electronic design

THE AUTHORITY ON
EMERGING TECHNOLOGIES
FOR DESIGN SOLUTIONS

April 2016 electronicdesign.com

Turning Cars into Supercomputers

p|16

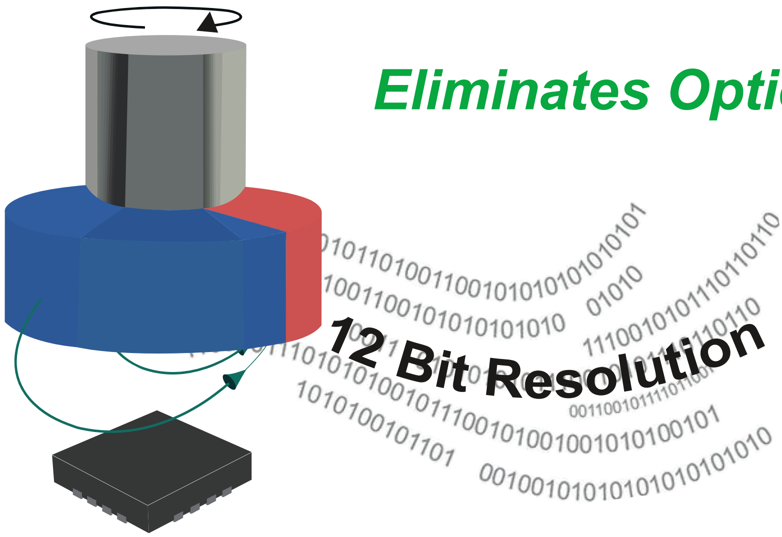
$10.00 Powered by Penton

MPS®
Simple, Easy Solutions

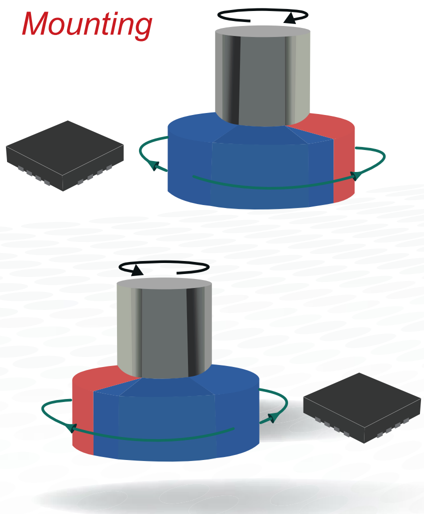
High Accuracy, High Speed Position Sensors!

MagAlpha Series

Eliminates Optical Encoders!



Flexible Mounting



MagAlpha MA300 Features

- UVW Signals for Block Commutation
- 12-Bit Resolution Absolute Angle Encoder
- 500kHz Refresh Rate
- Ultra-Low Latency: 3μs
- Serial Interface for Data Readout and Settings
- 10-Bit Incremental Output (A, B, Z)
- Built-In Linearization for Side-Shaft Mounting
- 7.5mA Supply Current

www.monolithicpower.com

Follow us on:

Powerful, Versatile and Affordable...

100 kHz Dynamic Signal Analyzer

- ***DC to 100 kHz frequency range***
- ***100 kHz real-time bandwidth***
- ***Dynamic range***
  - ***90 dB (FFT)***
  - ***145 dB (swept-sine)***
- ***Low-distortion (–80 dBc) source***
- ***Up to 32 Mbyte memory***
- ***GPIB and RS-232 interfaces***

FFT analyzers starting at $4950

The SR785 Dynamic Signal Analyzer offers state-of-art performance at a fraction of the cost of competitive analyzers. Standard features include swept-sine mode, order tracking, octave analysis, curve fit/synthesis, and arbitrary waveform source.

When compared to the Agilent 35670A, the SR785 comes out on top. It offers twice the frequency range (2 ch.) and 10 times the real-time bandwidth at less than half the price of the 35670A.

The SR785 is ideal for filter design, control systems analysis, noise measurement, audio or acoustical test, and mechanical systems analysis.

Take a close look at the SR785.

SRS **Stanford Research Systems**
1290-D Reamwood Ave., Sunnyvale, CA 94089 • e-mail: info@thinkSRS.com
Phone (408) 744-9040 • Fax (408) 744-9049 • **www.thinkSRS.com**

electronic design

InThisIssue

FEATURES

16

22

26

32

NEWS & ANALYSIS

IDEAS FOR DESIGN

COLUMNS & DEPARTMENTS

abm The Association of Business Information & Media Companies

BPA WORLDWIDE BUSINESS

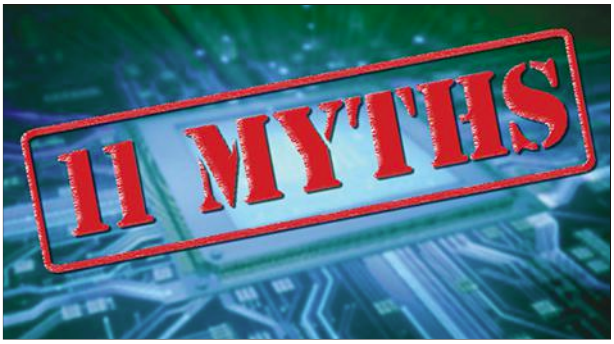
THE 2008 EDDIE & OZZIE AWARDS 2008 Winner GOLD EXCELLENCE IN MAGAZINE DESIGN

ASBPE American Society of Business Publication Editors 2008 Winner SILVER EDITORIAL AWARD OF EXCELLENCE

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

ELECTRONIC DESIGN (ISSN 0013-4872) is published monthly by Penton Media Inc., 9800 Metcalf Ave., Overland Park, KS 66212-2216. Paid rates for a one-year subscription are as follows: $120 U.S., $180 Canada, $240 International. Periodicals postage paid at Kansas City, MO, and additional mailing offices. Editorial and advertising addresses: ELECTRONIC DESIGN, 1166 Avenue of the Americas, New York, NY 10036. Telephone (212) 204-4200. Printed in U.S.A. Title registered in U.S. Patent Office. For subscriber services or to order single copies, write to Electronic Design, PO Box 2100, Skokie, IL 60076. POSTMASTER: Send change of address to Electronic Design, PO Box 2100, Skokie, IL 60076. Canadian Post Publications Mail agreement No. 40612608. Canada return address: IMEX Global Solutions, P.O. Box 25542, London, ON N6C 6B2.

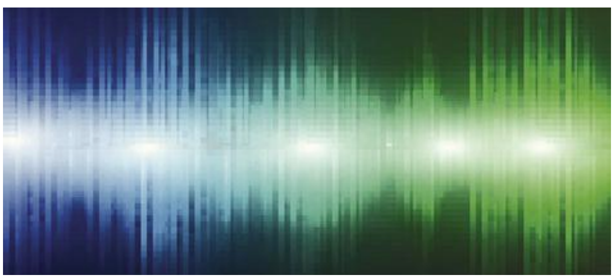
on electronicdesign.com



11 MYTHS ABOUT USING AN RTOS IN IOT DEVICES

http://electronicdesign.com/embedded/11-myths-about-using-rtos-iot-devices

Express Logic's William E. Lamie reveals and debunks the 11 myths embedded-systems engineers "hold true" about using (or not using) RTOS in development projects.



WIRELESS 101: BASIC PHYSICS OF RADIO

http://electronicdesign.com/blog/wireless-101-basic-physics-radio

With all the wireless design activity going on these days, it makes Tech Editor Lou Frenzel wonder just how many engineers are actually educated in wireless principles anymore. Not many, he suspects, noting, "From what I have seen of EE education, the curricula are still based on classical circuit theory, basic devices, some linear, and a massive dose of digital, along with microcontrollers and related software programming. No radio theory." Here, he takes a look at some of the basics of how wireless actually works.

join us online

Follow us on Facebook: http://tinyurl.com/odzo6hc
and Twitter: http://tinyurl.com/k5pum39

Q&A: JAMES R. BIARD, GaAS INFRARED LED INVENTOR

http://electronicdesign.com/power/qa-james-r-biard-gaas-infrared-led-inventor

Dr. James R. "Bob" Biard is an American electrical engineer and inventor who holds 72 U.S. patents, including the GaAs infrared light-emitting diode (LED), the optical isolator, the Schottky transistor, and Metal Oxide Semiconductor Read Only Memory (MOS ROM). This year marks 55 years since Dr. Biard and Gary Pittman first observed light emission from a GaAs LED at Texas Instruments (TI) in Dallas. Recently he spoke with Technology Editor Maria Guerra, sharing his memories and thoughts on a number of topics.

GM BUYS CRUISE AUTOMATION IN SELF-DRIVING PUSH

http://electronicdesign.com/iot/gm-greases-wheels-self-driving-plans

As part of its aggressive plans to develop fully autonomous vehicles, General Motors has agreed to purchase Cruise Automation, a startup company that develops software for self-driving cars. The deal represents GM's latest push to include more automated features in vehicles, reducing the role of humans behind the wheel. Find out more about this industry-changing move.

Actual size of Keysight E36104A DC Power Supply

Small footprint, big performance.

These compact (2U, ¼ rack) power supplies bring a powerful punch to your bench. Packed full of features, the five models offer 30 to 40 W and up to 5 A or 100 V of reliable power. Whatever the task, with the E36100 Series DC Power Supplies you'll have everything you need to power DUTs quietly, safely and accurately.

- Intuitive on-screen menus
- LAN and USB connectivity
- Low current measurements

See the E36100 Series videos, datasheet and more at: www.keysight.com/find/BenchPowerUS

Buy from an Authorized Distributor:

microlease Newark element14 TESTEQUITY

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Agilent's Electronic Measurement Group is now **Keysight Technologies.**

electronic design
Powered by Penton
APRIL 2016

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
DISTRIBUTION: **VICTORIA FRAZA KICKHAM** SourceESBeditor@penton.com
EMBEDDED/SYSTEMS/SOFTWARE: **WILLIAM WONG** bill.wong@penton.com
ANALOG/POWER: **MARIA GUERRA** maria.guerra@penton.com
ASSOCIATE CONTENT PRODUCER: **LEAH SCULLY** leah.scully@penton.com
ASSOCIATE CONTENT PRODUCER: **JAMES MORRA** james.morra@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: **FRAN VAUGHN** fran.vaughn@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: **GREGORY MONTGOMERY** **T** | 480.254.5540 gregory.montgomery@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 paul.milnamow@penton.com
CT, DE, FL, GA, MA, MD, ME, NC, NH, NJ, NY, RI, PA, SC, VA, VT, WV, EASTERN CANADA: **SHANNON ALO-MENDOSA** **T** | 978.501.7303 Shannon.alo-mendosa@penton.com

INTERNATIONAL SALES

GERMANY, AUSTRIA, SWITZERLAND: **CHRISTIAN HOELSCHER** **T** | 011.49.89.95002778 christian.hoelscher@husonmedia.com
BELGIUM, NETHERLANDS, LUXEMBURG UNITED KINGDOM, SCANDINAVIA, FRANCE, SPAIN, PORTUGAL: **JAMES RHOADES-BROWN** **T** | +011 44 1932 564999 **M** | +011 44 1932 564998 james.rhoadesbrown@husonmedia.com
PAN-ASIA: **HELEN LAI** **T** | 886 2-2727 7799 helen@twoway-com.com
PLEASE SEND INSERTION ORDERS TO: orders@penton.com
PENTON REPRINTS: **WRIGHT'S MEDIA** **T** | 877.652.5295 penton@wrightsmedia.com
CIRCULATION: **CUSTOMER SERVICE** **T** | 866.505.7173 **F** | 847.763.9673 electronicdesign@halldata.com

LIST RENTALS:
SMARTREACH CLIENT SERVICES MANAGER: **DAVID SICKLES** **T** | (212) 204 4379 david.sickles@penton.com

ONLINE

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

DESIGN ENGINEERING & SOURCING GROUP

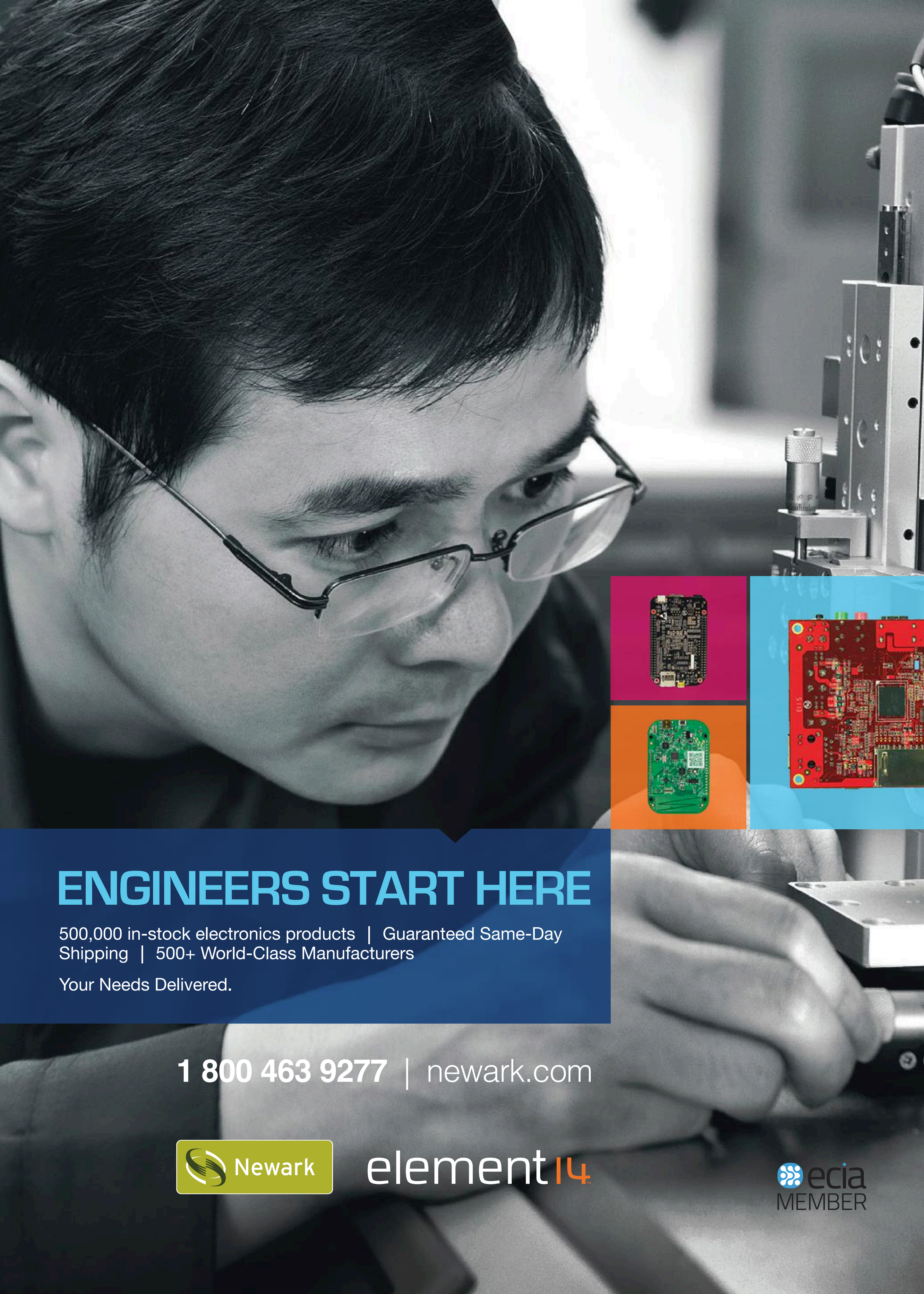
EXECUTIVE DIRECTOR OF CONTENT AND USER ENGAGEMENT: **NANCY K. FRIEDRICH**
GROUP DIRECTOR OF OPERATIONS: **CHRISTINA CAVANO**
GROUP DIRECTOR OF MARKETING: **JANE COOPER**

PENTON

CHIEF EXECUTIVE OFFICER: **DAVID KIESELSTEIN** david.kieselstein@penton.com
CHIEF FINANCIAL OFFICER: **NICOLA ALLAIS** nicola.allais@penton.com
INDUSTRY GROUP, PRESIDENT: **PAUL MILLER** paul.miller@penton.com
1166 AVENUE OF THE AMERICAS, 10TH FLOOR
NEW YORK, NY 10036 **T** | 212.204.4200

Penton

Electronic Design | Machine Design | Microwaves & RF | Medical Design | Source ESB | Hydraulics & Pneumatics | Global Purchasing | Distribution Resource | Power Electronics | Defense Electronics | Electronic Design Europe | Engineering TV


ENGINEERS START HERE
500,000 in-stock electronics products | Guaranteed Same-Day Shipping | 500+ World-Class Manufacturers
Your Needs Delivered.
1 800 463 9277 | newark.com
Newark
element14
ecia MEMBER

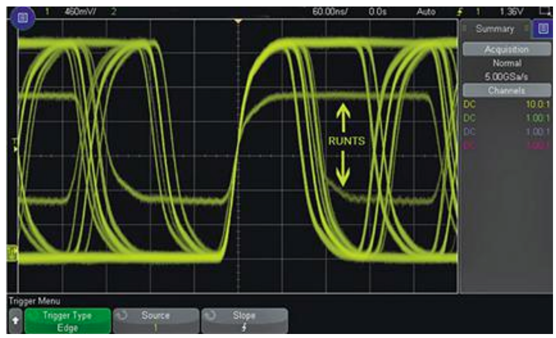
BILL WONG | Embedded/Systems/Software Editor
bill.wong@penton.com

Taking Advantage of Zone Triggering

Zone triggering is a feature found in high-end, high-speed oscilloscopes that has been available for a few years, and that many developers may not be aware of. It goes way beyond the conventional edge- or threshold-triggered approaches available on all scopes. It makes capture of infrequent anomalies much easier, especially for complex signals.

