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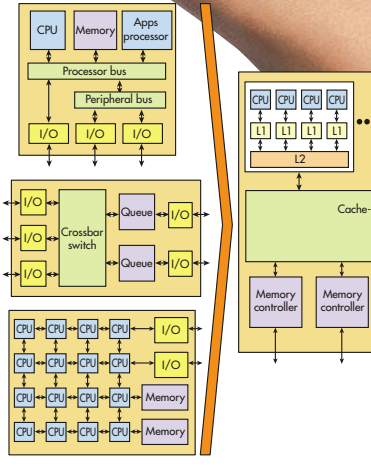

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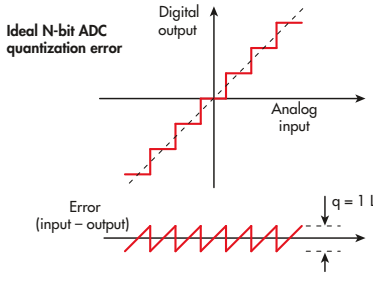

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EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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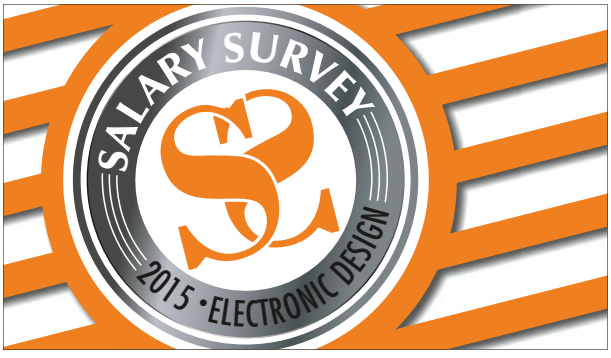


2015 COMPENSATION SURVEY: IT'S NOT ALL ABOUT THE MONEY

http://electronicdesign.com/salarysurvey

According to the nearly 3,000 electrical engineers that participated in *Electronic Design*'s 2015 Compensation Survey, the engineering profession is in a period of transition. On the one hand, companies are still in the process of recovering from the economic recession and risk-averse corporate culture. On the other hand, the Internet of Things (IoT) is slowly maturing into a reality for technology companies, igniting demand—and competition—for engineering expertise.

IMAGE GALLERY: RECAPPING MAKER FAIRE 2015

http://electronicdesign.com/iot/latest-3d-printing-and-iot-maker-faire-2015

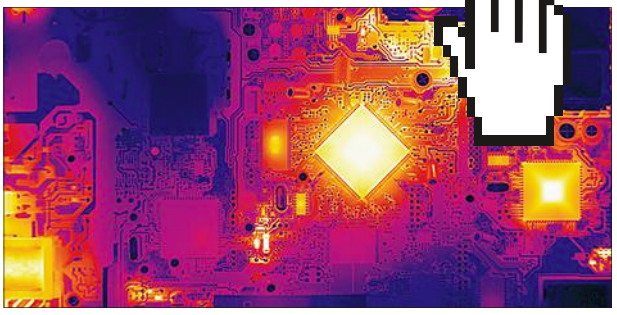
The 6th World Maker Faire at the New York Hall of Science brought together an estimated 100,000 DIY enthusiasts, makers, inventors, artists, and technologists. Along with a raft of fun projects, the event saw some real advances in technology application, including the unveiling of the first mobile 3D smartphone printer, floating wireless lightbulbs, increasingly dramatic drone wars and races, and cloud-based home-security projects.

blogs

LOUIS FRENZEL
COMMUNICATIONS
• Will Noise and Interference Throttle the Internet of Things?

BILL WONG
EMBEDDED/ SYSTEMS/SOFTWARE
• On the Matter of Volkswagen, and Cheating Benchmarks

PATRICK MANNION
TEST & MEASUREMENT
• True Big Data on Display at ITC 2015



ELECTRONIC COMPONENT TESTING: A NON-CONTACT SPORT

http://electronicdesign.com/test-measurement/electronic-component-testing-non-contact-sport

Electronics don't like it hot. That's why electronic systems designers are looking for ways to keep their components cool in ever-smaller devices. As chips shrink and densities within components grow, heat can become a real problem—not only for devices used in civilian life, but in the military as well. In the latter case, the problem expands beyond inconvenience to one of safety.

Q&A: SIZING UP SILVER-NANOWIRE TECHNOLOGY

http://electronicdesign.com/displays/qa-cambrios-lemoncheck-talks-about-silver-nanowire-technology

Cambrios CEO John LeMoncheck and *Electronic Design* Technology Editor Bill Wong discuss silver nanowire technology's rise in popularity, as well as the challenges facing the display and sensor industry.

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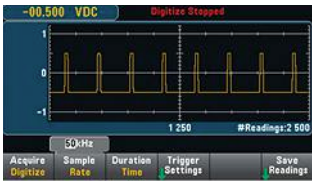

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Histogram

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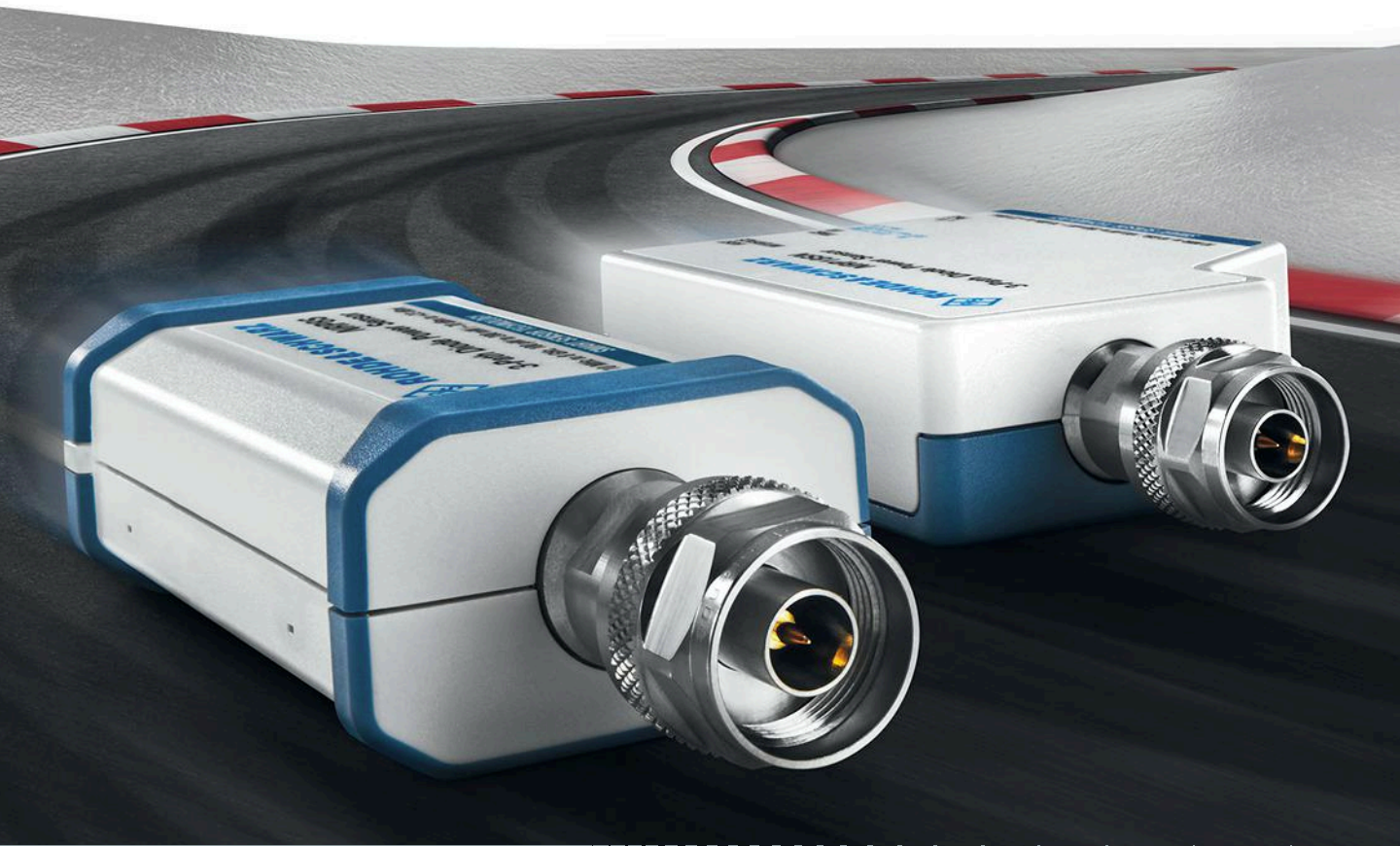

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PETER REESE /Contributing Editor

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MEETING FUTURE CHALLENGES with Solutions

Through the use of an open-systems architecture and industry cooperation, it will be possible to develop cost-effective EW systems for use in ever more complex EM operating environments.

ELECTRONIC WARFARE (EW) is undergoing what is arguably its most broad-based, innovative, and pervasive transformation since the Cold War. Not only is EW regaining the first-tier role it had more than 25 years ago, but it is also joining forces with cyberspace. It is leading the charge to the use of open-system architectures, and is one of the core ingredients in the Pentagon's mission to ensure that the United States maintains the long-held "spectrum dominance" that it is in jeopardy of losing. To understand the significance of this paradigm shift, it is important to delve into each of these changes.

The first use of "electronic attack" probably occurred when telegraph wires through which the Federal Army communicated were cut (possibly dispatching the telegrapher in the process). The advent of radio communications and then radar brought EW into the RF domain, which led to a continuing stream of innovations during World War I, World War II, the Korean War, the Vietnam War, and various other conflicts. By the end of the Cold War, EW had become an indispensible military tool.

With the fall of the Soviet Union, the U.S. and allied pow-

(continued on p. S18)

HERMETIC CONNECTOR Seals Portable Memory Devices

IN SUPPORT of Datakey portable memory devices from ATEK Access Technologies (www.atekaccess.com), Sigma Space Corp. (www.sigmaspace.com) has developed a solid-state-recording-device (SSRD) hermetic memory connector. The connector employs a Datakey receptable mounted inside a MIL-SPEC circular metal shell. When combined with the appropriate portable memory device, the connector forms a removable memory component that can withstand the high shock and vibration found in military vehicles and airborne environments.

Roman Machan, Chief Technology Officer (CTO) at Sigma Space Corp., explained that "Sigma Space needed a military connector that was protected from the elements and could function under the shock, vibration, electromagnetic interference (EMI), and low-pressure environments found in airborne platforms at 60,000 ft." He added that "ATEK was instrumental in allowing us to develop a removable memory solution that meets the extreme demands of high-altitude airborne instruments."

The firm's RUGGEDrive memory token is physically constrained within the sealed connector enclosure for protection. The connector is designed specifically for RUGGEDrive and serial memory tokens and provides protection, even in high-vibration environments. Sigma Space will use the SSRD connector and the Datakey RUGGEDrive memory token for the logging of instrumentation data onboard NASA high-altitude research aircraft. ■

(continued on p. 6)

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More Surveillance Means More Data

SURVEILLANCE MARKETS would appear to be growing steadily (see p. s10), even as stories leak out about the U.S. Air Force's insect-sized drones with spying capabilities. What these and other unmanned aerial vehicles (UAVs) provide are full capabilities to perform surveillance around the world—and even on any domestic targets, as required. Of course, what may not be quite so obvious about these expanding surveillance capabilities is the accompanying need to process the data from all those subjects, and this could be quite a bit of data.

Both government and private users are projecting futures where surveillance is commonplace—and even a way of life—due to the large number of miniature drones with detection devices for capturing audio and video information on a person of interest. Any activities that present security concerns will undoubtedly be accompanied by these little spies, thus ensuring that a financial deal is above board, a contract is upheld, and so forth (not to mention what such surveillance drones may mean to married life).

For example, DARPA wants micro aerial vehicles (MAVs) that can hide in plain sight and perform surveillance as if they were insects. And the Air Force is rumored to be working with the University of Pennsylvania, School of Engineering, as well as private industry, on the design and development of its own miniature drones.

With the ease of adding Global Positioning System (GPS) devices to the many portable electronic communications devices currently being sold to the general public, details about a person's precise whereabouts at a certain time can be readily known and monitored. In fact, with the public's growing reliance on portable communications transceivers, such as cell phones, surveillance data can be easily gathered from cellular base stations and other components of the wireless communications infrastructure—including in-building communications systems.

But in addition to being processed and stored efficiently, this spy data must be managed securely, so as to protect whatever privacy might be left for an individual. With regard to this growing private-sector surveillance market, several business opportunities immediately present themselves: Larger and more efficient solid-state memory devices represent one, with software capable of filtering and managing data being another. The data must also be protected from "prying eyes," especially in sensitive matters where legal decisions and courtrooms may be involved.

As noted before, the potential amount of data from future surveillance activities is enormous. Details concerning any event or activity captured as a result of these activities can appear suspicious if taken out of context. As a result, meaningful data from surveillance activities will also require additional data that establishes a context for the captured information. All this will create the need for larger, more efficient data storage devices, faster computers, and software written to find meaning in all of the data captured as a result of surveillance, whether for commercial, industrial, or military reasons.

Having a need for surveillance in this world is unfortunate. But since there is a need, it should be performed as honestly and effectively as possible. Such a task can be greatly aided by advances in computers, memory, and software. de

JACK BROWNE, *Technical Contributor*

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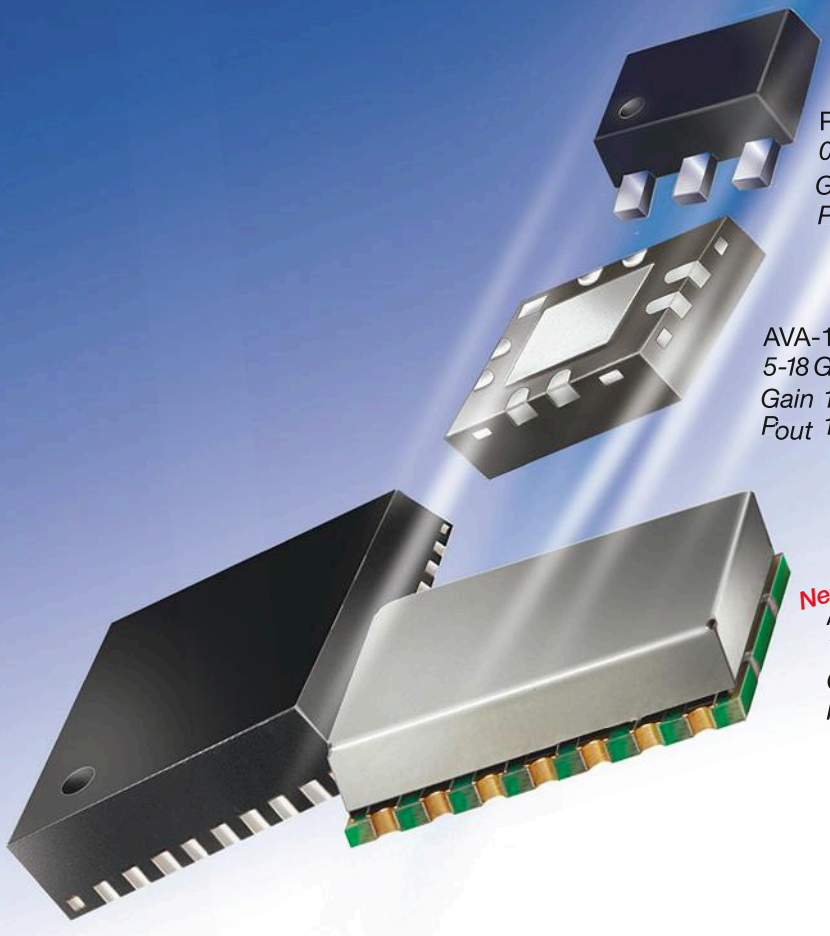

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ARINC UrgentLink
Promises Disaster Coms

ROCKWELL COLLINS (www.rockwellcollins.com) recently demonstrated its answer to the need for reliable communications during disasters and emergencies: the Aeronautical Radio, Inc. (ARINC) UrgentLink network. This is a communications network designed to provide reliable service to first responders and public safety officials in the event of an emergency and/or when other forms of communications have been destroyed. The network was unveiled at the recent Annual Association of Public Safety Communications Officials (APCO) 2015 event (www.apco2015.org) in Washington, DC.

According to Jeff Standerski, senior vice president for information management services for Rockwell Collins, "ARINC UrgentLink is the first network capable of providing reliable communications coverage, even inside the area most directly impacted by the disaster."

The ARINC UrgentLink network, which is available as a subscription-based service, uses radio frequencies licensed by the Federal Communications Commission for disaster use. The proprietary radios developed by Rockwell Collins use high-frequency (HF) signals to provide one-touch voice and data communications for emergency service providers inside a disaster zone. The HF radios are not hindered by the limitations of other communications systems, including ionospheric fluctuations, sunspots, and frequency jamming. ■

FOURTH MUOS SATELLITE Added to Secure Coms Systems

SECURE communications by way of satellite is now fully global, with the delivery and launch of the fourth Mobile User Objective System (MUOS) satellite for the U.S. Navy by Lockheed Martin (www.lockheedmartin.com). The MUOS-4 satellite was set to launch this past August 31 aboard a United Launch Alliance Atlas V rocket. The Navy's mobile communications network employs a network of orbiting satellites and relay ground stations to provide beyond-line-of-sight communications to mobile military users. The communications network can provide voice, video, and high-speed data over an Internet-Protocol (IP) based system.

According to Iris Bombelyn, vice president of narrowband communications at Lockheed Martin, "Delivery of this fourth satellite for the U.S. Navy completes the initial MUOS constellation and provides near-global coverage for the network. For our mobile forces, that means for the first time they will be able to have secure, high-fidelity voice conversations, networked team calls, and data exchange—including video—with anyone around the world connected with a MUOS terminal."

