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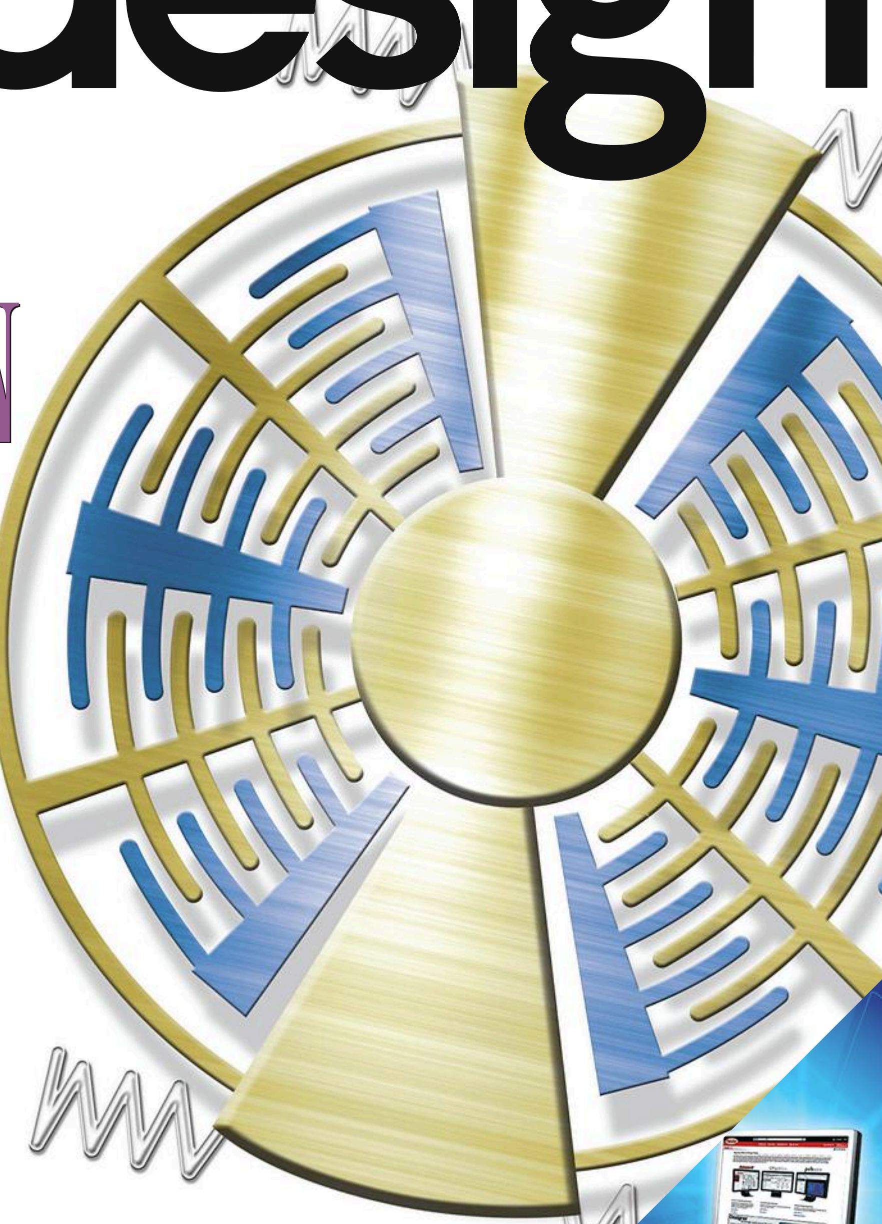

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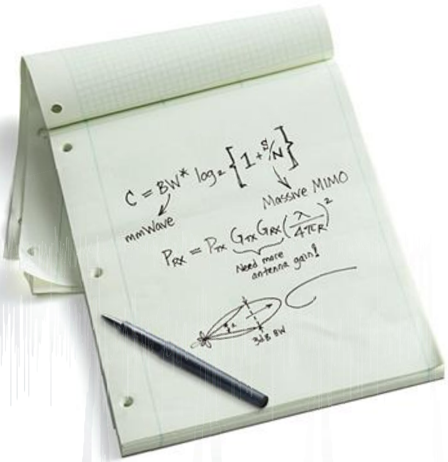

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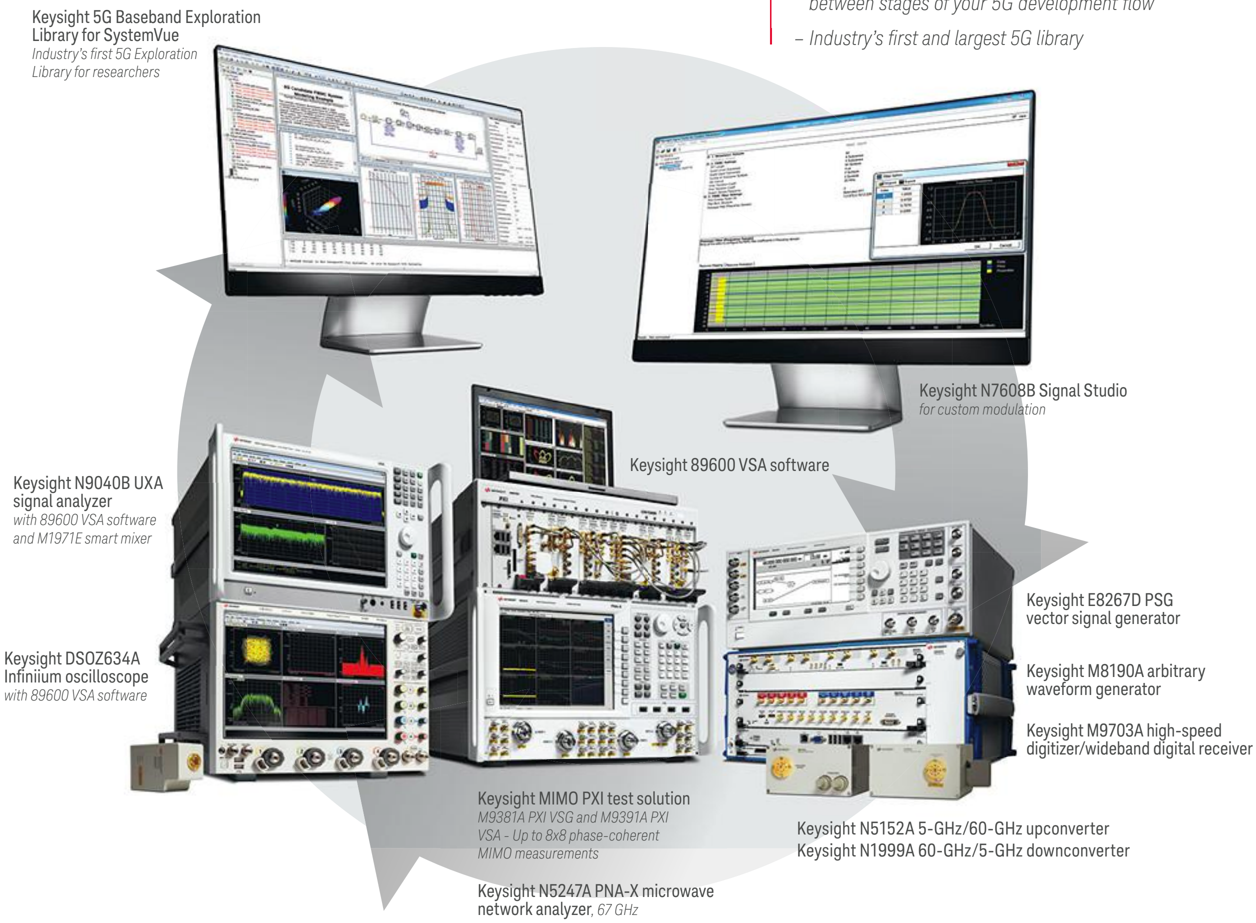

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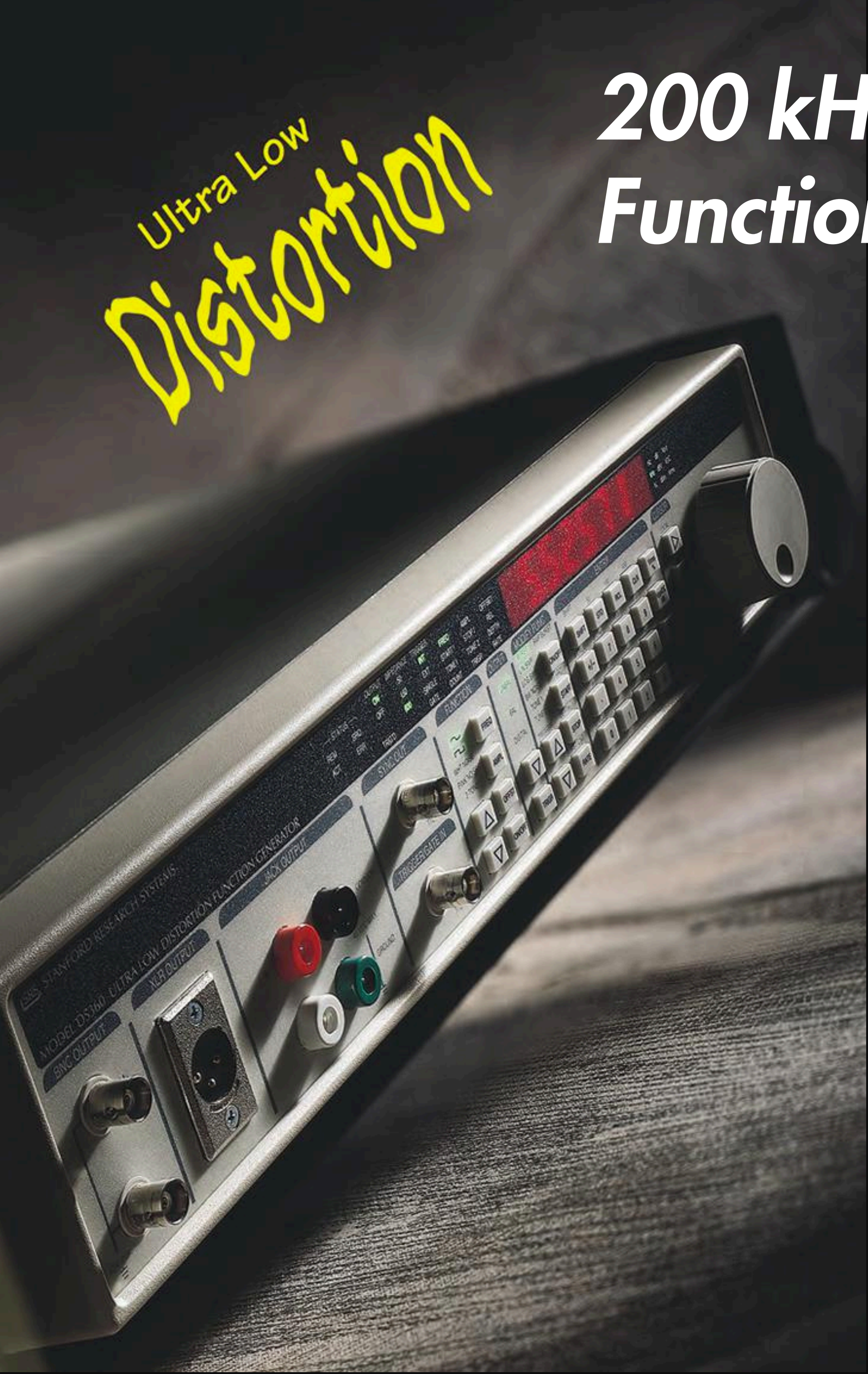

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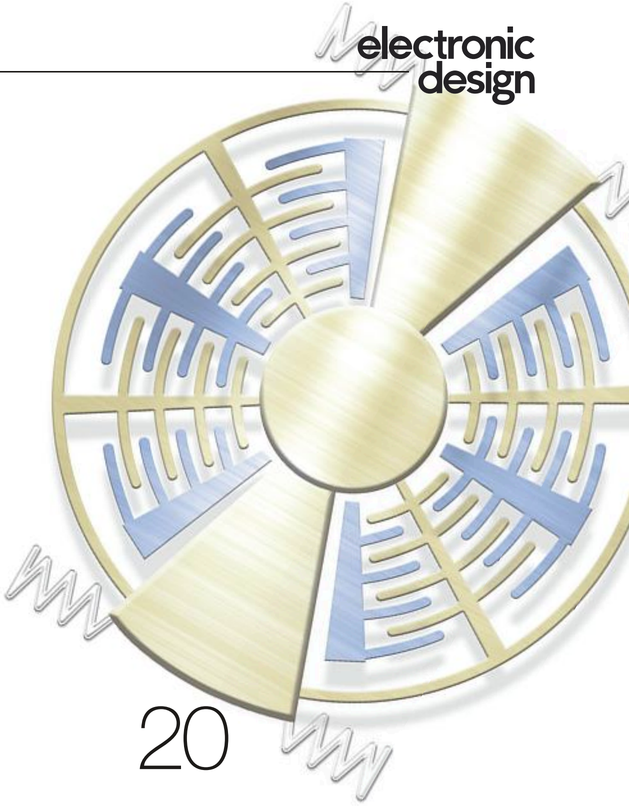

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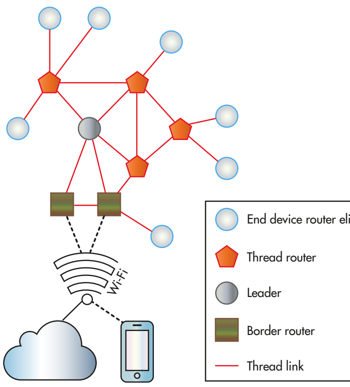

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HEALTHY OUTLOOK FOR WEARABLES

http://electronicdesign.com/embedded/wearable-s-role-modern-healthcare-industry

Wearables will soon allow healthcare providers to analyze patient health data on the go, ushering in a new era of preventive medicine.

INSIDE BATTERY-MANAGEMENT SYSTEMS

http://electronicdesign.com/power/look-inside-battery-management-systems

Careful consideration of battery requirements and battery-life goals will help determine the right architecture, functional blocks, and related ICs to create an optimal battery-management system and charging scheme.

blogs

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• What's Happening with Wi-Fi?

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• IntelISEF Students Flock to Pittsburgh for Director's Farewell Bash

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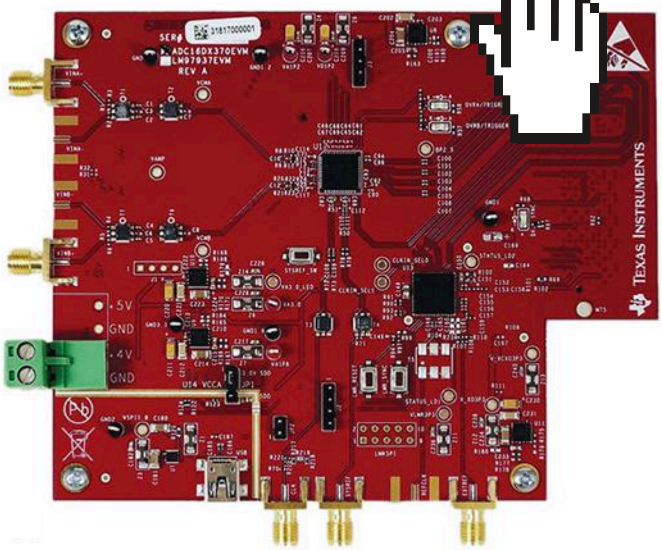

VENDOR REFERENCE DESIGNS SPEED DEVELOPMENT

http://electronicdesign.com/boards/vendor-reference-designs-accelerate-systems-development-0

Contributing Tech Editor Rick Zarr of Texas Instruments addresses how reference designs and the new category of application-specific reference designs (ASRDs) are helping engineers get their analog and digital semiconductor products to market on time.

VIDEO: SPARKFUN BADGERS INTEL ISEF STUDENTS

http://electronicdesign.com/sparkfun-badgers-intel-isef-students

SparkFun Electronics' BadgerStick was a hit with students at this year's Intel International Science and Engineering Fair in Pittsburgh. The kids learned to program the BadgerStick to control electronics, such as lights and LCDs.