Zone triggering is easier to do with today's touchscreen interfaces. Dragging a box around a signal is a quick way to block out desired region of interest. Some products allow different types of region and region construction. They can often be combined with other triggers, which is typical for more conventional triggering methods.

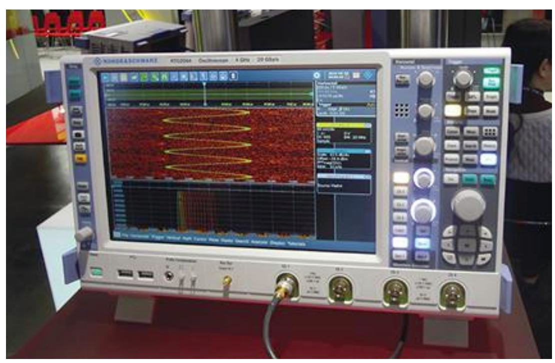
Johnnie Hancock, product manager at Keysight Technologies' Oscilloscope Products Division, has a detailed write-up of the technology (*see "Zone Triggering Demystifies Scope Glitches" on electronicdesign.com*). One example presented is the "runt trigger" designed to capture a signal that does not reach an intended high or low logic level (*Fig. 1*).



1. Zone triggering is useful in catching runts, or out-of-spec signals. *(Keysight Technologies)*

Runt and zone triggering are typically easier to set up than more complex parametric trigger modes, although they are also useful, because of the graphical interfaces now available with oscilloscopes. Using a touch interface or a mouse to select regions is fast and more intuitive.

Zone triggering is available in Rohde & Schwarz's RTO2000 oscilloscope (*Fig. 2*) that I saw recently at Embedded World 2016 (*see "Checking Out Embedded World 2016" on electronicdesign.com*). One neat thing about the RTO2000 is that this feature also operates in the frequency domain, allowing it to trigger when a signal's frequency moves into or out of a zone.



2. Rohde & Schwarz's RTO2000 oscilloscope can use zone triggering within the frequency domain.

It is not easy staying abreast of the latest features, but it is worth the effort when they can significantly simplify development and diagnostic chores. Zone triggering is one of those features. It takes a fast scope with a sufficient update rate to catch infrequent signal anomalies, but at least zone triggering will make it possible to catch those glitches.

News

Auto Companies Speed Toward DIGITAL, WIRELESS SERVICES

It's widely apparent that the future of the automobile industry is being built inside foundries and software programs—not inside parts factories. Computer processors, image sensors, and wireless chips are being combined in vehicles to provide wireless internet access, automated highway driving, and safety features like blind spot warnings and collision avoidance.

New technologies are creeping into cars from all sides—image sensors from Sony, graphics chips from Nvidia, processors from Intel, artificial intelligence from Google and Tesla—but at the heart of recent advances are wireless networks. Connectivity has not only enabled drivers to access their smartphones on dashboard displays, but also cleared the way for vehicles to communicate with each other and infrastructure.

This shift toward connectivity has been underlined at many of the largest technology events this year. Mary T. Barra, chief executive of General Motors, and Herbert Diess, chief executive of Volkswagen, both gave keynotes at the 2016 Consumer Electronics Show (CES) in January. Mark Fields, chief executive of Ford, delivered a keynote address at Mobile World Congress (MWC) in Barcelona last month.

During his keynote, Fields emphasized that Ford was adopting more of a "mobility" focus. In addition to plans to expand its car-sharing services in Europe, he also said that Ford would triple its engineering staff at its autonomous vehicle research center in Silicon Valley. These measures are meant to counteract pressure from ride-hailing companies like Uber and Lyft. Apple and Google have also placed pressure on auto companies, plugging their software—CarPlay and Android Auto, respectively—into dashboard displays.

All signs are pointing to a future of connected cars. The research firm IHS Automotive expects that, in 2022, nearly 98% of all cars sold around the world will be connected to the Internet. In 2015, only around 30% were connected. Another research firm, McKinsey & Company, has said that 37% of

consumers would change cars if another company offered connectivity features.

That future depends on the collective efforts of several different industries. That has not been clearer than over the last few weeks when wireless, automotive, and electronics companies have signed agreements to accelerate the process. Here are the latest announcements underlining the multi-pronged approach that companies are taking with connected cars:

LG AND INTEL TEAM UP ON TELEMATICS

LG Electronics recently announced that it would work with Intel to develop a new telematics platform. The new technology could enable services including GPS tracking, hands-free calling, and wireless Internet access for vehicles. The new technology will be designed to work with Fifth-Generation (5G) wireless technology. LG already supplies telematics technology to General Motors' OnStar system, which runs on 4G networks.

AT&T SUPPLIES WIRELESS TO PORSCHE AND AUDI

AT&T reached an agreement to connect Porsche vehicles to its Fourth-Generation (4G) wireless network. Starting in 2017, the wireless carrier will support Porsche's Connect Plus service, which includes a Wi-Fi hotspot, navigation system, and news and weather updates sent directly to the dashboard.

AT&T also extended an agreement with Audi, lending support to the auto company's telematics platform, Audi connect. The agreement lasts through 2018. Using the AT&T network, Audi plans to introduce new safety, security, and entertainment features, such as remote locking and unlocking and online roadside assistance.

VOLVO TAKES KEYS OUT OF THE EQUATION

At this point, car keys have largely been replaced by wireless key fobs—and in some cases, ignition keys have been replaced with push-button starts. Now, Volvo is taking keys out of the equation entirely. The company announced that, starting in 2017, it will give customers the option to buy cars without keys. Instead, owners would use Volvo's smartphone app to unlock their cars.

Volvo will pilot the keyless feature with its car-sharing service "Sunfleet" over the next few months. That service, which works on a similar concept as ZipCar in the United States, operates about 1,000 cars at 50 locations around Sweden. The keyless option will be available in commercial models in 2017.

KUGA AND SMART MOBILITY PLANS AT FORD

Ford launched the new Kuga S.U.V. and announced plans to bring its Sync 3 connectivity technology to Europe. In a statement about the new Kuga, Ford stressed that it would have wireless internet access and automated features, including hands-free parking, collision avoidance, and headlights that adapted to light conditions.

The company also said that it would further expand Smart Mobility, the company's initiative surrounding autonomous vehicles, big data, and connectivity. Among its other experiments into "transportation services," it has started testing a system in London that directs drivers to streets where they are most likely to find parking. Ford also said that it would test car-sharing businesses in England and Germany.

NOKIA TESTS 5G VEHICLE TECHNOLOGY

Nokia recently displayed an early version of 5G radio access technology in a commercial base station—part of its plan to install preliminary 5G networks in 2017. In an attempt to tests its advanced features, the company piloted its technology with test cars on the Autobahn highway in Germany. Using Deutsche Telekom's 4G network, the cars were able to share location information between each other.

Sharing information between vehicles quickly is central to systems that help prevent accidents and enable automated safety features. Deutsche Telekom's base stations were upgraded with wireless modules (also known as cloudlets), which ensure that data is directly routed through the cell rather than the cloud, reducing latency to under 20 milliseconds.

SAMSUNG DONGLE CONNECTS UNCONNECTED CARS

Samsung recently revealed its Connect Auto dongle, which brings 4G networks to older cars by plugging into the vehicle's on-board diagnostic port. Most vehicles built in the last two decades have this port and with the dongle they can send real-time diagnostic information and even automatic updates to contacts in case of an accident. The dongle also functions as Wi-Fi hotspot. It will be available later this year, and AT&T will be the first carrier to offer it in the United States.

QUALCOMM'S SELF-DRIVING CONCEPT

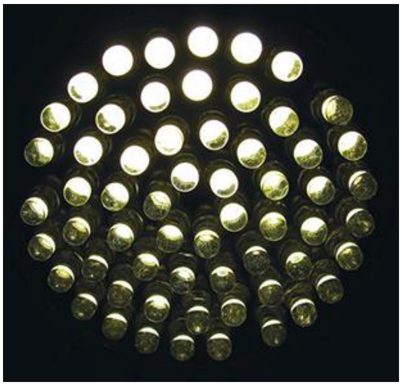
Qualcomm, which supplies processors and modem chips for smartphones, has been working with Mercedes-Benz on its futuristic self-driving prototype—the 2016 Mercedes F015. Underling its efforts to put more wireless components into cars, Derek Aberle, Qualcomm's president, appeared on a panel with Lewis Hamilton, the driver for Mercedes AMG Petronas racing team, at last month's Mobile World Congress. Qualcomm has worked with the team over the last year to install Wi-Fi systems that download diagnostic information during practice runs.

"Today the car already has certain kinds of connectivity," Aberle said in his introduction to the panel. "LTE is already enabling connections to the cloud from the vehicle. And also within cars things like Bluetooth allow you interact with devices in the car. But in the future the car's going to be connected to everything…The car itself will become a mobile platform." ■

LI-FI Leaves the Laboratory

WITH NEWLY DEVELOPED technology, accessing wireless networks nearly 100 times faster than Wi-Fi could be as simple as switching on a light bulb. That technology, known as Li-Fi or light fidelity, involves encoding data into visible light instead of the radio waves used by traditional wireless technology like Wi-Fi.

Though Li-Fi has been largely confined to research labs, several new products have begun to leak out of laboratories. These products appeared in the shadowed corners of this year's



Tiny LED lamp. Using Li-Fi technology, LED bulbs send data into visible light instead of the radio waves used by traditional wireless technology like Wi-Fi. *(Image courtesy of Gina Haubge, Flickr).*

Mobile World Congress in Barcelona, while most of the wireless industry focused on fifth-generation, or 5G, wireless technology. PureLiFi, one of the earliest companies to develop Li-Fi products, presented a new dongle for computers and laptops. In addition, the French startup Oledcomm demonstrated its Internet lighting system for offices and hospitals.

Li-Fi takes advantage of the fact that light-emitting diodes (LEDs) used in light bulbs are semiconductor devices. The same electric current sent through them to produce light can be switched at extremely fast speeds, flickering the light to encode parallel data streams. Though the flickering is imperceptible to the human eye, it works almost like a digital version of Morse code.

When an LED is combined with signal processing technology, it can send data into photo detectors built into smartphones, dongles, and other devices. It works on a similar principle as remote controls, which use infrared light to send tiny data streams to televisions and toys. But visible light can reach intensities that capture much larger amounts of data. Researchers have used these properties to create Li-Fi networks with download speeds over 200 gigabits per second.

"All we need to do is fit a small microchip on every potential illumination device and this would combine two basic functionalities: illumination and wireless data transmission," said Harald Haas, a professor of mobile communications at the University of Edinburgh, during his first TED Talk in 2011, in which he introduced the term Li-Fi.

Less than a year after his initial demonstration in 2011, Haas spun out pureLiFi from his research at the University of Edinburgh. The company recently unveiled LiFi-X, which includes an access point that connects to LED bulbs and a dongle that provides 40 Mbits/s downloads and uploads. Earlier pureLiFi products delivered only a fourth of the throughput, making it comparable to early versions of Wi-Fi.

The widespread growth of LED lighting—combined with the largely untapped visible spectrum—has inspired a wave of new startups. Last year, the Estonian company Velmenni tested Li-Fi technology in the field with speeds around 1 Gbit/s. For its part, Oledcomm sells development kits for building Li-Fi into devices. Others, like ByteLight, have focused on using visible light communications to build systems for supermarkets and retail stores, allowing customers to use smartphone apps to find products.

Larger companies like Philips Lighting are investigating the technology to help build out smart cities and smart buildings. Thus far, most Li-Fi products have targeted houses, businesses, offices, and even hospitals, where interference with medical equipment is a concern. But startup companies have begun to point out that Li-Fi would be ideal for the Internet of Things (IoT), linking low-power sensors in industrial equipment or home appliances.

Deepak Solanki, chief executive of Velmenni, said in an interview with Agence France-Presse that new devices with gigabit Li-Fi technology are still around two or three years out. He noted that while an existing LEDs were widely available, retrofitting these lights for Li-Fi would be problematic.

Most analysts envision Li-Fi as a supplement to Wi-Fi rather than a replacement. One reason is that Li-Fi only works with devices in the light. Naturally, it also cannot travel through walls like Wi-Fi and other wireless technologies—though it supporters maintain that this translates into tougher security. As for the Internet of Things, a new version called Wi-Fi HaLow boasts lower power consumption and more effective penetration through through walls and other obstacles.

These arguments seem like a moot point for Haas. Merging light bulbs and wireless communications is not about displacing older technologies but about recognizing the role of wireless technology in our lives. "Wireless communications has become a utility like electricity and water," he says. ■

WILLIAM WONG | Technical Editor

The Automotive

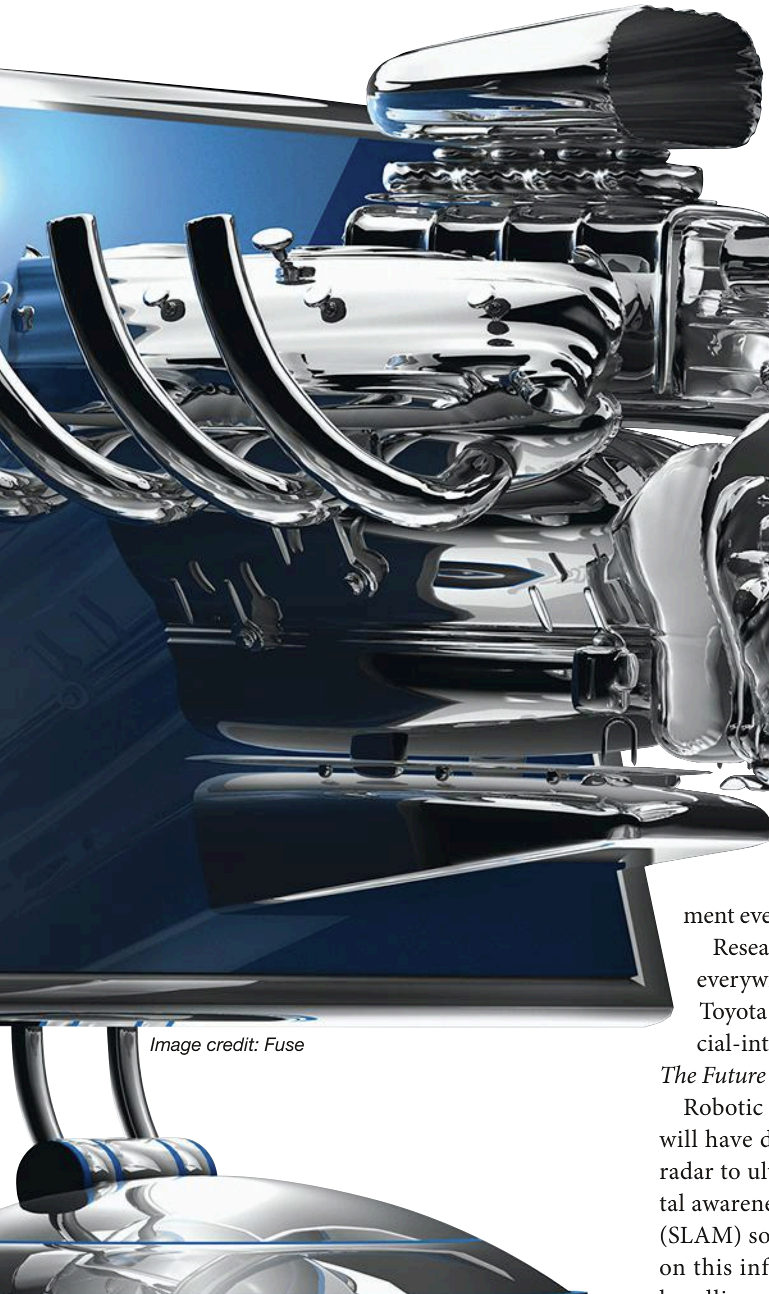


Image credit: Fuse

No question, automotive technology has evolved quite a bit since the days of a car telling you that you left a door open. Indeed, research on self-driving cars and augmented driving is leading to some rather remarkable innovations—and they're coming quickly.