The MUOS network supports the legacy ultra-high-frequency (UHF) communications satellite system, although with about 16 times the capacity of the legacy system. More than 55,000 currently fielded radio terminals can be upgraded for MUOS compatibility. The first three satellites in the MUOS network were launched in 2012, 2013, and early 2015, respectively, with a fifth, system-spare satellite with wideband code-division-multiple-access (WCDMA) technology scheduled to launch in 2016.

The Navy's Program Executive Office for Space Systems and its Communications Satellite Program Office are responsible for administering the MUOS program. ■

KRATOS NAMES ADELMAN President of Microwave Electronics Division

YONAH ADELMAN has been appointed the next president of the Microwave Electronics division of Kratos Defense & Security Solutions, Inc. (www.KratosDefense.com). He will be responsible for the firm's U.S. and international microwave and electronics business, which includes operations and manufacturing facilities in Israel. These facilities provide a wide range of products, including power amplifiers, integrated microwave assemblies (IMAs), beam-forming modules, waveform and signal generators, and other subsystems for a wide range of applications. These include guided munitions, electronic warfare (EW), radar, and satellite communications (satcom) systems.

Concerning this new appointment, Eric DeMarco, Kratos' president and CEO, observed: "The opportunities that Kratos has in the microwave and electronics business are significant, and we believe that we have the potential for significant international sales growth if we successfully execute our strategy over the next few years."

Adelman began his professional career at General Microwave Corp., Amityville, N.Y., as a research and development microwave engineer. He later moved to Israel to help establish General Microwave Israel, which was acquired by Kratos in 2011. ■

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Missile Defense Agency Eyes Raytheon for Study

THE UNITED STATES MISSILE DEFENSE AGENCY has expressed interest in a multiple-object kill vehicle concept, which in turn has spurred an award to Raytheon Co. (www.raytheon.com) for a study contract to learn more about developing a vehicle that can destroy several objects within a threat complex.

The study will consider the use of advanced sensors, communications, and attitude control technologies. The competitive cost-plus-fixed-fee contract is valued in excess of $9 million.

Dr. Thomas Bussing, vice president of advanced missile systems for Raytheon, explained the reasoning behind the work: "We fully support the Missile Defense Agency's goal of increasing the effectiveness and reliability of our homeland defense by exploring a wide range of capabilities against long-range ballistic missiles, and using proven technologies combined with innovative designs."

The work will be performed in Tucson, Ariz., and Huntsville, Ala., by Raytheon's advanced missiles product group. The contractor will define critical functional aspects of the concept and propose risk mitigation activities. In addition, Raytheon will define a proof-of-concept prototype demonstration program. The estimated completion date for the study is May 2016. ■

Cubic Works on ACTS for F-35 Joint Strike Fighter

CUBIC GLOBAL DEFENSE, part of Cubic Corp. (www.cubic.com), has been awarded a series of contracts from Lockheed Martin Aeronautics (www.lockheedmartin.com) to produce and enhance the Air Combat Training System (ACTS) in the F-35 Joint Strike Fighter (JSF).

The enhancements will enable the F-35 to maintain stealth cover even during training. The P5 Combat Training System (P5CTS) ensures the stealth characteristics and provides secure, real-time, and post-mission training for air-to-air, air-to-ground and surface-to-air combat missions. The JSF P5 is an encrypted training system that is interoperable with the P5CTS/Tactical Combat Training System (TCTS) used by the U.S. Air Force, Air National Guard, Navy, and Marine Corps, plus many international partners.

"We are very proud to continue to team with Lockheed Martin to support the fifth generation community," said Bill Toti, president of Cubic Global Defense. "This latest award demonstrates Cubic's long history of delivering air combat training solutions to air forces across the globe, and assures the F-35 community an integrated and comprehensive secure training environment including previous generations and other F-35 aircraft."

As the prime contractor, Cubic is responsible for performance in all areas of systems engineering and for development, integration, and installation of the ground instrumentation subsystem. Engineering work for the training systems will be performed in San Diego and Fort Walton Beach, Fla. ■

Cree Constructs Power Module for F-35 JSF

A FIRM STRONGLY associated with power semiconductors, Cree (www.cree.com), has been awarded a follow-on contract by the U.S. Air Force for qualification of a high-performance power electronic module for the F-35 JSF. The contract, valued at $4.1 million, will be completed in the firm's Fayetteville, Ark., facilities.

According to U.S. Sen. John Boozman, the contract is a boost for the state of Arkansas: "Cree is on the forefront of a number of exciting advancements, including the effort to modernize our aircraft for the U.S. Air Force. The company's contributions to an increase in high-tech domestic manufacturing in Northwest Arkansas help drive economic growth in our state and create more well-paying jobs for Arkansans."

Cree began operating in Arkansas this past July with the acquisition of Arkansas Power Electronics International (APEI). John Palmour, chief technology officer (CTO) for Cree's power and RF division, added that the contract is a boost not only to defense requirements, but for industrial applications as well: "We're excited to get this high-performance module commercially qualified through this program—not only for Department of Defense requirements, but also for a wide range of industrial applications."

The F-35 JSF is one of the first major programs implementing the USAF's new "More Electric" or "All Electric" design philosophy to employ lighter electronic components on aircraft in place of heavier mechanical ones. ■

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JACK BROWNE | Technical Contributor

Scrutinizing Expansion of Surveillance Markets

Surveillance around the world is growing, accompanied by the continued use of satellites and a rapid increase in the number of UAVs for surveillance.

SURVEILLANCE HAS long been a key ingredient in any military command-and-control effort. Of course, what once involved sending personnel behind enemy lines to collect information on troop movements and weapons placements is now almost entirely electronically, and is largely dependent upon advanced cameras, sensors, and video technologies.

Surveillance is now conducted from space (via satellites); with GPS precision location data; and by means of robots, such as unmanned aerial vehicles (UAVs) that are remotely piloted and monitored. In military endeavors, every attempt at surveillance is usually accompanied by some form of counter-surveillance, so that technologies in support of surveillance are constantly of interest to military electronics contractors.

Government use of surveillance equipment is expected to extend well beyond military forces, with U.S. agencies such as the Federal Bureau of Investigation (FBI)and Drug Enforcement Administration (DEA) recruiting surveillance equipment and technologies to collect data on suspects. In addition, the activities of the Department of Homeland Security (DHS) increasingly involve data gathered by means of surveillance systems. Also, the police departments of many major U.S. cities now employ wide area surveillance systems as part of their law-enforcement activities.

With this growing list of users for surveillance systems and technologies added to existing military users, many research organizations are projecting sizable growth in the global surveillance markets over the next decade. Fueled by advances in video technology and more affordable remote cameras and video equipment, research organizations such as MarketsandMarkets (www.marketsandmarkets.com) have projected that the global security and surveillance market will grow at a compound annual growth rate of 5.9% over the next several years; it is expected to reach a global market size of more than $8 billion by 2019.

Cuts in defense spending worldwide have introduced some instability to military surveillance and radar markets. But a growing need for border surveillance, including in the Far East and in South America, are expected to increase the need for radar and surveillance systems to monitor those borders from neighboring countries. Comprehensive projections on surveillance markets, in particular video surveillance markets, are also available from research firm Visiongain (www.visiongain.com).

Many modern surveillance activities, including for video and audio content, rely on satellite-based systems—or "spy satellites," as they have come to be known. Satellites for military surveillance employ a number of different data-gathering technologies, including visible and near-infrared (IR) imaging, thermal infrared imaging, and radar sensors. Satellites have been a part of military surveillance efforts for many decades, including and before the time

The MQ-1 Predator surveillance UAV has proven to be an effective means of checking on threats, including with a recent deployment with troops to Latvia.

of the KeyHole series of surveillance and reconnaissance satellites that use video or electro-optical cameras to achieve high-resolution images (in the centimeter range) of the ground.

Lockheed Martin (www.lockheedmartin.com) has been a major supplier of surveillance satellites to the military. More recently, Boeing (www.boeing.com), perhaps better known for its GPS satellites, has also been a major surveillance satellite supplier. Many of these surveillance satellites are launched from Vandenberg Air Force Base (www.vandenberg.af.mil) in California. In additional, global satellite surveillance is conducted by NATO members, such as the French Helios spy satellites.

FLYING WITH CAMERAS

Manned aircraft have been used for military surveillance since the time of the U-2 spy plane, but military troops are looking more to UAVs for future surveillance applications. The Pentagon recently reported that it was planning to increase its use of UAVs for surveillance and other purposes by about 50% over the next several years. The need for drones is spurred by a request by the U.S. Air Force to decrease its number of daily combat air- patrol missions and have them replaced by Army- and civilian-operated missions.

With the growing number of security threats around the world, the number of surveillance flights by UAVs is expected to increase even further. The decision to add Army- and civilian-operated missions to the mix was triggered by increasing military activity in such areas as China and Russia, as well as continued activities in the Middle East. China's rising military power and island-building program in the South China Sea have increased tensions, prompting a greater demand for U.S. surveillance in the Far East.

ReportsnReports.com, an online research firm, projects the military drones market to reach $11 billion by 2011 from a level of $3 billion in 2014. According to the study "Military Drones Market Shares, Market Strategies, and Market Forecasts, 2015 to 2021," military as well as government users will rely more heavily on drones for surveillance in the coming years. In support of surveillance and other functions, these drones are evolving with improved launches, softer landings, better navigation, and longer operating distances. In addition to surveillance reconnaissance and control missions, they are supporting ground troops with three-dimensional (3D) terrain-mapping activities. The drone

aircraft offer better energy efficiency and lower cost than manned aircraft for similar functions, including surveillance. The report profiles some of the major contractors and drone suppliers, including Boeing, Lockheed Martin, and Northrop Grumman.

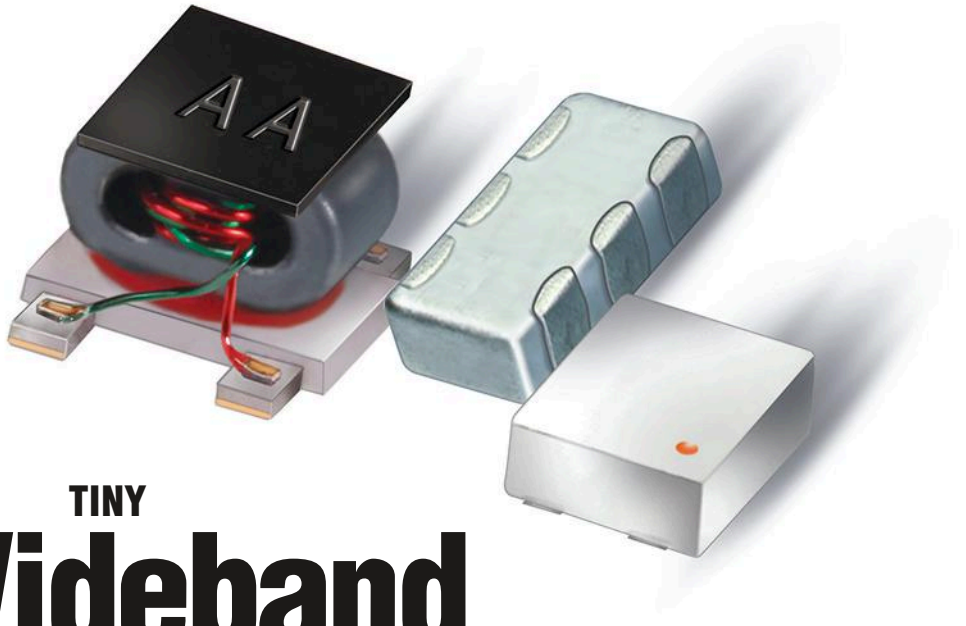
As an example of the use of unmanned drone aircraft for surveillance missions, the U.S. military recently deployed two MQ-1 Predator surveillance drones *(see figure)* to Latvia, along with 70 airmen, for a training mission targeted at improving surveillance of Russia. The U.S. has increased surveillance training and efforts in Eastern Europe following Russia's annexation of Crimea, and the country's conflicts in the Ukraine between nationalists and pro-Russian separatists. This represents the first deployment of unmanned surveillance aircraft by the U.S. military to Latvia for a training mission with allies.

The drones will be controlled from the Lielvarde Air Base. Of the launch, Pentagon spokesman Major James Brindle explained, "This temporary assignment of aircraft and personnel will test their ability to forward deploy remote piloted aircraft (RPA) to conduct air operations." He noted that "it will assure our Latvian allies, NATO allies, and European partners of our commitment to regional security and safety."

Surveillance markets are being fueled by increasing surveillance activities by different U.S. government departments. Although details about their aviation surveillance efforts are censored from the general public, the FBI and its Special Surveillance Group is increasingly using low-flying piloted planes over American cities for video surveillance and taps on cellular telephones. The FBI is also working with unmanned drone aircraft and sensitive video cameras and monitoring equipment to perform long-distance observations on suspects.

Also, the Drug Enforcement Administration has enlisted the aid of manned and unmanned aircraft in its video surveillance efforts. And the U.S. Department of Homeland Security is increasingly using military surveillance technologies for law-enforcement purposes.

In some cases, surveillance solutions developed for commercial use are being modified and adapted for military applications. One such case is the Military Airborne Surveillance System, based on commercial automatic dependent surveillance broadcast (ADS-B) technology, and can support military flight and surveillance requirements in commercial airspace. de



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Tracking the Latest EW/ECM Technologies

Complex EW and ECM systems employ a wide range of electronic technologies, with systems designers constantly searching for advancements and improvements.

ELECTRONIC-WARFARE (EW) systems rely upon control of the electromagnetic (EM) spectrum to disable or confuse an opponent's electronic systems. These systems are installed on most large military vehicles for use on land, at sea, and in the air. As they've grown more sophisticated through the years, they have come to rely on analog, digital, and RF/microwave technologies to achieve performance levels in smaller, lighter, units that are capable of operating at lower power levels.

Advances in these technologies extend from semiconductor processes through component and circuit levels, even in improved circuit substrate materials. The improvements may start out small, but they build to enhanced performance in next-generation EW and electronic-countermeasures (ECM) systems.

Digital RF memories (DRFMs) are representative of the types of components employed in EW and ECM systems. A DRFM combines the latest analog and digital circuit technologies—such as wideband analog amplifiers, high-speed field-programmable gate arrays (FPGAs)—and analog-to-digital converters (ADCs), to capture and analyze the complex modulated signals used by modern military systems. Captured waveforms are stored in digital form and often return as part of waveform libraries for identification purposes in EW and ECM systems.

A major, longtime contractor for EW and ECM systems, Raytheon Co. (www.raytheon.com), is well versed in available electronic technologies that can serve these systems—both from within the company and from companies working with Raytheon. The firm has been the contractor for the U.S. Navy, for example, on the Next Generation Jammer (NGJ) system, a platform which employs active electronically scanned array (AESA) technology common to many different EW systems. Raytheon's years of investing in advanced semiconductor technologies such as gallium-nitride (GaN) power transistors and integrated circuits (ICs) contributed a great deal to the selection of Raytheon for the NGJ by the Navy.

The AN/SLQ-32(V) is one of the most widely used shipboard EW systems, with more than 450 systems produced. *(Photo courtesy of Raytheon Co.)*

In terms of applying advanced technologies such as GaN semiconductors to EW and ECM systems, Travis Slocumb, vice president of Electronic Warfare Systems at Raytheon's space and airborne systems business, had this to say: "Eight months after award of the NGJ program, we successfully flew the integrated prototype system against representative threat radars…This demonstrates the capability and readiness of the core enabling technologies for the next generation of EW systems, and we did it on our first flight." Some of the subsystems incorporated in the NGJ system, such as the high-power AESA front end and multiple-channel techniques signal generator, can serve other EW and ECM systems as well, whether on ground, in the air, or at sea.

Raytheon is also working on a low-cost decoy airframe for the U.S. Air Force's Miniature Air-Launched Decoy (MALD) program. The MALD work will leverage advanced materials technologies to save weight without sacrificing strength, as well as robotics techniques to provide automatic functionality.

The firm has produced one of the most widely used EW systems, the AN/SLQ-32(V) shipboard EW system *(see figure)* with more than 450 systems produced. The different AN/SLQ-32(V) systems provide different functions, including early warning, threat identification, direction-finding (DF) capability, and jamming capabilities for multiple threats. The system employs a sensitive receiver with fast response time and high-power jammer sources and transmitters. It uses a digital library of emitter types for rapid identification of threat signals. Raytheon is also well known for the Advanced Countermeasures Electronic System (ACES), a leading ECM system for aircraft.

Many other contractors are involved in EW/ECM systems development and the application of advanced technologies, including BAE Systems (www.baesystems.com), Dynetics (www.dynetics.com), Exelis (www.exelisinc.com), Lockheed Martin (www.lockheedmartin.com), Mercury Defense Systems (www.mrcy.com), and Northrop Grum-

man (www.northropgrumman.com).

High-power GaN amplifier modules such as the model DM-X1K0-01 pulsed GaN amplifier from Diamond Microwave are allowing radar, EW, and ECM system designers to re-think their block diagrams because of the performance possible in such small packages. This amplifier measures just 244 × 134 × 50 mm and weighs 3 kg, but delivers 1 kW pulsed output power at X-band frequencies. It is a compact alternative to traveling-wave-tube amplifiers (TWTAs) with high power-added efficiency (PAE) of better than 20% for a better than 1-GHz bandwidth centered at 9.5 GHz.

Of course, older technologies such as TWTs and TWTAs have powered EW and ECM systems for many years, and developers of those technologies are not about to step aside for GaN. As an example, dB Control (www.dbcontrol.com) recently introduced high-power microwave power modules (MPMs) and TWTAs for EW and ECM applications, including the model dB-3907 TWTA with impressive 12-kW pulsed output power from 9 to 10 GHz. The tradeoff with GaN (among other things) is size, with this TWTA measuring 18 × 28 × 36 in. in an enclosure weighing 280 lb. But, for EW and ECM systems (such as land-based systems) with room for this size amplifier, this air-cooled unit can provide reliable pulsed microwave power with high gain and low distortion.

MODELING THREATS

Computer software simulations will have a great deal to do with next-generation EW and ECM systems, allowing system designers the opportunity to explore the impact of such things as environmental conditions and adversary responses on the performance of a system. Recognizing the importance of simulation software on EW/ECM system advancement, the Air Force recently awarded an $84-million, five-year contract to Avariant, which will enable EW system simulations for different aircraft.