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EDITORIAL

CONTENT DIRECTOR: **NANCY K. FRIEDRICH** nancy.friedrich@penton.com
CONTENT PRODUCTION DIRECTOR: **MICHAEL BROWNE** michael.browne@penton.com
CONTENT PRODUCTION SPECIALIST: **ROGER ENGELKE** roger.engelke@penton.com
PRODUCTION EDITOR: **JEREMY COHEN** jeremy.cohen@penton.com
ANALOG/POWER: **DON TUITE** don.tuite@penton.com
DISTRIBUTION: **VICTORIA FRAZA KICKHAM** SourceESBeditor@penton.com
EMBEDDED/SYSTEMS/SOFTWARE: **WILLIAM WONG** bill.wong@penton.com
ASSOCIATE CONTENT PRODUCER: **ILIZA SOKOL** iliza.sokol@penton.com
ASSOCIATE CONTENT PRODUCER: **LEAH SCULLY** leah.scully@penton.com
CONTRIBUTING EDITOR: **LOUIS E. FRENZEL** lou.frenzel@penton.com

ART DEPARTMENT

GROUP DESIGN DIRECTOR: **ANTHONY VITOLO** tony.vitolo@penton.com
SENIOR ARTIST: **JIM MILLER** jim.miller@penton.com
CONTRIBUTING ART DIRECTOR: **RANDALL L. RUBENKING** randall.rubenking@penton.com

PRODUCTION

GROUP PRODUCTION MANAGER: **CAREY SWEETEN** carey.sweeten@penton.com
PRODUCTION MANAGER: **JULIE GILPIN** julie.gilpin@penton.com

AUDIENCE MARKETING

USER MARKETING DIRECTOR: **BRENDA ROODE** brenda.roode@penton.com
USER MARKETING MANAGER: **DEBBIE BRADY** debbie.brady@penton.com
FREE SUBSCRIPTION/STATUS OF SUBSCRIPTION/ADDRESS CHANGE/MISSING BACK ISSUES
T | 866.505.7173 **F** | 847.763.9673 electronicdesign@halldata.com

SALES & MARKETING

MANAGING DIRECTOR: **TRACY SMITH** **T** | 913.967.1324 **F** | 913.514.6881 tracy.smith@penton.com

REGIONAL SALES REPRESENTATIVES

AZ, NM, TX: **BILL YARBOROUGH** **T** | 713.636.3809 **F** | 913.514.7251 bill.yarborough@penton.com
AK, CA, CO, ID, MT, ND, NV, OR, SD, UT, WA, WI, WY, W/CANADA: **JAMIE ALLEN** **T** | 415.608.1959
F | 913.514.3667 jamie.allen@penton.com
AL, AR, IA, IL, IN, KS, KY, LA, MI, MN, MO, MS, NE, OH, OK, TN: **PAUL MILNAMOW** **T** | 312.840.8462
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INTERNATIONAL SALES

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LIST RENTALS:
ONLINE MARKETING MANAGER: **SARAH NOWOWIEJSKI** **T** | (212) 204 4295 sarah.nowowiejski@penton.com

ONLINE

PRODUCT DEVELOPMENT DIRECTOR **RYAN MALEC** ryan.malec@penton.com

DESIGN ENGINEERING & SOURCING GROUP

VICE PRESIDENT & MARKET LEADER: **BILL BAUMANN**
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CHIEF FINANCIAL OFFICER: **NICOLA ALLAIS** nicola.allais@penton.com
SENIOR VP, DESIGN ENGINEERING GROUP: **PAUL MILLER** paul.miller@penton.com
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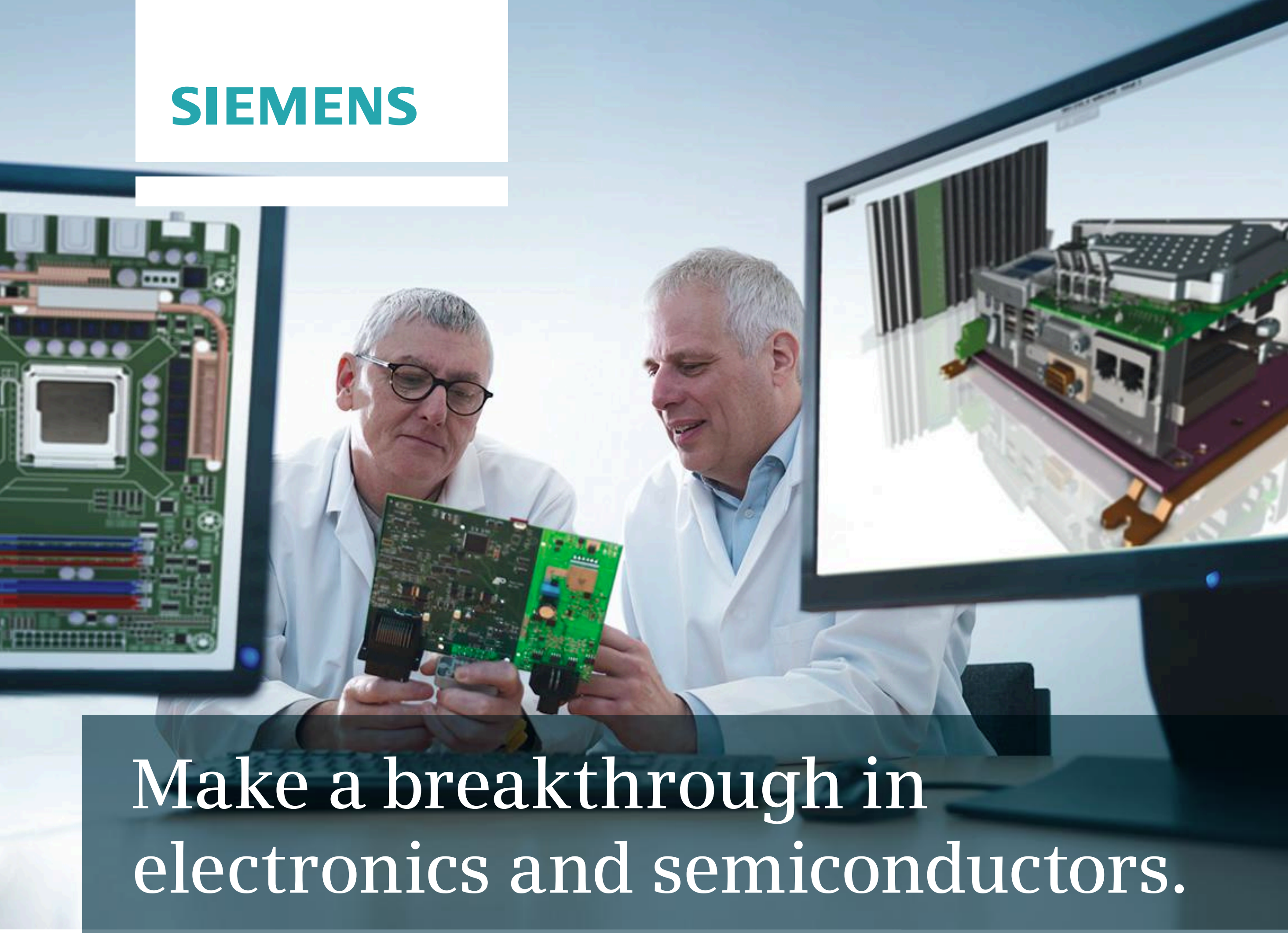

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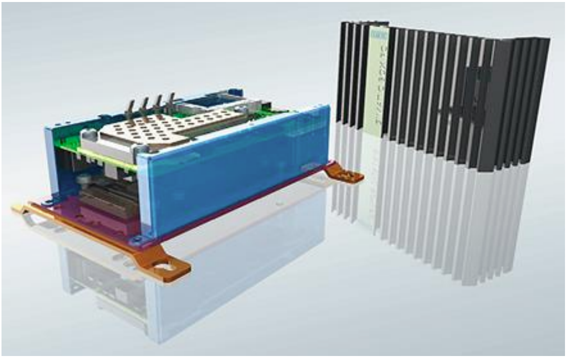

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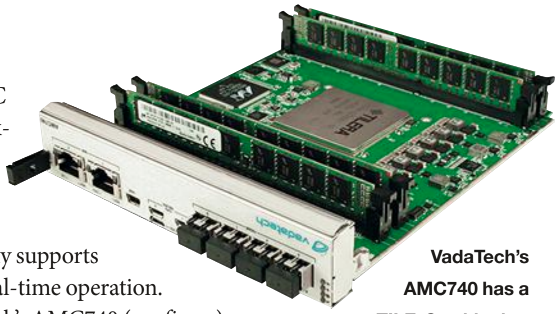
100 ARM Cortex-A53 Cores on One Chip



VadaTech's AMC740 has a TILE-Gx chip that packs in 72 64-bit RISC cores along with eight 10 Gbit Ethernet ports.

EZchip's TILE-Gx packs up to 72 64-bit VLIW RISC cores along with eight 10 Gbit Ethernet ports, making an excellent platform for Software Defined Networking (SDN) and Network Function Virtualization (NFV) using its mPIPE (multicore Programmable Intelligent Packet Engine) packet processing front end. The family supports Zero-Overhead Linux (ZOL), a tickless kernel feature for real-time operation.

The TILE-Gx has found a home in platforms like VadaTech's AMC740 (*see figure*). Advanced Mezzanine Cards (AMCs) are often used in MicroTCA systems for communication applications. The AMC740 front panel exposes four 10-Gbit Ethernet LC ports. The board has four banks of DDR3 64-bit memory with ECC and a bank of flash memory. The PCI Express x8 ports are available on the backplane connector.

One the drawing board is EZchip's TILE-Mx that swaps out the custom VLIW RISC core for a 64-bit ARM Cortex-A53. EZchip also ups the ante with 100 cores and support for 100 G Ethernet in the TILE-Mx100. The chip also supports various combinations of 1 G, 10 G, 25 G, 40 G, and 50 G Ethernet. EZchip's original claim to fame was network processing units (NPUs), so it has extensive networking expertise that it added to Tilera's already impressive network accelerators. The TILE-Mx100 delivers 200 Gbits/s of throughput.

Internally the TILE-Mx has a 3-level, coherent, 40 Mbyte of cache courtesy of the SkyMesh architecture and access to 1 Tbyte of DDR4 memory. There is a 5-level hierarchical Traffic Manager with 256,000 queues that feeds the MiCA engine for over 100 Gbit/s of crypto acceleration. There is even precision packet time stamping with IEEE1588v2 support.

Packing lots of 64-bit ARM cores on a chip is not unique. Cavium's ThunderX scales up to 48 2.5 GHz, 64-bit ARMv8 cores. Cavium builds its multicore fabric around the Cavium Coherent Processor Interconnect (CCPI) and surrounds it with network accelerators.

Of course, Broadcom has been delivering massive, multicore chips as well that can be combined into larger fabrics. The XLP900 series had 80 MIPS64 cores. The external interconnect allowed a system with up to 640 cores to be constructed. This was in 2013. The Broadcom XLP II family utilizes 3 GHz ARMv8-a cores. Notice a trend here?

Unfortunately, getting your hands on a TILE-Mx100 will take a little time since samples will not be ready until next year. In the meantime, the AMC740 is available now as is the ThunderX and Broadcom's offerings. Many ARMs help finish jobs quickly.

This composite image of NGC 2207 and IC 2163 contains data from Chandra, NASA's Hubble Space Telescope, and the Spitzer Space Telescope. *(Image courtesy of NASA)*

NASA Selects Proposals for NEXT-GEN SPACE TECHNOLOGY

Proposal programs such as Small Business Innovation Research (SBIR) and Small Technology Transfer (STTR) give NASA a wealth of options to wade through in its search for the next great technology. The agency recently selected 149 more research and technology proposals to help pave a quicker path toward future missions into the solar system, as well as benefit American small businesses and research institutions.

The chosen proposals will work to develop efficient energy and power systems for human and robotic spacecraft, new concepts for in-space propulsion, advanced telescope technologies to enable a new class of critical observatories, and next-generation sensors for planet exploration.

One study in particular will look at ultra-high-energy solid-state batteries with the potential to power traveling spacecraft, rovers, and human habitat systems. The technology, if successful, could then be transformed for use in electric cars to travel greater distances between charges, or for cellphones to keep their charge for months instead of days.

The SBIR and STTR Programs are competitive, awards-focused programs with selection criteria based on technical merit, feasibility, experience, qualifications, and facilities. The selected aerospace technology and innovation projects have a total value of approximately $118.1 million, supporting 117 U.S. firms and research institutions in 26 states.

LONGER-LIFE LITHIUM-SULFUR Battery Enhances Safety in the Field

WHILE ADVANCES IN battery technology are critical for next-gen products across multiple markets, the requirements of military applications take on a different meaning in terms of safety. A new lithium-sulfur-based battery, which offers energy density greater than 300 Wh/kg, has an enhanced safety chemistry that can prevent fire yet retain functionality, even after accidents. Developed by OXIS Energy, the technology has a long lifecycle of 2,000 cycles

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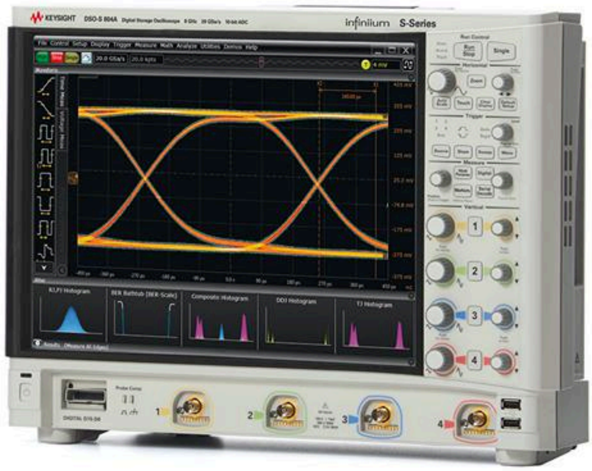

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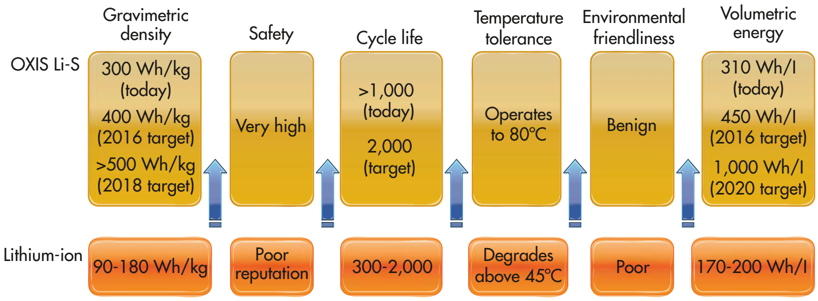


OXIS Energy's lithium-sulfur battery technology provides greater energy density and a safer chemistry for rugged military applications. *(Image courtesy of OXIS Energy)*

before capacity reduces to 80% of its beginning of life (BoL).

OXIS' lithium-sulfur batteries have a potential performance five times greater than Li-ion batteries. The cells also have a 100% available depth-of-discharge, superseding previous 80% discharge ranges that left the door open to damage caused by over-discharge. The batteries' two main features—a ceramic lithium sulfide passivation layer and a nonflammable electrolyte—help it withstand extreme abuse scenarios, another key factor for military applications.

The extremely lightweight battery is suitable for soldiers and electric vehicles (OXIS is already in the planning stages to reduce its weight by a further 50%). It could also be used for automotive, solar energy storage, marine transportation, and advanced nanotechnology-enabled applications. OXIS recently received a Frost & Sullivan Award for Technology Innovation for the lithium-sulfur battery. ■

BATTERY-CHARGING ADVANCE Extends Lifetimes, Lowers Losses

MOUNTING DATA-PROCESSING demands placed on our smartphones and tablets no doubt put more pressure on their batteries to deliver longer run times and better performance. To solve the problem without elevating USB connector cost, Texas Instruments opted to increase the input voltage in its MaxCharge family.

Featuring a 5-A current charge, the bq25890, bq25892, and bq25895 family of chargers allows for faster, cooler, and safer charging. Resistance compensation (IRComp) helps facilitate high charging currents, which in turn induces a voltage drop on the charging-path parasitic resistance and internal battery impedance.

The IRComp also increases the charger's terminal voltage so that it can stay

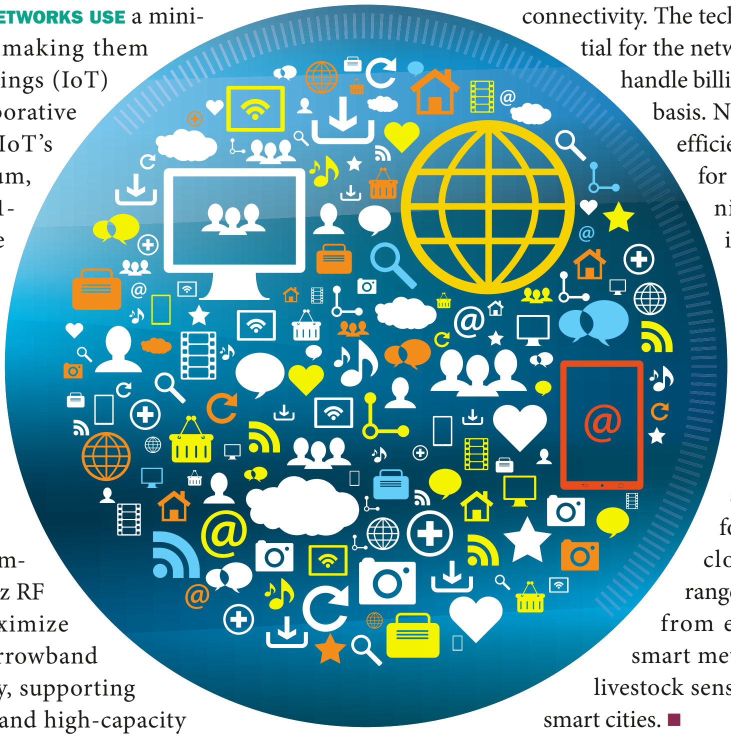
(continued on next page)

PARTNERSHIP PUSHES IoT Below 1 GHz

PROPRIETARY SUB-1-GHZ NETWORKS USE a minimal amount of power, making them ideal for Internet of Things (IoT) applications. In a collaborative effort to increase the IoT's presence in that spectrum, Texas Instruments' sub-1-GHz transceivers can be used with SIGFOX's dedicated cellular network to deploy low-power wireless sensor nodes. TI's CC1120 sub-1-GHz RF transceiver extends the sensor nodes' battery lifetimes, helping reduce overall maintenance.