What will soon be one of the most sophisticated robots around? Your trusty automobile. While there won't be a bipedal robot replacing the human driver, the car itself will be the robot, sporting more sensors and software to provide a safe driving experience. Though expected for self-driving cars, this technology is also finding its way into the more conventional vehicles of today and tomorrow. It will help provide a safer driving environment even when a person is driving the vehicle.

Research on self-driving cars and augmented driving is going on everywhere, at companies ranging from Google to Ford *(Fig. 1)*. Toyota is dropping $1 billion over five years to help foster artificial-intelligence (AI) research for self-driving cars *(see "Gallery: The Future of Transportation" on electronicdesign.com)*.

Robotic cars will not have a pair of Mark 1 eyeballs. Instead they will have different sensors arrayed about the car, from lasers and radar to ultrasonic and visual sensors. This advanced environmental awareness will be fed to simultaneous localization and mapping (SLAM) software and utilized by AI applications to analyze and act on this information. There will be multiple computers and cores handling all of this information, ultimately pushing automotive

Supercomputer

platforms into the high-performance embedded computing (HPEC) arena.

Sensors are not the only way cars will be getting information about their environment. We already have GPS for mapping applications, but vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I)—collectively known as V2X—is coming into play, as well. This requires a cooperative infrastructure that is costly to implement and change, so it needs to be done as flexibly and correctly as possible the first time.

1. Ford's experimental Fusion Hybrid has the obvious LIDAR on the roof, but there are a host of other sensors and support hidden throughout the car.

ADVANCED ENVIRONMENTAL AWARENESS

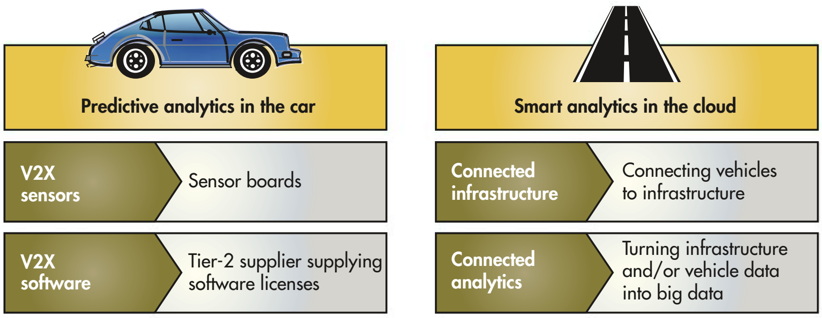
The challenge for automotive sensing systems is the range of environments encountered by a car. It is easy to garner information about the environment when nothing is moving on a clear day or night. However, add dozens of moving objects, rain, fog, glare, and other problems, and the job becomes much more difficult.

No single sensor can address all situations, which is why a variety of sensors are being employed. There tends to be overlap in range and performance, with each sensor being optimized for a particular aspect of the application. Sensor integration—a common term with regard to smartphones and other Internet of Things (IoT) devices—is something automotive sensors are being tied into, but the problem is much more complex. The sensor information is often used to build up a view of the surrounding environment, not just the operation of the device itself.

Nearby objects need to be tracked and decisions need to be made based upon a wide variety of inputs. The problems are actually more complex than those encountered by fighter aircraft, which already perform many of these functions (e.g., tracking objects).

This is where SLAM comes into play. The challenge is dealing with the large amounts of information from the growing array of sensors and incorporating them into a changing 3D map. Complex algorithms such as Extended Kalman Filters (EKFs) are being employed, which have been used in robotics research for decades.

SLAM needs to track a variety of objects from stationary landmarks to moving objects. The sys-



2. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), collectively known as V2X, use wireless communication to provide a vehicle with information about its environment. *(courtesy of Savari)*

tems need to deal with data that is incomplete, having limited accuracy and possibly a wide margin of error. The systems also need to deal with uncertainty because objects will be occluded, and an object's makeup can affect the results from the sensors. For example, reflectivity can affect the results of most sensors, albeit to different degrees. This is why a variety of sensors can help improve overall analysis.

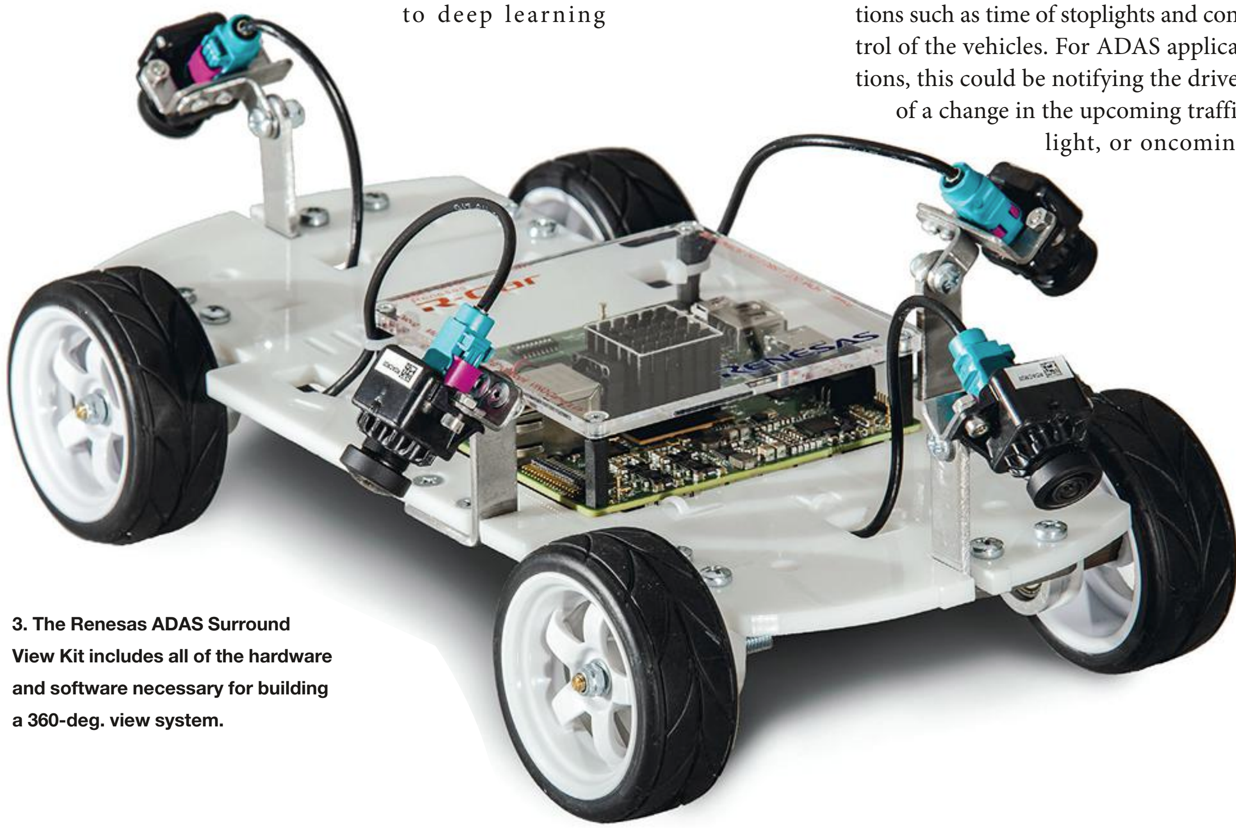
Automotive Ethernet is helping tie together multiple sensors, such as cameras *(see "Automotive Ethernet Was the Hidden Trend at CES 2016" on electronicdesign.com)*. Technologies like this are important because the resulting system cannot be big, bulky, hard-to-maintain, or expensive. The 360-deg., birds-eye, surround view is done by knitting together the output from four cameras with fisheye lenses.

Artificial intelligence (like the cloud and IoT) comes in many forms, from rule-based systems to neural networks to deep learning applications. Various forms of AI will be employed for self-driving cars, but also for Advanced Driver Assistance Systems (ADAS) that are being deployed now. The ADAS systems are typically providing warnings such as lane-change systems and backup where the driver has to handle actual collision avoidance.

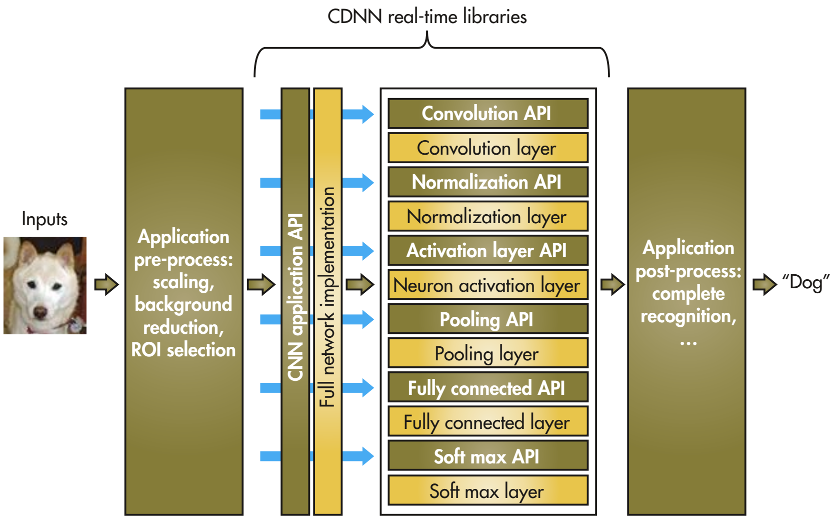
INFRASTRUCTURE AWARENESS

Creating a standalone system would be complex enough, but adding cooperative, wireless communication to the mix can simplify the job. This is where V2X *(Fig. 2)* comes in. This technology uses wireless communication between a vehicle and the surrounding infrastructure, as well as nearby vehicles equipped with V2X support.

With V2X, the position and movement information of a vehicle obtained from GPS and other location technology is shared with nearby vehicles. This information can also be shared with the infrastructure, allowing for optimizations such as time of stoplights and control of the vehicles. For ADAS applications, this could be notifying the driver of a change in the upcoming traffic light, or oncoming



3. The Renesas ADAS Surround View Kit includes all of the hardware and software necessary for building a 360-deg. view system.



4. CEVA's Deep Neural Networks (DNNs) framework runs algorithms created using Caffe.

cross traffic that might not be visible to a vehicle. Such information could also be used help alleviate traffic congestion.

Companies like Savari are developing and testing the sensors and communication support for V2X. There have been a number of voluntary deployments and pilot projects to show the viability of V2X, in addition to finding issues that need to be addressed.

V2X will be most useful when all vehicles are equipped with the technology, but there are benefits even when a subset of vehicles and infrastructure is in place. Vehicles with V2X will have the advantage, but everyone will benefit if the infrastructure components provide advantages such as congestion notifications. Some of this is already in place, using smartphones to track people in vehicles to generate maps with congestion information.

AUTOMOTIVE PROCESSING

V2X tends to be a more straightforward communication and computation application, but sensor analysis, SLAM, and AI support are placing heavy demands on processing power with the car. There are a variety of solutions being delivered and often multiple platforms are being utilized in a distributed fashion.

For example, Renesas' R-CAR H3 family is built around a multicore, 64-bit ARM Cortex-A57/53 system and Imagination's PowerVR GX6650 as the 3D graphics engine. That tends to be a typical platform, but dual lock-step Cortex-R7 and IMP-X5 parallel programmable engines set it apart. The IMP-X5 delivers advanced image-recognition support. The H3 can be used to generate 360-deg. views from multiple cameras, as well as perform image analysis to identify objects and people. QNX Software Systems' QNX CAR supports the H3, providing ADAS support.

The Renesas ADAS Surround View Kit *(Fig. 3)* is an example of the R-CAR platform in action. It has four IMI Tech cameras, and the open-source software combines the output into a single 360-deg. view.

Nvidia's Jetson TX1 *(see "Module Delivers Supercomputer Performance" on electronicdesign.com)* and Drive PX 2 are platforms targeting automotive applications. The Jetson TX1 is also built around a multicore Cortex-A57/53 system but it pairs the cores with a heftier GPU. The Maxwell GPU has 256 cores delivering over 1 TFLOPS of computing power that can be targeted at applications like deep learning using software such as Nvidia's CUDA Deep Neural Network (cuDNN) library. The Drive PX 2 module provides even more computing power. It has 12 cores and delivers 8 TFLOPS using two Tegra and two discrete GPU chips.

Deep learning is a class of machine-learning technologies, also known as deep structured or hierarchical learning. It's designed to operate on large datasets and tends to be computationally intensive. Deep learning can employ other technologies (e.g., neural networks) and has been applied to many fields, such as computer vision and natural language processing.

There are a number deep learning frameworks being developed. Caffe, for one, was developed at the Berkeley Vision and Learning Center (BVLC) at the University of California, Berkeley. It can process more than 60 million images per day running on an Nvidia K40 GPU. Inference takes 1 ms per image, while learning takes 4 ms per image.

Not all deep learning applications require hefty floating-point support. CEVA's Deep Neural Networks (DNNs) framework *(Fig. 4)* runs on the CEVA-XM4 *(see "Framework Ports Deep Neural Network to Vector DSP" on electronicdesign.com)*. Developers start by building Caffe applications, which the software then converts into fixed-point support provided by the CEVA-XM4. The framework is distributed so that a host processor can handle part of the workload.

No doubt about it: We have come a long way from a car telling us that "a door is ajar" to providing warnings about lane changing and adjacent vehicles. There is much more to come—and a lot of work still to be done—regarding applications that are needed to meet safety demands like ISO 26262 (ASIL-B). New cars will need to become robotic supercomputers to meet these challenges. ed

MARIA GUERRA | Technical Editor

Is the Electrical Grid SMART SOLAR

Today's solar inverter technologies do more than convert the variable dc output of a photovoltaic solar panel into utility frequency ac that's suitable for a commercial grid or to a local, off-grid electrical network.

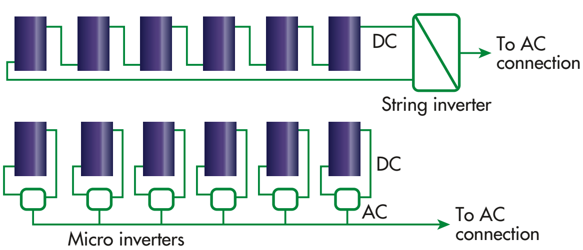
Within the fast-growing solar-energy market, solar-inverter suppliers must keep pace with electronic technology advances in order to deliver more efficient and reliable parts at a lower cost. Inverter efficiency indicates the percentage of the available solar power that's actually converted by the inverter and fed into the utility grid; some smart inverters reach a total efficiency of 98%. To achieve high efficiency, it's important to design the inverters using the most reliable components from power semiconductors (MOSFETs and/or IGBTs), capacitors (electrolytic capacitors, high-capacity film capacitors), transformers, cooling systems, etc.

An inverter is a highly demanding power electronic device. Recognizing the smart inverter's vital role in the solar renewable-energy market, ABB announced the creation of a multimillion-dollar facility with a utility-scale solar-inverter testing laboratory earlier this year.

The laboratory features a unique, large climate chamber capable of full power electrical testing in simulated conditions ranging from the arctic tundra to an equatorial rainforest. The chamber also allows for accelerated product testing, which is important when the inverters are typically expected to operate for more than 20 years. The laboratory that opened in Helsinki supports the following: testing and verification of inverters for safe operation; compatibility to the most demanding renewables-specific grid code requirements; and the measurement and testing of harmonics and grid interactions.

Europe has been working on grid modernization for quite a while and the United States is taking the first steps toward the implementation of a smart grid. Early this year, U.S. Secretary Ernest Moniz announced that the Energy Department's (DoE) Grid Modernization Initiative would improve the resiliency, reliability, and security of the nation's electrical power grid.

