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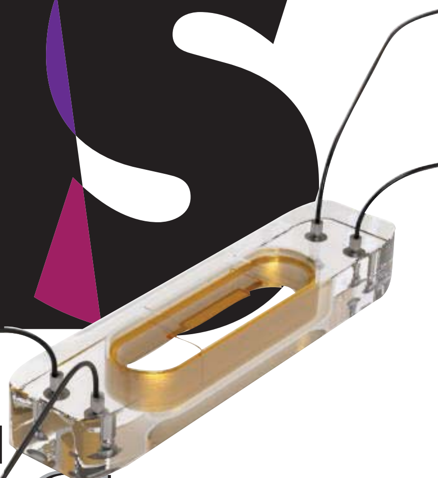

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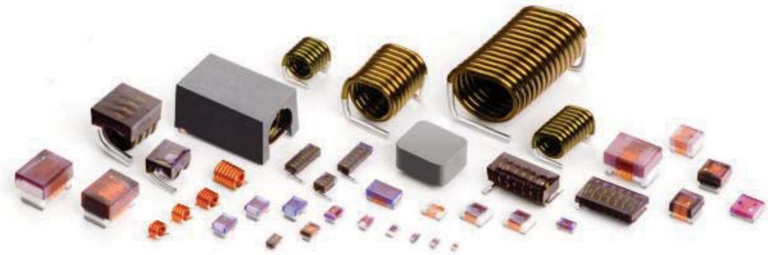

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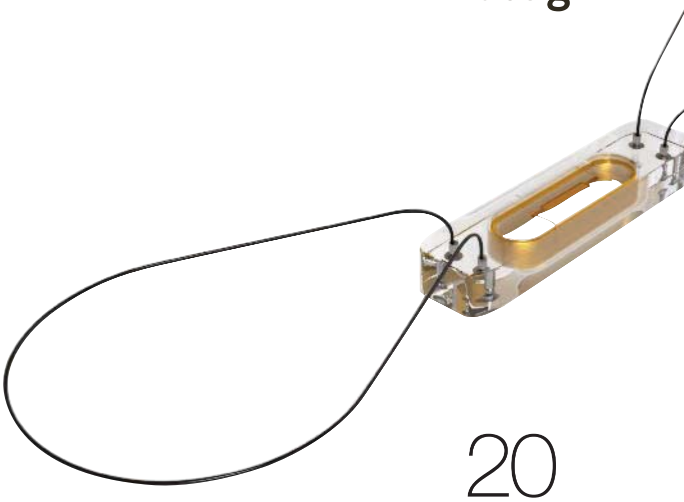

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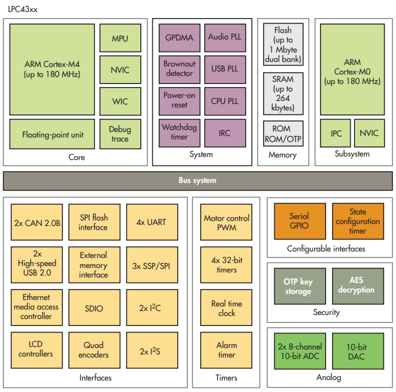

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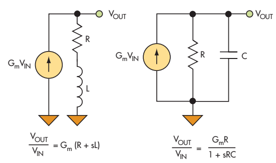

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To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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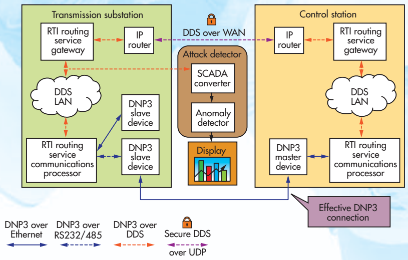

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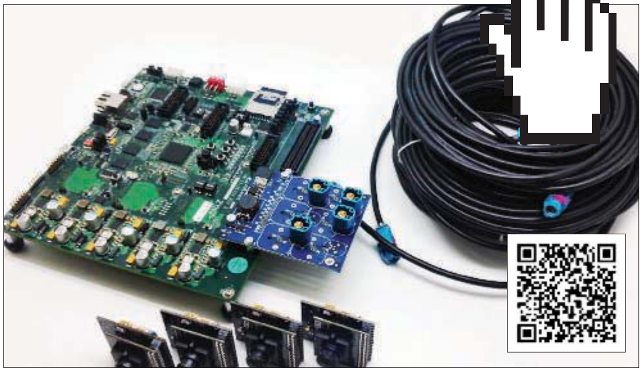

PLATFORMS STREAMLINE THE ADAS DEVELOPMENT CYCLE

A platform approach to advanced driver assistance systems reduces risks and increases the speed of innovation.

SAMSUNG GALAXY S5: THE GOOD, THE BAD, AND THE ANNOYING

It's the hottest phone on the market, with many great features, but the S6 is going to need some tweaks.

THESE ROBOTS CAN KILL YOU OR CURE YOU

Today's innovative robots offer medical miracles and battlefield destruction alike.