The contract is called the Virtual Integrated Electronic Warfare Simulations (VIEWS) II and will focus on testing and evaluation of advanced sensors for EW and ECM systems. It also enables system developers to keep up with new and different technologies as adversaries develop their own EW and ECM capabilities. The Air Force is also funding an EW-technology-based program called the Spectrum Warfare Assessment Technologies (SWAT) program, which is geared toward evaluating how different EW technologies will perform in real-world environments. de

JACK BROWNE | Technical Contributor

Portable Radios
Provide Two-Way Communications

The latest portable tactical radios make use of analog and digital technologies to provide secure, reliable communications, typically over HF through UHF bands.

THEY MAY leverage some of the technologies that connect commercial radios, but military radios must not fail—no matter how severe the operating conditions. Tactical radios come in many shapes and sizes, operating over many different frequency bands and with a wide range of analog and digital modulation formats, but they largely share design goals to fit in smaller packages with improved performance and increased battery life.

One of the better-known portable radios for high-frequency (HF) use is the Falcon II AN/PRC-150(C) military radio produced by Harris Corp.'s Tactical Communications division (www.harris.com).

1. The Falcon II AN/PRC-150(C) is a portable HF tactical military radio for voice and data communications from 1.6 to 59.999 MHz. *(Photo courtesy of Harris Corp. Tactical Communications)*

Operating in the 1.6-to-59.999-MHz HF band, this rugged portable battlefield radio *(Fig. 1)* provides secure omnidirectional voice and data communications across long distances when line-of-sight communications may not be available. The radio incorporates Type-1 encryption and communications security (COMSEC) technology for high levels of security in the field.

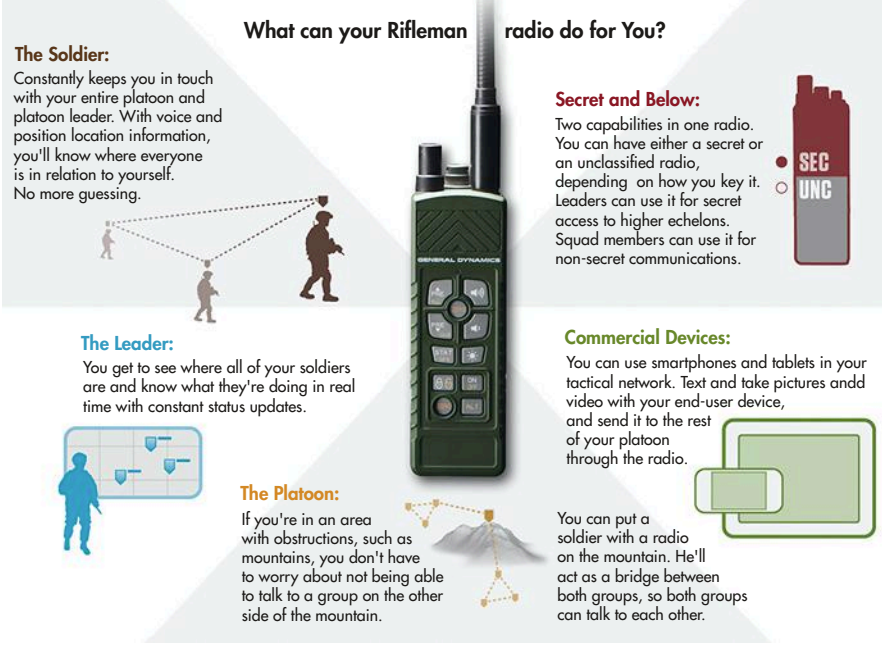
The software-defined-radio (SDR) can be functionally reconfigured by means of software upgrades to meet changing requirements. It supports synchronous or asynchronous data interfaces, working with commercial RS-232C and military MIL-STD-188-114A data links.

The compact Falcon II AN/PRC-150(C) tactical radio runs on a rechargeable nickel-metal-hydride (NiMH) battery package. The radio measures 10.5 × 3.5 × 13.2 in. with battery case and weighs 10 lb. (4.7 kg) without batteries. It features single-sideband (SSB) sensitivity of −113 dBm minimum for a 10-dB signal-to-noise-and distortion (SINAD) ratio.

The portable radio system offers greater than 80-dB intermediate-frequency (IF) rejection and greater than 80 dB image rejection, with intermodulation distortion (IMD) of better than −80 dBc for two −30-dBm signals separated by 30 kHz or more. Carrier suppression and undesired sideband suppression is better than 60 dB below the peak-envelope-power (PEP) output level.

With its frequency-hopping technology, the SDR can maintain secure and reliable communications even in the presence of jamming signals. It incorporates automatic link establishment (ALE) for secure communications with error-free data communications.

In a similar physical footprint, the digital modular radio (DMR) design developed by General Dynamics C4 Systems (www.gdc4s.com/hms) has been built with open-architecture guidelines to enable successful voice and data communications between different branches of the U.S. Armed Forces. The naval networking DMR system is capable of long-range communications using mobile-user-objective-system (MUOS)



2. The compact DMR is a portable tactical radio that provides voice and data communications by means of the MUOS satellite system. *(Photo courtesy of General Dynamics C4 Systems)*

waveforms with the military's next-generation, narrowband satellite-communications (satcom) system.

General Dynamics' AN/PRC-155 manpack radios were recently tested for their compatibility with the MUOS satcom system. The MUOS waveforms, which enable voice and high-speed data communications to and from the MUOS satellites, represent one aspect of evolving tactical radio technologies and their designed flexibility to adapt to changing operating conditions around the world.

As differentiated by their AN/PRC designations, tactical radios are designed for various applications. These include being used as battlefield, survival, and combat search-and-rescue (CSAR) radios.

Also from General Dynamics, for example, the AN/PRC-154A Rifleman radio *(Fig. 2)* is a handheld communications device that packs a great deal of performance into a compact, lightweight package. This non-cryptographic-controlled-item (non-CCI) radio measures just 7.5 × 2.5 × 1.7 in. The military radio provides continuous transmission of position location information (PLI) to aid in situational awareness requirements.

In spite of its small size, the AN/PRC-154A Rifleman radio include a GPS radio and antenna for precise positioning information, and can provide transmit power levels to 5 W for a line-of-sight (LOS) communications range to 2 km.

General Dynamics also supplies the AN/PRC-112G CSAR radio, which provides secure two-way messaging and LOS voice. The radio receives encrypted GPS updates at a rate of one per second.

One of the most widely fielded tactical radios, used by NATO forces and the U.S. Special Operations Command (SOCOM), is the AN/PRC-148 multiband inter/intra team radio (MBITR). Developed by SOCOM and Thales Communications (www.thalescomminc.com), which also supplies the AN/PRC-154 Rifleman radio, the AN/PRC-148 is a handheld radio designed for secure communications. It operates from 30 to 512 MHz and provides transmit modes at power levels of 0.1, 0.5, 1, 3, and 5 W.

In some cases—such as with the MOTOTRBO SL300 portable radio from Motorola (www.motorolasolutions.com)—many of the design elements normally used for military-grade tactical radios were applied to the design and implementation of the SL300 for industrial and commercial markets. Available in 1-, 2-, and 3-W versions, the handheld two-way radio can be specified for use at VHF (136 to 174 MHz) or UHF (403 to 470 MHz). de

(continued from p. C1)

ers "took a breath," as the all-consuming threat to which they had devoted their energies seemed to have disappeared. As a result, EW funding was significantly reduced for these allies. Of course, the Gulf War in 1990 drove home the point that EW was still essential, and this was further substantiated by the wars in Iraq and Afghanistan; EW played a key role in defeating Iraqi air defenses and improvised explosive devices (IEDs).

To advance its goal of maintaining spectrum dominance, which is affected to a large extent by EW, the Pentagon recognized the following:

- EW will be an increasingly essential asset for conducting every type of conflict or war—on the ground, in the air, and at sea (or even under it). This now includes cyber activities, as well.
- All assets in every domain must be coordinated with information from their sensors. This information is distributed autonomously based on priority and many other factors to those places where it is needed most, in more or less real time.
- To be affordable and usable on multiple platforms, EW subsystems must be built from the ground up based on a current open-system architecture or architectures.

The word "cyber" initially brought to mind gaining access to a network or database through wired connections. So, it took some time for the defense community to understand that the synergy between EW and cyber efforts lies in their ability to complement each other. For example, air-defense systems, command center, and many other vital defense-related facilities are typically networked by a combination of wired and wireless means.

A cyber attack on one or more points in a wired network can disrupt the network at the "back" end long enough for traditional RF-based electronic attacks—such as by jamming or interference—to be employed to disable or deceive the network at the "front" end. This allows kinetic attacks to be used to destroy the network. In the case of wireless command and control networks, an EW system can be used as the delivery method for RF-based cyber attacks.

Many other such scenarios are possible, in which traditional EM-based EW efforts will complement cyber capabilities. Rather than competing for the same attention (funding), they achieve the same overall goal of defeating an adversary by electronic means, but in different ways. In this way, EW and cyber efforts can be equally considered "electronic warfare."

Success in future battle theaters will require coordinated EW assets and efforts against an adversary wielding similar electronic weapons. Cognitive (adaptive) capability will also be essential in dealing with adversaries developing new and complex threats at an unprecedented pace, thanks in part to the global availability of advanced technology.

Such technology has historically only been available to military users, but is now available on an open market and through ingenious development efforts. The U.S. can no longer rely on capturing signals, analyzing them in a laboratory, and returning in six months with an algorithm to counter them. Electronic countermeasures (ECMs) must now be accomplished in the field, and often in seconds.

No EW system, no matter how advanced, can achieve its goals without effective, real-time management of all assets. This especially holds true given the dense EM environments created with radar, EW, communications, and other defense electronics systems; these systems operate simultaneously and requiring precise, complex scheduling of emitters.

Scheduling algorithms will prioritize these threats based on lethality. Swarm algorithms that collectively analyze information from sensors on various platforms, and autonomously make such decisions, will be invaluable. These processing-

A technician completes final pre-flight checks on a U-2S "Dragon Lady" system before an Open Mission Systems demonstration flight. The demonstration allowed fighters from different services and generations to exchange a wide range of data, including surveillance, reconnaissance, signal intelligence, and EW data. *(Photo courtesy of Lockheed Martin)*

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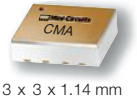

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intensive systems will not only address lethality, but when and where specific types of emitters such as communications and radar signals can operate, and when jamming can be used without becoming interference for a required system.

OPEN FOR BUSINESS

None of these EW capabilities can be developed, tested, and produced in large quantities within any reasonable budget without an open-system design approach adopted by all manufacturers. The approach will also result in a cost savings for the U.S. Department of Defense (DoD), since the commonality of subsystems will reduce the number of single-function, single-platform systems. Ideally, it would allow manufacturers to create subsystems, such as integrated microwave assemblies (IMAs), that can be "mixed and matched" to create more comprehensive multiple-function assemblies within a common form factor.

Of course, some functions will always fall outside the electrical and mechanical parameters or a common module, but the open-systems approach should reduce the number of these "rogue" modules. The OpenRFM initiative from Mercury Systems (www.mrcy.com) is currently the only open architecture proposed by industry as a standard-based open-system approach to subsystem design and fabrication.

The DoD has also embraced open systems through the Army's Modular Open RF Architecture (MORA), the Navy's Hardware Open Systems Technologies (HOST), and the Air Force's Mission System Open Architecture Science and Technology (MOAST) initiative, for which a Broad Agency Announcement (BAA) is expected shortly. Major contactors such as Northrop Grumman (www.northropgrumman.com) and Lockheed Martin (www.lockheedmartin.com) have also been demonstrating the Open Mission Systems (OMS) approach sponsored by the Air Force *(see figure on page S18)*.

Achieving the performance levels expected for the next generation of EW systems will be a formidable task, but not one without precedent in terms of importance. More advanced EW technologies will be needed to operate in an ever-more-crowded EM environment, and a more cost-effective open-system approach will help to achieve challenging design goals.

There is no question that the DoD and the defense industry will achieve new levels of cost-effective EW system performance through the open-system approach—the question is when. de

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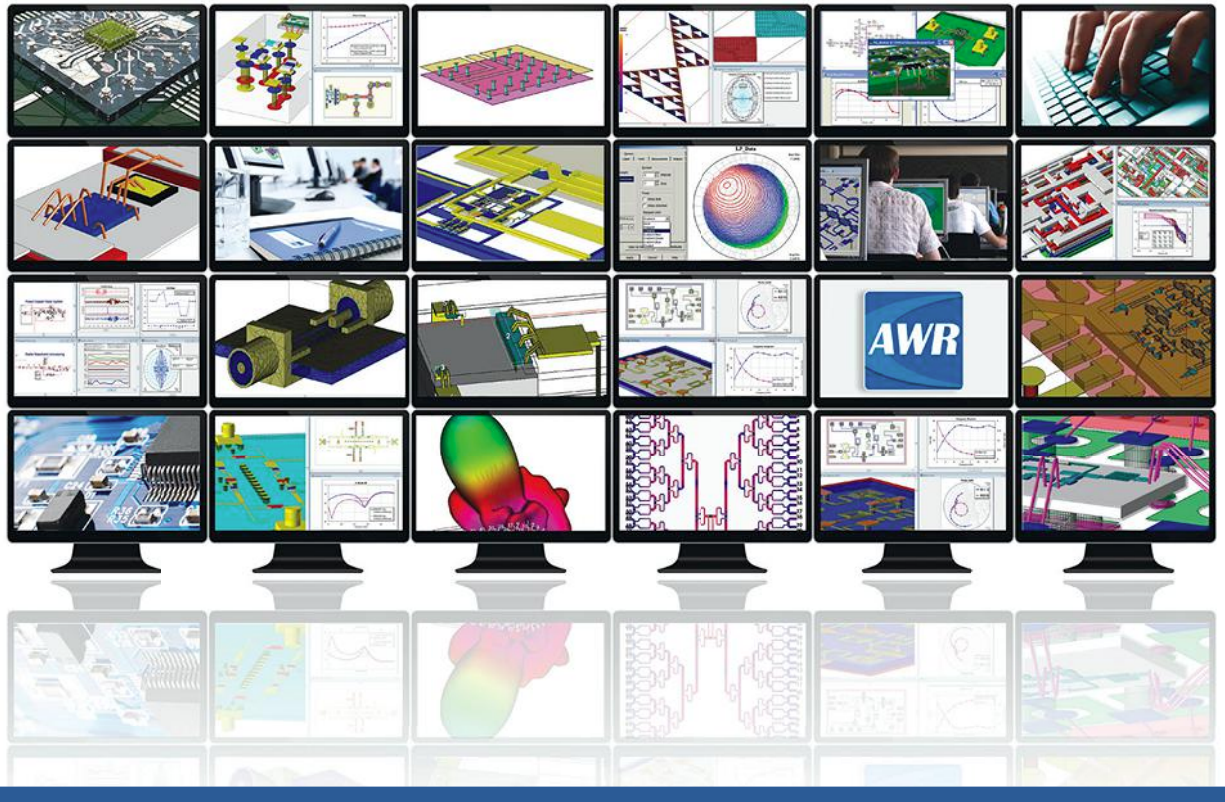

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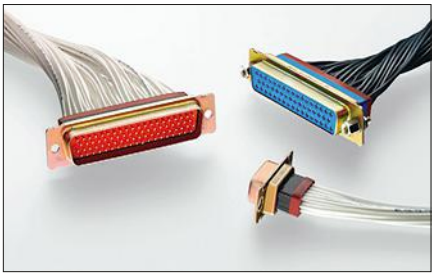

These sealed cable connectors are available in two product lines: series 109 standard-density connectors, using size 20 contacts, and series 90 high-density connectors, with size 22 contacts. The connectors include both grommet sealing on the wire-entry end and a one-piece interfacial seal on the mating face. The connectors, which are supplied with rear-release crimp contacts, employ AS39029 QPL contacts and can mate with standard D-subminiature connectors. They are rated for operating temperatures from –55 to +125ºC.

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	ZVE-3W-183+	5900-18000	35	2	3	1295
	ZHL-4W-422+	500-4200	25	3	4	1160
	ZHL-5W-422+	500-4200	25	3	5	1670
	ZHL-5W-2G+	800-2000	45	5	5	995
	ZHL-10W-2G+	800-2000	43	10	12	1295
•	ZHL-16W-43+	1800-4000	45	12	16	1595
•	ZHL-20W-13+	20-1000	50	13	20	1395
•	ZHL-20W-13SW+	20-1000	50	13	20	1445
	LZY-22+	0.1-200	43	16	30	1495
	ZHL-30W-262+	2300-2550	50	20	32	1995
	ZHL-30W-252+	700-2500	50	25	40	2995
	LZY-2+	500-1000	47	32	38	2195
	LZY-1+	20-512	42	50	50	1995
•	ZHL-50W-52+	50-500	50	63	63	1395
•	ZHL-100W-52+	50-500	50	63	79	1995
•	ZHL-100W-GAN+	20-500	42	79	100	2395
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Listed performance data typical, see minicircuits.com for more details.

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PCs Fight Back with MORE POWER

Smartphones and tablets have replaced PCs and laptops for many users, but PC platforms are more functional and powerful than ever. They are also sporting the latest technologies like PCI Express Gen 3, USB 3.1 with the new Type C connector, and M.2 connectors for motherboard-based flash storage.

Desktop PCs pack a punch that is hard to carry around and they usually have displays that exceed the capabilities or size of most mobile devices. Tower and mini-tower systems are still the norm for high-end gaming and workstations, but more compact solutions are available when top-end performance is not a requirement.

Gigabyte's Z170X-Gaming-G1 motherboard handles Intel's 6th generation Core processors with optional liquid cooling support.

Building a PC from scratch used to be common, but now it is more common for those looking for high-performance platforms like gamers. Leading the charge is Gigabyte's Z170X-Gaming-G1 motherboard for Intel's 6th generation Core processors (*see figure*). It uses an Intel Z170 chipset and it will be paired with the hottest chips around so liquid cooling might be used with the processor. Keeping the rest of the board cool can also be done using liquid cooling as the motherboard heatsinks have G1/4 thread fittings.

