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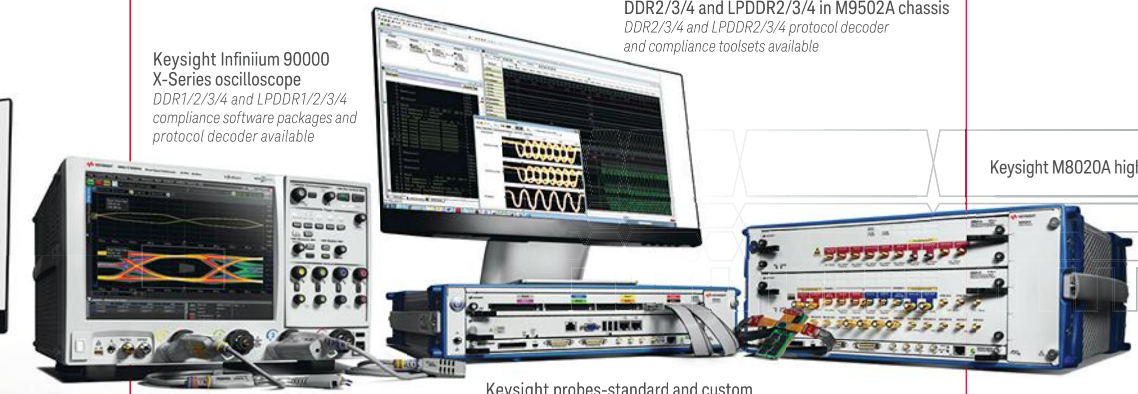

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March 2015 VOLUME 63, ISSUE 3

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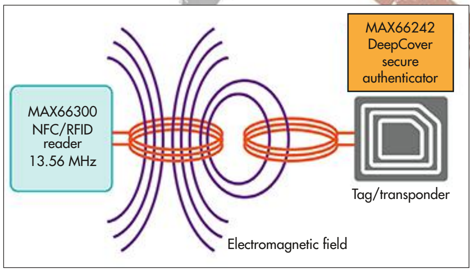

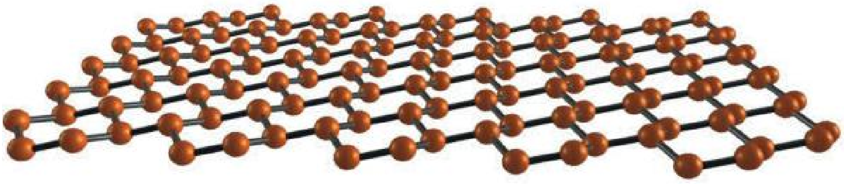

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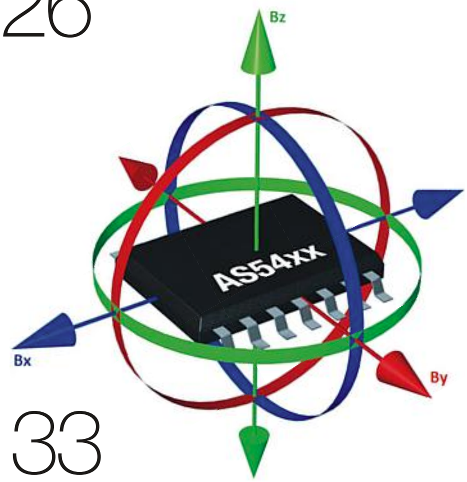

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EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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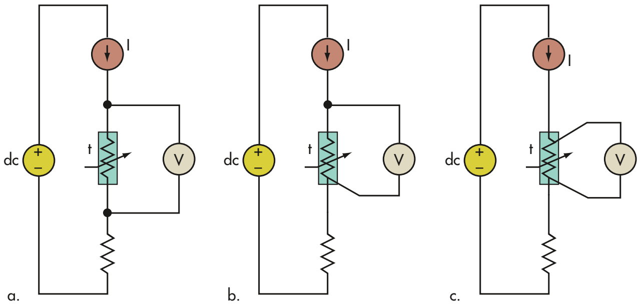

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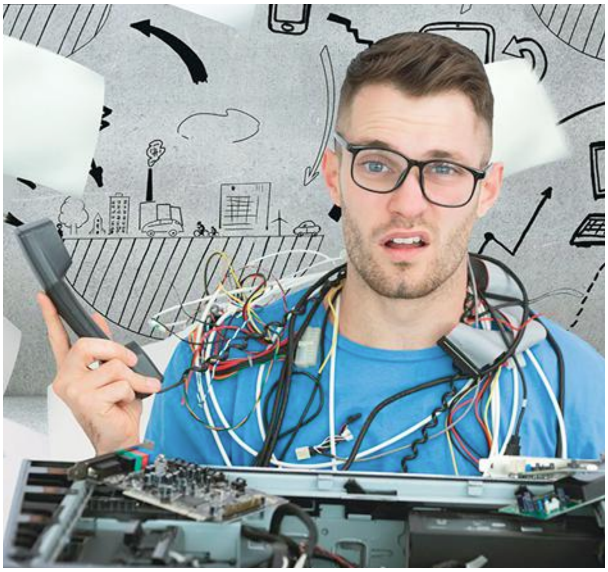

DUMBING DOWN SMART ELECTRONICS

http://electronicdesign.com/blog/how-dumb-down-smart-electronics

Guest Blogger and senior electrical engineer Roger Watkins observes that a microcontroller or larger computer is not always the best solution to a low-tech problem, adding that engineers and designers need to carefully evaluate what they should be doing with products and features to truly add value.

blogs

DON TUITE ANALOG/POWER	• A Look Back at Engineering Detectives
LOUIS FRENZEL COMMUNICATIONS	• G.fast Promises Faster DSL over Existing Wiring
BILL WONG EMBEDDED/SYSTEMS/SOFTWARE	• Zombies at Solidworks World 2015!

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WI-FI DASH CAMERA DOUBLES AS ACTION CAM

http://electronicdesign.com/embedded/wi-fi-dash-camera-doubles-action-cam

Technology Editor Bill Wong takes a close look at the Ojocam Chameleon, a 3 Mpixel dashboard/action camera with a 2-in LCD screen and built-in WiFi, and notes that "it highlights the level of miniaturization available these days combining Wi-Fi, camera and sensors."

VIDEO: NEW STORAGE SOLUTIONS

http://electronicdesign.com/new-enterprise-ssd-storage-solutions-sandisk

Flash memory goes well beyond thumb drives and memory cards for your camera. Brian Cox from SanDisk reveals some of the company's latest SSD (solid-state drive) products for enterprise servers and storage systems such as data centers.

THE MELTING OF THE ICE AGE

http://electronicdesign.com/test-measurement/melting-ice-age

Many designers still use ICE, but a designer's verification perspective typically changes once he or she experiences transaction-based verification through emulation.

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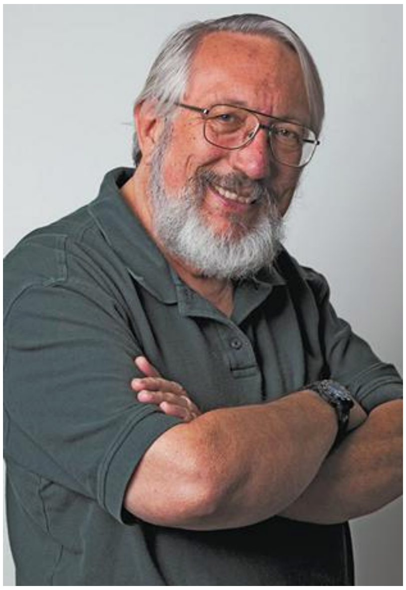


Ideas and Media

In an online piece in *The Atlantic* (see "A Warehouse Fire of Digital Memories" at *www.theatlantic.com*), Adam Chandler writes about an event of the American Association for the Advancement of Science, during which Internet pioneer Vint Cerf "warned of a 'forgotten generation, or even a forgotten century' that awaits us when 'bit rot' takes hold and our digital material gets lapped by the new hardware and software racing around it."

Cerf said in an interview with *The Guardian*, "We are nonchalantly throwing all of our data into what could become an information black hole. We digitize things because we think we will preserve them, but what we don't understand is that unless we take other steps, those digital versions may not be any better, and may even be worse, than the artifacts that we digitized. If there are photos you really care about, print them out."

Nice thought, but, alas, too late. I've been writing for publications since 1966, and the only things that are archived are the descriptions of physics demonstration experiments I wrote back then for RPI Professor Harry Meiners. Those got printed in books (*Physics Demonstration Experiments, Volumes 1 and 2*).

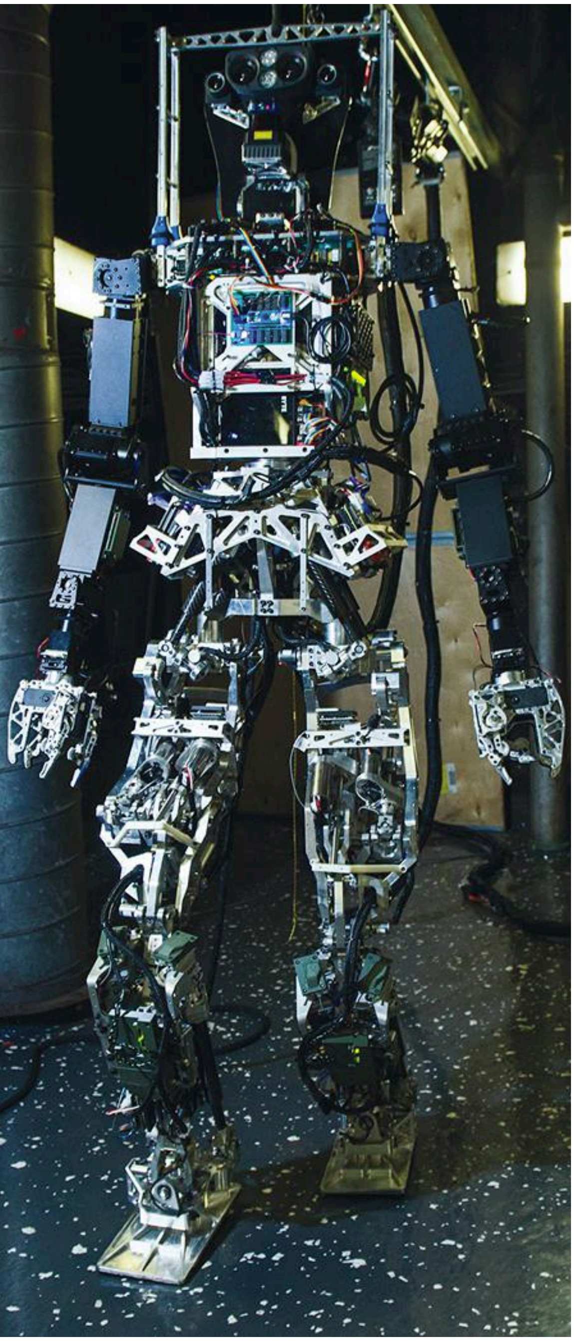
Not that there are a lot of people who want to know how to build an analog X-Y plotter attachment for an overhead projector out of war-surplus servo motors, but you never know what new idea somebody might think of some day.

That's my palimpsest theory. In ancient times, thrifty people reused old manuscripts by scraping them clean and writing new stuff on them. That's like Cerf's reference to old digital media. Happily, with old palimpsests, it's possible, with extreme care, to read back past later writers' scratchings to get to the valuable old stuff. That doesn't work so well with reused floppies, and even if it turns out to be possible to extract real information from a few magnetic domains here and there, where is that old media? It takes some truly dedicated pack rats to hang on to all of those old floppies and backup tape drives. And even then, how long is magnetic media good for?

So, going forward, is the cloud the answer? Cerf apparently doesn't think so. I think he'd agree that, no matter how much redundancy we build in, we are at the mercy of entropy, which isn't noted for showing much mercy.

Cerf does give us a clue, though. "If there are photos you really care about, print them out," he said. The key word is "you." The reason we still have pre-media classics like the *Iliad* or *Táin Bó Cúailnge* is that somebody cared enough to learn them and pass them on to others. That's what Professor Meiners did at RPI. He taught the basics to generations of engineers, who are now passing that on to new generations. Harry is no longer with us, and those books—well, most of their contents are obsolete. But the people who care, and use whatever media the zeitgeist provides them to fight entropy and pass on the information (not the media), are the ones we need to keep moving forward. ed

News & Analysis



AUTONOMOUS FIREFIGHTING ROBOT
Finds Its Balance

A major challenge faced by developers of humanoid robots is the ability to balance on unstable terrain, especially for bipedal robots. One potential solution is whole-body momentum control—it allows a robot to optimize its joint locations and maintain a center of mass.

At the Naval Future Force Science & Technology EXPO, researchers at Virginia Tech for the U.S. Navy successfully demonstrated this technology at work in its Shipboard Autonomous Firefighting Robot (SAFFiR). The long-term goal of the robot is to keep Navy operatives from the danger of direct exposure to fire.

SAFFiR was able to walk across uneven floors, identify overheated equipment via thermal imaging, and use a hose to extinguish a small fire in a series of experiments. Standing 5 ft. 10 in. tall and weighing 143 lb., the robot utilizes a special mechanism designed to give it a "super-human" range of motion to maneuver in complex spaces. It houses a variety of sensors, including infrared stereovision and a rotating laser for light detection and ranging (LIDAR), enabling it to see through dense smoke. The robot is helping the Office of Naval Research (ONR) evaluate the applications of unmanned systems in damage control and inspections aboard naval vessels.

The robot can complete tasks autonomously, but a human operator is kept in the loop to intervene if necessary. Though the current prototype is programmed to take measured steps and handle hoses on its own, researchers currently give it instructions from a computer console.

A more advanced design of the robot is in the works, with features such as enhanced intelligence, communications capabilities, and greater speed, computing power, and battery life for extended applications. The robots could then be configured to take shipboard measurements, scan for corrosion and leaks, and identify changes in the shapes of rooms from their original configuration. ■

SAFFiR is a bipedal humanoid robot being developed to assist U.S. Navy sailors with damage control and inspection operations aboard naval vessels. *(Photo courtesy of U.S. Navy/John F. Williams.)*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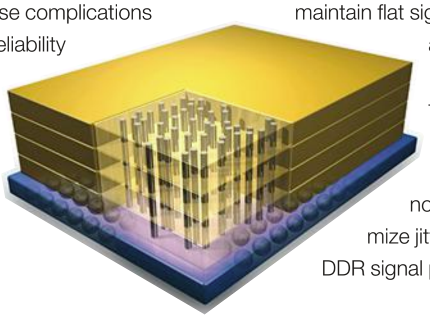
FROM COMPLICATED TO CAKEWALK: Partnership Focuses on 3D-ICs

THREE-DIMENSIONAL INTEGRATED CIRCUITS (3D-ICs) help to increase power and performance, but not without the tradeoffs of increased complexity and associated challenges. A partnership between ANSYS and Fujitsu aims to limit those complications by leveraging the former's power noise and reliability solutions to create 3D-ICs for high-performance central processing units (CPUs). Thanks to the full-chip capacity and fast turnaround time of ANSYS' RedHawk and Sentinel platforms, Fujitsu can optimize IR drop, electromigration (EM), and thermal-reliability analysis of large processor designs.



Above is a rendering of a stack of individual chips connected by through-silicon vias (TSVs). *(Image courtesy of IBM)*

Floorplanning for 3D-ICs requires the placement of through-silicon vias (TSVs) and a power/ground network. RedHawk allows for the exploration of various TSV placement options to meet the chips' power noise and reliability requirements, which can be difficult to analyze and debug later in the design process. Specifically, RedHawk enables an IC-aware power noise analysis and sign-off package to ensure the tightest noise margin is met without wasted resources, as well as prevent failure risks.

Other key capabilities include SPICE-accurate transient simulation results at the SoC level using dynamic power models and simulation of 100 M+ instances with 2 B+ node designs that maintain flat sign-off accuracy. An out-of-box vectorless algorithm enables quick hotspot identification and high sign-off coverage, plus support for advanced device architectures such as sub-20-nm FinFETs.

The Sentinel platform, an I/O DDR power noise and timing analysis solution, helps minimize jitter and the impact of power/ground noise on DDR signal propagation. Design engineers can perform a time-domain solution of the entire DDR interface channel, including the bank of DDR buggers; on- and off-chip decoupling capacitors; and on-chip, package, and PCB interconnect parasitics. The software then predicts the impact of simultaneously switching noise on signal propagation and ensuing jitter.

Sentinel further creates I/O buffer models and on-die signal and power routing by using I/O layout information provided through RedHawk. ■

WITH SILICENE, Science Turns Theory into Actual Material

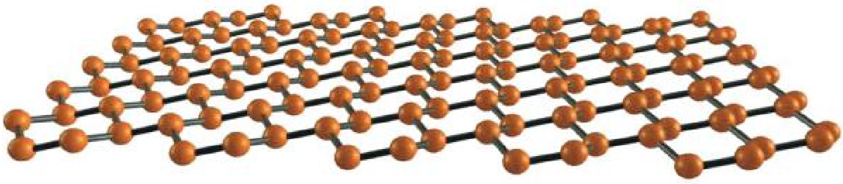
MOST OF US have heard about graphene. First produced in 2003, it is a single layer of graphite atoms in a lattice and is 100 times stronger than steel and is an efficient heat and electric conductor. As it turns out, there are other atoms that also have some interesting properties when arranged in a single layer.

Researchers at the University of Texas (UT) at Austin's Cockrell School of Engineering have created silicene (*see the figure*), a one-atom-thick layer of silicon. It has a hexagonal honeycomb structure. Silicene, like graphene, has been known but turning theory into actual material was a challenge that has now been overcome, at least on a small scale. Previously, very high temperatures were required to make small amounts of silicene.

UT's Deji Akinwande teamed with Alessandro Molle at the Institute for Microelectronics and Microsystems in Agrate Brianza, Italy, and used a new method that initially limits the material's exposure to air. The process starts with a block of crystalline silver in a vacuum chamber. Silicon is evaporated and condensed on the block. Next, a nanometer-thick layer of alumina is added. This allows a film of the layers of silver, silicone, and alumina to be removed by peeling them off the block. Silicene has also been grown on ZrB_2 and iridium.

This film was transferred to an oxidized-silicon substrate for testing. Some of the silver was carefully removed so there were two silver electrodes on either side of the silicene sheet. This was done under vacuum conditions. The transistor was then tested. Subsequent tests in open-air conditions will follow.

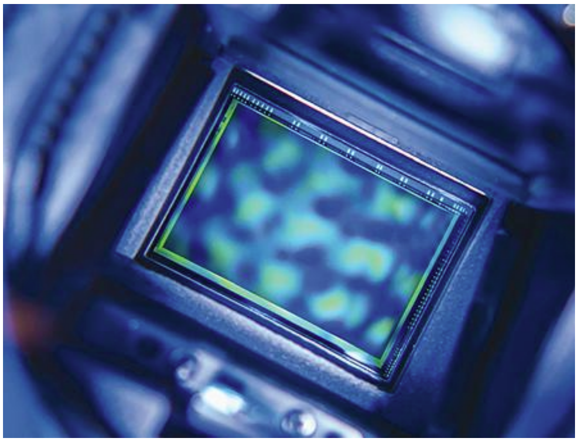
The characteristics of silicene are still under investigation. Silicene can be used with different dopants to change the material and do things like tune the band gap of the material as is done with bulk silicon. In theory, it could be used to construct faster and more power-efficient transistors. ■



Silicene is a one-atom-thick layer of silicon organized in a buckled honeycomb lattice.

GLASS-WELDED HERMETIC Seals Secure CMOS Sensors from Thermal Shifts

TO HELP ENSURE LONG-TERM stability and overcome thermal challenges in satellite-bound CMOS sensors, Primoceler and ON Semiconductor collaborated to encase the devices in an impermeable seam of glass using laser welding technology. The companies designed and manufactured the CMOS sensor packages for orbital missions conducted by the European Space Agency (ESA). Testing on the hermetic design of the packages revealed that they exceed current military and aerospace standards.



Optical sensors are used in a variety of applications, ranging from military to consumer. *(Image courtesy of Primoceler)*

The primary challenge associated with orbital missions usually centers on fabricating hardware that can protect sensitive electronics while enduring rapid temperature and pressure changes, as well as the vacuum of space. Glass offers a fully hermetic seal for all components and an extremely small heat-affected zone during the welding process. Primoceler's solution includes a finished seam that requires no adhesives, thus enhancing durability. It exceeds the MIL-STD-750E Test Method 1071.9 "Hermetic Seal" standard 6.0x10-12 atm cc/s Krypton-85 leakage rate.

Previously, Primoceler and ON Semiconductor teamed up to develop an optical sensor package. The new hermetic package design for a HAS3 CMOS sensor will be used for a variety of ESA missions. The partnership with ON Semicondcutor intends to explore other global industries, including healthcare, military, and consumer electronics. ■

PROJECT PAVES A PATH Toward Optical-System Miniaturization

AS SMART MICRO- and nano-systems move to 300-mm wafers, new technology must be developed to support the miniaturization of these optical systems. The Lab4MEMS II project, led by ST Microelectronics, focuses on micro-opto-electromechanical systems (MOEMS) that leverage MEMS with micro-optics to sense and manipulate optical signals. The project will aid the design, fabrication, and testing of various devices, including optical switches, arrays of micro-mirrors, optical cross-connects, lasers, and micro lenses.

Lab4MEMS II was initially launched by the European Nanoelectronics Initiative Advisory Council (ENIAC) Joint Undertaking (JU). The Pilot-Line project will expand ST's operational 200-mm-wafer manufacturing facility to handle higher volumes, while also adding optical technology capabilities. This will help increase production of switches, displays, and devices used in micro-projectors, laser micro-scanners, next-generation human-machine interfaces, and micro-spectrometers. Another goal of the project is to optimize the production of dual single-axis mirrors, and potentially dual-axis single mirrors in the future.

ST Microelectronics currently offers a variety of MEMS products spanning different applications. *(Image courtesy of ST Microelectronics)*

Lab4MEMS II is a $30 million project with 20 industrial, academic, and research partners spanning nine European countries. ST's designation as leader and coordinating partner offers manufacturing, technical, and organizational competencies. Other partners include the Politecnico di Torino and di Milanom, the Consorzio Nazionale Interuniversitario per la Nanoelettronica, the Commissariat Al Energie Atomique Et Aux Energies Alternatives, the University of Malta, MURATA Electronics, and more. ■

ONE POWERFUL ISSUE

Engineering Feature

ROBERT GREEN | Keithley Instruments Inc.

What Constitutes the IDEAL BENCH

Gaining a strong understanding of power requirements, maximum noise tolerance, and critical specifications helps paint a clearer picture.

Although variable dc power supplies might appear to be relatively simple instruments, engineers rely on them to deliver stable, precise, and clean voltages and currents, regardless of the load. To pinpoint the appropriate bench power supply for a particular application, one must come up with answers to several important questions and understand the basics of how power supplies are specified.

Allot enough time early in the selection process to thoroughly consider the following power-supply questions—it will save substantial time and money later in the system configuration process.

How much power does the application require to energize the device under test (DUT)? What are the maximum voltage and current requirements?

Different types of power supplies can have very different power envelopes *(Figs. 1a, b, and c)*. In a highly versatile rectangular power envelope type of supply, any current can be supplied to the load at any voltage level. Another type has multiple rectangular envelopes for multiple ranges. The latter power envelope offers the option of higher values of one parameter at the expense of the other. For example, a supply with this type of envelope can output a higher level of current, but only at a lower maximum voltage.

Yet other supplies can deliver a hyperbolic envelope that provides a more continuous transition than multi-range power supplies. In this kind of supply, one parameter is inversely proportional to the other. High-power output supplies tend to have either a multi-range or a hyperbolic envelope. To make the right selection, take the time to evaluate the power levels required by the application.

How many outputs do I need?

Multi-output power supplies with high output accuracy have become more affordable, but it makes sense to ask which applications really demand them and those in which they're not a necessity. In many cases, a single output will be sufficient; however, multi-output supplies can sometimes deliver several important advantages:

- When creating a device that has digital and analog circuitry, or bipolar circuitry, a multi-output supply will be the more convenient power source. Triple-output power supplies typically contain two higher voltage outputs for analog circuits (to power multi-voltage circuits or to create bipolar power supplies for testing bipolar analog circuits) and a third output intended to power a digital circuit. Also, many triple-output power supplies maintain a fixed 5-V output for the third output source. If this voltage must be varied, or if the digital circuit is powered with a lower voltage, the third output cannot be used to power that circuit. Therefore, for the greatest flexibility, make sure that all three outputs are programmable.
- If the DUT requires individual isolated power-supply sections, a decision must be made: configure multiple isolated supplies (which can be expensive, as well as inconvenient to operate) or buy a multi-output supply. The catch is that multi-output supplies can either have isolated outputs, or output channels tied to a common point on their low side. When the outputs connect to the same common point, they're not suitable to power circuits that are isolated from each other.
- Digital board designs often include circuits that operate at different voltages. When testing these circuits with external power supplies, it's important to power-up the circuits in the correct order to avoid stressing and damaging the low-voltage

POWER SUPPLY?

circuits. For applications that require powering circuits up and down in a specific sequence, a multi-output supply with independently controllable outputs is usually better than a set of individual supplies.