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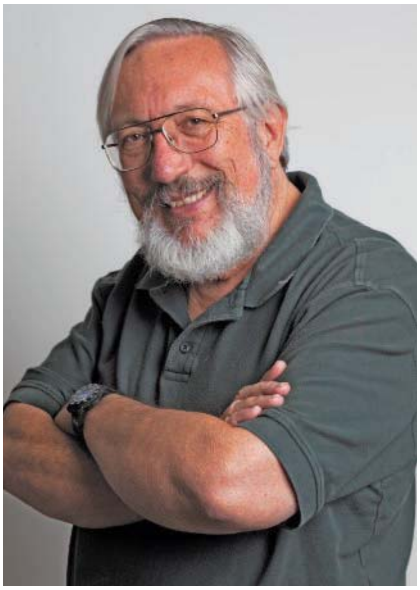

The Maker/ HackerSphere Evolves

TechShop recently threw a party at its San Francisco facility to celebrate a relationship with National Instruments. NI has developed a package of instruments and software expressly for product development and learning at TechShop. The hardware stays at TechShop on multiple benches. TechShop members can walk in with nothing more complicated than an iPad (or a Mac or Windows machine) and access (wirelessly or with cables) the functionality of an oscilloscope, logic analyzer, arbitrary waveform generator, and multimeter using an app called Data Dashboard for LabVIEW.

This is important news because it relates to the whole "Maker" phenomenon. I have attended Maker Faires in the San Francisco Bay area and have been amazed at the enthusiasm of participants. But there's been a gap between the fairly basic kits for sale and the tents full of people learning to solder and the magnificent steam-punk vehicles and Tesla-coil ballet extravaganzas. The only organizations catering to advanced analog or mixed-signal hackers have been Hacker Dojo and the amateur radio societies.

Also, the only organization providing access to advanced mechanical fabrication tools has been TechShop, with its mills, lathes, brakes, shears, plasma cutters, and educational programs. TechShop offers member-based workshops in San Jose, San Carlos, and San Francisco in California, as well as in Arlington, Va., Pittsburgh, Pa., Allen Park (near Detroit), Mich., and Chandler, Ariz. TechShops in New York City and Los Angeles are in the planning stage.

Membership isn't cheap. Pay-as-you-go is discouraged by a charge of $175 a month. That goes down to $125 with automatic monthly billing, or what amounts to $116.25 if you pay for a whole year all at once. You can add a family member for what starts at $50 per month.

There are many special-interest groups where coders meet in person—giving rise to hackathons, which may take place at corporate facilities. (Google and Microsoft both do that in the Bay Area.) But in the Maker spirit, Hacker Dojo has a really nice facility in Mountain View, Calif. The denizens of the Dojo characterize it as part coworking space, part events venue, and part community center. It doesn't cost anything to drop in during the normal hours of 8 a.m. to 10 p.m. But for $120 a month, you can have 24/7 access and the ability to host events, like, say, a hackathon—or anything else. I went to a birthday party there once and spent an evening talking to people about the traditions of the Argentine tango.

Finally, on the Maker theme, let's not forget the oldest Makers, the ham-radio community. Fascinatingly, there's quite a synergy these days between hams and the Arduino community. My buddy Leigh Klotz, WA5ZNU, has written *Ham Radio for Arduino and PICAXE*, published by the American Radio Relay League, which is probably the oldest and most popular Maker organization on the planet. ed

MICHAEL WHITE | Contributing Technical Expert
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Get Ready to Hit 10 nm Out of the Park

This sure is a fun and exciting industry we work in! Despite all the naysayers, each year, the focus is on the next up-and-coming IC technology. A couple of years ago, attention was on 20 nm. This year it is 16/14 nm. Behind closed doors, there are already early peeks as to what 10 nm could be.

Here in the United States, we're in the middle of the baseball season, which provides the perfect metaphor. The batter at home plate is actively involved in the game, facing a variety of 90-mph-plus pitches and trying to get on base and score runs, while the next batter in line is "on deck," warming up and watching the pitcher to analyze what might be coming. When he steps up to the plate, he wants to be as prepared as he can be, so he isn't surprised by anything the pitcher might throw at him. So in our baseball game, where are we in the technology node lifecycle?

THE BATTING ORDER

Just a couple of years ago, all the hype was about the move to 20 nm and the challenges of double patterning. Now, 20 nm is "on base" and in volume production. Many customers have released 20-nm designs to production, with more on the way.

This year, 16/14 nm is at the plate and looking to make some hits. As you recall, 16 and 14 nm are essentially two names for the same process, which is a 20-nm back end of line (BEOL) with FinFET transistors. It is still an emerging technology node, in early production and likely to remain so through the remainder of this year, but with dozens of test chips and early production chips coming off the line.

On deck, 10 nm awaits. It is in the midst of final process development tweaks, with early intellectual property (IP) development now in full engagement across the early process node adopters and the ecosystems. The node should see its very first customer test chips starting now and growing in the second half of 2014, with far more following in 2015.

So, what are the curveballs and fastballs that each of these nodes must face?

The greatest impact of these nodes falls on the designers. The designer's job of creating circuitry and layout that comply with the fabs' design rules has always become more challenging node over node as new and more complex design rules were introduced. But at 20 nm and below, it has become dramatically more difficult.

The 20-nm node introduced double patterning, which significantly increased the designer's need to understand the ramifications of how designs are manufactured. Requiring designers to design and verify layouts that could be accurately split between two masks meant familiarizing them with a host of new design concepts and rules. Also, 20 nm saw a change from minimizing fill to intelligently maximizing fill.

The 16/14-nm node added on a new transistor design (FinFET), while maintaining the rest of the 20-nm BEOL. The FinFET design offers clear IC performance and power benefits. But with this new transistor design comes the need for far more accurate parasitic extraction (PEX) models, additional convoluted fill requirements, and, as always, more complex design rule checks (DRC).

The 10-nm node will face even more exciting challenges. If early indications are correct, it puts us back on the 30%+ node-over-node increase in DRC checks that we have been slogging through since the 40-nm node. At 20 nm, some double patterning layout coloring was supported/required. At 10 nm, designers can expect to see significantly more requirements to color layouts before tapeout.

