaps the most important aspect of using a radio-channel emulator and software simulations for lab testing is to select the proper channel model. In performance evaluations, channel models must be realistic, and they must model a known type of environment. It's not meaningful to optimize system performance against a rural model if the target environment is an urban street canyon. Equally, it doesn't make sense to use simple line-of-sight models for systems designed to mitigate urban fading.

Channel models specified for different standards can be categorized in different families by their mathematical form. Channel models always require a tradeoff between complexity and accuracy. Correlation-based models are easy to implement but lack realism, especially for tests involving beamforming. Ray-tracing models, or recorded impulse responses, are the most accurate models, but they are typically location specific and require heavy computational effort. The most promising models, and also the most widely used, are GSCMs (geometry-based stochastic channel models).

Unlike correlation-based models, GSCMs are antenna independent, and a realistic antenna model can be embedded in the channel model. This is important because beamforming antennas have a strong impact on the complete system performance. The modeling approach is simple—there is a good selection of models available for different types of environments. Radio-channel models such as SCME (spatial-channel model extension), IMT-Advanced (International Mobile Telecommunications), and WINNER (wireless world initiative new radio) models are based on this approach. The latest TD-LTE beamforming test development in China relies also on this approach.

Figure 5 shows two examples of the typical test cases. Beamforming testing with real fading gives the necessary confidence to engineers that a new technology works. Throughput is the key question—does beamforming really deliver the promised data throughput?

Testing with proper channel models lets you verify throughput. Technology will be more mature after systematic lab testing, which will result in easier and faster field deployment.

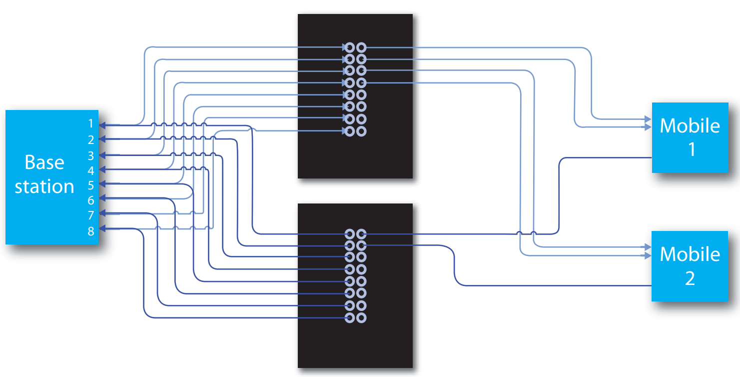


FIGURE 4. In a typical TD-LTE downlink, the connection topology is two times 8x2 and in the uplink, it is two times 1x8. The complete setup must be phase accurate in order to allow uplink channel estimation, user tracking, and interference suppression performance.

Fading environments

Techniques such as beamforming that are used for testing LTE devices can also be used for testing IEEE 802.11ac WLAN devices. IEEE 802.11ac is the evolution of IEEE 802.11n for very high data-rate-to-end-user devices, offering improved performance. IEEE 802.11ac device performance gain is, however, highly reliant on physical-layer extensions compared to 802.11n systems because 802.11ac has a wider RF bandwidth (up to 160 MHz), more MIMO spatial streams (up to eight), multi-user MIMO, and high-density modulation (up to 256 QAM). The extension towards higher data rates is also known as the VHT (very high throughput) mode of 802.11ac. WLAN performance expectations are set to a new level with 802.11ac, yet vendors still must focus on keeping manufacturing costs low. Therefore, these devices require more effective physical-layer test methods than did older mobile devices.

Verifying MIMO techniques like spatial multiplexing and beamforming that

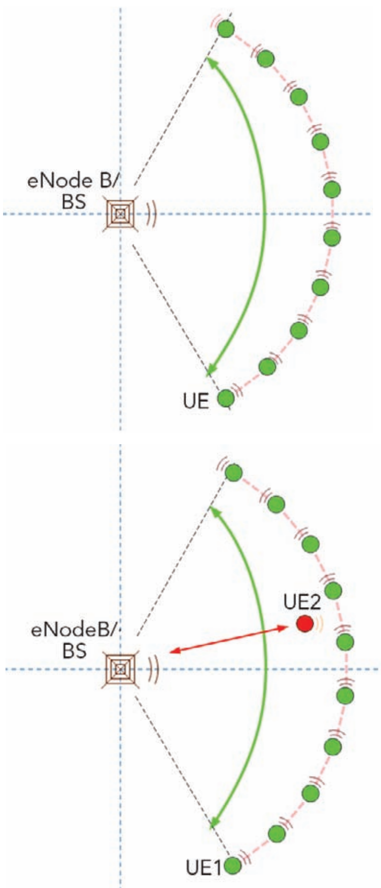


FIGURE 5. Top) In user tracking, user equipment (the green dot in the picture) travels back and forth radially around the BS (base-station) sector. Bottom) Adding a second user tests a mobile device's interference suppression by stressing the wireless network.

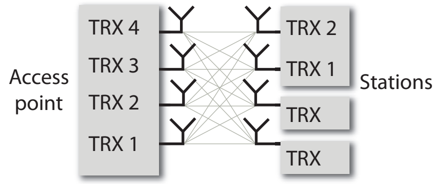


FIGURE 6. This MU-MIMO transmission scenario with three users shows the paths among antennas.

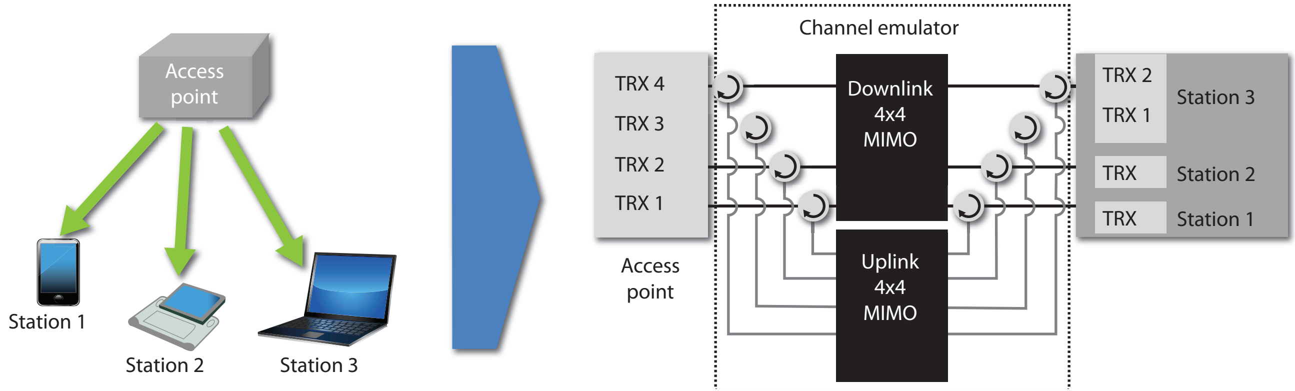


FIGURE 7. A MU-MIMO test procedure uses a radio-channel emulator to simulate fading among three users and a base station.

are defined in the 802.11ac standard requires the use of advanced propagation modeling and emulation as well as multichannel fading capability with a mandatory 80-MHz bandwidth. The spatial multiplexing technique uses spatial diversity between separate data streams, and a receiver uses channel estimation to separate the streams and demodulate the data. A receiver's radio-channel transfer characteristics need to be programmable for efficient and controllable testing to verify a device's MIMO performance under different propagation conditions.

IEEE 802.11ac introduces MU-MIMO (multi-user MIMO) to WLAN. Single-user MIMO improves the data throughput to an individual device, whereas MU-MIMO re-uses resources to improve network performance, although the data rate to any individual user is not improved. The IEEE 802.11ac standard defines up to eight MIMO spatial streams and allows simultaneous transmission to up to four users. **Figure 6** depicts example MU-MIMO transmission with four spatial streams and three users.

MU-MIMO system design and verification bring on new challenges compared to single-user MIMO systems. Channel conditions between the users are critical for spatially multiplexing multiple users, and accurate CSI (channel state information) is required for proper transmission control and scheduling. Accurate CSI at the transmitter improves the capacity of the system by allowing simultaneous transmission to multiple users in a way that minimizes inter-user interference. In real environments, the channel characteristics between the separate users are not always independent of each other due to the short distance between users and the geometric arrangement of antennas. To verify MU-MIMO systems, carriers and vendors must be able to model and emulate the different propagation scenarios where the users can be located on geometrical basis. The use of a radio-channel emulator makes it possible to verify any environmental scenario in order to guarantee the MU-MIMO system performance under non-ideal conditions with several different levels of correlation between the parallel MIMO spatial streams for multiple users.

The MU-MIMO scenario in Figure 6 can be tested with a multichannel fading emulator. There is a separate fading channel between each transmitter and receiver when the downlink and uplink topology consist of 4x4 MIMO links with a total of 16 fading channels in both directions. Correlation between the channels is based on the antenna arrangement and the location of the users and their movement. GSCMs are good models for testing MU-MIMO where any kind of environmental scenario can be created and, additionally, where real antenna beam patterns can be included.

The test setup shown in **Figure 7** enables manufacturers to design and verify the 802.11ac device spatial multiplexing and beamforming algorithms as well as the critical CSI functionality with a single multichannel-fading emulator unit. An emulator that provides full control of the radio-channel characteristics enables performance testing that allows manufacturers to optimize the air interface performance and to maximize the achievable system throughput before launching products on the market. T&MW

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ON THE WEB

Sorting out 4G: Are we there yet?

Thanks to clever marketing campaigns, the general public believes 4G has arrived, but how close are we really to achieving the performance levels laid out in the IMT-Advanced global standard for international mobile telecommunications?

Janine Love reports that 4G/LTE mobile handset performance is much better than that of previous generations, and that designers are pushing the outer limits of performance in all parts of the handset to inch closer to the IMT-Advanced rates. In many cases, the factor limiting the technology is the available spectrum, so until governments act, engineers need to find creative solutions.

www.edn.com/120216LTE

Microcontroller circuit calibrates current loops

A team of engineers designed a 4–20-mA loop calibrator that costs less than $100.

BY ABDULKADIR ÇAKIR, FIRAT YÜCEL, AND HAKAN ÇALIŞ

Many industrial systems use the 4–20-mA loop to transmit measurements from sensors to displays, dataloggers, computers, PLCs (programmable logic controllers), and other devices. Unlike sending a voltage, sending a current eliminates losses in long wires and reduces interference from outside sources that can impair measurements. Plus, by using a measurement range that starts at 4 mA rather than 20 mA, the system can detect a failure should the current drop below 4 mA and take appropriate action that can prevent runaway conditions.

A 4–20-mA current loop circuit consists of a sensor, a transmitter, a receiver, and a current source (**Figure 1**). The sensor measures a physical attribute and converts it to a voltage. The current-loop transmitter converts the voltage into 4–20-mA current. The receiver converts the current back to voltage and most often sends the voltage to a digitizer embedded in the receiver for processing.

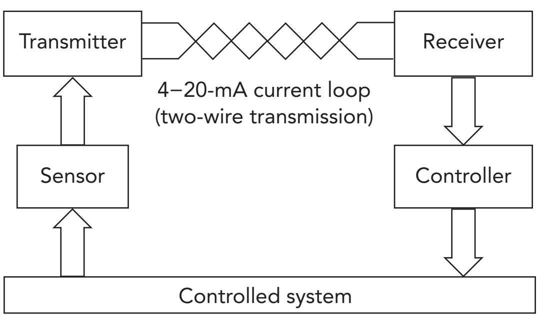

FIGURE 1. In a 4–20-mA measurement loop, the amount of current represents the measured value of a sensor, such as temperature, pressure, or weight.

Like any measurement system, though, 4–20-mA loops need calibrating. There are many loop calibrators on the market (**Figure 2**), but they can cost up to $2000. As an alternative, we've designed and built a low-cost calibrator based on a microcontroller. The calibrator we designed can be adjusted to the desired current level through a keypad. The calibrator can produce current with adequate precision and can automatically or manually perform a calibration on a measurement system.

FIGURE 2. The Fluke 707 loop calibrator sells for around $700 to $800.

Before designing our calibrator, we studied commercial calibration devices and found that they have these general properties:

- current production and reading in the interval of 4–20 mA,
- an operating voltage of 0–20 V,
- 0.001-mA (1-μA) resolution of current source,
- 0.012% accuracy of current reading,
- powered by a 9-V alkaline battery,
- 240-VAC tolerance,
- indication of current level as percentage (%) on the LCD indicator, and
- used with a two-wire transmitter.

Design of current-loop calibration device

Our calibrator consists of a numerical keypad, an encoder, a microcontroller, a DAC, an ADC, current sources, and an LCD indicator (**Figure 3**). We use a PIC16F877 microcontroller to control the system. We chose this microcontroller because it has a sufficient number of input ports for the LCD, keypad, and DAC. It also has an SPI (serial peripheral interface) port, an interrupt property for the keypad, and an internal ADC.

For the current source, the calibrator needs a microcontroller-controlled DAC with a current output range between 4 mA and 20 mA. We use a digitally programmable AD420 chip, which has a sigma-delta architecture with 16-bit precision, a current-output capability, and an SPI port.