The motherboard uses DDR4 and exposes the HDMI support available with the processor's integrated graphics, but most gamers will populate one or all of the four PCI Express Gen 3 slots that have metal reinforcement for those large GPU cards. There are two x16 and two x8 slots plus three x1 slots. They support 2-, 3-, and 4-way AMD CrossFire/NVidia SLI technologies for multiple GPU configurations.

Full-size motherboards and even more compact systems like those based on Mini-ITX are still common and they are often used for embedded applications. The flexibility to plug in an expansion card allows systems to be customized for particular applications.

Still, packing the standard display and communication interfaces with a processor, memory, and storage is often all that is needed except for the display and user interface peripherals. Intel's NUC (Next Unit of Computing) is a popular form factor that has been adopted by a number of vendors. The 4-in. by 4-in. motherboard typically includes an Intel Core processor plus Gigabit Ethernet and flash storage. The NUC often includes WiFi, Bluetooth, and even NFC support. Core i3 and i5 versions are often fanless with higher-end versions running tiny fans. Standard VESA mounts for the back of monitors is typical as well. Flash and DRAM are in sockets to allow user configuration of storage.

Even smaller platforms are available in HDMI sticks like Intel's Compute Stick. It is more of a scaled-down NUC in an even smaller-form factor designed to plug into a HDMI socket. The quad-core Atom has access to 2 Gybtes of memory and 32 Gbytes of flash, making it suitable for Windows 10, Ubuntu, and other operating systems. A USB port and micro SD card slot provide limited but useful expansion options. WiFi and Bluetooth are standard. The Stick is handy for digital signage applications.

For more details on these and other PC trends, check out my complete article at *www.electronicdesign.com*.

News

FIBER-OPTIC SENSORS

Enable Smart Battery-Charge Management

In the pursuit of more efficient and low-cost designs, a growing number of battery storage devices are turning to embedded fiber-optic sensors and machine learning to optimize the main battery charge. The Palo Alto Research Center (PARC) is partnering with LG Chem Power Inc. to develop such a battery management system, with an initial focus on lithium-ion battery packs used in hybrid and electric (xEV) vehicles.

The Smart Embedded Network of Sensors with Optical Readout (SENSOR) system is capable of monitoring cell degradation and health information (SOX), in addition to predicting remaining battery life. During initial validation, the system demonstrated "2.5% or better SOX accuracy across various xEV use-cases" at both the cell and module levels, explains Ajay Raghavan, research area manager at PARC and the principal investigator of the technology.

SENSOR measures the signals from Fiber Bragg Grating sensors and other optical sensors embedded within the active chemistry of the battery. *(Image courtesy of ThinkStock).*

The SENSOR system is designed with wavelength-shift detection technology, which measures the signals from Fiber Bragg Grating sensors and other optical sensors embedded within the active chemistry of the battery. With resolution down to 30 fm and speeds up to the kilohertz level, this approach yields information about the battery's state of charge as well as advanced warning of failure. These measurements are transmitted to a read-out unit and evaluated by machine learning algorithms to provide real-time performance management.

PARC recently completed testing at the module level of xEV batteries, following the validation of the technology in individual lithium-ion cells. The initial module-level validation of the SENSOR system builds on the cell-level testing reported by PARC at the ARPA-E AMPED annual meeting earlier this year.

The SENSOR system is a continuing research project funded under the United States Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) within the Advanced Management and Protection of Energy Storage Devices (AMPED) program. According to the ARPA-E project abstract, the capabilities of the new system could reduce the form factor of xEV batteries by more than 25%, resulting in a lower manufacturing cost at the same energy density.

The next step in the development process for the SENSOR system includes additional hardening, validation, and research into efficient scaling. PARC's Raghavan explains that the company will continue working with original equipment manufacturers to transition the technology into field xEVs "as well as to explore its applicability for other energy and structural systems."

The SENSOR project is only one part of PARC's Energy Technology Program, which seeks to develop clean and abundant energy for a wide range of technologies. Thus far, it has focused on chemical energy storage for xEVs, consumer electronics, and the electrical grid; advanced energy-conversion devices; wireless sensors; and advanced analytics to maximize energy utilization. ■

TELECOM EQUIPMENT MARKET Will Have Steady Growth Through 2019, Report Says

IN AN EFFORT TO bolster network capabilities against an explosion of mobile data traffic, service providers are increasing their investments into wireless and wireline infrastructure. According to a recent report from the Dell'Oro Group research firm, the market for telecommunications equipment will continue its upward trajectory until the end of the decade. In spite of plans to introduce more efficient and lower-cost networks, companies are increasing their installed base of cellular stations, fiber-optic cable, and wireless access points.

The entire market for telecommunications equipment is expected to surpass $500 billion between 2014 and 2019, according to the Dell'Oro report. In addition, report predictions indicate the market will earn approximately $26 billion more over that period than it did from 2008 to 2013.

Tam Dell'Oro, president of the research firm, notes that wireless infrastructure will continue to expand over the next four years, carried mainly by the rise of small cells, heterogeneous networks (HetNets), and local-area networks (LANs). All of these technologies are viewed as integral to constructing 5G networks. At the same time, Dell'Oro explains that wireline equipment, such as fiber-optic cable, will grow a percentage of total investments over the next four years.

The entire market for telecommunications equipment is expected to surpass $500 billion between 2014 and 2019, according to the Dell'Oro report. *(Image courtesy of ThinkStock).*

While total investment in telecommunications equipment is growing, the market for wireless infrastructure will increase at a compound annual growth rate (CAGR) of -2% from 2014 to 2019. On the other hand, the wireline market will grow at a 3% CAGR over the same period. The report examined the access, carrier IP telephony, microwave, mobile RAN, optical, router, Wi-Fi, and wireless packet core industries to predict revenues for the entire market. ■

WILLIAM WONG | Embedded/Systems/Software Editor

CONSUMER IoT

(a)

(b)

(c)

1. Fitbit's Zip (a) is a basic fitness tracker while the Charge (b) adds features like sleep tracking. The Surge (c) is a full-fitness smartwatch with a heart-rate monitor and GPS tracker, and links to a smartphone.

The Internet of Things remains vaguely defined, but that hasn't halted the flood of consumer IoT products on the market.

The Internet of Things remains vaguely defined, but that hasn't halted the flood of consumer IoT products on the market. They are coming in all shapes and sizes, utilizing every type of sensor, and using almost every wireless connectivity mechanism known to man—from near-field communication (NFC) with door locks to Bluetooth 4.0 for proximity sensing.

These days, talking about Wi-Fi enabled refrigerators or washing machines is downright commonplace, and our cars often have more computing elements than the home. I'll leave cars to another time and concentrate on some of the IoT consumer solutions already available.

SPORTING IoT

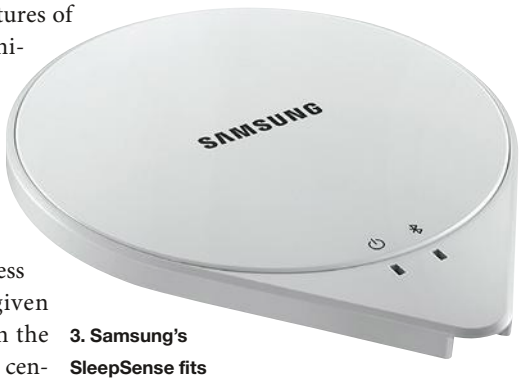
One of the first low-cost sensors was the 3D accelerometer, which was in the first Fitbit sports tracker I had. That utilized a USB interface with its own wireless connectivity, but it was useful and waterproof. The Fitbit Zip *(Fig. 1)* has replaced the original tracker, adding Bluetooth 4.0 support that allows it

2. The Apple Watch (a) with its NFC support and the Pebble Steel (b) watch with its low-power, color e-paper display highlight the range of functionality available with smartwatches.

to link to most smartphones.

Of course, there is an app for that. This tends to be true for most IoT devices; many have limited or no display to speak of, but they typically are full of sensors, microcontrollers, and a communication link. This allows the Fitbit Charge to add functionality like sleep tracking, as well as tracking the number of floors climbed.

The Fitbit Surge moves into the smartwatch arena with features like text notifications and control of music apps. It includes the features of the Charge, plus a heart-rate monitor and GPS tracker. Not bad for a smartwatch with a seven-day battery life.



3. Samsung's SleepSense fits between a box spring and mattress to track a person's sleep pattern.

TIME FOR IoT

It is always fun to listen to people argue about the merits of fitness trackers versus smartwatches, given the amount of crossover between the two categories. Much of the debate centers around where they differ. A fitness tracker with a display can easily show the time and the number of steps taken, but not much else. A smartwatch tends to be distinguished by its display adding a more robust user interface.

The Apple Watch and Pebble's Steel smartwatches *(Fig. 2)* are just two out of dozens of options available to consumers. While smartwatches can be found for under $100, more pricey models tend to be the norm, with many pushing style over functionality. The ability to install and use applications also tends to differentiate a smartwatch from more basic fitness trackers. This means more processing power, more memory, and hence a shorter battery life. As with smartphones, the display tends to be a major power hog, although the e-paper watches usually have multi-day battery life.

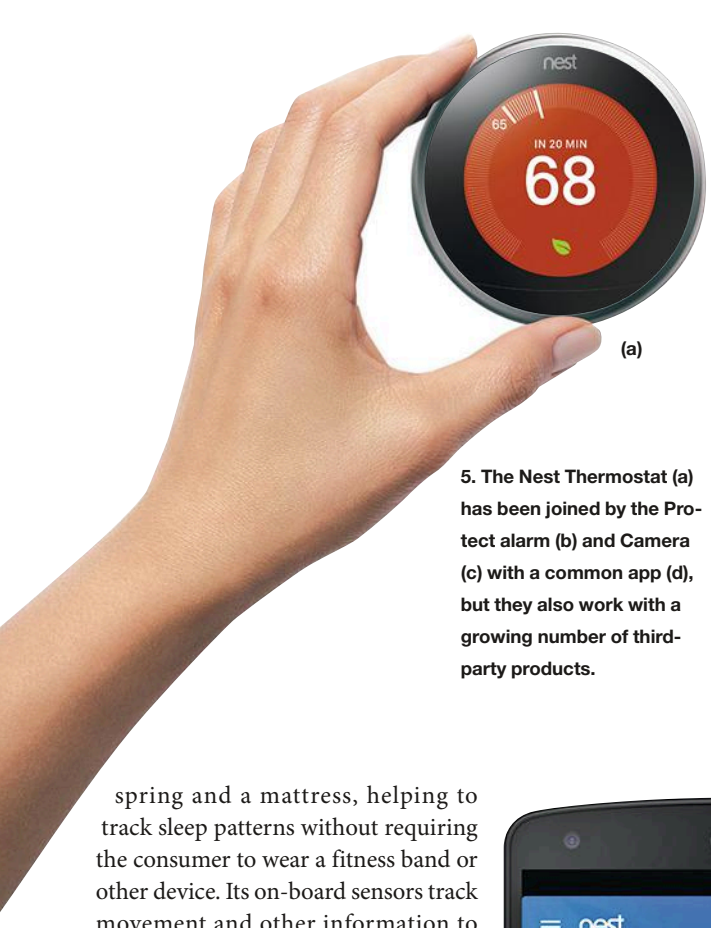
Smartwatches also tend to have more sensors. Some even have cameras built into the watch. Their connectivity can sometimes allow them to operate without close proximity to a smartphone within, although they tend to be used more to augment a smartphone rather than replace it. One feature that is emerging is NFC support that can be used for electronic payment already found with some smartphones. Placing the smartwatch next to a payment kiosk is often more convenient than pulling out a smartphone.

HEALTHY IoT

The tracking features found in fitness bands and many smartwatches can help improve a person's health—providing information about movement and pulse rate—but this is just the tip of the iceberg when it comes to mobile medical devices. The challenge for developers in this space is where and how devices will be prescribed and used. Medical devices that require FDA approval will be more targeted and more expensive because of the need to meet FDA requirements *(see "Successfully Navigate FDA Medical Device Approval" on electronicdesign.com)*. This includes medical IoT devices like a mobile electrocardiogram (EKG). This still leaves a lot of possibilities that do not target that end of the market.

One example of a sleep-related IoT device is Samsung's SleepSense *(Fig. 3)*. This wireless device fits between the box

4. Kwikset's Kevo Bluetooth Electronic Lock door locks use Bluetooth 4.0 to link with a smartphone app.

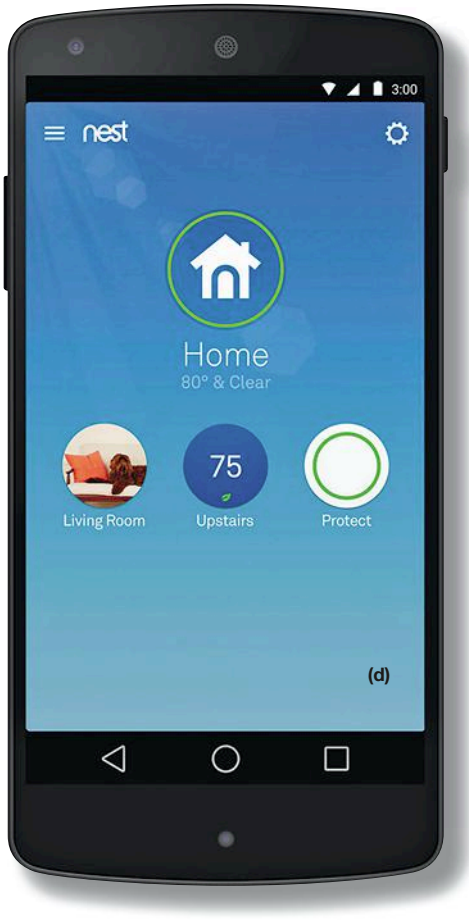


5. The Nest Thermostat (a) has been joined by the Protect alarm (b) and Camera (c) with a common app (d), but they also work with a growing number of third-party products.

spring and a mattress, helping to track sleep patterns without requiring the consumer to wear a fitness band or other device. Its on-board sensors track movement and other information to analyze sleep patterns.

The SleepSense app provides visual feedback to users. It can also connect to other devices—enabling it, for instance, to turn off a television when a person goes to sleep. Its alarm features a gradual alarm instead of a loud ringing that can leave a person dazed and irritable. The alarm is synched with sleep patterns to select the user's optimal wake-up time.

The system can also adjust heat and air conditioning temperature settings to increase comfort. Samsung claims a 97% accuracy rate using its real-time contactless sensor to track heart and respiratory rates in addition to movement.



IoT HOME

Home automation has been around for ages, with technologies such as the venerable X10 being challenged by other wired, wireless technologies and powerline technologies like SmartHome's Insteon *(see "EiED Online> > Insteon Now" on electronicdesign.com)*. Wireless standards groups like the ZigBee Alliance and Z-Wave Alliance have standards or profiles that target home automation and related areas such as lighting and HVAC.

The twin challenges for home automation solutions are cost and complexity. In the past, costs were very high, and setup and management were typically delegated to professionals. Wiring was often an issue and wireless was the exception rather than the rule. These days, wireless is at least a component of the solution. This includes all wireless technologies from NFC to Wi-Fi. Low-power solutions even make battery operation practical for many components.

Much has changed, although home automation costs are still nowhere near the cost for non-enabled systems. It is hard to argue with a light switch that costs under a dollar, although you do have to walk near it to be able to turn

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6. LG's Twin Wash supports Wi-Fi and NFC for wireless connectivity.

it on or off. Still, there are neat implementations offering compact solutions that are remarkably easy to install and use. Sengled Pulse Solo is an LED lightbulb with a stereo speaker *(see "The Internet of Things Is Here to Stay" on electronicdesign.com)*. It has Bluetooth connectivity for control and audio streaming. Lifx chose Wi-Fi for its lightbulb. The Original is equivalent to a 75-W bulb, delivering 16 million colors or 1,000 shades of white. Of course, there is an app for adjusting brightness and color.

I have had an electronic door lock with a combination for many years, but with Kwikset's Kevo door-lock family *(Fig. 4)* I could use my Samsung Galaxy with the Kevo app to unlock my doors. There are door locks that use NFC or proprietary wireless solutions, but Kwikset uses Bluetooth 4.0 found in most newer smartphones. A key fob is included.

The Kevo Bluetooth Electronic Lock works similar to the keyless entry systems for cars. The smartphone can remain in your pocket with Bluetooth enabled. You touch the lock to lock or unlock the door. The cloud can be used to share eKeys that would enable other smartphones to unlock the door. The lock does not require an Internet connection, although it does run on batteries. It supports a physical key and Kwikset's SmartKey Re-keying technology. This allows anyone to rekey a lock, not just a locksmith.

One name that keeps popping up in the home automation discussion is Nest. Now part of Google, it started with the Nest Thermostat *(see "An Elegant Thermostat Designed For The Internet" on electronicdesign.com)*. The family now includes the Nest Protect and Nest Camera *(Fig. 5)*.

What sets Google's Nest apart is that the API and infrastructure that are available to developers of so many other IoT devices (not just for the home) are often highlighting Nest support. This is probably the closest to a generic IoT environment that a consumer will be seeing at this point. Many of the other IoT-related products in general tend to be siloed, with the smartphone being the common element. Exchange of information between devices is less common. Nest-compatible devices include products like Samsung's SleepSense.

IoT WHITEGOODS

People would scoff at the thought of an Internet refrigerator or washing machine when the additional cost was more on par with putting a laptop into the device and the need for large screens was driven by standalone operation.

Well, things have changed—starting with smartphones and tablets providing a more robust interaction with these devices. It will be more common for a consumer to be "programming" a device using a smartphone rather than interacting with a user interface on a device. That is not to say that these devices will be totally headless, but rather, the functionality of the device's user interface will tend to be more limited. This will allow for smaller displays while providing more advanced functionality.

For example, LG's Twin Wash *(Fig. 6)* includes Wi-Fi and NFC support. This allows a smartphone application to control the type of cycle, in addition to knowing when the cycle is complete. The Twin Wash is actually two washing machines in one. The conventional washer is on top while a second, smaller unit is hidden in the drawer normally used for storage. The two can operate independent of each other, with the smartphone app having access to each.