For example, the DoE announced $18 million in funding for six new projects across the United States. It said that the six new integrated photovoltaic (PV) and energy storage projects will utilize Internet-capable inverters, working with smart buildings, smart appliances, and utility communication and control systems. The results developed under this effort will enable the sustainable and holistic integration of hundreds of gigawatts of additional solar energy onto the electric grid throughout the U.S.



1. This diagram compares a string-inverter arrangement versus a microinverter arrangement. *(Courtesy of Wind and Solar)*

Internet-capable inverters or smart inverters have a digital architecture with

Keeping Up with INVERTERS?

bidirectional communications capability and robust software infrastructure to provide the following functionalities to improve the grid:

- **Remote ON/OFF:** Smart inverters can connect/disconnect from the grid.
- **Power factor control:** Smart inverters allow rising or sinking the reactive power by setting the ratio of real power to apparent power.
- **Reactive power control:** Smart inverters are able to set the level of reactive power generation or consumption.
- **Volt/reactive power management:** Smart inverters provide voltage regulation by modulating reactive power output.
- **Volt/ real power management:** Smart inverters provide voltage regulation by modulating real power output.
- **Frequency/watt management:** Smart inverters allow distributed-energy-resources (DER) systems to help with frequency regulation by changing its real power output.
- **Low/high voltage and frequency ride-through:** Smart inverters can remain connected to the grid and adjust their output to operate at high/low frequencies and under zero-, low-, and high-voltage ride-through conditions.
- **Power curtailment:** Smart inverters specify an upper limit for inverter active-power output to reduce the array's power output.

Solar inverters, also known as grid-tie inverters, may be classified as string inverters, central inverters, and micro-inverters *(Fig. 1)*:

- A string inverter is the type most commonly used in applications up to 100 kW, such as home and commercial solar PV systems where a maximum-power-point-tracking (MPPT) system captures the maximum energy from the PV panel.
- Central inverters are designed for applications above 100 kW, such as large arrays installed on buildings, industrial facilities, and field installations.

2. The Power Xpert Solar Inverter consists of three 500-kW blocks, which can be individually isolated in the unlikely event of a fault. *(Courtesy of Eaton Corp.)*

> "Utilities are seeing their value and, therefore, solar-inverter products will keep advancing while significantly contributing to the modernization of the electrical power grid."

- A micro-inverter is a string inverter with a MPPT module placed to capture every panel, optimizing each solar panel instead of the entire solar PV system—much like central inverters but at a lower power (typically 300 W).

Are micro-inverters better than string inverters, though? The answer isn't a simple yes or no. It depends on so many factors: number of panels, shading issues, operating temperature range, maintenance costs, longer warranties, system monitoring options, future system expansions, etc. The main advantage of micro-inverters is that they can isolate a panel without affecting the system's overall performance, plus they're easy to fix. On the other hand, string inverters offer an initial lower cost-per-peak-watt price and are easier to install.

SMART-INVERTER EXAMPLES

Most inverters in operation in the United States are IEEE1547 and UL 17451 certified. Some have smart functionalities built-in, but are disabled in order to comply with present standards and rules. Let's take a look at some smart-inverter examples/products currently on the market that could meet future grid-support functionality.

In industrial facilities, the centralized architecture offers the best levelized cost of electricity (LCOE). Eaton Corp., a power-management company, offers its Power Xpert Solar Inverter *(Fig. 2)*. Built for the utility-scale class, it features a large power block inverter (1.5 MW and 1.67 MW). The Power Xpert is made up of conservatively designed critical components (magnetics, IGBTs, capacitors, dc switches, and ac breakers) and features a wide MPPT voltage range (500-1000 V dc) that maximizes inverter operation time. Its rugged and robust design is outdoor-rated; no extra shelter is needed.

The Power Xpert Solar Inverter is certified by Intertek per UL174 and complies with IEEE 1547 (total harmonic distortion at rated power) with a maximum inverter efficiency of 98%. Like many other inverters, this grid-tied inverter also offers grid-management features: low- and high-voltage ride-through (LVRT and HVRT), frequency ride-through (FRT), voltage control, frequency-droop control, power-ramp control, islanding detection, etc.

3. The Sunny Tripower TL-US delivers advanced smart-inverter features, including active power curtailment; adjustable power factor and reactive power supply; frequency and voltage ride-through; and soft-start reconnection ramp controls. *(Courtesy of SMA)*

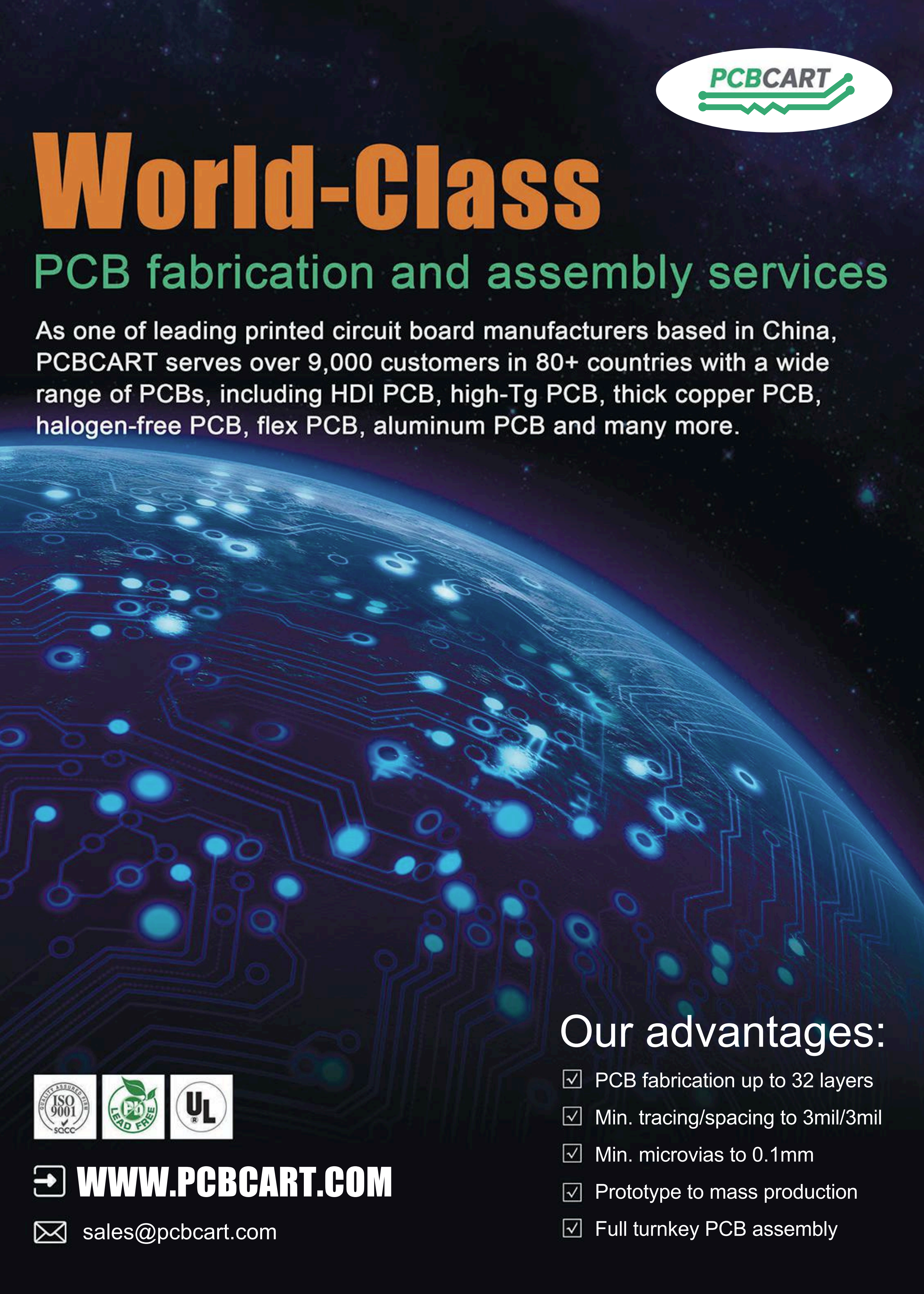
4. The ABB's MICRO inverter reduces susceptibility to fault. If a component fails, only the energy produced from one PV module will be lost. *(Courtesy of ABB)*

SMA offers a string inverter applicable for 1000 V dc in decentralized commercial applications, allowing for the creation of longer strings. The SMA Sunny Tripower 30000TL-US *(Fig. 3)* is a 30-kW, three-phase transformerless inverter with a peak efficiency of above 98% with two independent MPP trackers feeding a eight strings and OptiTrac Global Peak for shade mitigation. It includes emerging interconnection requirements, such as the recent revisions to California's Rule 21 and HECO's transient overvoltage and ride-through requirements, and it complies with the National Electrical Code's (NEC) new Section 690.12—Rapid Shutdown of PV Systems on Buildings.

Micro-inverters have seen a rise in popularity even though it's not a new technology and they cost more per peak watt than string inverters. The reason is they've become a solution for inverters in residential and commercial applications, where every panel can be individually controlled. ABB's MICRO inverter *(Fig. 4)*, at 0.25 to 0.3 kW, promises to reduce shading and mismatching effects at a maximum efficiency of 96.5%. With a precise MPPT algorithm and outdoor enclosure, it complies with Safety and EMC standards.

CONCLUSION

Solar inverters represent the heart of solar-power systems. Utilities are seeing their value and, therefore, solar-inverter products will keep advancing while significantly contributing to the modernization of the electrical power grid. In the United States, equipment standards, safety standards, and current grid codes need to be updated to roll out smart inverters at their fullest potential.


PCBCART
World-Class
PCB fabrication and assembly services
As one of leading printed circuit board manufacturers based in China, PCBCART serves over 9,000 customers in 80+ countries with a wide range of PCBs, including HDI PCB, high-Tg PCB, thick copper PCB, halogen-free PCB, flex PCB, aluminum PCB and many more.
Our advantages:
PCB fabrication up to 32 layers
Min. tracing/spacing to 3mil/3mil
Min. microvias to 0.1mm
Prototype to mass production
Full turnkey PCB assembly
WWW.PCBCART.COM
sales@pcbcart.com

LOU FRENZEL | Contributing Editor

The Future of WIRELESS

In a nutshell: More wireless *is* the future.

Electronics is all about communications. It all started with the telegraph in 1845, followed by the telephone in 1876, but communications really took off at the turn of the century with wireless and the vacuum tube. Today it dominates the electronics industry, and wireless is the largest part of it. And you can expect the wireless sector to continue its growth thanks to the evolving cellular infrastructure and movements like the Internet of Things (IoT). Here is a snapshot of what to expect in the years to come.

THE STATE OF 4G

4G means Long Term Evolution (LTE). And LTE is the OFDM technology that is the dominant framework of the cellular system today. 2G and 3G systems are still around, but 4G was initially implemented in the 2011-2012 timeframe. LTE became a competitive race by the carriers to see who could expand 4G the fastest. Today, LTE is mostly implemented by the major carriers in the U.S., Asia, and Europe. Its rollout is not yet complete—varying considerably by carrier—but nearing that point. LTE has been wildly successful, with most smartphone owners relying upon it for fast downloads and video streaming. Still, all is not perfect.

1. The Ceragon FibeAir IP-20C operates in the 6- to 42-GHz range and is typical of the backhaul to be used in 5G small-cell networks.

While LTE promised download speeds up to 100 Mb/s, that has not been achieved in practice. Rates of up to 40 or 50 Mb/s can be achieved, but only under special circumstances. With a full five-bar connection and minimal traffic, such speeds can be seen occasionally. A more normal rate is probably in the 10- to 15-Mb/s range. At peak business hours during the day, you are probably lucky to get more than a few megabits per second. That hardly makes LTE a failure, but it does mean that it has yet to live up to its potential.

One reason why LTE is not delivering the promised performance is too many subscribers. LTE has been oversold, and today everyone has a smartphone and expects fast access. But with such heavy use, download speeds decrease in order to serve the many.

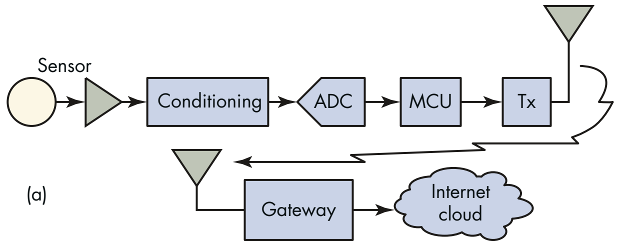
There is hope for LTE, though. Most carriers have not yet implemented LTE-Advanced, an enhancement that promises greater speeds. LTE-A uses carrier aggregation (CA) to boost speed. CA combines LTE's standard 20-MHz bandwidths into 40-, 80-, or 100-MHz chunks, either contiguous or not, to enable higher data rates.

LTE-A also specifies MIMO configurations to 8 × 8. Most carriers have not implemented the 4 × 4 MIMO configurations specified by plain-old LTE. Therefore, as carriers enable these advanced features, there is potential for download speeds of up to 1 Gb/s. Market-data firm ABI Research forecasts that LTE carrier aggregation will power 61% of smartphones in 2020.

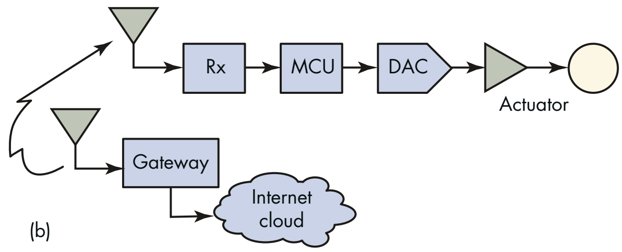
This LTE-CA effort is generally known as LTE-Advanced Pro or 4.5G LTE. This is a mix of technologies defined by the 3GPP standards development group as Release 13. It includes carrier aggregation as well as Licensed Assisted Access (LAA), a technique that uses LTE within the 5-GHz unlicensed Wi-Fi spectrum. It also deploys LTE-Wi-Fi Link Aggregation (LWA) and dual connectivity, allowing a smartphone to talk simultaneously with a small cell site and an Wi-Fi access point. Other features are too numerous to detail here, but the overall goal is to extend the life of LTE by lowering latency and boosting data rate to 1 Gb/s.

But that's not all. LTE will be able to deliver greater performance as carriers begin to facilitate their small-cell strategy, delivering higher data rates to more subscribers. Small cells are simply miniature cellular basestations that can be installed anywhere to fill in the gaps of macrocell site coverage, adding capacity where needed.

Another method of boosting performance is to use Wi-Fi offload. This technique transfers a fast download to a nearby Wi-Fi access point (AP) when available. Only a few carriers have made this available, but most are considering an LTE improvement called LTE-U (U for unlicensed). This is a technique similar to LAA that uses the 5-GHz unlicensed band for fast downloads when the network cannot handle it. This presents a spectrum conflict with the latest version of Wi-Fi 802.11ac that uses the 5-GHz band. Compromises have been worked out to make this happen.



2a. This is a model of the typical IoT device electronics. Many different input sensors are available. The usual partition is the MCU and radio (TX) in one chip and the sensor and its circuitry in another. One-chip solutions are possible.



2b. This block diagram shows another possible IoT device configuration with an output actuator and RX.

So yes, there is plenty of life left in 4G. Carriers will eventually put into service all or some of these improvements over the next few years. For example, we have yet to see voice-over-LTE (VoLTE) deployed extensively. Just remember that the smartphone manufacturers will also make hardware and/or software upgrades to make these advanced LTE improvements work. These improvements will probably finally occur just about the time we begin to see 5G systems come on line.

5G REVEALED

5G is so not here yet. What you're seeing and hearing at this time is premature hype. The carriers and suppliers are already doing battle to see who can be first with 5G. Remember the 4G war of the past years? And the real 4G (LTE-A) is not even here yet. Nevertheless, work on 5G is well underway. It is still a dream in the eyes of the carriers that are endlessly seeking new applications, more subscribers, and higher profits.

The Third Generation Partnership Project (3GPP) is working on the 5G standard, which is still a few years away. The International Telecommunications Union (ITU), which will bless and administer the standard—called IMT-2020—says that the final standard should be available by 2020. Yet we will probably see some early pre-standard versions of 5G as the competitors try to out-market one another. Some claim 5G will come on line by 2017 or 2018 in some form. We shall see, as 5G will not be easy. It is clearly going to be one of the most, if not the most, complex wireless system ever. Full deployment is not expected until after 2022. Asia is expected to lead the U.S. and Europe in implementation.