The network, when combined with the sub-1-GHz RF transceivers, helps maximize the benefits of ultra-narrowband (UNB) radio technology, supporting long-range, low-power, and high-capacity connectivity. The technology is virtually essential for the network, which is expected to handle billions of messages on a daily basis. Narrowband's high spectral efficiency makes it the standard for such long-range communications—a major factor in the seemingly infinite increasing number of IoT devices.

The scalable, two-way network offers low energy consumption and high efficiency, according to SIGFOX. Its architecture is optimized for data retrieval from the cloud, opening up a wide range of end-user applications, from environmental sensors, smart meters, and agriculture and livestock sensors to asset tracking and smart cities. ■



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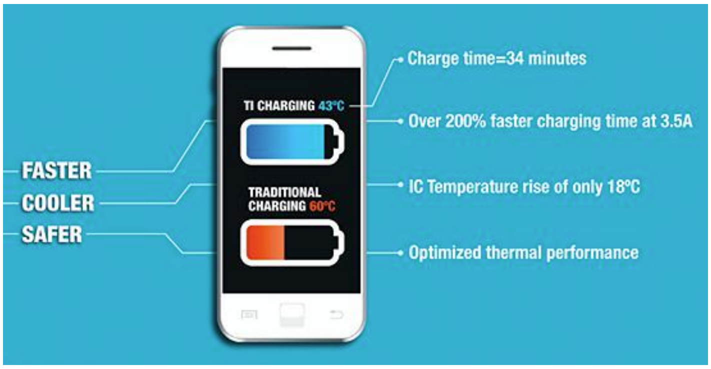


Texas Instruments' MaxCharge technology upgrades smartphones and tablets with input-voltage-driven, higher-efficiency batteries for quicker charging. *(Photo courtesy of Texas Instruments)*

in constant-current mode long enough for quicker charging.

The greater input voltage helps change the loss distribution of the charger's power converter. The family's redesigned power stage minimizes power loss to reach efficiencies up to 91% at a 3-A current charge. The technology reportedly charges devices fully in 34 minutes, over 200% faster than at 3.5 A. It also provides optimized thermal performance with an IC temperature rise of only 18°C. ■

QUALITY PV Production Focus of Standards Effort

IN 2011, the International Photovoltaic (PV) Quality Assurance Task Force (PVQAT) was established to develop standards for PV products. Now, the U.S. Department of Energy's (DoE) National Renewable Energy Laboratory (NREL) is taking a co-leadership role, along with the National Institute of Advanced Industrial Science and Technology in Japan, in a further push to ensure the reliability of solar panels.

The standards provide support in three main areas. First is qualification of the design for the geographic and climate conditions of the area. The second concerns quality management of the manufacturing process—all panels must be of the same quality no matter when they are produced. Finally, support is provided for system quality. System-level inspections will confirm proper installation and design, and that the system is operating smoothly.

The PVQAT is also developing a rating system, to be implemented by the International Electrotechnical Commission (IEC), which will define tests that

differentiate among three climate zones—moderate, tropical, and desert—and two mounting configurations—open-rack and close roof. The new rating system will follow alongside current international standards to ensure operability.

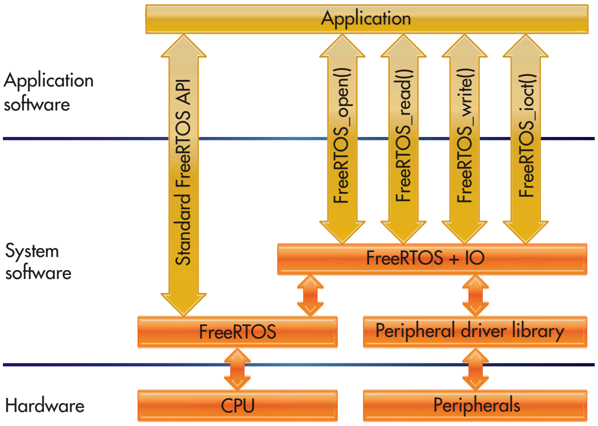
Last year, the IEC accepted the PVQAT's proposal "Guidelines for Increased Confidence in Module Design Qualification and Type Approval," which has already pushed forward certain standardized procedures for PV production. ■

DSPS LEVERAGE FreeRTOS Kernel

IN THE SEARCH for easier ways to develop complex real-time software, many designers turn to FreeRTOS—a scalable, easy-to-use real-time kernel designed for small, low-power embedded systems. Cadence Design Systems recently announced that the FreeRTOS operating system (OS) would now be available for its Tensilica processors and digital signal processors (DSPs).

FreeRTOS provides specific support for Internet of Things (IoT) applications, which is the province of Tensilica processors. The OS has minimal ROM, RAM, and processing overhead and is relatively simple—the RTOS kernel's core employs just three C files. A typical RTOS kernel binary image requires only 4 to 9 kB, and the platform contains a pre-configured example for each port to ease setup.

Cadence's offerings include the Tensilica Fusion DSP, a scalable solution that can be designed into SoCs for wearable activity monitoring, indoor navigation, context-aware sensor fusion, secure local wireless connectivity, face trigger, voice trigger, and voice recognition. It combines a 32-bit Xtensa control processor with DSP features and flexible algorithm-specific acceleration for a more programmable approach. ■



FreeRTOS will now be available for Cadence Design Systems' Tensilica processors. *(Image courtesy of FreeRTOS)*

NEW POSITION SENSORS Follow Many Paths

The goals are the same, but three different companies illustrate three different approaches.

By the start of the 21st century, the classic limit switch had been largely replaced by the hall-effect sensor, but both were handicapped by their binary outputs. System designers seeking to control the positions of mechanical devices had only one bit of data to work with—not optimum for control loops. The last several years, extending into 2015, have seen remarkable innovation in position-sensing technology, both in terms of resolution (now surpassing 28 bits of precision) and in relative immunity to stray fields. *(For a list of older technologies that were developed to supplant the mechanical micro-switch, see "Older Distance-Sensing Technologies," beginning on page 22.)*

TI's 2- AND 4-CHANNEL-INDUCTANCE-TO-DIGITAL SENSORS

In late 2013, Texas Instruments introduced its single-channel LDC1000, a unique position-sensing semiconductor device with 20-bit precision based on a technology that can be described as an "inductance-to-digital converter." This April, TI introduced a multi-channel version, the two-member LDC1614 family, which provides either two or four matched channels and

to Precision

up to 28-bit resolution—all in a single integrated circuit.

Anyone familiar with the electronic musical instrument called the Theremin (en.wikipedia.org/wiki/Theremin) will grasp the concept, although not necessarily the engineering, that goes into translating that concept into a digital-output measuring device with 28-bit precision. (To be precise, there are two sensors in a Theremin: one for the pitch of the output sine wave, the other for volume control.)

In any channel of a TI LDC device, what is being digitized are the de-tuning effects of nearby conductors on LC tank circuits. Typically, the tank coil is a small helix in a PC board. In parallel with the coil is a fixed capacitor. The tank resonant frequency on the latest devices can be anywhere from 1 kHz to 10 MHz. (On the original single-channel LDCs, the range was 5 kHz to 5 MHz.)

In operation, the tank circuit is driven at its resonant frequency. Some of the radiated energy can be picked up by a nearby conductor, and eddy currents in that conductor will generate a field that creates opposing currents in the tank coil. An ac current in a coil will generate a field that causes eddy currents in nearby conductors.

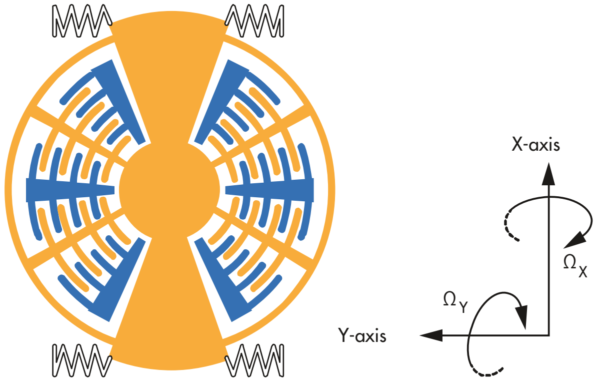
The eddy currents depend on the distance, size, and composition of the target conductor. In turn, they then generate their own field, which opposes the field around the coil.

What the TI LDC devices measure is an equivalent parallel resonance impedance, Rp, which is related the distance, d, to the external conductor, where:

$$Rp(d) = (1/([Rs + R(d)]) \times ([Ls + L(d)])/C$$

The d designation indicates that those variables are functions of the distance to the disturbing conductor.

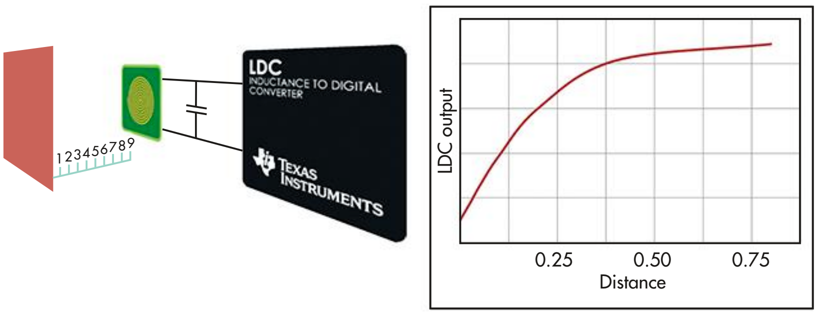
Meanwhile, there's a lot going on inside the LDC. It measures the impedance and resonant frequency of the tank and uses that information to regulate the oscillation amplitude to a constant level while monitoring the energy dissipated by the resonator. It simultaneously solves for Rp. Rp and frequency are output as digital values via the I2C interface. *(For more information about applications suitable for these devices, along with some background about the history of this technology, see "Redefining Inductive Sensing" at electronicdesign.com.)*



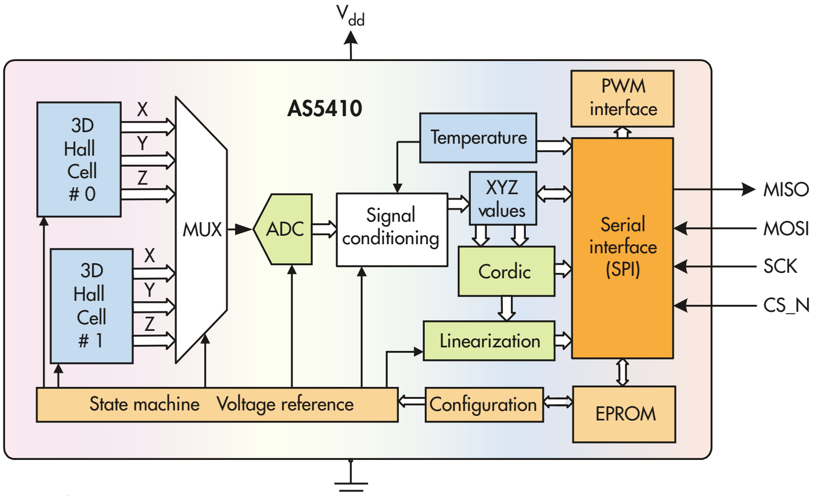
Analog Devices' MEMS sensor operates as a vibratory rate gyroscope.

Late last year, Analog Devices announced its ADXRS290, a high-performance MEMS pitch-and-roll (dual-axis, in-plane) angular rate sensor gyroscope ideal for such applications as optical image stabilization, platform stabilization, and wearable products. It's based on a resonating disk-sensor structure that enables angular rate measurement about the three axes normal to the sides of the package. Angular rate data is formatted as 16-bit twos complement and is accessible through a SPI digital interface. The device incorporates programmable high-pass and low- pass filters that allow it to achieve a noise floor of 0.004% per root Hz. Its sensitivity spec is 200 LSBs per degree per second.

Essentially, the MEMS device operates as a vibratory rate gyroscope to sense pitch and roll displacements and report their angular displacement rates. There are four coupled structures like the one shown in the figure at the top of this page, all fabricated in polysilicon. Each structure comprises an electrostatically driven resonating disk that produces the necessary rotating velocity element needed to generate a Coriolis torque when experiencing angular displacement.



Texas Instruments' "Inductance to Digital" sensors measure the distance between a metallic object (red) and the helical inductor of an LC tank circuit (green) that is driven by the sensor IC. The latest generation delivers 28-bit precision.



ams' AS54xx sensors use a pair of "pixels," to eliminate the effects of stray magnetic fields.

After demodulation and analog-to-digital conversion, the rate signal is filtered using a single-pole band-pass filter. The high-pass and low-pass poles of this filter are programmable via the digital interface.

The gyro runs off 5 V, but the sensing structure requires 31 V, so the gyro incorporates a step-up dc/dc converter. This requires an external 1-µF capacitor, which does require some board space in the final design. The MEMS itself comes in a 4.5 × 5.8 × 1.2 mm, 18-terminal cavity laminate package. Output is via a 4-wire SPI bus.

AMS' DUAL-PIXEL AS54XX FAMILY

Earlier this year, *Electronic Design* reported on a new generation of 3D magnetic position sensors that can sense magnetic flux in three dimensions, permitting their use in a wider range of position sensing applications. *(See "Differential Technology Helps Magnetic Position Sensors Reject Stray field Interference," at electronicdesign.*

OLDER DISTANCE-SENSING TECHNOLOGIES

GAUGING DISPLACEMENTS and the angular positions of motor shafts has always been an interesting challenge on the cusp between mechanical and electronic engineering. Here are a few approaches that have been popular in the past:

Linear-position and displacement sensors are the most likely choice for industrial and commercial applications of 100 min. to 100 in. (2.5 mm to 2.5 m). Generally, electromechanical linear position and displacement sensors are one of six basic technologies: resistive, capacitive, inductive, magnetic, time-of-flight, and pulse encoding.

Resistive sensors or potentiometers slide a contact against a fixed resistive element to generate changes in resistance. Hooked to a dc source as a voltage divider, they produce a proportional voltage output when used with high-impedance loads. They are relatively economical; servos on radio-controlled model airplanes frequently employ potentiometers for position feedback. However, their use of a sliding contact gives them poor repeatability, large hysteresis, and an output that tends to deteriorate over time from wear, particularly in the presence of vibrations.

Magnetoresistive sensors are sometimes considered contact-free variations on the potentiometer. They are comprised of a special metallic film whose electrical resistance varies in a magnetic field. This sensing material is often configured in a Wheatstone bridge to cancel out temperature coefficients (around 0.3%/K) and resistor tolerances. The bridge may be balanced by laser-trimming the magnetoresistive material.

Magnetoresistive sensing is sometimes confused with magnetostrictive sensing. Magnetostriction is a property of ferromagnetic materials such as iron that expand or contract when placed in magnetic field. Magnetostrictive sensors are used to measure linear position. They measure the position of a permanent magnet (position magnet) to determine the distance between the permanent magnet and the sensor head. The magnet doesn't touch the shaft and thus has no wear.

Magnetostrictive sensors use the principle of time-of-flight for gauging distances. The electronics send out some type of wave (usually sound or light) down the waveguide of magnetostrictive material toward the moving target (magnet) and measure the time necessary to receive a reflection. The moving magnet creates a torsional pulse in the magnetoresistive waveguide. The pulse moves down the waveguide at a known speed to a wave detector. Thus the output is proportional to the magnet position relative to the detector.

Magnetostrictive sensors offer high resolution, high repeatability, and exhibit good temperature stability over a limited temperature range. They are particularly useful for relatively long ranges, typically from 6 to 120 in. (150 mm to 3 m) or more.

There are other sensors that use the time-of-flight principle to gauge distances. Ultrasonic and laser time-of-flight sensors depend, of course, on timing the reflection of sound and light, respectively. Both are contactless but the dimensions of the target and its orientation can affect the measurement. For ultrasonics, air temperature, humidity, and wind also can introduce errors into readings. Nevertheless, ultrasonic sensors are generally economical

(continued on p. 25)

com). Known as "3D dual-pixel sensor ICs," they help machine designers comply with the new functional safety standards developed for vehicles with multiple magnetic-field-inducing electrical systems. The technology was developed by ams, an Austrian sensor maker.

The usual approach to protecting hall-effect sensors from stray fields is to shield them. This is often unsatisfactory for reasons cited in the *Electronic Design* article referenced above.

What is usually done is to place the position sensor very close to a magnet that has very high remanence (Br). This improves the signal-to-stray-field ratio and, in fact, the overall SNR. Unfortunately, really strong magnets made out of materials such as NdFeB are as much as 10 times more expensive than cheap hard ferrite or plastic-bounded magnets. The approach that the ams engineers came up with—and made work—is a dual-pixel magnetic sensing element. Using two pixel cells instead of one makes it possible to apply differential measurement techniques, because each pixel cell can measure all three vectors of the magnetic field: Bx, By and Bz. In ams' AS54xx sensor family, the two pixel cells need to be separated by 2.5 mm.