Additionally, although fill was subject to double patterning coloring requirements at the 20- and 16/14-nm nodes, fill analysis, insertion, and balancing will be significantly more "interesting" at 10 nm. We are also seeing significantly more interest in modeling and controlling sensitive net parasitics to maximize performance, control variability, and other factors.

One of the toughest 90-mph pitches that designers will need to hit at 10 nm is multi-patterning (MP). Because extreme ultraviolet lithography (EUV) continues to slip out, critical layer layouts must be divided across even more masks to resolve the structures we need. Designers are still making final adjustments to their processes, but expect to see, in addition to double patterning, the introduction of triple patterning (TP), quadruple patterning (QP), and various forms of spacer-assisted double patterning (SADP).

AT THE PLATE

The foundries have been working on 10-nm process development and enablement for some time. Their preparation includes creating test layouts and DRC/MP decks, then undertaking process exploration to determine what patterns/structures are manufacturable with what design rules. This exploration is an iterative process in which the foundries continually refine the layout decks and design rules, based on test results.

Once a foundry begins to converge on a process, decks, and design rules that look to be manufacturable, it begins creating a standard library and other key IP. In conjunction with this process, the foundries and their primary EDA suppliers partner closely to ensure that their preferred EDA tools have the necessary functionality and performance for the new node. Major foundry ecosystems are in the midst of this development effort to get ready for 10 nm.

Also, fabless customers are (or should be) building designs at 20 and 16/14 nm. Each of these technology nodes introduces new types of verification and analysis that help designers transition from one node to the next. A jump from, say, 28 nm directly to 10 nm would be challenging, requiring designers to adopt all these new methodologies simultaneously while also trying to intercept a market window on schedule. To attempt this, one would be swinging for the fences—a very tall order indeed.

Working closely with your foundry to understand the flows, decks, and EDA tools it is using internally is especially critical during the first few years of a node ramping into production, given all the changes that occur in the process, decks, and elsewhere. Common approaches and preferred solutions ensure you are in synch and help avoid delays in getting updated decks and flows. The introduction of MP at 10 nm means new ways of making and verifying coloring assignments. Critical to your success is partnering with your key EDA supplier and foundry early to understand the design methodology changes and flow changes that MP brings, so you can train and prepare your team.

All in all, while a lot of new pitches are being thrown at 10 nm, the old adage of "You play like you practice" still applies. Using 20- and 16/14-nm process nodes to become acquainted with the expanding complexity and new manufacturing requirements of advanced nodes will help designers step up to the plate at 10 nm with confidence. ed

MICHAEL WHITE is the director of product marketing for Calibre Physical Verification products at Mentor Graphics. He has a BS in system engineering from Harvey Mudd College and an MS in engineering management from the University of Southern California.

News & Analysis

RICHARD GAWEL | PRODUCTION EDITOR

Quadriplegic Uses Thought TO MOVE HIS HAND

Ian Burkhart was paralyzed four years ago during a diving accident. Thanks to a partnership between the Ohio State University Wexner Medical Center and Battelle, though, the 23-year-old quadriplegic became the first patient to move his fingers and hand simply by thinking. Neurobridge technology bypasses spinal cord injuries to allow voluntary and functional control of paralyzed limbs.

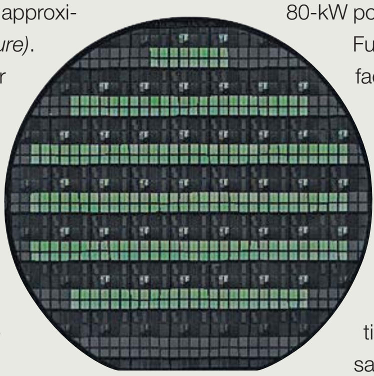
On April 22, Dr. Ali Rezai implanted a chip smaller than a pea onto the motor cortex of Burkhart's brain. The chip interprets brain signals and sends them to a computer, which recodes and sends them to a custom, high-definition electrode stimulation sleeve that stimulates the proper muscles to execute Burkhart's desired movements *(see the figure)*. Within a tenth of a second, his thoughts are translated into action.

Battelle scientists worked for nearly a decade to develop the algorithms, software, and stimulation sleeve. First,

Neurobridge technology enables Ian Burkhart, a quadriplegic since 2010, to move his paralyzed hand simply by thinking about it. A chip implanted in his brain sends signals to a computer that decodes and recodes them before sending them to a sleeve that stimulates the muscles required to execute the desired movements.

MARKET RESEARCH FIRM Yole Développement's "Power GaN Market" report forecasts a $600 million market for gallium-nitride (GaN) devices by 2020, which translates to approximately 580,000 six-inch wafers *(see the figure)*. Philippe Roussel, Yole's business unit senior manager, says that starting in 2016, compound annual growth rate (CAGR) will be an estimated 80% through 2020, based on the assumption that electric vehicles/hybrid electric vehicles (EVs/HEVs) will begin adopting GaN during the 2018-2019 timeframe.

Auto manufacturers said that despite the long qualification time (slowing time to market), EVs/HEVs offer a good landing spot for GaN technology. Carmakers will target dc-dc converters at the outset and consider using GaN for battery chargers. Still, it's unclear at this point whether GaN can withstand the 80-kW power required in EVs/HEVs.



Fujitsu GaN power devices are built on 6-in. wafers.