The rationale for 5G is to overcome the limitations of 4G and add capability for new applications. The limitations of 4G are essentially subscriber capacity and limited data rates. The cellular networks have already transitioned from voice-centric to data-centric, but further performance improvements are needed for the future.

Furthermore, new applications are expected. These include carrying ultra HD 4K video, virtual-reality content, Internet of Things (IoT) and machine-to-machine (M2M) use cases, and connected cars. Many are still forecasting 20 to 50 billion devices online, many of which will use the cellular network. While most IoT and M2M devices operate at low speed, higher network rates are needed to handle the volume. Other potential applications include smart cities and automotive safety communications.

5G will probably be more revolutionary than evolutionary. It will involve creating a new network architecture that will overlay the 4G network. This new network will use distributed small cells with fiber or millimeter-wave backhaul *(Fig. 1)*, be cost- and power-consumption-conscious, and be easily scalable. In addition, the 5G network will be more software than hardware. 5G will use software-defined networking (SDN), network function virtualization (NFV), and self-organizing network (SON) techniques. Here are some other key features to expect:

3 THINGS WIRELESS MUST HAVE TO PROSPER

SPECTRUM – Like real estate, they are not making any more spectrum. All of the "good" spectrum (roughly 50 MHz to 6 GHz) has already been assigned. It is especially critical for the cellular carriers who never have enough to offer greater subscriber capacity or higher data rates. The FCC will auction off some available spectrum from the TV broadcasters shortly, which will help. In the meantime, look for more spectrum-sharing ideas like the white spaces and LTE-U with Wi-Fi.

CONTROLLING EMI – Electromagnetic interference of all kinds will continue to get worse as more wireless devices and systems are deployed. Interference will mean more dropped calls and denial of service for some. Regulation now controls EMI at the device level, but does not limit the number of devices in use. No firm solutions are defined, but some will be needed soon.

SECURITY – Security measures are necessary to protect data and privacy. Encryption and authentication measures are available now. If only more would use them.

- Use of millimeter (mm) -wave bands. Early 5G may also use 3.5- and 5-GHz bands. Frequencies from about 14 GHz to 79 GHz are being considered. No final assignments have been made, but the FCC says it will expedite allocations as soon as possible. Testing is being done at 24, 28, 37, and 73 GHz.
- New modulation schemes are being considered. Most are some variant of OFDM. Two or more may be defined in the standard for different applications.
- Multiple-input multiple-output (MIMO) will be incorporated in some form to extend range, data rate, and link reliability.
- Antennas will be phased arrays at the chip level, with adaptive beamforming and beamsteering.
- Lower latency is a major goal. Less than 5 ms is probably a given, but less than 1 ms is the target.
- Data rates of 1 to 10 Gb/s are anticipated in bandwidths of 500 MHz or 1 GHz.
- Chips will be made of GaAs, SiGe, and some CMOS.

One of the biggest challenges will be integrating 5G into the handsets. Our current smartphones are already jam-packed with radios, and 5G radios will be more complex than ever. Some predict that the carriers will be ready way before the phones are sorted out. Can we even call them phones anymore?

So we will eventually get to 5G, but in the meantime, we'll have to make do with LTE. And really, do you honestly feel that you need 5G?

WHAT'S NEXT FOR WI-FI?

Next to cellular, Wi-Fi is our go-to wireless link. Like Ethernet, it is one of our beloved communications "utilities." We expect to be able to access Wi-Fi anywhere, and for the most part, we can. Like most of the popular wireless technologies, it is constantly in a state of development. The latest iteration being rolled out is called 802.11ac, and provides rates up to 1.3 Gb/s in the 5-GHz unlicensed band. Most access points, home routers, and smartphones do not have it yet, but it is working its way into all of them.

Also underway is the process of finding applications other than video and docking stations for the ultrafast 60 GHz (57-64 GHz) 802.11ad standard. It is a proven and cost-effective technology, but who needs 3- to 7-Gb/s rates up to 10 meters?

At any given time, there are multiple 802.11 development projects ongoing. Here are a few of the most significant.

- **802.11af:** This is a version of Wi-Fi in the TV-band white spaces (54 to 695 MHz). Data is transmitted in local 6- (or 8-) MHz bandwidth channels that are unoccupied. Cognitive radio methods are required. Data rates up to about 26 Mb/s are possible. Sometimes referred to as White-Fi, the main attraction of 11af is that the possible range at these lower frequencies is many miles, and non-line of sight (NLOS) through obstacles is possible. This version of Wi-Fi is not in use yet, but has potential for IoT applications.

- **802.11ah:** Designated as HaLow, this standard is another variant of Wi-Fi that uses the unlicensed ISM 902- to 928-MHz band. It is a low-power, low speed (100s of kb/s) service with a range up to a kilometer. The target is IoT applications.
- **802.11ax:** 11ax is an upgrade to 11ac. It can be used in the 2.4- and 5-GHz bands, but most likely will operate in the 5-GHz band exclusively so that it can use 80- or 160-MHz bandwidths. Along with 4 × 4 MIMO and OFDA/OFDMA, peak data rates to 10 Gb/s are expected. Final ratification is not happening until 2019, although pre-ax versions will probably be complete.
- **802.11ay:** This is an extension of the 11ad standard. It will use the 60-GHz band, and the goal is at least a data rate of 20 Gb/s. Another goal is to extend the range to 100 meters so that it will have greater application, such as backhaul for other services. This standard is not expected until 2017.

WIRELESS PROLIFERATION BY IoT AND M2M

Wireless is certainly the future for IoT and M2M. Though wired solutions are not being ruled out, look for both to be 99% wireless. Predictions of 20 to 50 billion connected devices still seems unreasonable. However, by defining IoT in the broadest terms, there could already be more connected devices than people on this planet today. By the way, who is really keeping count?

The typical IoT device is a short-range, low-power, low-data-rate, battery operated device with a sensor *(Fig. 2a)*. Alternately, it could be some remote actuator *(Fig. 2b)*. Or the device could be a combination of the two. Both usually connect to the Internet through a wireless gateway but could also connect via a smartphone. The link to the gateway is wireless. The question is, what wireless standard will be used?

Wi-Fi is an obvious choice because it is so ubiquitous, but it is overkill for some apps and a bit too power-hungry for others. Bluetooth is another good option, especially the Bluetooth Low Energy (BLE) version. Bluetooth's new mesh and gateway additions make it even more attractive. ZigBee is another ready-and-waiting alternative. So is Z-Wave. Then there are multiple 802.15.4 variants, like 6LoWPAN.

Add to these the newest options that are part of a Low Power Wide Area Networks (LPWAN) movement. These new wireless choices offer longer-range networked connections that are usually not possible with the traditional technologies mentioned above. Most operate in unlicensed spectrum below 1 GHz. Some of the newest competitors for IoT apps include:

- **LoRa:** An invention of Semtech and supported by Link Labs, this technology uses FM chirp at low data rates to get a range up to 2-15 km.
- **Sigfox:** A French development that uses an ultra narrowband modulation scheme at low data rates to send short messages.

3. This Monarch module from Sequans Communications implements LTE-M in both 1.4-MHz and 200-kHz bandwidths for IoT and M2M applications.

- **Weightless:** This one uses the TV white spaces with cognitive radio methods for longer ranges and data rates reaching 16 Mb/s.
- **Nwave:** This is similar to Sigfox but details are minimal at this time.
- **Ingenu:** Unlike the others, this one uses the 2.4-GHz band and a unique random phase multiple access scheme.
- **HaLow**: This is 802.11ah Wi-Fi, as described earlier.
- **White-Fi**: This is 802.11af, as described earlier.

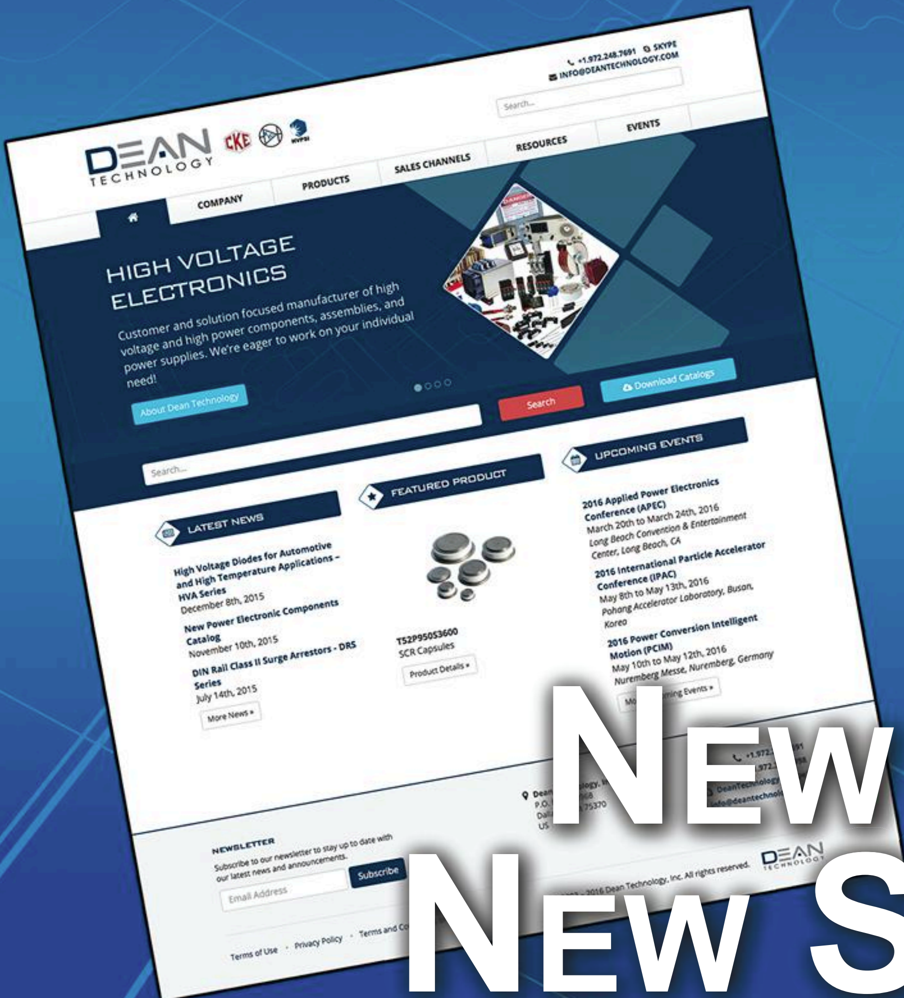
Lots of choices confront any developer. But there are even more options to consider.

Cellular is definitely an alternative for IoT, as it has been the mainstay of M2M for over a decade. M2M utilizes mostly 2G and 3G wireless data modules for monitoring remote machines or devices and tracking vehicles. While 2G (GSM) will ultimately be phased out (next year by AT&T, but T-Mobile is holding on longer), 3G will still be around, at least for the foreseeable future.

Now a new option is available: LTE. Specifically, it is called LTE-M and uses a cut-down version of LTE in 1.4-MHz bandwidths. Another version is NB-LTE-M, which exploits 200-kHz bandwidths for lower-speed uses. Then there is NB-IoT, which allocates resource blocks (180-kHz chunks of 15-kHz LTE subcarriers) to low-speed data.

All of these variations will be able to use the existing LTE networks with software upgrades. Modules and chips for LTE-M are already available, such as those from Sequans Communications *(Fig. 3)*.

One of the greatest worries about the future of IoT is the lack of a single standard. That is probably not going to happen. Fragmentation will be rampant, especially in these early days of adoption. Perhaps there will eventually be only a few standards to emerge, but don't bet on it. It may not even really be necessary. ed



New Site
New Start

INTRODUCING THE NEW WWW.DEANTECHNOLOGY.COM

In a world that demands more information, faster, we're introducing a new site that exceeds those expectations. Built on top of a comprehensive product database, and using the most contemporary technology, our new site offers simple navigation to the most accurate and constant product information in the industry.

And that's just the first step… we're reinventing the delivery of electronics product information while maintaining our commitment to world class engineering and customer support. It is now easier than ever to find exactly what is needed for your high voltage or high power design.

Visit us today and discover how easy it should be.

HVCA CKE HVPSI

PRODUCTS BY:
DEAN TECHNOLOGY

WILLIAM WONG | Technical Editor

Performance Heats Up with Cool Modules

Going fanless with modules? Attaching a good heat plate helps facilitate that process—just ask VersaLogic and Nvidia.

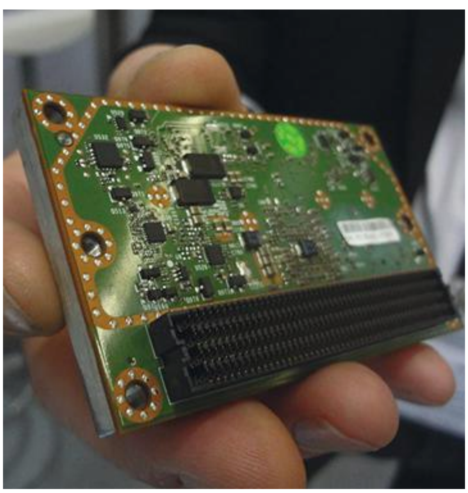
Computer modules offer a simpler route for implementing the latest processor technology, rather than having to design a whole board. Typically, the carrier board is much easier to design. It can also be more cost-efficient since the carrier board often has fewer layers.

Of course, pushing the performance envelope generally means dissipating a bit more heat. This is where cold plates, heatsinks, and heat pipes come into play. Incorporating cold plates into modules not only helps with heat issues—it also simplifies mechanical design chores.

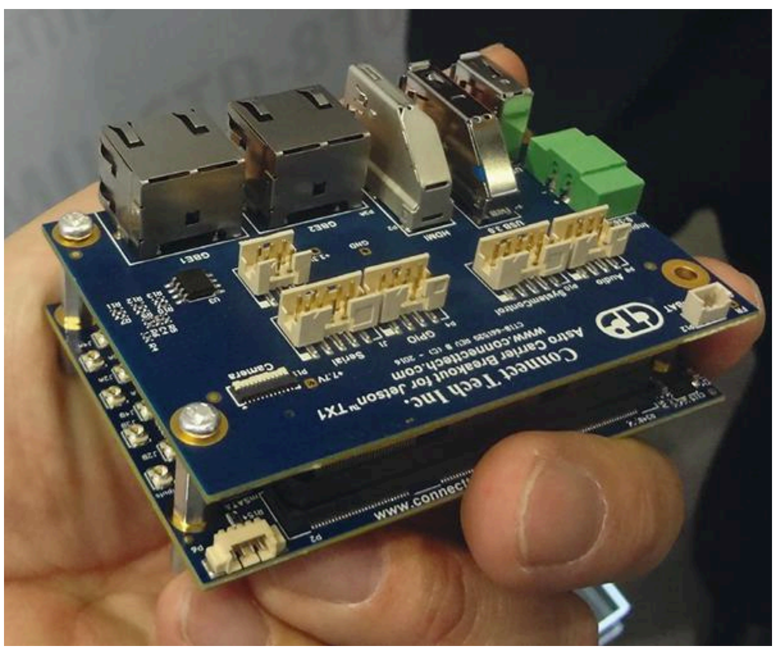
Cool, fanless solutions are available in a multitude of forms. For instance, the Hawk *(Fig. 1)* from VersaLogic is a multi-board solution that situates the cold plate at the bottom of the stack, where it can then be easily mounted on a metal case to help dissipate the heat. The Hawk takes advantage of a quad-core, 1.9-GHz, Intel Atom Bay Trail processor. The processor board includes up to 4 GB of DDR3L RAM as well as 8 GB of eMMC flash storage.

The top board in the stack integrates a microSD socket, a SATA connection, and a Mini PCIe card socket that can handle a range of peripheral and storage solutions *(see "PCI Express Mini Card Tackles Compact Embedded Expansion" on electronicdesign.com)*. The system is designed for industrial operations from –40° to +85°C and shock/vibration-qualified to MIL-STD-202G.

Most plates have a hole pattern that allows them to be bolted to a case. Often, a conductive paste is placed between the two surfaces to improve thermal exchange.



1. The quad-core Atom Bay Trail processor stays cool thanks to VersaLogic's Hawk. The multi-board stack positions the cold plate on the bottom, next to the processor.



2. Nvidia's Jetson TX1 module incorporates a single chip that features the Maxwell GPU and Cortex-A57 and Cortex-A53 cores in ARM's big.LITTLE arrangement.