The original *Electronic Design* article includes an illustration of the mathematics. Essentially, it shows that when the magnet is exactly centered over the package of the IC, the north-to-south pole transition of the magnet is exactly between the two pixels. Since the pixels are 2.5 mm apart, there is a ±1.25 mm phase shift between the responses for the two pixels, from which the algorithm in the sensor's internal processor can derive two differential signals, representing x and z vectors.

If a stray field is present, it probably comes from a source much further away from the sensor than the field from the paired magnet is. It has the identical effect on both pixels. This is what enables the differential of position measurement. The longer explanation in the original argument is more rigorous, but that's the gist of the explanation. In brief, the position of the sensor magnet can be extracted through an arctangent calculation.

AS54XX CHARACTERISTICS

ams's AS54xx series of automotive-qualified position sensors provide 14-bit resolution. They are usable between −40°C and 150°C, with no external temperature compensation. Data sheets cite an input range from 5 to 100 mTesla. Other features include integrated self-monitoring, a safety layer that provides protection in the event of a failed ground connection or power supply, as well as under- and over-voltage protection. An EEPROM self-check detects bit-flips.

The dual-pixel differential principle of operation doesn't just provide for stray field immunity; it also eliminates the need to offset for drift over temperature and time. ed

(continued from p. 22)

and reliable enough for range finding and liquid-level sensing where precision is not a key. Depending on the operating frequency, ultrasonic sensors measure distances ranging from a few inches up to 33 ft. (0.1 to 10 m).

Laser sensors also work from reflection time and offer high precision and excellent repeatability. But they are relatively expensive and generally require targets with the right reflectivity for best results. Lasers also may pose a hazard to human eyesight. Typical ranges are from fractions of an inch to hundreds of inches (a few millimeters to dozens of meters).

For smaller distances, capacitive or inductive sensors may fit the bill. Capacitive sensors rely on the changing capacitance between two plates—one fixed, the other free to move—to signal changes in linear position of up to about 0.4 in. (10 mm). Their support electronics is more complicated than resistive devices and they are susceptible to humidity changes and temperature extremes. Their primary use is in short-range dimensional gauging of mechanical parts, and in these applications, they have high resolution and good accuracy.

Inductive sensors measure inductance variations caused by movement of a flux-concentrating element (usually a wire coil). They are contact-free and often used where long-term reliability is important, particularly in harsh and hostile environments. There are three basic types of inductive sensors: LVDTs (linear-variable differential transformers), LVRTs (linear-variable reluctance transducers), and LVITs (linear-variable inductance transducers). All of them need ac signal conditioning or support electronics.

LVDTs usually measure movements between 0.01 and 10 in. (0.25 to 250 mm). They generate a signal proportional to the linear displacement from a mechanical reference (zero, or null position). The signal contains phase (for direction) and amplitude (for distance) information. An LVDT typically has three solenoid coils placed end-to-end around a tube. The center coil is the primary and the two outer coils are secondaries. A cylindrical ferromagnetic core, attached to the object of interest, slides along the axis of the tube. An ac signal to the primary induces a voltage in each secondary proportional to the length of the core linking to the secondary. The frequency is usually in the low kilohertz range.

The amount of linkage between the primary and the two secondary coils changes as the core moves. The coils connect so the output voltage is the difference between the two secondary voltages. When the core is equidistant between the two secondaries, the two secondary coil voltages cancel, so the output voltage is theoretically zero.

As the core moves, the voltage in the corresponding secondary coil rises while the voltage in the other drops, pushing the output voltage away from zero. This output voltage is in phase with the primary voltage. When the core moves in the other direction, output voltage also rises from zero, but in the opposite polarity. The phase of the output voltage gives the direction of the displacement, and amplitude indicates the amount of displacement.

LVDTs can serve as absolute position sensors because they show the same output on restart after power is switched off. LVITs generally use just one coil. A conductive target, typically a rod or slide, is set up to pass over or through the coil. As with LVDTs, eddy currents are induced in the target, which changes the inductance of the coil. Typical targets are conductive but nonmagnetic materials such as aluminum and stainless steels. However, they generally operate in the 2-MHz frequency range, making them sources of and susceptible to electromagnetic interference. They can be found in ranges up to 40 in. (1 m).

LVRTs also use one coil and are usually configured as half bridges with a central connection to the middle of the coil. They are widely used in Europe where they serve as spool position feedback sensors in servo-valves and in short-range dimensional gaging probes. They are thought of as less expensive than LVDTs but have lower outputs for a given size. LVRTs typically have ranges under 0.4 in. (10 mm).

Finally, pulse-encoding sensors usually measure incremental movements and don't note absolute position without some kind of homing operation, although there are some absolute encoders. The typical orientation of these devices is to optically read linear graduations on a glass scale or detect magnetic poles uniformly spaced on ferromagnetic material. Ancillary electronics counts the graduations or poles to discern the amount of movement over a given time period. These devices perform with high precision generating quasi-digital output and are used primarily in robots, machine tools, and similar applications. Encoders have a limited frequency response, however, so they are best suited for slower dynamic applications. Measurement distances range from 6 to 60 in. (0.15 to 1.5 m). ■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BILL WONG | Embedded/Systems/Software Editor
bill.wong@penton.com

IoT Standards

Building the Internet of Things requires cooperation that frameworks can streamline.

You're not building the next smart sports band, so should you care about Internet of Things (IoT) frameworks? If you've heard the buzz, you know that IoT has replaced everything from the cloud to machine-to-machine (M2M) communication. Essentially, it is the same thing that was going on, though the scope tends to be larger. The devices involved may number in the millions, with hundreds or thousands on premise.

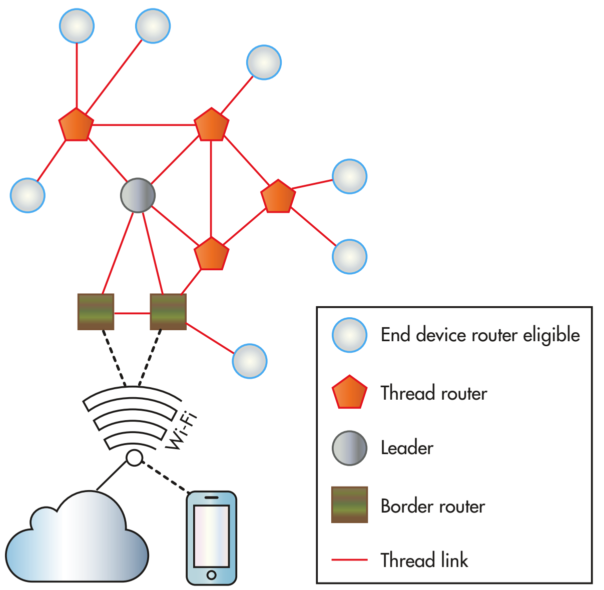
Programming for an IoT environment is no longer simply a TCP/IP socket connection. Even a Transport Layer Security (TLS) connection is insufficient for providing system security. Likewise, more programmers are having to deal with transient connections or connections with varying bandwidths. Wireless connectivity brings even more complexity to the environment, and data can hop through any number of gateways that may or may not perform data massaging along the way.

Standards and frameworks help simplify programming chores. Sometimes the choices are dictated by a chosen platform. There are a number of vendors that provide hardware and software support, and developers will be hard pressed to work outside of these confines. There are other open solutions that do not necessarily address an end-to-end approach, but rather, leave providing significant portions of the environment to the programmer. They also may not address issues such as system and power management, remote updates, and so on.

Here we examine some of the alternatives available. The collection is by no means exhaustive, as this is one programming area with a very large number of options. No one platform

Thread	Standard
Application layer	
UDP and DTLS	RFC 768, RFC 6347, RFC 4279, RFC 4492v, RFC 3315, 5007
Distance vector routing	RFC 1058, RFC 2080
6LowPAN (IPv6)	RFC 4944, RFC 4862, RFC 6775
IEEE 802.15.4 MAC (including MAC security)	IEEE 802.15.4 (2006)
IEEE 802.15.4 PHY	IEEE 802.15.4 (2006)

1. The Thread Group's Thread framework is built on existing standards like 6LoWPAN and 802.15.4 to address wireless IoT applications.

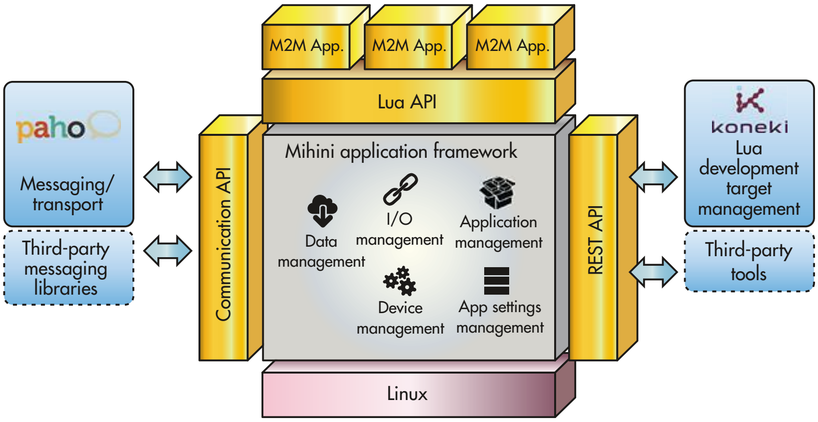


2. The Thread architecture is similar to most wireless, mesh network solutions. Routers provide connectivity to the cloud for end devices. Routers may also provide end-node services such as providing local sensor data.

and Frameworks

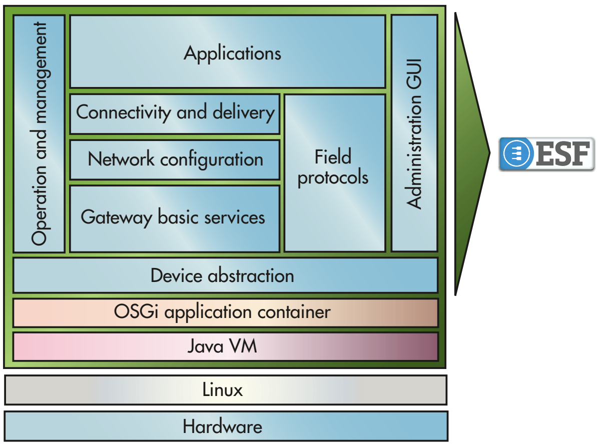
is suitable for all applications, although many purport to be so.

Typically IoT frameworks are built on top of or otherwise utilize standard communication protocols like TCP/IP. They may be more specific in support such as using IPv6 over Low power Wireless Personal Area Networks (6LoWPAN). They may also use higher-level protocols like Message Queue Telemetry Transport (MQTT), Advanced Message Queuing Protocol (AMQP), or Extensible Messaging and Presence Protocol (XMPP). It is also possible to use something like Object Management Group's (OMG) Data Distribution Service (DDS).



4. Mahini works with the Poho open source MQTT implementation.

Often the challenge lies in determining the scope of the application as well as the framework. Some solutions are designed for millions of nodes, others for dozens or hundreds.



3. Eurotech's Everyware Software Framework (ESF) is the basis for the Eclipse Open IoT Working Group Kura.

OPEN FRAMEWORKS

One organization that has garnered significant vendor support for its wireless framework is the Thread Group. It provides an application framework built on existing IETF and IEEE standards like IEEE 802.15.4 *(Fig. 1)*. It is designed to handle over 250 devices in a Personal Area Network (PAN) or Home Area Network (HAN). These often will be low-power devices that sleep, so timing of communication will be critical to efficient operation. Parent routers can hold data for sleeping devices.

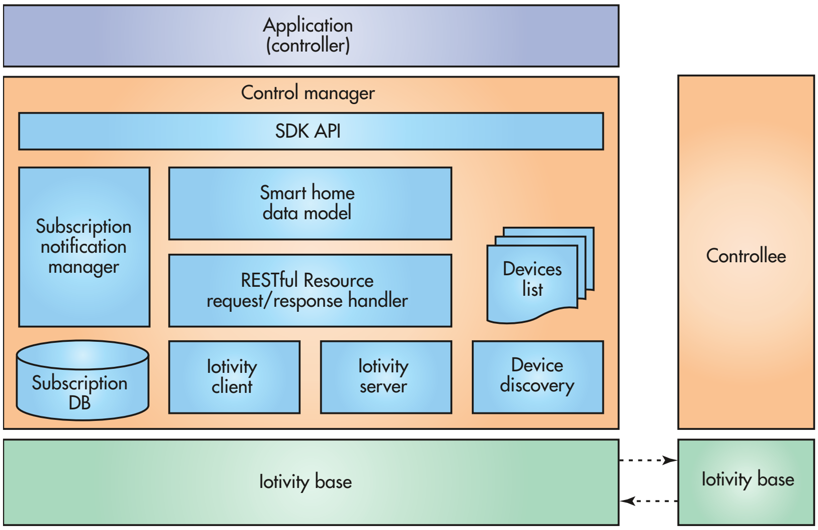
The Thread architecture *(Fig. 2)* is similar to most wireless, mesh network solutions. The system is designed so it is possible to build a system without a single point of failure. This requires at least two border routers, which may not always be possible or economical. Border routers provide a gateway between the Thread network and another network (*e.g.*, a local wireless or wired network).

Within the network, each device has an IPv6 address plus a shorter HAN alias. Devices within the local network can use the HAN addresses while IP addressing is used for services on the other side of the border routers. Devices can route eligible or end devices. The latter only communicates with a router.

Devices that can be a router are enabled as necessary.

A router maintains state with all other routers in the network using a trickle mechanism and the MLE (mesh link establishment) protocol. The Leader router manages the network. Another router will take over for the Leader if the Leader fails or becomes incommunicado. New nodes can be authorized by a user with an app running on a GUI device like a smartphone .

The Thread Group is also working with other organizations like the ZigBee Alliance. The Thread stack is used in frameworks like ARM's mbed. The Eclipse Open IoT Working Group has two IoT frameworks: the Kura OSGi-based gateway framework and the Mihini framework for the Lua programming language.



5. The IoTivity Control Manager uses REST to communicate and manage devices within the network.

Kura uses the same Java-based OSGi framework from the OSGi Alliance that the Eclipse IDE is based upon. OGSi runs Java bundles. Kura has bundles that provide services like remote management and system configuration, in addition to cloud and data services. Kura components are designed as configurable OSGi Declarative Services exposing the service API with the ability to raise events.

Kura is based on work from Eurotech. The firm's Everyware Software Framework (ESF) provides the same common services as Kura *(Fig. 3)*. Eurotech builds on this with features such as reverse NAT support and the Everyware VPN as well as Everyware Cloud Web Console management tool. ESF uses MQTT as its transport mechanism. It can handle device updates and remote diagnostics.

The Mihini framework uses the Lua programming language. It is based on work done by Sierra Wireless. Developers can take advantage of Eclipse's Koneki tool suite to develop Mihini-based applications. Mihini also works with the Eclipse Poho project services that provide MQTT support *(Fig. 4)*. Poho include Lua support in addition to MQTT drivers for C/C++, C#, Java, Javascript, Python and Go. Mahini and Kura can run on platforms like Texas Instrument's BeagleBone Black. *(See "Arduino, Raspberry Pi or BeagleBone?" on electronicdesign.com.)*

IoTivity is another open-source project that targets IoT applications. It is sponsored by the Open Interconnect Consortium (OIC) and hosted by the Linux Foundation. The IoTivity framework incorporates four major building blocks: discovery, data transmission, data management, and device management. It runs on Linux platforms including Ubuntu, Tizen, and Android, as well as Windows 8, iOS, and Arduino.

IoTivity's architecture uses profiles on the application side. The Protocol Plugin Manager handles the other side of the framework where one or more transport drivers exist. Other managers include a Control Manager (CM), Thing Manager (TM), and Soft Sensor Manager (SSM). The CM manages the connectivity within the network using a REST interface *(Fig. 5)*. The TM allows developers to manage a group of devices or "things" within the network. The SSM handles physical, as well as logical/virtual sensors.

ARM's mbed is a bit more focused. It starts as a development environment for ARM Cortex-M microcontrollers. It includes development tools as well as the mbed OS. The environment can be used to develop standalone applications as well as networked applications.

The mbed Device Server is an optional component that also uses a REST API *(Fig. 6)*. It provides links between devices as well as connections to cloud-based services. It supports C, Java SE, and Java ME clients. The architecture supports open-source, data-communication, and device-management protocols such as CoAP/HTTP, MQTT, TLS/TCP, DTLS/UDP, and OMALWM2M.

The environment can support any number of cloud services. One that has been integrated with Freescale K64F Freedom board is IBM's cloud services. *(See "mbed IoT Starter Kit Links to IBM's Cloud" on electronicdesign.com.)* The ARM mbed Ethernet Starter Kit can be linked to an IBM account to start IoT development immediately with the Freedom board.

VENDOR FRAMEWORKS

There are a number of vendors that provide environments that address everything from the hardware on up. This can greatly simplify system implementation, allowing developers to concentrate on application-specific details. These type of frameworks tend to target specific application areas.