We also use an ADC to measure current. The PIC16F877's ADC has 10-bit resolution and can measure voltage values between 0 V and 5 V. Current passes through a 0.47-Ω resistor and is amplified to 0–5 V by means of a noninverting amplifier. In addition, the calibrator uses a 4x3 numerical keypad and a 16x2-sized GDM1602B LCD module with an HD44780 LCD interface.

The calibrator has two modes. First, it produces current at the level of the entered value, and second, it reads the current sensed from the external current loop. In the current-source mode, the current information the user enters with the keypad is sent to the microcontroller, which analyzes it with a decoder.

The decoded current information is then transmitted to the DAC over the SPI bus, and the calibrator produces the desired current. In the measurement mode, the calibrator displays the value of the external current loop on an LCD.

We developed the microcontroller using Code Composer Studio in the PIC C language. The software sets the calibrator to work in the current-source or current-measurement modes. **Figure 4** shows the flow chart of the main program.

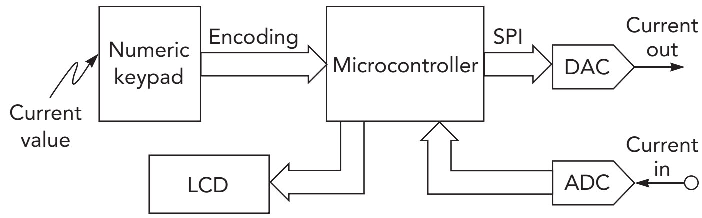

FIGURE 3. The microcontroller-based design uses a DAC, an ADC, a keypad, and a display.

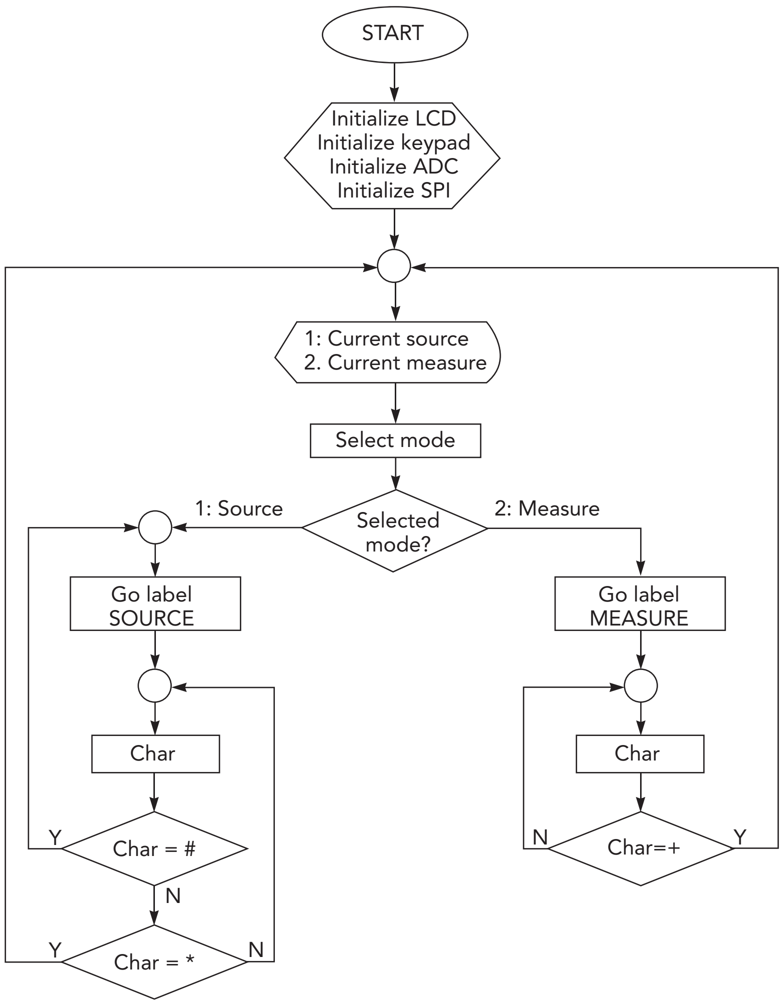

FIGURE 4. Embedded software lets the calibrator both produce current and measure loop current.

In the current-source mode, the embedded program runs according to the flow chart in **Figure 5**. The user enters a current value with two digits to the left of decimal point and three digits to the right of decimal point (at precision of 0.1%). If the user wants to use a step-base proceeding, the calibrator can produce five step values: 4 mA, 8 mA, 12 mA, 16 mA, and 20 mA.

Once the third digit to the right of decimal point of current value is entered, the data for generating current transfers to the AD420 using SPI protocol. The calibrator generates the output current and "OK" appears near the current value on the LCD. If the user enters a current value out of the allowed range (below 4 mA or above 20 mA), the message "Output range is exceeded" appears on the display. *(continued)*

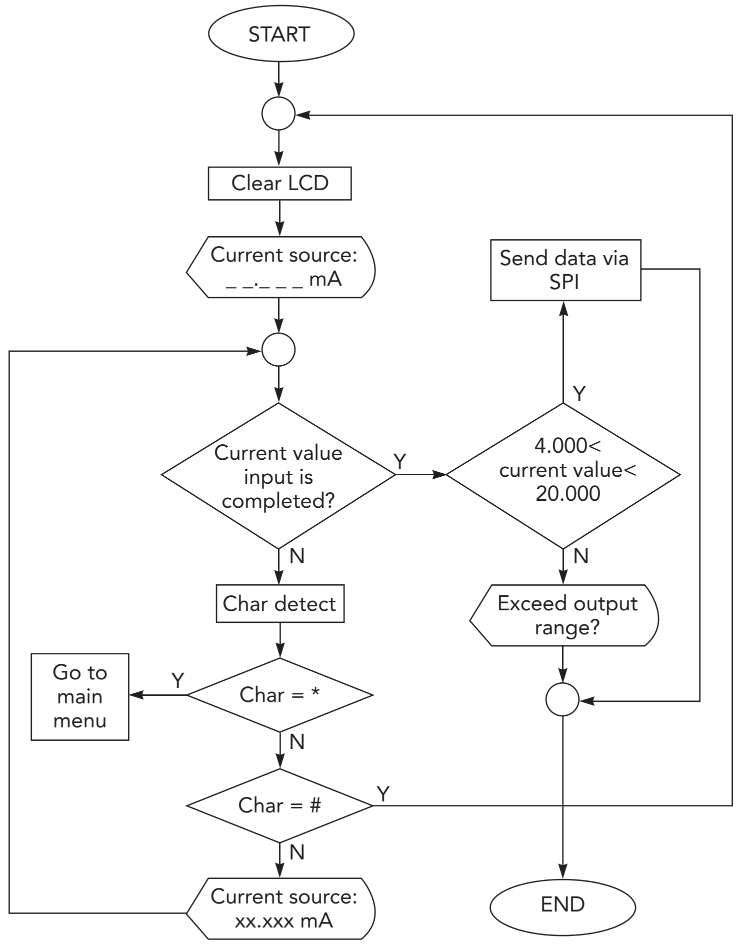

FIGURE 5. Software checks that the user input falls within the range of 4–20 mA.

In current-measurement mode (**Figure 6**), the calibrator's ADC reads the level resulting from the voltage amplification layer, and the screen displays the measured current value.

When designing the keypad interface, we used the "change on-state" interrupt property of the PIC16F877 for sensing when a key is pressed. With this property, when the state is changed on the B input ports of the microcontroller, an interrupt is started automatically. Thus, when the device is not in use, the microcontroller passes to sleeping mode to save power.

Two important keys in the keypad are the * and # keys:

• When a user presses the * key, the system will return to the mode-selection menu (main menu).

• When a user presses the # key, the device will cancel the current operation and display a clean screen on which the user can enter a new current value.

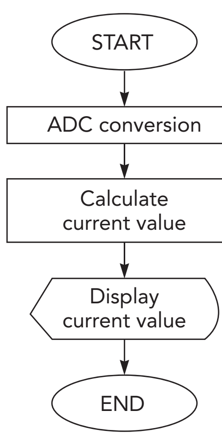

FIGURE 6. Microcontroller software converts a digitized voltage across a known resistor into units of current for the display.

Current source and measurement

Figure 7 shows the digital outputs of the microcontroller that connect to a DAC circuit (AD420) with 16-bit CMOS current output using the SPI protocol. With this circuit, the device acquires a current output value in the range of 4–20 mA (according to range selection).

The DAC has 16-bit resolution and this resolution is used at the 4–20-mA range. We can determine the acquired current source sensitivity (Ss) with this equation:

$$S_S = \frac{\text{Range of Current}}{\text{Resolution}}$$

$$S_S = \frac{20\text{ mA} - 4\text{ mA}}{2^{16}} = 244.14\text{ nA}$$

Thus, a change of ±1 LSB (least-significant bit) in data transmitted to the DAC produces a change in the output current of ±244.14 nA. But because the user can enter a current value with three digits after the decimal point, the calibrator's current-sourcing resolution is 0.001 mA. We can adjust this precision value through software.

For the current measurement, we use the ADC module inside the microcontroller. The conversion process is achieved over the resolution of 10 bits. To measure the current, the calibrator passes the current over a very low-value resistance and sends it to the ADC. During the current measurement, the device is connected in series with the measurement loop. We assume that the internal impedance of the device won't affect the circuit or that, at the least, the effect of that impedance is very low. For the current-to-voltage conversion, we use a resistance of R_X = 0.47 Ω. As a result of using the low-value resistance, the acquired voltage level (V_{ACQ}) at the maximum current level (I_{MAX} = 20 mA) is very low:

$$V_{ACQ} = I_{MAX} \times R_X = 0.020 \times 0.47 = 9.40\text{ mV}$$

In order to increase this low voltage level to 0–5 V, we designed a noninverting amplifier circuit with an LF351. The gain of this amplifier (G) is calculated in the following equation, where V_O defines output voltage, and V_I defines input voltage:

$$G = \frac{V_O}{V_I} = \frac{5}{9.4 \times 10^{-3}} \simeq 531.91$$

As a result, we can calculate the measurement sensitivity (S_M) with the following equation:

$$S_M = \frac{V_I}{\text{Resolution}} = \frac{9.4 \times 10^{-3}\,\text{V}}{2^{10}} = 9.18\ \text{nV}$$

This value corresponds to a high enough sensitivity value for the 4–20-mA range. But due to the characteristics of the op amp and because of noise effects, this sensitivity ratio decreases.

At the end of the digital-to-analog conversion process, the calibrator produces a DC current. But there are limits for this current to drive the connected load and keep the linearity. One of these limits is current-loop voltage compliance, which is the maximum voltage projected over the load that can be connected to current output.

Basic properties of the calibration device

During our first experiments, we used a DAC908 IC, which has 8-bit resolution, to create the output current. The output compliance limit for this IC is between −1.0 V and +1.25 V, which means a maximum load resistance of 1.25 V / 20 mA = 62.5 Ω can be connected to the current output. This value is too low for a process-control system using a voltage of 24 V for the current loop. Additionally, the DAC908 is a high-speed DAC Making it difficult to acquire signal at such low frequencies. For these reasons, we chose the AD420 instead.

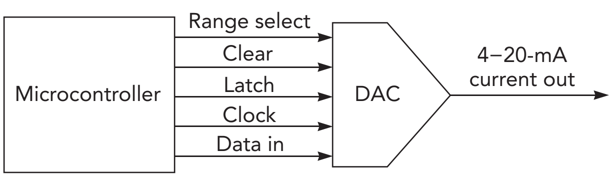

FIGURE 7. A DAC takes a digital value from the microcontroller and converts it into a 4–20-mA loop current.

Our resulting calibration device has an input and output range of 4–20 mA. The current output error is ±1 nA in experiments done at room temperature. The maximum load drive capacity is 600 Ω for a 12-V loop voltage.

For the 4–20-mA current production range, a 24-V operating voltage level is required. The externally applicable loop voltage is 32 V at maximum. The total cost of the implemented calibrator is about $50 to $100 (US$).

The device has only English language support for now. In the future, we hope to make several improvements: add a percentage mode to the display, provide support for multiple languages, and enable input through a touch pad. **Table 1** summarizes the calibrator's specifications. T&MW

ACKNOWLEDGEMENT

The authors thank Süleyman Demirel University, Scientific Research Projects Coordination Center for the financial support of this work under grant #1022-M-05.

Table 1. Specifications of the microcontroller-based loop calibrator.

Parameter	Value
Type	4–20-mA digital current-loop calibrator
Input and output range	4–20 mA
Current output error[1]	±0.15% @ T_A = 25°C
Current source resolution	0.001 mA
Measurement sensitivity (S_M)	9.18 nV
Temperature deviation[1]	0.003% full-scale/°C
Maximum load (drive capacity)[1]	600 Ω @12 V
Voltage compliance	10.5 V
External conversion loop	Maximum 32 VDC
Display	16x2 LCD (3.00x5.23-mm character font)
Keypad	4x3 numerical keypad
Feedback warning indicator (LED)	Output-error recognition and open-loop recognition
Power supply	220 V/12 VAC Adapter

[1] These parameters were determined based on the ADC data sheet.