- For applications that require sourcing of more voltage or current beyond a single output's capability, some multi-output power supplies allow outputs to be combined in series or in parallel. The catch is that a multi-output supply that has a positive and a negative output with their low connections tied together (non-isolated) cannot parallel the two outputs. To ensure flexibility, look for a multi-output power supply with isolated outputs.
- During circuit development, it's essential to confirm that the circuit operates within its performance specifications over its defined voltage operating range. Multi-output supplies with tracking functionality offer a convenient way to test a bipolar circuit by linking both channels (positive-configured and negative-configured outputs) so that they change synchronously with each other.

What level of output accuracy is required?

If tight control of voltage at the load is essential for research experimentation or device characterization, it's important to review the power supply's output accuracy and read-back specifications. Even that accuracy can be compromised if the supply controls the voltage at its output terminals. Feedback control at the DUT is essential; i.e., the supply should include sense connections (remote sensing) that can connect to the DUT where the power leads are also connected *(Fig. 2)*.

Bear in mind that lead wires separate power supply and load. The wires' resistance, R_{LEAD}, is determined by the length of the lead, the conductor material's conductivity material, and the geometry of the conductor. Voltage at the load is:

$V_{LOAD} = V_{PROGRAMMED} - 2 \times V_{LEAD} = V_{PROGRAMMED} - 2 \times I_{LOAD} \times R_{LEAD}$

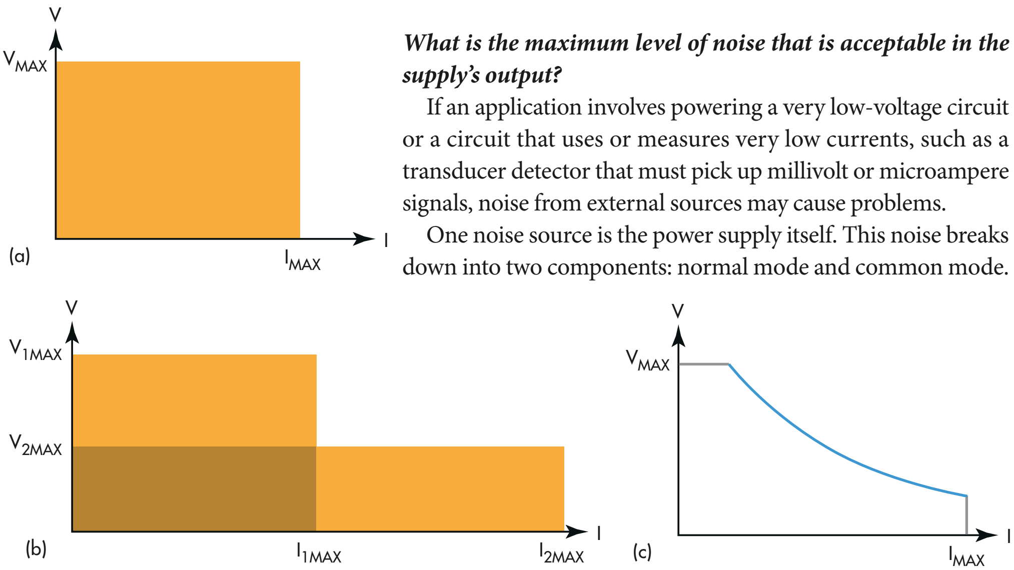
If the load requires high current, then I_{LOAD} is high, and V_{LEAD} can easily be a few tenths of a volt, especially with long power-supply leads. A voltage at the load could easily be 80 to 160 mV lower than the desired voltage (with 2 to 4 A flowing through five feet of 0.004-Ω/ft., 16-gauge wire).

The remote-sensing technique solves the problem of voltage drop in the leads by extending the power-supply feedback loop to the input of the load. Two sense lines from the power supply connect to the DUT power inputs. These sense leads, which measure voltage, connect to a high-impedance voltage-measuring circuit in the power supply. Due to the circuit's high input impedance, the voltage drop in the sense leads is negligible. The sense-lead voltage-measurement circuit becomes the feedback control loop for the power supply. The voltage at the load is fed back to the power supply by the sense leads. The power supply raises its output to overcome the voltage drop in the source leads and $V_{LOAD} = V_{PROGRAMMED}$. Therefore, the accuracy of the supply can only be applied to the load via remote sensing.

What is the maximum level of noise that is acceptable in the supply's output?

If an application involves powering a very low-voltage circuit or a circuit that uses or measures very low currents, such as a transducer detector that must pick up millivolt or microampere signals, noise from external sources may cause problems.

One noise source is the power supply itself. This noise breaks down into two components: normal mode and common mode.



1. One type of bench supply features a highly versatile rectangular power envelope that can supply any current to the load at any voltage level (a). A second type has multiple rectangular envelopes for multiple ranges (b). Yet another type confines its outputs to a hyperbolic envelope, which provides a more continuous transition than a multi-range power supply (c).

Normal-mode noise, which is generated across the power supply's output terminals, emanates from the power supply's internal circuitry. Common-mode noise is earth-referenced noise originating from the powerline and stray capacitance across the main transformer.

Two types of bench dc power supplies are commonly used today—linear and switch-mode, or "switching." Linear power supplies operate by rectifying ac line power to create dc, and then filtering and regulating it to produce user-selectable voltage or current levels. Linear supplies tend to be heavier simply because the 50- or 60-Hz transformer and associated filters are physically larger.

The linear topology generates a minimum of noise on the power supply's output. Switch-mode supplies start out the same way, rectifying and filtering ac line input voltage. However, they chop (or "switch") the dc into high-frequency ac, which is then converted into well-regulated dc.

The switching technique, due to its operation at kilohertz frequencies, makes it possible to use much smaller components in the input stage. Switch-mode power supplies are significantly smaller, lighter, and more efficient than linear power supplies, so they have replaced linear supplies for higher power requirements. On the negative side, their kilohertz switching frequency generates five to 10 times more noise than a linear supply. Whenever it's imperative to minimize noise, choose a linear supply (if one is available) based on the power requirements.

What interfaces are needed?

Even for benchtop applications, remember that a power supply is just part of a larger interconnected system. Take the time to list the interface requirements (GPIB, USB, RS-232, RS-485, LAN, etc.) of every other piece of hardware. Will the system require a PC controller with which the supply must communicate? Is it necessary to control the power supply's output using analog inputs? When long control lines or control lines exposed to an electrically noisy environment create signal-integrity concerns, isolated analog inputs can reduce or eliminate the susceptibility to signal degradation.

One other point to consider: Would a digital I/O interface make it easier to generate fault status outputs, or control an external relay or status lamp?

What about placement of output connectors?

Broadly speaking, front-panel connections, which simplify frequent access, are more common with supplies designed for benchtop use. Rear-panel connectors are generally considered superior for rack-based automated test systems—these rarely require changes after set up.

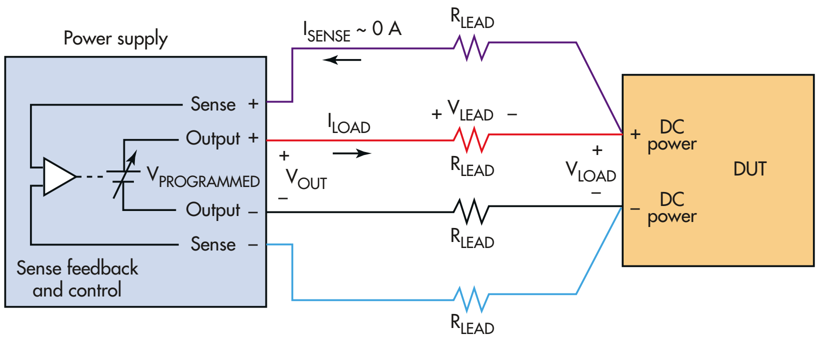
However, more manufacturers now offer power supplies equipped with both front- and rear-panel connections. This simplifies the transition from benchtop experimentation to high-speed automated test, because the same power supply suits both environments.

How should the supply be specified?

Although many key power-supply specifications will vary depending on the application, the following specs are critical in all cases:

Accuracy and Resolution

- **Setting accuracy** determines how close the regulated parameter is to its theoretical value. Output uncertainty in a power supply is largely due to error terms in of the digital-to-analog converter (DAC), including quantization error. Setting accuracy is tested by measuring the regulated variable with a traceable, precision measurement system connected to the power supply's output. Setting accuracy is given as: ±(% of setting + offset).



Without sense leads:

$$V_{LOAD} = V_{OUT} - 2 \times V_{LEAD} = V_{OUT} - 2 \times I_{LOAD} \times R_{LEAD}$$
$$V_{OUT} = V_{PROGRAMMED}$$
$$V_{LOAD} < V_{PROGRAMMED}$$

With sense leads:

$$V_{LOAD} = V_{OUT} - 2 \times V_{LEAD} = V_{OUT} - 2 \times I_{LOAD} \times R_{LEAD}$$
$$V_{OUT} = V_{PROGRAMMED} + 2 \times V_{LEAD}$$
$$V_{LOAD} = V_{PROGRAMMED}$$

2. Remote sensing ensures that the programmed voltage is delivered to the load. Sensing circuits must measure the voltage at the DUT so that the supply can compensate for any voltage drop in the test leads. No matter how accurate the power-supply output, it's impossible to guarantee that the programmed output voltage equals the voltage at the DUT's load. That's because a power supply with just two source terminals only regulates its voltage at its output terminals. However, the voltage to be regulated is at the DUT load—not at the power supply's output terminals.

- **Setting resolution** (sometimes called programming resolution) is the smallest change in voltage or current settings that can be selected on the power supply. The resolution specification limits the number of settable discrete levels. Often, this is defined by a combination of user-interface digits available and the number of bits in the DAC. A DAC with more bits has finer control of its output and can deliver more distinct values for the control loop to use as a reference. But, with corrections for offset and gain errors, resolution will be less than the number of bits in the DAC would suggest. Setting resolution may be expressed as an absolute unit value or as a percentage of full scale.
- **Readback accuracy** determines how close the internally measured values are to the theoretical value of the output voltage (after setting accuracy is applied). It's expressed as: ±(% of measured value + offset)
- **Readback resolution** is the smallest change in internally measured output voltage or current that discernible by the power supply. It's usually expressed as an absolute value, but can also be given as a percentage of full scale.

Stability

Over the long term, a power supply's performance inevitably changes due to aging. Maintaining long-term stability demands regular verification and calibration.

- **Temperature stability:** A power supply's accuracy is usually specified as being valid over a particular temperature range, often between 20° and 30°C (68° to 86°F). When used in a stable ambient temperature environment, the effect of temperature on the output is usually minimal.
- **Load regulation** (voltage and current): Load regulation is a measure of the ability of an output channel to remain constant during changes in the load. As the impedance of the DUT changes, the regulated parameter should not change significantly.

Of course, if the load changes too much, the regulated (controlled) parameter may change between voltage (constant-voltage control) and current (constant-current control), depending on the limit setting for the unregulated parameter. Assuming the power supply doesn't reach this crossover point, it maintains a low output impedance when operating as a voltage source, and a high output impedance when operating as a current source.

Load regulation may be specified in several ways. For example, voltage regulation can be expressed as voltage change per ampere drawn. However, most power-supply manufacturers express load regulation as output accuracy during a significant change in the unregulated parameter. This familiar format is easy to understand and verify through testing: ±(% of setting + offset).

- **Line regulation** (voltage and current): Line regulation is a measure of the power supply's ability to maintain its output voltage or output current while ac line input voltage and frequency vary over the full allowable range. Line voltage and frequency greatly affect the available power to feed the output, especially when drawing maximum current from the supply.

  Line regulation can be ignored in a lab with stable ac load voltage when testing for short periods. However, when working in an area prone to sags and swells in ac line voltage or when testing over extended periods, line regulation becomes an important consideration. Power-supply manufacturers usually express line regulation as an uncertainty in the output over the range of acceptable ac line parameters. This offers a worst-case picture, given as: ±(% of setting + offset).

AC CHARACTERISTICS

Direct-current power supplies don't actually produce perfect dc outputs; there's always some ac in the output. For certain types of applications, high ac on the output can produce unexpected circuit behavior. In addition to ac noise, it may be useful to know the power supply's transient response to changes in both load and settings.

- **Ripple and noise**, spurious ac components on the output of a dc supply, are also often referred to as periodic and random deviation (PARD). These terms are often used interchangeably.

  The term ripple refers to periodic ac on the output. When viewed in the frequency domain, ripple shows up as spurious responses.

  Unlike ripple, noise is random. Noise covers a broad spectrum, and when viewed in the frequency domain, manifests itself as an increase in the baseline.

  PARD specifications must include a bandwidth and should be specified for both current and voltage. Current PARD becomes relevant when using a power supply in constant-current mode, and is often specified as an RMS value. Because the shape of PARD is indeterminate, voltage PARD will usually be expressed both as a root mean square voltage, which can provide a sense of the noise power, and as a peak-to-peak voltage, which may be relevant when driving high-impedance loads.

- **Transient response** is tested by applying significant step changes to load impedance and power-supply settings, and measuring the time to settle to a stable dc value. Most power supplies have a large capacitance in parallel with their outputs to help deliver clean, steady dc. Placing this capacitance in parallel with the load resistance results in a time constant; the size of the time constant varies with the load impedance. Due to the heavy dependence on the resistance of the load, response to setting changes must be specified for a specific load. It's common to see specifications for open circuits, short circuits, or specific resistance values.

To learn more about choosing the right bench power supply for your application, download the Power Supply Selector Tool tablet app, downloadable from the iTunes Store and Google Play. ed

ROBERT GREEN, senior market development manager at Keithley Instruments (part of Tektronix's test and measurement portfolio), has been involved in the definition and introduction of a wide range of instrumentation. He holds a BSEE from Cornell University and an MSEE from Washington University, St. Louis, Mo.

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NFC/RFID Ripe for Application Expansion

Wireless security, an increasingly important factor across the electronics landscape, will open the door to a multitude of NFC-related applications.

Near-field communications (NFC), previously considered merely the next generation of barcodes, has proven to be much more than practical and robust. New applications have moved beyond traditional simple, intuitive, safe, contactless transactions to an array of new applications driven by unconventional thinking.

At the physical or RF layer, NFC is still essentially an evolved form of RFID. In fact, NFC was built over the 13.56-MHz (HF) RFID. The NFC Forum, an industry consortium,[1] started with the RFID physical-layer protocol and added a few new layers to the protocol stack. Then the NFC Data Exchange Format (NDEF) was put in place to identify, encapsulate, and exchange application data between NFC-enabled devices.

READERS AND TAGS

NFC/RFID works over a distance of a few inches up to a meter. The technology leverages inductive coupling to transfer energy through a shared magnetic field between two devices. Essentially, the reader's antenna coil is the primary and the tag's antenna coil is the secondary.

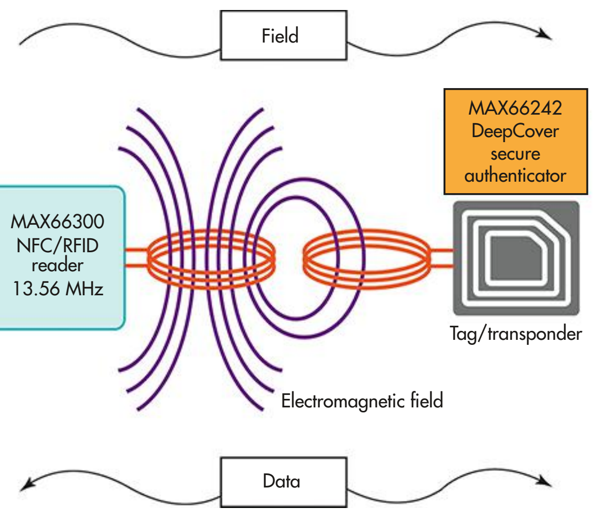
When placing a tag in close proximity to the reader, the field from the reader's antenna coil couples to the tag's antenna coil. A voltage is induced in the tag, which is then rectified and used to power the tag's internal circuitry.

The reader modulates the field to communicate its data with the tag *(Fig. 1)*. The figure represents an example of a passive tag that doesn't need an external energy source in order to function. Instead, a passive tag obtains its energy from the reader's electromagnetic field. Some of the more typical applications include access control, smart posters, loyalty cards and coupons, mobile payments (contactless credit cards), ticketing, and transportation toll collection.

Beyond that, with passive authentication, designers can now collect and exchange secure system configuration and calibration data with portable electronics, even when the device loses its main power source or isn't operational. The solution in *Fig. 1* allows any embedded electronic product to interface wirelessly with any surrounding devices/networks via its I^2C interface.

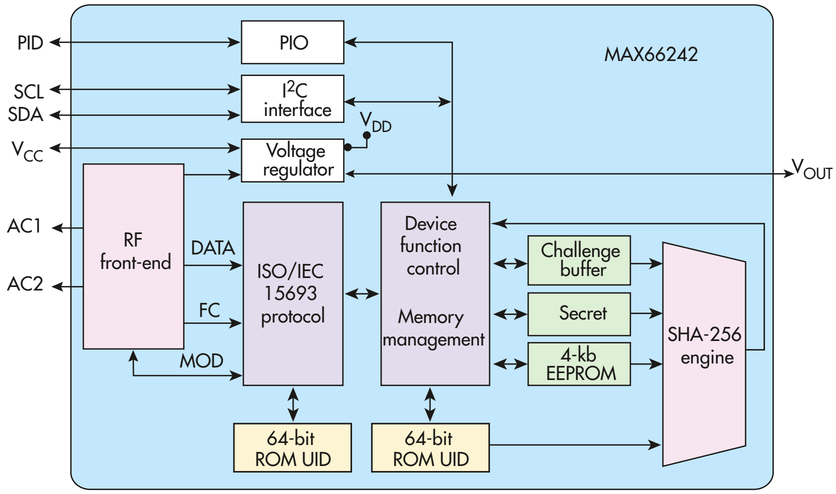
MORE ADVANCED SECURITY

Security is essential for wireless NFC/RFID applications. One way to achieve that is to integrate advanced security into the passive tag authenticator, which combines a wireless NFC/



1. To pass data back from the tag to the reader, the tag's circuitry changes the load on its coil while the unmodulated carrier from the reader remains on. This is detected by the reader as a result of the mutual coupling. Such functionality is called load modulation.

2. Shown is a typical circuit block to enable NFC/RFID capability in any embedded design. The block, combined with the key features of the MAX66242 secure authenticator tag, lets any embedded system enable new contactless applications for today's portable and secure systems.



RFID interface with an I^2C interface, data-protection modes, fast data transfer, and energy harvesting in the tag. NFC/RFID operates at a carrier frequency of 13.56 MHz, which is part of the globally available and unlicensed radio frequency ISM band. The technology has a few existing released standard specifications, including ISO/IEC 14443 Types A&B, and ISO/IEC 15693.[2]

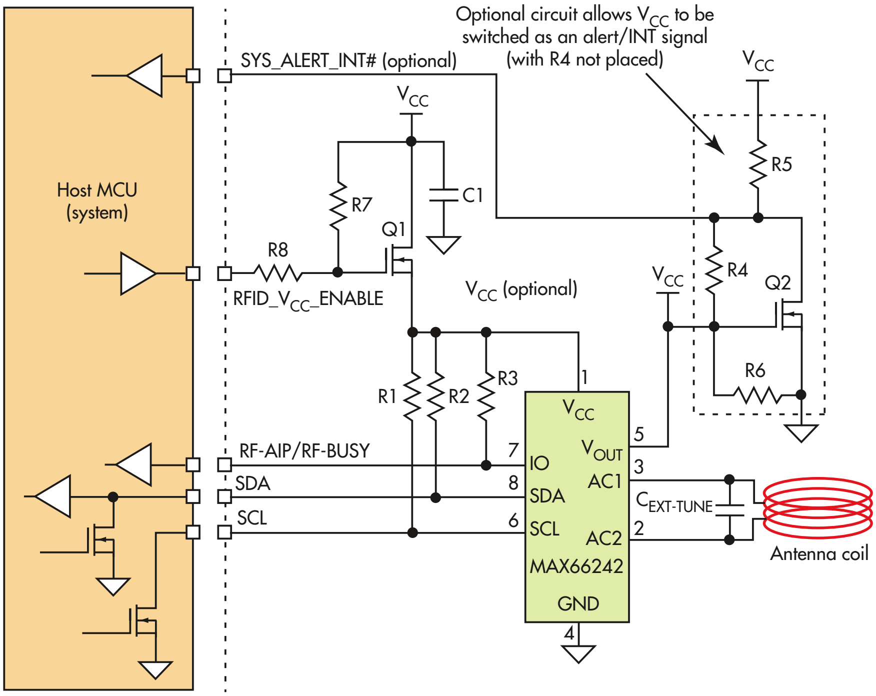
Such security is the bailiwick of the MAX66242 *(shown in Fig. 1)*, which integrates SHA-256 crypto engine that provides a symmetric challenge-and-response authentication capability based on a shared secret key *(Fig. 2)*. A 32-byte SRAM buffer facilitates fast data transactions over the I^2C interface.

ENERGY HARVESTING, ADDED FLEXIBILITY AND SCALABILITY

Energy harvesting is very useful because it makes the MAX66242 a flexible and scalable solution for a wide range of NFC/RFID applications.

As a generic passive tag, the IC doesn't require an external power source. It only needs a very small amount of power to operate—around 50 µA or slightly more depending on the features supported. The tag extracts all of its energy from the reader's 13.56-MHz HF electromagnetic field. When the antennae have been constructed correctly and tuned for an efficient and optimized link, this passive tag gets much more energy than is necessary to power itself. The leftover energy is often shunted to ground.

The rectifier's unused harvested energy in the MAX66242, on the other hand, is collected and sent out of the IC through its V_{OUT} pin. This harvested power can now be used to power surrounding ICs in an application such as the temperature-sensor patch, from which temperature conversion data is also collected. The IC's V_{OUT} pin can be configured to provide either 1.8 or 3.3 V (typical). This configurable supply output can deliver up to 5 mA, given adequate field strength.



3. As a wired-to-wireless conversion box, the I²C signals carry data to the outside world. The data flow is controlled by the RF-AIP (RF-Access-In-Progress) pin, also multiplexed as the RF-BUSY pin.

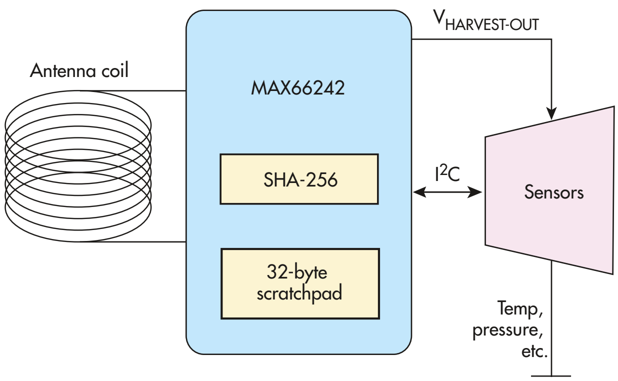
ENABLING NFC/RFID IN A PORTABLE DEVICE

It's fair to say that NFC/RFID is currently making a grand entrance in the consumer wearables technology mass market. Operating under the banner of the Internet of Things (IoT), more sensor-enabled embedded systems will be designed and set up to collect user-biometric and other data from multiple device systems on a network. Scads of NFC/RFID-enabled medical and industrial applications are anticipated, and we have yet to see the limits.

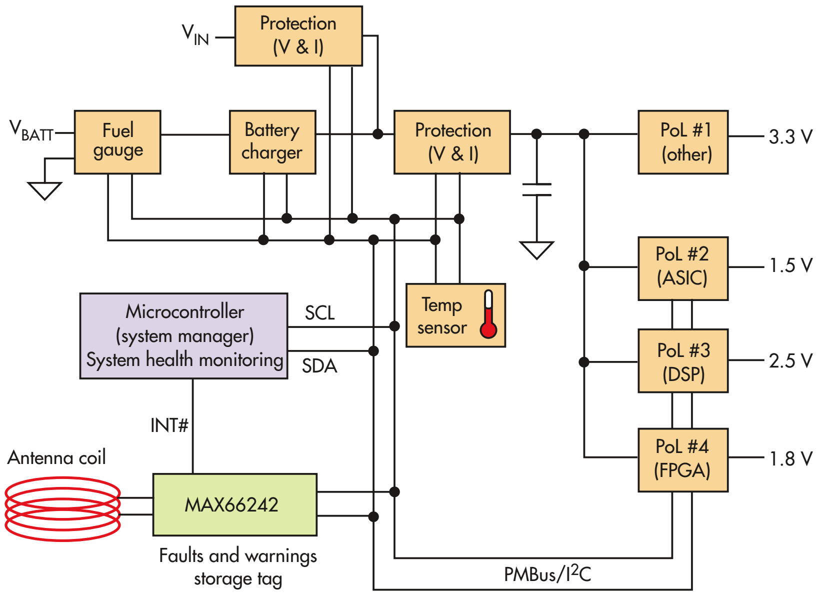
A basic circuit architecture that will enable NFC/RFID in an embedded design can be achieved with the MAX66242 (note that the system needs a communication path to the outside world) *(Fig. 3)*.

In the figure, while the I²C interface (SDL and SDA) and the PIO signals (a multiplexed line of the RF-AIP and RF-BUSY functions) are necessary to connect to the host microcontroller, the RFID_V_{CC}_ENABLE and SYS_ALERT_INT# signals are optional. The MOSFET Q1 is utilized for isolation. Because the tag's internal EEPROM is accessible through both the RF and I²C interfaces, Q1 powers the tag when the host microcontroller must interface with it in the absence of an HF field. The optional Q2, however, is utilized so that the open-drain SYS_ALERT_INT# can be switched with a regulated V_{CC} on the board. (R4 is not placed in this case.)