DESIGN NOTES

Powering Altera Arria 10 FPGA and Arria 10 SoC: Tested and Verified Power Management Solutions

Design Note 549

Afshin Odabaee

Introduction

FPGA development kits allow system developers to evaluate an FPGA without having to design a complete system. Figures 1 and 2 show Altera's new 20nm Arria 10 FPGAs and Arria 10 SoCs (System-on-Chip) development boards. These boards are tested and verified by Altera, exemplifying best design practices in layout, signal integrity and power management.

Figure 1. Arria 10 GX FPGA Development Kit Board

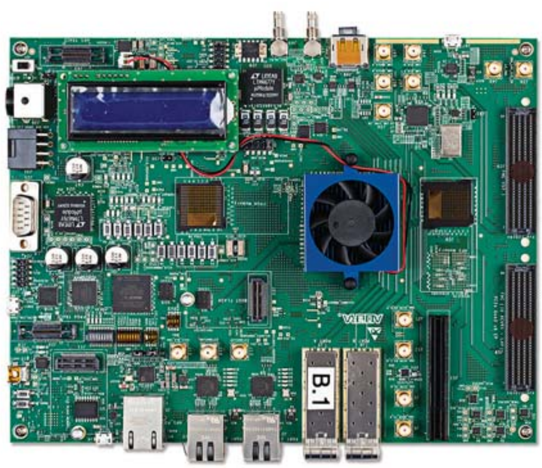


Figure 2. Arria 10 SoC Development Kit Board

Power Management for Core, System and I/O

The power management solution for high end FPGAs, including the Arria 10, should be carefully selected. A well thought-out power management design can reduce PCB size, weight and complexity, as well as lower power consumption and cooling costs. And it is essential to achieve optimal system performance. For example, the 0.95V at 105A supplied by the 12V DC/DC regulator powering the core of the Arria 10 GX FPGA in Figure 1 has several features that complement the power saving schemes of the SoC:

1. The DC/DC regulator's integrated 6-bit parallel VID interface is used by the Arria 10's SmartVID to control the DC/DC regulator and reduce FPGA power consumption during static and dynamic states.
2. The DC/DC regulator's very low value DCR current sensing improves efficiency by minimizing power loss in the inductor. Temperature compensation maintains the accuracy or the DCR value at higher inductor temperature.

Table 1 summarizes the Arria 10 development kit's power rails and functions shown in Figure 1. The table lists Linear Technology parts and descriptions for each function. Visit www.linear.com/altera, click on Arria and access technical details for the two boards presented here.

Table 1. Power Management Bill-of-Materials for the Arria 10 GX FPGA Development Kit Shown in Figure 1

Rail/Function	Part Number	Description
FPGA Core	LTC3877 + LTC3874	105A at 0.9V Regulator Seamlessly Interfaces with Arria 10 SmartVID
High Speed Transceivers	LTM4637	20A μModule® Regulator
Power UP/DOWN Sequencing, Voltage and Current Monitoring, Voltage Margining and Fault Management	LTC2977	8-Channel PMBus Power System Manager
PowerPath™ Management	LTC4357	High Voltage Ideal Diode Controller
3.3V Intermediate Bus from $12V_{IN}$	LTM4620	Dual 13A or Single 26A μModule Regulator
Input Overvoltage Protection	LTC4365	Overvoltage, Undervoltage and Reverse Supply Protection Controller
Housekeeping System Power and Power Management	LT1965, LT3082, LTC4352, LTC3025-1, LTC2418	Low Noise Linear Regulators, 24-Bit ADC; Low Voltage Ideal Diode

Customize the Power Tree with the LTpowerPlanner Design Tool

What if your power requirements differ from the designs exemplified in a development kit? For these cases, use the LTpowerPlanner® PC-based design tool to personalize and optimize a system's power tree. Start with the suggestions given in the development kit; then easily reorganize power blocks, alter power ratings, compute efficiency and power loss, simulate each power block, select DC/DC regulator part numbers and authenticate a customized solution. LTpowerPlanner was used to generate the power trees (Figure 3) for the Arria 10 development kit's FPGA and system requirements, and is available within the more encompassing LTpowerCAD® design tool, available for free download at www.linear.com/ltpowercad.

LTpowerCAD enables users to:

- Select specific Linear Technology DC/DC regulators to match a given power specification
- Select appropriate power components such as inductors, resistors and capacitors
- Optimize efficiency and power loss
- Optimize regulator loop stability, output impedance and load transient response
- Export the design to LTspice® for time domain simulation

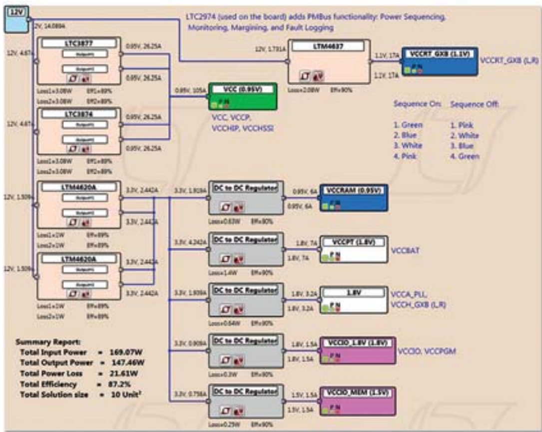


Figure 3. Power Tree for Arria 10 GX FPGA Board (Figure 1). Designed in LTpowerPlanner, An Analytical and Simple First Step Design Tool for Mapping System Power Requirements

Conclusion

Development kit design guides for Altera Arria 10 FPGAs and SoCs, as well as other Altera FPGAs including power trees and bill-of-materials are available at www.linear.com/altera. These development kits have been tested and verified by Altera or third-party developers.

Development Kit Design Guides Download

www.linear.com/altera

For applications help,
call (408) 432-1900, Ext. 2463

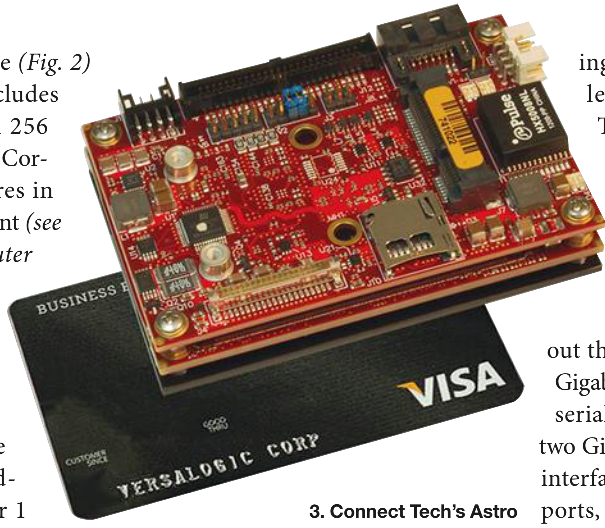
DN549F LT/AP 0416 111K • PRINTED IN THE USA

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

Nvidia's Jetson TX1 module *(Fig. 2)* features a single chip that includes Nvidia's Maxwell GPU with 256 CUDA cores along with ARM Cortex-A57 and Cortex-A53 cores in ARM's big.LITTLE arrangement *(see "Module Delivers Supercomputer Performance" on electronicdesign.com)*.

It is one hot chip, in more ways than one. However, it can be conduction-cooled, hence the plate covering the back of the Jetson TX1 module. The system delivers over 1 TFLOPS of performance and supports 4K video encode and decode. It also supports OpenGL 4.5, OpenGL ES 3.1, and Vulkan, and manages up to six cameras running at 1400 Mpixels/s. Bluetooth and 802.11ac wireless is built into the module as well.

The Nvidia platform supports a range of software, including cuDNN, a CUDA-accelerated library for deep learning. It's also compatible with deep-learning frameworks like Caffe, Theano, and Torch.



3. Connect Tech's Astro Carrier is designed to plug into Nvidia's Jetson TX1.

The Jetson TX1 module includes 5 GB of LPDDR4 memory and 16 GB of eMMC flash. It's designed to plug into carriers like Connect Tech's Astro Carrier *(Fig. 3)*. The device brings out the wired interfaces like SATA and Gigabit Ethernet, along with the various serial ports. Among other features are two Gigabit Ethernet ports, three camera interfaces, audio ports, USB 2.x and 3.0 ports, and HDMI ports. Both the Astro Carrier and Jetson TX1 can handle industrial temperature ranges. The middle carrier board has a half-size mSATA socket, plus a Mini-PCIe socket with PCIe and USB support.

Creating fanless, small-form-factor solutions doesn't mean designers need to give up performance. It's just a matter of keeping the hardware cool enough using solutions like the Hawk and Jetson TX1. ed

DUNCAN BENNETT
Everspin Technologies
ANDREW POCKSON
Anglia

MRAM Optimizes

Neither EEPROM nor flash can come close to MRAM in terms of shrinking system energy consumption.

For many wireless and portable applications, especially in the growing Internet of Things (IoT), the energy budget (total power consumed over time) is a critical component. When calculating a design's power budget, engineers typically look at the rated power consumption of the device. However, other factors can come into play.

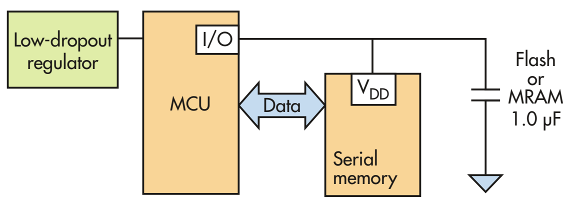
For example, for non-volatile memory, the write current is very much higher than the read or standby current. Consequently, the write time needs to be considered in power-sensitive applications, especially in systems that sustain frequent memory writes. A technology such as MRAM, with fast-Write and power-up-to-Write times, can significantly reduce total system energy consumption compared to either EEPROM or flash.

In this article, we compare system energy consumption in a typical data-acquisition system using flash, EEPROM or MRAM. Overall, the comparisons showed that:

- Non-volatile memory write time is a major contributor to overall system energy consumption; thus, the shorter write time of MRAM can actually reduce total energy consumption.
- Further system energy reductions are possible using a power-gating architecture with MRAM. That's because its faster power-up to write time makes it possible to reduce MRAM standby power to zero.

TYPICAL SYSTEM

The schematic in *Fig. 1* represents the low-voltage dropout regulator (LDO), microcontroller (MCU), non-volatile memory, and a decoupling capacitor typical in data-acquisition applications like medical monitors, data loggers,



1. This typical data-acquisition application, with flash or MRAM, uses power gating for standby mode.

TABLE 1: ENERGY CONSUMED DURING WRITE OPERATIONS FOR EEPROM							
	Number of SPI bytes	Capacitance (µF)	Rise-time energy[3] (µJ)	Write time (ms)	Write energy[1] (µJ)	Total energy (µJ)	Energy/data byte[2] (µJ)
EEPROM	4	0.1	0.44	5.0	49.5	49.9	12.5
	46	0.1	0.44	5.0	49.5	49.9	1.0
Notes	1. Write energy is V_{DD} × Write current × time. 2. The number of data bytes is four less than the number of SPI bytes due to the required overhead. 3. Rise-time energy = 1/2 CV^2.						

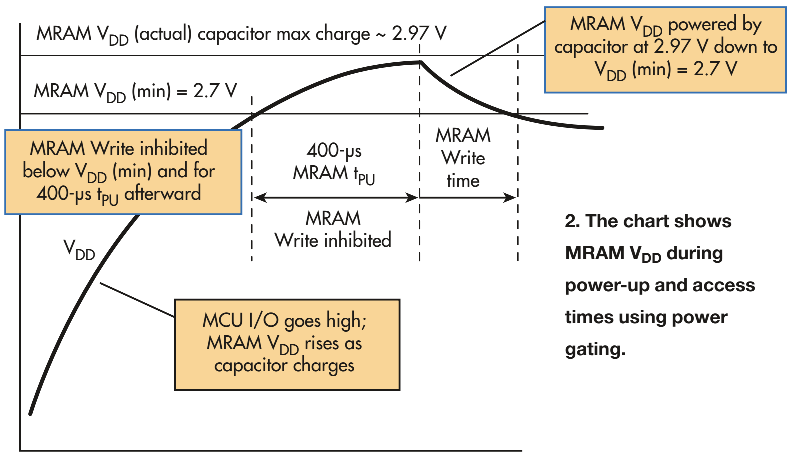
System Energy Consumption

etc. Other system components, such as sensors and their power consumption, were not considered in this situation.

The MCU was assumed to be in a low power sleep state and with a periodic wakeup for data acquisition. The data acquired was stored in the non-volatile memory, and then the system returned to the sleep state.

We will compare non-volatile memory with an SPI interface and look only at Write operations, which typically consume much more power than Read operations. The number of data bytes that can be written is four less than the number of bytes on the SPI bus due to overhead of the Write command, the WREN bit, and two address bytes.

The number of bytes written to the non-volatile memory was selected as 4 and 46. Four is perhaps most likely, representing the storage of one data-acquisition sample. Meanwhile, 46 represents the optimum amount of data that can be written to an MRAM when powered from a 1.0-µF decoupling capacitor.



2. The chart shows MRAM V_{DD} during power-up and access times using power gating.

POWER-GATING CONSIDERATIONS

A few quick calculations revealed that the decoupling capacitor is very important when power gating. The energy that was used to charge the capacitor from zero is significant.

EEPROM can be powered directly from the I/O of a standard microcon-

TABLE 2: ENERGY CONSUMED DURING WRITE OPERATIONS FOR SERIAL FLASH

	Number of SPI bytes	Capacitance (µF)	Rise-time energy[3] (µJ)	Write time (ms)	Write energy[1] (µJ)	Total energy (µJ)	Energy/data byte[2] (µJ)
Flash	4	1.0	4.41	3.0	148.5	152.9	38.2
	46	1.0	4.41	3.0	148.5	152.9	3.3
Notes	1. Write energy is V_{DD} × Write current × time. 2. The number of data bytes is four less than the number of SPI bytes due to the required overhead. 3. Rise-time energy = $1/2\ CV^2$.						

troller, typically 4 mA. As a result, a small 0.1-µF capacitor was used for decoupling. MRAM and flash need more current than is available from a standard MCU I/O. Therefore, a larger decoupling capacitor is needed so that flash or MRAM could run on the energy stored in the device.

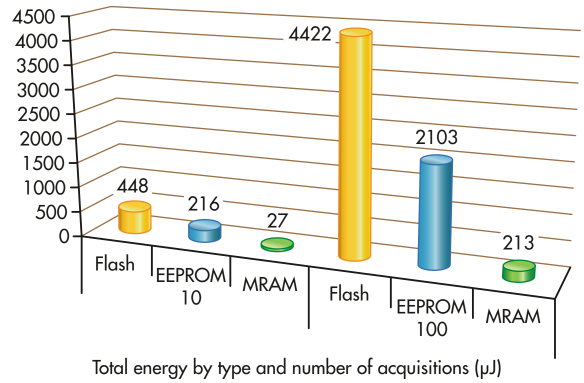
PHASES OF THE WRITE OPERATION

The energy consumption of the non-volatile memory was calculated during the phases of the write operation *(Fig. 2)*:

Rise time: During this phase, we assume that all of the energy goes into the decoupling capacitor and that the non-volatile memory consumes negligible energy.

Power-up time: Once the voltage on V_{DD} is above a threshold, a small delay (t_{PU}) is required for MRAM to become ready, but not for EEPROM or flash. During this phase, we assume that the MRAM consumes the current shown in the standby specification of the datasheet.

Write time: During this phase, the non-volatile memory consumes the current shown in the active specification of the datasheet. Assuming a 3.3-V system with a tolerance of ±10%, the lowest voltage on the I/O could be 3.3 V – 10% = 2.97 V. This voltage of 2.97 V was used in calculations.



3. A graphical summary of the results listed in Table 4 shows energy consumed by different systems making 10 and 100 acquisitions per second.

TABLE 3: SERIAL MRAM ENERGY CONSUMED DURING WRITE OPERATIONS

Number of SPI bytes	Capacitance (µF)	Rise-time energy⁴ (µJ)	t_{PU}	t_{PU} energy¹ (µJ)	Write time at 40 MHz (µs)	Write energy² (µJ)	Total energy (µJ)	Energy/data byte³ (µJ)
4	1.0	4.41	400	0.14	1.6	0.06	4.6	1.15
46	1.0	4.41	400	0.14	10	0.48	5.0	0.11
Notes	1. The energy consumed by the MRAM during the power-up delay (t_{PU}) is given by V_{DD} × standby current × time. 2. Write energy is given by V_{DD} × Active current × time. 3. The number of data bytes is four less than the number of SPI bytes due to the required overhead. 4. Rise-time energy = 1/2 CV^2.							