FOR FURTHER READING

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Standards define test impulses differently

Different standards use different definitions for voltage and current waveforms based on the amplitude, rise time, duration, and impedance.

BY JEFF LIND, COMPLIANCE WEST

Electronic products must pass some level of immunity tests when subjected to conducted or radiated energy. Some of those tests include subjecting the equipment under test to electrical impulses: short-duration single events using defined voltage and current waveforms. Engineers also use impulse tests to verify electrical spacings on PCBs (printed-circuit boards) and to periodically check motor insulation.

Several international standards define impulse voltage and current waveforms, but only at certain points. The waveform shape, peak voltage, impedance, and application of the pulse vary among standards. So, the test pulse you use will depend on the standard you apply.

Waveform definition

The IEC (International Electrotechnical Commission) has at least two standards that define impulse tests and their waveforms. You would use IEC 60060-1, "High-Voltage Test Techniques," when testing insulation systems, and you would use IEC 61000-4-5, "Testing and Measurement Techniques – Surge Immunity Test," when performing switching and lightning-transient tests. Many end-use standards that define the testing of specific products reference one of these two standards.

In some end-use standards, both the insulation system of the DUT (device under test) and the ability of the device to withstand lightning and switching transients are important. The requirements of IEC 60060-1 and IEC 61000-4-5 are different, though, so the authors of an end-use standard must decide which is the better standard to reference. A relevant example is IEC 61730-2, a standard that covers safety qualification testing for PV (photovoltaic) panels.

In the PV standard, the authors note that the purpose of the test is "To verify the capability of the solid insulation of the module to withstand over-voltages of atmospheric origin. It also covers over-voltages due to switching of low-voltage equipment." While this scope seems to be closer to that of IEC 61000-4-5's surge-immunity test, the authors elected to conduct the test under the requirements of IEC 60060-1's insulation-impulse test, which they deemed a better definition of their test program.

Insulation system testing

IEC 60060-1 defines a waveform by a rise time, peak value, decay time, and tolerances. These parameters can completely define a voltage or current waveform. Since the insulation tests are conducted on open circuits, this is all the definition that is needed, and IEC 60060-1 notes that the specified wave shape should be delivered to the DUT. Footnotes to Paragraph 19.2

allow some deviation in waveform shape and peak voltage for instances when the DUT is capacitive or reactive. But because the waveform will check an insulation system, no significant capacitance or reactance is anticipated, and the standard gives no impedance specification. Thus, no current requirement exists in the case of a voltage tester.

This may seem to be a problem if the DUT is capacitive, but raising power offers little improvement in the resulting waveform. Furthermore, these tests are always conducted on equipment that's not connected to mains power or otherwise energized.

Lightning and switching transient testing

IEC 61000-4-5 defines a waveform by a rise time, peak value, decay time, impedance, and tolerances. Because tests can be conducted in many configurations, the waveform is specified into an open circuit (voltage waveforms) or short circuit (current waveforms). IEC 61000-4-5 specifies only a 2 Ω, 1.2x50/8x20 combination generator. Appendix 2 of the standard, however, gives guidance regarding the tester's impedance depending on the location of the test application:

- 2 Ω, mains testing;
- 12 Ω, mains to ground testing; and
- 42 Ω, secondary to ground testing.

Annex B of IEC 61000-4-5 provides for powered and unpowered testing and gives guidance for maximum impulse levels depending on the application. In Annex C, the standard provides guidance for judging the DUT's performance. The authors of an end-use standard define these points.

While the IEC gives organizations that develop end-use standards the tools to administer impulse tests in a standardized fashion, the organizations are under no requirement to adopt the tools in their standards. For example, IEC 60601-1, which defines safety requirements for medical equipment, implements an impulse test that simulates a defibrillator. The input voltage and circuit components are defined, while the output waveform and voltage aren't. Although the guidance in IEC 60060-1 and 61000-4-5 is well-written and well-received, the standards can't cover every instance.

In addition, standards may use different impedance values for their testing. In some cases, the impedances provide a special current level at a breakdown voltage. Sometimes, a standard's authors choose an impedance value to minimize breakdown damage, or they show a value in response to a known circuit parameter. For example, a standard might specify that a purely resistive load such as a meter socket be tested with a 500-Ω impedance tester.

Impulse waveform uses

If an end-use standard references either IEC 60060-1 or IEC 61000-4-5 or a standard otherwise defines a pulse by rise time, peak, decay time, and possibly impedance, the resulting waveform will be as shown in **Figure 1a**. One of the most popular voltage waveforms is the 1.2x50, where the rise time is 1.2 µs and the decay or duration time to half value is 50 µs. Tolerances for this waveform are 1.2 µs to rise from 30% to 90% of peak ±30%, and time to half value is 50 µs ± 20%.

Both reference standards use the same definitions and tolerances for this waveform, but IEC 61000-4-5 specifies delivery into a short circuit and IEC 60060-1 requires this waveform be applied with the DUT attached. Voltage impulse testing is used to find dielectric breakdowns in insulation systems and to test for performance when transients are present.

Figure 1b shows that the popular current waveform of 8x20 has a rise time of 8 µs ±20% into a short circuit (IEC 61000-4-5) or with the DUT attached (IEC60060-1). The waveform has a decay to half time of 20 µs ±20%. Use a current pulse with a known breakdown voltage. The test is designed to stress the breakdown components with a specific current. In these cases, the impedance requirement of the tester may be tailored to provide the desired test current to the DUT at the breakdown point. Specifically, one of the impulse tests for gas-tube devices requires a 100-Ω impedance to provide a 10-A pulse at a breakdown voltage of 1000 V. *(continued)*

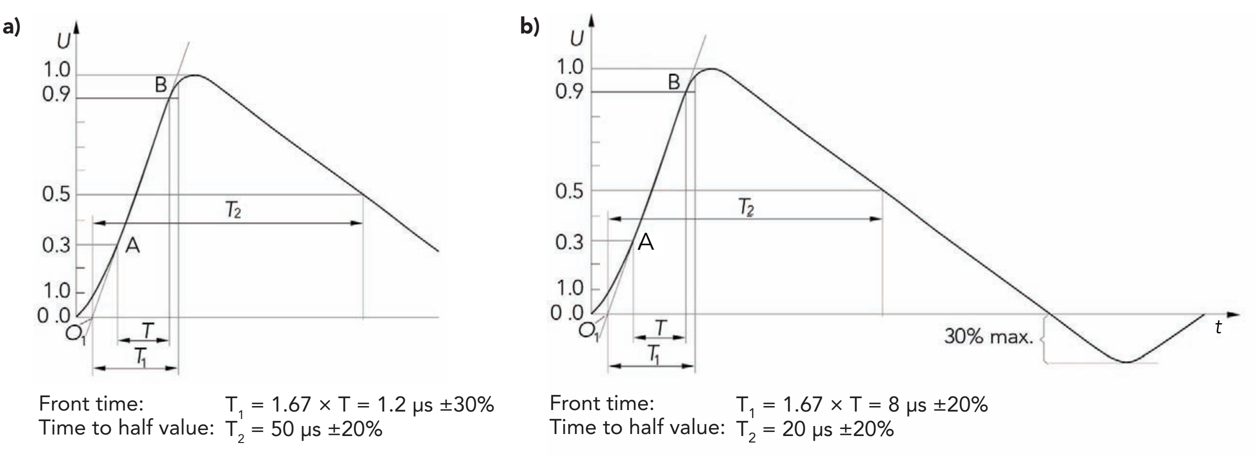

FIGURE 1. a) Specifications such as rise time, peak value, and time to decay to 0.5 of peak define voltage and current test waveforms. The "U" in the vertical scale indicates portion of peak value. b) The waveform for test current into a short circuit rises within 8 µs ±20% (value of T) and can go negative by as much as 30%.

IEC 61000-4-5 defines the popular combination waveform impulse tester as well as both the voltage and current waveforms. As noted above, the standard defines only a 2-Ω tester, but it notes other output impedances as well. The impedance of a surge tester is defined as the ratio of the peak open-circuit voltage to the peak short-circuit current. These values will change when a device is being tested.

Coupling-decoupling networks

When conducting a powered test in accordance with IEC 61000-4-5, you should use a CDN (coupling-decoupling network) to present a high back impedance to the surge waveform toward the supply. That still lets the impulse flow to the DUT. The standard presents circuits for CDNs used for various tests, and the CDNs have to be designed to provide a waveform that is within tolerances specified in IEC 61000-4-5. Because of these performance requirements, CDNs have to be designed for specific waveforms, voltages, and currents, or there is a chance the CDN may not perform to the specifications. Always use a CDN when performing mains-powered tests. IEC 61000-4-5 has various schematics that illustrate how to use a CDN with other ports as well. A CDN isn't required for unpowered tests because there's no power supply to protect.

Depending on which of these two standards your end-use standard references, the tester you select can vary greatly. If the end-use standard uses IEC 61000-4-5 as the referee document for impulse waveforms, then the pulse will be defined without the device being tested in place. That is, the tester's voltage pulse will be evaluated when delivered into an open circuit, and the current pulse will be evaluated into a direct short. If the end-use standard uses IEC 60060-1 as the referee document, then the pulse will be evaluated with the device being tested as part of the circuit. This can cause huge differences in the pulse if the device being tested presents anything other than an open circuit to the impulse tester in its tested configuration. Although IEC 60060-1 does allow waveforms to vary when the load is capacitive, these variances are limited. In these cases, the limiting factor may not be impulse tester power but the lead and internal tester impedance, which may be difficult to decrease.

Waveform verification

There are many definitions of impulse waveforms, and different referee documents differ in the way they treat the application of the impulse to the device being tested. Some waveforms are used to evaluate insulation systems, or determine behavior at an expected breakdown voltage, or to evaluate systems when presented with a mains transient.

The different definition schemes may make it difficult to verify whether the waveform was delivered correctly. If an end-use standard covering the equipment being tested specifies either IEC 61000-4-5 or IEC 60060-1 as the referee document, then you can verify correct operation by using an oscilloscope and comparing the waveform to the standard. Some waveforms in end-use standards, however, are defined by specifying the input voltage and circuit components. These pulses have undefined output peak voltage. While this is a valid method for defining a pulse, it is difficult to verify correct pulse delivery unless you can access the source voltage and can check component tolerances.

Some end-use standards use proprietary circuits that include the impulse tester and a CDN. The tester controls component values and input voltages. In these testers, you may have difficulty finding the correct output as well, so comparing the waveform to a waveform record taken at the last equipment calibration may be the best verification method.

Check the scope of your end-use standard to see which standard defines the impulse waveforms used. Be sure to read that standard to make sure your test will be in compliance with all required standards. T&MW

Jeffrey D. Lind *has more than 33 years of electrical engineering experience. He launched his career at Underwriters Laboratories and then worked for Atari and Sega Gremlin. In 1997, Lind started Compliance West. He received his BS in electronic engineering from Cal Poly San Luis Obispo.*

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STEVE SCHINK
President
LXI Consortium

Steve Schink is a marketing planner at Agilent Technologies. With more than 20 years of technical, marketing, and management experience at Hewlett-Packard and now Agilent, he has participated in numerous connectivity solutions, including the development of the IO Libraries Suite, and he has worked with the IVI Foundation, USB Implementers Forum, and the LXI Consortium on standards efforts. He earned MSCS and BSCS degrees from the University of Wisconsin–Madison.

LXI Consortium: Keeping up the momentum

As the new president of the LXI Consortium, I am fortunate to have inherited a well-accepted instrumentation standard. In just six short years, our members have introduced more than 1700 products with LXI-compliant LAN ports to reduce the size and cost of test systems, while increasing performance and simplicity. And these LXI devices are available in over 180 different product classes: Virtually any stimulus, measurement, or power source required for test and measurement applications can be controlled via Ethernet and the LXI standard.

These numbers have greater significance when you look at them compared to the overall test and measurement market. Von Campbell, my predecessor as president of the Consortium, did some preliminary market research and found that at least 90% of the major companies in the test and measurement market are members of the consortium. It was his estimate that if you purchase a new instrument or power supply, in most cases, the device will have LXI as a communication port.

While GPIB is still strong, we do see new instruments being released without it. The LAN port is ubiquitous, and LXI standardizes the user experience and is interoperable.

So in 2012, what does the LXI Consortium plan to do to keep the momentum going? Well, for one thing, we will continue to inform engineers about LXI's ease of integration, standardized driver architecture, and built-in Web page, and we will also work to increase awareness about the breadth of companies implementing and encouraging LXI usage to support test engineers in making the transition to LXI-based equipment. In a *Test & Measurement World* survey of 305 test engineers, 69% have test systems with measurement instruments that connect via Ethernet, but 38% were familiar with LXI and 8% use LXI. We'd like to improve these numbers in 2012.

To help increase awareness and use of LXI, we plan to offer a quarterly newsletter that will talk about the latest LXI test solutions, applications, and standards technological development. You can sign up for the newsletter on our Website (www.lxistandard.org).