With a variant of this proposed circuit block implemented in the device schematics, the OEM's product is ready to communicate with any NFC/RFID reader or initiator system. Once the board enters an HF field, V_{OUT} comes up and turns on Q2. The open-drain signal SYS_ALERT_INT# goes to low, which interrupts or wakes up the host microcontroller, thereby indicating that the system is in an HF field. The host microcontroller then drives the RFID_V_{CC}_ENABLE into a logic-high state, switching the MOSFET Q1 on. The host microcontroller is now ready to exchange data bytes with the NFC/RFID reader device that supplied the HF field.



4. In this generic discrete sensor tag, the MAX66242 master I²C port allows a smartphone to access a sensor and collect temperature data without using a microcontroller.



5. In this typical power-management system each of the point-of-load regulators (POLs) is configured and monitored by a common power-management bus (PMBus). The PMBus is just a variation of the I2C bus.

Again, MAX66242's V_{CC} pin needn't be connected to power, as the IC's internal circuit is powered from the energy harvested from the HF field. However, the V_{CC} pin is left connected so that the host MCU can access the IC in the absence of an HF field.

DEVELOPING NEW APPLICATIONS

As mentioned, NFC/RFID promises to empower new potential usages in the industrial and medical sectors. A partial list of these new applications includes automated device configuration (also known as behavior setting), usage limit setting, system alert setting (e.g., system wakeup), slave-device secure authentication, and sensor-tag implementation, just to name a few.

One particular emerging growth area for NFC/RFID is the sensor tag. A sensor tag is an assembly (e.g., a patch) that contains a sensor IC to monitor defined physical parameters from the users' behavior and the surrounding environment *(Fig. 4)*. This sensing operation occurs along with the tag's normal identification function.

An attractive feature of a secure sensor tag is its ability to collect and report physical parameter measurements without a wired connection. In this case, the example MAX66242 is the key component for a sensor-tag discrete implementation.

Medical consumable applications of a sensor tag include the temperature patch and the sun-protection-factor (SPF) patch. Once a patient is fitted with the disposable temperature-sensor tag patch, the nurse can take core body temperature measurements without physically touching the patient. Given the global concerns about hidden and dangerous viruses, this offers a healthy way to mitigate or completely eliminate cross-contamination situations in a hospital or medical clinic.

In the same manner, an SPF sensor-tag patch can help a beachgoer apply the correct sunscreen lotion to avoid sunburn. The user would only need to read the SPF patch occasionally with a smartphone.

A sensor tag can also help monitor the integrity of a shipment. For example, a shock or vibration sensor tag will provide evidence of shock during the transportation of a valuable and/or fragile item.

In such an application, the MAX66242's master I^2C port is a key differentiating feature. If there were no master I^2C port, the design would need a small MCU to collect the temperature conversion data, and then write this data into the tag's memory for collection later by the reader *(Fig. 4)*. As mentioned earlier, the sensor tag transforms (or transduces) physical analog quantities into digital outputs. Here, the NFC device is essentially the bridge or conduit connecting these outside analog parameters to useful information that can be read on smartphone or tablet screen. Again, no external energy source is needed with a sensor tag using this design, because it uses its energy-harvesting V_{OUT} pin as a power source for the sensor IC.

DIAGNOSTICS/ERROR DATA COLLECTION

A design such as that in *Fig. 4* literally enables any embedded system to communicate with NFC-enabled portable communication devices. The NFC/RFID port can also represent a warning display to the service technician similar to the service-engine-soon light seen on a car's dashboard.

After implementing this circuit architecture in any embedded design, the new system can now exchange wireless information with the outside world, including diagnostics and error codes, data gathered from failing circuits, runtime warnings, and other system configuration/commissioning and calibration data. All of this flexibility allows an OEM to add even more value-added features to its end products.

It's even possible to store system runtime vital diagnostics and error data. Such data could be uploaded later after the system is "dead" or not powered. The collection of this system health and faults data is done over the NFC/RFID tag's interface *(Fig. 5)*. During normal system operation, certain vital operating parameters of each point-of-load (PoL) regulator are continuously monitored. While in this constant monitoring mode, the system manager can also perform corrective measures in response to faults or operational warnings.

It's even possible to create a "message-in-the-bottle" or "black-box flight recorder" scenario where the vital out-of-range parameters can be stored (e.g., the parameters of trip points from all of the monitored fault protections circuits). Using the RFID/NFC reader, the technician now has access to the deregulation measurements recorded just instants prior to the actual failures.

Such data can also be used later to predict certain specific faults as well as help recognize abnormal operating conditions much earlier than before. This added intelligence about faults would help predict, mitigate, or even eliminate root causes of known catastrophic failures with next-generation products.

An NFC/RFID application in industrial control and automation can be found with field sensors and I/O cards. The MAX66242 tag allows for the commissioning of the sensor card while the device is sitting unpowered on the shelves. Analog calibration data, key parameters, or other system-level information is downloaded into the tag on the sensor or I/O card using a smartphone just before it is installed. Thus, consumers can use their smartphones to buy credits for certain devices and use the smartphone application (app) to load the credits or enable the feature via the portable device's NFC/RFID connection. ed

REFERENCES

1. For more information, go to http://nfc-forum.org/.
2. These specifications are in an ISO Standard document. They are known but not freely available on the Internet. One must pay to receive a copy. For more information, go to www.ansi.org.

HAMED SANOGO, executive business manager at Maxim Integrated Products, is responsible for the Secure Authenticator and NFC/RFID product lines. Hamed graduated from the University of Alabama at Birmingham (UAB) with a BSEE, and earned an MSEE at the University of Michigan-Dearborn and an MBA in Technology Management at the University of Dallas.

DAVID SCHNEIDER and MARCEL URBAN | ams AG

Overcome Stray Field Interference in Magnetic Position-Sensor ICs

Dual-pixel technology has proven to be invaluable in dealing with stray fields.

Magnetic position sensing has proved popular in a range of motion- and motor-control applications in the industrial and automotive markets. Various methods for measuring flux density have evolved, leading to the development of the fully integrated magnetic position-sensor ICs that incorporate the magnetic sensing element, signal conditioning, and signal processing on a single chip.

The latest generation of 3D magnetic position sensors from ams uses a pair of sensor elements (pixels) that make it possible to sense magnetic flux in three dimensions. The pixels are essentially the same sensing elements used on more common magnetic position sensors; in this case, however, there are two, positioned 2.5 mm apart.

The pixel pair, coupled with more sophisticated on-chip signal-processing algorithms, gives the new devices a wider range of applications than ever before.

MAGNETIC POSITION SENSING

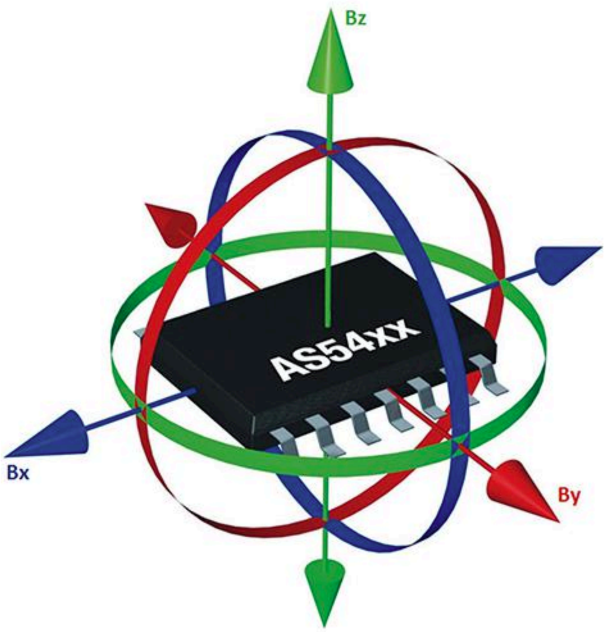
For position sensing, magnetic technology has always been more robust and reliable than optical sensing or contacting (potentiometer) methods for position sensing. It is unaffected by the dust, dirt, grease, vibration, and humidity commonly found in harsh automotive and industrial applications.

Yet design engineers who use conventional magnetic position sensors increasingly have found themselves running into a problem: interference from stray magnetic fields. These tend to corrupt the sensor's output or reduce the signal-to-noise ratio (SNR) to unacceptable levels.

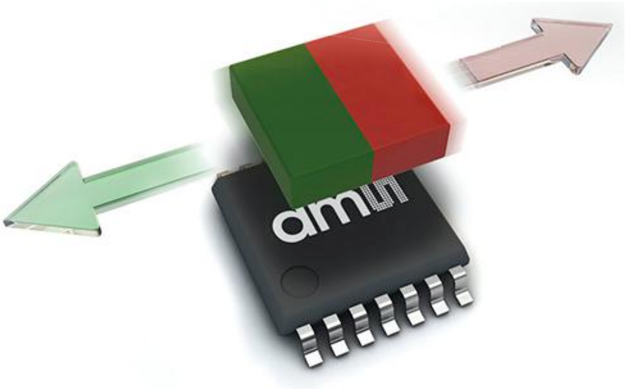
This has significant impacts. The known risk alone of malfunction due to stray magnetism is damaging to safety-critical designs, which in the automotive field must comply with the stringent risk-management requirements of the ISO 26262 standard *("Road vehicles – Functional safety"; www.iso.org/iso/catalogue_detail?csnumber=43464)*.

The risk has increased as electrification in vehicles has been extended. Motors and cables carrying high current are particularly powerful sources of stray magnetism in vehicles. (These can equally be found in multiple industrial applications.)

Counter-measures to protect a vulnerable magnetic position sensor from stray magnetism have been cumbersome and expensive. A newer approach—making the sensor highly immune to stray magnetic fields—has proven to be superior.



1. The magnetic field around a 3D magnetic position sensor can be reduced to three vectors. An analysis shows why a single sensor, with two sensor elements (pixels) a known distance apart, can be used with a mathematical ATAN2 function in firmware to detect motion in the presence of stray fields.



2. Although one sensor can detect the position of a magnetic object in two dimensions, the example uses linear motion in order to simplify the analysis.

TRADITIONAL METHODS FOR PROTECTING SENSORS FROM STRAY FIELDS

One common approach to dealing with magnetic stray fields is simply to shield the sensor IC. This is less than optimum for two reasons. First, the shielding material interacts not only with the magnetic stray field, but also with the field of the magnet with which the sensor is paired. In a typical implementation, the paired magnet is attached to the moving object to be measured. The static position sensor converts the changes in magnetic flux into precise measurements of displacement as the paired magnet moves toward or away from it.

Unfortunately, the shielding material may itself become magnetized, and its characteristics will tend to change with temperature. In addition, shielding materials exhibit hysteretic behavior, potentially redirecting the paired magnet's flux lines away from the sensor.

To prevent these parasitic properties of the shield disrupting the system's operation, it must be placed at some distance from the magnet. This limits the system designer's freedom to place, route, and enclose the sensor module's components. It also makes the system larger and heavier, as well as more complicated, difficult to assemble, and expensive.

THE PAIRING ALTERNATIVE

A common alternative approach, which requires no shielding, is to pair the position sensor with a magnet that has very high remanence (B_r), and to assemble it in close proximity to the sensor. Remanence (or remanent magnetization), according to Wikipedia, "is the magnetization left behind in a ferromagnetic material (such as iron) after an external magnetic field is removed." The effect is to make the signal-to-stray-field ratio much more favorable; it also improves overall SNR.

Unfortunately, strong magnets, such as those made from neodymium or samarium-cobalt, are up to 10 times more expensive than cheap hard ferrite or plastic-bounded magnets, ruining the economic case for position sensors in many cases. In addition, this option is not available to the many applications, which cannot accommodate positioning the magnet close to the sensor IC.

BUILT-IN IMMUNITY

Better than either of these approaches is to make the sensor immune to stray magnetism. In fact, a basic mathematical operation enables the noise from stray magnetic fields to be cancelled—as long as the sensor's hardware is able to support the technique.

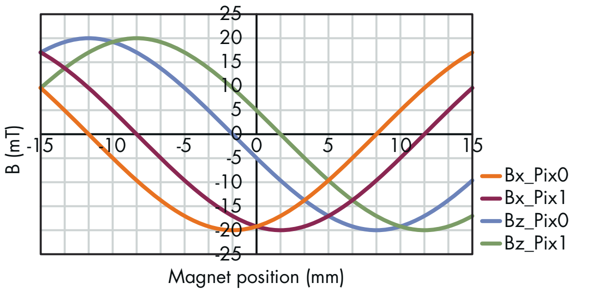
In addition, intelligent placement of the paired magnet, as close to the IC as possible, will always help to increase a sensor module's tolerance of stray magnetism. Yet the only way to achieve immunity to stray fields is to use a position sensor that has this feature built in.

The essential hardware feature of a magnetic position sensor with stray field immunity is a dual-pixel magnetic sensing element, described above. This dual-pixel structure then enables the implementation of differential measurement. Here's how: Each pixel cell can measure all three vectors of the magnetic field: Bx, By, and Bz *(Fig. 1)*. As noted, in members of ams' AS54xx sensor family, these two pixel cells are spaced just 2.5 mm apart.

To illustrate the mathematical operation simply, the following description of the sensor's working principle focuses on a linear application *(Fig. 2)*. In sensing linear motion, only the vectors designated Bx and Bz in Figure 1 need be measured by the device.

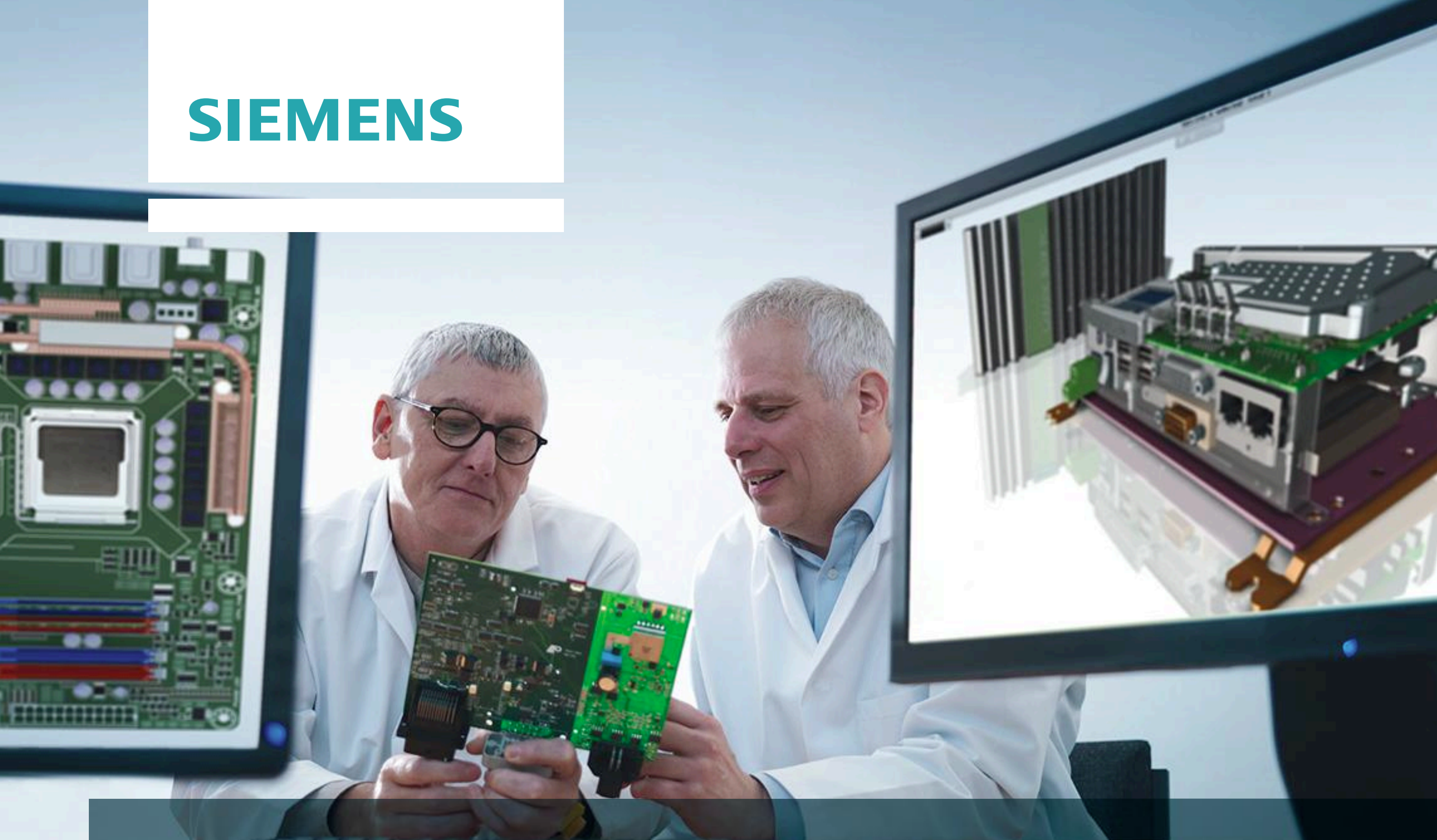
The sensor IC measures the following values to determine the position of the magnet *(Fig. 3)*:

Bx_Pix0...x vector of the magnetic field; measured by Pixel 0
Bx_Pix1...x vector of the magnetic field; measured by Pixel 1
Bz_Pix0...z vector of the magnetic field; measured by Pixel 0
Bz_Pix1...z vector of the magnetic field; measured by Pixel 1.



3. These output curves apply over a magnet travel of –15 to +15 mm. At magnet position = 0, the magnet is exactly centered over the package of the IC and the north-to-south pole transition of the magnet is exactly between the two pixels on the sensor. Since the pixels are 2.5 mm apart, there is a ±1.25-mm phase shift between the Pix0 and Pix1 curves.

SIEMENS



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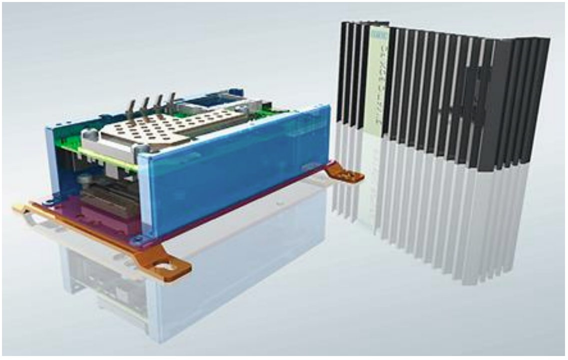

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From these values, the sensor IC calculates two differential signals, Bi (for the x vector) and Bj (for the z vector):

$Bi = Bx\_Pix0 - Bx\_Pix1$

$Bj = Bz\_Pix0 - Bz\_Pix1$

REJECTING STRAY FIELDS

To understand how stray field rejection works, imagine a stray field, Bs, applied to the device being measured. The source of a stray field is usually much further away from the sensor IC than its paired magnet. This validates assumptions that the same stray field vector is applied to both pixel cells.

Below are the same Bi and Bj formulas, but applied with stray field Bs. Bs has no influence on the values of Bi and Bj. Bs can be eliminated from the calculation to produce accurate position measurements without interference from stray fields. This is the differential principle of position measurement.

$$Bi = Bx\_Pix0 \pm Bs - Bx\_Pix1 \pm Bs \quad \Rightarrow \quad Bi = Bx\_\cancel{Pix0} \pm Bs - Bx\_\cancel{Pix1} \pm Bs$$

$$Bj = Bz\_Pix0 \pm Bs - Bz\_Pix1 \pm Bs \quad \Rightarrow \quad Bj = Bz\_\cancel{Pix0} \pm Bs - Bz\_\cancel{Pix1} \pm Bs$$

POSITION CALCULATION

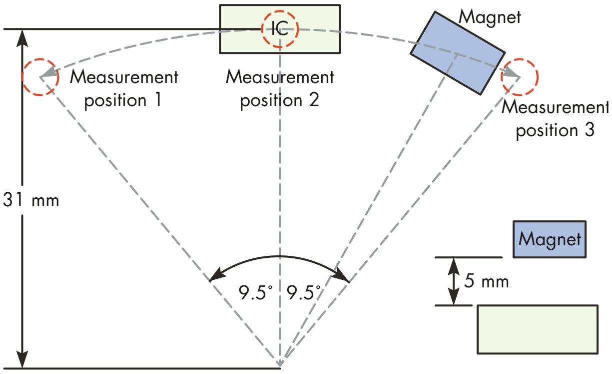
The magnet's position (MPos) may then be calculated from the values of Bi and Bj by an ATAN2 function: MPos = ATAN2(– Bj; Bi). According to Wikipedia: "ATAN2 is the arctangent function with two arguments. The purpose of using two arguments instead of one is to gather information on the signs of the inputs in order to return the appropriate quadrant of the computed angle, which is not possible for the single-argument arctangent function."

EXPERIMENTAL RESULTS

More empirical information is available from ams. The performance of a dual-pixel magnetic position sensor with differential sensing has been demonstrated in a laboratory setting.

The test in question compared the measurement results from an automotive position sensor module containing a dual-pixel sensor with another automotive module that implemented a conventional single-pixel sensor. The modules measured the movement of a magnet in an arc above the sensor IC *(Fig. 4)*. This kind of measurement would typically be required in an application such as measuring the movement of a car's brake, accelerator, or clutch pedal.

In the tests, a Helmholtz coil applied a stray field to the modules. The coil was configured to generate a stray field of known strength in the vectors Bx, By, or Bz.



4. The tests described in the article measured the movement of an object in an arc, as would be the case in measuring pedal movement in a vehicle.

The output voltage of the modules was measured with an oscilloscope. The captured data showed that the error of the single-pixel sensor IC was more than 30 times greater than the error of the dual-pixel IC when exposed to a stray field in the z direction.

COMMERCIAL DUAL-PIXEL SENSOR PARTICULARS

Specifications for ams' AS54xx series of automotive-qualified position sensors include an operating temperature range of –40° to +150°C, with no temperature compensation. Extremely sensitive, they can operate in a large input range from 5 to 100 milliTesla. When combined with high tolerance of magnetic stray fields, this allows for the use of small and cheap magnets.

The dual-pixel differential principle of operation does not, however, only provide for stray field immunity: It also eliminates the need to offset for drift over temperature and time. Featuring 14-bit resolution, these position sensors offer both accuracy and precision, making them suitable in a wide variety of applications.

LOOKING AHEAD

In the automotive arena, stray field immunity is going to become an increasingly important attribute of magnetic position sensors as the drivetrain of vehicles becomes partially or wholly electrified. New standards such as ISO11452-8 add to the challenge.

In this electromagnetically and mechanically harsh environment, three-dimensional dual-pixel sensor ICs provide a means by which designers can achieve relatively robust performance, as well as provide for compliance with the most exacting functional safety standards. On top of that, it's all possible without the need to incorporate complicated and expensive magnetic shielding. ed

PRASAD SAGGURTI | Product Marketing Manager, Synopsys

High Availability is Not Just for the Data Center

Many embedded designs need to incorporate high-availability features.

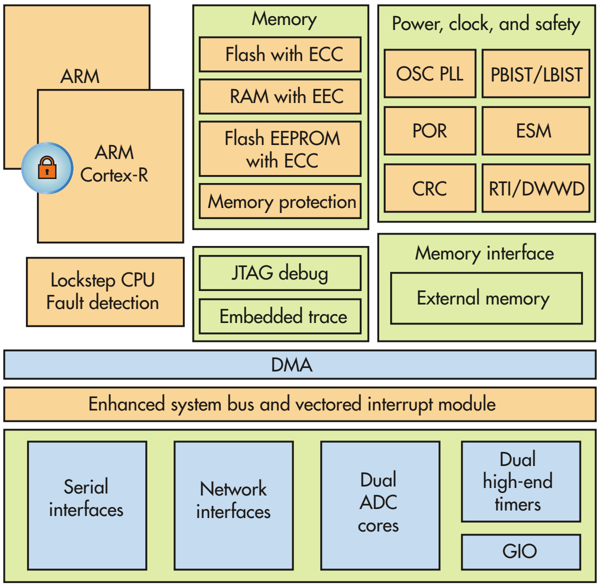
High availability (HA) is commonplace in many data-center applications where downtime costs money. Replication and redundancy are worth the added cost because the cost for downtime is even higher. For embedded applications, HA has more often been related to safety. Be it planes, trains, or automobiles, safety is a requirement. Electronics have made redundancy much easier to implement, making X-by-wire control feasible and economical. Some HA support in embedded applications is common, such as RAID 1 mirroring of storage.

HA in embedded applications is often a matter of degree and timing. For example, many motor-control applications need to maintain very strict timing for both the device being controlled as well as failover, should one of the controlling subsystems fail. At the other end of the spectrum, a door may take anywhere from a microsecond to a few seconds to unlock without any problems, so there is often quite a bit of time available to handle a failure.

HIGH-AVAILABILITY COMPUTATION

High-availability systems can employ replication of all or some components to provide a more reliable system. At the extreme end on the hardware side are high-availability systems that come implemented with hardware synchronization and checking support.

One example is Texas Instrument's (TI) Hercules line, which utilizes a pair of ARM Cortex-R cores *(Fig. 1)* that operate in lockstep mode where the hardware checks that both systems generate the same results *(see "Lock Step Microcontroller Delivers Safe Motor Control" on electronicdesign.com)*. These are often used in safety-critical areas where the hardware needs to run continuously, and additional latency for checking could cause more problems.