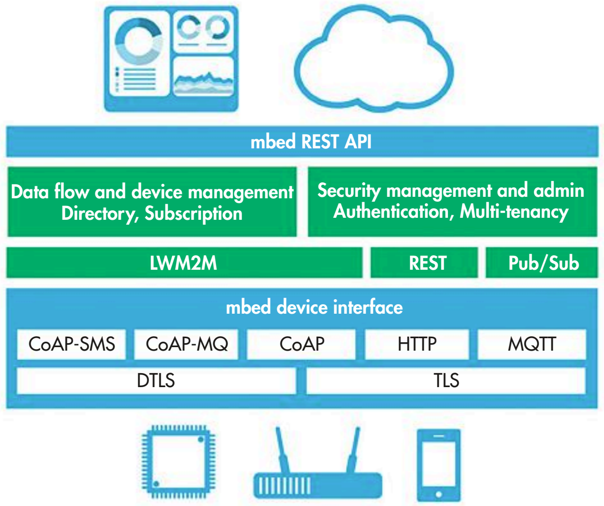
One example is Linear Technology's SmartMesh technologies. SmartMesh IP supports 6LoWPAN and 802.15.4e. Its terminology for nodes is "motes." SmartMesh WirelessHART uses the WirelessHART (IEC 62591) standard. Its Eterna SoC is based on an ultra-low power Arm Cortex-M3.

A key feature of SmartMesh is the robustness of the mesh network. It is self-configuring and the network will adjust if a mote becomes inaccessible. The protocol stacks implement a Time Synchronized Mesh Protocol (TSMP). The stack uses a Time Slotted Channel Hopping (TSCH) media access layer (MAC) that divides time into "slots." Timeslots are mapped to channels with a pre-assigned hopping sequence.

Motes transmit, listen, and sleep on a precise schedule. Packet exchanges are synchronized so there are no packet collisions. Packets are scheduled for energy efficiency with no extra, transmit side preamble or receive side guard interval. The approach allows multiple transmissions to occur simultaneously on different channels, thereby increasing overall network bandwidth. SmartMesh is designed to implement very large industrial networks.

Oracle and Microsoft are major software vendors that are large enough to have their own approach to IoT that garners a significant following—both cloud-based solutions and services, such as Microsoft Azure and Oracle Cloud Computing services. These database services are often the cloud target for other IoT frameworks.

Microsoft Windows 10 IoT Core was introduced at Microsoft's Build 2015. It targets IoT end nodes. The core is a compact version of Windows 10 that runs on platforms like Raspberry Pi. It primarily provides communication and operating system services rather than a full Windows 10 GUI platform. An even more compact implementation called Windows Remote Arduino allows applications running on an Arduino microcontroller to communicate with a Windows 10 platform,



6. The mbed Device Server provides a REST API to manage devices within an mbed network.

including the Windows 10 IoT Core.

Oracle's IoT solution takes advantage of its Oracle database and Java platforms to provide the infrastructure of IoT solutions. Partners like PTC fill in the gaps using these platforms. PTC's Axeda provides an end-to-end approach using Axeda Connect connectivity middleware: Axeda Build, which includes data management and scripting support, and Axeda Manage, with Web-based applications for managing IoT networks.

All these frameworks have a number of common goals, including reducing time to market, offloading core development, and providing a coordinated communication and security environment. Although many use standard protocols and database solutions, they rarely have the ability to communicate across frameworks. This can lead to environments with mixed solutions in place that may only exchange information and control in the cloud. The advantage of using standards at the communication level is that they can typically coexist even with multiple wireless installations in place.

Unfortunately we have had to gloss over the details of the frameworks to provide an overview of some available solutions. The challenge for developers is identifying the aspects of the framework they will have to deal with as well as the capabilities that the frameworks provide.

In any event, anyone building IoT solutions is unlikely to build their own framework from scratch, given the complexity and components involved—*e.g.*, microcontroller-based applications communicating with database servers in the cloud. ed

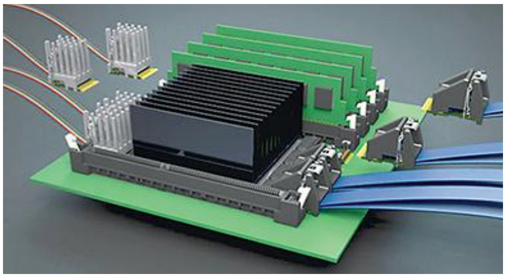
BILL WONG | Embedded/Systems/Software Editor
bill.wong@penton.com

Backplane Optical Interconnects Speed Past Copper

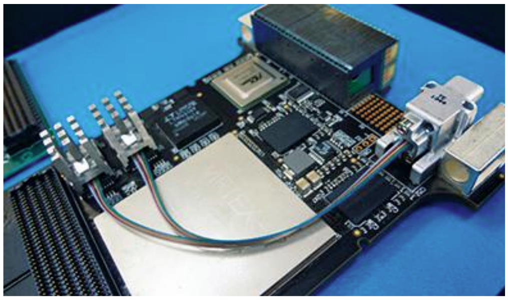
Changing economics for optical interconnects make them an even more desirable option to handle soaring serial interconnect speeds.

The limitations of copper become more apparent when trying to move data at gigabit throughput. When running digital signals with clock rates over 20 GHz for any distance, the solution is fiber. System interconnects already incorporate fiber, and deployments like Verizon's FiOS use fiber for the last-mile connections. Custom fiber chip-to-chip and board-to-board interconnects have made the rounds, but the technology is gaining more ubiquity among these applications.

Standards like VITA 66.4 *(see "Will Optics Spell the Death of the Copper Backplane?" at electronicdesign.com)* are driving vendors to deliver products like Samtec's FireFly product family *(Fig. 1)*. FireFly actually addresses copper and fiber with data rates up to 28 Gb/s. A common connector is used to plug in modules that handle a dozen serial links via copper or fiber micro-ribbon cable. The protocol-agnostic system can handle Ethernet, InfiniBand, FibreChannel, and PCI Express. Key to its design is the implementation of a vertical-cavity surface-emitting laser (VCSEL) array.



1. Samtec's Firefly family addresses high-speed serial connections between chips, boards, and systems.



2. Pentek's 5973 3U VPX FMC carrier board supports the VITA 66.4 standard with a dozen fiber connections via Samtec's Firefly.

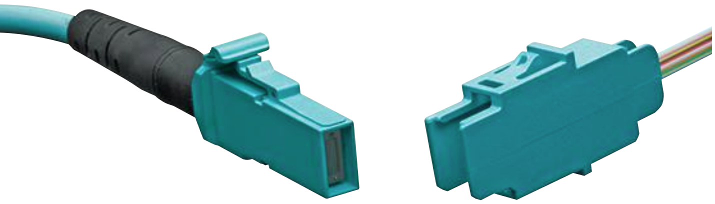
FireFly is not the only solution available. For instance, there's TE Connectivity's Coolbit, which delivers 25-Gb/s optical connections. The company's Lightray MPX system can handle 24 fibers on 250-µm centers.

A standards-based solution comes by way of Pentek. Its 5973 3U VPX FMC carrier board supports the VITA 66.4 standard and uses a dozen fiber connections on the backplane connector via Samtec's Firefly *(Fig. 2)*. The Pentek 5973 board contains a field-programmable-gate-array mezzanine card (FMC) socket and a Virtex-7 FPGA on-board. The optional VITA 66.4 support connects directly to the FPGA's multi-gigabit serial interfaces.

The Pentek 5973 board is able to handle a majority of FMC cards on the market today. These normally provide a front-end interface often incorporating analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). Sometimes the FMC cards feature high-speed serial interfaces. Such is the case with Techway's TigerFMC—it's a VITA 57.1 card that also takes advantage of Samtec's FireFly optical connection *(Fig. 3)*.

Different versions of the TigerFMC expose the optical interface on the front panel or via a cable for connection to the carrier board, a rear transition module (RTM), or backplane. The system can handle up to 14 Gb/s per channel. A 28-Gb/s per channel system is in the works.

3. Techway's TigerFMC uses Samtec's FireFly for high-speed optical input in this VITA 57.1 FMC card.



4. Molex's MXC connectors come with up to 64 fiber connections (four rows of 16 fibers).

Intel's Silicon Photonics remains a work in progress. As the enterprise arena moves to 100-Gb/s Ethernet and beyond, this technology was designed to link servers and switches using fiber connections. The system employs special micro-coaxial (MXC) connectors like those available from TE and Molex *(Fig. 4)*. These connections can be used with Molex's 12-fiber VersaBeam parallel optical device (POD) module.

The high-density MXC connector is designed to handle up to 64 fibers, while other connector technologies top out at around 24 fibers. A single-mode fiber can support distances up to 4 km. Transfer rates of 25 Gb/s translate to 1.6 Tb/s for a 64-fiber bundle—that kind of bandwidth will be essential to handle the growing data center and cloud requirements.

MXC employs expanded-beam lens technology, which can help reduce the impact of debris in the connection. It also requires less spring force for mating thanks to the greater tolerances enabled by this technology.

Copper continues to push the envelope, but it's getting harder and harder to meet the performance characteristics of fiber. When it comes to long-distance connections, there's simply no comparison. ed

BILL WONG | Embedded/Systems/Software Editor
bill.wong@penton.com

Software Leverages 3D Imaging Hardware

Innovations continue to push 3D imaging forward, such as with Microsoft's Kinect 2 and a 3D camera system born from an Intel/Creative Labs collaboration.

Microsoft's Kinect brought 3D sensor technology to the masses, even though it was neither the first nor the only type of 3D imaging technology available. *(See "How Microsoft's PrimeSense-based Kinect Really Works" on electronicdesign.com.)* The original Kinect utilized an infrared imaging system. The IR system projected a pattern that was then analyzed by an ASIC to provide extra depth information. It was coupled with a conventional color camera. Sensor integration delivered color-related, 3D-depth images for gesture and movement recognition in gaming applications.

Kinect 2, which shipped with the XBox One, switched to a time-of-flight (ToF) technology that's also used with SoftKinetic's DepthSense sensors *(see "Time-Of-Flight 3D Coming To A Device Near You" on electronicdesign.com)*. ToF needs an ASIC to do the heavy lifting, too, since it has to determine the time it takes light from an infrared LED on the camera to reflect off an object and return to the sensor. Like the DepthSense-based cameras, the Kinect 2 has a color camera paired with the sensor.

Microsoft has an SDK for the Kinect 2 that works with Microsoft Windows. The kit maintains Unity Pro support and features improved body tracking—it handles as many as six people in a scene with 25 skeletal joints per person. SoftKinect's IISU SDK works with its DepthSense systems and other cameras. It runs on Windows 7 and 8; Linux and Android support are in the works. There's also flash and Unity 3D plug-in support.

3D CAMERA INTEGRATES REALSENSE

Intel and Creative Technology paired up to support Intel's RealSense technology in the form of Creative Technology's latest F200 3D camera *(see figure)*. The USB 3.0 device uses a ToF sensor with VGA resolution and a 1080p HD color camera. The depth sensor has an operating range of 0.2 to 1.2 m. The camera, which has a pair of built-in microphones, is designed to sit atop an LCD display.

Intel's RealSense SDK runs on Windows 8.1 and only works with the F200 camera and R200 rear-facing camera. The technology is intended to be embedded much like the way conventional HD cameras are in laptops, tablets, and smartphones.

Intel's RealSense SDK, which features an extensible plug-in framework, targets Creative Technology's latest F200 3D camera.

Available for free via download, the SDK is a work in progress. Some of the latest enhancements include a new Depth Camera Manager (DCM) with 3D scanning support, pulse estimation, and a blob tracking module. C and C++ support was initially provided, but it now includes Java and Javascript support. It also works with the Unity gaming engine, which has capabilities that extend beyond just creating games. Power management was added, too, because the camera will often place a heavy load on battery-based systems. The SDK's extensible, plug-in framework enables support for new features and devices.

The SDK is a human-computer interface environment that addresses gesture and body/facial recognition, as well as voice recognition and control. Collaboration, gaming, and natural control were on the initial list of apps, but it also adds 3D capture.

The Intel RealSense website features a number of demos, including games that highlight the capabilities of the SDK. For instance, Nevermind is a game that uses biofeedback to detect the player's heart rate via the RealSense cameras. In the adventure-style Nevermind game, players need to unlock terrifying mysteries and solve puzzles while the game tracks stress levels.

There Came an Echo from Iridium Studios takes advantage of the SDK's voice-recognition support as well as its gesture support. Voice commands direct small squad operation in this real-time tactical strategy game. Military-style hand gestures can also invoke or control actions in the game.

Three-dimensional cameras are not as ubiquitous as conventional cameras—yet. Applications and support is still being defined, but these tools nonetheless make it possible to create 3D-enabled applications. ed

CHRIS LOBERG | Senior Technical Marketing Manager
Tektronix Inc.

New 100-Gb/s Transmission Standards Put Testing to the Test

Though 100 Gb/s is significantly faster than more mature high-speed technologies, enough similarities exist to help ease navigation through the new test landscape.

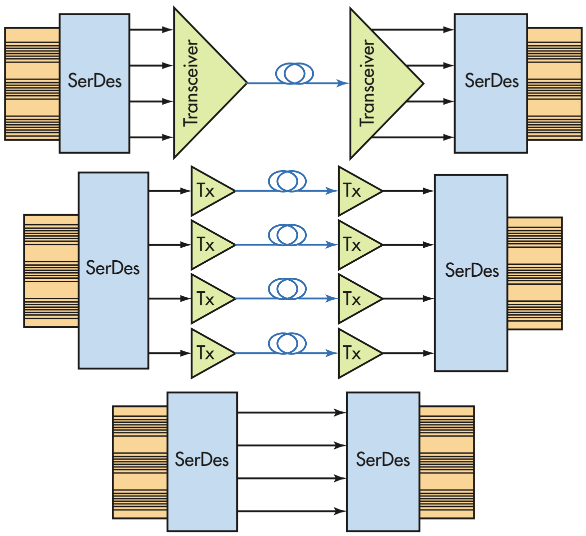
Varistors, also called metal-oxide varistors (MOVs), are used to protect sensitive circuits from a variety of overvoltage conditions. Essentially, these voltage-dependent, nonlinear devices have electrical characteristics similar to back-to-back Zener diodes.

Many data-communications and telecommunications technologies, such as Infiniband and Fibre Channel, now use 100 Gigabit Ethernet (100 GbE) for transport. High-speed-serial (HSS) technology makes it possible (*Fig. 1*). It encompasses noise-resistant differential signaling and jitter-resistant embedded clocking, along with closed-eye equalization. HSS enables 25+ Gb/s on printed circuit boards (PCBs). Furthermore, 100-Gb signal transmission to optical transceivers can be achieved by paralleling HSS links, thus easing connectivity to the fiber-optic backbone.

Dealing with HSS requires an understanding of the way analog waveforms relate to digital-signal bit-error rates (BERs). Looking at signals on a scope, less than 3 ps of random jitter closes the eye altogether. The latest standards typically permit less than 700 fs of random jitter.

With that in mind, the question is: "How does one test a 100G system?" Fortunately, commonalities exist with 100 GbE, Fibre Channel's 32GFC, and the Agreements of the Optical Internetworking Forum's Common Electrical Interface (OIF-CEI). Looking at those technologies, one can find familiar themes in the interplay of jitter, noise, and crosstalk (*Table 1*).

As standards evolve, the committees that generate them may use terms in different ways. For example, it's important to distinguish between "data" rate and "payload" rate. Data rate is the propagation rate of raw data. Payload rate doesn't



1. In a typical 100G system, a SerDes serializes a signal and transmits four over-25-Gb/s differential pairs. For each pair, the electrical signals from the SerDes go to an optical transceiver, which re-times the signals and transmits over either single-mode (SM) or multi-mode (MM) optic fibers. A second transceiver turns the optical signals back into electrical signals for a deserializing SerDes. A purely electrical version would follow the same scheme without the intermediate transceiver-driven optical signaling. At the top is a typical 4×25-Gb/s 100G SerDes-transceiver WDM optical system, and below that is a 4×25-Gb/s 100G SerDes-transceiver optical system. At the bottom is a 4×25-Gb/s 100G SerDes-to-SerDes electrical system. (The figure does not show the symmetric return paths.)

include overhead from error correction and coding, so payload rate is always less than or equal to data rate.

In addition, because signaling is always non-return to zero (NRZ), the proper unit for data rate is Gb/s rather than Gbaud. On the other hand, the terms "symbol" and "bit" may be used for the same fundamental communications element, depending on the standard being discussed.

ANALYZING THE STANDARDS

100 GbE – IEEE Std 802.3ba

To begin an examination of existing standards, consider the Long Reach (100GBase-LR4) and Extended Reach (100GBase-ER4) 100-GbE standards noted in the first column of Table 1. They're part of 100-GbE optical transmission specifications, under IEEE Std 802.3ba.

One can see that the differences between them are primarily at the receive end. The ER4 receiver needs greater sensitivity and must pass a more difficult stress tolerance test than the LR4 receiver. Moving down the table, the Short Reach, 100GBase-SR4, 4×25 Gb/s low-cost, multimode (MM) standard, along with the 100GBase-CR4 and 100GBase-KR4 for electrical transport over cables and backplanes, are works in progress. When finished, the 100GBase specifications will provide a complete suite of optical interconnect systems.

Ethernet

Below the 100GBase specifications in the table's first column are SONET/SDH standards. With Ethernet rapidly becoming the default for both datacom and telecom, it's becoming obsolete, so skip discussion on these.