We have also heard from you, our customers, that issues can arise with corporate IT and networking policies that limit the use of LXI instruments on corporate networks. For the majority of applications, placing the LXI instruments on a subnet connected to a PC eliminates this fear. Going forward, I'd like the Consortium to help take the fear out of network-based test by providing information to assist customers who are using LXI instruments on corporate networks.

We are also preparing for future technologies such as IPv6 with plans to support the next generation of Ethernet as IPv4 addresses run out. Also, we are working closely with the IVI Foundation to add a new high-speed LAN instrument protocol (Hi-SLIP) that will bring higher performance and backward compatibility to our systems.

I'm eager to begin 2012 with these and more endeavors to accelerate the use and understanding of LXI. Together with our members and you—our customers—we hope to clear the way in terms of improved system performance, reduced test costs, and easier use and integration, so that together we can build successful programs and test systems and accelerate innovation.

To learn more about the latest revision of the LXI standard (Rev. 1.4), go to www.lxistandard.org and click on the link to view "LXI Today and Tomorrow – Evolution, Certification and Choice." T&MW

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

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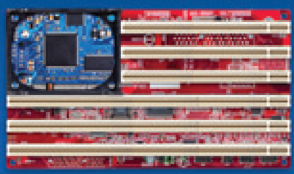
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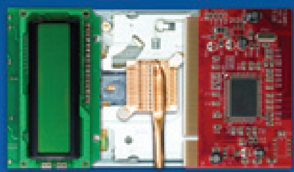
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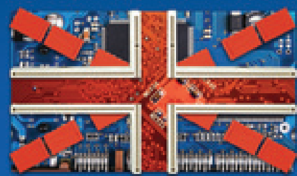
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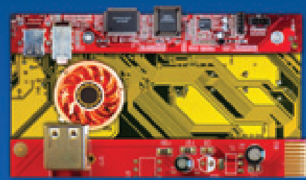
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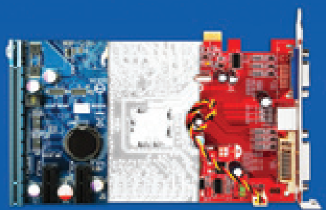
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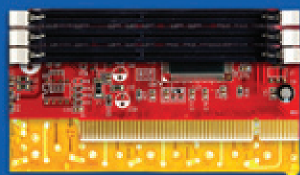
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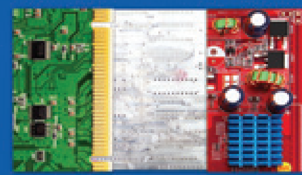
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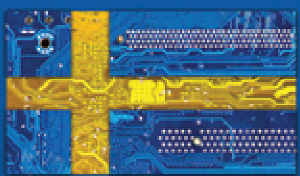
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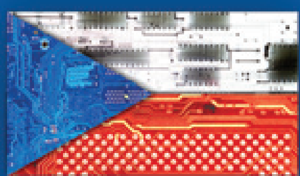
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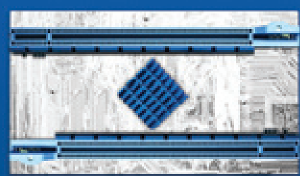
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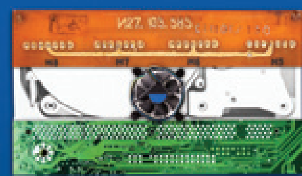
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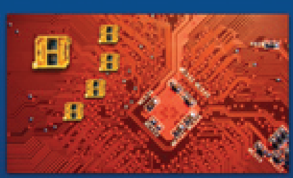
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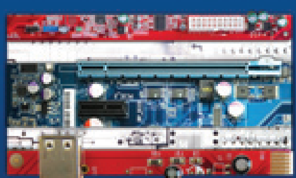
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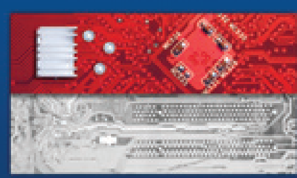
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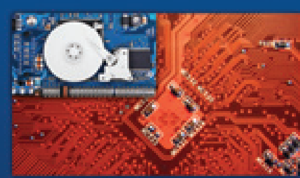

Taipei **TAIWAN**

An industry in transition

By Bolaji Ojo

Nobody has come up with a catchy alternative yet, but it is becoming increasingly clear that the term "electronics distributor"— harking back to the group's origin as middlemen that linked component vendors with customers worldwide—has outlived its usefulness. The misnomer does little justice to the range of services that the sector's diverse participants perform nowadays, and it might be time to dump it altogether.

A look at Avnet Electronics' latest annual filing with the U.S. Securities and Exchange Commission bolsters that argument. The filing states that Avnet "provides engineering design, materials management and logistics services, system integration and configuration, and supply chain services that can be customized to meet the requirements of both customers and suppliers." Of course, the company still functions as an "industrial distributor of electronic components, enterprise computer and storage products, and embedded systems," but it is no mere middleman. Rather, it is "a vital link in the technology supply chain."

Distributors have added design, inventory management, logistics, subassembly and other services. How much deeper into the electronics design and supply chains are they willing to extend themselves?

The description is not hyperbole. And it applies not only to distribution giants like Avnet, Arrow, World Peace Group, Future, Digi-Key, Mouser and Element14, but also, increasingly, to midsize and niche players. This editorial package, a joint project among the publications of UBM Electronics, provides ample evidence that in all segments of the electronics industry, the companies we know today as distributors are increasingly critical resources for design and related value-added services. In short, today's distributors have taken on many more responsibilities than tradition has assigned them.

The expansion of distribution's role raises key questions not just about distributors, but also about the fundamental changes occurring in the industry and in society at large. As distributors add design functions to their slate of offerings,

INSIDE

what is the effect on their relationship with their various constituencies—component makers, the OEMs that have traditionally handled design, the outsourcing community on which equipment vendors rely for production, and the customers who rely on their services? How many more OEM and vendor functions can distributors absorb? What are the implications of this brand extension for the design and supply chain? Who benefits most from the new twists in relationships among suppliers, distributors and their customers? And how do the players get reimbursed for their services in an environment where goods and ideas crisscross national and corporate boundaries?

The lines of demarcation are being erased across all industry segments

The articles in this special editorial package examine those questions and provide perspective on how the industry can best manage its evolving web of interrelated business models.

The discussion is only just beginning. As technology innovations have accelerated, so has the complexity of the industry's relationships. The lines of demarcation are being erased not just between OEMs and their EMS providers, but across all industry segments.

Indeed, even the definition of OEM is changing rapidly.

The OEM ranks thinned out during the recessionary Y2K period but have expanded fast since then to accommodate some players that bear little resemblance to the typical OEM of 2000. In addition to "traditional" companies like Microsoft and Apple, industry participants now include bookseller and Nook e-reader vendor Barnes & Noble; online retail titan, Kindle creator and, if speculation proves correct, aspiring smartphone market participant Amazon; and Google Inc., which leveraged its high value in search engine optimization to launch Android and purchase a traditional OEM (Motorola Mobility).

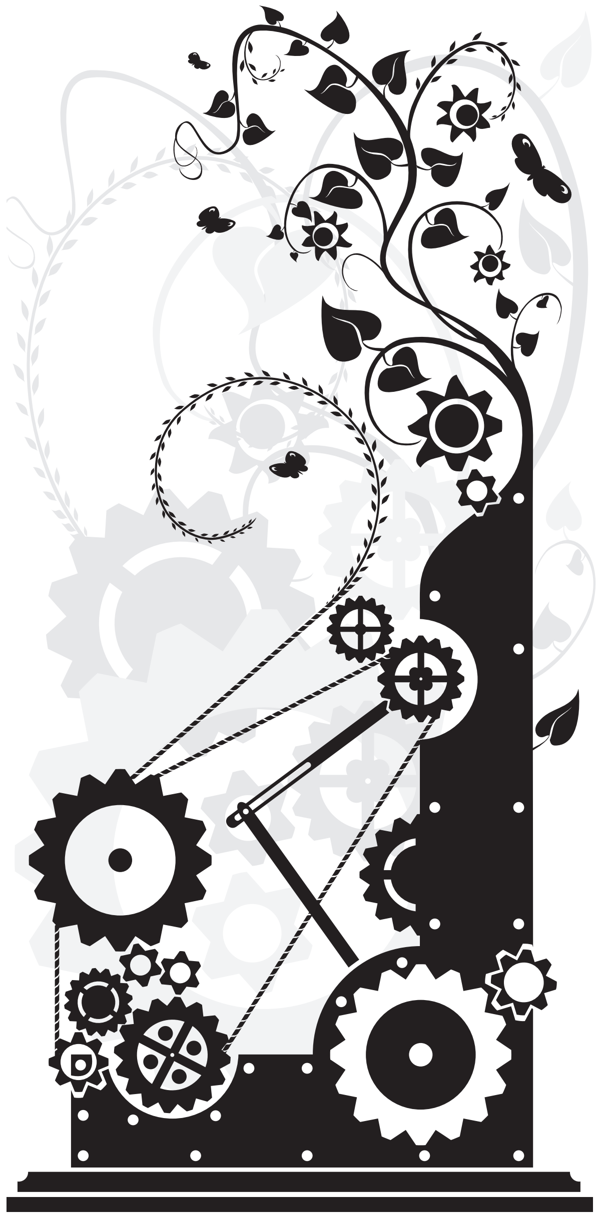
I suspect distributors will somehow find new ways to serve everyone in the industry, whatever direction they pursue. That's because they've changed faster than any other segment over the past 20 years and have a depth of offerings and market penetration that few can match. Avnet alone says its roster of customers includes "more than 100,000" OEMs, EMS providers, ODMs and VARs, in addition to hundreds of component makers.

Such companies can rightly still be called distributors only in the context of how extensively their distributed services touch all segments of the industry. ■

Bolaji Ojo (*bolaji.ojo@ubm.com*) is editor in chief of *EBN*.

Keeping the channel relevant in an ever-changing world

By Barbara Jorgensen



Electronics distributors have seen wrenching changes in the industry over the past two decades and have had to adjust rapidly to the demands of their customers. The channel's traditional model of order fulfillment has evolved to include design services and engineering support. Meeting the needs of both the engineering and procurement departments isn't always easy, and distributors are resolving this dilemma in a number of ways.

Until fairly recently, distributors' main focus was on purchasing—securing large-volume orders to be shipped to manufacturing sites around the world. Engineers either interfaced directly with component suppliers or worked with catalog distributors.

A number of factors have changed that. First, suppliers are cutting back on their technical support to all but their major customers. Second, the global regulatory environment has made the supply chain increasingly complex. Distributors, which interface extensively with both their suppliers and their customers, have seen an opportunity to fill in some gaps by expanding their role in the supply chain.

As component suppliers have cut back on their support, customers have been turning to distribution for design assistance. As extensions of their suppliers' sales forces, distributors are trained in many technologies. Since most distributors carry a wide variety of suppliers—some in the hundreds—the channel has a bird's-eye view of how these technologies interact.

Distributors are in a unique position to assist designers in selecting the best mix of components for their end products.

That has required a change in the way distributors interact with suppliers and customers. In the past, distributors would typically push a supplier's product—a Texas Instruments or Intel part, for example—as the mainstay on a customer's pc board. Now, instead of focusing on a single product, distributors focus on solutions.

This approach takes a combination of products, directs them toward an application, test drives the solutions and offers them to the market. Intel and TI products may be on the board, but so are the capacitors, resistors and connectors that complete the solution. Even longtime competitors appear side by side on the same board.

Interactive communities like the Knode are 'a gateway into ... design solutions'
— Jeff Jussel, Premier Farnell

Some distributors are taking design assistance a step further and are guiding customers to design tools as well as components. Catalog distributor Element14, for example, has created an interactive site hosting component data, EDA tools, design-related content, pc board prototyping services, an engineering community and a components store.

For now the community, called The Knode, targets the pc board design and embedded systems markets, but there are plans to expand into other design areas, such as FPGAs, according to Jeff Jussel, senior director of global technology for Element14 parent company Premier Farnell plc.

"We see this as a gateway into engineering design solutions," Jussel told *EBN*. "We now provide solutions beyond component development kits and hardware tools: We can help engineers with the design, their component selection, their pc board services and their prototyping needs, and contain it all in one 'room.'

"The concept is to present these solutions to engineers and let them do their work faster, with less risk, and in a way that makes sense to them."

All this engineering assistance comes at a cost, however. Distribution is first and foremost a sales-driven business model. High-salaried engineers are a fixed cost in these organizations and have to be deployed toward distributors' most profitable opportunities. Distributors are trying to scale their design services toward a highly segmented customer base.

While distributors can spread the expense of hiring engineers over a customer base that numbers in the tens of thousands, they are also turning to their suppliers for support. Global distributors Arrow Electronics Inc. and Avnet Inc., for example, host several programs every year that include suppliers and customers. Events such as Avnet's X-Fest and its SpeedWay and On-Ramp programs offer intensive hands-on training sessions that bring suppliers and customers face-to-face.

On the fulfillment side of the business, distributors face many of the same challenges as OEMs. Electronics companies are under increasing pressure to become better global citizens. Manufacturers are being asked to provide information on the materials they use, where those materials are sourced and to whom their products are being shipped. Distributors are frequently conduits of such information.