ENERGY CALCULATIONS

Energy used by an EEPROM

Let's start by looking at the energy used by the non-volatile memory during writing by a typical 3.3-V EEPROM with a standby current of 1 µA, a write time of 5 ms and a write current of 3 mA *(Table 1)*. We will assume that:

- The EEPROM is ready to begin its operation as soon as V_{DD} rises to be within operating limits (a power-up time of zero).
- The amount of data written fits into one page and writing takes place using the block write capability.
- The write time of the EEPROM is only that required to perform the write operation of the EEPROM, so we ignore any processing and communication time of the MCU and SPI interface. (This assumption is the opposite of that used for MRAM; MRAM only

TABLE 4: SUMMARY OF THE ENERGY CONSUMED PER ACQUISITION

Memory type	Number of acquisitions per second⁴	Active time¹ (ms)	Sleep time² (sec)	Energy consumed sleep time³ (µJ)	Energy consumed making acquisitions (µJ)	Total energy (µJ)
MRAM	10	4.5	0.995	6.6	20.6	27.2
	100	4.5	0.955	6.3	206.4	212.6
EEPROM	10	5.05	0.950	6.3	93.4	99.6
	100	5.05	0.495	3.3	933.7	937.0
Serial flash	10	35.0	0.965	6.4	441.8	448.1
	100	35.0	0.650	4.3	4418.0	4422.3
Notes	1. Active time is given as 100 µs of MCU time + storage time. 2. Sleep time is given as 1 – active time. 3. Energy consumed while asleep is given by 3.3 V × 2 µA × time. 4. Four bytes per acquisition.					

requires communication time because the write time is so short that it can be considered to be zero.)
- The EEPROM is powered directly from the microcontroller I/O and uses a small (0.1 µF) decoupling capacitor.

Energy used by a serial flash

Serial flash has much higher write and standby currents, so we will use a standby current of 50 µA, a write time of 3 ms, and a write current of 15 mA in our evaluation *(Table 2)*. As with the EEPROM example, we assume zero power up time, the data fits into one page, and the write time is so long that we can ignore the communication time. In addition, we assume that the flash writes are to a pre-erased page.

Energy used by an MRAM

For MRAM, we based the evaluation on Everspin Technologies' MR25H256, a 256-kb serial SPI MRAM. *Table 3* shows the energy per data byte is lowest when using all of the energy from the decoupling capacitor. The decoupling-capacitor size should be chosen to match the amount of data that typically would be acquired by the system.

A 1-µF capacitor allows for the writing of 50 bytes (46 data bytes) on the SPI bus at 40 MHz, with the MRAM consuming a total of 27 mA. This calculation is the source of using 46 bytes for comparisons.

Energy used by the MCU and LDO

For the MCU, it might take 100 µs to wake up, make a measurement, and communicate the result to non-volatile memory and any required housekeeping. During this time, we assume an active current consumption of 500 µA (typical of small microcontrollers running at ~5 MHz). Thus, energy consumed is 3.3 V × 500 µA × 100 µs = 0.165 µJ per data acquisition.

In addition to the energy to make an acquisition, we should consider the energy required to keep the MCU active during the non-volatile memory write. When not acquiring or storing data, the MCU was in a sleep state that consumed 5 µA. The power supply was assumed to be an LDO that consumes 1 µA during all phases of operation (active and sleep).

RESULTS SUMMARY

Table 4 shows the energy used by systems that make 10 and 100 acquisitions per second (four bytes per acquisition). For 100 acquisitions per second, EEPROM required 0.5 seconds just in write time. A larger number of acquisitions would have to look at caching the acquisition data and performing block writes. *Figure 3* graphically summarizes the results.

Energy Consumption Effect: Power Gating vs. Sleep Mode

EEPROM has low standby power consumption, so operating it with V_{DD} always present could be considered. However, the write energy of just one write operation to EEPROM is equivalent to it being in standby mode for about 15 seconds. Again, the write energy is dominant.

Power gating really applies to MRAM, where the fast Write time significantly reduces the amount of energy that's utilized. The energy consumption of an acquisition using MRAM is 1.54 µJ. This is the same as a 3.3-V EEPROM with a standby current consumption of 1 µA being in standby for 0.46 seconds.

The write energy is dominant over standby energy.

CONCLUSION

The write time of a non-volatile memory greatly affects the total energy consumption of a system. The effects are less pronounced for systems with a low duty cycle, but become more pronounced with rising acquisition rates.

The write time of EEPROM and flash significantly increase the energy consumption of the MCU, since they cause the MCU to be active for longer. Energy consumption could be reduced if the MCU was in a sleep mode while the writes to EEPROM and flash complete. However, the energy consumed by the EEPROM or flash represents most of the system's energy consumption. Consequently, having the MCU in sleep mode will not have a major impact on overall consumption.

It's clear that the lowest energy consumption can be achieved with a fast-write, non-volatile memory that's power gated. ed

DUNCAN BENNETT, product marketing manager, Everspin Technologies, Chandler, Ariz., has 27 years of experience in the electronics/semiconductor industry. He has spent the last 20 years in varied sales roles.

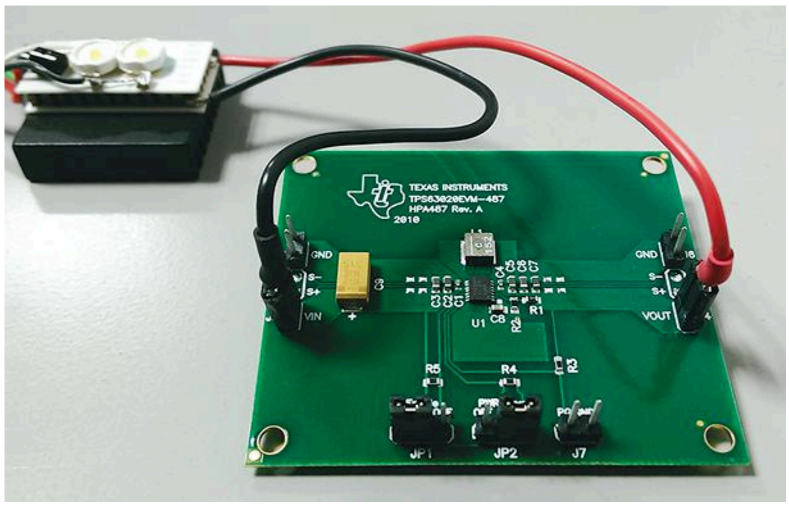
ANDREW POCKSON, divisional marketing manager at Anglia, Wisbech, U.K., is responsible for wireless and semiconductor products. He has over 15 years of distribution experience in technical and marketing support roles.

Simple Single-Chip Circuit Heats/Cools Laser's TEC

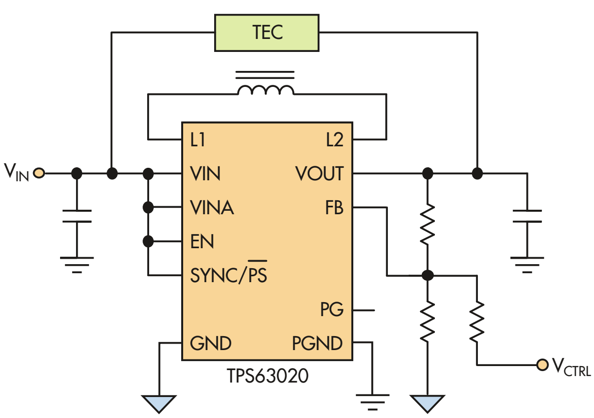
CHRIS GLASER | Applications Engineer, Texas Instruments

A MOST CRITICAL DEVICE in an optical networking system is the laser diode, since it's responsible for converting the electronic data to light pulses. This diode must be carefully controlled to stabilize the light output, and temperature is a key variable to determine the light's wavelength. Thermoelectric coolers (TECs) are commonly used as part of this stabilization process. Since TECs come in many different power levels and have unique power requirements, a specific type of power supply is required to drive them properly.

A TEC transfers heat energy from one plate to another to make the first plate cooler or warmer. A TEC doesn't consume energy itself; in other words, no energy is lost, but energy is required to operate the TEC. A TEC is modeled as a simple resistor that can withstand a certain voltage across it and current through it. This power corresponds to a maximum temperature difference between the two plates for a given TEC. The higher the power applied, the higher the temperature difference between the plates.



1. Shown is an example of a simple circuit (TI reference design PMP9759) that bidirectionally drives current through a TEC; the single-chip buck-boost converter requires a minimum number of components.

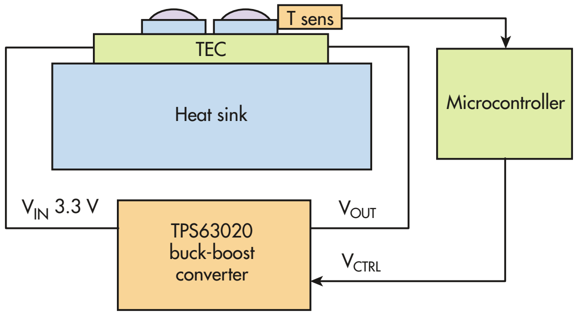


2. This circuit generates a bidirectional current flow through a TEC with just one converter and a few passive components.

An important aspect of TECs is their ability to both heat and cool. Since a TEC is permanently mounted or attached to the laser or other device needing temperature regulation, only one plate controls the laser's temperature. The other plate must be mounted to a heat sink to release the energy moved from the first plate. Both plates require very good thermal connections for best system performance.

Once installed in a system, the plates cannot be reversed. The TEC must support cooling and heating from a given orientation. TECs support this complementary function by controlling the direction of current flow. Current flowing in one direction cools one plate and heats the other, while current flowing in the reverse direction reverses this action, heating the first plate and cooling the second one. The result is a wider range of temperature control compared to current flowing in one direction only.

Since TECs require bidirectional current flow to achieve the desired performance, their power supply must support this dual mode as well. However, many power supplies can



3. In a complete closed-loop TEC temperature-regulation circuit, the MCU reads the temperature sensor and generates an output control signal to the buck-boost converter to adjust the TEC's temperature appropriately.

only source current. Therefore, a special circuit needs to be designed to swap the connections from the power supply to the TEC when cooling is needed versus heating, which complicates implementation of the supply.

An alternative approach is to design a power supply that can both source and sink current with unchanged connections to the TEC, thus meeting the current-flow requirements. However, only some power-supply designs support both sourcing and sinking current. In addition, the supply must support operation near a zero-current value, which is a common operating point.

The power-supply in *Fig. 1* is a circuit that can source and sink current for a low-power TEC. For example, a buck-boost converter such as the TPS63020 is used to either buck or boost the supplied input voltage in order to generate the desired current-flow direction. The topology of a buck-boost converter supports a wide output-voltage range, in this case from 1.2 to 5.5 V.

By integrating all power MOSFETs and requiring a minimum of external components, this circuit is a more preferred approach for low-power TECs where size is critical, such as in the smallest optical-networking modules. The buck-boost converter is powered from the common 3.3-V rail found in optical networking modules. The TEC's connections to the power supply (*Fig. 2*) allow a +2.1- to –2.2-V voltage difference across the TEC. Furthermore, the commonplace operating point near zero-current is easily supported in this configuration.

TEC orientation is critical to its heating or cooling. Modern electronics often appear to be somewhat warm and easy to further heat up. However, it's usually more difficult to cool a TEC enough to achieve the desired laser wavelength. Therefore, it's better to wire the TEC so that it's cooling when the buck-boost converter is sourcing current. The TPS63020, like many converters that both source and sink, can source more current than it can sink. Therefore, it can deliver a smaller amount of power when sinking, so sinking current should be used to heat the TEC.

In the complete system (*Fig. 3*), a microcontroller (MCU) monitors a temperature sensor on the TEC. Based on the TEC's actual-versus-desired temperature (the setpoint), the MCU adjusts the control signal (VCTRL) to move the buck-boost converter to a new operating point, sourcing or sinking more or less current to adjust the temperature.

CHRISTOPHER JAMES GLASER is an applications engineer for TI's Low Power dc/dc group. In this role, he supports customers, designs evaluation modules (EVMs), writes application notes, trains field engineers and customers, and generates technical collateral to make TI parts easier to use. He received his bachelor's degree in electrical engineering from Texas A&M University in College Station, Texas, and can be reached at ti_cglaser@list.ti.com.

REFERENCES

1. TEC TI Design (http://www.ti.com/tool/PMP9759).
2. TPS63020 datasheet (http://www.ti.com/lit/ds/symlink/tps63020.pdf).

Isolated Circuit Digitally Indicates 120-/220-V Line Voltage

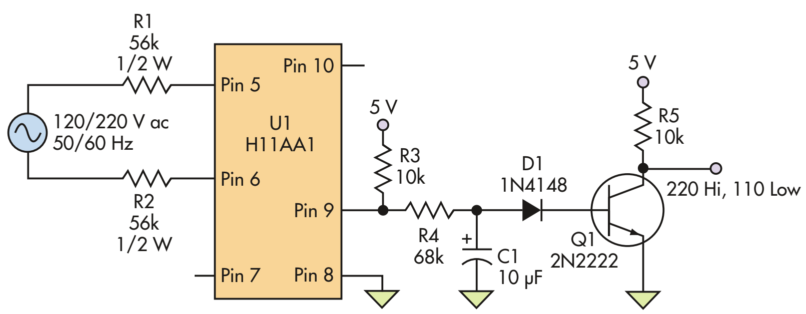
EDWARD K. MIGUEL | Independent Contractor

FOR APPLICATIONS SUCH AS MOTOR CONTROL or power supplies, it's often necessary to know whether the ac line is at 120 V or 220 V to adjust the operation. The circuit illustrated in the figure monitors the ac line and provides a basic output indicating whether it is at 120 V or 220 V, with the output at the transistor collector going low for 120-V and high for 220-V inputs.

The principle behind the circuit is to make the output of the optocoupler LEDs high enough at 220 V so that it will drive the internal phototransistor to turn transistor Q1 (a standard 2N2222) off to produce a high output, but low enough at 120 V for the phototransistor to turn Q1 on and yield a low output. Optocoupler U1 was chosen because it's rated and certified for line-voltage applications.

The ac-voltage input goes through resistors R1 and R2 and drives the back-to-back (antiparallel) LEDs inside U1. The LED current, about 1 mA at 120 V and 2 mA at 220 V, is set low to minimize the degradation in current transfer ratio (CTR) over time, which is common with optocouplers (*see references*). Voltage spikes, which occur at the output of U1 due to the zero crossings where the LEDs aren't conducting, are narrowest at 220 V as the phototransistor is driven to saturation.

After RC filtering with a 0.7-second time constant, the average voltage isn't sufficient to turn on Q1; thus, the output is



At 220-V ac input, the optocoupler's LEDs turn Q1 off and it has a high output; at 120-V ac, Q1 is on and its output is low.

high. Since the current at 120 V is insufficient to fully drive the phototransistor, its output is pulled up by R3 (after filtering by C1/R4) and drives Q1 into saturation. In effect, Q1 is functioning as a low-gain comparator that's slowly switching between the high and low states at the "don't care" line voltages of 150 to 170 V, 50/60 Hz.

When the line is at 120 V, there's a short period of about one second at power-on when the output will go high and then low, while the capacitor is being charged. This temporary state may need to be ignored, depending on your monitoring circuit. If the 120-V input will always be at 60 Hz, or the 220 V will always be at 50 Hz, and if the monitoring circuit has some time-measuring capability, C1 can be removed. This results in a square wave that can be used to measure the half-period of the ac input (8.33 ms for 120 V and 10 ms for 220 V). Finally, if the output is coupled into a low-impedance load, it's a good idea to buffer the output with an emitter-follower transistor stage to reduce the loading.

EDWARD K. MIGUEL is now an independent contractor in DeKalb, Ill., who has worked for 40 years in design and management, specializing in frequency control. He received his BS and MS in EET from Northern Illinois University, with a specialty in quartz frequency control. He can be reached at northerlabs@gmail.com.

REFERENCES:

"Calculate Reliable LED Lifetime Performance in Optocouplers," Avago Technologies/Broadcom.
"How to simulate Current Transfer Ratios (CTR) and long-term CTR degradation in transistor optocouplers," California Eastern Laboratories.
"Study and Modelling of Optocouplers Ageing," Journal of Automation & Systems Engineering.