The Twin Wash's second washing unit differentiates it somewhat from more conventional washing machines, but the control panel console is similar. The added IoT functionality is accessible from the console, though the smartphone application handles the heavy lifting when it comes to a graphical user interface.

Most consumer IoT devices tend to be custom-made to reduce size and improve ease of use and presentation style. Larger devices can take advantage of modules like Samsung's ARTIK platform. The smallest is the ARTIK 1 coming in at 12-mm by 12-mm. It has Bluetooth/BLE support in addition to a nine-axis sensor. It is designed for low-power operation with security designed into the hardware. Of course, it comes with its own ARTIK IoT stack—joining the many others like ARM's mbed and the Thread Group's Thread framework—but that is another story. ED

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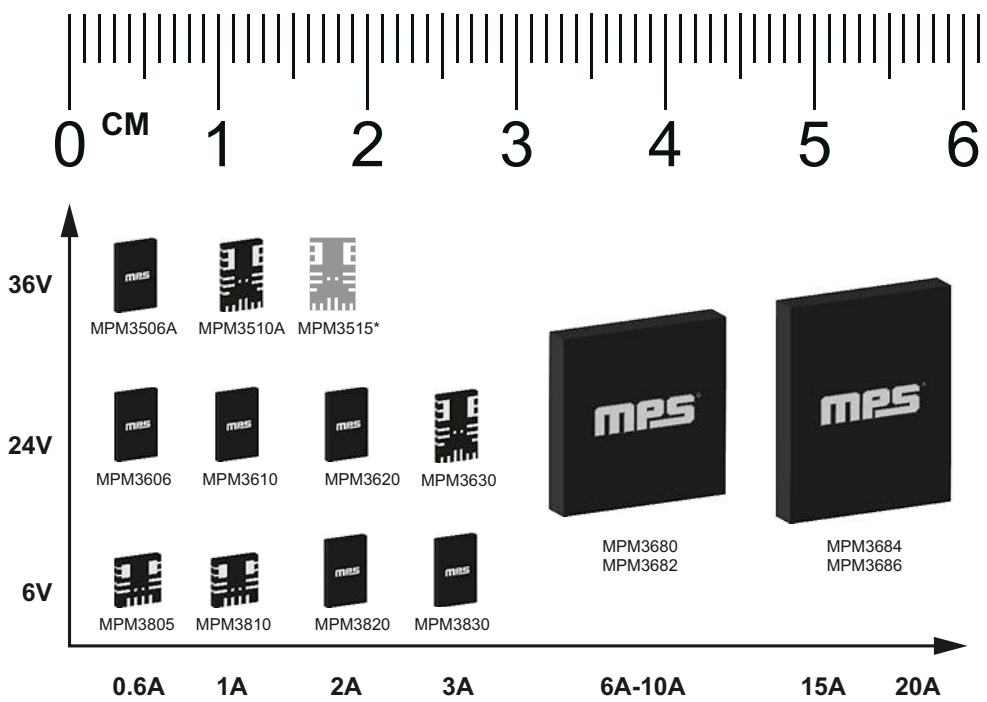

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5 Industry Trends Dominating EDA Today

From UVM extensions to portable stimulus to the onslaught of the IoT, the push is underway to enhance and streamline EDA functionality to meet industry demands.

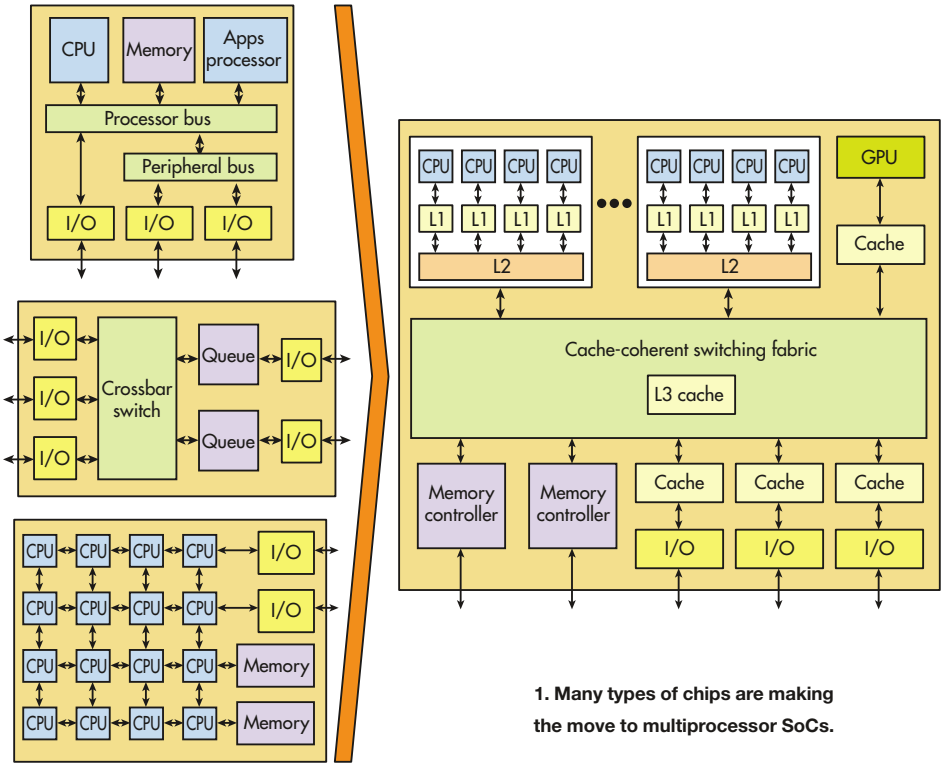
At any given time in the electronics industry, thousands of product areas and new technologies are in development. No one person can keep track of them all, but the major publications and Web sites do a remarkably good job overall.

Every once in a while, it helps to step back a bit and look for the industry trends behind many of the specific development projects currently underway. It's a useful way to cut through some of the clutter, make investment decisions, search for promising employment opportunities, or choose new career paths. With that approach in mind, this article highlights five trends permeating the EDA space in the electronics industry.

UVM EXTENSIONS

One clear trend within the verification space is the need for extensions to the well-established Universal Verification Methodology (UVM). The UVM, an Accellera standard that was recently handed off to the IEEE, defines how to build reusable testbench components for simulation. It has been remarkably successful at verifying blocks and subsystems, automating sequence generation, and largely replacing hand-crafted test vectors. However, the UVM cannot be all things to all engineers, and some cracks are starting to show.

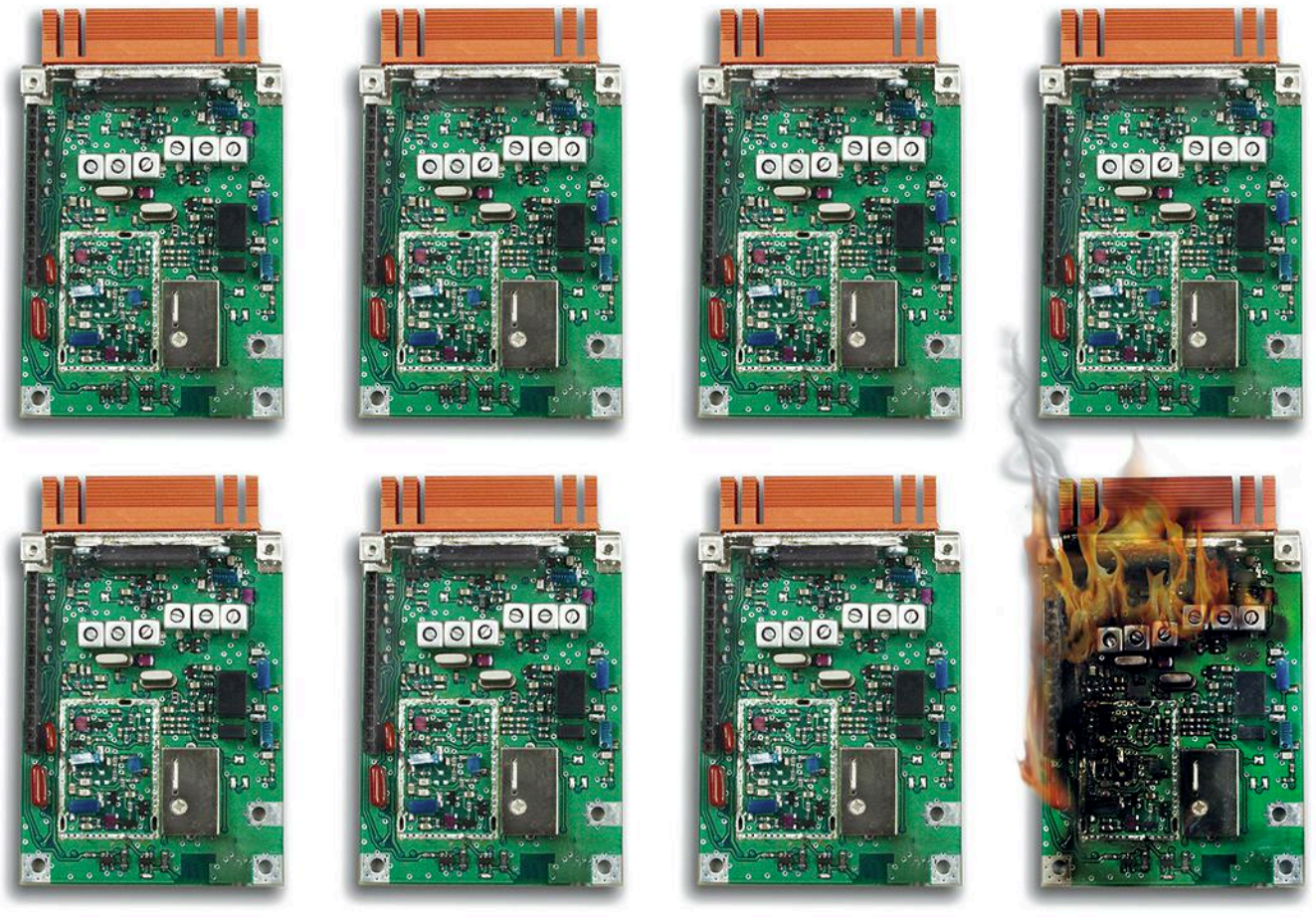
Many companies have extended the UVM to languages beyond the original SystemVerilog: to system-level verification beyond the original target of RTL, to hardware platforms beyond the original focus on simulation, and to verification of chips with analog/mixed-signal (AMS) content. Currently, a number of companies have plans on the table for future revisions and extensions.



1. Many types of chips are making the move to multiprocessor SoCs.

ESL GAINING MORE TRACTION

The second trend is the slow but steady move toward electronic-system-level (ESL) design and verification. One of the reasons this trend is hard to track is that ESL means many things to many different people. The design side usually focuses on describing the chip in SystemC and using high-level synthesis (HLS)



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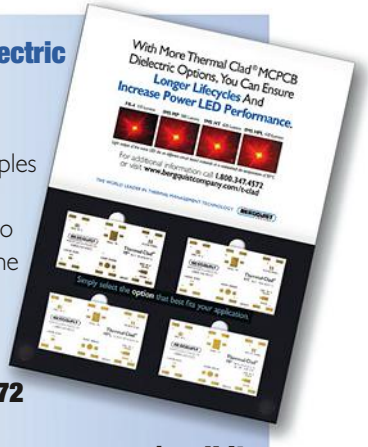

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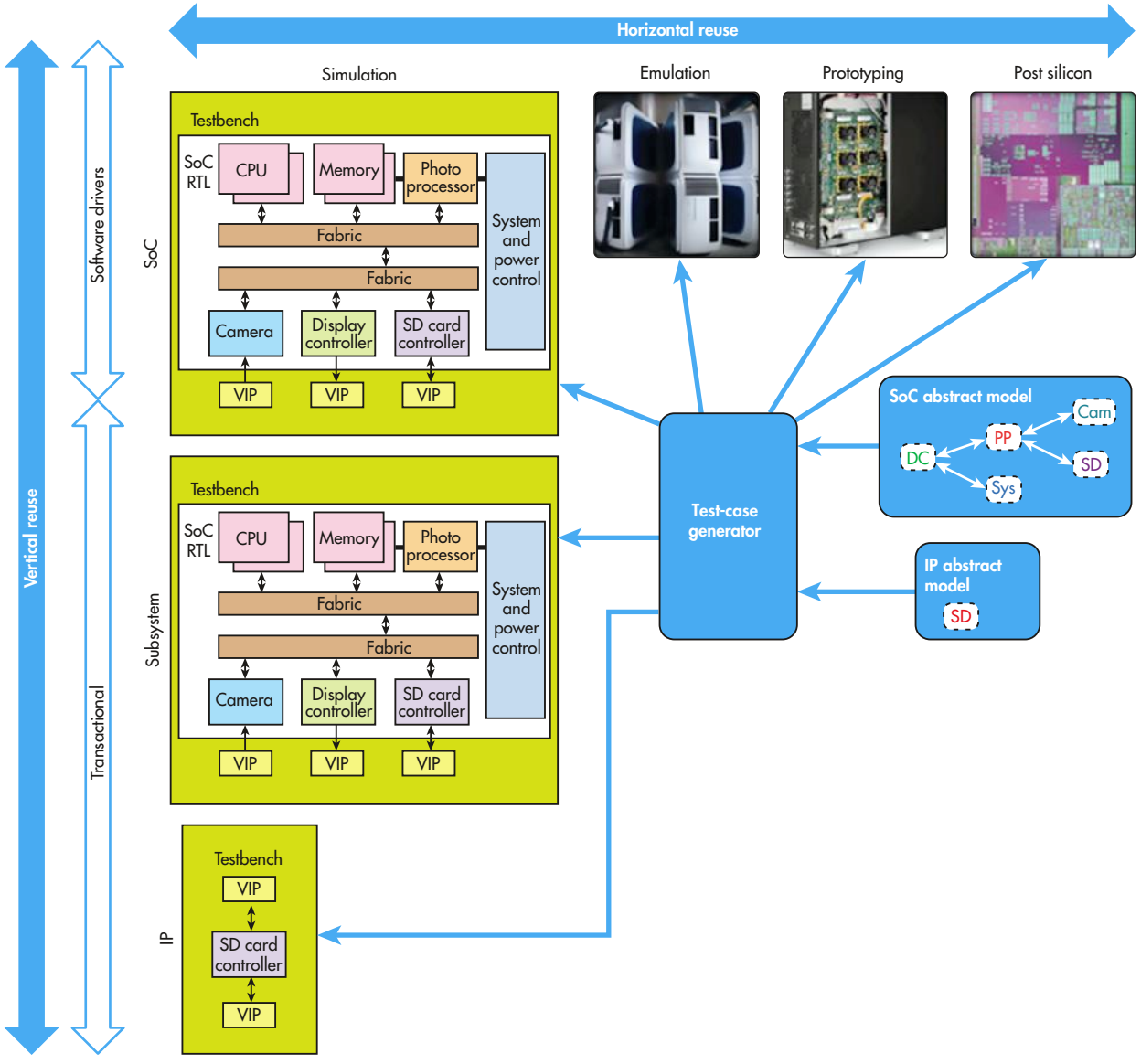
to map to RTL and gates. Commercial solutions for HLS have been in place for more than a decade, though the technology has yet to become mainstream. But adoption continues to grow every year, so it is part of the ESL trend.

On the verification side, ESL mostly refers to high-level modeling of a system or SoC in a virtual platform. The level of detail is enough to run software, estimate power consumption, and measure performance metrics, but not enough to run HLS. There's much speculation (and some actual research) about whether a single model can suffice for virtual platforms and synthesis. In the meantime, the virtual model is often written in SystemC so that it can be transformed into the HLS source by a series of successive refinements introducing more design details.

MULTI-EVERYTHING

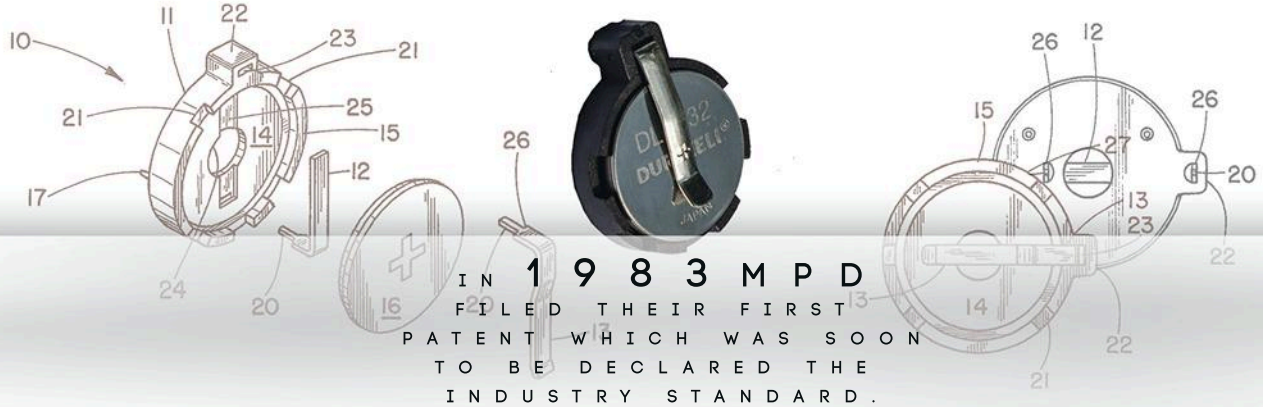
In the architecture space, many chips are moving toward multiprocessor system-on-chip (SoC) designs with multiple memories and multi-level caches. It's resulting in an architectural style that depends heavily on embedded software content to differentiate the end application and product (*Fig. 1*). This trend stems from a series of sub-trends in chip architecture:

- Large chips are adding embedded processors to implement complex functionality while retaining flexibility.
- Single-processor chips are adding multiprocessor clusters to get better performance at a given process node.
- Multiprocessor chips are using shared memory for effective data transfer and inter-process communication.



2. The industry today demands a Portable Stimulus solution, in order to have a single source for abstract verification specification.