For example, environmental mandates such as the European Union's RoHS directive require manufacturers to document their compliance. Most OEM systems aren't set up to track and sort millions of components, but distributors' systems are. So OEMs rely on distributors to stay on top of a variety of environmental laws.

Only a decade ago, the Internet threatened to render the distribution channel irrelevant. That hasn't happened, but distributors realize they have to keep evolving to keep customers engaged. The channel has moved from the parts-fulfillment business into the design realm and still has room to grow.

"We've moved from selling parts to making complexity seem simple," Arrow CEO Michael Long said at a recent industry conference. "But innovation is the cost of entry." ■

Barbara Jorgensen (*barbara.jorgensen@ubm.com*) is community editor at *EBN*.

Need design guidance? Ask a distributor

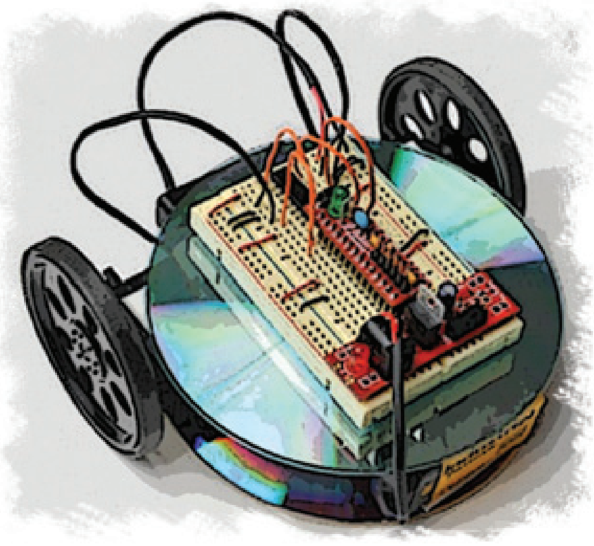
By Paul Rako

Component vendors and resources like *EDN* are go-to sources for design guidance, but electronics distributors can also help you get your designs off the ground.

Many distributors have their own teams of application engineers. Companies such as Newark offer libraries of application notes and white papers, as well as training and design tools.

In addition, distributors like Avnet Inc. have long championed reference designs as a way to help OEMs speed product evaluations. Sometimes component vendors do these reference designs, but distributors have also stepped up to the challenge of creating their own. If enough customers request a design, many distribution companies have the engineering talent on hand to supply it. So even if you don't see the reference design you need, be sure to ask your distributor if it can come up with the required reference platform.

Distributors also partner with other vendors to provide design services. For example, Avnet's Technology Solutions group partners with Palo Alto Networks to help with firewall solutions, and it teams with Lincor Solutions to handle clinical assessment and entertainment systems. Avnet's Electronic Marketing division conducts technical seminars and workshops on such topics as designing with USB or ARM. There's a Design with Avnet section on the company's Web site, and there's even a technology museum at Avnet's Phoenix headquarters. And Avnet Express is UBM Electronics' partner in the Drive for Innovation, a program in which Brian Fuller of *EDN* sister publication *EE Times* has been driving a Chevy Volt around the country and meeting with engineers.



The One-Hour CoasterBot, built with a handful of parts and unreadable CD castoffs (derisively nicknamed coasters), is one of the fun—and instructive—DIYs featured on Jameco's Web site.
Photo credit: Jameco

Digi-Key has long helped design engineers get the job done. If you need information on the on-resistance of a 200-volt p-channel FET, you could go to five or more component vendor Web sites and look up the parts. But it's far easier to conduct a search on *digikey.com* and filter for your desired specs, such as the lowest on-resistance available from the vendors that distribute through Digi-Key.

The distributor also offers product training modules and videos to help customers understand their design challenges and trade-offs, and it has reference designs on hand and application engineers on staff to help designers get started.

Perhaps Digi-Key's most valuable design-related service is its TechXchange forum, where designers can share information and pick the brains of Digi-Key's application engineers. A recent discussion centered on how to power an LCD through a microcontroller output pin. Alec, a Digi-Key engineer, was monitoring the forum and responded: "I asked one of the other engineers here at Digi-Key, and he says he has used small LCDs with that level of current draw and powered them directly from an MSP430 GPIO pin without any problems."

Digi-Key also partners with National Instruments, NXP, Screaming Circuits and Sunstone in what the participants call a circuit design ECOsystem. The capitalized ECO riffs on the engineering change order, but the use of "ecosystem" reminds designers they need distribution, board fabrication, simulation and testing, as well as an IC vendor, to get a design working and ready for production. The ECOsystem helps them move from parts research to circuit design, fabrication and assembly, and validation and test.

Mouser is another distributor that does more than just stock parts. Its Product Knowledge Center has information on more than 1,700 topics to help engineers strategize and refine designs. The company also offers a search accelerator that can be added to a browser to expedite part searches, an often frustrating part of the design process. And Mouser's project sharing system lets designers share projects with coworkers.

Even smaller distributors, such as Jameco, offer design assistance. Electronics guru Forrest M. Mims III describes his favorite designs on Jameco's Web site. The site also offers a DIY section that offers fun projects, such as the One-Hour CoasterBot kit. Such diversions might not solve an immediate design problem, but they let engineers get hands-on experience in areas such as robotics and analog design.

Be sure to consider the resources and talents of distributors as you plan your next design project. They have the tools and expertise to help you get a jump on the competition. ■

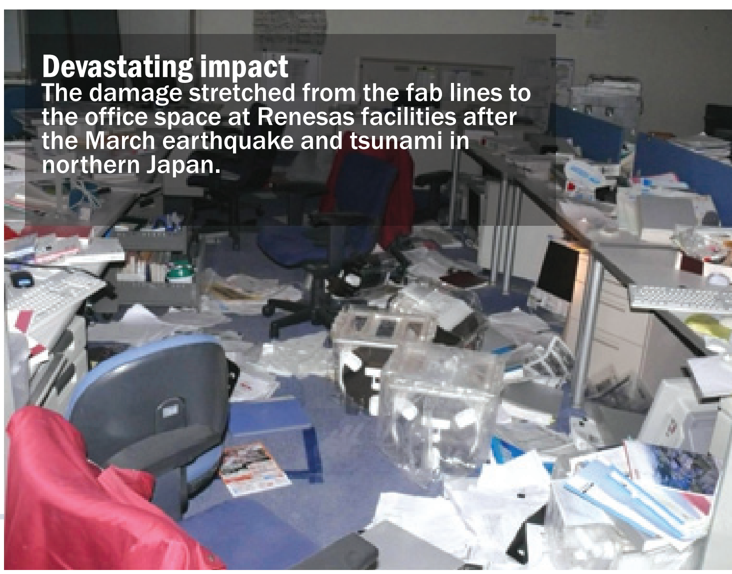
Paul Rako is a former *EDN* technical editor.

Disasters, shortages, counterfeits: For industry, 2011 was a year of wakeup calls

By Junko Yoshida

The electronics industry got a rude awakening—or a series of them—in 2011. It was a year in which any hiccup in the supply chain posed the threat of profound disruption for OEM businesses ranging from automaking to light bulb manufacture.

Supply chain issues that plagued the industry last year included the great earthquake and tsunami that hit Japan in March; the increasing rarity of rare-earth materials; and an alarming uptick in chip counterfeiting, which has brought new national-security headaches.



Devastating impact
The damage stretched from the fab lines to the office space at Renesas facilities after the March earthquake and tsunami in northern Japan.

Their finest hour
Dan Mahoney, president and CEO of Renesas Electronics America, characterizes the rebuilding period as his colleagues' finest hour. Part of the process, once the crisis was over and manufacturing capability was restored, was to draft a 'fab network' plan that would get the company through the next disruptive event.

Before and after
Although there was damage to equipment inside clean rooms like this one, shown before and after the repairs, the buildings themselves held up well, having been engineered and constructed to withstand seismic activity.

Everyone in the industry knows their business lives or dies by the supply chain, but nobody fully appreciates its centrality until a catastrophe serves as a reminder. Then, at least for a time, folks get serious about devising plans to cope with the next distribution crisis.

The problem is, every supply chain problem is unique in terms of its cause, its impact and its appropriate solution.

Often, distribution ruptures cannot be repaired by distributors alone. It takes serious collaboration all along the supply chain—component suppliers, distributors and OEMs included.

To complicate matters, the supply chain itself has become increasingly fragmented. The rise of Internet trading, the increased use of electronics manufacturing service providers in diverse locations, and system vendors' giving in to the temptation of faster and cheaper solutions have all compromised supply chain visibility. That, in turn, has created new entry points for counterfeit chips, as the industry and government discovered last year.

Topping the list of 2011 events in terms of damage to the supply chain was the March 11 earthquake and tsunami. The catastrophe's repercussions were spread broadly among the materials, components and equipment segments of the supply chain. A shortage of MCUs from Renesas—hardest hit among the Japanese chip companies slammed by the quake—sent shock waves of production-line disruptions through tier-one automotive manufacturers like Nissan and Honda, as well as through second- and third-tier-automotive subsystem suppliers.

Thanks to the combined efforts of the IC vendors themselves and their suppliers, customers and competitors, even the most damaged chip vendors resumed full production before the end of the third quarter. But a robust redundancy program to stave off the next supply crisis is still in the works.

In an interview with *EE Times* last fall, Yasushi Akao, CEO of Renesas, laid out his vision for a "fab network" of production lines operated both inside and outside Renesas fabs. During a crisis, the fab network would allow the company the flexibility to change, on the fly, the volume and mix of products run on the various fab lines.

Renesas' three-pronged plan for the

redundancy program involves securing multiple production lines, asking customers to evaluate and qualify production lines at different fabs in advance, and requiring each fab to maintain an inventory of "semi-finished" products. Renesas aims to restore production at any given fab—no matter what happens—"within a month," said Akao. "That's our endgame."

But, of course, no supply chain issue can be sorted out just by one party.

The fab network won't function properly if Renesas and its customers fail to disclose and share information on specifics such as available capacity at fabs, product road maps and qualification processes. Further, they must agree on how to share the cost of building the needed redundancy into the model.

At a time when many leading integrated device manufacturers have been busy downsizing in-house production capacity and going fab-lite, Japan's earthquake was a shock to even the best-laid fab plans. The question semiconductor companies need to answer is no longer whether they should maintain their own fabs, but how they can build a network of production lines on which they can reliably depend.

Artificial scarcity

Along with reliable access to fab capacity, reliability of materials supply was an issue last year as China tightened restrictions on production of the rare earths used in electronics manufacture. The problem originated with a tiff between Japan and China in 2009 and quickly escalated beyond those traditional rivals. By last summer, China had cut already-short export supplies by a third. The unsurprising upshot has been skyrocketing prices for the vital materials.

Australia, Canada and the United States all have programs under way to open or reopen rare-earth mines outside China, including new mines in Malaysia and Russia. But the added mine capacity isn't expected to reduce the shortfall appreciably for at least three years.

Rare earths are used in slurries for mechanical planarization of everything from glass to semiconductor wafers. Chip makers are resorting to silicates and other minerals to substitute for rare earths, but manufacturers of phosphors for such products as fluorescent bulbs and white LEDs are having a hard time finding alternatives.

For some, moving production to China—the source of the needed materials—addresses the problem, albeit by sidestepping it. Meanwhile, phosphor manufacturers' research and engineering teams are working to develop alternative phosphors in the United States.

Ultimately, regardless of how the rare-earths shortage is addressed, the lesson that should linger well after last year's wakeup call on materials supply is that relying on a single source for anything is never a good idea.

Crackdown on counterfeits

Nothing reveals the complexity of today's supply chain issues more plainly than the counterfeit chips that have crept, with growing sophistication, into the electronics pipeline in recent decades.

Last May, customs officials at the Port of Long Beach, Calif., intercepted a shipment of almost $1 million worth of fake SanDisk memory chips stashed inside nearly 2,000 karaoke machines, shipped in a container from China.

In a U.S. Dept. of Commerce survey of original component manufacturers conducted in 2010, China topped the list of suspected sources of counterfeits by country. In the same survey, "brokers," "independent distributors" and "Internet-exclusive sources" were identified as the three worst offenders by supply chain segment.

As the electronics industry and law enforcement step up their efforts to ferret out the fakes, counterfeiters are becoming even more devious. Some are using dice harvested from decapped scrap ICs and repackaging them.

The best defense against counterfeit parts is prevention. For OEMs and EMS providers, traceability to the source—knowing where every part comes from—is the obvious first step. But equally important are heavy-handed diplomacy—particularly with China—and legislative oversight to combat the flood of counterfeit electronics parts coming into the defense supply system.

In today's interconnected world, design engineers cannot afford to ignore politics—just as they dare not disregard natural disasters, manmade shortages and chips of questionable pedigree. If past is prelude, however, they probably will—until the next rude awakening. ■

Junko Yoshida (*junko.yoshida@ubm.com*) **is editor in chief of** ***EE Times*****.**

Stemming the counterfeit tide

By Bruce Rayner

Counterfeit components have been a thorn in the side of the electronics industry for decades. And every year the incidents seem to grow more common—and more costly.