IDEAS FOR DESIGN WANTED

Send us your Ideas For Design. We'll pay you $150 for every Idea For Design that we publish. In addition, this year's top design as selected by our readers will earn an additional $500, with two runners-up each receiving $250. You can submit your Ideas For Design via:

- E-mail: roger.engelke@penton.com

OR BY

Postal mail to:

Ideas For Design

Electronic Design

1166 Avenue of the Americas, 10th Floor

New York, NY 10036

Go to www.electronicdesign.com for our submission guidelines.

EBX-compatible SBC, IO60 Data Acquisition Module Unveiled

WINSYSTEMS' NEW IO60-M410 is a reliable data acquisition module for embedded systems with IO60 expansion featuring 24 GPIO tolerant to 30 Vdc. Activity LEDs indicate device communication and DAC fault. Custom configurations are available for OEM clients. Other features include eight-channel ADC, four-channel DAC, 24 channel DIO, and a –40°C to +85°C operational range. The RoHS-compliant IO60-M410 data acquisition module supports Windows and Linux x86/64-bit drivers.

Expected to be released soon, the EBC-C413 is an EBX-compatible SBC, which uses Intel's BayTrail processor. Its rugged design and –40°C to +85°C operational temperature range suit the EBX computer for industrial applications. The SBC includes PC/104 and PC/104-Plus expansion buses, 8 USB 2.0 ports, four serial ports (RS-232/422/485), two 10/100/1000 Mbps Ethernet ports, 48 bidirectional GPIO, and two MiniPCIe sockets, 1 MSATA, and onboard CompactFlash sockets.

Also expected soon from WinSystems is the SBC35-CC411, an industrial SBC with 5th Gen Intel Core i7/i5/i3 processors. Features include four USB 2.0, two USB 3.0, three Ethernet Channels, two MiniPCIe, and a –40°C to +85°C operational temperature.

WINSYSTEMS

www.winsystems.com

Reference Design Describes USB-PD Fast Chargers

POWER INTEGRATIONS in association with Cypress Semiconductor, has produced a joint reference design, DER-533, which describes a 20 W, USB-PD compliant ac-dc power converter targeted at chargers for smart mobile devices. The design pairs the EZ-PD CCG2 USB Type-C port controller from Cypress with Power Integrations' InnoSwitch-CP off-line CV/CC flyback switcher IC, enabling designers to produce a standards-compliant power adapter that is compact and energy-efficient. Cypress' EZ-PD CCG2 USB Type-C port controller integrates a Type-C transceiver, termination resistors and system-level ESD for passive EMCA cables, active EMCA cables, notebooks, power adapters, monitors, docks and cable adapters.

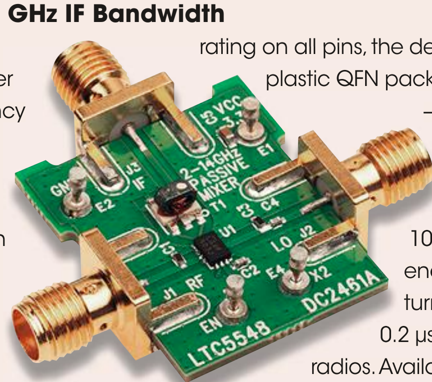
By providing a constant power output, InnoSwitch-CP allows battery-operated devices to draw up to the maximum power of the charger at any selected output voltage. InnoSwitch-CP ICs use Power Integrations' FluxLink technology, eliminating the need for an optocoupler and enabling secondary-side control that boosts transient performance and CV/CC regulation with low no-load power consumption. The DER-533 reference design implements Profile 2 of the USB-PD standard and is capable of 5 V / 3 A and 9 V / 2.2 A of power delivery over a standard 3 A USB Type-C cable.

POWER INTEGRATIONS

www.power.com

2 to 14 GHz Mixer Delivers DC to 6 GHz IF Bandwidth

THE LTC5548 from Linear Technology is a double-balanced mixer that operates either as an up- or downconverter with a frequency range from 2 to 14 GHz. The mixer features integrated balun transformers at the RF and LO ports, providing 50 Ω match from 2 to 13.6 GHz and from 1 to 12 GHz at each port, respectively, while enabling single-ended operation. Additionally, the IF port is capable of dc to 6 GHz, supporting wideband transmitters and receivers at the baseband, and its linearity is 24.4 dBm IIP3 at 5.8 GHz, and 21.4 dBm at 9 GHz.



With an ESD handling capability of 2,000 V ESD HBM rating on all pins, the device comes in a 12-lead 3 × 2 mm plastic QFN package and is rated for operation from –40°C to 105°C case temperature. It is powered from a single 3.3 V supply, drawing a nominal supply current of 120 mA and when deactivated, 100 µA maximum standby current. The enable pin can be driven directly to turn the device on and off in less than 0.2 µs, supporting TDD or burst mode type radios. Available now, the LTC5548 double balanced mixer is priced starting at $9.50 each/1,000.

LINEAR TECHNOLOGY

www.linear.com

32 kHz Super-TCXO Includes In-System Auto-Calibration

THE SIT156X/7X FAMILIES of 32 kHz Super-TCXOs from SiTime Corp. are available in a 1.2-mm² footprint and utilize TempFlat MEMS technology. The SiT1568 also offers an in-system, auto-calibration feature that helps to eliminate timing inaccuracies introduced during system assembly, reflow, underfill and overmolding. The MEMS Super-TCXOs also feature ±5 ppm accuracy initial offset and variations over industrial temperature (–40°C to +85°C); a programmable temperature sensing update rate that maintains dynamic and overall stability in the presence of fast thermal gradients; optional factory-programmable frequencies from 1 Hz to 1 MHz (SiT1576) to support low-power RF and wireless charging; and the ability to drive multiple loads and the SiT1566. Both can also be used as audio references in wearable electronics.

Available now in a 1.5 × 0.8 × 0.6 mm CSP, the SiT1566, SiT1568, and SiT1576 Super-TCXOs can perform the following critical functions in a wearable, IoT, or mobile system: reference for RTC function; sleep clock for connectivity—Bluetooth, BLE, and Wi-Fi; and reference for audio subsystem. Samples of the rest of the SiT156x and SiT157x families are available now for qualified customers. General availability and production volumes will be available in Q2 2016.

SITIME CORP.

www.sitime.com

Support for OpenSwitch Extended to XPliant Switches

CAVIUM IS NOW PROVIDING support for the OpenSwitch open-source NOS on its XPliant Ethernet switches. Additionally, the company has introduced Open APIs for the XPliant Programmable Switch (OpenXPS) open-source software. OpenSwitch, a Linux-based NOS, is optimized for the scale and architecture requirements of next-generation data center networks. It boasts a developer ecosystem with the ability to accelerate innovation, allowing for the construction of data center networks customized for particular business applications.

OpenXPS APIs map the XPliant Software Development Kit (XDK) feature–set to an open-software interface enabling integration of custom applications on the extensible XPliant switch hardware platforms. The APIs free up users to select their software control plane in disaggregation with the hardware. Visit www.openswitch.net for more information.

CAVIUM

www.cavium.com

Ultra-Compact Mini-PC Based on Intel's NUC Platform

LOGIC SUPPLY'S NEW SMALL-FORM FACTOR, fanless and ventless industrial PC, the CL100 Series is built around Intel's Next Unit of Computing (NUC). Developed with feedback from a large network of IPC users, the series features a Quad-Core Intel Celeron N3150 processor with onboard Intel HD Graphics. Aimed at the industrial market, the systems also include a range of features suited to both commercial and consumer applications. Powering triple independent displays and accommodating 4k resolution, the mini-PC series is suited for digital signage, kiosk and other multimedia applications.

Connectivity includes 3x USB 3.0, USB Type C, 2x HDMI, DisplayPort, and Gb LAN. The PCs can be configured with up to 16 GB of RAM and are Wi-Fi- and Bluetooth-capable. Operating system options include Windows and Ubuntu Linux. The CL100 Series industrial mini-PCs utilizes a unique Hardshell Fanless Technology, which combines proprietary solid-state cooling, ingress protection, and ruggedization to create dependable industrial computers.

LOGIC SUPPLY

www.logicsupply.com

COM Express Integrates 6th-Gen Intel Core i7/i5/i3 SoCs

THE MB-73430 BASIC-SIZE COM EXPRESS MODULE from WIN Enterprises features Type-6 pin-outs and supports a wide range of the new Intel 6th Generation Core i7/i5/i3 SoC processors. With low power usage and more powerful graphics support, the 6th gen Intel processor family boosts productivity in areas like 3D gaming, factory automation and counter- and cart-based medical applications. The high performance of the new processors supports fluid video streaming to enhance training, visualization, and other data-intense applications.

The module also has three DDI channels and one LVDS. It supports up to three independent displays and supports Intel Gen9 HD Graphics with HEVC (H.265). The unit enhances high-density streaming applications and optimized 4K video conferencing with HEVC (8-bit), VP8, VP9, and VDENC encoding, decoding, and transcoding. The MB-73434 COM Express module provides up to 32 GB dual-channel DDR4 memory; and enables a range of voltage inputs for environments from mobile, embedded, countertop, and desktop.

WIN ENTERPRISES

www.win-ent.com

For more information on products or services visit our website www.electronicdesign.com, menu item Reader Service. The advertisers index is prepared as an extra service. *Electronic Design* does not assume any liability for omissions or errors.

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

New Cameras and Apps Drive Augmented and Virtual Reality

Augmented and virtual-reality glasses are taking off with the help of 360-deg. cameras and new applications.

At the 2016 Consumer Electronics Show and since then, there have been hordes of people wearing funny goggles, waving their hands or pointing to something only they can see. Welcome to the world of augmented reality (AG) and virtual reality (VR). The advent of eye-based, high-resolution mobile displays is upon us and it is going to change the way we look at the world, real and imaginary.

Facebook's Oculus Rift is an example of virtual-reality goggles that provide an immersive environment where all visual feedback is through the goggles. Head tracking is critical to the presentation for gaming where VR is popular, especially when combined with other tools like the Virtuix Omni (*see "Consumer Electronics Take User Interfaces Beyond Your Fingertips" on electronicdesign.com*) or Kat Walk treadmill (see *"Kat Walk Omnidirectional Treadmill Enhances Virtual Reality" on electronicdesign.com*).

Microsoft's HoloLens is an example of AR goggles (*Fig. 1*). AR adds to what a person normally sees. It can be used for gaming, but there are many other AR applications. It provides a heads-up display that can show general information or location/viewing information based on a person's current location. Some applications synchronize the view with objects in the view allowing overlays such as training or support information.

1. Microsoft's HoloLens is an augmented reality system designed to overlay imagery that blends with the user's real view of the world.

2. Vuze VR generates a 360-deg. stereoscopic view using eight cameras.

3. Kodak PIXPRO SP360 Action Camera is a 4K, 360-deg. hemispherical camera. Two can be paired to record a complete sphere.

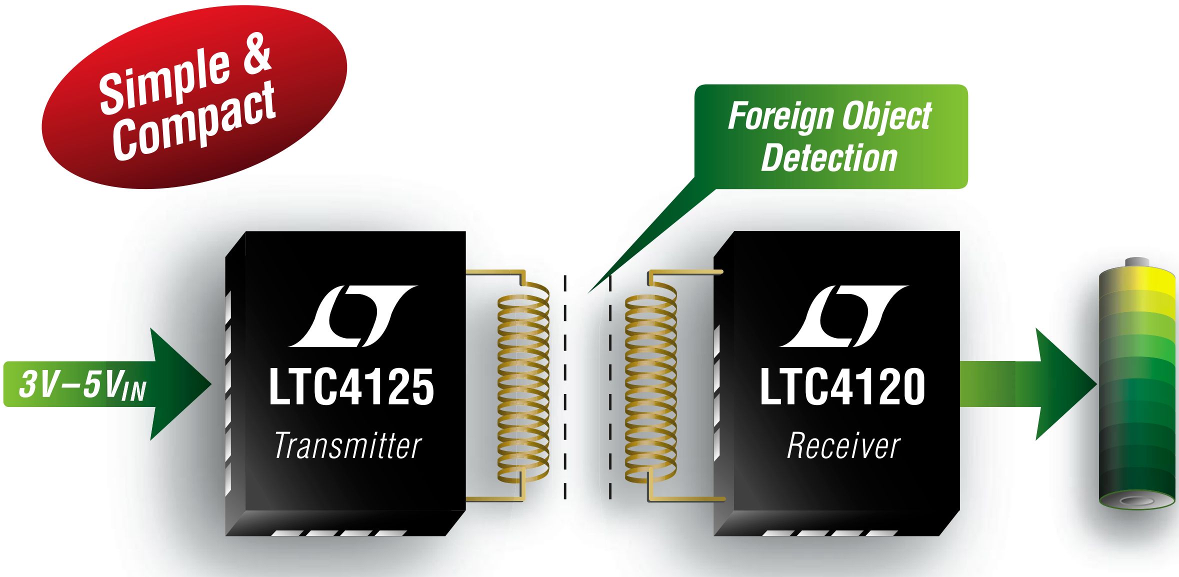
Many AR and VR applications are being made more practical with 360-deg. cameras. The Vuze VR Camera (*Fig. 2*) can record 360-deg. HD video streams simultaneously from eight cameras spaced around the unit. It can record to an SD flash card for an hour. Each camera has an ultra-wide and vertical angle lenses to capture 120-deg. horizontal and 180-deg. vertical images. The videos are knitted together to create a 4K resolution, 360-deg. video. The cameras have overlapping coverage to provide stereoscopic videos.

The $449 Kodak PIXPRO SP360 Action Camera records a 360-deg. hemisphere with a 1080p resolution (*Fig. 3*). A 4K version is also available. The SP360 uses a single, 16 Mpixel camera and an interesting curved, spherical lens. It records at 10 frames/s. The battery-operated camera can record at 1080p for 160 minutes. The camera records to a microSD card or via the wireless 802.11n support.

Not all AR/VR applications need recorded video, but many do. This may eventually be the norm in the same way that smartphones have replaced cameras and camcorders for most users. The PIXPRO SP360 and Vuze VR are just two of a growing number of similar cameras. Likewise, the Oculus Rift and HoloLens are just two of a similar growing family of VR and AR goggles. The best is yet to come. ed


MAKING
HEROES
OUT
OF US
EVERYDAY
DURACELL
MPD
MEMORY PROTECTION DEVICES
MPD IS A GLOBAL MANUFACTURER OF BATTERY HOLDERS AND OTHER ELECTRONIC COMPONENTS. WE BELIEVE THAT OUR COMPONENTS SHOULD FIT EASILY INTO YOUR DESIGNS, WHICH IS WHY WE ARE ALWAYS CREATING INNOVATIVE NEW PRODUCTS.
BATTERYHOLDERS.COM
ALL PRODUCT NAMES, LOGOS, AND BRANDS ARE PROPERTY OF THEIR RESPECTIVE OWNERS.
MPD TRADE MARKS, ALL OTHER REGISTERED TRADEMARKS OR TRADEMARKS ARE PROPERTY OF THEIR RESPECTIVE OWNERS.
USE OF THESE NAMES DOES NOT IMPLY ANY CO-OPERATION OR ENDORSEMENT.

Complete Wireless Charging



Reliable Charging Tolerant of Coil Coupling Misalignment

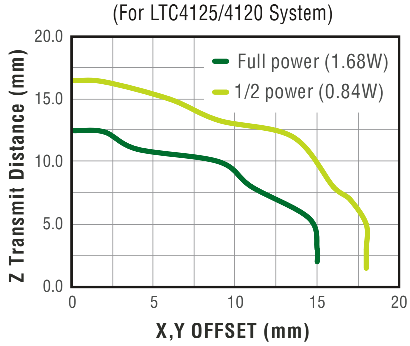
The LTC®4125 wireless power transmitter brings a new level of performance and simplicity to the transfer of up to 5W of power wirelessly to an electrically isolated receiver capable of that power level. It is a monolithic driver that controls the current flow in a series-connected transmit coil LC network. The LTC4125 features auto-resonant switching, allowing it to automatically adjust its driving frequency to match the LC network resonant frequency. It also implements foreign object detection, and auto-resonant switching improves performance with mismatched resonant components and poorly coupled coils. The LTC4125 completes a simple wireless power solution when combined with one of Linear's wireless power receiver ICs.

Features

- Uses Standard Coils
- Auto-Resonant Switching Frequency Adjusts to Resonant Capacitor & Transmit Coil Inductance
- Transmit Power Automatically Adjusts to Receiver Load
- Integrated 100mΩ Full Bridge Switches
- Foreign Object Detection
- 4mm x 5mm QFN-20 Package

Power Transfer vs. Alignment

(For LTC4125/4120 System)



Info & Free Samples

www.linear.com/product/LTC4125

1-800-4-LINEAR