Furthermore, Yole expects the power-supply/power-factor-correction (PFC) segment to dominate the GaN market from 2015 to 2018, accounting for 50% of device sales. The report says that by the time that segment's "streak" is over, automotive will likely catch up.

"The market is huge and represents a very small fraction of business," says Roussel. "But, when done in Yole Développement's cost simulation with GaN solution, it worked very well. GaN will save money because it will reduce the amount of devices used by allowing you to perform a function at a higher frequency."

they recorded neural impulses from an electrode array implanted in a paralyzed person's brain. They then used that data to illustrate the device's effect on the patient. Two years ago, the company began collaborating with Ohio State to design the clinical trials.

The sleeve is precise enough to activate small muscle segments in the arm and enable individual finger movement such as pinching or making a fist as well as coordinated dynamic hand and wrist movements. The Ohio State and Batelle teams worked together to figure out the correct sequence of electrodes that would allow Burkhart to move his fingers and hand functionally. Burkhart also worked for months with the sleeve to stimulate his forearm and rebuild his atrophied muscles.

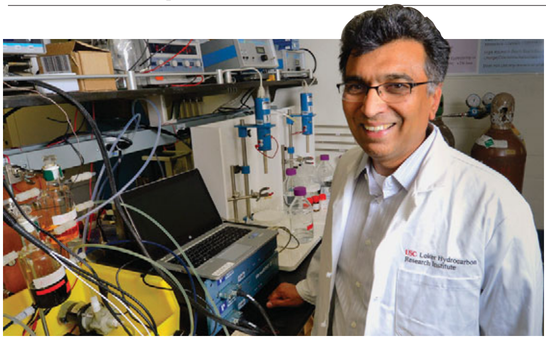
"One of our goals is to allow individual finger movement by decoding detailed signals from the brain and recoding them for high-definition stimulation," said Chad Bouton, research leader at Battelle. The researchers also envision wireless connections between the chip and the sleeve in the future, though some technological hurdles remain.

"As with any wireless implant, there are challenges around miniaturization of the electronics, power dissipation and resulting heat, and transmitting large amounts of data quickly (bandwidth)—or having a processor that can run the algorithms effectively while drawing a low level of power," Bouton said.

The system relies on standard medical-grade power systems. It also uses an off-the-shelf, 96-electrode Utah Array to provide the detailed neuronal signals that it requires. Rezai believes the technology one day may help patients affected by other brain and spinal cord injuries including strokes. According to Bouton, it potentially could be applied to the control of prosthetic limbs as well. ■

Payback time for GaN is about six months, with PFC being a little more expensive at the start. Subsequently, however, the cost could decrease, saving 1% to 2% in terms of efficiency. GaN technology will also likely take a 15% market share in uninterruptible power supply (UPS) applications by 2020.

For motor-drive applications, automakers are unlikely to assume extra costs. Thus, incentives to implement new technologies like GaN must be strong. Due to the possible improvement of conversion efficiency (and bolstered by anticipated price parity with silicon solutions by 2018), the report expects GaN's implementation in motor control to start gradually in 2015-2016, reaching $45 million by 2020. ■

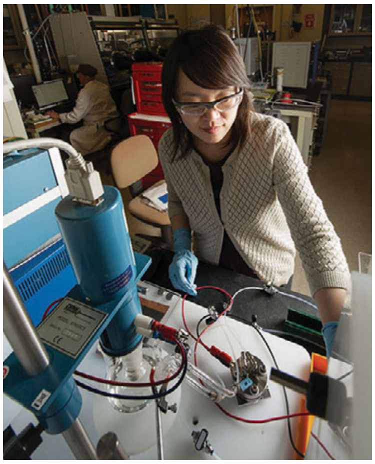


ORGANIC BATTERY Lasts Longer Than Li-ion

SCIENTISTS AT THE University of Southern California have developed a long-lasting, water-based organic battery that's built from cheap, eco-friendly components. The new battery, which doesn't use any metals or toxic materials, is designed for use in power plants where it can make the energy grid more resilient and efficient by creating a large-scale means to store energy for use as needed. Sri Narayan, professor of chemistry at the USC Dornsife College of Letters, Arts and Sciences, says the battery lasts for about 5000 recharge cycles and a 15-year lifespan, unlike lithium-ion (Li-ion) batteries, which degrade after about 1000 cycles and cost 10 times more to manufacture. *(USC Photo/Gus Ruelas)* ■

NANOTUBES BOOST Li-ion Efficiency

LITHIUM-ION (LI-ION) BATTERIES can get too hot and weigh too much, and they don't conduct electricity particularly well. They also are sluggish when it comes to charging and discharging. Yet Chunmei Ban and other scientists at the National Renewable Energy Laboratory have created crystalline nanotubes and nanorods to overcome these challenges. Typical Li-ions use separate materials for conducting electrons and binding active materials, but NREL uses the carbon nanotubes for both functions. This packs more energy into the same space for better battery output and improved reversibility. Researchers expect prices to fall as their use increases. *(photo by Dennis Schroeder, NREL)* ■



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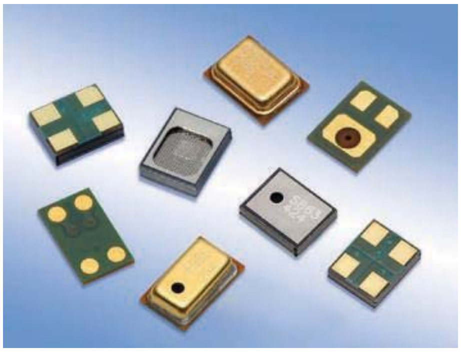
MEMS Move To MULTIPLE

Integration has long been the key to the adoption and growth of microelectromechanical-systems (MEMS) technology. MEMS-based devices are already used in a broad range of electronic products, from audio microphones for sound to optical components for displays and vision, and should only continue to expand into different application areas.