One estimate suggests that counterfeit parts account for more than $5 billion, or about 2 percent, of the total available market for semiconductors worldwide. The Semiconductor Industry Association claims counterfeiting costs U.S.-based semiconductor companies more than $7.5 billion each year.

Law enforcement and government agencies are collaborating to catch fakes before they enter the supply chain. Between 2007 and 2010, the U.S. Immigration and Customs Enforcement agency (ICE) worked with U.S. Customs and Border Patrol on more than 1,300 seizures involving 5.6 million counterfeit semiconductors. The confiscated counterfeits bore the trademarks of 87 North American, Asian and European semiconductor companies.

A 2010 government case against chip broker VisionTech Components of Clearwater, Fla., charged two company officials with knowingly importing more than 3,200 shipments of counterfeit semiconductors into the United States, marketing some of the products as "military grade" and selling them to the U.S. Navy, defense contractors and others. The case involved the coordination of multiple government agencies, including the Department of Justice Task Force on Intellectual Property, the Naval Criminal Investigative Service (NCIS) and ICE.

New efforts to keep fakes out of the military supply chain have made headway, but are they enough to protect against tomorrow's threats?

VisionTech "set a ticking time bomb of incalculable damage and harm to the U.S. military, U.S. servicemen and -women, the government, all of the industries to which VisionTech sold goods, and consumers," the U.S. attorney who prosecuted the case wrote in the government's sentencing memo.

Congressional response

In 2011, electronics counterfeiting caught the attention of the Senate Armed Services Committee. A series of hearings explored the extent and severity of the counterfeit problem within the military and government sectors, and a congressional investigation documented more than 1,800 instances of counterfeit electronic parts in the defense supply chain. Some of those parts had wound up in military equipment operating in the field.

One case involved suspect counterfeit parts in forward-looking infrared radar (FLIR) units supplied to the U.S. Navy by Raytheon Co. Some of the FLIR units had been installed on helicopters deployed to the Pacific Fleet. In another case, suspect counterfeit parts were used in color multipurpose display units (CMDUs) that L3 Communications had installed on U.S. Air Force C-27J aircraft. Two of the C-27Js had been deployed in Afghanistan.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More

In the case of the CMDUs, the counterfeit parts were traced back to a company in China that had sold them to a U.S. independent distributor. The U.S. company in turn had sold the parts to L-3 Communications, according to an Oct. 31 letter to Michael Donley, secretary of the Air Force, from Senate Armed Services Committee Chairman Carl Levin and Ranking Minority Leader John McCain. "More than 500 of those [CMDUs] were sold to both L-3 Communications Integrated Systems, the prime contractor on the C-27J, and Lockheed Martin, the prime contractor to the C-130J," Levin and McCain wrote.

HIGHLIGHTS OF THE LEVIN-McCAIN AMENDMENT TO THE FY 2012 NDAA

- Prohibits contractors from charging the DOD for the cost of fixing the problem when counterfeit parts are discovered.
- Requires the department and its contractors whenever possible to buy electronic parts from original component manufacturers and their authorized dealers, or from trusted suppliers that meet established standards for detecting and avoiding counterfeit parts.
- Requires contractors and military officials who learn of counterfeit parts in the supply chain to provide written notification to the contracting officer, the DOD inspector general and the Government-Industry Data Exchange Program.
- Requires the secretary of Homeland Security to establish a methodology for the enhanced inspection of electronic parts after consulting with the secretary of Defense as to the sources of counterfeit parts in the defense supply chain.
- Mandates that large defense contractors establish systems for detecting and avoiding counterfeit parts, and authorizes reductions in contract payments to contractors that fail to do so.
- Requires the DOD to adopt policies and procedures for detecting and avoiding counterfeit parts in its direct purchases, and for assessing and acting on reports of counterfeits.
- Adopts provisions of a bill sponsored by Sen. Sheldon Whitehouse, D-R.I., to toughen criminal sentences for counterfeiting of military goods or services.
- Requires the DOD to define "counterfeit part" and to include in that definition previously used parts that have been misrepresented as new.

SOURCES: OFFICE OF SEN. CARL LEVIN; TITLE VIII, SUBTITLE C, SECTION 848 OF THE NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2012

The investigation culminated last month in an amendment to the National Defense Authorization Act (NDAA) for Fiscal Year 2012 co-sponsored by Levin and McCain that would "bolster the detection and avoidance of counterfeit electronic parts." The amendment, which was signed into law on Dec. 31, puts the responsibility squarely on the shoulders of contractors such as Raytheon and L-3 to ensure that counterfeits never make it into equipment deployed to the field.

The Levin-McCain amendment requires the contractor to absorb the cost for any equipment rework or refurbishment resulting from counterfeits. It also calls for a fine of up to $5 million and 20 years in prison for individuals convicted of selling counterfeits to the U.S. government that are used in critical infrastructure or national security applications. Guilty companies could be fined up to $15 million.

The amendment further requires contractors to obtain electronic parts from original manufacturers, their authorized dealers or other "trusted suppliers." Those trusted suppliers can include independent distributors as long as they have adequate policies and procedures in place to detect counterfeits.

Because military systems are often deployed for decades, replacement parts are typically out of production and often not available from either the original component manufacturer (OCM) or a franchised distributor. A few franchised distributors, such as Rochester Electronics, specialize in obsolete parts for defense systems. But when those sources don't have the parts—or, more precisely, don't have them when the customer needs them—the only recourse for defense contractors is to buy from independents and brokers on the open market.

While the vast majority of independents are aboveboard, most do not have the systems in place to catch counterfeits. In fact, some independent distributors have estimated their incoming inventory to be as high as 35 percent counterfeit, according to Leon Hamiter of Components Technology Institute Inc. (Huntsville, Ala.).

Catching the fakes is expensive. Outlays for the equipment needed for physical inspection and test can run into the hundreds of thousands of dollars. The instrument roster includes high-powered laboratory-grade microscopes, X-ray fluorescence equipment, scanning electron and acoustic microscopes, and decapsulation test equipment. In addition to

absorbing the capital costs, companies must invest to hire and train staff for both physical and electrical testing.

Contractors and defense agencies are reviewing their relationships with independent distributors and brokers in light of the Levin-McCain amendment. “Many are cutting their approved vendor lists to just three or four independents,” said Tom Sharpe, vice president of independent distributor SMT Corp. (Sandy Hook, Conn.).

Sharpe hopes SMT will be one of the few independents that make the cut, though a few years ago it would not have been considered a standout. In 2005 and 2006, SMT unknowingly sold counterfeit parts to a defense contractor. The contractor discovered the fakes during a stock sweep and in early 2007 filed two Government Industry Data Exchange Program (GIDEP) reports against SMT.

Appearing in the GIDEP database amounts to being blacklisted by the defense community. But “that event was the best thing that ever happened to SMT,” Sharpe said. “It made us reassess our capabilities and develop a mitigation strategy.”

SMT took a year off from selling to the military to enhance its ability to identify counterfeits. It invested more than $1 million in test and inspection equipment, earned certification to three industry quality standards, trained and certified its quality-control lab staff, and built new capacity and processes.

The company reentered the defense market in July 2008 and has since gained a reputation as a leader in authenticating semiconductors, according to a number of industry sources.

SMT has contributed to the industry’s understanding of counterfeit practices by documenting some of the more advanced methods used to resurface and remark semiconductor packages. In 2009, it identified a surface recoating material that is immune to acetone surface permanency testing. And last year, it uncovered two new processes used by counterfeiters: one for removing part markings without requiring surface recoating, and the other to remove and recondition the surfaces of ceramic components.

“There’s no college degree in detecting counterfeit parts,” said Sharpe. “You need to be looking at parts and work with the stuff every day.”

The counterfeiting problem is hardly confined to the public sector. About 98 percent of all semiconductors are sold to commercial customers in all market segments—including the automotive, industrial and medical sectors, in which safety and quality standards are rigorous. And there are plenty of cases in all of these sectors of counterfeits’ causing system failure.

The recommendations made in Levin-McCain are as valid for commercial applications as they are for the military. All companies should source only from OCMs or their franchised distributors whenever possible. And if there’s no alternative to the open market, they should source only from “trusted sources” that have robust test capabilities.

Still, there’s no telling how long today’s test regimes will protect the electronics supply chain, as counterfeiters are constantly refining their capabilities. As soon as companies identify a counterfeiting technique, counterfeiters respond with even more sophisticated approaches.

One of the most serious new threats is the “clone” component—a part manufactured to look and function exactly like the OCM’s product. Typically, clones pass both physical and electrical testing. Taking the concept a bit further is “malicious insertion,” whereby malware is embedded in a piece of industrial equipment with the intent of causing a malfunction or to gather intelligence. Targets include commercial companies, the military and the government.

One suspected example of malicious insertion, reported roughly a year ago, involved software embedded in a piece of industrial equipment manufactured by Siemens. The software contained a sophisticated worm known as Stuxnet that was allegedly responsible for causing malfunctions of nuclear centrifuges at an Iranian nuclear enrichment plant. Israel has been implicated in that attack, according to *The New York Times*.

A November report by the Office of the National Counterintelligence Executive titled “Foreign Spies Stealing U.S. Economic Secrets in Cyberspace” argued that the pace of industrial espionage against U.S. corporations and government agencies is accelerating. While the report did not mention clone components specifically, it did address the increased incidence of malware.

Don’t let your guard down. ■

Bruce Rayner (*bruce@afitplanet.com*) is a contributing editor to *EE Times*.

Five regulations to watch in 2012

By Suzanne Deffree

Messy, confusing, expensive and often limiting to design, government regulations and legislation are ever changing—and always influential.

Like it or not, the task of understanding and complying with these directives is a necessary evil of the electronics supply chain. Quality distributors stay on top of the directives to usher designers and manufacturers through challenging processes, even going so far as to keep an eye on product end-of-life for the consumer. But every link in the chain needs to be aware of current regulations and legislation.

As we move into 2012, here are five regulations, directives and laws across the globe that will affect the electronics supply chain—the manufacturers, distributors, design engineers and, ultimately, users of electronics.

1. RoHS recast

If you thought you were done with the European Union's Restriction of Hazardous Substances (RoHS) directive, think again. A "recast" or reimplementation of RoHS was written into the original directive's documentation. Its subsequent changes became law in the summer of 2011.

The changes include new product categories under RoHS and a coming analysis of additional substances, as well as new challenges in terms of meeting requirements for the CE mark, a mandatory conformity mark for products placed on the market in the European Economic Area.

"The requirements of the CE mark included in the recast will prove a massive burden on industry," said Gary Nevison, head of legislation at Newark/Element14. "There will be a massive data collection exercise required, including a new 'declaration of conformity' document. There is already widespread concern in industry around the CE requirements ... this can impact manufacturers, importers and distributors."

As to other changes brought by the recast, Nevison noted, "Manufacturers of products in categories 8 (medical devices) and 9 (monitoring and control instruments) will need to have RoHS-compliant products from 2014 onward. Those ready 'early' could gain market share."

2. China RoHS

The term "China RoHS" has been used in the electronics supply chain for more than five years, yet its meaning remains a mystery to many. China RoHS, officially known as Measures for Administration of the Pollution Control of Electronic Information Products, is a Chinese Ministry of Information

Industry regulation that aims to control certain materials, such as lead, that have been used in electronics and are considered to have negative environmental or health effects.

Because of the long road this regulation has taken, the measure seems to have fallen off many watch lists. To be sure, however, so-called China RoHS is alive and strong. Its "Standard Product Catalog for the Pollution Control of Electrical and Electronic Products" was published in July; in November, the first "voluntary certification" measures took effect for some parts, materials and components used in computers, household electronics and telecommunications products.

3. Eco-design of Energy-related Products directive

Until recently, the EU Eco-design of Energy-related Products (ErP) directive's focus had been on increasing energy efficiency, particularly during the use phase of a product's life. Now looking at the electronics supply chain from start to finish, the directive aims to improve the environmental performance of products throughout their life cycle, from mining of the raw material through recycling at end-of-life.

By definition, this is a framework directive, meaning that while it defines the legal context for "implementing measures" for specific target groups of products, it does not itself impose any obligations on industry. Nonetheless, the European Commission (EC) reports that 12 Eco-design regulations, two amendments and five energy labeling regulations came into force between 2008 and 2011.

At press time, an EC Consultation Forum on the Eco-design directive working plan and the new methodology was slated for Jan. 20, 2012. It was expected to address a working plan for 2012 through 2014 and to include a review of the directive's methodology. It was also expected to address the need for additional guidance and clarity in producing a uniform method for implementation of regulations.

Element14 reports that 2012 is expected to be a big year for the Eco-design directive, with more regulations due to be implemented. Adoption of the revised Eco-design directive is due by March 2012.

4. U.S. e-cycling

About half of the states in the United States—including tech centers like California, New York and Texas—have passed electronics recycling (e-cycling) laws to varying degrees. Under the New York law, which took effect in April and so far is the most comprehensive in terms of covered products, manufacturers must provide an electronic waste acceptance program at no cost to consumers. Such state e-cycling laws are expected to continue to pass and go into effect in 2012, with Pennsylvania's law being the first to go into force this year, on Jan. 1.