1. Texas Instrument's Hercules line utilizes a pair of ARM Cortex-R cores that operate in lockstep.

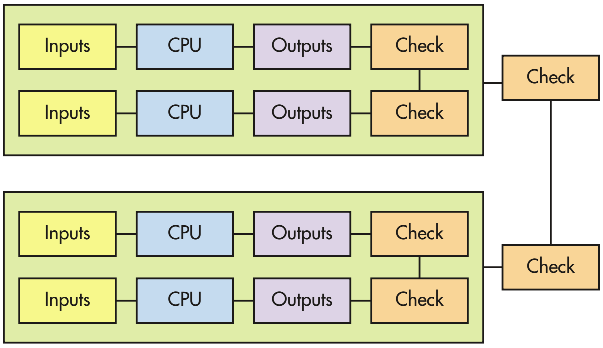
Freescale has a triple-core Qorivva line *(see "Multicore Processor Tackles SMP, AMP and Lock Step Mode" on electronicdesign.com)* that supports ISO 26262 ASIL-D safety integrity functional safety certification. Two of the three cores can operate in lockstep like the Hercules system, with the third operating solo and providing additional system functionality.

Dual-core, lockstep systems can detect errors usually by checking outputs on each clock cycle, but they cannot determine which result is correct when a difference is detected. NASA has often used triple-redundant implementations where a failed device is detected when results from two of the three disagree with the failing device. In this case, the checking hardware is enhanced by the voting hardware that in turn disables a failing device, allowing the other two to continue to run.

Another mode of operation for a dual-core setup is to operate in a master/slave or hot-spare mode. In this case, hardware is generally used to detect an error in the CPU such as a memory fault. The system checks for these faults in the master (or primary) system and switches to the slave (or secondary) system.

The approach taken is often dictated by the types of failures a designer has to address and how rapidly the systems need to recover. The lockstep approach is usually designed to support a failover in a single clock cycle. This is often needed in safety critical applications but not for all high-availability applications.

System configuration often dictates how a high-availability system is implemented. For example, Men Micro has an interesting approach that uses a dual-dual system lockstep approach *(Fig. 2)*. It employs two subsystems in a master/slave mode. Each subsystem is like a dual-core lockstep system, but operating at the motherboard level for hardware error checking. The master



2. Men Micro's approach for safety critical systems uses a dual-dual approach that essentially has four complete systems.

subsystem runs as long as the results from the two internal systems match; otherwise it assumes a failure. This would be similar to a dual-core SoC operating in lockstep detecting a memory error. The slave system becomes the master when an error is detected and the failing system is halted.

The advantage of this approach is that the subsystems are hot-swappable, much like blade servers or hot-swap disk drives. A failed system can be easily replaced while the other continues to run and the replacement now becomes the slave or hot-spare. Typically, some time is required to get the new system into a condition to be the slave since minimally it has to boot up.

Another advantage of this approach is that while the subsystems must run the same applications and have the same I/O, internally there may be hardware differences. That being said, most systems will tend to be very similar or identical. For example, there may be different brands of DRAM or different processor chips used that provide essentially the same functional characteristics for overall system operation. The key is that the software operates in a similar fashion.

Synchronization and voting times for more system- or software-based approaches are not as tight as with chip-based, lockstep mechanisms, but hardware-only mechanisms are significantly faster than pure software-based approaches. Conversely, software-based solutions provide more flexibility in implementing different synchronization and error-checking systems.

Replication of the I/O can be a challenge especially on the output side, since many devices are harder to replicate. For example, a disk-braking system for a single wheel may have only a single rotor, set of pads, and hydraulic system but a redundant processor controlling the hydraulics. It is possible to have a second system or replicate parts of it, such as a second set of pads. The design challenge is to examine both the failure points and the likelihood of failure of each of the components, in addition to the failure modes and their consequences. A car with four independent brakes—one for each wheel—will usually be able to stop a car if one (or possibly two) of these brakes fails, depending on where the failure occurs, since most cars have a single master cylinder and two separate pressure lines, one for a pair of wheels.

The input side of the equation tends to be a little easier to address since replicating sensors is sometimes less expensive and easier to implement. A motor shaft can easily drive multiple encoders that are used by redundant software systems. Another approach used with some motor control systems is employing sensor feedback to implement virtual encoders. The results of these can be compared with physical encoder inputs.

FENCING AND STONITH

Software-based high-availability systems are replacing traditional storage options, like storage-area networks (SANs), in data centers. They do not require lockstep and error checking hardware, but may employ other means to detect and control multiple systems.

The simplest mechanism for detecting many software failures is heartbeat detection. Many microcontrollers have some hardware support for this approach in the form of a watchdog timer. The timer is started in software with the idea that the application will complete its work and restart the timer before it expires. A watchdog timer can be implemented strictly in software, but a timer interrupt routine is needed to increment the timer and check for expiration. Regardless of whether the timer is hardware or software, the result is to perform an action such as restarting or halting the system.

Systems with two or more cores can implement a heartbeat system in software providing more flexible control. Heartbeat systems can involve servers as well. This is typically what happens with virtual machines (VMs) that are often used to implement high-availability systems. If the VM's heartbeat is lost, the VM can be restarted. Likewise, if the heartbeat of the system hosting the VMs is lost, then all of the hosted VMs could be restarted on another server.

A simple heartbeat is something like a watchdog timer or a message received within a specific timeframe in response to a query. More complex systems or detection is also possible. For example, the data within a message may have to meet certain criteria, such as the number of active nodes within a cluster. A three-node cluster might be restarted if two of the nodes fail.

The process of managing a system when it fails is called fencing. A system performing the fencing has the ability to detect a failure and then perform some action like resetting the failed system. This is what happens for a microcontroller that has a watchdog timer to restart the system if it times out. This is a very simple case of STONITH (shoot the other/offending node in the head).

There are a variety of STONITH mechanisms available to most designers of systems that provide a variety of services, ranging from restarting to isolating a system. Some examples include controlling the power-supply unit (PSU), IPMI (Intelligent Platform Management Interface), and VM control. Network-based PSU and IPMI control is often used in data centers on a management network that's independent of the application network to control the servers. Isolation can also be achieved by controlling network switches or storage services that a system or VM requires to operate.

Server operating systems like Linux, Windows, and Solaris include HA services that use these fencing mechanisms. They have typically targeted the data center, but the same tools are found in many embedded HA environments like carrier-grade communication servers.

One system that is popular for managing HA systems on Linux is Pacemaker from Cluster Labs. It supports the orderly startup and shutdown of applications and services. Applications are often VMs running on a KVM (kernel-based virtual machine). Pacemaker can manage multiple servers within a cluster and multiple clusters. It can scale from small embedded systems to data centers with many clusters and VMs, and it can handle multiple fencing mechanisms. It can even run on small Linux targets like Raspberry Pi.

FAULT-TOLERANT HARDWARE

One way to minimize downtime is to use one of the forms of local-disk RAID support. RAID configurations typically include RAID 0, 1, 5, and 6, or variations of those like RAID 10, which is a combination of RAID 0 and RAID 1. RAID 0 does not provide any fault tolerance, but it increases overall transfer rate. RAID 1 is full drive mirroring. It keeps a copy of the data on two disks of the same size. The system continues to work if one disk fails.

RAID 5 and 6 use distributed parity. RAID 5 requires at least three disks and continues to work if one fails. RAID 6 uses at least four disks and continues if two disks fail. Most engineers will be familiar with software RAID or hardware controllers that have RAID support. It is also possible to utilize software RAID support using network storage like iSCSI devices.

HIGH-AVAILABILITY STORAGE

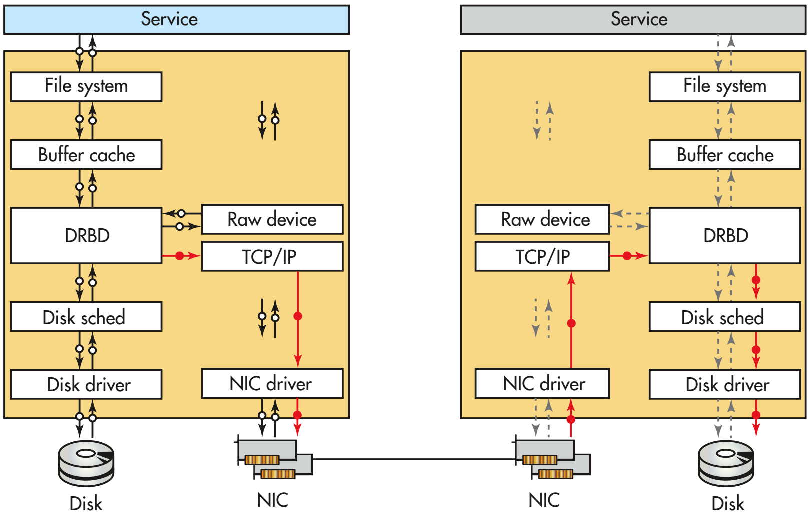
A full system approach is to use services like LINBIT's DRBD (Distributed Replicated Block Device), which provides distributed storage over the network *(Fig. 3)*. DRBD presents a logical block device on each host. This means that any service or application that can write to a hard drive, can be made fully redundant and highly available. Various configurations are possible, including active/active and active/passive setups where an active device can be used by local applications, and VMs while a passive device is kept up to date synchronously. In this HA environment, a passive device can be made active if its partner fails.

DRBD works with multiple hosts, although two to four host machines tend to be the most common configuration. In addition to fault-tolerant hardware, having at least three hosts with the same data provides the ability to survive the loss of one host without restart issues. A two-host active/active configuration can have split-brain problems. This occurs when both hosts are out of sync, but both want to be active. The using of fencing and STONITH support can minimize and/or overcome this problem.

Another Linux tool for clusters that provides HA support is CLVM (cluster logical volume manager). This offers a distributed locking mechanism for logical volumes that can be used by local applications and VMs. The latest version delivers RAID support and can use network storage like iSCSI devices. Distribute file systems can also be utilized with HA systems. Sometimes they are combined with underlying HA storage, such as DRBD and CLVM. Some cluster file systems can be used alone, requiring only local storage and a communication mechanism.

Microsoft Windows ReFS (resilient file system) is a distributed file system for Microsoft Servers. Oracle's Solaris supports a file system named ZFS. ZFS is also available for Linux. Red Hat Enterprise Linux (RHEL) can use GFS2 on CLVM-managed volumes. Another Linux-based cluster file system is Gluster File System. All of these can be employed on embedded systems capable of supporting the underlying operating system.

Database services are another form of storage that can often be configured to support HA. The type of underlying storage and



3. DRBD provides a logical block device that replicates data on local storage

network communication required varies between databases, but typically they can use local file systems and TCP/IP networks. Distributed database services are even available for mobile devices and devices designed for the IoT. Typically, device side is a lightweight client that often uses a memory-based or flash-based file system, with data being replicated to the cloud.

HIGH-AVAILABILITY COMMUNICATIONS

Ethernet and TCP/IP tend to be the communication mechanisms for data centers, as well as for many embedded applications. Multiple channels can be bonded together to provide link aggregation that presents a single logical channel to an environment. This approach can provide additional throughput for HA environments.

Embedded systems are not restricted to Ethernet, although it is very popular. RapidIO and InfiniBand are used in HA systems as well. Even PCI Express (PCIe) has been tasked with providing the communication mechanism using links like Dolphin Interconnects. PCIe, RapidIO, and InfiniBand have the advantage of low overhead and high throughput.

Higher-level systems can be built around these network communication systems. One popular platform is Distributed Data Service (DDS), which uses a publish/subscribe methodology.

HA applications may or may not interact directly with the underlying HA software and hardware support. HA configurations using tools like Pacemaker can manage application VMs and use HA storage and communications support without modifying the applications. At the other extreme are applications that are tailored to understand the HA support and interact with it more intimately.

Image courtesy of Thinkstock

Defense Markets Continue to Falter

New study predicts a flattening of the global defense market over the next two years.

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR

SUPPLY-CHAIN COMPANIES serving defense markets have watched as shrinking budgets in the United States have slowed business to that sector, and many have started to broaden their reach to new market opportunities as a result. Such decisions may be wise, as a new report from industry researcher IHS predicts a flattening global defense market over the next two years, accompanied by key changes in the market going forward.

In its Defense Budgets Annual Report, the researcher notes that declining oil prices will hinder defense market growth in the Middle East and Africa over the next two years, and that Asia Pacific is set to become the driver of world growth by 2020. The report also says that by 2019, NATO will no longer account for the majority of global defense spending for the first time in the alliance's history.

"Spending in Asia Pacific, meanwhile, is expected to grow to $547 billion by 2020, over 30% of the global total," according to Craig Caffrey,

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The Realities of Global Pricing

Electronic component buyers' desire for "worldwide pricing" continues to spur a healthy dialog throughout the supply channel.

MICHAEL KNIGHT | TTI, INC.

GLOBAL PRICING IS a frequent discussion topic with many customers who have global operations, and even with some who are confined to only one region of the world but are hunting for the lowest component acquisition cost. The discussion starts after a request for global pricing runs into a brick wall with component manufacturers and distributors. It is a perfectly logical request to which a negative answer, on the surface, seems perfectly illogical.

To start with, what a customer is asking for when they request a global price is the lowest price at which that component is sold for in the world. Behind that is the implied realization that the manufacturing cost for that component, should it be manufactured in multiple geographies, is likely to be different at each site. Often, parts made in low-cost regions in Asia are assumed to have the lowest manufacturing cost, so what customers frequently are asking for is the Asia price for their out-of-Asia production requirements. This is actually a good starting point for the discussion, as it acknowledges right up front that price is a function of cost. With that in mind, what the conversation quickly turns into is one about the realities of "cost."

Just as price is a function of cost, a component cost is itself a function of other things, starting with the already mentioned manufacturing location. The obvious factor in this is differences in labor costs. Less obvious are differences in utility costs, currency conversion, regulatory costs, labor

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Realities of Global Pricing

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skill, and transportation costs. The location with the lowest labor costs doesn't always enjoy the lowest relative costs for these other location-dependent elements, which is why reshoring, or the practice of moving manufacturing out of these lowest-labor-cost areas back to the Americas, is happening. Any component manufacturer with global operations can probably talk specifically about the differences between their plants. And what all of us are experiencing firsthand is the impact of rising freight costs.

Another element of cost is volume. The higher the volume a component is manufactured in, the lower the piece price. One of the advantages of the Internet is that it allows an engineer to search for and find a component with all of the ideal attributes he or she wants. The disadvantage is that the more ideal the part the engineer selects, the more chance there is that it is only going to be used by a very small group of customers.

The cost of raw materials, and the volumes in which they themselves are purchased, is the third major element of a component cost. The acquisition cost of a given raw material often fluctuates around the world as a function of labor and transportation costs at the site where the material is mined and/or produced. While it is true there are global commodity indexes for raw materials, what they are reflecting are price averages and they do not factor in distribution costs. This is another topic of conversation with customers who believe that the price paid for a finished component should perfectly track that of the price indexes for the raw materials that go into that component.

There are two final major factors in a component's cost as it pertains to "globalness," both of which are business-related. The first is the intercompany transfer pricing structure that the manufacturer uses when moving its parts from one region to another. One would think that within the manufacturer itself, its products would move from one region to another at the same cost at which they were originally produced. This is almost always not the case. Things like taxes, duties, freight (air versus ocean), and cost-accounting rules all factor in. For example, parts made in Japan by Japanese component manufacturers are usually sold to their overseas operations, as the manufacturing site is run as a profit center. The selling organization is buying the parts from the plant at an uplift, and then, in effect, reselling them, after applying another uplift as they, too, are a profit center. The solution would seem to be to buy parts directly from the manufacturing site, which some customers are exploring, but that too has many less-than-obvious factors to be considered.

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Defense Markets

Continued from Page 45

senior defense budgets analyst at IHS Aerospace & Defense.

Other key findings include:

- The UK resumed its position as the third-highest defense spender in 2014, ahead of Japan, Russia, and France.
- Russian defense spending is forecast to reach its peak of $63 billion in 2015.
- India is forecast to become the third-largest defense market by 2020.

ASIA PACIFIC DRIVES GROWTH, U.S. DECLINES

Growth in Asian defense spending is expected to increase from 3.3% in 2014 to 4.8% in 2015, making the region a global leader of growth going forward. What's more, by 2020 defense spending in the region is set to outpace that of the U.S. if sequestration continues here at home. Today, the U.S. outspends Asia Pacific by $170 billion.

"By 2020, the center of gravity of the global defense spending landscape is expected to have continued its gradual shift away from the developed economies of Western Europe and North America and toward emerging markets, particularly Asia," Caffrey said. "In terms of overall growth in each region between 2015 and 2020, Asia Pacific is expected to solidify its role as the key driver of growth in the defense sector."

The change in global outlook is compounded by slowing conditions in the Middle East and Africa, where falling oil prices are affecting the short-term outlook, IHS says. The region saw a 30% increase in defense spending from 2011 to 2014, but such conditions are ending as the region struggles with the economic challenges of lower oil prices.

TOP 5 GLOBAL DEFENSE BUDGETS, 2014

United States	$589 billion
China	$176 billion
United Kingdom	$58 billion
Japan	$55 billion
Russian Federation	$54 billion

Source: IHS Jane's Annual Defense Budget Report, 2014

Here at home, companies supplying the U.S. military market continue to face tough times, as shrinking budgets are expected through fiscal year 2019. This is due to both declining troop strength in Afghanistan and ongoing pressure from sequester reductions, analysts said. They expect investment, procurement, and research and development in FY '14 in the U.S. to be at its lowest value in a decade, with even lower investment projected for FY '15.

"We expect a decent increase in investment starting in FY '16, yet dependent on a potential sequester becoming reality once again," said Guy Eastman, also a senior defense budgets analyst at IHS Aerospace & Defense. ■


Semiconductors power the
INTERNET OF THINGS

Realities of Global Pricing

Continued from Page 46

The second business-related factor is current market conditions. In slow markets, component manufacturing capacity can greatly exceed demand. At such times, a given supplier is often willing to sell incremental volume at a lower price than they normally would in order to cover fixed costs and achieve some level of contribution margin. An added benefit of this practice during a slow time is the capture of additional market share that may, or may not, stick to the company when the market improves. This, in fact, describes the market conditions of the past seven years or so, and is the principal underlying reason behind the period-on-period component price declines that the customer base has experienced over time. But even this isn't straightforward, as any given product category can have a range within it that is high-demand while everything around it is anemic.

The bottom line is that there is no common bottom line from which a global price can be built today. The closest that a component manufacturer, or even a distributor, can realistically come today is an average global cost from which a single price can be constructed, much like the above-mentioned commodities index. This isn't the lowest price in the world, nor is it the highest, but it can meet some of the needs of those customers who must have a global price in order to standardize their finished goods pricing for their own products.

All of that said, this is a very healthy dialog to have between component customers and suppliers. Globalization is a reality, and it brings with it a host of new requirements, challenges, and opportunities. I believe that something along the lines of global pricing is inevitable. The World Wide Web (www) will play a big role in the development of a World Wide Price (wwp), and given the speed of change that the Internet is driving in virtually everything, I think it's a safe bet that before I retire my company will be quoting global pricing, of some sort, to our customers. ■

Michael Knight is senior vice president, Americas, for authorized distributor TTI Inc. This column previously appeared on www.globalpurchasing.com.

Researcher Lists Top LED Trends for 2015

Restructuring at leading companies could lead to new investment, lower product prices in LED market, according to industry researcher IHS.

GLOBAL PURCHASING STAFF

RESTRUCTURING AT THE top three LED makers in 2014 may pave the way for improved margins and potentially lower product prices for consumers, according to a new report from research firm IHS. In a white paper titled "Top Lighting and LEDs Trends for 2015," the firm points to the changes and some resulting trends in the LED market for this year and beyond.

"For the big three lighting suppliers, the road was bumpy: All of them recorded falling revenue in the first three quarters of 2014," said William Rhodes, research manager of lighting and LEDs at IHS Technology. "Industry watchers are now looking to see if these giants of the lighting industry can turn the tide in 2015."

Restructuring at Philips, Siemens AG, and GE could make the companies pure-play lighting firms that are better able to capitalize on growth potential over the next few years, according to IHS, which identified 10 market trends to watch as a result; here are the top five:

China, the LED dragon, will continue to grow. China's LED industry has grown rapidly over the last five years, and IHS predicts that trend to continue.

The sky is the limit for cloud-based smart lighting. Although the market for cloud-based "smart lighting" is unlikely to gain share in 2015, the researchers expect companies to increase their marketing of such solutions, paving the way for longer term growth.

Changing fortunes for lighting companies expected in 2015. "Changes in the corporate structure could lead to improved margins for the companies, and possibly lower-priced products for consumers," Rhodes said.

Li-Fi, a brighter way to communicate. Visual light communication, or LI-Fi, is an emerging technology that competes with WI-Fi, using visible LED light for high-speed data transmission. IHS said it expects to see pilot projects and greater media interest in 2015.

QD-LEDs are a technology to watch. Research is ongoing, but IHS predicts that quantum-dot LEDs (QD-LEDs) may "kill off" the organic LED (OLED) display market, in particular, in the years ahead.

The other five trends include growing interest in OLED luminaires, improvements in LED filament bulbs, an enhanced and improving packaged LED industry, advances in LED street lighting, and growth in the optoelectronic components market driven by automotive industry demand. ■

LINEAR TECHNOLOGY
DESIGN NOTES

Precision Op Amp Enables Fast Multiplexing at Low Power

Design Note 536

Kris Lokere

Introduction

If you are designing a system that measures a number of analog voltages, but not all at the same time, you can reduce downstream circuitry by multiplexing the measurements into a single output signal, then serially process and digitize the original voltage levels using shared components. The benefit is that the number and size of signal chain components is a fraction of that required by a per-channel design. Properly implementing a multiplexing solution requires attention to a few details, especially if you want to quickly switch between channels, measure accurately and maintain low power consumption.

Respond Quickly

Multiplexing increases the frequency content of the combined signal, since every time the multiplexer switches channels, the multiplexed signal changes value. Even if the input signals do not change quickly, the multiplexed signal does, so any circuitry after the multiplexer must respond quickly to these transitions. For instance, if the output signal does not fully settle to the target accuracy before the next channel is read, then the measured value of a given channel can depend on the value of the previous channel, equivalent to channel-to-channel crosstalk.

Because a multiplexer has non-zero on-resistance, it is often necessary to buffer the output using an op amp. Figure 1 shows a multiplexed circuit, with per-channel op amps before the MUX, and one shared op amp after. It's the performance of the shared downstream op amp that we consider here.

Op amps with low power consumption tend to be slow. In particular, op amp slew rate is typically closely related to op amp supply current. This is because the current available to charge internal capacitors is a fixed proportion of the op amp total supply current.

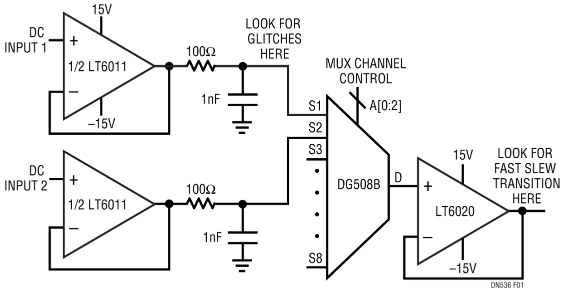

Figure 1. Multiplexed system. LT6011 buffers at inputs have high input impedance. The LT6020 after the MUX can slew fast when MUX changes channel. LT6020 special input circuitry avoids voltage glitches at MUX inputs.

The LT®6020 op amp, on the other hand, has a much higher slew rate than you would expect for its low supply current. It performs this feat by adjusting the slew rate based on the size of the input step, so large input steps are processed just as fast as small input steps.

Figures 2a and 2b show the impact on transient step response of the LT6020 compared to a conventional op amp of similar power consumption. For conventional op amps, the large-signal response is much slower than the small-signal response. The LT6020, however, responds just as cleanly to a 10V step as to a ±200mV step. This ability to slew fast and settle quickly to a new value, while still drawing only 100μA of supply current, makes the LT6020 a good choice as a buffer after a multiplexer.

Avoid Glitches

Even if the op amp following the multiplexer is fast enough, there is another important detail that is often overlooked. Most precision op amps have internal protection diodes across the input stage to avoid reverse biasing sensitive bipolar transistors at the input stage.

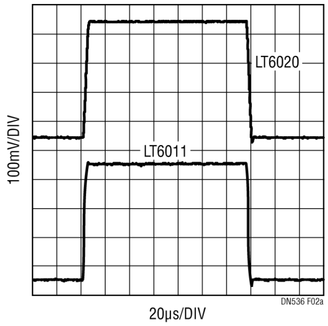

Figure 2a. For small output signals, the LT6020 performs similarly to other op amps of the same power level. The response is dominated by gain bandwidth.

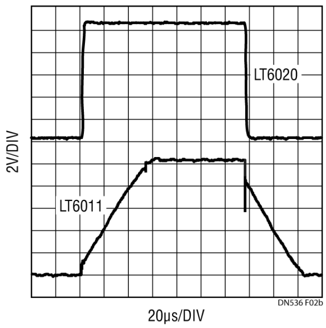

Figure 2b. For large output signals, the LT6020 preserves signal fidelity compared to other op amps of similar power level. The response is dominated by slew rate.