With a growing number of commercial MEMS foundries, opportunities are increasing to experiment with MEMS design approaches. Future success may depend on how well they can combine MEMS technology with their current blend of semiconductor and other electronic technologies.



1. MEMS-based microphones from Knowles Corp. consume much less power in a fraction of the size of competing microphone technologies.

POPULAR APPLICATIONS AND DEVICES

MEMS devices are chips that combine electronic and mechanical functions. They can be mass produced using modified semiconductor processes, utilizing substrate materials (such as silicon) to form mechanical parts (like switches and sensors) on the same chip as transistors and ICs. Three-dimensional (3D) structures are typically formed on the substrates for the mechanical portions of the device, which may include levers, hinges, and gears, with actuators controlling mechanical motion.

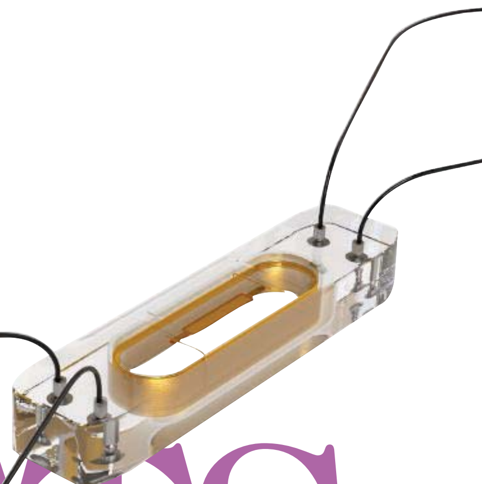
Actuators may control motion by means of electrostatic, magnetic, or thermal energy. A human body can even be the source of energy for a MEMS device. The MEMS structures can be used for small machines that produce different motions or for sensors that detect and measure small motions, such as acceleration in car engines and blood pressure in medical applications.

The largest market for MEMS technology right now is at audio frequencies for microphones in smartphones and other portable communications devices. MEMS-based sensors are already well established and widely used in many consumer electronics applications, including gaming consoles, computer tablets, and navigation devices. MEMS pressure sensors are also used extensively throughout modern automobile designs for measuring different fluids and gases, such as air-conditioner systems *(see "MEMS Technology Gears Up For Big Innovations,"* Electronic Design*, August 8, 2013)*.

Improvements among the largest MEMS applications such as microphones areas are taking place on a regular basis. According to Knowles Corp., its SPH0641LM4H-1 digital MEMS microphone consumes a third the power of other digital MEMS microphones and boasts high signal-to-noise-ratio (SNR) performance in low-power mode *(Fig. 1)*. It provides a

As MEMS technology becomes more practical and versatile, it's spreading to commercial, industrial, and military applications.

MARKETS



The implantable HF System from CardioMEMS monitors the heart for dangerous pressure buildup following cardiac surgery.

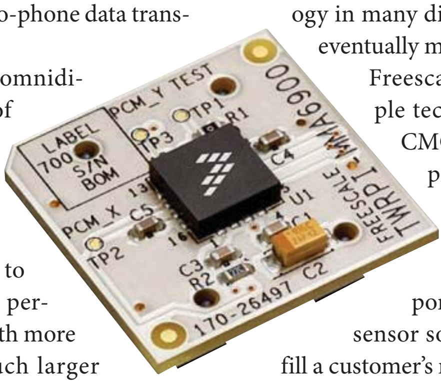
low-power alternative to the use of an analog microphone and analog-to-digital converter (ADC).

Since it's as much as 20% smaller than other models, the SPH0641LM4H-1 also does away with the previous tradeoff between designing a portable product and choosing between a microphone with high SNR or low current draw. It handles 20 Hz to 20 kHz and measures 3.50 by 2.65 by 0.98 mm.

Similarly, the Knowles SPH0641LU4H-1 MEMS microwave provides ultrasonic bandwidth to 80 kHz for use in advanced applications with ultrasonic sound waves, such as touchless gesture recognition and phone-to-phone data transmission between smartphones.

The InvenSense ICS-40720 low-noise omnidirectional MEMS microphone consists of a MEMS microphone element, impedance converter, and output amplifier housed in a compact 4- by 3- by 1.2-mm surface-mount package. It provides linear response at sound pressure levels (SPLs) to 122 dB and offers sensitivity of –32 dBV, performance levels that compare favorably with more conventional, more expensive, and much larger discrete-element microphones.

MEMS sensors are also being used in large numbers, largely in automobiles for safety applications. More companies are already manufacturing many different types of MEMS-based sensors. Some of the leading developers are investing in improved fabrication capabilities for possibly integrating MEMS technology with semiconductor and other microscale electronic technologies.



2. With extensive experience in developing MEMS for vehicular applications, Freescale Semiconductor supplies a wide range of MEMS sensors for automotive safety systems.

STMicroelectronics is establishing a pilot fabrication facility to process 200-mm wafers using a combination of MEMS, magnetic, and piezoelectric technologies on the same IC. Already one of the leading suppliers of MEMS sensors, the firm is well aware of the growth potential for MEMS technology in many different application areas, with plans to eventually move that facility to 300-mm wafers.