Several federal bills have been presented that would affect e-cycling. Bill S.1397 was just one such effort to go beyond e-waste dumping and call for "sustainable design" of electronic equipment, as well as funding for research and development of more sustainable designs.

While Bill S.1397 did not become law, similar legislation is expected to continue to be presented. Such efforts, as

More information on legislation can be found via these sources and links:

European Commission's information page on the recast of the RoHS directive
http://bit.ly/uuUZ90

China Ministry of Commerce English translation of Measures for Administration of the Pollution Control of Electronic Information Products
http://bit.ly/tWHoJR

Element14's legislation information page
http://bit.ly/i886Qu

Export.gov information page on Eco-design of Energy-related Products directive
http://1.usa.gov/sinoj1

National Center for Electronics Recycling
http://www.electronicsrecycling.org

Dodd-Frank Wall Street Reform and Consumer Protection Act
http://1.usa.gov/dohxqC

IPC's conflict minerals information page
http://bit.ly/u5fRIN

well as the various state e-cycling laws, will affect the supply chain.

5. Dodd-Frank Wall Street Reform and Consumer Protection Act

Dodd-Frank is largely focused on financial supervision. But 838 pages into this act, which became law in the summer of 2010, information on regulating so-called conflict minerals is presented. A provision requires public companies trading on a major U.S. exchange to determine whether their products use any gold, tantalum, tin or tungsten from the Democratic Republic of Congo or surrounding countries, described as conflict areas.

The law's conflict minerals provision aims to deter what the United Nations describes as genocide in the area, as it is believed that terrorist activity is being financed through the illegal sale of minerals from the region's mines.

The task of determining the origination of such minerals and then reporting it to the SEC is enormous but is necessary to comply with the law. Various electronics industry organizations and groups have begun addressing the requirement. For example, the IPC, the Electronic Industry Citizenship Coalition and the Global e-Sustainability Initiative have a standard in the works to assist companies in demonstrating compliance.

In September, the IPC separately announced that it had agreed to participate in a pilot evaluation program to review and refine the Organization for Economic Cooperation and Development's due-diligence guidance for conflict minerals. And in mid-October, the IPC's Solder Products Value Council began urging tin smelters to use conflict-free minerals and recommended the Electronic Industry Citizenship Coalition/Global e-Sustainability Initiative Conflict-Free Smelter program. ■

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Niche suppliers point to hardware democratization

By Margery Conner

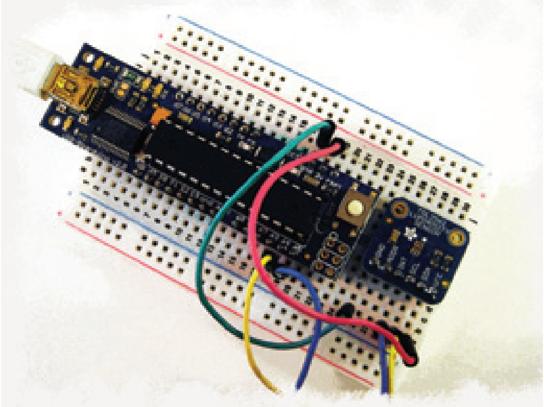
One not-so-obvious side benefit of the miniaturization of electronics is that folks far removed from the engineering realm become comfortable with small electronic devices and think, "Wouldn't it be neat if I had a gadget that did ... ?"

Back when computers were called "workstations," their inner workings seemed mysterious, complex and expensive. Few consumers thought about how they could exploit the computational power. But now that the equivalent of a workstation fits into a smartphone, complete with a rechargeable power source and a high-definition screen, software creation has become more appealing to a nontechnical audience. There's an app for seemingly everything, and even 10-year-olds are creating them.

Similarly, hardware itself is becoming more open. A decade ago, distributors like Avnet and Arrow began to create their own corps of application engineers to intermediate between manufacturers' new, increasingly complex products and customers who wanted to solve design problems without necessarily becoming experts in a highly specialized IC. Fast-forward to the present, and a new breed of electronics supplier is emerging to facilitate the "democratization of hardware"—that is, the use of hardware in new designs by nontechnical people.

One leader in this niche is SparkFun Electronics, started by Nathan Seidle, a newly minted EE from the University of Colorado. Seidle had been looking for a source of small quantities of sometimes-obscure electronic parts and began offering them himself. Shortly thereafter, he began receiving questions from customers on how to use them, and he started posting tutorials. That made for a virtuous circle: The tutorials served as link bait to draw in new, often nontechnical customers who found the company through Google.

Seidle contrasts the thinking of professionally trained engineers and nontechies: "I've seen a lot of senior projects in the university EE department, and they are all very good and very technical. And they all have to do with some kind of solar tracker or a digital music player or a power supply. But in the digital media classes, [the art students] are doing the most amazing, ridiculous, beautiful things with the same electronics. It's important to show creative people that they can achieve a grand project—and, yes, it has some current and voltage, but don't worry about that. We'll teach you that part." It's the opposite of a traditional EE educational approach, which is: We'll give you the technical background, and after a couple of years you can implement your grand ideas—if you remember what they were.



This combination of an Arduino microcontroller platform on the left and a TSL 2561 light-to-digital converter simplifies the detection and measurement of light.

Adafruit Industries has a similar story of how it got into the parts/kit business with detailed tutorials that include step-by-step instructions and photographs to lead newbies through the basics of Ohm's Law and soldering, and on to programming the open-source hardware Arduino platform.

Whereas traditional electronics distributors often have application engineers on staff, the Adafruit site effectively crowdsources its application engineering support through its forums and FAQ pages on the kits and parts. This reliance on the knowledge of the site's fans is part of a well-thought-out business plan: Adafruit's founder, Limor Fried, detailed the company philosophy in the *EDN* article, "15 steps to starting your own electronic-kit business" (*http://bit.ly/sIFA7f*).

Individual parts offered by Adafruit benefit from the company's excellent documentation and tutorials. I speak from personal experience. A couple of years ago, I bought a TLS 2561 light-to-digital converter from TAOS Semiconductor (now part of Austriamicrosystems). It seemed like a handy component for getting a quick, objective measurement of LEDs. However, although documentation existed for the part, its outputs were hard to interpret, and it was not easy to hook it up to a computer for data logging. I quickly gave up and forgot about it.

Then Adafruit fielded the part premounted on a small pc board with a couple of chip resistors and some headers, along with a tutorial as well as a software library for the open-source Arduino platform. As the Adafruit tutorial says, "To use this sensor and calculate Lux, there's a lot of very hairy and unpleasant math. You can check out the math in the data sheet, but really, it's not intuitive or educational—it's just how the sensor works. So, we took care of all the math and wrapped it up into a nice Arduino library" (*http://bit.ly/rNMbL7*).

My sentiments exactly; I just wanted to start using the sensor. Adafruit took a part that sells competitively for about $2 each, added a couple of passive components and a well-thought-out online tutorial, and sold it for $12. It was worth every penny.

Digi-Key Corp. had a similar start back in 1972, selling its Digi-Keyer Kit to ham radio enthusiasts. Today it's a $1 billion company. History could repeat itself with a whole new generation of parts and kits providers. ■

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Web, economy shift distrib models for automation/control products

By Ann R. Thryft

Selling automation and control products through distribution has traditionally been the domain of local and regional resellers that serve customers in their own geographic markets. Because products in this market are niche-oriented and designs are highly customized, the smaller operations that serve it function more like system integrators than traditional broadline electronics distributors. They provide specialized hardware and software design services, often targeting only one or two main control platforms.

But other models for selling these products have emerged, partly as a result of the economic downturns of the past decade and the shift to the Web for research and e-commerce.

In particular, the recessions of 2001-2002 and 2008-2009 were hard on smaller distributors and smaller manufacturers. Many were forced to reduce inventory when their access to capital all but dried up, said Scott McLendon, vice president of product management and marketing for Allied Electronics.

"They also typically aren't quite as strong logistically as some larger distributors, nor do they have the full breadth of product solutions available for many customers," said McLendon.

Consequently, some larger distributors, including Allied, have been able to build rapidly growing business in this sector. Just last year, Allied's growth in automation and control exceeded 50 percent.

B&R Industrial Automation's compact, high-performance ACOPOSmulti drive system reflects the trend toward greater integration in control systems.

SOURCE: B&R INDUSTRIAL AUTOMATION

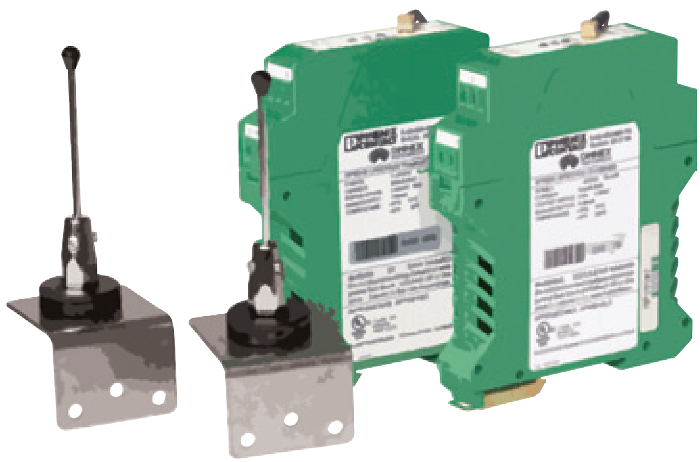
Channel strategy and the selling process for electronics are quite different from those for automation/control or mechanical products, said Chris Beeson, vice president of global sales and business development for Digi-Key. "An automation design is typically characterized by a higher mix and lower volume," Beeson said. "Some of these products are a one-time sale and might be capital expenditures, vs. selling less-expensive components to an OEM on a repeat basis."

For larger distributors whose model is based on moving large numbers of parts, these differences can be especially challenging. On top of that, consolidation among the large semiconductor distributors means that mindshare becomes even more important to automation and control suppliers. "Smaller suppliers are competing with very large companies under the same umbrella," said Beeson. "How does the supplier know they are getting share of mind through the large distributor?"

While price is always important, other critical considerations in the automation and control sector include whether a product will be applied in a finished system or an OEM application, whether it will target domestic or global use, and the harshness of the operating environment.

"In today's business climate, buyers are looking for a better price on the brands they already know and trust, but they are not necessarily looking to sacrifice quality or performance in the process of getting a lower product price," said Allied's McLendon. Making those sacrifices on the front end could potentially require much more on the back end in warranty and repair, as well as in downtime costs.

Therefore, Allied approaches the mix/volume issue more strategically. "Within a given technology, we try to offer the customer 'good,' 'better' and 'best' options," McLendon said. A "good" product "may do the job, but it might not last as long or be as accurate, or it might have fewer features," compared with the alternatives.



The Phoenix RAD-ICM-900 integrated radio and I/O module eliminates cable and conduit for one 4- to 20-mA current loop and two digital signals in harsh industrial environments.

SOURCE: ALLIED ELECTRONICS

Specialist AutomationDirect takes an altogether different tack from the traditional reseller model by relying primarily on e-commerce and phone sales. "We don't have sales reps who visit customer sites to demo products, take orders or take the customer out to lunch," said Tina Gable, focused image team advertising manager at AutomationDirect. "We don't provide full assistance with designing a solution or with programming. We do have qualified internal support, plus external support through system integrators and VARs [value-added resellers] that are fully acclimated to our products and solutions."

The distributor also provides free online tutorials, videos and other training assistance tools. "AutomationDirect is like the Walmart of automation, with a business model similar to that of Dell," Gable said. "If you phone us, someone knowledgeable answers immediately. All our products are stocked in a gigantic warehouse and are available for same-day shipping."

One of the biggest changes in how the sector operates has been customers' use of the Web. "There's been a wider adoption of Web-based everything in users' lives: tools, social media, user sites and user groups," said Gable. "Therefore, it's become many people's whole mechanism for researching products and services. And they are researching vendors and sources, too, not just products and tools."

As machine builders and OEMs increasingly look to the Web for research, they are more open to ordering products online, Gable said. "In a down economy, with price more important than it has been, if you are a low-price leader you can procure opportunities you did not have before. In the past, some people may have not considered us, because they were buying from the sources they were most familiar with. But now, more are coming to us because often we are the price leader [and offer] immediate product availability. Those buyers often become our best customers."

Said McLendon: "I think people are doing more comparative shopping today, and the Web makes that a lot easier. Buyers in this sector are definitely shifting more to e-commerce. Over the last four years, we've seen the online percentage of our revenue increase from 10 percent to over 40 percent, while our overall business has grown dramatically in that time frame, so the increase in online is substantial. Last year, we grew our online sales by more than 80 percent."

Some users conduct research online first before talking to the local distributor, said Beeson. "The small niche distributor or rep may have a Web site, but their customers may not be using it, since the rep is always in front of their customers anyway. The niche-oriented suppliers to this segment can really get into a tier-one company and get into the details of design. We fit more of the long-tail equation—that is, working with tier-two, -three or -four customers who may have similar design requirements but may not need the same degree of support from us."