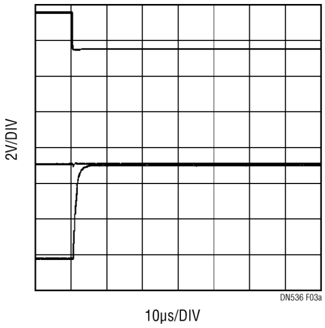

Figure 3a. As soon as the control signal (top trace) changes the MUX channel, the LT6020 output (bottom trace) transitions from the voltage on the previous channel to the next channel. The middle trace shows the input to the multiplexer, with almost no voltage glitch.

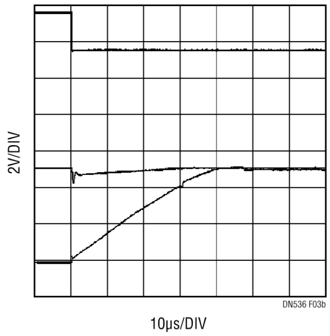

Figure 3b. Same setup as 3a, but with a conventional op amp after the multiplexer (LT6011). The signal at the input to the multiplexer (middle trace) shows a noticeable glitch due to current flowing through the multiplexer into the protection diodes of the op amp.

When the multiplexer switches from one channel to the next, the input voltage at one terminal changes quickly, with the output (and therefore the feedback node) not yet changed. This causes a large current spike to flow through the internal protection diodes. Where does that current come from? It must come from the circuitry connected to the input of the multiplexer. If that circuitry is high impedance, or slow, then this current spike causes a voltage glitch. The output of the system then tries to follow that input voltage glitch, so that the output cannot settle accurately until after that voltage glitch has resolved itself.

The LT6020 op amp provides a unique solution to this problem. Its input devices are very accurate, but also robust enough to allow more than 5V reverse bias. Therefore, rather than internal protection diodes, a pair of back-to-back Zeners protects the input. As a result, no current spikes occur for input steps of 5V or less. Figures 3a and 3b show that the LT6020 op amp causes almost no voltage glitches at the output of the sensor, while a traditional precision op amp (LT6011 shown as example) causes a large voltage glitch.

Conclusion

Correctly multiplexing precision signals into one output signal requires careful attention to detail. The LT6020 op amp simplifies the design of multiplexed solutions with a set of unique features. For instance, its slew rate is much faster than other op amps at this low supply current level, allowing it to respond quickly to channel changes. Also, its unique input protection scheme avoids current spikes that would otherwise cause upstream glitches during channel changeover using a traditional precision op amp.

Data Sheet Download

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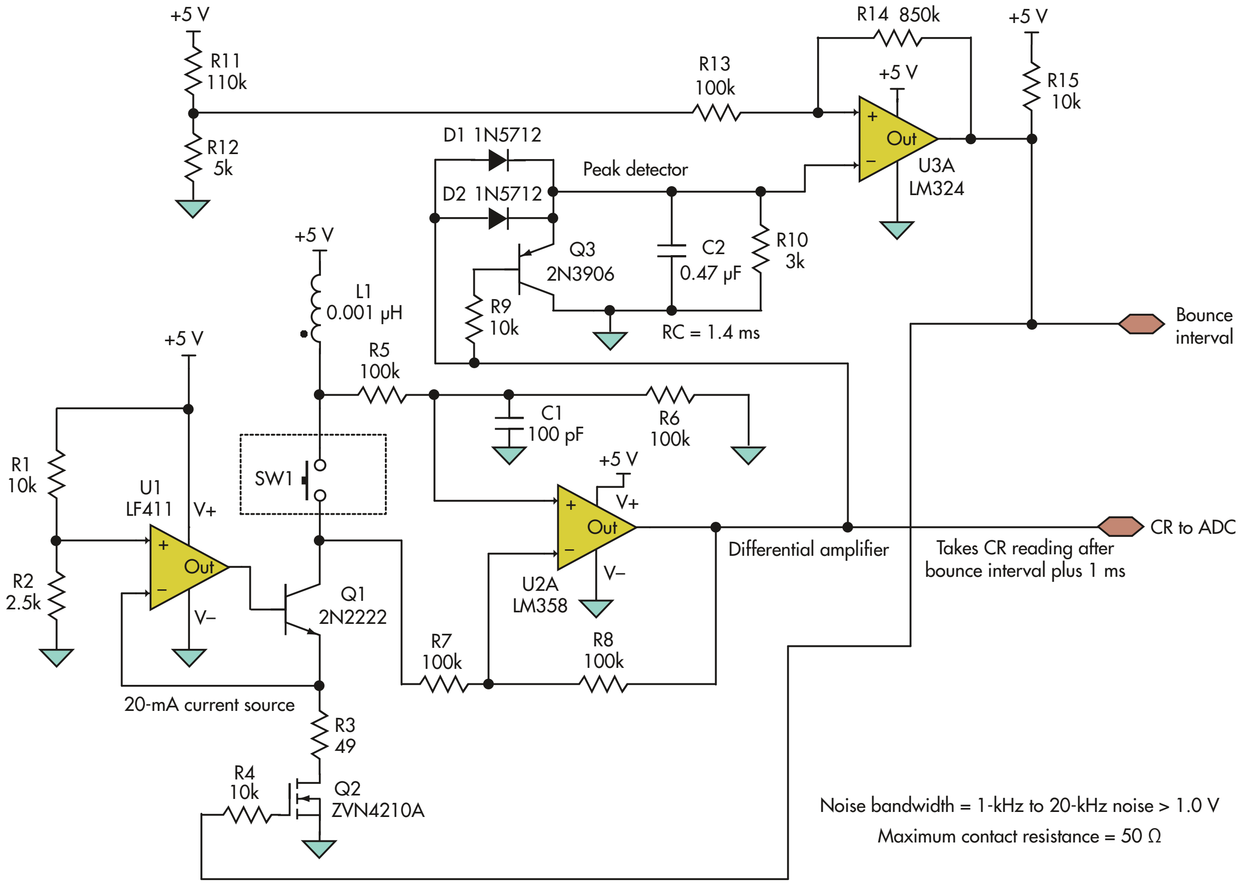
Analog Peak Detector Frames Mechanical Bounce, Quantifies Contact Resistance

DAVE CARTY | indigo1255@yahoo.com

MECHANICAL BOUNCE OFTEN OCCURS while trying to measure current or resistance on experimental materials or from routine switch-contact action. It can be a problem if you are trying to preserve the bounce or noise phenomenon within the measurement system itself. Typically, such switch-bounce or similar noise is eliminated by using filtering or software delays that implement "guesses" on when the unknown disturbances may have subsided.

The circuit in Figure 1 allows analysis of noise or mechanical bounce within time intervals set by a simple peak detector with an associated comparator. Switch-contact resistance then can be read automatically through the differential amplifier by using the known current source (set here at 20 mA).

The resultant signal can be digitized to measure bounce times. When the bounce has subsided, it allows very accurate contact-resistance measurements. This band-limited process requires



1. The analog peak detector develops a "window" around the switch-bounce period, enabling measurement of contact resistance using a current source.

no oscilloscope, time delays, or filtering. It also automatically quantifies the mechanical-noise activities.

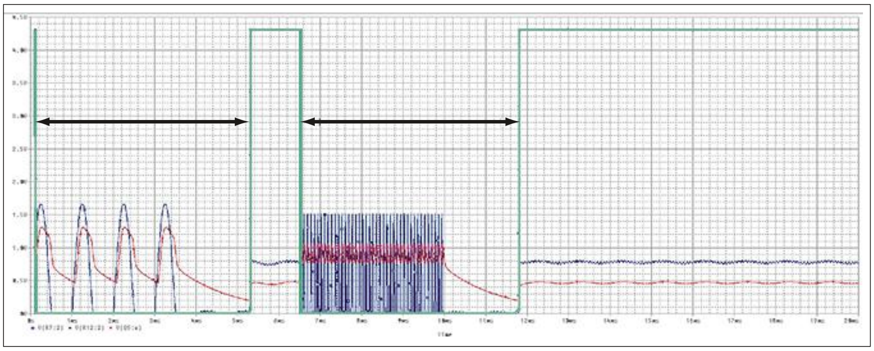
This circuit will enable a contact-resistance measurement only when noise is not present at the output of differential amplifier U2, pin 1 (V_{PEAK}). The switch bounce/noise amplitude will have to be larger than 1 V (peak), and the bounce/noise frequency must be greater than 1 kHz (period less than 1 ms).

When the sample switch is closed, potential noise could develop at the simple differential amplifier, which has gain of R6/R5 ($V_{IN+} - V_{IN-}$). An output greater than 1 V will be enough to overcome the threshold of peak-detector diodes D1 and D2 and, at the same time, turn off transistor Q3, which enables the RC-time constant of R10 and C2, currently set at 1.40 ms.

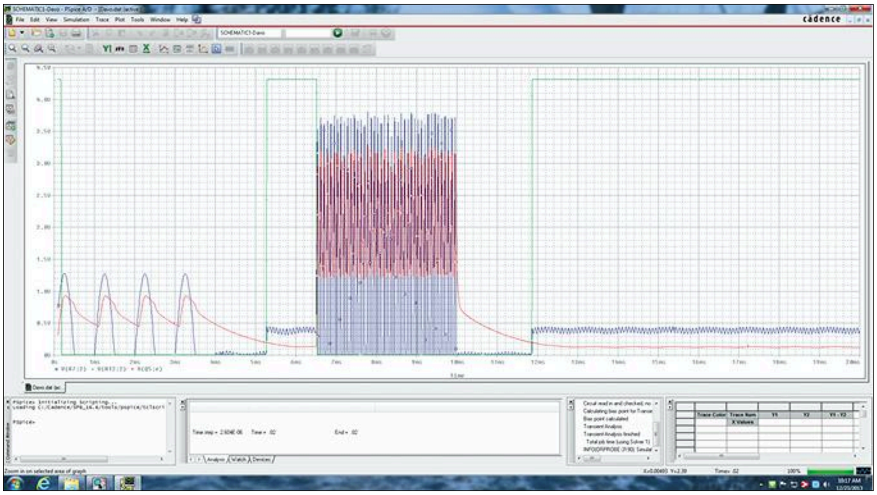
However, it can be set higher, which will enable slower-frequency components to influence the hysteresis comparator. The RC time constant must be longer than the desired noise transitions. (Note that the comparator is also designed to incorporate hysteresis.)

For the hysteresis detector to disable the current source, V_{PEAK} from output of the differential amplifier must be greater than ($8.5/9.5 \times V_{REF}$) + 5/9.5 + 0.4 V. Similarly, for the comparator to enable current-source readings, V_{PEAK} must be below $8.5/9.5 \times V_{REF}$. In this example, peak-detector voltage V_{REF} is set at 0.217 V.

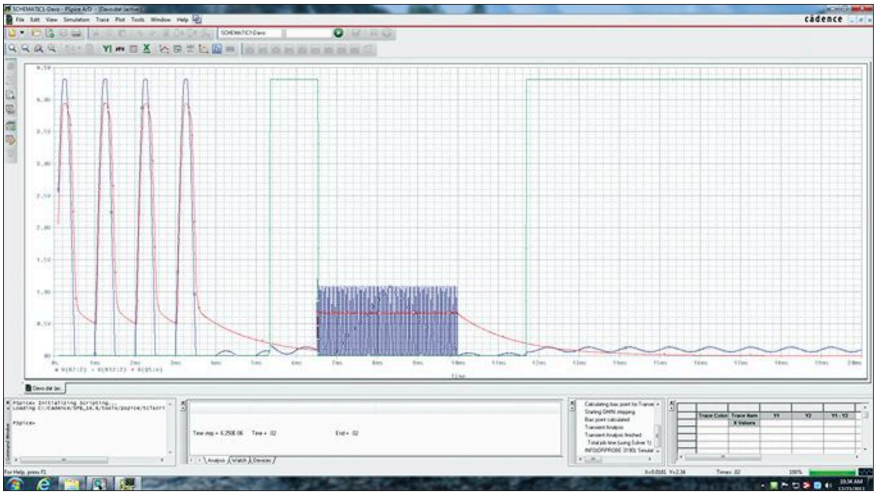
Once the noise from the output of the amplifier drops below 1 V or the transitions become longer than the RC time constant set by R10 and C2, transistor Q3 will turn on, quickly disabling the RC time constant available for the detector. At this juncture, the comparator will reset. After the comparator is reset, it can then enable FET transistor Q2 to provide the contact-resistance reading without experiencing interference.



2. The noise-capture event is characterized by the output of the differential amplifier (blue trace), the output of the RC-peak detector network (red), and the action of the hysteresis detector (green) here for a pair of noise bursts of different periods.



3. The noise bursts are set at 1.25 and 3.5 V, and the contact resistance is 0.4 V, indicating a resistance of 20 Ω.



4. The noise bursts are 4.25 and 1.10 V, and the contact resistance is close to 0 V, which indicates a resistance of 0 Ω.

The current source is used to provide constant current through transistors Q1 and Q2, here set to 20 mA via the 1-V/50-Ω pairing. The 1-V control is provided by the simple op-amp U1. (Be sure to include the on-resistance $R_{DS(on)}$ of the enable FET when setting up the current source.)

In the noise-capture event simulation, the blue trace is the voltage output of the differential amplifier, the red trace is the voltage developed by the output of the RC-peak detector network, and the green trace shows the action of the hysteresis detector *(Fig. 2)*.

The first noise-bounce burst is set at 1 kHz, 1.5 V. The second burst is at 20 kHz, at the same amplitude. The white arrows indicate a time interval representing switch bounce. Contact-resistance readings then can be enabled when the square pulses (green) are high. The contact resistance (the blue trace, when enabled) is close to 0.8 V, which indicates a resistance of 40 Ω.

In *Figure 3*, the noise bursts are set at 1.25 and 3.5 V, and the contact resistance is 0.4 V, indicating a resistance of 20 Ω. Finally, in *Figure 4*, the noise bursts are 4.25 and 1.10 V, and the contact resistance is close to 0 V, which, of course, indicates a resistance of 0 Ω.

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Active Emulator Supports Multiple RTD Wiring, Sense Configurations

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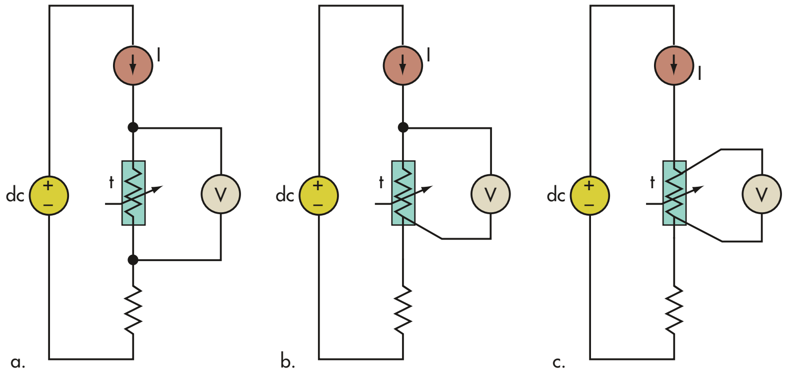
BEFORE RUNNING A formal test with multiple resistance-temperature-detector (RTD) sensors, it is often necessary to calibrate and debug a data-acquisition system to verify basic functionality. The brute-force approach would be to wire all of the sensors to the front-end board and use an environmental chamber to set the temperature of the RTDs. An easier way is to use a software-controlled RTD emulator to produce voltages that span the range of the RTD's output.



1. In the various RTD wiring configurations (two-, three-, and four- wire), the use of extra sense wires increases precision by reducing errors induced by cable resistance, but at the cost of extra leads.

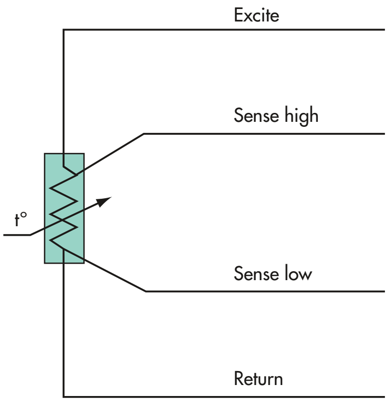
RTD sensors are available using two-, three-, and four-wire configurations, which differ in their use of sense wires *(Fig. 1a, 1b, and 1c, respectively)*. The most basic type of RTD has two wires and no sense wire, while the three-wire RTD has one sense wire attached directly to the RTD lead, and the four-wire RTD has two sense wires.

The extra sense wires are used to minimize the effects of parasitic resistance, which occurs when using long cables and reduces the achievable precision of sensor readings. Four-wire RTDs offer the highest precision, but are the most expensive *(Fig. 2)*. The RTD excite wire is connected to constant-current source, and return wire is typically connected to a load resistor.

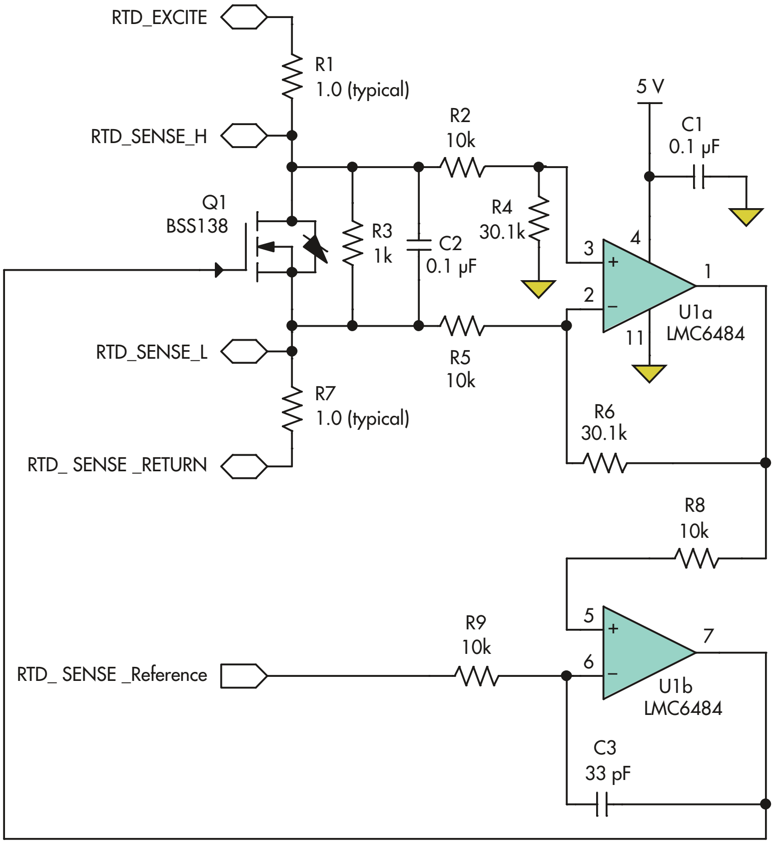
This emulator supports all three RTD configurations *(Fig. 3)*. It uses an external current source and load resistor provided by the external sensor board to emulate characteristics of a real RTD device. The constant-current source should have relatively low current to prevent self-heating of the RTD sensor. It is usually selected to be in the range of few hundred microamperes to 1 mA. Readings are usually done via an instrumentation amplifier followed by a 12- to 16-bit analog-to-digital converter (ADC).

In the emulator, U1a is configured as a differential amplifier with a gain of 3.01. U1b is configured as a comparator. Transistor Q1 (a low-level FET) is used as the active element that generates voltages according to the RTD reference voltage. C1 provides basic decoupling from power-supply noise while C2 and C3 prevent parasitic oscillations. The values of resistors R1 and R7 are chosen to emulate long cable connections of RTD sensors. Here, they are shown as 1 Ω, a representative value.

Input RTD_Reference is used as the basis of the generated voltage. In this case, it is connected to a 16-bit digital-to-



2. Nomenclature for the RTD sensor wires maintains consistency, regardless of the number of wires used.



3. In the RTD emulator, Q1 (an N-channel logic-level enhancement-mode FET) is the active component that provides the controllable voltage to emulate the RTD.

analog converter (DAC) (not shown). The output voltage V_{RTD} across RTD_SENSE_H and RTD_SENSE_L is determined by voltage applied to the RTD_SENSE_reference input and the gain of U1a:

$$V_{RTD} = V_{REF}/Gain$$

Using a 16-bit DAC and a 2.5-V reference to generate V_{REF}, this RTD emulator can produce 0 to 830 mV in 12.7-µV increments. This easily covers the RTD temperature range of –200°C to 384°C, according to the sensor datasheet from Omega Engineering Corp.[1] By changing the gain of the differential amplifier or the range of V_{REF}, you can easily adjust circuit parameters for different ranges.

Also in this circuit, the RTD voltage is independent of the current source. You can use a 100-µA or 1-mA current source, or even a resistor, to provide the required current and still get the same RTD voltage for all three cases. The RTD voltage is independent of the value of the load resistor as well.

To emulate nonlinear characteristics of a real RTD, use a lookup table to generate voltages according to discrete temperature values, all under software control. The same circuit can be used with minimal modifications to emulate thermistor characteristics. Doing this requires a new lookup table to allow the software to generate voltages matching the temperature/voltage curve of a chosen thermistor.

REFERENCE
"RTD Temperature vs. Resistance Table," www.omega.com/temperature/Z/pdf/z252-254.pdf

VARDAN ANTONYAN is a senior hardware engineer at Aitech Defense Systems Inc. (www.rugged.com), Chatsworth, Calif., with over 15 years of experience. He also has a patent.

USB Arbitrary Waveform Generator Relieves CPU Load

THE USB-AO-ARB1, developed by ACCES I/O Products, is an 8-MHz, 16-bit, USB arbitrary waveform generator (AWG) featuring flexible ranges and configurable digital I/O lines. Standard BNC connectors are used for the analog waveform output and gate control input; utility digital I/O lines are accessed via a 16-pin shrouded connector. The AWG, thanks to an integrated on-board FIFO and control logic, helps relieve some of the load placed on the CPU by handling the waveform timing at the hardware level. The board suits a range of embedded applications, including stimulus-response, test, simulation, industrial-equipment control, cyber security systems, and more.

ACCESS I/O

accesio.com

COM Express Module Packs in 16 GB of DDR3L

THE CEXPRESS-BL from ADLINK is a COM Express Compact Size Type 6 module based on fifth-generation Intel core processors. With up to 16 GB of dual-channel DDR3L memory, it will find homes in fanless edge device solutions that require intense graphics performance and multitasking capabilities in a space-constrained environment. It's pin-to-pin compatibility with the previous generation of cExpress-HL modules enables seamless scaling. The module integrates Intel HD Graphics 5500 and 6000 and provides two DDI channels and one LVDS channel supporting three independent displays. It also provides high-bandwidth I/O, including four PCIe x1 or single PCIe x 4, four 6-Gb/s SATA, two USB 3.0, and six USB 2.0, for peripheral devices and data transfer.

ADLINK

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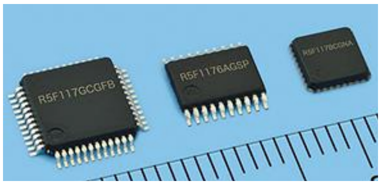
Snooze Mode Reduces MCU Power Consumption

RENESAS' RL78/I1D microcontroller (MCU) family offers a variety of analog functions for sensing applications. A data-transfer controller (DTC), event link controller (ELC), and data operation circuit (DOC) help reduce power consumption and enable data processing and transfer without CPU intervention. The DTC and ELC can be used to activate sensors; activate op amps to amplify sensor signals; and/or transfer analog-to-digital conversion results. The DOC then compares the transferred analog-to-digital conversion results and threshold values to determine whether the CPU needs to be activated. With these snooze-mode functions, power consumption can drop by as much as 30%. The RL78/I1D group also allows for dynamic switching between low-power and high-speed operation modes to match the system status. Depending on the package, the devices include four differential input op amps (each with two input pins and one output pin), up to 17 channels for the analog-to-digital converter, and two analog comparators.



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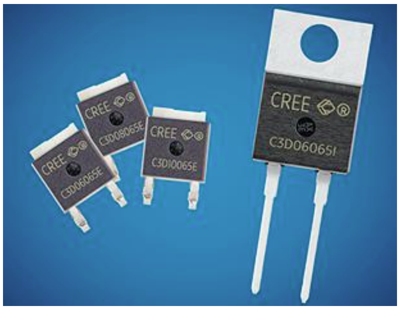

SiC Schottky Diodes Boast Zero Reverse Recovery Current

CREE ADDED four new 650-V diodes to its silicon-carbide (SiC) Schottky diode family. The new offerings feature zero reverse recovery current, high-frequency operation with low EMI, temperature-independent switching behavior, reduced heatsink requirements, and higher surge and avalanche capabilities. The 6-A C3D06065E, 8-A C3D08065E, and 10-A C3D10065E Z-Rec diodes come in compact TO-252-2 (DPAK) packages. The devices are automotive-qualified to AEC-Q101 for use in power factor correction and onboard power electronic-conversion systems. The fourth new diode, the 6-A, 650-V C3D06065I internally isolated Z-Rec Schottky diode, is an alternative to full-pack diodes.

CREE

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Enhanced Flash Boosts Storage for Next-Gen Connected Cars

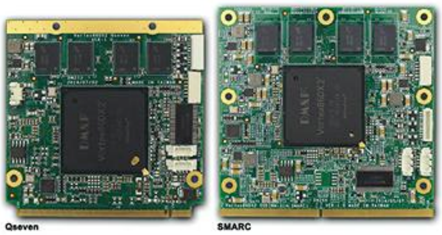
SANDISK IS launching a new suite of automotive-grade NAND flash solutions for next-generation connected cars and infotainment systems. Typical in-vehicle applications include 3D mapping and advanced augmented reality for navigation systems, intuitive driver-assist technology, and data event recorders. The portfolio includes an automotive-grade SD card and an iNAND embedded flash drive. Up to 64 GB of storage is available; operating temperature for components ranges from -40°C to 85°C.