OIF CEI

This is where changes in testing start to get interesting. Implementation Agreements (IAs) from the OIF-CEI do not prescribe compliance tests like that of the aforementioned specs. The emphasis is on "informative" and "normative" tests that are intended to assure interoperability. "Normative" tests are akin to compliance tests, while "informative" tests are intended to develop a more thorough understanding of performance and margin. For example, consider the two OIF-CEI IA tests summarized in Table 1.

Short-reach IA, OIF-28G-SR has the following features:

- Multiple lanes at 19.90-28.05 Gb/s
- Uses differential pairs
- Spans across 300 mm of PCB
- Up to one connection
- Operates at a BER of less than 10^{-15}

As of this writing, IA, OIF-28G-VSR reach has yet to be officially published. However, taking guidance from the preliminary version of the standard, it will probably be multiple electrical lanes at 19.60 to 28.05 Gb/s for signaling between SerDes (called "hosts" in the IA) and transceivers (called "modules").

The SerDes and transceiver may be separated by 100 mm of PCB to a connector, with an additional 50 mm or so of conducting trace; the system is required to operate at a BER below 10^{-15}.

TABLE 1: HSS STANDARDS

Standard		Geometry	Reach	Data rate	Bit-error rate (BER)
100 GbE	100GBase-LR4	4 SM fibers	10 km	4 x 25.78125 Gb/s	$\leq 10^{-12}$
	100GBase-ER4		40 km		
	100GBase-SR4*	4 MM fibers	$\leq$10 m	iOS, Android	$\leq 10^{-12}$
	100GBase-CR4*	4 cables, backplane	*	*	$\leq 10^{-12}$
	100GBase-KR4*				
OIF-CEI	OIF-28G-SR	n traces on PCB	30 cm	19.90-28.05 Gb/s	$\leq 10^{-15}$*
	OIF-28G-VSR*		15 cm*		
Fibre Channel	32GFC	n channels, optical and electrical	TBA*	28.05 Gb/s	$\leq 10^{-12}$*

*In recent discussions with standards committees

Fibre Channel 32GFC

The Fibre Channel standard, 32GFC, calls for a 28.05-Gb/s data rate. Why does "32GFC" refer to 28.05-Gb/s technology? The idea is that the name of each generation reflects a doubling of the payload rate in each generation. The payload rate for 32GFC is 25.6 Gb/s, twice that of 16GFC, even though the data rate didn't double.

As the table indicates, the 32GFC document has not been published, and the preliminary version has few reference values.

TEST TYPES

Whether for transmitter or receiver testing, optical or electrical, test patterns that put every aspect of a component and every component of a system to the test are essential. One example is pseudo-random binary sequences (PRBSn), which are standardized patterns with every permutation of n bits.

The OIF CID jitter tolerance pattern is designed to have the most aggressive elements of the PRBS31, plus 72-bit sequences of consecutive identical (CID) bits. However, it's at a manageable length.

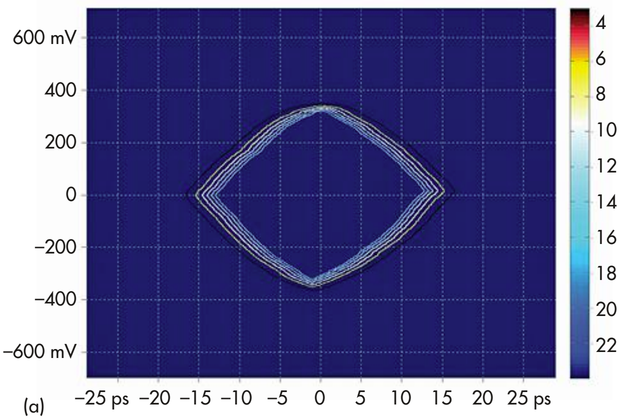
Transmitter Tests

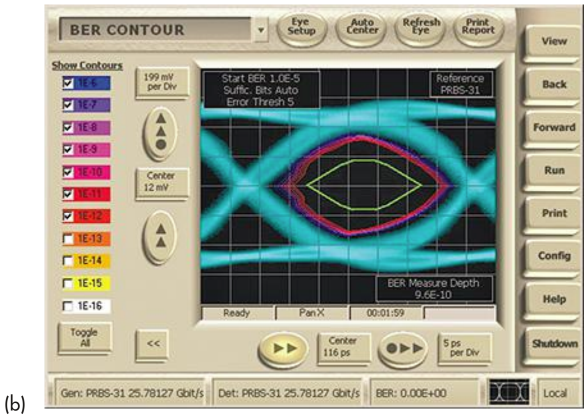
All transmitter tests, both electrical and optical, should be performed with all system channels active in both directions in order to include all reasonable sources of crosstalk interference. To prevent unrealistic data-dependent interference, test patterns on the crosstalk channels should be different than the test signal pattern (or at least introduce sufficient delay between them so that the patterns aren't synchronized).

Crosstalk channels should also operate asynchronously. For one thing, except in special cases, each channel operates with a clock that's been independently recovered from its incoming data. Although each clock operates at the same nominal rate, they're neither frequency- nor phase-locked. In addition, synchronous-crosstalk degradation occurs in the same region of the test-signal eye diagram every time an aggressor makes a logic transition. However, synchronous crosstalk itself is random.

If all of the SerDes are integrated on one chip with multiple serialized outputs, there may be inter-chip crosstalk. Also in that case, if the outputs use a common clock, then they need to be active and synchronized with the test channel, and each channel should transmit a unique signal.

Do not overlook the frequency response of the printed-circuit board. Proper testing requires pre-emphasis at the transmitter and equalization at the receiver. Stressed receiver tolerance tests





2. In eye-mask testing with BER contours, the BER=10^{-6} contour (the outer yellow-orange contour) corresponds to a 5×10^{-5} hit ratio (a). A BERTScope using a 30-Gb/s signal displays a typical BER contour (b).

assure that receivers can operate at the specified BER even with the worst-case compliant input signal.

Eye-Mask Tests

Eye-mask tests (*Fig. 2*) on wide-bandwidth optical-to-electrical receivers and clock-recovery units are essential. Note that the clock recovery –3-dB bandwidth differs among the specs.

To perform the tests, the optical-to-electrical receiver should apply a 4th-order Bessel-Thompson filter with a reference frequency of three-fourths the data rate. It's needed so that different test platforms can operate under uniform measurement conditions.

Eye-mask testing is inherently random. This can be addressed by requiring a minimum "hit ratio," defined as the ratio of the number of mask violations to the total number of samples acquired per unit interval. The more hits, the greater the accuracy. A transmitter is compliant if it achieves a hit ratio of less than 5×10^{-5}.

Optical Receiver Testing

This kind of testing resembles the optical receiver stress tests for the long and extended reach 4×25-Gb/s topologies. Dedicated test equipment obviously facilitates such testing. Table 2 summarizes some of the test patterns.

TABLE 2: OPTICAL RECEIVER TEST PATTERNS

0 x 0 off square wave	8 bits low, 8 bits high
PRBS 9	511 bits
PRBS 15	32,767 bits
PRBS 31	2.1 Gbits
Scrambled idle	
OIF CEI jitter tolerance pattern	(72 CID bits + ≥ 10328 from PRBS31 + seed) + complement

Essentially, what's happening during optical receiver testing is that the test equipment generates inter-symbol interference (ISI) with a 4th-order Bessel-Thompson filter that removes higher-order harmonics from the test-generator output. Then, random jitter is applied via a precision Gaussian noise generator. This can be imposed by adding the noise and then running the signal through a limiting amplifier.

Electrical Receiver Tests

Stressed receiver-tolerance testing subjects the receiver to the worst-case signal while looking at BER. For 100 GbE and 32GFC, the receiver is compliant if BER $\leq 10^{-12}$. For OIF-CEI, compliancy equates to BER $\leq 10^{-15}$. There are different levels and types of stress. Some only require sinusoidal jitter, while others need more.

ISOLATING FAILURES

At this point, an interesting question arises: "What if some element in the chain fails to meet compliance requirements—what's the process for isolating a failure source?"

Compliance tests tend to include too many elements to provide simple answers. To determine which elements or components of a system might be causing problems, product designers need to plan diagnostic tests that probe specific weaknesses. This means adding complexity, test upon test, to find problems and determine margins.

For example, if the transmitter fails, one should simplify the test conditions by removing any test-compliance boards. Subsequently, the transmitter output would be analyzed with as direct a connection as possible.

In addition, it's essential to perform jitter and noise analysis. Analyze the breakdown while applying more complex patterns, or introducing longer PCB copper runs. Apply pre-emphasis, and turn on crosstalk aggressors. For each set of conditions, analyze eye diagrams, BER-eye, BER-contours, and the jitter and noise breakdown.

This is where dedicated test equipment comes into play. For instance, jitter maps can distinguish different types of jitter. Non-periodic bounded uncorrelated jitter (BUJ) may imply that crosstalk isn't being sufficiently shielded. Duty-cycle distortion (DCD) suggests a look at the transmitter; ISI probably means trouble with the output path. And high levels of random jitter suggest problems with transmitter clocking, while sinusoidal or periodic jitter can be a symptom of electromagnetic interference from a nearby component, such as a switching power supply.

For more information on this topic, including test-equipment screen shots, download "Physical Layer Tests of 100 Gb/s Communications Systems" *(http://info.tek.com/www-physical-layer-tests-of-100gbs-comm-systems.html).*

INSTRUMENTATION

Essentially, eye diagrams are created by collecting and displaying voltage/time data samples, acquired at a sample rate that's orders of magnitude below the data rate. For example, the sampling rate for a 10-Gb/s (1010 bits/second) data rate might be 105 samples per second. These eye diagrams offer a way to quickly and intuitively assess the quality of a digital signal, providing information about rise times, fall times, jitter, overshoot, and other aspects of the digital signal.

Test equipment for creating eye diagrams requires a bit-error-ratio tester (BERT) that generates pseudo-random repeating test patterns. BERT testers usually have a range of trigger choices.

For example, a "clock trigger" provides a classical eye diagram that implements all possible bit transitions in one display. Alternatively, a "divided clock trigger" may be handy when the instrument used to construct the eye has a narrower trigger input bandwidth than the signal data rate. And with a "pattern trigger," it's possible to scroll through the signal on the display device. In general, the test engineer should avoid triggering on the data itself, because long runs of identical characters don't supply enough transitions to trigger from.

Sometimes it might be necessary to trigger from a recovered clock. This would occur, for example, if a clock signal weren't available. Or, in the case of long-distance fiber-optic communications, corruption may occur to either the clocks at the transmit end, or the data at the receive end link. In either of those cases, the clock must be recovered.

Some recovery circuits that are usually characterized by narrow loop bandwidth can be accomplished by a filtering function. It removes some of the jitter from the clock signal and some of the jitter that was present on the data signal so that delay between jittered clock and jittered data adds destructively.

For a more extensive treatment of the above information, check out "Anatomy of an Eye Diagram" *(www.tek.com/application-note/anatomy-eye-diagram).* ed

CHRIS LOBERG, senior technical marketing manager at Tektronix, is responsible for oscilloscopes in the Americas Region. During his more than 13 years with the company, he has held multiple positions, including Marketing Manager for Tektronix's Optical Business Unit. Loberg earned an MBA in marketing from San Jose State University, Calif..

Image Courtesy of Thinkstock

Auto Sector Keeps Buyers Busy

The auto industry is putting new pressures on direct and indirect suppliers to car makers.

BRIDGET McCREA | CONTRIBUTING EDITOR

WITH THE AUTOMOTIVE market in full economic recovery mode, the entities that directly and indirectly support this growing industry are seeing new levels of demand for the many different electronic components that go into the average vehicle. According to the Alliance of Automobile Manufacturers, sales of light vehicles in the United States increased by 5.8% in 2014, representing the highest level of sales since 2006.

As a maker of plastic bushings and other components for the automotive industry, igus, Inc., of East Providence, R.I., manufactures Energy Chain cable carriers, Chainflex Motion Cables, DryLin linear bearings and linear guides, iglide plastic bushings, and igubal spherical bearings. Buyer Kevin Perito says he's seeing several trends developing within the auto-related electronic components market right now. For one, he says some connector manufacturers are "more willing to work with you when it comes to keeping up on the increased demand as the automotive industry continues its explosive comeback."

Continued on Page 46

CFO Survey Reveals Manufacturing Optimism

Manufacturing leaders are confident about the economy, as companies remain focused on capital investments, new products, and research and development.

A SURVEY RELEASED this spring showed continued economic optimism among manufacturing executives, as many companies remain focused on business investment in 2015.

Conducted yearly by manufacturing buying group Prime Advantage, the Group CFO Survey polls executives at small and mid-sized manufacturing companies representing more than 25 industries with annual revenues ranging from $20 million to $1 billion.

This year's survey of more than 100 chief financial officers revealed a strong focus on large capital investments in particular, with 96% of respondents saying their companies plan to purchase new manufacturing equipment for their plants in 2015. The reinvestment trend is also related to new products, the researchers said, as 67% of respondents said their companies are planning new products and services in 2015, while 44% said they are boosting research and development efforts. Other key findings include:

Image Courtesy of Thinkstock

Confidence in the economy is high, with 93% of manufacturing CFOs expecting their industries to either remain constant or grow over 2015;

Executives want to help their companies control rising health care costs, with 55% working to implement preventive health-care programs in 2015 (up from 39% in 2014);

Concern about the U.S. budget deficit has declined, while confidence in government has gone up—a change of about 40% from the 2014 survey.

Overall, the survey shows that business leaders pre-

Continued on Page 46

Auto Sector

Continued from Page 45

LEAD TIMES AND COSTS

In assessing order lead times, Perito says that ODU connectors have become harder to procure on set timelines. Accustomed to 8- to 10-week lead times on ODU connectors, Perito says he's now seeing deliveries within 14- to 16-week windows.

"That's happened on our last few connector orders," said Perito, whose firm has been negatively affected by the extended delivery times. "This has put a tremendous strain on our production—to the point where we had no choice but to involve our end customer in the negotiation to [maintain] stock stateside."

Perito says he hasn't seen any notable pricing fluctuations within the electronic component sector.

"As a matter of fact," he explained, "for the most part we've been able to maintain the same cost for the past two years for the connectors we purchase, and that benefits us greatly. It also benefits our customers, who can rely on stable pricing of our products."

According to Perito, one of igus' largest automotive customers is in the process of retrofitting and/or replacing the ReadyChain systems across all of the robotics within the manufacturer's assembly plants. He says this undertaking has greatly increased igus' Harting consumption. "Working closely with Harting, along with distributors Madison Electric and Allied Electronics, has made this increase in demand relatively painless," Perito said.

Going forward, Perito says he sees the automotive market's continued, positive sales momentum as a good sign for the remainder of 2015.

"The explosive 2014 year in automotive sales has led these [auto] companies to invest in upgrades and retrofits," said Perito, adding that the growth could pose challenges for the burgeoning sector's suppliers. "Our key to preventing those challenges is having solid relations among the manufacturers, distributors, and ourselves—a strategy that's worked well for us over the last few years."

SHORING UP THE SUPPLY CHAIN

Joe Venturella, vice president of electronic component distributor TTI Inc.'s Transportation Business Unit in Chicago, says he's seeing more companies moving to "localize products" that are being consumed by their factories.

"They are attempting to flatten the supply chain and have one company move products around the globe with the ultimate destination being the country where they are manufacturing the product," said Venturella. "The key goal of this activity is to have more flexibility for manufacturing without having extended lead times for components."

Venturella says that both product lead times and costs have remained stable over the last few months.

"We aren't seeing a lot of price fluctuations due to the stability of overall raw material costs," said Venturella. "Some key suppliers are using this opportunity to analyze product life cycles and make some price adjustments for lower-volume part numbers that are more mature in the product life cycle."

Pointing to electric vehicles and high-power products as particularly active markets now, Venturella says effective supply-chain management is coming more into play more as suppliers strive to meet the demands of the auto industry.

"The key issue right now is managing the supply chain for electronic components and providing the service and flexibility that customers demand," says Venturella. "Many of our key customers work with very short lead- and manufacturing turnaround time from their customers. In order to make this work, somebody in the supply chain has to have the inventory in place to service this demand." ■

CFO Survey

Continued from Page 45

dict "another impressive year" for small and mid-sized industrial manufacturers, as 90% expect revenues to increase or match 2014, according to the survey. A healthy bank of orders is contributing to the positive outlook.

"Much of this optimism can be attributed to strong order pipelines, with 50% of member companies seeing new orders exceeding the levels they saw at this time last year," the researchers said. "In another encouraging result, 100% of respondents anticipate revenue growth with their key customers over the next three years."

The survey emphasized the greater focus on production this year. In addition to the 96% of firms saying they will purchase manufacturing equipment in 2015, 44% plan to purchase computer hardware and software in the coming year.