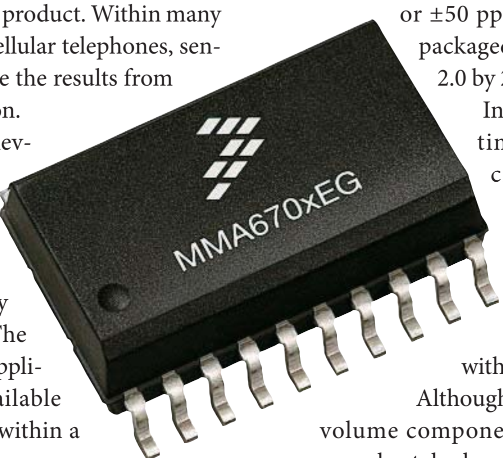
Freescale Semiconductor has melded multiple technologies such as silicon MEMS and CMOS circuits as part of its Xtrinsic sensor products. These devices rely on a modular approach to combine multiple sensor inputs, logic, and other circuits into compact solutions. They are supported by customizable software to create sensor solutions that efficiently and effectively fill a customer's requirements.

Freescale, which has been making MEMS sensors for almost 30 years, applies its high-aspect-ratio MEMS (HARMEMS) technology to many different automotive safety systems, including vehicular airbag systems *(Fig. 2)*. The same technology is being investigated for health-care monitoring applications, with

MEMS pressure sensors used for patient diagnostic functions. The HARMEMS technology has also been used in dual-axis accelerometers for vehicular electronic-stability-control (ESC) systems to measure lateral acceleration. And, the firm assists with development platforms that help customers integrate different MEMS sensors into their applications *(Fig. 3)*.

The increasing number of sensors in portable electronic devices, vehicles, and even clothing is creating a growing need for what is known as "sensor fusion," or the practical combination of data from the many different sensors (both MEMS and non-MEMS sensors) within a device or product. Within many portable electronic products, such as cellular telephones, sensor hubs are used to collect and analyze the results from different sensors for effective application.

Sensor fusion can occur at different levels within a product, such as within an individual MEMS sensor, within a sensor hub, or within a microprocessor and software of a product, so some amount of data partitioning may be required as part of sensor fusion. The evolution of sensor fusion will enable applications that might not have been available previously, such as indoor navigation within a shopping mall, using a cellular telephone.



3. The TWRPI-MMA6900 board from Freescale Semiconductor holds the firm's Xtrinsic MMA6900Q inertial sensor for automotive and industrial applications.

MEMS COMPONENTS

MEMS devices are also moving into application areas where they can replace traditional technologies, such as semiconductor-based switches and oscillators, with lower-power alternatives. Some companies have developed MEMS-based clock oscillators as replacements for traditional quartz-crystal clock oscillators.

Discera's DSC1102 and DSC1122 low-voltage-positive emitter-coupled-logic (LVPECL) oscillators are based on silicon MEMS technology. These devices offer frequencies ranging from 2.3 to 460.0 MHz with low root-mean-square (RMS) phase jitter of typically less than 1 ps. The oscillators differ in their disable approaches, with the DSC1102 fully powering down in standby mode and the DSC1122 disabling its outputs in standby mode.

Both oscillators are qualified to MIL-STD-883 for shock and vibration and are available for the commercial temperature range of –20°C to 70°C or industrial temperature range of –40°C to 85°C. They can be supplied in very small footprints (2.5 by 2.0 mm, 3.2 by 2.5 mm, 5.0 by 3.2 mm, and 7.0 by 5.0 mm) with stability levels of ±10, ±25, and ±50 ppm as drop-in replacements for standard six-pin lLVPECL quartz-crystal oscillators. These lead-free and RoHS-compliant (Restrictions on Hazardous Substances) MEMS oscillators are designed for supply voltages of +2.25 to +3.60 V dc as well.

MEMS clock oscillators are available from a number of additional suppliers. For example, SiTime manufactures its oscillators with standard silicon CMOS semiconductor equipment. Based on a common resonator, they perform on-chip electronic tuning to achieve different output frequencies.

Silicon Labs' Si50X CMEMS general-purpose oscillators are based on a combination of silicon CMOS and MEMS technologies. They feature a 10-year operating lifetime at output frequencies to 100 MHz. They are available in single-, dual-, and quad-frequency models, with stability levels of ±20, ±30, or ±50 ppm and only 1.1-ps RMS jitter. The packaged CMEMS oscillators measure only 2.0 by 2.5, 2.5 by 3.2, and 3.2 by 5.0 mm.

Integrated Device Technology, a longtime supplier of traditional quartz-crystal clock oscillators, also has developed lines of MEMS clock oscillators based on its own silicon MEMS resonators. The MEMS oscillators provide LVPECL outputs at frequencies to 625 MHz with better than 1-ps phase jitter.

Although MEMS sensors have become large-volume components by merit of their use in cellular telephones, MEMS switches have also seen their fair share of use in these same applications. Omron Corp., perhaps most associated with its MEMS sensors and wafer foundry services, has offered its 2SMES-01 MEMS switch for several years. It is designed in a single-pole, double-throw (SPDT) switch configuration and rated for more than 100 million switching operations.

Measuring just 5.2 by 3.0 by 1.8 mm and operating with low current consumption, the 2SMES-01 boasts low insertion loss of just 1 dB at 10 GHz and high isolation of 30 dB at 10 GHz. The switch has a three-layer structure, on glass, silicon, and glass. The top glass layer provides a hermetic seal. The middle silicon section contains the actuator and movable electrode. The bottom glass layer is the base.