SANDISK

www.sandisk.com

Ultra-Low-Power Processors Catapult COMs Toward IoT

ICOP'S QSEVEN and SMARC computer-on-modules (COMs) now incorporate ultra-low-power DMP Vortex DX2 system-on-chip (SoC) processors. A die-integrated crossbar switch delivers flexible I/O connectivity in combination with the scalable, ultra-low-power x86 performance. As a result, the modules are well-suited



for IoT devices and appliances tailored to manage multiple, smaller package-sized applications. The 800-MHz COMs feature 1 GB of DDR2 system memory and an operating temperature range from –20°C to +70°C. Integrated graphics support resolutions up to 1280 × 1024 via VGA, LVDS, and HDMI; storage media can be implemented via PCIe x1, SPI, I2C, and GPIO.

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What Can You Make with These Development Boards?

Developers have access to a host of options to work with the latest processing platforms. We take a look at the Raspberry Pi 2, Gizmo 2, and Creator CI20.

I remember when building a computer from scratch was a major undertaking. Hobbyists and developers used to plug together S100 boards to make a system that is less functional than a microcontroller that fits inside a 2 mm by 2 mm chip. The PC revolution was built around motherboards that eventually usurped the collection of peripheral boards that normally included a disk controller, display controller, and network adapter or modem.

These days the entire system fits on a small, single-board system like the Raspberry Pi 2, Gizmo 2, and Creator CI20 (*see the figure*). They sport USB, 1080p HDMI video, and 1 Gbyte of DRAM.

What can you build with these compact wonders? Just about anything from 3D printer controllers to robots. They even make great multimedia platforms running Kodi (formally XBMC).

Raspberry Pi 2 (top), Gizmo 2 (bottom left), and Creator CI20 (below) are just some of the new development boards available.

RASPBERRY PI 2

The $35 Raspberry Pi 2 updates the popular Raspberry Pi by moving to a quad-core, 900 MHz Broadcom BCM2836 system-on-chip (SoC). It has a 10/100 Ethernet port (*see "Raspberry Pi 2 Goes Quad Core" on electronicdesign.com*). The four USB ports are very handy when turning the system into a compact PC and the microSD slot lets you pack in gigabytes of flash. The 40-pin header provides access to a plethora of expansion boards that have grown up around the Raspberry Pi series.

GIZMO 2

The $199 Gizmosphere Gizmo 2 has a dual-core, AMD GX0210HA APU (*see "APU Blends Quad Core x86 with 384 Core GPU" on electronicdesign.com*). The Radeon HD 8210-class GPU delivers 85 MFLOPS while using under 9 W of power. It has a miniPCIe/mSATA port underneath, along with a microSD slot. It is a high-performance system with Gigabit Ethernet socket and PCI Express expansion interfaces. It even has a USB 3.0 port. Most compact platforms still deliver USB 2.0. This board exposes additional interfaces using edge connectors. It comes preloaded with TimeSys Linux.

CREATOR CI20

The $65 Creator CI20 uses Ingenic's dual-core, 1.2 GHz JZ4780 that is based on Imagination's MIPS32 processor with a PowerVR SGX 540 GPU. The GPU is similar to what is found in an iPhone 4. Digilent's chipKIT Max32 uses Microchip's PIC32, also based on the MIPS32 architecture (*see "Arduino, Raspberry Pi, or BeagleBone?" on electronicdesign.com*).

The CI20 has 10/100 Ethernet, but it also has Bluetooth and 802.11b/g/n support. The other two need additional boards for wireless support. It actually makes a very nice wireless bridge for Internet of Things-type applications.

These days Linux typically is the operating system of choice with Linux-based Android a close second. Platforms like the Gizmo 2 can run Microsoft Windows and other x86 operating systems out of the box.

While all three are similar in size, they are quite different in features and target applications. They get mixed in with platforms like Arduino, BeagleBone, and Edison. They are all readily available from a range of suppliers like Avnet, DigiKey, Element14, Mouser, and Sparkfun. ed

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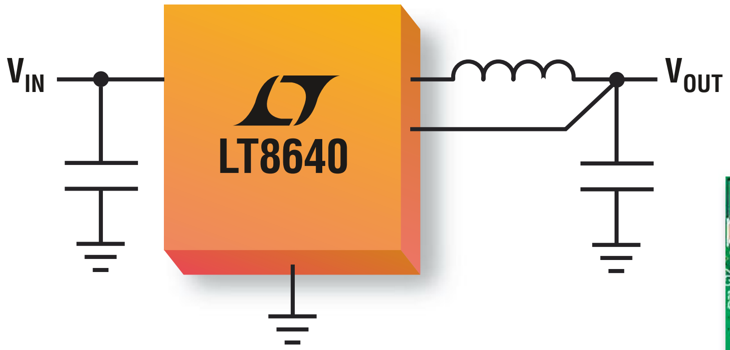
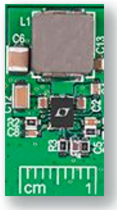
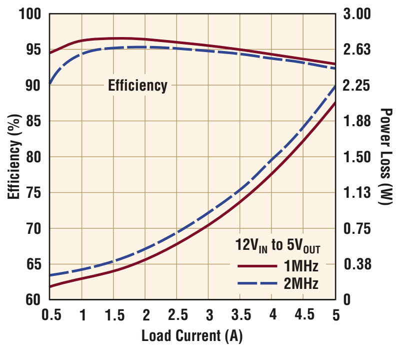




Actual Size
Demo Circuit



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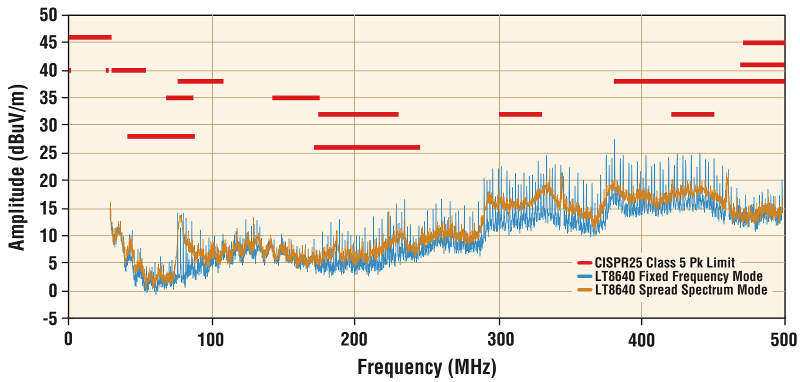

LINEAR TECHNOLOGY

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A Special Section to PENTON'S DESIGN ENGINEERING & SOURCING GROUP 02/03 2015

Calming military testing concerns p|S14

Sizing up measurement solutions p|S18

Software, test team on simulations p|S24

The M8195A arbitrary waveform generator packs as many as four differential channels with 65 GSamples/s sampling rate and 20-GHz bandwidth into a single AXIe module.

Sources Generate WIDE RANGE OF SIGNALS

JACK BROWNE | Technical Contributor

SIGNAL GENERATORS have long been wideband in nature, as have sources of signals for testing and operating both military and aerospace systems. Nowadays, they are increasing in their modulation capabilities as those systems to be tested gain in complexity. At one time, military signal sources were generally associated with pulsed signals, for radar system testing. But many applications now require continuous-wave (CW) signals, often with some form of elaborate digital modulation format.

Military and aerospace signal sources are still largely wideband sources, such as the 2-to-18-GHz signal sources popularized for electronic-warfare (EW) testing, and an increasing number of signal sources are being offered for frequencies through 40 GHz and even to 70 GHz. Another trend in RF/microwave signal sources is the growing number of test signal sources in modular formats, like VXI modules. The use of modules allows rapid interchanging of instrument functions within one rack, along with the capability of fitting more functionality within smaller spaces (to learn more about modular test solutions, including analyzers, see the special report beginning on p. S14).

As an example, the M8195A arbitrary waveform generator (AWG) from Keysight Technologies (www.keysight.com) leverages several innovative technologies to provide current state-of-the-art capabilities in signal generation. For one thing, it is a physical departure from the traditional 19-in. instrument rack-mount form factor, with all necessary components and circuits fitting within a single AXIe module *(see photo)*. That single one-slot AXIe module contains four digital-to-analog converters (DACs) capable of generating four differential output signals. This generates the complex signals required by military users by

(continued on p. S28)

CURTISS-WRIGHT ADVANCES RUGGED COTS Enclosure

THE DEFENSE Solutions division of Curtiss-Wright Corp. (www.curtisswright.com) has introduced the industry's first rugged air-cooled three-unit (3U) nine-slot D2D chassis in a three-quarter air-transport-rack (3/4-ATR) enclosure. The firm's new Hybricon D2D-34TLA enclosure allows a system integrator to use the same commercial-off-the-shelf (COTS) enclosure throughout a system's lifetime, from development phases through deployment.

The nine-slot Open-VPX 34TLA enclosure is well suited for aerospace and defense applications. Using the enclosure eliminates the need to design a custom backplane for system since the D2D-34TLA chassis employs a standard COTS backplane and input/output (I/O) cables, using standard +28-VDC power supplies and industrial-grade fans for

(continued on p. S8)

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The combination of simulation software and measurement hardware can provide invaluable feedback when designing military systems.

S24 SIZING UP MODULAR MEASUREMENT SOLUTIONS
Modular test equipment is winning more and more users away from traditional, full-sized rack-mount measurement gear.

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Making the Move to Modular Test

MODULAR MEASUREMENT technologies have made great strides over the last several decades. Commercial, industrial, and military users of test equipment now enjoy an unprecedented selection of test instruments in modular form (see. p. S24), from audio through microwave frequencies. The excellent track record of the VXI modular format, with its 25-year history, has shown that it is reliable even across the environmental extremes faced by many military users.

In addition, the performance levels achieved in some recent products introduced in the AXIe and PXIe modular instrument formats show that these mechanical structures and electronic bus configurations sacrifice nothing in terms of performance compared to older test instrument setups. Still, adoption of test equipment that slides into a standardized module-holding chassis can be as much of a philosophical as a technological decision.

"Old-guard" engineers might remember when the VXI modular format was first introduced … and the skepticism throughout the high-frequency industry that such "toy-like" products could ever perform at the level of those trusted rack-mount instruments. To this day, many engineers still feel that way. While they might eye the specifications for the latest analyzer or arbitrary waveform generator (AWG) introduced in one of the modular instrument formats, the equipment that they depend upon is all contained within 19-in. enclosures.

Adoption of critical test functions in modular form requires a willingness to abandon a long-trusted approach and to start with a new outlook on how measurements can be performed. A modular format offers many benefits, with the small size and conservation of power compared to full-sized instruments quite appealing to any electronic-facility manager.

To the working engineer, the flexibility to add or subtract test functions, such as a signal source or a digitizer, as needed represents a huge extension of engineering capabilities for any project. The fact that the functionality of a modular test system can be easily modified within one or two modular instrument chassis that can be moved around an engineering facility, and quickly reprogrammed by means of a commercial measurement software, makes modular measurement solutions quite attractive to many users.

For the most part, these modular test-equipment users are part of the next generation of engineers: younger users willing to try a new format because they did not grow up with the rack-and-stack instruments of their predecessors. de

JACK BROWNE, *Technical Contributor*

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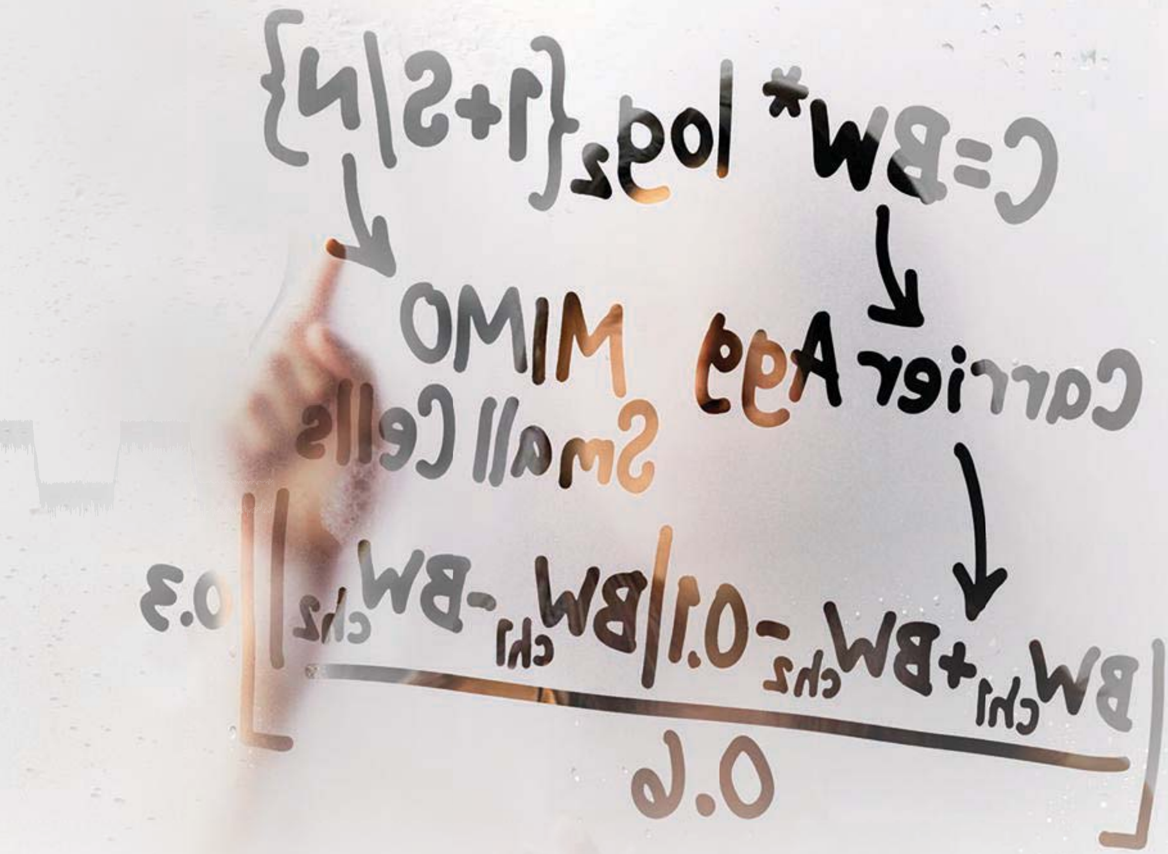

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KEYSIGHT
TECHNOLOGIES

Unlocking Measurement Insights

(continued from p. C1)
cooling purposes.

Of course, when an application is ready for deployment, it is also possible to replace the standard backplane with a custom backplane and I/O panel as required by a particular application, and the industrial-grade fans can be upgraded to military (MIL) grade components.

Still, this use of standard COTS chassis and components in the development phase of a program should help both in speeding development and saving on design costs. The chassis meets many MIL requirements, including MIL-STD-461F for electromagnetic interference (EMI).

According to Lynn Bamford, senior vice president and general manager for Curtiss-Wright's Defense Solutions division: "Curtiss-Wright is dedicated to reducing risk, schedule and program cost for defense and aerospace system integrators.

"With our innovative Hybricon D2D-34TLA, we've extended the benefits of D2D to demanding programs using 3U air-cooled OpenVPX modules." ■

REPORT FORECASTS VETRONICS Market

INFORMATION PROVIDER Visiongain (www.visiongain.com) has assembled a long-term report on the vehicular electronics (Vetronics) market for the next 10 years, notably for military land vehicle applications. The forecast, "Military Land Vehicle Electronics Market Forecast 2015-2025," projects healthy growth for this expected market for electronic products for communications, computers, sensors, and remote weapon stations for military land vehicles.

This is a market that has already grown considerably during U.S. ground troop deployments to Iraq and Afghanistan, although a downturn is expected in U.S. spending from 2015 onwards. However, strong investments in the market are expected from France and Australia, as both countries invest in major modernization programs in this area. The Scorpion and LAND 400 programs are cited as reasons for new ground platforms for the two countries and for their major investments in vetronics equipment. ■

THIRD MUOS SATELLITE Ready for Launch

THE U.S. Navy and contractor Lockheed Martin (www.lockheedmartin.com) both invested considerable efforts to ready the launch of the third Mobile User Objective System (MUOS) secure communications satellite. The launch of MUOS-3 from Cape Canaveral Air Force Station, Fl., aboard a United Launch Alliance Atlas V rocket, was scheduled for January 20. Lockheed Martin is under contract to deliver five MUOS satellites and the associated ground system to the Navy.

The MUOS satellites provide secure mobile satellite communications (satcom) services for warfighters. These satellites feature up-to-date electronic capabilities, providing on-demand, beyond-line-of-sight capabilities to transmit and receive prioritized voice and mission data by means of a high-speed Internet protocol-based system.

According to Iris Bombelyn, vice president of Narrowband Communications at Lockheed Martin, "The launch of MUOS-3, and the near-term certification of our fourth and final Radio Access Facility, brings us to the brink of the global coverage we anticipate for MUOS communications. This government and contractor team knows how important this capability is for our protectors in harm's way."

The MUOS satellites have been developed to replace legacy UHF systems. Each MUOS satellite carries two payloads, ensuring access to legacy UHF narrowband communication systems as well as the flexibility to support new communications capabilities. The satellites incorporate wideband code-division-multiple-access commercial technology but with a new waveform for providing security and supporting priority-based access. The MUOS system can provide more than 16 times the capacity of the legacy UHF communications system. ■

AESA RADAR "SEES" Far in Test Flight

THE F/A-18C/D Hornet fighter/attack aircraft is facing some serious upgrades, following the successful flight testing of the APG-79(V)X active electronically scanned array (AESA) radar system from Raytheon Co. (www.raytheon.com). The radar system features simultaneous air-to-air and air-to-ground capabilities along with high-resolution synthetic-aperture-radar (SAR) mapping capabilities. The AESA radar system also offers extended detection ranges compared to older radar systems.

As Mike Garcia, business development director of Tactical Airborne Systems for Raytheon's Space and Airborne Systems business, notes: "We put our latest AESA radar capability to the test and it exceeded our expectations." Garcia, a former F/A-18E/F Super Hornet pilot/instructor, adds that "Our APG-79(V)X combines the best features of our AESA portfolio to ensure low risk and give F/A-18C/D a tactical advantage for the next 15 to 20 years."

Roy Azevedo, vice president for Raytheon's Space and Airborne Systems business, explains: "Raytheon fielded the world's first operational AESA radar for fighter aircraft in 2000. Our portfolio of tactical AESA radars has now flown more than 500,000 operational hours—an industry first. We will continue to advance this technology to give our warfighters the greatest possible tactical advantage." ■

COMS METHOD Cuts NTDS Costs

THE U.S. Navy may be enjoying improved communications without suffering increased costs, as GET Engineering Corp. (www.getntds.com) launches its Virtual Naval Tactical Data System (V-NTDS) for use in place of existing NTDS setups. The new software-driven V-NTDS approach is designed to reduce development and deployment costs compared to existing NTDS method by eliminating the need for expensive adapters and cables currently used in NTDS setups. The NTDS was first developed in the 1950s and introduced to combat ships the following decade.

According to David Grundies, president and CEO of GET Engineering Corp., "We created Virtual NTDS to allow for a seamless transition of a functioning system with NTDS hardware to Ethernet communication, reducing the system's overall cost. V-NTDS provides a turnkey solution to aging NTDS applications." The new V-NTDS products require little or no modification of existing NTDS setups and eliminate the need for specialized NTDS converters.

GET Engineering Corp.'s virtual NTDS approach provides complete emulation of existing NTDS operations, with separate channels for data and external interrupts. The virtual system approach also supports a wide range of aborting conditions and termination events in the manner of the existing NTDS setups, and can perform data transactions between different NTDS setups. Using the virtual approach, an NTDS Type-A device can now communicate with other parallel types (Type B/C/H), or even with NTDS Serial data types (Type D/E). This technology has not been previously available and opens new realms for NTDS application development. ■

ELBIT SYSTEMS TO Fuel Israeli C4I Efforts

ELBIT SYSTEMS Ltd. (www.elbitsystems.com) has been awarded a number of defense contracts by the Israeli Ministry of Defense (IMOD) to supply equipment for communications systems as well as for Command, Control, Computer, Communications and Intelligence (C4I) systems. The contracts, which are scheduled to be completed over a six-year period, have an approximate total value of $117 million.

As guided by these contracts, Elbit Systems will be working on the next generation of the Digital Army Project (DAP), a program tasked with computerizing land-force operations. The DAP program is being developed to connect all field and command personnel into a central data-transfer network, enabling forces to effectively and securely exchange information between field locations and established installations. Elbit Systems will also be working on developing new communications systems as well as upgrading existing communications networks and wideband radio systems, and also provide logistic support and maintenance for these communications systems.

Elbit Systems has been a reliable supplier of advanced analog and digital communications equipment and has supplied equipment for use in electronic-warfare (EW) and signal-intelligence (SIGINT) systems, in addition to wideband radios. As Bezhalel Machlis, president and CEO of Elbit, notes: "The new contracts attest to the customer's satisfaction from our systems' past performance. Being awarded contracts for next generation DAP and communications systems, based on advanced Command and Control and communications capabilities, further strengthens our position as world leaders in this field." ■

Norsat Aids Challenging Military Communications

NORSAT INTERNATIONAL (www.norsat.com) has received an order from an unidentified military contractor for its SigmaLink AUTO and Ranger satellite-communications (satcom) product lines. These satcom systems enable the transmission of video, voice, and data communications in remote and hostile locations, at the same time providing high performance in small form factors.

The SigmaLink AUTO transportable satellites provide connectivity for mobile base camp operations and other military users in need of reliable, broadband communications with minimal setup times. The systems allow an operator to establish a communications link in less than 15 minutes using 1.8- and 2.4-m satellite antennas. The product line represents an extension of the firm's existing satellite terminal platform technology used by commercial and military customers around the world.

The Ranger is a multiple-band microminiature satcom terminal that also supports rapid deployment. It is a small system that provides large throughput for operations requiring reliable performance under hostile conditions. As Dr. Amiee Chan, CEO of Norsat, notes: "A key objective to our growth strategy is the introduction of new products to the market that capitalize off the base technology platform that Norsat has created. The SigmaLink AUTO and Ranger products offer new capabilities and aperture sizes to meet the evolving needs of customers that require speed, portability, and constant reliability of communications." The company expects this first order for its SigmaLink AUTO and Ranger products to ship in the first quarter of 2015. ■

Phonon to Supply SAW Radar Modules

PHONON CORP. (www.phonon.com) recently received a large order from an undisclosed prime defense contractor for pulse compression modules for a radar application. The $8-million contract is for 2015 delivery of these surface-acoustic-wave (SAW) modules for an air defense system.

The firm, based in Simsbury, Conn., was founded in 1982 and is celebrating its 30th year in operation. The company designs and supplies a variety of components and modules based on SAW technology, including filters, delay lines, and oscillators for portable, airborne, and satellite systems. The use of SAW technology in this application enables a significant saving of physical volume and weight in the airborne radar system. It has proven to provide high reliability over time and in the face of the extreme environmental conditions faced by defense electronic systems. ■

Pentagon Eyes Lockheed Martin for C-130Js

THE U.S. Pentagon recently awarded several contracts to Lockheed Martin Corp. (www.lockheedmartin.com) for various aircraft and weapon systems over the next several years. One contract is a $244 million modification contract tied to the delivery of 61 C-130J aircraft and the materials procurement for them. The C-130J aircraft are expected to be delivered no later than early 2020.

In addition, the Pentagon awarded Lockheed Martin a modification contract worth $23.8 million to supply one KC-130J weapons system trainer by Oct. 30, 2017. A third contract, valued at $8.7 million and due by November 2015, requires Lockheed Martin to support technical evaluation of the Remote Minehunting System with the Littoral Combat Ship.