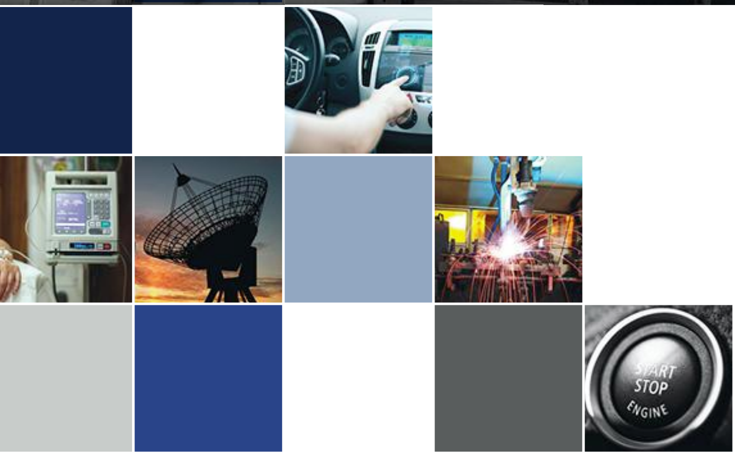
Employment and pricing pressure remain top concerns among small and mid-sized manufacturing executives, with 70% of respondents experiencing difficulty finding capable employees in their markets, due to insufficient levels of skilled employees in their area.

The report echoes optimism among purchasing executives at manufacturing companies worldwide. The *Global Purchasing Index* (*www.globalpurchasing.com*) has remained above the 100-point mark indicating optimism this year after falling below 100 in December 2014. The GPI is a monthly survey of purchasing executives at manufacturing and contract manufacturing companies, gauging their business outlook in five areas: new orders from customers, inventory levels, purchasing activity, pricing, and lead times. ■

CLARIFICATION

As part of our May 2015 Top 50 Electronics Distributors report, sales figures for Future Electronics were not available at press time. Future's estimated sales are $7.7 billion. Go to *www.globalpurchasing.com* for the updated report.


What do you want to build?


START
STOP
ENGINE

Multi-MCU Configuration Provides High-Reliability Temperature Readings

RICARDO JIMENEZ-GARCIA and GERARDO VELASCO-EQUIHUA | INSTITUTO TECNOLÓGICO DE MEXICALI ricardojimenezg@itmexicali.edu.mx

APPLICATIONS SUCH AS healthcare or aerospace systems require high reliability when making basic measurements. By using a microcontroller as the "master" to perform majority-logic voting of measurements performed by three small independent microcontrollers, this circuit design provides a high-reliability thermometer based on triplicated modular redundancy (TMR) (*Fig. 1*). The TMR scheme is able to tolerate the failure of one MCU or associated thermistor sensor to provide a correct temperature reading from 0 to 100°C with a resolution of 0.1°C, while the master MCU will discard the reading of the failed unit.

The reliability of each microcontroller module M is defined as:

$$R(t) = e^{-\lambda t} \quad (1)$$

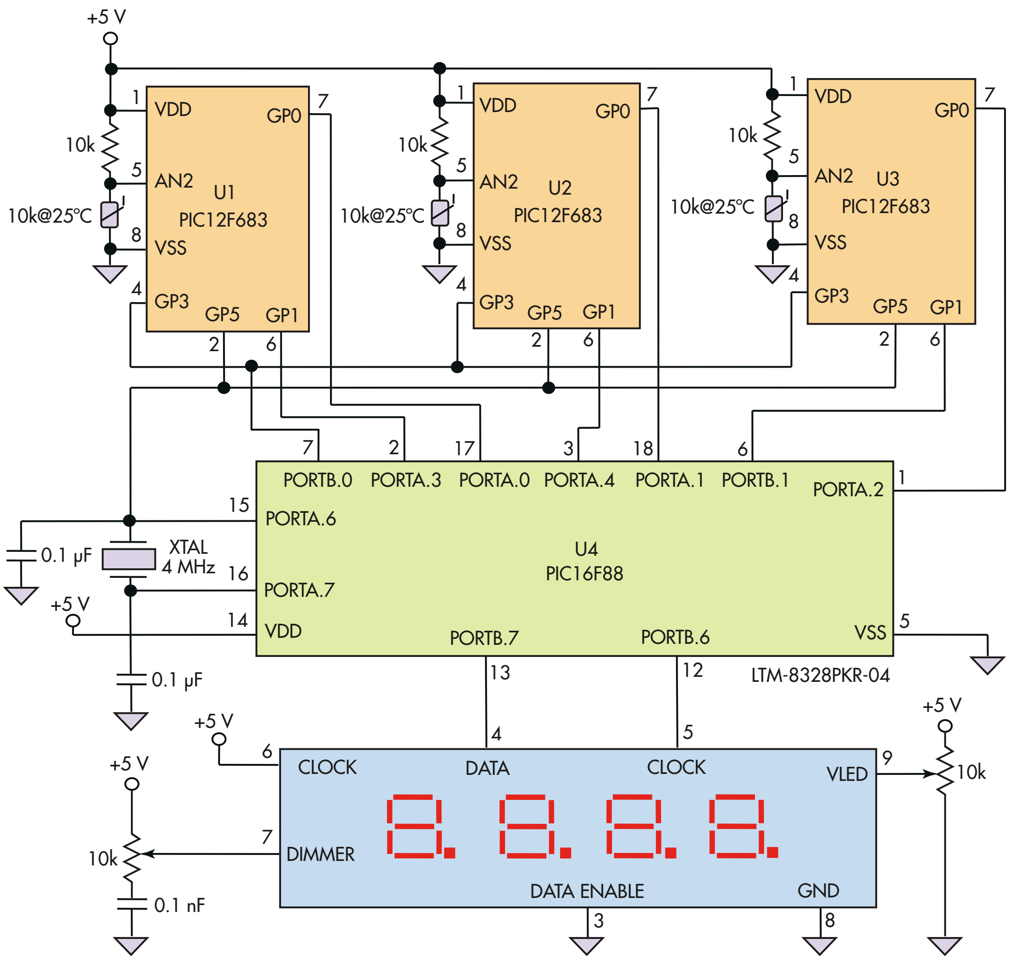
where λ is the failure rate defined by the standard MIL-HBDK-217. Using the Reliability Analytics toolkit[1], you can obtain λ for this specific device. The reliability for each PIC12F683 microcontroller in 1000 hours equals 0.9979 and is given by the formula:

$$R(t) = e^{-2.152t} \quad (2)$$

The reliability for the voting microcontroller is 0.9978 in 1000 hours and is defined by:

$$R(t) = e^{-2.228t} \quad (3)$$

while the total system reliability is given by:



1. A trio of PIC microcontrollers implements a high-reliability thermometer using a trio of microcontrollers and of sensors to deliver independent data to a voting supervisory master PIC unit. The latter then decides if any thermistor reading is invalid; the final temperature reading is based on the approved data values.

DESIGN NOTES

Determine Balancing Current for the LTC3305 Lead-Acid Battery Balancer

Design Note 539

Jim Drew

Introduction

The LTC®3305 is a lead-acid battery balancer that uses an auxiliary battery or an alternative storage cell (AUX) to transfer charge to and from individual batteries within a series-connected stack. The balancer controls external NMOS switches to sequentially connect the auxiliary battery to each battery in the stack. To prevent damage to the NMOS switches and their interconnecting PCB traces, a current limiting device is required. One such device is a ceramic positive temperature coefficient (PTC) thermistor.

The PTC thermistor limits the peak current in the connection between the AUX cell and the battery. For relatively small differential voltages (V_{DIFF}) between the AUX cell and the battery that is connected, the current through the PTC remains low, as does its temperature, and the PTC exhibits the characteristics of a constant value resistor. As V_{DIFF} increases, current increases, and the temperature of the PTC rises. When the temperature of the PTC reaches its Curie point, its resistance increases sharply, as shown in Figure 1. Once the Curie point is reached, current is limited by the resistance of the PTC. In this way, the PTC acts as a constant power device, limiting the pass-through current as the V_{DIFF} increases.

Predicting the balancing current of the LTC3305 involves plotting a current-voltage curve for the total circuit resistance between the AUX cell and the battery that is being balanced. This line is then superimposed on the current-voltage static characteristic curve (Figure 2) for the PTC. The PTC current-voltage characteristic curve can be obtained from the PTC vendor or produced in the lab. The PTC current-voltage characteristic curves can then be used to calculate the current through the battery and the AUX cell, once the total circuit resistance is known.

Predicting the Balancing Current

The total circuit resistance between the AUX cell and the battery consists of the ESR of the AUX cell (ESR_{AUX}), the ESR of the battery (ESR_{BAT}), the $R_{DS(ON)}$ of the MOSFET switches and the PTC resistance (R_{PTC}). When balancing BAT1 and BAT4, there are four series (N_{FET} = 4) MOSFET switches in the circuit, while BAT2 and BAT3 have five series (N_{FET} = 5) MOSFET switches (see the first page of the LTC3305 data sheet). Any interconnection resistances between the batteries and the auxiliary cell can be lumped into the ESR of the respective battery and the AUX cell. This interconnection resistance must include both the positive and negative terminals' interconnection resistances. The expression below is the total resistance (R_{TOTAL}) between the auxiliary cell and the battery, where N_{FET} is the number of series MOSFET switches.

$$R_{TOTAL} = ESR_{AUX} + ESR_{BAT} + R_{PTC} + N_{FET} \bullet R_{DS(ON)}$$

Figure 3 shows R_{TOTAL} superimposed on the I-V characteristic curve of the PTC. The arrow line is the locus of balance currents for various V_{DIFF}. As V_{DIFF} increases, the balancing current increases along the total resistance curve. When the differential voltage produces a balancing current that exceeds the Curie point current, the PTC resistance increases, eventually dominating the total circuit resistance. The Curie point current is referred to as the trip current in the data sheet. With increasing PTC resistance, the balancing current drops sharply, approaching the negative slope of the I-V curve for the PTC.

Eventually, enough charge is transferred between the AUX cell and the battery being balanced and V_{DIFF} begins to drop. As V_{DIFF} decreases, just follow the I-V characteristic the other way. As V_{DIFF} decreases, the balancing current increases as it follows the R_{TOTAL} I-V curve until it reaches the Curie point current. The PTC resistance remains constant at this point, with the balancing current following the R_{TOTAL} line.

Design Example

The example shown here uses a PTC (PTGLASAR-R27M1B51B0) with a trip current of 1.9A and a cold resistance of 0.27Ω. The I-V curve for the PTC, shown in Figure 4, was generated in the lab.

The ESRs of the auxiliary cell and the battery are 100mΩ and 50mΩ, respectively. Four MOSFET switches each have an $R_{DS(ON)}$ of 10mΩ. V_{DIFF} for each battery and the auxiliary cell can be calculated using the following:

$$V_{DIFF} = I_{PTC} \bullet (ESR_{AUX} + ESR_{BAT} + N_{FET} \bullet R_{DS(ON)}) + V_{PTC}$$

Figure 5 shows the current flowing through the system plotted against various values of V_{DIFF} along with the current flowing through the PTC, or the balancing current (I_{BAL}). The system curve is the locus of balancing currents as a function of V_{DIFF}. The differential trip voltage is increased above the PTC trip voltage due to the additional voltage drop across the parasitic resistance within the circuit. As the differential voltage increases, the two curves overlay each other as the R_{PTC} dominates R_{TOTAL}.

When the differential voltage is above the V_{TRIP}, the balance current is lower since the PTC resistance is increasing. For differential voltages below V_{TRIP}, the balance current is the differential voltage divided by the total circuit resistance. A battery voltage of 12.5V and an auxiliary cell voltage of 12.0V produces a balancing current of 1.12A, which agrees with the I-V curve of Figure 5.

Conclusion

The LTC3305 balances the voltage across a series stack of lead-acid batteries and an auxiliary storage cell. Balancing currents can be controlled with the use of a ceramic PTC thermistor. Using the trip current and cold resistance parameters specified for the PTC thermistor along with the other balancing circuit parasitic resistances, the balancing currents can be predicted for various differential voltages between the batteries and the auxiliary cells.

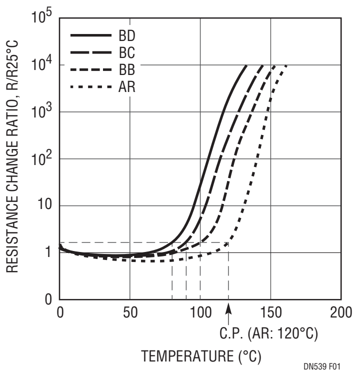


Figure 1. Resistance-Temperature Characteristic of Murata PTCs

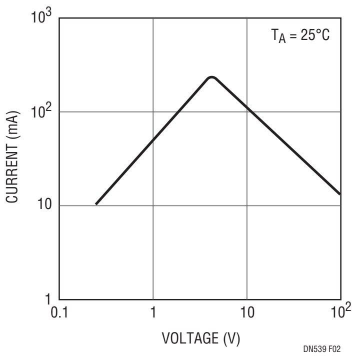


Figure 2. PTC Current-Voltage Characteristic Curve

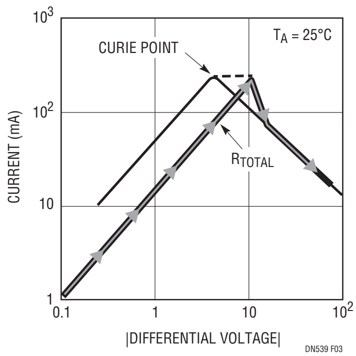


Figure 3. R_{TOTAL} Superimposed on PTC Characteristic Curve

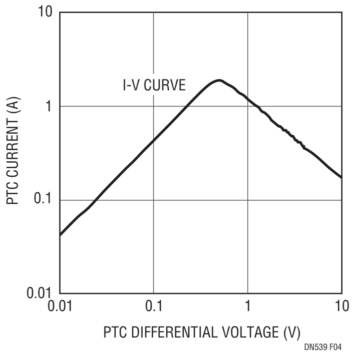


Figure 4. Design Example PTC I-V Characteristic Curve

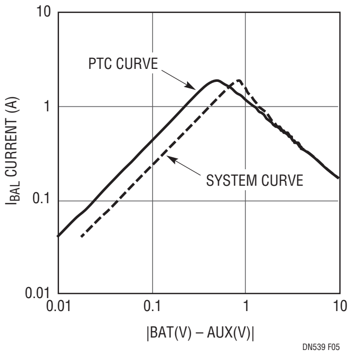


Figure 5. System I-V Characteristic Curve. System Curve to V_{DIFF} and PTC Curve to V_{PTC}

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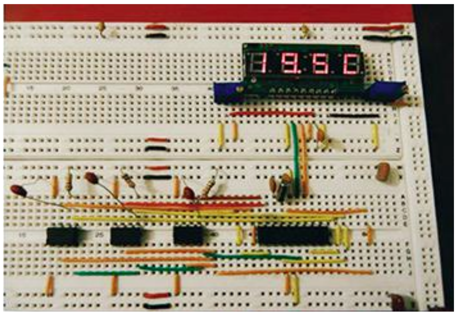


2. The circuit requires very few passive components and has no critical circuit paths, as seen in this breadboard construction. The three thermistor-interface microcontrollers and the master microcontroller are located at the bottom (left to right) and the four-digit LED display is at the top, here indicating 19.5°C.

$$R_{M\_of\_N} = \sum_{i=m}^{N} \binom{N}{i} R^{i}(t)[1 - R(t)]^{N-i} \quad (4)$$

where N is the number of modules, and M is the number of modules required for the system to survive (in this case, equal to 2). Therefore, total system reliability is defined by:

$$R_{TMR} = e^{-2.228t}(3e^{-4.304t} - 2e^{-6.456t}) \quad (5)$$

To get the most accurate temperature measurements using three equal but independent thermistors, use the Steinhart-Hart equation:[2]

$$\frac{1}{t} = a + b \ln(R) + c\,(\ln(R))^3 \quad (6)$$

Each PIC12F683 MCU (U1, U2, U3) reads a temperature with its own thermistor and solves the Steinhart-Hart equation *(see the online version of the article for "Listing 1")*. All four microcontrollers are synchronized with an external 4-MHz crystal connected to master microcontroller U4 (PIC16F88).

A program for the majority voting *(see "Listing 2" in the online article)* serially receives the temperature data from each slave U1, U2, U3 (PIC12F683). The Steinhart-Hart algorithm was adapted for the PIC12F683 PICs, which use software-based serial communications to send the temperature data to the master microcontroller.

When the program starts, it will not run until GPIO.3 goes to logic 1. After meeting this condition, it will begin computing the temperature. When the process is complete, GPIO.1 will go to logic 1, and a small pause is inserted to start the transmission, which places the value of each bit of the variable that stores the temperature reading on GPIO.0. When finished, GPIO.1 goes to logic 0 for 725 ms to allow the voter to perform its process and display the data on the display. The program then will go to the main label.

The Voting microcontroller starts by setting PORTB.0 = 1, and this pulse starts the individual modules. Then, if PORTA.3, and PORTA.4, and PORTA.1 are equal to logic 1, it will start with the instructions. Each module generates this pulse before starting the transmission. When this condition is met for the serial input, the Voter continues with the instructions by reading the different ports on which the data enters, and stores it in different variable BITs. These will be the bits of the variable WORD where the final temperature will be stored. Once the serial communication is finished, the Voter proceeds to perform the following operations:

$$\begin{aligned} t1 - t2 &= c1 \\ t2 - t3 &= c2 \quad (7) \\ t3 - t1 &= c3 \end{aligned}$$

where c1, c2, and c3 represent the difference among the temperature readings. The instruction ABS is used to get the absolute values of these differences. The smallest difference between two temperatures means that these are the most precise readings, which are then averaged and displayed (*Fig. 2*). The module that provides a major difference will be discarded, and the display (Lite-On LTM-8328PKR-04) will indicate which module has failed.