That's why Web-based solutions and tactics work for Digi-Key, which is somewhat new to this sector: The one-to-many equation yields economies of scale and builds on the distributor's origins as a cataloger with an engineering orientation. "Many of our customers in this sector can now be self-serviced," Beeson said. "The few customers that need additional support can rely on the supplier and/or their manufacturers' reps for followup."

Worker checks inventory for fulfilling an order in AutomationDirect's warehouse.

SOURCE: AUTOMATIONDIRECT

AutomationDirect is evaluating social networking's role in marketing, said Gable. "Is it a trend yet in automation? We don't know," she said. "Most of the engineers who buy from us now don't use it, at least not in their work lives. They might be more open to user groups, like technical forums. But the next generation of engineers will be open to social networking."

One supplier, B&R Industrial Automation, combines a highly technical distributor network with direct sales and engineering staff in regional offices. The privately owned Austrian company, which has done business in the United States and Canada since 1987, uses distribution as the main push of its sales strategy, said Nathan Massey, sales channel manager. "In addition to its sales staff, each regional office and distributor has in-house, local engineering resources, something that's a big part of our regional strategy but not common among our competition. Our regional engineers provide design assistance and support our customers throughout the whole development process."

Some customers take complete ownership of their designs, said Massey. "We help them with training and the initial design, but they do 100 percent of the programming." Others contract for a B&R engineer or one of its distributors' engineers to develop the entire system. Most fall somewhere in between: They want training and support with the first product line, but when expanding to other machines and product lines they take all design functions in-house.

Products get more integrated

Automation and control products are becoming more interconnected via open communications standards, more dependent on software, and more integrated. These changes can pose challenges for distributors.

"Today, through open-source software and open standards, manufacturers are developing products that are more plug-and-play and that communicate with each other wirelessly, or, if wired, via open protocols like Ethernet," said McLendon. "Not only communication among devices, but also interoperability among vendors, has proliferated over the last few years."

For B&R, programming support is more important as software becomes a key factor in differentiating customers' machines through increased performance, faster time-to-market and ease of maintenance, said Massey. Many distributors the company encounters don't have such engineering resources in-house, and are strictly hardware-oriented.

B&R was among the first automation companies to release an all-in-one control solution, said Massey. Now, customers are quickly migrating to integrated control. "In the past, a control system [might include] an HMI, a PLC, a motion controller and a safety relay, all from different suppliers and requiring different software, multiple communication links, individual training and separate troubleshooting. Integrated control solutions combine these into a single, efficient package with a single, integrated development environment."

Open communications and connectivity-oriented networking standards are also becoming more important, visible in the rapid growth in demand for real-time Industrial Ethernet protocols. As a result, OEMs can select products from multiple sources, instead of choosing a single vendor with older, proprietary protocols.

In a related trend, machine builders' customers are increasingly removing the control system brand from their machine specifications and are concentrating on a machine's performance and capability. "This allows the machine builder to focus on their core competencies and not remain handcuffed to aging, limited technology," said Massey. "This encourages automation suppliers to innovate in order to stay competitive."

Overall, there's been a lot of demystifying in the control world, making it easier for design engineers to compare products, spec them in or out of a design, or specify multiples within the control system. "Today, you rarely see only one brand of controls in a system," said McLendon. "The challenge, or opportunity, that arises for distributors is: How do you support a customer who is using multiple platforms and multiple products? How do you provide the service they require?" ■

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Parts 'ownership' questions defy easy solutions

By Barbara Jorgensen

As the supply chain moves closer to JIT, distribution still manages upside and downside demand

Until the twin natural disasters that shook Japan in mid-March, the supply chain seemed to have gotten its inventory management practices down pat. The old habit of purchasing inventory well in advance of demand has shifted to just-in-time (JIT), relieving most companies of the burden of financing inventory they aren't sure they are going to need.

Most companies, that is, except distributors.

Distributors have become the de facto warehouses for the entire supply chain, storing enough inventory for customers' upside forecasts or inventory that is consigned by EMS companies or OEMs. Under most JIT, build-to-order (BTO) and consignment practices, distributors own inventory, and its attendant risks, until customers consume it.

Such programs make sense for suppliers and customers who don't want to carry inventory on the balance sheet. Although inventory is considered an asset, explains Charlie Barnhart, principal of consultancy Charlie Barnhart & Associates, certain supply chain practices—such as buying inventory on credit—make it look like a liability. OEM customers don't want unused components or work-in-progress on their books when quarterly earnings periods come around.

But distributors are likewise beholden to Wall Street and to shareholders, so the channel is always in the middle of some kind of inventory adjustment. How do distributors maintain enough inventory for customers without bogging themselves down?

Lessons of 2001

Memories of the inventory glut of 2001 still sting, yet it has taken a decade for the supply chain to even come close to a JIT inventory model. The first hurdle was convincing partners to share demand forecast data in a timely manner; the next was interpreting that data in a meaningful way. Distributors, as the link between component suppliers and manufacturing customers, have become the clearinghouse not just for inventory, but for the information used to manage the supply chain.

Before 2001, customers had little incentive not to over-order; the market was so hot that excess inventory was invariably gobbled up. It was only when demand slammed on the brakes that anyone questioned who was responsible for all the stock in the supply chain: Was it the customer who ordered it, the distributor that delivered it or the supplier that made it?

Facing huge write-downs on devalued parts, customers tried to return inventory to distributors, which, in turn, pressed suppliers to take it back. The supply chain wrote off an estimated $13 billion worth of components.

Ten years later, the distribution channel has become so big that it can push back a bit on OEM and EMS customers. Distributors now require more frequent forecasts from their partners. They compare the data to historic buying patterns, flag major upside/downside trends and follow up to rectify discrepancies.

But distribution has to deal with component makers as well as OEMs. Component manufacturers rely on distribution information to manage their own production schedules. The better the information coming from the distributor, the better manufacturing can be managed.

All of this requires closer partnerships. Indeed, over the past decade, trust has built up among the partners, and upside/downside forecasts work themselves out pretty quickly.

Globalization, meanwhile, has been a plus for inventory management. Global distributors manage pockets of inventory in all major regions, so a global distributor can internally move inventory out of, say, the Pacific Rim to the Americas if demand in Mexico suddenly spikes. The channel can also position inventory based on geographic demand cycles, accommodating seasonal shifts in ordering for the yearend holidays in the Americas, the August vacations in Europe or the Chinese New Year in the Pacific Rim .

But the natural disasters of 2011 have some in the industry rethinking the Lean supply chain. Coupling inventory management so closely to forecasts leaves little maneuvering room for upside demand.

Late last year, for example, the flooding in Thailand, a manufacturing hub for hard drives, forced many companies to suspend production. Although demand for the Christmas season had been met before the disaster, future orders were expected to be delayed. Such uncertainty drives some companies to pad inventory for orders that may or may not materialize.

Distributors manage their way through inventory imbalances by selling to a diverse customer base: If one customer orders too many widgets, others can take up the slack. The same should hold true for EMS companies, but industry watchers say that isn't the case.

"Inventory in many cases makes up the largest asset on the balance sheets of global EMS providers," IHS iSuppli EMS/ODM analyst Thomas Dinges wrote for *EBN* (*http://bit.ly/sIBcir*). "The latest results from several of the largest global EMS providers show, in fact, that nearly one-third of their tangible asset base is tied up in inventory."

While EMS companies serve many customers, their base isn't as broad as the channel's. Selling off excess EMS inventory usually has meant selling to the gray market. Anecdotally, however, distributors say EMS providers are turning increasingly toward authorized distribution to manage their inventory imbalances. Given the lingering market uncertainty, that's a sound move.

So as long as the electronics supply chain operates on a demand forecasting model—which it still does, despite JIT, BTO and Lean—the channel will play a leading role in global inventory management. Whether the electronics market is in an up-cycle or down-cycle, Barnhart says, "We are always in the middle of some kind of inventory question." ■

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Is your supplier's distrib deal good news for you?

By Patrick Mannion

For manufacturers, the question is almost as old as engineers' make-or-buy dilemma: use in-house support or commit to a distributor? The latter is attractive in a time when global reach and rapid turnaround are necessary in order to compete and grow, but there are implications for both the manufacturers and the designers using the product in terms of reputation, intellectual property protection, design support and trust.

A case in point: In June, Vicor (Andover, Mass.) committed to Future Electronics, making the Canadian company its global distributor for all of its power conversion devices. The phased rollout began in August. It was a big move for Vicor, which to date had been its own distributor within the United States while relying solely on smaller, specialty distributors, such as Craftec and ACAL Technology, elsewhere.

'We're going all-in with Future Electronics'
— *Rich Begen of Vicor*

Vicor traditionally has been self-reliant, keeping all its intellectual property, as well as its manufacturing, in-house to maintain a tight inner circle and thereby avoid the risk of exposing its road maps to anyone who might take the knowledge elsewhere. Now, in a quick turnabout, it's "going all-in" with Future globally, said Rich Begen, vice president of distribution at Vicor.

Why now, and why Future?

To explain the "why now" part, Begen referred back to 2003, when Vicor introduced the Factorized Power Architecture. FPA was the invention of company founder and CEO Patrizio Vinciarelli—a true engineer's CEO.

The FPA could be called a solution to a solution. At the time of its arrival, the distributed power architecture (DPA), with power "bricks" that brought power to the point of load (POL), was widely deployed and had been in broad use since the 1980s. DPAs solved the problem of distribution losses, but multiple onboard voltage levels meant the number of DPA bricks also multiplied, sucking up board space and increasing cost. They also proved inadequate for the loads' increasing transient-response requirements.

FPA concepts were realized in ASICs that led to the development of V•I Chips, which divide voltages and multiply currents while keeping the voltage-current product (the "•" in V•I) constant. The chips, in turn, led to a popular series of power components that in the years since have garnered key design wins and solidified Vicor's position in the power market, most recently with the Picor line of semiconductors.

But the technology has matured, and it is with that in mind that Vicor now needs to broaden its reach and distribution capabilities to ramp up volume.

That's where Future comes in.

Given the distributor's size, it's not intuitively obvious that Future would be the best choice. In a UBM Electronics distributor customer evaluation study (May 2011;

http://tinyurl.com/brerw5s), Future was ranked eighth in overall patronage for all products. Digi-Key led the category, followed by Arrow, Mouser, Avnet, Element14, Allied and McMaster-Carr. Worse, Future placed tenth among the study's "most preferred" distributors. Digi-Key again sat securely at the top; Arrow and Avnet were a distant second and third.

Begen makes it clear that size doesn't matter; on the contrary, it can sometimes be a liability. "Arrow and Avnet are too encumbered with large engagements," such as Texas Instruments and Analog Devices, he said. "Future is better with niche suppliers; it's in their DNA."

Begen speaks with some authority on the matter. Until last June, he was a principal of LJ James LLC, a consulting business focused on sales and channel management strategy.

Some suppliers have abdicated their responsibility for tech support

Implications

For suppliers and designers, the implications of working through a distributor are manifold. First there's the issue of trust, as the supplier has to expose its road map, as well as train the field application engineers (FAEs) at the distributor. That's "secret sauce" information, but in general, NDAs cover exposure liability pretty well.

Then there's a concern that a distributor might push one supplier's line at the expense of another's, depending on which supplier's product has the higher margin or who's being the squeakiest wheel about how much product is moving. That's a trust issue not just for suppliers, but also for designers seeking reliable support from a distributor. Begen, however, said the distributor model has matured enough that neither suppliers nor designers need be worried.

Designers over the years have expressed concern about suppliers' overreliance on distributors to provide technical support; in some cases, suppliers have abdicated their responsibility and gutted their own tech support infrastructure.

That's not the case at Vicor, Begen said. He acknowledged that handing over support to a third party is a bit like trusting your baby to a stranger. With four months' training, the distributor FAEs come up to speed but can't completely replace in-house support. "An FAE or two may get to a supplier-level FAE, but they [generally] won't have the depth," and while they tend to be more available than the suppliers' own support staff, "it's the luck of the draw" in terms of quality.

"You have to ferret out the FAEs who can best serve [the designers'] needs," Began asserted. That said, the distributor FAE can always refer to the supplier for help.

Web-based support

Increasingly, before attempting to reach an FAE, designers refer to both suppliers' and distributors' Web sites for technical information, application tips and notes—and, in some cases, community knowledge. The Future Electronics Web site's reputation as a comprehensive information source—supported by the UBM study—belies the company's size.

In general, distributors have tended to be a good starting point for basic product search and selection, but that bright spot may be fading. Comments on a recent *EE Times* article (*http://bit.ly/tbKbje*) bemoan the lack of solidly tabulated and parameterized data on distributors' sites, and instead recommend using one of a number of paid product selection sites, such as Octopart, Partminer or SiliconExpert.

Thus, the answer to whether it's a good move for suppliers and their customers to work through distributors is, "It depends." It depends to what degree a supplier relies on the distributor, and to what degree the distributor's FAEs can be trusted. You may get them on the phone quicker, and you may get the part quicker—but is it the right part? ■

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JOIN THE DISCUSSION

See "Suppliers, distributors and the issue of trust" on *EDN* at *http://bit.ly/tkBD4J*.