Finally, as part of the latest U.S. defense budget, Lockheed Martin will receive $224 million for two additional F-35 Lightning II Joint Strike Fighter (JSF) aircraft for the U.S. Navy. This brings the total of F-35 fighter aircraft to 38 for fiscal 2015, compared to a total of 29 F-35 fighter aircraft produced and delivered in fiscal 2014. ■

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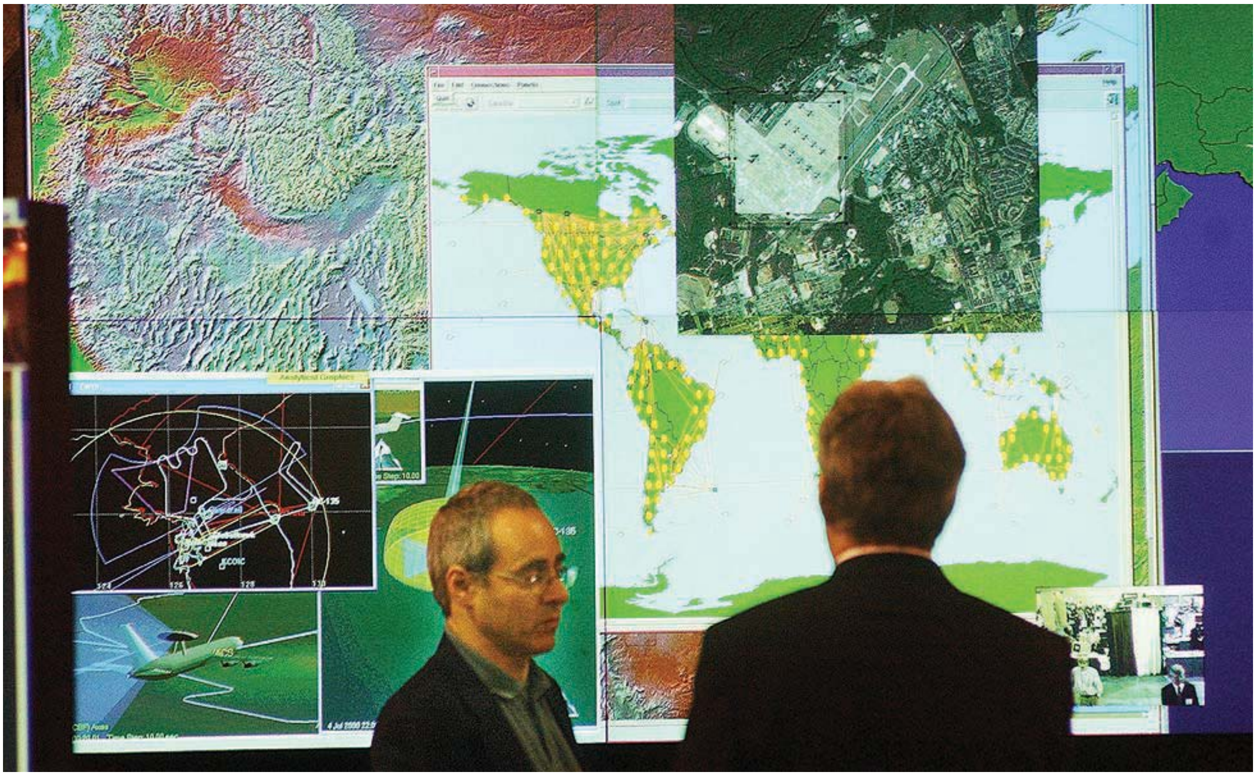

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Calming Concerns over Military Testing

Measurement challenges have long confronted the Armed Forces as they try to remain at the forefront of technology while attempting to find economical solutions at higher frequencies.

TEST EQUIPMENT and measurement solutions have assisted the technological growth of military and aerospace users since World War II, but not without concerns and challenges. Military applications have long been viewed as the backbone of the RF/microwave industry. Not since the early 1990s, with the development and growth of commercial wireless markets, has this industry benefitted from another market sector with the comparable economic size and strength as the military electronics market.

But in spite of the worldwide adoption of wireless technologies and associated electronic devices, military electronics still play a key role this industry. It is also a market that has faced many challenges over the years in terms of measurement equipment and solutions. As the industry has regularly shown, it includes individuals with the ingenuity to meet the changing needs of military and aerospace markets, as those changing needs have encouraged the development of mechanical and electrical modifications to high-frequency test equipment to keep pace with changing requirements.

Traditional measurement systems for military and aerospace systems have been based on the use of full-sized,19-in. rack-mount instruments, although military users have steadily been exploring the benefits of smaller, modular measurement systems (see p. S24). The model R&S TS6710 tester (see *photo*, facing page) from Rohde & Schwarz (www.rohde-schwarz.com) is an example of such a full-sized rack-mount test system. It was initially designed to evaluate the performance of components and devices in broadband radar systems.

The R&S TS6710 includes a vector-network-analyzer (VNA) system and associated switching and power-supply units to provide amplitude, frequency, and phase measurements using scattering parameters (S-parameters). The test system operates from 1 Hz to 24 GHz and was assembled to provide the fast measurement speeds needed to quickly test radar transmit/receive (T/R) modules over wide bandwidths and operating conditions. Its wide frequency range enables a wide range of users—even with classified radar specifications—to be able to program the system for their particular measurements.

“Covering wide bandwidths, such as the 2 to 18 GHz typically occupied by EW and radar systems, has long been a challenge for all RF/microwave test equipment and test systems.”

This test system, while offering impressive performance, is physically large; one of the challenges posed to suppliers of test equipment for military and aerospace applications is to deliver more compact equipment. As a result, modular measurement solutions will be a growing part of military test systems. Users will continue to seek more integrated test solutions, with more functions per module at lower power levels, and smaller overall test systems in modular form using industry-standard and cost-effective test software.

One benefit of a modular measurement equipment format such as VXI is that it allows more functionality within a smaller physical size than a traditional rack-mount test system. In addition, by exchanging instrument modules in a VXI chassis, functionality can be added and subtracted as needed to meet changing measurement needs of military and aerospace customers. Modular instruments from different suppliers must work together within an industry-standard modular chassis format. This has been well demonstrated for more than 25 years by the VXI modular test equipment format.

Covering wide bandwidths, such as the 2 to 18 GHz typically occupied by EW and radar systems, has long been a challenge for all RF/microwave test equipment and test systems. EW and radar systems traditionally have relied on analog RF/microwave electronic components, such as microwave mixers for frequency conversion and filters for signal selection. However, these systems are now increasingly turning to more digital components, such as analog-to-digital converters (ADCs), digital-to-analog converters (DACs), digital signal processors (DSPs), and field-programmable gate arrays (FPGAs), for inclusion in their signal-processing arsenal.

The increased use of digital components alongside of high-frequency RF/microwave components poses the challenge of how to efficiently and cost-effectively characterize the analog components, such as oscillators and mixers, and the digital components in these military and aerospace systems, especially as they work at faster clock rates, without simply adding more test instruments to a large test system.

Practical solutions are available from a number of companies that have developed broadband vector signal generators (VSGs) and vector signal analyzers (VSAs) capable of generating and analyzing in-phase (I) and quadrature (Q) signal components that can be used for evaluating the performance of both analog and digital components at clock rates to 6 GHz and higher. These VSG/VSA-based systems are available in traditional rack-mount formats, as well as in compact modular instrument formats, such as VXI and PXI.

To enable analog measurements, as well as testing of digital components within some military systems, the test systems must also be equipped with appropriate digital test equipment. Examples of this include a logic analyzer, digital storage oscilloscope (DSO), and digital signal source to provide stimuli for the digital components.

In terms of physical size, when such instruments are added to a measurement system in VXI or PXI format, they may occupy only a matter of a few slots within one instrument chassis, compared to significant portions of a full-sized 19-in. rack-mount enclosure. For military users challenged with meeting physical size requirements, the modular measurement formats offer some obvious advantages compared to traditional rack-mount systems.

The full-sized, rack-mount R&S TS6710 test system from Rohde & Schwarz (www.rohde-schwarz.com) was designed for use from 1 Hz to 24 GHz to perform high-speed testing of radar modules without being tied to a classified frequency range.

Some of the challenges facing those tasked with performing military measurements are related to newer developments in military and aerospace markets, such as the projected increased use of sensors for military applications. U.S. Army leadership is predicting a greater use of sensors (within clothing, in vehicles, and throughout military equipment) as a means of collecting environmental data and even location data on individual soldiers. By doing so, computers and software can be used to track personnel and program the battlefield.

The large number of sensors brings with it a major concern in finding ways to maintain the operation of these sensors. Because the sensors will be mounted in portable, movable applications, the implied solution for testing the sensors is a portable test system with the versatility to handle an array of different sensors and their parameters.

Changing technologies will always pose new measurement challenges for military system integrators, such as the growing use of software-defined radios (SDRs) for military communications applications. SDRs can readily change their scope of waveform usage by means of programming and software, without the need of hardware modifications. But testing SDR-based equipment requires something of a departure from conventional test solutions. Mathematical software—like Mathcad from Parametric Technology Corp. (www.ptc.com) and MATLAB from MathWorks (www.mathworks.com)—can be employed to assist in the testing.

Some military and aerospace test challenges have been ongoing, such as meeting new measurement requirements at lower costs and providing proper thermal management for different test systems. Cost control has been handled largely through the use of commercial-off-the-shelf (COTS) test hardware and software whenever available as well as the use of cost-effective test modules and modular test chassis that enable multiple measurement functions to be handled through the use of a single chassis rather than a full-sized rack-mount system.

For thermal management and ensuring that measurement accuracy is maintained over wide operating temperature ranges, once again, the use of modular measurement formats can simplify meeting some of the challenges. This is true especially in applications such as airborne systems, where size, weight, and power (SWaP) may be concerns. Effectively dissipating heat in full-sized systems can require significant amounts of thermal gasketing and absorbing materials, with fewer materials (in terms of weight, size, and cost) required in the smaller modular measurement systems.

Equipment manufacturers needing assistance on optimizing the thermal design of their system or subsystem may seek the expertise of service-oriented firms such as Thermacore (www.thermacore.com) and their European branch, Thermacore Europe (www.thermacore-europe.com). The firm can perform thermal analysis on a design and suggest a customized solution to optimize the thermal performance of the design. The company also offers qualification testing, such as for thermal shock, thermal cycling, shock, and vibration to fully prepare the system or equipment for withstanding the effects of a wide operating temperature range. Mercury Systems (www.mrcy.com) offers thermal expertise with experience in designing its OpenVPX modular systems, to create modular measurement solutions that can be fortified for wide operating temperature ranges.

Adding thermal-management materials to test solutions for effective dissipation of heat—either generated by the equipment itself or by high-power test input signals—requires careful selection of materials based on the expected operating environment. For example, for test systems onboard aircraft, thermal-management materials should be as light in weight as possible. Thermal-management materials for naval-based systems must be capable of handling corrosive fluids (e.g., salt water).

AVOIDING OBSOLESCENCE

One of the major concerns for test equipment intended for military and aerospace applications is obsolescence—that newer test equipment must be capable of providing measurements not only on newer systems and their components, but also on legacy systems and their components. Obsolescence was a major concern in the adoption of modular PXI instrumentation technology by Marvin Test Solutions (www.marvintest.com) in its MTS-3060 test system. The use of instrument modules simplified the challenge of enhancing the test system to meet the newer measurement needs brought on by numerous upgrades to the avionics and armament systems in modern fighter aircraft, including the F35 and the A-10. The MTS-3060 test system was upgraded to support testing of AIM-20 aircraft systems with new AMRAAM test capability.

Modular instrument approaches enable fairly straightforward equipment upgrades and performance modifications as measurement requirements change. The compatibility of modular test-instrument formats such as PXI and VXI effectively allows for an upgrade with the change of a card, regardless of the manufacturer. The large number of suppliers for VXI and the growing number of suppliers for PXI ensure that a steady flow of instrument products will be available for these formats, to minimize the threat of obsolescence for any one instrument. These and other test-equipment modular formats, such as AXIe, have shown that they are capable of performance levels comparable to the best full-sized, rack-mount instruments.

In terms of measurements themselves, developers of test equipment for military and aerospace applications have long been challenged with maintaining low phase noise, harmonic levels, and spurious levels in signal sources, and achieving high sensitivity and wide dynamic range in analyzers—usually for the widest-possible frequency ranges.

Measurements that have always posed challenges for radar developers include the capture of multiple simultaneous signals and the capture of closely spaced RF/microwave signals, especially within communications bandwidths. Of growing concern will be the effects of passive intermodulation (PIM) signal distortion on different military/aerospace systems, and how to measure PIM levels without adding specialized equipment. mw

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Software Teams with Test Gear FOR SIMULATIONS

The combination of simulation software and measurement hardware can provide invaluable feedback when designing and upgrading a wide range of military systems.

SIMULATION IS a vital part of military electronics systems, especially with the growing complexity of these systems. It has long been used to investigate the possible behavior of different systems and their components under different conditions, such as changes in temperature, humidity, shock, and vibration. Simulation methods work hand-in-hand with test equipment and measurement techniques—typically with measurements providing feedback to a simulator on how well an actual electronic system performs under different conditions compared to the virtual or modeled version of that system in software.

Combining test and simulation functions can help drive the design and development of different military systems, including electronic-warfare (EW), electronic-countermeasures (ECM), and radar systems. For that reason, it is not surprising to find that many companies that are developers of simulation software are also suppliers of test and measurement gear or designers of custom test solutions.

The Visual System Simulator for RADAR from AWR Corp. (www.awrcorp.com) can provide full behavioral modeling of different types of radar systems, as well as three-dimensional modeling of the antennas that are part of those systems. It can create models by means of manipulating software code or by working with data from actual measurements.

The simulator models continuous wave (CW) radars, pulsed radars, and pulsed frequency-modulated (FM) chirp radars. It can show the many effects of changes in a radar system because of the environment and how it affects system performance, such as how the height of a radar system above the ground impacts the line of sight for that system, or how noise levels change performance.

The VSS simulation software leverages a large library of system and antenna simulation models, including clutter and phased-array antenna models. The simulator provides quick links to other useful software programs, such as LabVIEW from National Instruments (www.ni.com), the parent company of AWR Corp. In working with such measurement programs, the VSS simulation software provides the synergism needed to integrate measurements into the simulations, creating a two-way arrangement that allows measurements to improve simulation models and simulations to enhance hardware designs and prototypes. Using LabVIEW as an example, the VSS simulation software is compatible with any and all measurement instruments it supports.

The R&S SMW200A vector signal generator series covers a total frequency range of 100 kHz to 20 GHz with fast switching speed and low noise needed to produce simulated signals.

Another major test equipment supplier with strong support for signal simulation is Keysight Technologies (www.keysight.com) and its Signal Studio software. The software can model and modify a wide range of different EW and radar signals and work with rack-mount and modular test instruments, such as the firm's new lines of arbitrary waveform generators (AWGs; see p. S1), to generate CW and pulsed signals as needed for testing. The company offers free-of-charge 30-day trial use of the software for interested parties to explore its many capabilities.

The Signal Studio software allows users to call waveforms from a stored collection or, alternately, to define a waveform by tuning the different parameters to create a specific CW or pulsed signal with precise characteristics. The software employs a Windows-based graphical user interface (GUI) to speed an operator through waveform creation, also providing pop-up screens to show the waveform as it is being created and modified.

Once a signal is defined, it can be used in a higher-level simulation—such as within the company's SystemVue system-level simulation—to predict the effects of the simulation waveform on different systems and their components. The waveform file can also be sent to a variety of hardware test instruments offered by Keysight, among them lines of vector signal generators (VSGs) both in traditional rack-mount and emerging modular instrument card formats. The PSG line of VSGs, for example, can produce output waveforms to 44 GHz for defense and aerospace testing.

This signal simulation software provides a great deal of flexibility by offering different operating modes: specifically, the waveform playback and real-time modes. The former permits a user to select from two levels of functionality to control their operating functionality. The latter includes closed-loop control of modifications to signals during signal generation, so that users can instantly see the effects of changes to a waveform's programming. These different program choices within the software are designed to allow a user to select the level of control needed for an application so that the software can be used cost- and time-effectively.

The Signal Studio software provides extensive pulse creation functions, allowing an operator to quickly build a library of pulses from measured data or defined characteristics. Custom pulse patterns can be created with 80-dB on/off ratios and advanced modulation formats, with such things as frequency, phase, and power offsets defined on a pulse-by-pulse basis. In addition to extensive signal library models for commercial cellular and wireless signals, Signal Studio features library models of different radar signals, multiple-satellite signals for GPS and a wide range of signals for Global Navigation Satellite System applications.

The Simulink simulator from MathWorks (www.mathworks.com), although technically a "block-diagram" system-level simulation, is often used to generate and model different waveforms and video signals for commercial and military systems. Using mathematical modeling methods, including the firm's MATLAB mathematical software, the simulator has been used to evaluate the impact of modeled waveforms on system performance.

The waveforms created by these software tools will be limited in the real world to the hardware test instruments used to generate those waveforms. As the signal sources story (see p. S1) explains, high-frequency signals can be generated by a number of different technologies, from analog circuits to arbitrary waveform generators (AWGs) and direct-digital synthesizer (DDS) signal generators. The performance parameters vary widely among the difference signal sources.

Typically, simulation software compatible with a certain type of hardware signal source will include programmability limits for the performance levels of the hardware—not permitting the creation of waveform files with parameters, such as frequency switching speed, that exceed the limits of the hardware. Still with the high-speed signal sources currently available from Keysight, National Instruments, and other test-and-measurement equipment suppliers, simulation software can be readily teamed with available hardware signal sources to create most waveforms needed for simulating and testing military and aerospace systems.

The R&S SMW200A series of VSGs from Rohde & Schwarz (www.rohde-schwarz.com), for example, includes models covering a total frequency range of 100 kHz to 20 GHz with typical frequency switching speed of 0.6 ms. It offers the performance levels needed to match to any signal simulator on the market for EW and radar testing. These VSGs can

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M105RX	2.0 - 8.0	1.5	10

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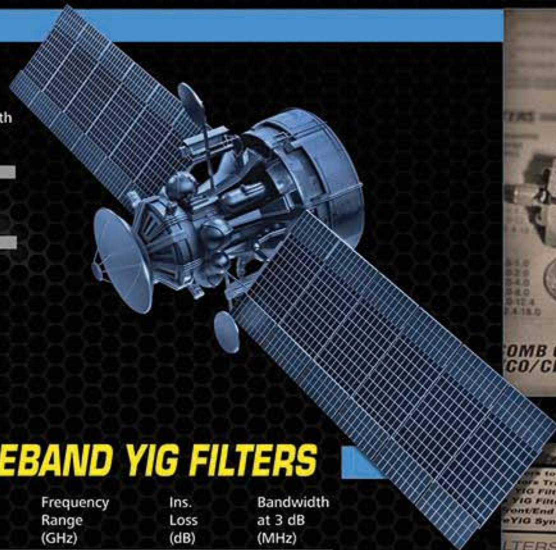

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Omniyig Model No.	Frequency Range (GHz)	Ins. Loss (dB)	Bandwidth at 3 dB (MHz)
4-STAGE			
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M2997	6.0 - 18.0	6.0	400 min
M3513	8.0 - 18.0	6.5	500 min

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ODZ0004A	0.1 - 18.0	1200	-52
ODZ0328A	2.0 - 18.0	1200	-52
ODZ0441A	6.0 - 26.0	1000	-51

STANDARD LIMITERS

Omniyig Model No.	Frequency Range (GHz)	Insertion Loss (dB)	Leakage Power (dBm)
Pin			
OLP2645A	8.0 - 18.0	2.0	+19
OLP2726A	2.0 - 18.0	1.2	+19
PL473	0.5 - 12.0	1.8	+19
OLP2652	2.0 - 18.0	2.5	+20
Schottky Turn-on			
SL048	2.0 - 26.0	2.5	+14
OLD2635A	4.0 - 18.0	2.5	+14
OLD2733A	0.4 - 18.0	2.5	+14

Leakage Power Measured at P(in) = +30 dBm

STANDARD COMB GENERATORS

Omniyig Model No.	Input Frequency (MHz)	Output Frequency (GHz)	Output Power (dBm)
OHG10118	100	0.1 - 18.0	-40
OHG20218	20	0.2 - 18.0	-35
OHG51026	500	0.5 - 18.0	-28
OHG81026	1000	1.0 - 18.0	-18

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be supplied with an optional second signal path, and standard models include an in-phase/quadrature (I/Q) modulator with a modulation bandwidth as wide as 2 GHz for generation of complex modulated waveforms.

Each R&S SMW200A VSG supports pulse modulation with on/off ratios of better than 80 dB and rise/fall times of less than 10 ns. The phase noise is typically −139 dBc/Hz offset 20 kHz from a 1-GHz carrier. The generator includes a large graphical display screen *(see figure on p. S18)* to simplify operation and is housed in a traditional 19-in. rack-mount enclosure.

Similarly, the fast-switching model MG37020A signal generator from Anritsu Co. (www.anritsu.com) is contained within a 19-in. rack-mount enclosure and includes a large display screen, and also offers the performance needed for creating most EW and radar signals. It covers 10 MHz to 20 GHz with 100-µs typical frequency switching speed, and is characterized by high signal amplitude and low phase noise.

An important part of blending the capabilities of computer simulation and measurement hardware is support for the control interfaces that can help tie the software and hardware together. The Bus-Tools-1553 (BTP-1553) software from GE Fanuc Intelligent Platforms (www.defense.ge-ip.com) is an integrated, Windows-based application solution for MIL-STD-1553 test, analysis, and simulation. It can work over a wide range of interfaces, including PCI, PCI Express, CompactPCI, PMC, VME, VXI, and Universal Serial Bus (USB) to control instruments and related hardware as part of the test and simulation process for evaluating MIL-STD-1553/1760 networks.

The software provides a straightforward GUI and can work with single- and multiple-function circuit boards, controlling multiple boards simultaneously as needed. The simulation software can inject and detect errors in a system for flexible simulation, and can record and readily display data during tests and simulations. BT-1553 includes a Selective Data Watch feature that allows a user to select individual data words as search parameters from any bus message.

When assistance is needed in developing simulations and test solutions for different systems, a number of firms specialize in offering professional services. Dynetics (www.dynetics.com), for example, can perform full testing and evaluation of EW threat weapon systems to develop detailed waveform descriptions of those systems for simulation and testing.

Dynetics' high-fidelity models and simulations of threat weapon systems, including models of radars, jammers, seekers, and radar warning receivers, support all phases of EW equipment development from concept of operations, through design and development, to test and evaluation. The firm's systems simulations are used in a number of different hardware-in-the-loop (HWIL) test facilities throughout the U.S.

The company manufactures specialized test equipment as needed in support of its system simulation efforts. Its integrated threat aircraft weapon system models have been used in the development of a wide range of systems, including aircraft combat simulation systems, identify-friend-or-foe systems, and fire control systems.

Dynetics supports the development of NGES, the Next Generation Electronic Warfare Integrated Reprogramming Database (EWIRDB) System. NGES, an open architecture database for representing radar threat systems as models, significantly improves the dissemination of threat RF waveform descriptions. The NGES tools developed by Dynetics allow interactive analysis and visualization of threat RF waveforms and interface of these waveforms into RF simulators for testing of EW equipment.

EW Simulation Technology Ltd. (www.ewst.co.uk) has developed radar and ECM threat simulations since 1984 by applying the latest technologies to its hardware and software solutions. Operating as part of Herley Industries (www.herley-cti.com), the firm has supplied simulation solutions to Army, Navy, Air Force, and civilian customers around the world.

Mercury Computer Systems (www.mrcy.com) has developed a series of solutions for simulating and testing radar systems, its Radar Environmental Simulators. They provide simulations of radar signals returning from different targets, for testing a wide range of active radar sensors in different systems, such as fire-control radars, surveillance systems, and imaging and guidance systems. These simulators have also been used in testing EW and signal-intelligence systems. They build upon the company's electronic-warfare digital-radio-frequency-memory (DRFM) technology with a goal of cost savings.

By receiving and digitizing real radar systems by means of the DRFMs, digitized samples can be stored and edited as needed, with such things as targets, clutter, terrain, and weather added to the radar signal models to evaluate the performance of a radar system under different conditions.

Within the Armed Forces, many of the services conduct their own simulation and test efforts, with and without the help of industry contractors. For example, in 1996, the Air Force founded the Air Force Agency for Modeling and Simulation (www.afams.af.mil) based in Orlando, Fla., as a means of supporting simulation, education, and training.

The U.S. Army's Simulation Center (www.smdc.army.mil) is referred to as the "laboratory of laboratories" for its computer simulations of space-based and missile-defense systems. The Army maintains simulation capabilities throughout its different facilities, such as the White Sands Missile Range (www.wsmr.army.mil).

In fact, the U.S. Army Research, Development and Engineering Command Communications-Electronic Research, Development and Engineering Center is currently conducting Rapid Fielding Initiative to determine the availability and development status of technologies to support an electronic-countermeasures (ECM) technique for ECM simulation, as well as for radar ECM studies. de

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USB-1SPDT-A18	1	0.25	1.2	85	10	385.00
USB-2SPDT-A18	2	0.25	1.2	85	10	685.00
USB-3SPDT-A18	3	0.25	1.2	85	10	980.00
USB-4SPDT-A18	4	0.25	1.2	85	10	1180.00
USB-8SPDT-A18	8	0.25	1.2	85	10	2495.00

NEW USB and Ethernet Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
RC-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	895.00
RC-2SP4T-A18	2 (SP4T)	0.25	1.2	85	2	2195.00
RC-1SPDT-A18	1	0.25	1.2	85	10	485.00
RC-2SPDT-A18	2	0.25	1.2	85	10	785.00
RC-3SPDT-A18	3	0.25	1.2	85	10	1080.00
RC-4SPDT-A18	4	0.25	1.2	85	10	1280.00
RC-8SPDT-A18	8	0.25	1.2	85	10	2595.00

*The mechanical switches within each model are offered with an optional 10 year extended warranty. Agreement required. See data sheets on our website for terms and conditions. Switches protected by US patents 5,272,458; 6,650,210; 6,414,577; 7,633,361; 7,843,289; and additional patents pending.

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Sizing Up Modular Measurement Solutions

Modular test equipment is winning more and more users away from traditional, full-sized rack-mount measurement gear with its compact size and flexibility.

MODULAR MEASUREMENT equipment and its associated software are gaining ground, even as the number of different modular formats grows and users have more options for different applications. Test equipment for different types of analog, digital, and RF/microwave measurements can constitute a major investment for users—even military and aerospace users—to such a degree that modular test instrumentation has gained a great deal of favor from them over the past decade.

Modular measurement equipment offers tremendous flexibility and testing capabilities, with the potential to pack a great many different test functions within a small equipment space. Unfortunately, no single modular measurement has ever won over the electronics field, and end-users now have a choice of numerous modular instrumentation formats (including AXIe, PXIe, and VXI test equipment).