...SOME THINGS CHANGE...



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> "Every once in a while, it helps to step back a bit and look for industry trends behind many of the specific development projects currently underway."

- Neighbor-connected processor arrays are moving to shared memory to reduce cross-chip data latency.
- Multiprocessor designs are adding caches to reduce memory access time and bypass memory bottlenecks.
- Multiprocessors with caches require coherency to ensure that the right data is always accessed.

Since embedded software is so central to this style of chip, it becomes very difficult to verify the design using a traditional simulation testbench. It's preferable to run test cases on the embedded processors in simulation, and beyond, through emulation, field-programmable gate-array (FPGA) prototypes, and even actual silicon in the lab. UVM provides no facility for linking code running on SoC processors with a testbench, so once again the need arises for an extension or new approach. But since UVM works so well on blocks and subsystems, any new method must link to existing testbenches as much as possible.

PORTABLE STIMULUS

These requirements are driving the fourth industry trend: the search for a portable stimulus solution. The goal is to have a single source for abstract verification specification, and some sort of automatic generation of test cases tuned for specific targets (*Fig. 2*). This enables vertical reuse (from IP block to full SoC) and horizontal reuse (from ESL and RTL simulations to silicon). Since it's such a critical need in the electronics industry, the Accellera Systems Initiative formed the Portable Stimulus Working Group to develop a standard in this area. Key areas of focus include graph-based verification, software-driven verification, and automated coverage.

All four trends discussed so far come together at this point. Thus, a portable stimulus standard:

- Might be viewed as an extension of the UVM.
- Must provide connections to existing UVM testbenches.
- Must support high-level ESL simulations as well as RTL.

- Must generate code to run on embedded processors.
- Must support test cases running on many-core SoCs.

IMPACT OF IoT

The final trend is probably the most obvious, since it's discussed all of the time in the trade press: the predicted exponential growth of the Internet of Things (IoT). Many feel that this area has been hyped beyond all rationality and that too many disparate technologies are being gathered under the IoT banner. However, it's quite clear that a large market exists for network-connected devices of all kinds, and it will very likely continue to grow at a rapid pace. Many new consumer and business applications are seemingly being proposed every day.

Most IoT devices will have to be small and inexpensive, which would place a lower design and verification burden on the chip projects. However, many will need to run on extremely low power, and some will be in locations difficult to access for repair or upgrade. Virtually all IoT services will be SoCs, with embedded software providing part of their product differentiation. Although some may not need multicore or many-core capabilities, the wide availability of these platforms may mean that they will be selected, anyway.

Over the next few years, much energy will be devoted to address these five trends. Engineers involved in any of these areas will want to benefit from all available information, whether it be from the trade press, technical journals, and/or industry conferences. Lots of very smart people face similar problems, so there's much to be gained in the industry by sharing ideas and results whenever possible. ed

TOM ANDERSON has more than 15 years of experience in EDA verification applications and marketing. He has served as product management group director for advanced verification solutions at Cadence, technical marketing director in the Verification Group at Synopsys and vice president of applications engineering at 0-In Design Automation. Before moving into EDA he was vice president of engineering at IP pioneer Virtual Chips, following roles in ASIC design and management. Tom has presented more than 100 conference talks, published more than 200 papers and articles, and contributed to 12 books. He holds a B.S. in computer systems engineering from the University of Massachusetts at Amherst and an M.S. in electrical engineering and computer Science from the Massachusetts Institute of Technology (MIT).

ROB REEDER | Analog Devices Inc.
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An Inside Look at High-Speed ADC Accuracy

Understanding how ADCs can experience multiple inaccuracies can clarify the best way to specify the device when defining system parameters for a new design.

Analog-to-digital converters (ADCs) are used in a wide range of applications, particularly measurement systems that need to process analog transducer signals. Examples include data-acquisition systems to measure pressure, flow, velocity, and temperature. Typically, these signals are time-domain signatures in the form of a pulse or step function.

In any design, it's important to understand the overall system accuracy, especially when systems must quantify very small sensitivities or changes in a waveform. In an ideal case, for every 1 V applied to the input of a signal chain, a 1-V output is digitally represented by the ADC. However, this is not the case. All converters, and all signal chains for that matter, have some finite amount of error associated with them.

Of particular interest are the errors associated with the ADC itself. Multiple inaccuracies accumulate within the converter to cause these errors. Understanding how this happens can help clarify how best to specify an ADC when defining system parameters for a new design.

ADC INACCURACY

In any signal chain, the converter is the foundation of the system. System accuracy can be no better than the converter's least-significant-bit (LSB) size.

Because ADCs are not ideal and don't exhibit infinite resolution, they can only output a finite number of representations. The actual number of representations is equal to the input full scale of the converter divided by 2^N, with N being the nominal number of bits that the converter puts out per conversion (*Fig. 1*).

For example, for any voltage applied to its input, a 12-bit ADC may output one of 4096 unique digital representations to represent it. These representations have some finite amount of error. Therefore, if the 12-bit ADC's datasheet specifies an input full-scale voltage (V_{FS}) value of 10-V_{PP}, its LSB would be 2.44 mV_{PP} and, ideally, an accuracy of ±1.22 mV.

$$LSB = V_{FS}/2^N = 10/4096 = 2.44\ mV = \pm 1.22\ mV \quad (1)$$

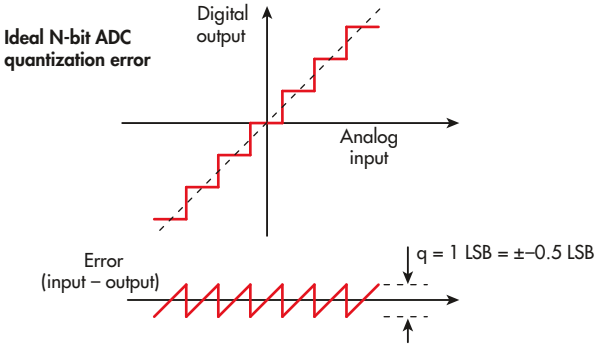
In reality though, ADCs are not ideal. Some finite amount of noise (k × T/C) exists within the converter itself—even at dc. Remember, a 1-kΩ resistor is equivalent to 4 nV/√(Hz) in a 1-Hz bandwidth at 25°C. Notice that when looking at a 12-bit ADC datasheet, the signal-to-noise ratio (SNR) is typically on the order of 70 to 72 dB. However, a 12-bit ADC should have 74-dB SNR in the ideal world, based on:

$$SNR\ (dB) = 6.02 \times N + 1.76 \quad (2)$$

Thus, in the real world, 12-bit precision can't be achieved, because the converter introduces inaccuracies (*Fig. 2*).

These inaccuracies or errors define how effective the converter represents the signal that ultimately is acquired throughout the signal chain. Such errors include:

- *Offset error:* The analog value by which the transfer function fails to pass through zero.
- *Gain error:* The difference in FSV between the ideal and actual transfer function when offset error is zero.



1. *ADC quantization error:* Representation of an ideal ADC that approximates a sawtooth waveform with a peak-to-peak amplitude equal to q.

LINEAR TECHNOLOGY

DESIGN NOTES

42V Quad Monolithic Synchronous Step-Down Regulator with 30µA Quiescent Current

Design Note 544

Zhongming Ye

Introduction

Industrial and automotive applications require robust, easy-to-use, compact DC/DC converters to produce a variety of low voltage power supplies. The LT8602 monolithic quad synchronous step-down converter in a 6mm × 6mm package is capable of providing four outputs from a wide input range of 3V to 42V. It is versatile and easy to use with features such as low EMI and adjustable operating frequency up to 2.2MHz. It consumes only 30µA quiescent current from the input source even when regulating the outputs.

Small Size, Low EMI, Quad Step-Down Solution

The LT®8602 integrates two high voltage (HV) and two low voltage (LV) synchronous regulators in a QFN (6mm × 6mm) package. Replacing external Schottky diodes with internal synchronous switches minimizes the solution size and also increases efficiency, reducing power dissipation.

The two HV channels (1 and 2) are capable of supporting 1.5A and 2.5A loads respectively, from an input of 3V to 42V. The two LV channels (3 and 4) can support up to 1.8A each from an input of 2.6V to 5.5V. Figure 1 shows the top center view of the demo circuit DC1949A. A simplified schematic with four outputs: 5V, 3.3V, 1.8V and 1.2V is shown in Figure 3. One LT8602 replaces four individual regulators, reducing overall solution size and cost. All four regulators in the LT8602 are synchronized to a single oscillator programmed at 2MHz, allowing the channels to operate anti-phase. The LT8602 reduces the input ripple current by operating channels 1 and 3 out of phase from channels 2 and 4, simplifying EMI filter design. The demonstration circuit DC1949A includes a small EMI filter. Figure 2 shows the radiated EMI performance of the board. It passes the CISPR25 class 5 peak limits with good margin.

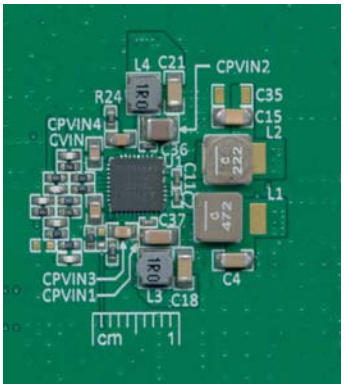


Figure 1. Top Center View of the Demo Board DC1949A

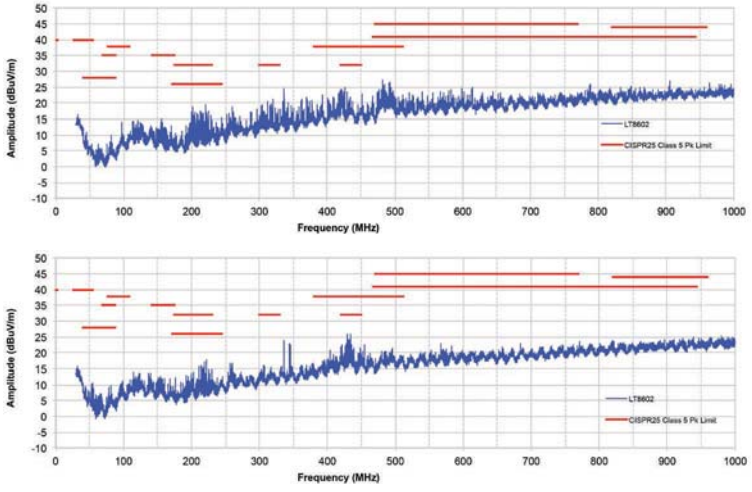


Figure 2. Radiated EMI Performance (CISPR25, Class 5, Peak Detector), $14V_{IN}$, 1A at All Outputs, Switching Frequency = 2MHz

Wide Input Range Even at High Switching Frequencies

A high switching frequency can be used to minimize DC/DC solution size, but increasing frequency usually comes with a trade-off: reduced input voltage range. This is a significant concern in automotive and industrial environments, giving designers pause when considering the advantages of increasing the switching frequency.

With low minimum on-time and low dropout, the LT8602 allows a wide input range, even at 2MHz. Figure 4 shows the dropout performance of channel 1. As the input voltage decreases toward the programmed output voltage, LT8602 maintains regulation by skipping switch-off times and decreasing the switching frequency up to a maximum duty cycle of 99.6%. If the input voltage decreases further, the output voltages remain 50mV–550mV below the input voltage, depending on the load. The boost capacitor is charged during dropout conditions, maintaining high efficiency.

Flexible Sequence Control

The LT8602 has a track and soft-start pin for each HV channel. For each LV channel, it has an internal soft-start of ~1ms. Each channel also has a power good indicator. Those pins simplify output tracking or sequencing.

Conclusion

The LT8602 integrates four synchronous buck regulators in a 6mm × 6mm QFN package, enabling compact, low EMI, high efficiency, fault robust solutions requiring only 30µA quiescent current. Individual inputs for each converter allow design freedom, while separate PG indicators and TRK/SS pins further extend tracking and sequencing flexibility. These features make the LT8602 ideal for the harsh environments common to automotive and industrial applications.

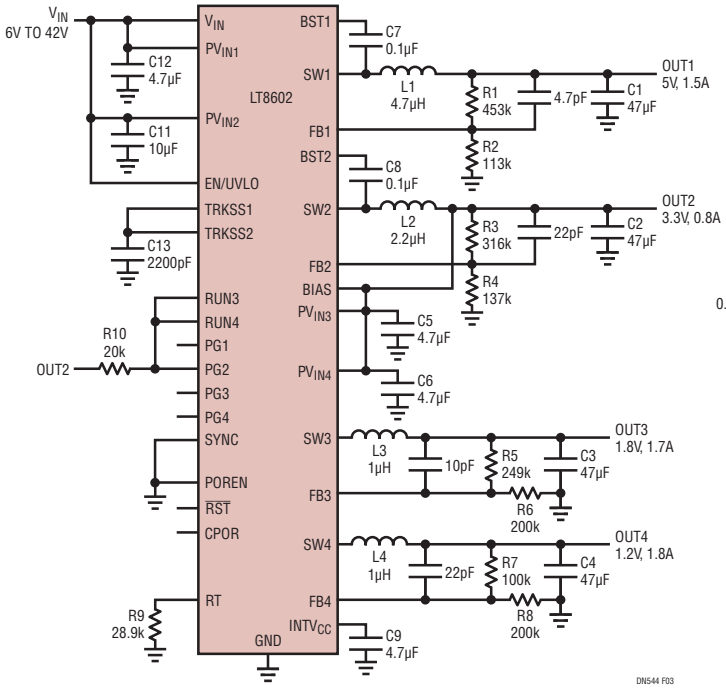


Figure 3. Schematic. 5V, 3.3V, 1.8V, 1.2V, f_{SW} = 2MHz Outputs

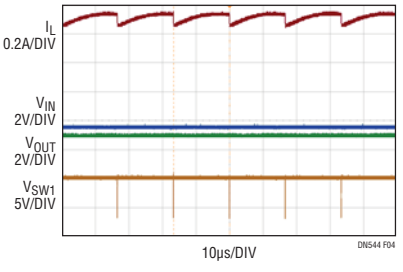


Figure 4. Dropout Performance at I_{OUT} = 1.5A

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• *Linearity error (commonly referred to as nonlinearity):* The deviation from a straight line drawn between zero and full scale as shown in *Fig. 1*.

MORE ADC INACCURACIES

Now that the most basic ADC errors have been defined and understood, it's useful to compare them. Typically, an ADC's offset and gain errors are so small that they can be either ignored or adjusted (nulled) by means of an external analog circuit or via digital processing. However, other errors, such as linearity, quantization, and temperature coefficient ("temp-co"), cannot be so easily adjusted or eliminated.

ADC linearity is only as good as the converter itself, which means it's influenced by architecture and process variation. To deal with nonlinearity, the designer generally has two choices: either purchase a better—and more expensive—converter, or digitally correct the linearity.

Digital correction can turn out to be as costly as buying a better converter, though, because it demands more resources on the DSP or FPGA, as nonlinearity will shift over temperature and process variation. Depending on the sample rate, IF, and resolution, digital correction may require extensive characterization and look-up tables to correct or adjust the ADC's performance on the fly.

DNL AND INL

Linearity involves two types of errors—differential and integral linearity (DNL and INL, respectively). DNL is defined as any error or deviation from the conversion's ideal value. In other words, it represents the deviation in the analog difference between two adjacent codes from the ideal code value of $V_{FS}/2^N$.

Think about this in relation to SNR performance of the ADC. As the code variation grows, the number of transitions shrinks. This error is bound to ±0.5 LSBs over temperature to ensure no missing codes.

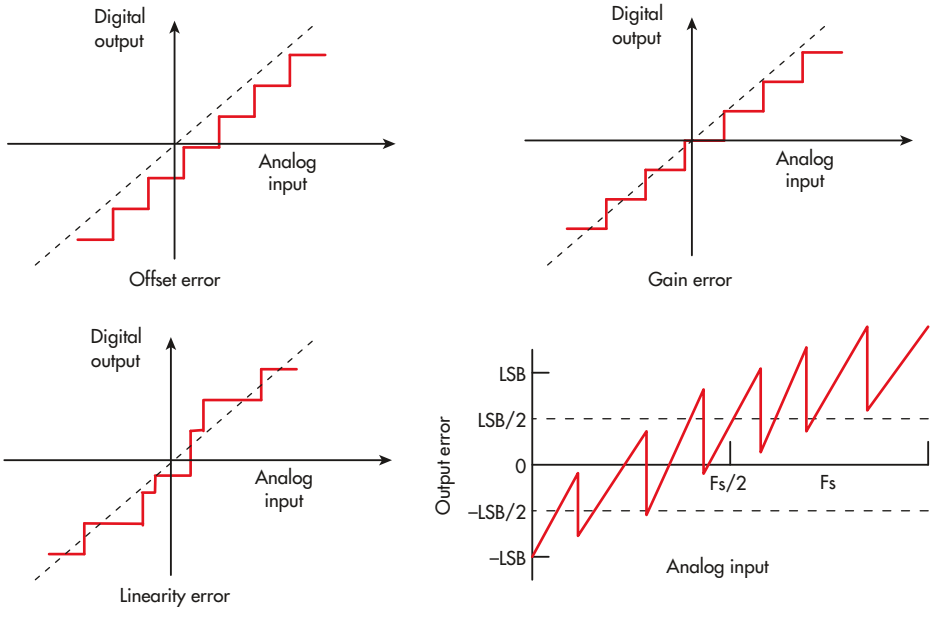
INL is defined as the curvature deviation from an ideal straight-line approximation of the transfer function between zero and full scale. INL, for the most part, determines the spurious-free dynamic range (SFDR) performance of the ADC.

The shape of the overall INL deviation affects harmonic performance. For example, a "bow" in the INL curve will yield worse even-order harmonics, and an "s-bow" in the INL curve will commonly yield odd-order harmonics. However, because this error is frequency-dependent, it doesn't relate to the type of error analysis under consideration here.

Thus, even though a null in the static offset and gain errors is feasible, the temperature coefficient related to offsets and gain errors will still exist (for example, a 12-bit ADC with 10-ppm gain error; or FSR/°C = 0.001%/°C). Likewise, 1 LSB in a 12-bit system is equivalent to 1 part in 4096, or approximately 0.024%.