When choosing what temperatures should be averaged, a process is followed to make sure that their difference is the smallest one. Then the instruction DIG stores each decimal digit of the temperature, and the instruction LOOKUP makes the conversion to a seven-segment format. The formatted data will be serially transmitted and synchronized with a clock signal generated by the microcontroller. A redundant 5-V dc power supply is recommended to ensure high reliability in this design.

REFERENCES:

1. Reliability Analytics Toolkit (http://reliabilityanalyticstoolkit.appspot.com/exponential_distribution).
2. R. Jimenez and R. Solorio, "Microcontroller Solves Complex Polynomial Temperature Equations," Electronic Design, December 5, 2013.

RICARDO JIMENEZ-GARCIA holds a Master's in electronics from Instituto Tecnológico de Mexicali (ITM), (Mexicali, BC, Mexico) and an electronics engineering degree from Instituto Tecnológico de Durango (Durango, Mexico). He is an adjunct professor at Imperial Valley College, Imperial, Calif., and at ITT Tech, Vista, Calif. He can be reached at ricardojimenezg@itmexicali.edu.mx.

GERARDO VELASCO-EQUIHUA is a student in electronics engineering at ITM.

Simple Tester Provides Readout of Crystal Frequency

J. B. CASTRO-MIGUENS | Cesinel Co., cmiguens@uvigo.es **C. CASTRO-MIGUENS** | Electronics Engineering Services, Vigo University, Spain

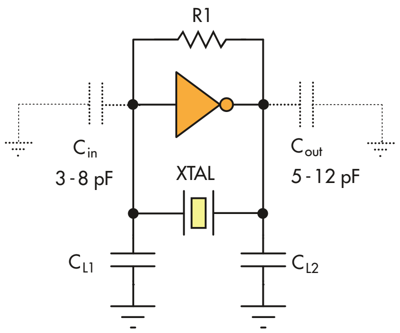
ALTHOUGH OSCILLATORS ARE critical components in most electronic devices, designers needn't design oscillators themselves in most cases, because the device contains a great deal of the oscillator circuitry. Instead, they only have to select the crystal and external capacitors needed for the oscillator function. If an incorrect crystal or external capacitors are selected, it can lead to a device that doesn't operate properly, fails prematurely, or will not operate over the intended temperature range.

Quartz crystals have parallel and series modes of resonance, and an oscillator circuit is calibrated for one mode or the other, but not both. The common Pierce-gate oscillator (*Fig. 1*) uses a parallel crystal mode. Here, the crystal is specified by the frequency and the load capacitance (C_L), which is the capacitance that the crystal needs to see to oscillate at the desired frequency. Phase-locked loops (PLLs) are commonly used to obtain inexpensive, high-frequency clock signals from low-frequency signals generated by oscillator circuits like the one shown, which mitigates the use of very-high-frequency crystals.

Designers must select the value of capacitors C_{L1} and C_{L2} to match the specified crystal load capacitance (C_L). The most common mistake is to assume that the value of C_{L1} and C_{L2} in parallel is equal to the value of the C_L, which isn't accurate. This is because most designers neglect the internal input and output capacitances of the inverter gate (see C_{IN} and C_{OUT}) and some other parasitic capacitances. These capacitances are significant in value compared to the external ones (C_{L1} and C_{L2}). Therefore, designers must calculate values C_{L1} and C_{L2} to match the C_L, as specified by the manufacturer, by using Equation 1:

$$\frac{(C_{L1}+C_{in})(C_{L2}+C_{out})}{C_{L1}+C_{in}+C_{L2}+C_{out}} + C_{stray} = C_L \quad (1)$$

If C_{IN} and C_{OUT} aren't specified, then assume each to be 5 pF and C_{STRAY} to be 3 pF, as a starting-point rule of thumb. The oscillator circuit must be optimized by changing the starting values of C_{L1} and C_{L2} to get a total capacitance equal to C_L specified by the crystal manufacturer. A trimmer capacitor can be substituted for C_{L1} and/or C_{L2} in order to manually tune their value. (Make sure that you use ceramic capacitors with a low temperature coefficient, either COG or NP0 types, for C_{L1} and C_{L2}, and avoid capacitors that are made from Z5U material.)



1. The Pierce-gate oscillator, which uses the parallel-resonance mode, is among the most common crystal-oscillator topologies. Any useful model of the circuit must take into account the gate and other parasitic capacitances.

Figure 2 shows the schematic of a circuit that provides the frequency (in megahertz) of a crystal connected to terminals X1 and X2. That circuit uses a Pierce-gate oscillator configured for parallel resonance (U1). Its output goes through an unbuffered inverter (U3), to a series of four-bit synchronous counters (U4, U5, U6) functioning as a frequency divider, and then to a frequency-to-voltage converter (U7), to generate a voltage proportional to the signal frequency as generated by the oscillator. This voltage is digitized by the 3 1/2-digit analog-to-digital converter with internal seven-segment drivers (U8) to display the frequency of the crystal via a two-digit LED readout.

The user needs to make two adjustments to the circuit before it can be used:

- Adjust potentiometer POT2 to obtain $V_{REF} = V_{REF\ Hi} - V_{REF\ Lo} = 0.1$ V
- Adjust potentiometer POT1 to obtain the voltage V_{AUX} a little higher than 10 α mV for a crystal of f_{OSC} = α MHz. Thus, for a crystal of f_{OSC} = 4 MHz, voltage V_{AUX} must be approximately 42 mV.

After making the adjustments, calculate the value of the capacitors C_{L1} and C_{L2} to measure the frequency of a crystal, using Equation 1; assume that C_{IN} and C_{OUT} each equal 7 pF, C_{STRAY} is approximately 3 pF, and $C_{L1} = C_{L2}$.

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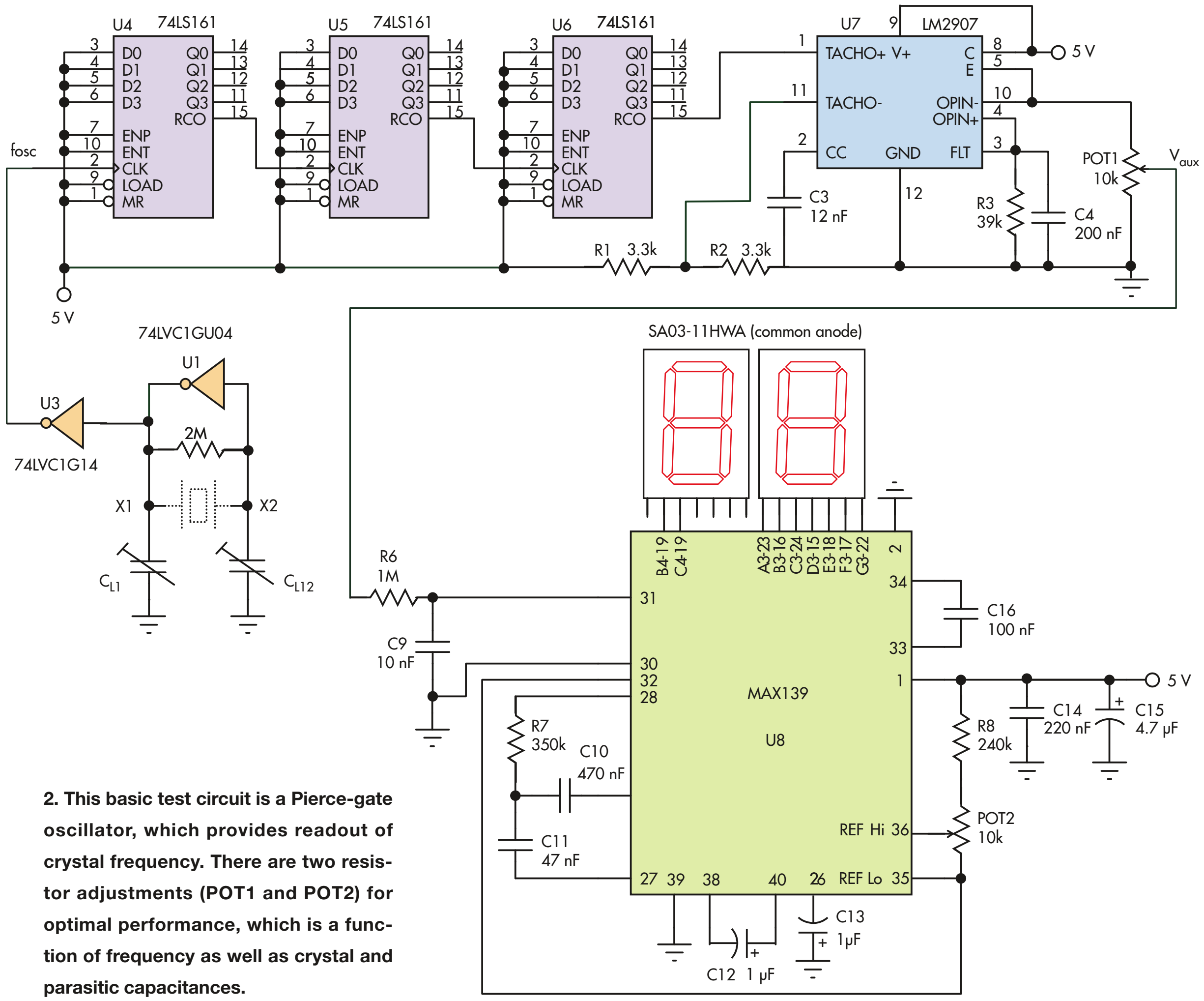

2. This basic test circuit is a Pierce-gate oscillator, which provides readout of crystal frequency. There are two resistor adjustments (POT1 and POT2) for optimal performance, which is a function of frequency as well as crystal and parasitic capacitances.

JOSE B. CASTRO-MIGUENS, design engineer at Cesinel Co. for power electronics, instrumentation engineering, signal processing, and electric power control, received an electrical and electronic engineering degree from UPCO University, Madrid, Spain. He can be reached at cmiguens@uvigo.es.

CARLOS CASTRO-MIGUENS, associate professor in the Electronics Department at Vigo University, Spain, received an electronic engineering degree from Vigo University. His primary research interests are in power electronics (dynamic modelling and control of power converters, design of magnetic components for powerconverters) and design of embedded systems.

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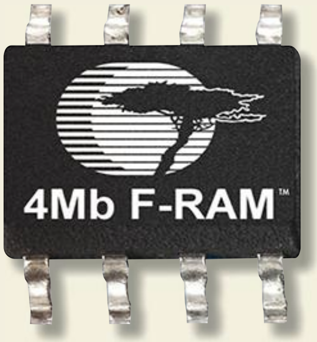

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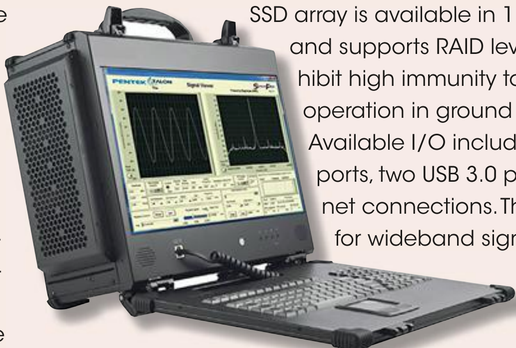

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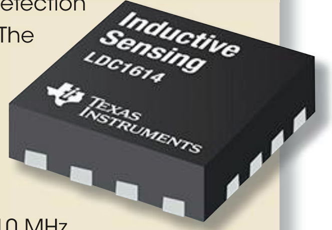

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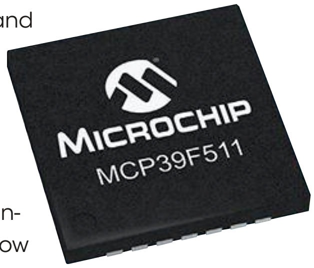

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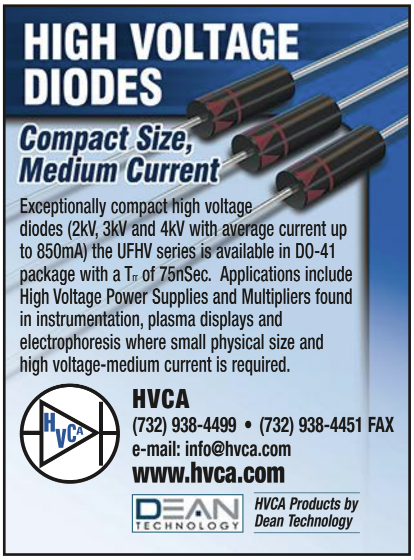

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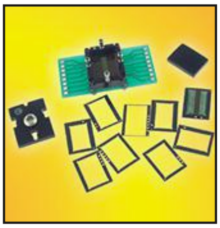

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Microsoft's Windows 10 will be the platform for Visual Studio 2015.

"To dream the impossible dream" when it comes to software is the concept of a universal programming language/environment/runtime that runs on any hardware. Of course, embedded developers know that attaining that goal is a lot harder than it looks. Just getting something to look good on two different-size displays is hard enough, let alone supporting multiple input devices, different power management schemes, a variety of connectivity mechanisms, and so on.

Oracle's Java originally touted the "write once, run everywhere" ideal. Java has been successful running across a wide variety of platforms, but it is still a "write once, run almost everywhere, otherwise customize" solution. The Java virtual machine (JVM) made running the code on another platform easier, but it does not address details like user interface or device support.

Even C was designed to provide a level of portability, but system interfaces are the bane of developers. Frameworks like Qt (pronounced "cute") provide a degree of display portability by providing the same API to developers while hiding the underlying operating system specifics. The graphics support allows an application to work on many different platforms, but there are challenges when providing controls to handle touch support because of differences in size and convention between platforms like PCs, tablets, and smartphones.

I was reminded of this challenge while working with Microsoft's Visual Studio 2015 and the company's new Universal App framework. The goal is to have an app in the Windows Store that would work across the Microsoft operating systems from phone to tablets to desktops. This is not the first time Microsoft has pushed portable application development. Its Common Language Infrastructure (CLI), C# and .NET provide portability similar to Java.

The Universal App framework builds on this and preserves common code within a project that is designed to be the bulk of an application with additional platform-specific code to address different platforms like smartphones and tablets (*see figure*). Shared Projects within Visual Studio allow developers to create contextually appropriate user interfaces for the target platforms. This approach allows projects to target a platform while sharing code with other related projects.

Visual Studio targets Microsoft Windows platforms including the forthcoming Windows 10. By adding the Xamarin plugin, Visual Studio projects can target Android and iOS platforms as well. Xamarin maintains Mono, an open-source implementation of CLI that runs C# applications.

Creating a Universal App for targets with different capabilities requires customization.
(Michael Crump, Telerik)

Using Visual Studio Tools for Apache Cordova is another way to enhance cross-platform support. Cordova supports Android, iOS 6, 7 and 8, Windows Phone 8.x and Windows 8.x. It is also designed to build native applications using HTML, CSS, and JavaScript.

Of course, Visual Studio can also package apps for the Windows Store and can upload the packages for multiple targets.

Designers still need to consider all targets and take into account their advantages and limitations. At least with Visual Studio 2015, the job is easier to manage. ed

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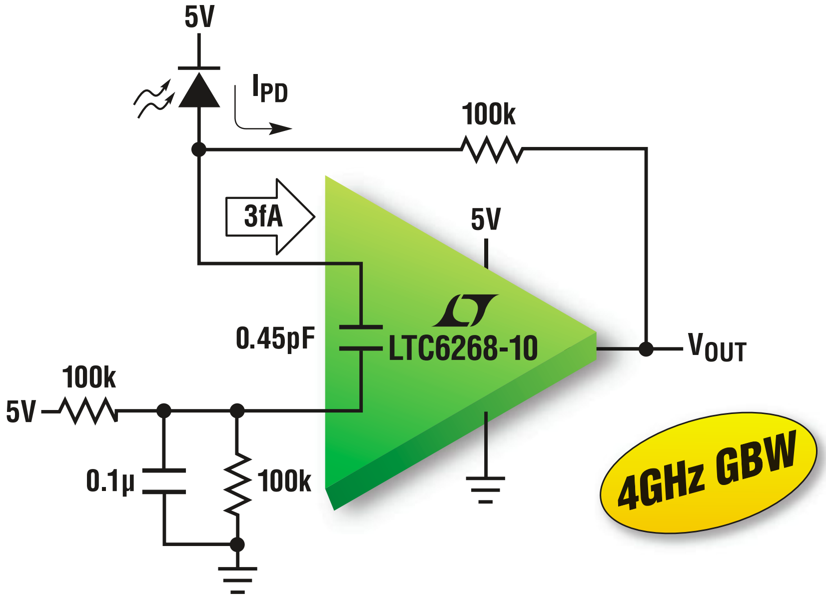

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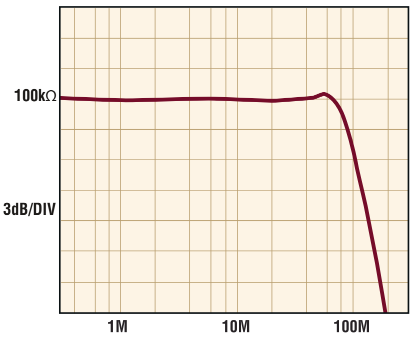

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