The VXI modular measurement format is the oldest modular instrumentation platform, and easily the most widely used of the different formats, with many major instrument suppliers offering some forms of VXI modular instruments or chassis. The organization behind the VXI format and standards, the VXIbus Consortium (www.vxibus.org), was formed in 1987 with the goal of creating a universal instrument-on-a-card standard that would allow instruments from any number of different vendors to work together.

1. This VXI chassis illustrates the close spacing of modules and small instrument size possible even when realizing multiple measurement functions. [Photo courtesy of Alimar Technology (www.alimartech.com).]

The VXI specification supported by the IEEE, IEEE 1155, was adopted in 1993. The VXI plug&play Systems Alliance (www.ivifoundation.org) formed later that same year to pursue higher-level VXI instrumentation developments and advances in software to control the hardware. The VXI specification is based on the Versa Module Europa (VME) or VMEbus bus architecture.

The goals for the VXI modular format are still to produce instrument cards that will plug into any standard VXI chassis *(Fig. 1)* and enable instrument cards from any one supplier to work with instrument cards from any other supplier. A VXI system can be controlled by means of a remote general-purpose computer using a general-purpose interface bus (GPIB) or a Multisystem eXtension Interface (MXI) bus interface. In many cases, computers are embedded into a VXI chassis for direct control of the instrument modules.

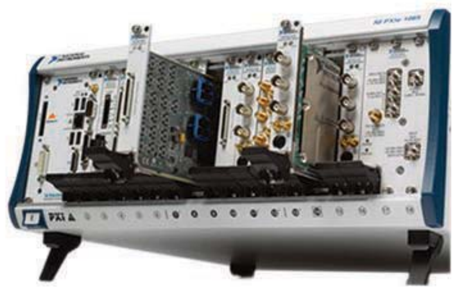
The VXI format allows a test system that might have formerly occupied a floor-standing 19-in. rack-mount enclosure to fit within the slots within a single VXI chassis. VXI instruments can be operated by means of many different control interfaces, including Ethernet, Firewire, GPIB, and PCI. The standard is defined to be independent of computer controller, so that its instruments and software can outlast trends in computer technologies.

It is strongly supported by most major instrumentation manufacturers, as well as some firms that specialize in VXI. One notable example of the latter is VXI Tech-

"No single modular measurement has ever won over the electronics field, and end-users now have a choice of numerous modular instrumentation formats (including AXIe, PXIe, and VXI test equipment)."

nology (www.vxitech.com), in business since 1990 and now known as VTI Instrumentation Corp. (www.vtiinstruments.com). In addition, firms like VXI Global Solutions (www.vxi.com) specialize in providing assistance to businesses wishing to develop and manage VXI test systems for their applications.

The VXI modular instrument format is well established with military and aerospace users, as well as in many high-volume manufacturing production facilities. That being said, a number of other modular instrument functions (such as AXIe) can tackle and adopt many of the functions still provided by VXI instrument modules. A growing number of analog, digital, and RF/microwave test-and-measurement functions are becoming available in compact modular formats, causing confusion for users in search of practical modular measurement solutions and wishing to know how the different instrument module formats match up.



2. The PXIe modular format is home to the NI PXIe-5668R vector signal analyzer and spectrum analyzer from National Instruments, which also contains a vector signal source.

One of the more popular of these newer instrument module formats is the PCI eXtensions for Instrumentation, or PXI. The PXI modular instrument format, which started in 1998, builds upon the personal computer architecture of the Peripheral Component Interconnect (PCI) standards and the CompactPCI specifications for communications and control. The goals for PXI are similar to those for VXI, including high mechanical integrity and ease of installation into PXI mainframes.

However, in contrast to the somewhat confined and tightly controlled specifications of the VXI standard, PXI designers and suppliers seek to leverage developments in the general-purpose (commercial) personal-computer (PC) market, achieving cost benefits in addition to performance improvements. As with VXI, instrument modules from different manufacturers are designed to be fully interoperable, although with lower costs than VXI modules and systems.

Of course, in addition to cost, there are numerous other differences between the PXI and VXI modular formats. The number of available instruments with PXI compatibility has been steadily gaining ground compared to VXI-compatible instrument modules. PXI supporters like to point to the strong link between modern PCs and PXI, and how PXI modules can benefit from enhancements in modern PCs. But VXI supporters refer to the stability of the VXI format and its bus standards, and the large number of supported instruments for military and aerospace and large-scale production test applications.

An example of another difference is in mechanical design, such as in electromagnetic-interference (EMI) shielding. The VXI standards specify that all VXI modules must be individually shielded, enclosed in metal housings and with gasketing material where appropriate to minimize the effects of electromagnetic (EM) radiated emissions, as well as EM susceptibility between and among different modules in a VXI chassis and system. For systems where EMI may be a concern, this level of engineering provides proven results, but also raises the costs of VXI modules and systems.

According to the PXI specifications, metal shields are not required on each PXI module. Manufacturers of PXI modules must comply with RFI/EMI regulatory emissions requirements, such as the CE specifications in Europe, but shielding can be achieved at component rather than module levels, with PXI module manufacturers applying EMI shielding around sensitive components within a module.

One mainstream supplier of test-and-measurement equipment that has supported the PXI format in a significant way is National Instruments (www.ni.com). The firm supplies PXI interface modules for a number of military and aerospace applications, including for MIL-STD-1553, ARINC 429, and AFDX buses. For avionics test system requirements, the firm collaborates with Avionics Interface Technologies (AIT; www.aviftech.com), a leading provider of avionic instrumentation and an independent division of Teradyne Defense & Aerospace (www.teradyne.com).

The PXI and PXI Express (PXIe) modular instruments feature some of the more versatile RF/microwave measurement solutions available anywhere *(Fig. 2)*, such as the NI PXIe-5668R vector signal analyzer (VSA) and spectrum analyzer. Some years ago, this PXIe instrument would have been realized as a full 19-in. rack of instruments, since it includes a vector signal generator (VSG), a VSA, and a spectrum analyzer. The system's measurement functions are coordinated through a Kintex-7 field-programmable gate array (FPGA) from

Xilinx (www.xilinx.com), with measurements programmable by means of National Instruments' popular LabVIEW test software.

The NI PXIe-5668R PXIe test solution can be supplied in versions with frequency ranges of 20 Hz to 14 GHz or 20 Hz to 26.5 GHz, with as much as 765-MHz instantaneous measurement bandwidth. It features a card-format VSG with high performance, and low phase noise of typically –129 dBc/Hz offset 10 kHz from an 800-MHz carrier. The NI PXIe-5668R operates with 12-b analog-to-digital converters (ADCs) and 12-b digital-to-analog converters (DACs) running at a sampling rate of 2 Gsamples/s.

A PXIe VSA and VSG combination is also available from Keysight Technologies (www.keysight.com) as the models M9391A PXIe VSA and M9381A PXIe VSG. The VSA is available for frequencies from 1 MHz to 3 GHz or 1 MHz to 6 GHz, typically supplied as four PXI modules: a model M9300A frequency reference, an M9301A frequency synthesizer, an M9350A frequency downconverter, and a model M9214A digitizer. The VSG also comes in versions for 1 MHz to 3 GHz and 1 MHz to 6 GHz, as well as in an arrangement with four PXI modules: the M9300A frequency reference, the M9301 synthesizer, a model M9311A digital vector modulator, and a model M9310A source output.

In the PXIe format, Marvin Test Solutions (www.marvintest.com) offers more than 20 chassis solutions in this modular configuration, to meet a wide range of physical requirements for PXIe systems. One example is the firm's GX7300 Series 20 slot, 3U PXI chassis *(Fig. 3)*. The chassis can hold as many as 19 PXIe instruments and a PXI controller and work with both PXI and Compact PCI (cPCI) 3U modules. It provides a total of 900 W power to its modules. As with many of the company's other PXI instrument chassis, the GX7300 Series incorporates forced-air cooling using a rear-mounted fan.

3. This chassis is designed to handle a total of 20 PXIe modules, which would typically consist of a controller and as many as 19 instruments.

Yet another modular instrument format is AXIe. It is supported by the AXIe Consortium (www.axiestandard.org) and is based on the AdvancedTCA format. It was developed to aid instruments for aerospace and defense as well as in semiconductor testing and research and development. At times referred to as the "big brother to PXI," AXIe follows the programming and basic architecture of PXI with some differences. Physically, it employs horizontal configurations to minimize rack space and vertical configurations where space is not an issue. In addition, it uses larger boards than PXI to achieve higher circuit densities than PXI. It is designed to integrate easily with PXI, IXI, and LXI formats.

Although Keysight's wideband VSGs and VSAs are based on the PXIe format, the company's new high-performance model M8195A AWG employs the AXIe modular instrument format, built into a five-slot chassis. Its impressive performance levels, including bandwidth of dc to 20 GHz and sampling rates to 65 Gsamples/s, provide evidence for the measurement capabilities of the AXIe modular format, which was developed to save power and space.

A number of major test instrument manufacturers have embraced the AXIe modular format, including Tektronix (www.tek.com) with its AWG70000A Series of AWGs. They operate at sample rates to 50 Gsamples/s for one channel or 25 Gsamples/s on each of two channels with 8-, 9-, or 10-b vertical resolution. These AWGs can deliver output signals to 20 GHz with spurious-free dynamic range of –80 dBc. The instruments can create complex waveforms or even sequences of waveforms and can work with files from Excel spreadsheets or mathematical programs such as MatLAB from MathWorks (www.mathworks.com) or Mathcad from Parametric Technologies Corp. (www.ptc.com) to create complex waveforms.

Tektronix's RFXpress software can also be used with the AWG70000 Series AWG for straightforward generation of radar and other waveforms for test applications. Of course, for proper operation, instruments such as AWGs that rely so heavily on digital signal generation and signal conversion must be supported by sufficient waveform memory to store the wide range of waveforms that will be used in testing.

While many instrument suppliers attempt to provide modular measurement equipment that can meet a wide range of needs and applications, some modular equipment solutions are still very focused on a very specific set of requirements, even as they benefit from the flexibility of the modular format. The T940 Digital Subsystem is one such application-specific modular instrument solution. It is a single-wide VXI module designed and manufactured by EADS North America Test and Services (www.ts.eads-na.com) as part of its Talon Instruments product line.

The T940 digital resource module (DRM) serves as the backbone of a modular VXI digital subsystem that can provide switching, analog functions, and RF/microwave measurement gear. The T940 driver/receiver daughtercard includes variable- and fixed-voltage processing for a wide range of interfaces, including transistor-transistor-logic (TTL), low-voltage-differential-signaling (LVDS), and RS-485 interfaces. The T940 DRMs are useful for a host of applications, including the testing of avionics systems, medical systems, semiconductors, and weapons systems. mw

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(continued from p. C1)
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Traditionally, wideband RF/microwave signal sources have been based on analog architectures, typically using wideband tunable oscillators, such as YIG or voltage-controlled-oscillator (VCO) sources, as their primary signal generators. As digital technology has gained in performance and sophistication, however, the bandwidths and performance levels of digital RF/microwave sources have increased a great deal over the last decade, with direct-signal-synthesizer (DDSs) sources and arbitrary waveform generators (AWGs) moving higher in frequency and performance.

Of course, analog oscillators and signal sources based on these oscillators are still widely used in high-frequency military and aerospace applications. These include fixed-frequency sources such as dielectric resonator oscillators (DROs), surface-acoustic-wave (SAW) oscillators, and electronically tunable sources—the latter including voltage-controlled oscillators VCOs) and yttrium-indium-garnet (YIG) oscillators.

Each differs in spectral characteristics, such as harmonic signal levels and single-sideband (SSB) phase noise, as well as in output power, output power stability with frequency and temperature, and tuning range. Creating an embedded test signal solution for a military or aerospace system typically starts at the component level and choosing which RF/microwave oscillator technology is best suited to a particular application.

ORGANIZING OSCILLATORS

Key performance parameters that are typically compared for signal sources incorporated into military and aerospace systems include frequency range, bandwidth, frequency tuning resolution, output power, phase noise, harmonic noise, spurious noise, power consumption, size, and weight. Another parameter that is dictated by the requirements of some applications is frequency switching speed. Signal generators may be required to produce continuous-wave (CW) or pulsed signals.

At lower frequencies, a wide range of electronic systems still rely on clock oscillators for their timing and synchronization. A number of suppliers have built strong reputations for crystal oscillators employing different methods of frequency stabilization, including temperature-compensated crystal oscillators (TCXOs) and oven-controlled crystal oscillators (OCXOs). Many of these crystal oscillators are now employed in surface-mount packages, such as the different lines of military-grade TCXOs supplied by Q-TECH Corp. (www.q-tech.com).

Available with analog or digital outputs, these oscillators feature low phase noise at frequencies typically below 100 MHz. Another longtime supplier of TCXOs is Greenray Industries (www.greenrayindustries.com), with sources from 20 kHz to 1 GHz, including RoHS-compliant models.

When frequency stability is mandatory for applications such as space and avionics, Frequency Electronics Inc. (FEI) (www.freqelec.com) offers a variety of packaging options for its OCXOs. In addition, the company designs and manufactures rubidium-base atomic oscillators for precise frequencies, such as its model FE-5650A, available from 1 Hz to 20 MHz and 50.255 MHz, in a housing measuring only 3.0 × 3.0 × 1.4 in.

Vectron International (www.vectron.com) was an early adopter of microelectromechanical-systems (MEMS) technology for military-grade oscillators in its HT-MM900A Military Temperature Range MEMS Oscillator line. These ruggedized sources, which are designed to survive 50,000 g's shock, are available at frequencies from 1 to 110 MHz. They can be supplied in housings as small as 2.5 × 2.0 mm and maintain ±25 ppm frequency stability across an operating temperature range of −55 to +125°C.

Some of the older high-frequency source technologies, such as DROs, are still used as signal sources in applications like missile-guidance and point-to-point-communications systems. As an example, the DRO-1000 line of DROs from Microwave Dynamics (www.microwave-dynamics.com) can be specified with single frequencies from 10 to 50 GHz, with 100-MHz mechanical tuning range and limited electrical tuning optional. Although a DRO may not be the first choice of RF/microwave signal source when miniaturization is required, these are dependable performers capable of excellent spectral purity.

The durable DRO-1000 DROs are constructed of dielectric resonators with field-effect-transistor (FET) or bipolar-junction-transistor (BJT) amplification at microwave frequencies. They are packed into housings measuring just 2.25 × 0.93 × 0.67 in. but delivering +13 dBm output power with only ±0.5 dB output variations across frequency and temperature. These DROs are designed to perform over an operating temperature range of −55 to +105°C with low phase noise, harmonics of typically −25 dBc, and low spurious noise of typically −85 dBc. The output frequency varies only by 4 ppm/°C with temperature.

When faster frequency-switching speed is required at the module or system level, designers may reach for a VCO or DDS. Synergy Microwave Corp. (www.synergymwave.com), for example, supports wide bandwidths by means of its patented VCO technology, with single sources capable of octave tuning bandwidths, such as 2000 to 4000 MHz and 3000 to 6000 MHz. The oscillators are designed for low-power and portable applications, such as portable radios, with current consumption of typically 50 mA at +5 VDC. Model DCYS200400-5 tunes from 2000 to 4000 MHz by means of tuning voltages from 0.5 to 16.0 V.

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At higher frequencies, the firm also offers low-phase-noise DROs, such as the 10-GHz model DRO100. It achieves better than −110 dBc/Hz SSB phase noise offset 10 kHz from a 10-GHz carrier. The DRO100 includes mechanical frequency tuning and is available in a surface-mount housing measuring just 0.75 × 0.75 × 0.53 in. as model SDRO100.

One of the more recent source technologies, DDS, has been gaining in frequency while maintaining its trademark fast frequency switching speed and low phase noise. A DDS incorporates a phase accumulator and lookup table with a digital-to-analog converter (DAC) at the output to generate clean analog signals. As the digital hardware has improved, the performance of available DDS sources has also improved, such as the model AD9914 DDS oscillator from Analog Devices (www.analog.com). It employs a 12-b DAC with 16-b phase tuning resolution to generate sine waves to 1.4 GHz with 190-pHz resolution.

Long specified for their low phase noise, YIG-tuned oscillators provide octave or wider tuning ranges over wide temperature ranges with excellent spectral characteristics. One supplier known for its permanent-magnet YIG oscillators, Micro Lambda Wireless (www.microlambdawireless.com), has refined its technology sufficiently to downsize YIG oscillators into small 0.5 × 0.5-in. surface-mount housings. The company refined its technology to fit permanent-magnet YIG oscillators into compact surface-mount housings. The MLSMO Series oscillators cover a total frequency range of 2 to 13 GHz with excellent spectral purity, albeit limiting frequency switching speed.

For those in need of instrumentation, Micro Lambda also produces the MLBS Series benchtop test synthesizers based on its YIG technology, with models ranging from 2 to 20 GHz. Model MLBS-2020 covers the full frequency range from 2 to 20 GHz with +10-dBm output power and 1-kHz frequency tuning resolution. The SSB phase noise is −92 dBc/Hz offset 10 kHz.

SORTING SIGNAL GENERATORS

Specifying a test signal generator is still a matter of meeting a set of minimum requirements and, for an RF/microwave source, it is usually a matter of tradeoffs among bandwidth, frequency tuning resolution, frequency switching speed, and spectral purity. As noted with the oscillators, the low phase noise of YIG-tuned oscillators generally requires a compromise in frequency tuning speed. What makes the model M8195A AWG from Keysight such a departure from traditional signal-generator choices is its rare combination of those key performance parameters without the usual tradeoffs.

Still, YIG-based signal generators have proven their worth over time in driving and testing many military and aerospace systems, and these test signal source maintain frequency, phase, and amplitude stability over time and across a wide range of environmental operating conditions, making them strong candidates for many wideband test applications not requiring fast frequency tuning speeds. Of course, some signal-generator suppliers, such as Giga-tronics (www.gigatronics.com), have refined their YIG technology to a level that coaxes the best possible switching speeds from YIG sources. Its 2500B series frequency synthesizer instruments manage to hold down phase noise while also achieving 500-µs frequency switching speed.

Signal sources based on VCOs and PLL technologies offer enhanced frequency switching speeds, typically with somewhat degraded phase noise, although designers of signal generators have developed different approaches to minimize noise. For instance, the ISB series test signal generators from FEI-Elcom Tech (www.fei-elcomtech.com) are based on a single-loop VCO frequency-synthesis architecture.

With performance suitable for radar-cross-section (RCS) measurements and W system testing, these test sources can perform frequency jumps across the full bandwidth in less than 200 µs with frequency resolution as fine as 1 Hz. The SSB phase noise is a function of carrier frequency, with typical phase noise of −105 dBc/Hz offset 10 kHz from a 2-GHz carrier, dropping to −85 dBc/Hz offset 10 kHz from a 20-GHz carrier.

Fast-tuning signal generators based on analog technologies previously reported in these pages include such models as the R&S SMA100A microwave signal generator from Rohde & Schwarz (www.rohde-schwarz.com) with an extremely broad frequency range of 100 kHz to 43.5 GHz. It achieves low phase noise of typically −102 dBc/Hz offset 10 kHz from a 10-GHz carrier, although frequency switching speed is in the range of 1.3 ms. With somewhat faster tuning, the MG37020A series of signal generators from Anritsu Co. (www.anritsu.com) covers 10 MHz to 20 GHz with 100 µs switching speed, with typical phase noise of −86 dBc/Hz offset 10 kHz from a 20-GHz carrier.

For fast frequency switching speeds in signal generators rivaling the performance of AWGs, a growing number of high-frequency signal sources employ DDS technology. The model NI PXI-565x from National Instruments tunes from 500 kHz to 6.6 GHz with the switching speed capable of a full frequency sweep in less than 2 ms for high-speed production testing. The source fits within a single PXIe module and is compatible with the firm's PXIe vector signal analyzer (VSA) for creating a modular test solution (see p. S24).

A line of fast-switching modular frequency synthesizers from Wide Band Systems (www.widebandsystems.com) serves EW applications with a 2-to-18-GHz frequency range and 5-µs frequency switching speed. Although somewhat larger, in a traditional 19-in.-rack-mount format, the model UFS-18 frequency synthesizer from FEI-Elcom Tech (www.fei-elcomtech.com) is also well suited for EW applications with a frequency range of 300 MHz to 18 GHz. It builds upon an almost-forgotten technology, direct-analog frequency synthesis (coupled with DDS technology), but its performance is noteworthy. It boasts remarkable full-band frequency-switching speed of 250 ns that is still unmatched by other wideband microwave test signal sources, regardless of technology. de

Compact Antenna Receives GPS Signals

THE ETHERHELIXGPS is reported to be the world's smallest standalone, right-hand-circularly-polarized (RHCP) Global-Positioning-System (GPS) antenna. The compact antenna measures just 35 mm in length and 15 mm in diameter, or about 27% smaller than other available GPS antennas on the market, without suffering in performance for its small size. The miniature GPS antenna is well suited for mission-critical products, including in military radios and public safety equipment. The EtherHelixGPS antenna can be tuned for a number of different satellite-communications (satcom) frequencies, as well as for right-handed circular polarization (RHCP) and left-handed circular polarization (LHCP). The RoHS-compliant antenna, which weighs just 11.8 g, is based on the firm's patented Isolated Magnetic Dipole (IMD) technology, providing high performance in a small size.

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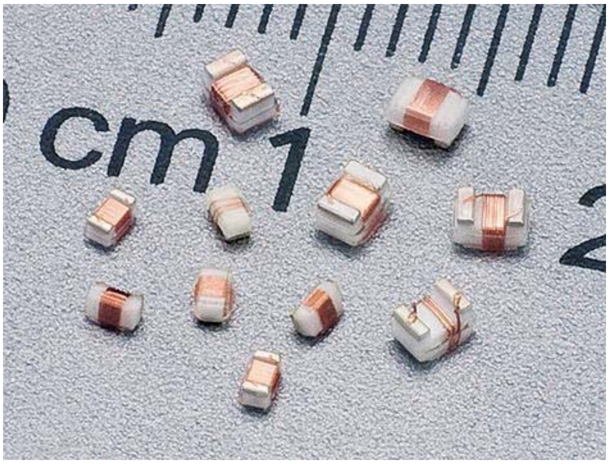
Chip Inductors Gain QPL Status

THE MLRF0603 and MLRF0805 lines of RF surface-mount chip inductors have achieved qualification to the military's MIL-PRF-83446 specification. These wire-wound coil, ceramic core chip inductors employ tin/lead terminations for processes where reflow soldering is used. They have earned Qualified Product List (QPL) status for this Department



of Defense (DoD) specification. These tin/lead-terminated QPL inductors offer a time-saving, solder-friendly solution for reflow-solder applications in circuits for military, aerospace, and defense systems, including in high-reliabilty (hi-rel) designs. The MLRF0603 line includes inductors with values from 1.8 to 270.0 nH QPL-approved to MIL-PRF-83446/36B. The self-resonant frequencies (SRFs) for these components range from 0.6 to 6 GHz with current ratings from 195 to 1000 mA and minimum quality factors (Q's) from 16 to 40. The MLRF0805 line contains inductors with values from 2.2 to 2200 nH with minimum Q's of 15 to 65, SRFs from 0.040 to 6 GHz, and current ratings from 140 to 1000 mA.

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of test-and-measurement applications. It is designed for more than 100 million switching operations. The switch is supplied with a compact disc (CD) containing programming software, in a metal housing measuring 4.5 × 6.0 × 2.25 in. with female SMA connectors, a DC socket, and a Universal-Serial-Bus (USB) Type-B port for remote control. The switches can be controlled separately or together, and can be operated remotely using the supplied graphical user interface (GUI) program or programmed by means of an included API DLL com object.

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Micro-Coaxial Assemblies Assist Ultrasound Systems

A line of custom fine-wire and fine-pitch diagnostic imaging assemblies have been developed for use with ultrasound analysis equipment for medical and other applications. These assemblies include coaxial cables with gauges from 40 to 50 AWG in ribbon-

ized or bundled assemblies. The cable assemblies include terminations ranging from 0.175 to 1.00 mm. In spite of the small sizes of these assemblies, they are designed for ruggedness and durability and can withstand more than 500,000 flexures at elevated temperatures. In particular, for medical applications, they can withstand the rigors of ethylene oxide gas sterilization. The capacitance specifications for the cable assemblies can be tuned to less than 12 pF/ft. with impedance similar controlled to tight tolerances.

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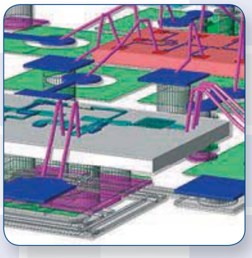
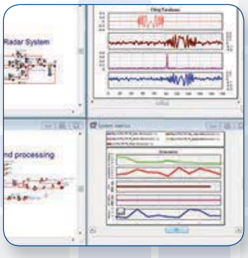
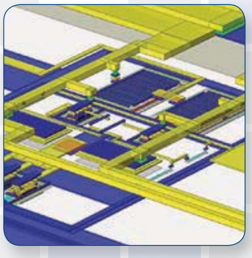
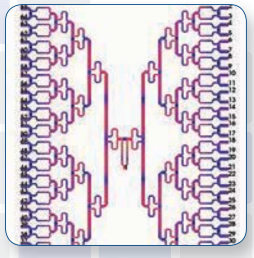
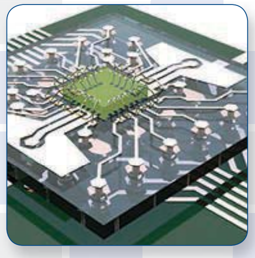

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