So, a 125°C delta (–40 to +85°C) yields a ±2.5-LSB gain temperature error, or 0.001% × 125 = 0.125%, in which 0.125/0.024 = 5.1 or ± 2.55 LSBs.

For offset tempco, a 5-ppm offset error or FSR/°C = 0.0005% per °C. This would yield a ±1.3-LSB offset temperature-coefficient error, or 0.0005% × 125 = 0.0625, in which 0.0625/0.024 = 2.6 or ±1.3 LSBs.



2. *ADC inaccuracies:* Representation of errors in non-ideal ADCs with offset error, gain error, and linearity error. All three errors are represented in the graph (lower right).

ADC ERROR ANALYSIS

Other error sources that can also play a role in the converter's performance are common-mode rejection ratio (CMRR), clock jitter, and inherent board noise and coupling. All of these errors ultimately determine how effective the ADC is at representing a signal and usually exhibit their effects more obviously in the frequency domain.

From a time-domain standpoint, the following five errors dictate the converter's overall accuracy:

- Relative accuracy, or DNL, which was defined as ±0.5 LSBs.
- Relative DNL is the typical number in the datasheet. Relative tempco DNL is the DNL variation over rate temperature of the ADC/device/IC.
- Gain tempco error, which was ±2.5 LSBs (from the example above).
- Offset tempco error, which was ±1.3 LSBs (also from the example above).
- Power-supply sensitivity, which is typically expressed in terms of low-frequency power-supply rejection ratio (PSRR) within the first Nyquist zone. This can be typically expressed as 60 dB or ±2 LSBs for a 12-bit ADC.

By simply taking the root-sum-square (RSS) of all these error sources, total converter error will equal ±3.5 LSBs, which might seem overly pessimistic. Yet a statistical tolerance may actually be overly optimistic, or in other words, the total sum of errors divided by the number of errors or (0.5 + 2.5 + 1.3 + 2)/4 = ±1.58 LSBs. The actual tolerance of the ADC should fall somewhere between these two, though.

Therefore, when adding accuracy errors in the converter, or in any accuracy system analysis, designers should use a weighted error source approach, then RSS these error sources together. This will provide the best method in determining the ADC's overall error.

As a result, the relative accuracy of ±0.5 LSBs should stay at 100%. However, the gain temperature compensation error of ±2.5 LSBs should be 66% of the total error or 2.5/(0.5 + 1.3 + 2) × 100. The offset compensation error of ±1.3 LSBs would be 26% of the total error or 1.3/(0.5 + 2.5 + 2) × 100. The power supply sensitivity error of ±2 LSBs would be 47% of the total error, or 2/(0.5 + 1.3 + 2.5) × 100. Adding these weighted errors together in an RSS fashion, or $\sqrt{((0.5\times1)^2 + (2.5 \times 0.66)^2 + (1.3 \times 0.26)\ 2 + (2 \times 0.47)^2)}$, provides a total error of ±2.0 LSBs, which yields something more realistic in between the optimistic and pessimistic method outcomes given earlier.

ACCURACY IN ADC BANDWIDTH

The ADC has a settling-time inaccuracy, too. Keep in mind that a converter's internal front end must have enough bandwidth (BW) to accurately sample the signal. Otherwise, an accumulation of errors will be greater than what was described above.

In general, an ADC's internal front end must settle within half a period of the sample clock cycle (0.5/Fs, where Fs = sample frequency) to provide an in-bounds accurate representation of the

analog signal to be acquired. Therefore, for a 12-bit ADC sampling at 2.5 Gsamples/s and a full-scale input range of 1.3 V_{PP}, the full-power bandwidth (FPBW) required can be derived by starting with the transient equation:

$$1\ LSB = V_{FS} \times e(-t/\tau)$$

Solving for t:

$$t = -\tau \times \ln(1\ LSB/V_{FS})$$

Substituting in $\tau = 1/(2 \times \pi \times FPBW)$ for one time constant, and solving for FPBW:

$$FPBW = -(1/(2 \times \pi t) \times \ln(1\ LSB/V_{FS})$$

let t = 0.5/Fs. That is the time needed for a sample to settle, where the sampling period is 1/Fs:

$$FPBW = -(Fs/\pi \times \ln(1\ LSB/V_{FS}) = -(2.5\ G/\pi) \times \ln(317\ \mu V_{PP}/1.3)) = 6.62\ GHz$$

This will yield the minimum required bandwidth for the ADC's internal front-end FPBW. The converter's internal front end needs this amount of BW to settle within 1 LSB and sample the analog signal appropriately. It will require the passage of several time constants to meet an accuracy of 1 LSB for this type of ADC, where one time constant is equal to 24 ps, or:

$$\tau = 1/(2 \times \pi \times FPBW)$$

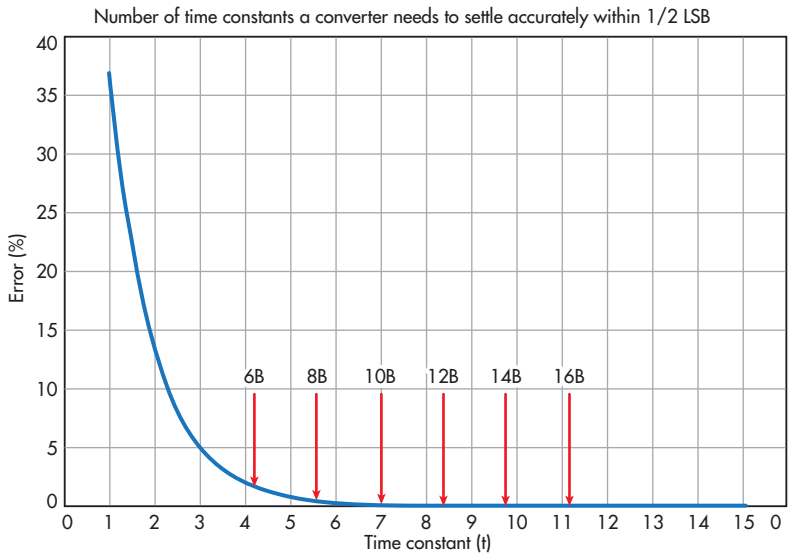
To understand the number of time constants required for the full-scale range of the ADC in LSB size, %Full-scale error, or %FS, needs to be found. Or, 1 LSB = FS/(2^N), where N = number of bits; or 1.3 V_{PP}/(212) = 317 μV_{PP}, and %FS = (LSB/FS) ×100 = 0.0244.

By plotting Euler's number, or $e\tau$, a graph can be developed that makes it easy to show the relative error with the passing of each time constant. In *Fig. 3*, it can be found that it takes 8.4 time constants for the 12-bit ADC example to settle appropriately within 1 LSB.

This analysis allows designers to estimate the maximum analog input frequency, or sample bandwidth, that the converter can handle and still settle within 1 LSB of error. Beyond that, the ADC cannot accurately represent the signal. Thus:

$$F_{max} = 1/(\tau \times \text{number of time constants}) \text{ or } 1/(24\ ps \times 8.4) = 4.9\ 6\ GHz.$$

Keep in mind that this represents a best-case scenario, and the assumption is for a single-pole model ADC front end. Not all practical converters will behave this in this manner, but this is good starting point.



3. *Settling accuracy vs. time constants:* Number of time constants an ADC needs to settle accurately with 1/2 LSB.

For example, the model described will be valid up to 12 bits. However, for 14 or 16 bits and beyond, a second-order model should be employed, because of subtle effects that can cause settling time to stretch out beyond the predicted first-order models.

A QUICK NOTE ON ADC BANDWIDTH

Keep in mind that an ADC's full-power bandwidth is different from converter "usable or sample" bandwidth as defined above. This effect is analogous to the FPBW of an op amp, where the signal looks more like a triangle and a great deal of distortion exists on its output(s). FPBW is the bandwidth that the ADC needs to acquire signals accurately and for the internal front end to settle properly, i.e., –6.62 GHz in the example above.

Selecting an IF and using the converter out in this region is not a good idea. That's because performance results will widely vary in the system based on the rated resolution and performance stated

in the converter's datasheet. The FPBW is much bigger than the maximum sample bandwidth of the converter itself, ~5 GHz as in the aforementioned example.

"Sample bandwidth," in this case, is where the design is centered. Any design should avoid using some or all of the highest frequency portions of the rated FPBW. Not doing so will de-rate dynamic performance (SNR/SFDR) that could vary widely.

The datasheet doesn't always provide the sample bandwidth of a high-speed ADC. To make that determination, follow the above example.

Typically, today's datasheets specify this information or even list production-tested frequencies that guarantee delivered performance within the converter's sample bandwidths. In older ADC generations, though, these test frequencies are not always shown out to the Fmax defined earlier in the article.

CONCLUSION

Keep these principles in mind for any signal-chain design. By request, a spreadsheet analysis can be sent to you highlighting the previously mentioned examples. Feel free to use this and tailor it to your next design. If you have further questions, connect with me on Analog Devices' EngineerZone online technical support community at RReeder.

Further discussions on how to go about generating a full signal-chain analysis will be covered in an upcoming Part 2, "Analog Signal-Chain Accuracy" *(to appear on electronic design.com)*. Finally, remember that simply increasing the performance or resolution of the ADC in the signal chain will not increase the measurement accuracy. If the same amount of front-end noise is still present, the accuracy will not improve. The noise will only be measured to a more granular degree and probably cost the designer's boss more money in the end. ED

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VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR victoria.kickham@penton.com NOVEMBER 2015

Global Distribution: Latin America

Manufacturing growth in Mexico spurs growth across the supply chain throughout Latin America.

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR

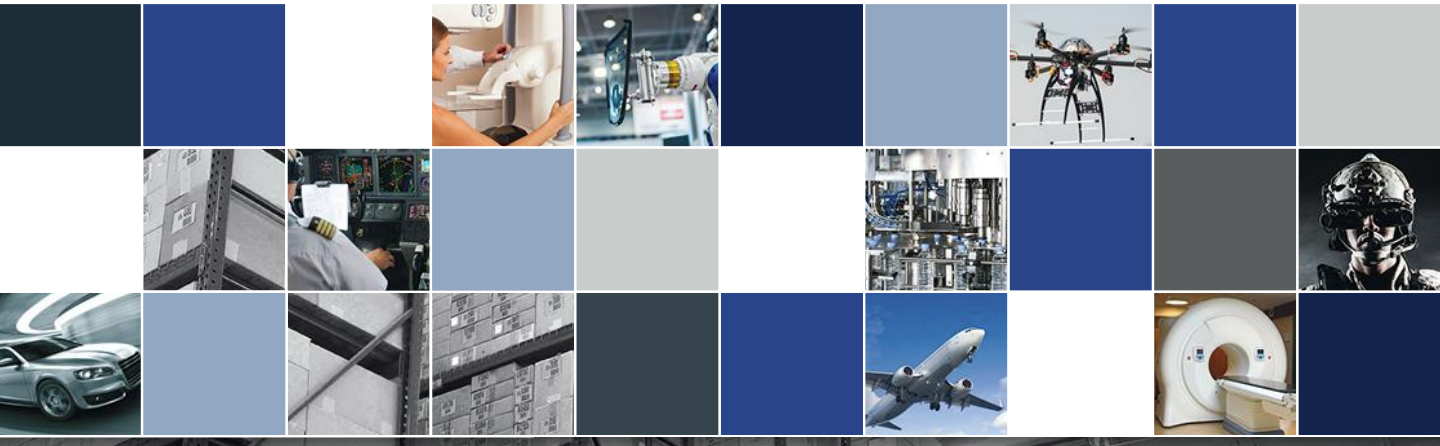
Image courtesy of Thinkstock

AMERICA II ELECTRONICS HAS expanded its business in Latin America in response to on-shoring trends, as well as the growth of automotive and medical business in places such as Mexico and Brazil. The distributor of electronic components points to Mexico as its fastest-growing region, but notes that all of Latin America represents a considerable market opportunity—something companies throughout the supply chain are taking advantage of today.

"From a market standpoint, there is a lot of opportunity in the region, especially for our company," says Esteban Polanco, America II's strategic sales director for Mexico. Located in Guadalajara, Polanco is responsible for the distributor's business throughout Latin America. "It's a huge opportunity. We're kind of the new kid on the block in Latin America, with our new focus in Mexico, so for us the potential is huge. We almost doubled from last year to this year from a revenue standpoint."

America II has done business in Mexico for more than 10 years, but stepped up efforts in the last two years, hiring Polanco in 2013 and beefing up its regional inside and outside sales teams. Polanco and his team are developing country-specific business strategies in an effort to grow throughout the region and become a larger portion of America II's overall business.

"We're pushing heavily in Latin America," adds America II's President Brian Ellison, pointing to growth in automotive-related business in Mexico in particular, and to the market for white goods throughout Central and South America as well. The distributor is responding by expanding both its line card and its sales staff, adding more than 55 franchised product lines in the last few years—some aimed at serving Latin American business.



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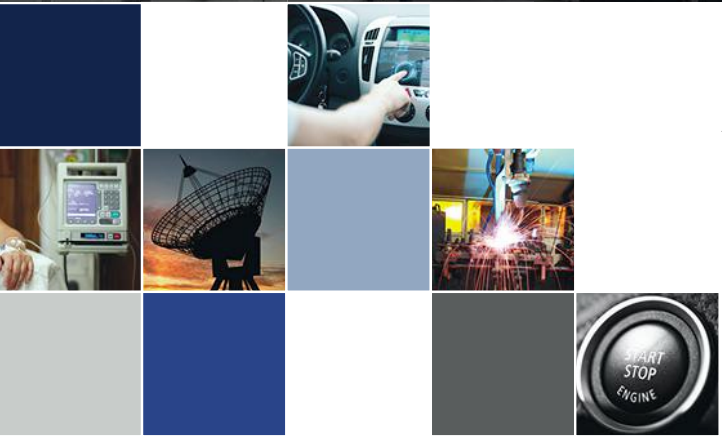

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Such trends are likely to continue. Manufacturing in Mexico has increased at a higher-than-typical rate over the last three years, and overall supply-chain growth is following suit. This condition is expected to play out over the next five to six years, according to Scott Stanley, senior vice president of NAPS, a firm that provides outsourcing and compliance management services to a variety of manufacturers looking to expand into Mexico. The growth of the country's automotive industry, its more affordable labor rates compared to other regions, and the increasing cost of doing business in the United States and Europe are key factors.

"It's sort of a perfect storm," says Stanley, whose company manages roughly 74 factories and close to 10,000 employees in Mexico. "To top it off, you've got a strong dollar against the peso."

Stanley says he sees a variety of companies moving into Mexico for new business opportunities—large multinational manufacturers are opening new locations there while smaller, one-location firms are relocating to the region, in many instances. Although many of these firms are still sourcing most of their materials and supplies from outside of Mexico, Stanley says the Mexican supply chain is growing as well, as more companies seek local sources of supply.

"Virtually every manufacturer you can think of has opened or is in the process of opening [locations in Mexico]," says Stanley. "[That is] driving a tremendous increase in the supply chain as well—and as that goes, the supply chain growth is significant and will continue."

> "...We're kind of the new kid on the block in Latin America, and with our new focus in Mexico, so for us the potential is huge."

Esteban Polanco, strategic sales director for Mexico, America II Electronics.

FOCUSED OPPORTUNITIES

America II's Polanco agrees with the potential for supply chain growth and points to the distributor's efforts to increase its local presence throughout Latin America. In addition to tripling its sales staff in Mexico and nearly tripling its Florida-based Latin America inside sales team over the last three years, America II plans to add local inventory in the region. Today, the region primarily is serviced from the distributor's St. Petersburg, Fla., warehouse.

"Relationships are important in the United States and Canada, but down here they are even more important," says Polanco. "Brazil likes dealing with Brazilians. As a company you have to react to that. So we have people [who] are Brazilian on our team—they are speaking to customers in Portuguese; they know the culture.

"Also, if you have a way to get closer to the customers when it comes to inventory—to provide them with flexibility—it helps them with cash flow, which is very important. There are more and more start-up companies [in the region] doing their own design. They need that."

Polanco lists Mexico as the greatest business opportunity for America II today, followed by Brazil, Colombia, Argentina, and Costa Rica. In Mexico, the focus is automotive, aerospace, and business related to electrical metering. With regard to the latter area, Polanco says the country has invested in the conversion of analog to digital metering, creating many new business opportunities. Brazil's automotive-related business, contract manufacturing base, and telecommunications business hold promise, as does Colombia's white-goods industry and Argentina's auto market. Polanco says Costa Rica is home to the region's largest cluster of medical customers.

"They are very, very good in medical devices, with many American companies operating there," he says. "From a trust factor, it's probably the No. 1 place to be. It's smaller than the other countries, but there is a huge plus with medical there."

Polanco's comments highlight the differences in doing business with each country when it comes to both culture and government regulations. That's why America II is developing strategic plans by country, rather than developing one over-arching plan to increase business throughout Latin America.

Navigating such issues is one of the biggest challenges to building new business in the region, to which Stanley agrees.

"Most of our clients have multiple concerns: One is just how to do business [and deal with] government compliance in Mexico. They want to make sure they are following the laws properly and that they are taking advantage of government incentives to do business in Mexico," he explains, adding that relocating knowledge and core competencies is often a greater hurdle to overcome. "The biggest challenge that our clients have is transferring the knowledge from wherever they are moving from. They still have to transfer production and quality control knowledge—and that takes the longest amount of time." ■

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Display	8.5″	8.5″ touch	12.1″ touch	12.1″ multi-touch
Zone Touch Triggering	N/A	YES	YES	YES
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ideas for design

Enhanced PWM Implementation Adds High-Performance DAC to MCU

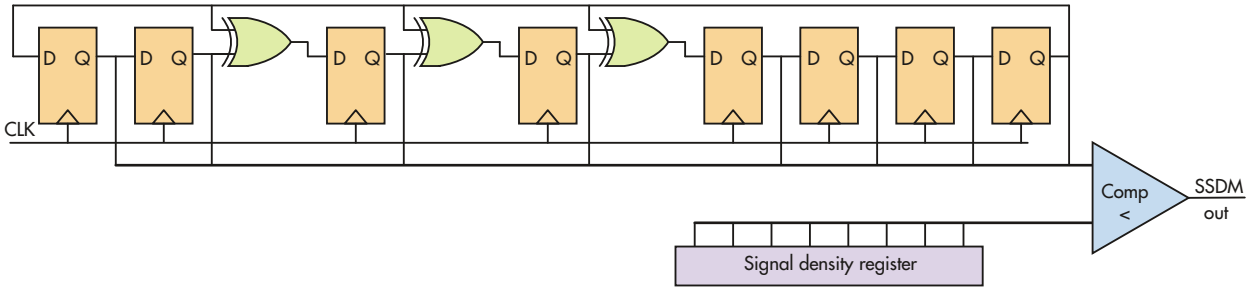
DENNIS SEGUINE | CYPRESS SEMICONDUCTOR CORP.