In addition to its MEMS oscillators, Radant MEMS has developed and has demonstrated MEMS switches capable of more than 1.5 trillion switching cycles in response to any concerns that the mechanical contacts in MEMS switches can degrade over time and with millions of switching cycles. The company recently introduced a pair of impressive MEMS-based switches for broadband, microwave applications.

The RMSW100HP single-pole, single-throw (SPST) reflective switch is supplied in hermetic die form for die-attach to printed-circuit boards (PCBs). It is designed for applications from dc to 12 GHz, with less than 0.17-dB insertion loss at 2 GHz and less than 0.28-dB insertion loss at 10 GHz. The switch exhibits switching speed of less than 10 μs; it provides isolation of better than 23 dB at 2 GHz and more than 11 dB at 10 GHz.

For even higher frequencies, the RMSW200HP SPST MEMS switch features a frequency range of dc to 40 GHz and is also supplied in hermetic die form. It boasts 20-dB typical isolation at 10 GHz with better than 12-dB isolation at 38 GHz. It offers less than 0.4-dB insertion loss at 10 GHz and less than 0.5-dB insertion loss at 38 GHz. Both switches are rated for more than 10 billion switching cycles at normal RF/microwave power levels.

MEMS FOR MEDICINE

Many companies involved in MEMS development recognize how the technology can serve some critical applications in the health-care industry. With its combination of MEMS and many other microelectronic technologies, STMicroelectronics is applying MEMS designs to sensors and graphical display monitors for health-care products.

Different types of MEMS sensors are used in low-power portable devices for such functions as glucose meters and blood-pressure monitors, while MEMS motion, pressure, and magnetic sensors are applied to medical imaging applications. MEMS devices are often included with many other microsystem technologies for medical applications as "BioMEMS" devices.

The CardioMEMS CardioMEMSHF System is an implantable, FDA-approved, MEMS-based sensor. It is implanted in a patient's pulmonary artery and monitors the heart for dangerous pressure buildup following cardiac surgery *(see the opening figure)*. The system wirelessly communicates information from the sensor to the physician, allowing patient heart monitoring without hospitalization.

More than a few companies see MEMS technology as a viable approach for reflective-type miniature displays. Qualcomm, for example, has based its mirasol graphic displays on MEMS technology. Based on the firm's interferometric modulation (IMOD) technology to achieve low-power displays with high contrast ratios, mirasol displays are fabricated by means of MEMS and thin-film optics technologies. The first commercial displays will be bichrome, with two colors.

The IMOD consumes much less power than other display technologies, such as LCDs or organic LEDs (OLEDs), Qualcomm says. It also offers much faster response times than competitive LCD technologies, which will reduce blurring when viewing fast-moving images, such as in video games. Not requiring a backlight, mirasol displays can be made much thinner than competing technologies. Time will tell if this use of MEMS technology will gain the popularity of microphones and pressure sensors in many portable electronic products.

SIZING UP MEMS FOUNDRIES

As MEMS technology becomes more widespread, more electronic manufacturers are exploring its integration in their own products. Working with one of the growing number of MEMS commercial foundries can make this process easier. MEMS foundries not only bring the necessary equipment and processing environments for designing and making MEMS products, they also offer the expertise and a willingness to share that knowledge with their customers.

To make it easier for customers to adopt MEMS technology, Micralyne has formed a partnership with CMC Microsystems to help reduce the costs and risks for MEMS developers. The partnership lets designers purchase part of a silicon MEMS fabrication run via a multiple-product wafer strategy, with CMC Microsystems spearheading the production run, rather than commit to the entire production run.

MEMS runs are based on Micralyne's MicroGEM-Si process technology, well suited for fabricating MEMS devices such as inertial sensors and optical switches. For those not willing to share their production runs, customers can purchase a full fabrication run for working directly with Microlyne on its MEMS product design and fabrication.

Designers interested in obtaining MEMS foundry services have a growing list of choices, including Silex Microsystems. The MEMS foundry has supported the commercialization of a wide range of MEMS devices, including accelerometers, infrared (IR) sensors, mirrors, humidity sensors, and RF switches. It operates two independent high-volume fabrication facilities with 6- and 8-in. wafer capacities, respectively.

All of the Silex technologies leverage the company's SmartBlock approach to applying modular methods for achieving the fastest possible way to stable production for a design without compromising performance and/or reliability. Foundry customers working with the Silex foundry can expect to bring their MEMS products to market in the fastest time possible.

Midwest Microdevices is benefitting from economic and educational support from such sources as the state of Ohio and the University of Toledo. This well-equipped MEMS fabrication facility employs LPCVD and plasma-enhanced chemical vapor disposition (PECVD) processes to deposit dielectric thin films with great precision and uniformity and a range of sputtering and evaporation capabilities to deposit metals, ranging from aluminum to gold, on those dielectric materials in forming many different MEMS structures and circuits.

The foundry uses fully automated LPCVD batch furnace tubes to process as many as 50 wafers at a time with wafer-to-wafer uniformity of better than ±3%. Each furnace tube runs on its own microprocessor and under software control to precisely match a customer's requirements while enabling support of smaller, specialized MEMS fabrication runs, including for optical MEMS devices. The foundry employs reactive ion etching (RIE), wet etching, and plasma etching for the precise control of MEMS features. Back-end processes include wafer dicing, laser dicing, laser drilling, and wafer probing.

The X-FAB MEMS Foundry offers MEMS design and manufacturing capabilities, along with a range of analog and mixed-signal IC foundry capabilities in silicon-on-insulator (SOI), silicon CMOS, and BiCMOS device technologies as well as experience in merging these different microminiature circuit technologies within the same chip or package.