SOMETIMES A DESIGN need more DACs than the mixed-signal microcontroller has available. An easy solution is to put in a pulse-width modulator (PWM) circuit and filter it output with an RC filter. An 8-bit digital/analog converter (DAC) can have 20-mV resolution from a PWM operating from a 5.0-V supply, and it's reasonable to require the AC noise on the RC filter's output to be less than a single bit.

The PWM output as seen in the frequency domain is:

$$V(n) = V_{DD}\left(d + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^n}{n}\sin(n\pi d)\cos(n2\pi f)\right)$$

where d is the duty cycle, f is the pulse rate (typically the PWM clock frequency divided by the Period value), and n is the harmonic number. At 50% duty cycle, the peak-to-peak value of the first harmonic is 2 × 5 × (2/π) or 6.18 VPP from a 5.0-V supply. To get this "noise" below a single bit requires a filter



1. The Stochastic Signal Density Modulator combines a pulse-width modulator and a linear feedback shift register to reduce noise in the digital-to-analog function.

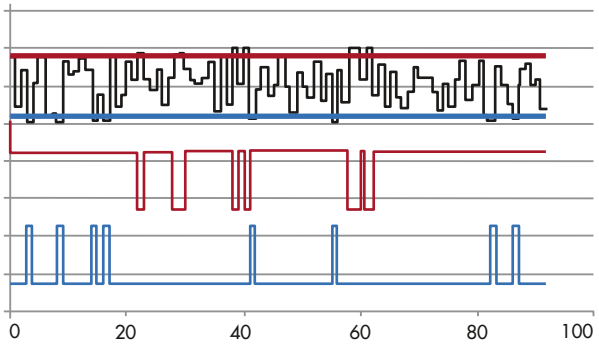
with attenuation of 20 mV/6.18 V = –50 dB at the first harmonic. That means the RC filter must attenuate the sum of the PWM's harmonics by a factor of 300.

At duty cycles above and below 50%, the peak-to-peak noise at the fundamental is lower, so the filtering gets easier. If the PWM is clocked at 8.0 MHz with 50% duty cycle, the output pulse rate is 31.25 kHz. Attenuating the noise to 20 mVPP takes a filter with a corner frequency of 104 Hz. That results in a slow update rate when you change the 'DAC' (PWM) value. That's not a problem if the DAC is meant to be static, as for a reference voltage.

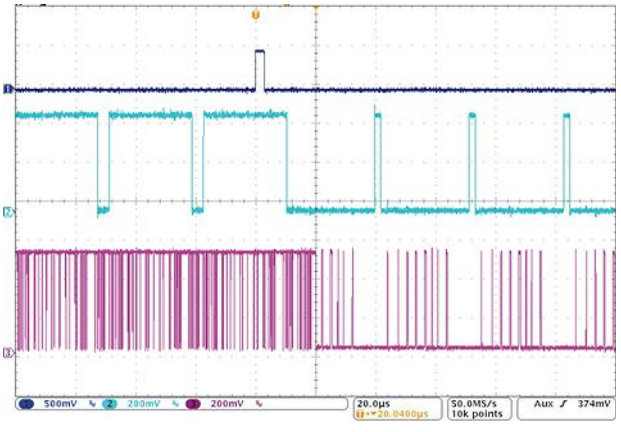
However, if you want a faster update rate, it's a problem. Using more filter poles don't help, they attenuate mostly the upper frequencies and slow the response without reducing the low-order harmonics. A better way to reduce the noise in the DAC is to modulate the PWM output randomly using a Stochastic Signal Density Modulator (SSDM). This is a melding of a PWM and a linear feedback shift register (LFSR) (*Fig. 1*).

The LFSR outputs a series of 2n-1 numbers in a pseudorandom order. At each step, the LFSR output is compared to a threshold value in an n-wide digital comparator. When the LFSR output is smaller than the threshold value, the SSDM output is a logical '1'; when the output is larger than the threshold value, the SSDM output is a logical '0' (*Fig. 2*), where there SSDM output is shown for two different threshold values.

The average density of the SSDM's output is the same as the duty cycle of the PWM, but the SSDM output is scattered about on the PWM period in a pseudorandom manner. The density of the SSDM is modified by an 8-bit number in code, essentially identical to changing the duty cycle of a PWM.



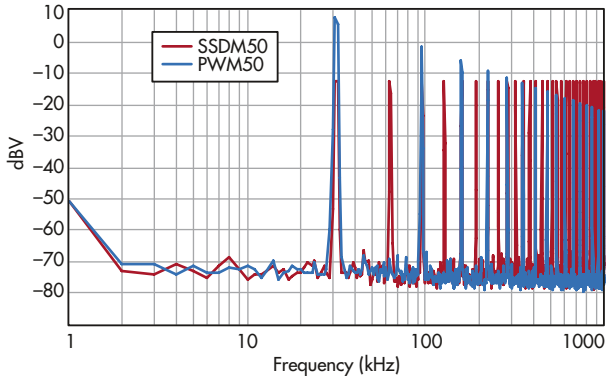
2. The output density of the SDM circuit is a function of the threshold value, shown here for two different threshold values.



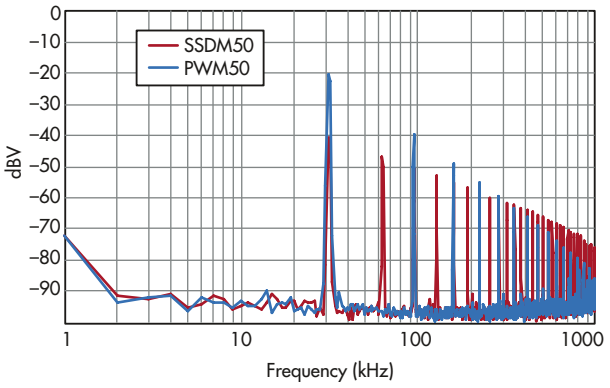
3. Shown is the PWM and SSDM duty cycle in time domain, with PWM duty cycle and SSDM density at 94% (first half) and 6% (second half).

A project was built in a PSoC microcontroller with PWM and SSDM at the same duty cycle and density. In the first half of the display (*Fig. 3*), the duty cycle of the PWM and the density of the SSDM are at 94%. In the second half, the duty cycle of the PWM and the density of the SSDM are at 6%.

A look at the results for PWM and SSDM outputs at the same frequency and duty cycle/density, as seen on a spectrum analyzer, shows that the low-frequency content of the SSDM is lower than the PWM (*Fig. 4*). Therefore, it should be easier to filter.



4. With lower low-frequency content, the SSDM output is easier to filter than the PWM output alone; the graph shows the unfiltered spectrum for PWM and SSDM with a 50% duty cycle.



5. While the SSDM has more higher-level components in the upper-frequency range, these can be attenuated with relative ease down to the level below the total noise level.

With density and duty cycle at 50%, the first harmonic of the SSDM waveform is –13 dBV (450 mVPP), which is 20 dB lower than that of the PWM. The harmonic content of the SSDM waveform is lower than the PWM up through the 8th harmonic (*Fig. 5*). The SSDM has higher-level components in the upper frequency range, but these are easily filtered to the level at which they don't affect the total noise level. The filter corner frequency is a tradeoff between lower for noise reduction and higher for faster settling. It takes a filter on the SSDM output with a corner frequency of 1.4 kHz to keep the peak-to-peak pulse noise level below the one-bit resolution. The same filter on a PWM output results in 10 counts (200 mV) of periodic noise.

At the 8th harmonic, the SSDM output is 2.0 mVPP, which is one-tenth that of the target noise level. Toggling the PWM and SSDM from one duty cycle and density shows that the rise time and settling time are the same for PWM and SSDM, as they have the same RC filter. The filtered SSDM output clearly has lower periodic noise (*Fig. 6*).

PWMs can be easily incorporated into almost any microcontroller. The SSDM can be implemented in standard logic in Cypress PSoC microcontrollers, CY8C3xxx, 4xxx, or 5xxx, using PSoC Creator. The density is modified at run time by writing to a control register; the comparator is simply an 8-wide implementation. The PWM, used here for comparison, is a standard component with the duty cycle also modified at run time.

The SSDM implementation is somewhat simpler in PSoC1 (CY8C24xxx, 27xxx, 28xxx, and 29xxx) with the 8-bit SSDM being a built-in function of the digital block. The length of the SSDM sequence (used here for comparison) is set in the GUI, and the density is selected by using a dedicated API in C, with this code: SDM_WriteDensity (hex value).

The RC filter is, of course, off-chip. The result of the SSDM implementation is a PWM-based DAC with the same peak-to-peak voltage noise as a standard PWM DAC, but with ten times the bandwidth. Wider DACs and SSDMs of 10, 12, or 16 bits can be implemented by using more digital blocks in PSoC1 or by using flip-flops and XORs up to 16 bits in PSoC4xxx. The higher-resolution DAC will have correspondingly slower update rates.

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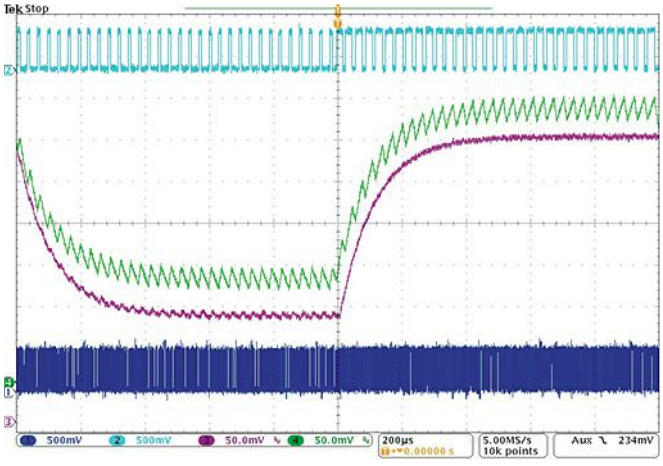
Dave Van Ess (the most stochastic of my friends) did the original work creating the SSDM User Module in Cypress PSoC Designer and drove the demand for including this functionality in all new PSoC designs.



6. Although the rise time and settling time are the same for both PWM and SSDM, the filtered SSDM output has lower periodic noise.

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Where Have All the Gamers Gone?

The last few years have been a bit flat for CPU performance for gamers, but not so for GPUs. If "you got game," then using the latest GPUs will deliver the best gaming experience.

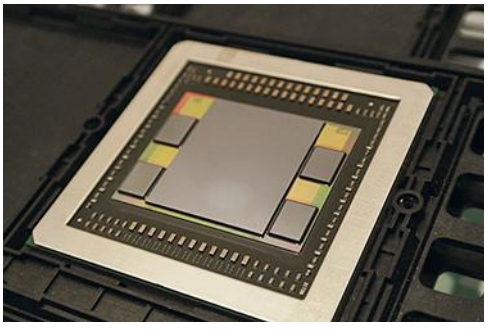
Gaming is all about performance, but there have been few gains on the CPU side. Game developers are taking advantage of multiple CPU cores in the latest processors as the number has been increasing, but the performance of the individual cores has been relatively flat for the past few years. The challenge is that the CPU cores are large, so providing a massive increase in core count is unlikely.

GPUs have similar challenges, but there are a number of factors that have allowed growth of graphics performance. Increasing the number of cores has been more practical than with CPUs, and features like high bandwidth memory help, as well.

AMD's compact R9 Nano (*Fig. 1*) highlights the improvements that GPUs have been going through for the past few years. The R9 Nano incorporates on-chip, 4,096-b wide, high-bandwidth-memory (HBM) to feed the 4096 stream processors in the 28-nm Fiji GPU. The board only uses 175 W versus the 300 W of high-end, full-length boards.

HBM puts a 3D DRAM memory stack on top of a silicon interposer layer along with the GPU die. This does a few things: First, it provides a wider interface than would be practical for off-chip memory. Second, it brings the memory closer to the GPU cores. Third, it provides a more power-efficient memory subsystem. Finally, it is more compact compared to off-chip memory.

1. AMD's compact R9 Nano incorporates on-chip, high-bandwidth memory (HBM) to help deliver high graphics performance.



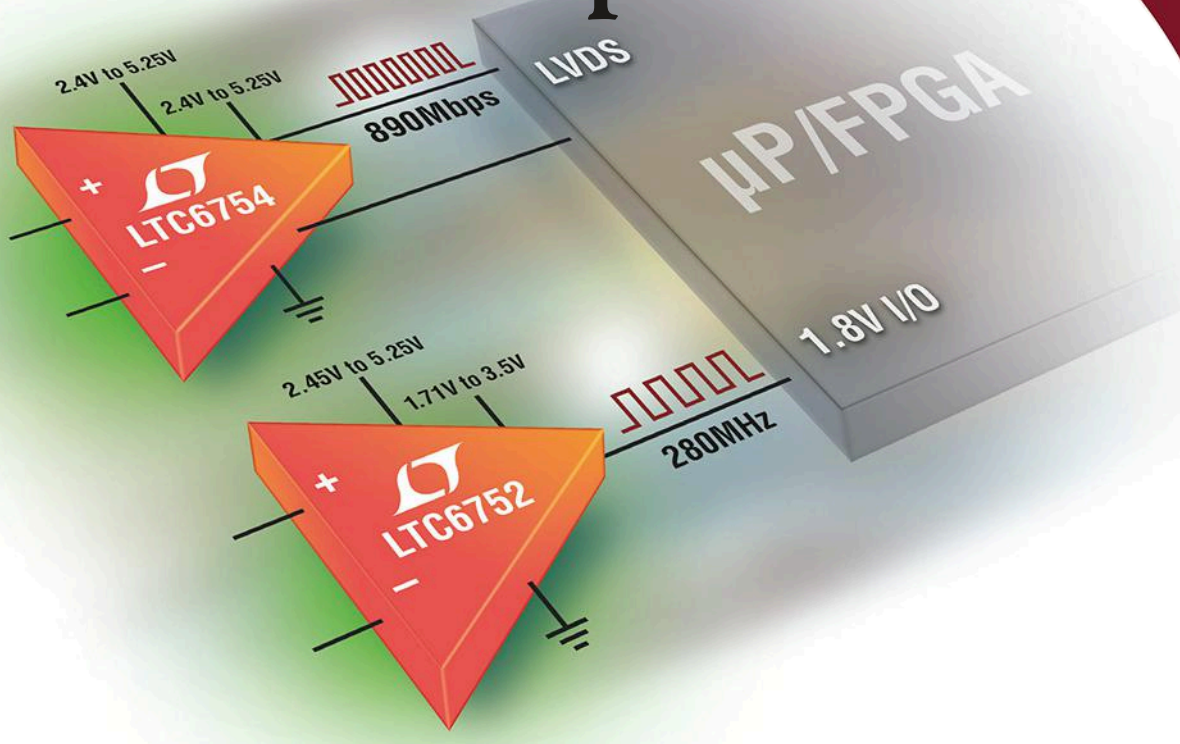
2. The HBM in the R9 Nano includes four stacks of four DRAM die for a total memory channel width of 4096 bits.

This R9 Nano HBM implementation has four die stacks with two 128-b memory channels per die (*Fig. 2*). This provides a 1,024-b channel. Four stacks provides the 4,096-b bus. The stacks are also found in the longer but more powerful Fury and liquid-cooled Fury X GPU boards, also from AMD. These deliver top-end gaming performance to multiple displays.

The R9 Nano and its siblings support Microsoft DirectX 12 and Microsoft Windows 10. DirectX 12 includes a host of new features, including Explicit Multiadapter support for multiple GPU solutions. This could be multiple GPU boards or to take advantage of a CPU/GPU combination like Intel's latest Silverlake as well as AMD's Accelerated Processing Unit (APU) in combination with a GPU board like the R9 Nano *(see "APU Blends Quad Core x86 With 384 Core GPU" on electronicdesign.com)*. DirectX 12 is the target for the latest crop of PC games. It is also providing a more efficient link to the underlying hardware.

So if you are looking to improve your gaming system, then don't worry if your motherboard and processor are a few years old. Instead, take a look at replacing your GPU. If you are building a new platform, then you might save a few dollars using an older processor chip with a few more cores. ed

UltraFast Comparators



Rail-to-Rail Comparators Interface to 1.8V CMOS and LVDS

Our new rail-to-rail comparators combine UltraFast performance, small packages and a whole lot of features. The LTC®6754 LVDS comparators support toggle rates up to 890Mbps and 1.8ns propagation delay. The LTC6752 comparators interface to CMOS down to 1.8V, exhibit a propagation delay of 2.9ns and support toggle rates up to 280MHz. Available features include a separate output supply, shutdown, output latch, adjustable hysteresis, and complementary outputs. With high performance and a wide selection, the result is true design flexibility.

Features

Part #	Toggle Rate	Prop Delay	Output	Package	Output Supply	Adjustable Hysteresis	Output Latch	Shutdown	Q/$\overline{Q}$ Outputs
LTC6754	890Mbps	1.8ns	LVDS	SC70					●
				QFN12	●	●	●	●	●
LTC6752	280MHz	2.9ns	CMOS	SOT23					
LTC6752-1				SC70		●	●		
LTC6752-2				MSOP8	●	●	●	●	
LTC6752-3				QFN12	●	●	●	●	●
LTC6752-4				SC70	●				

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