For designers seeking optical MEMS devices, Coventor backs its foundry facilities and experience with electromechanical finite-element models developed with popular computer-aided-engineering (CAE) software design tools, such as software from Cadence Design Systems and Matlab software from the Mathworks. By combining Coventor's software simulations with its foundry tools, customers can achieve faster design turnarounds with results close to performance expectations. ed

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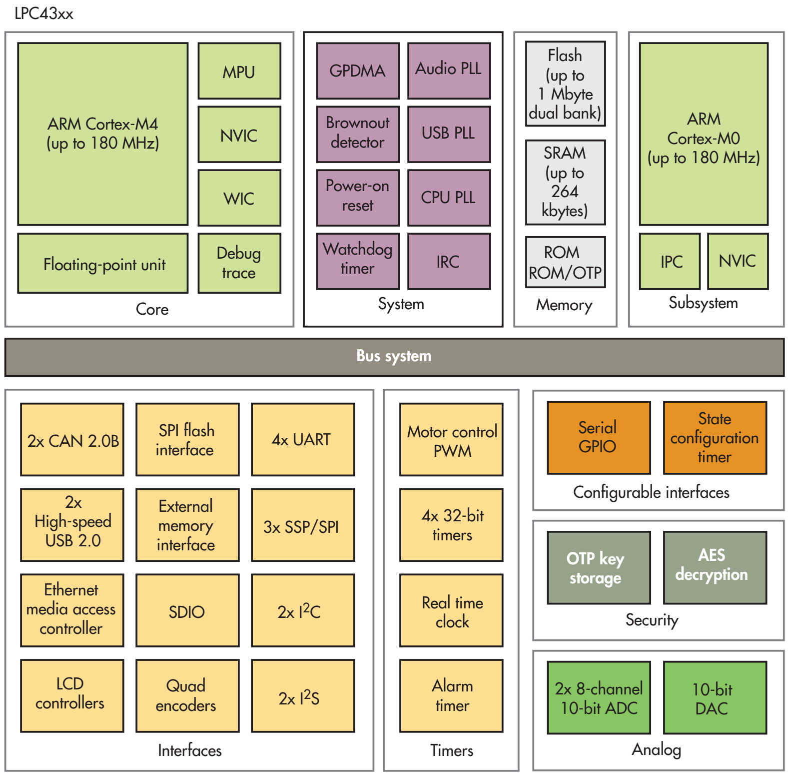
Asymmetric Microcontrollers
Tame Power Consumption

Now that asymmetric microcontrollers are becoming increasingly common, they are providing more opportunities for reducing power requirements and modularizing software development.

Multicore has dominated the high end of computing as well as the high end of mobile devices. Using Arm's big.LITTLE approach, some cores have even been mixed to reduce power consumption in more powerful smartphones and tablets *(see "Little Core Shares Big Core Architecture" on electronicdesign.com)*.

The closest off-the-shelf designs that typically have come to asymmetric solutions are platforms like AMD's accelerated processing units (APUs) that combine CPU and GPU cores on the same chip *(see "APU Blends Quad Core x86 With 384 Core GPU" on electronicdesign.com)*. GPUs and CPUs are combined on a single chip on a range of microcontrollers. The GPU also has been used for more computing aspects, not just for providing display support. Still, GPU computing normally requires a different programming environment—like OpenCL or CUDA—versus a common programming environment for symmetrical multiprocessing (SMP) systems.



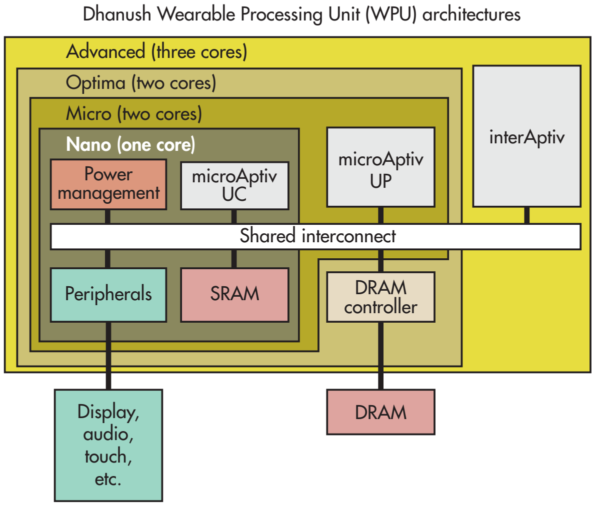
1. NXP's LPC4000 combines Arm Cortex-M0 and Cortex-M4 cores on the same chip.

Asymmetric multiprocessing (AMP) configurations have been less common. Off-the-shelf asymmetric microcontrollers are more readily available, though, giving developers more flexible solutions for power-challenged applications like battery-powered mobile devices.

AMP MICROCONTROLLERS

One of the first AMP microcontrollers was NXP's LPC4000 family *(see "New Platform Approaches Deliver Top Digital Designs In 2010" on electronicdesign.com)*. The LPC4000 combines 32-bit Arm Cortex-M0 and Cortex-M4 cores on the same chip *(Fig. 1)*. The Cortex-M4 runs a superset of the Cortex-M0 instruction set. The Cortex-M0 shares memory and some peripherals with the Cortex-M4. How application code is split between the two cores will be application-specific. For example, the Cortex-M0 might handle communication while the Cortex-M4 runs the user interface.

The LPC4000 is used in the Pixy Cam smart camera *(see "A Tale Of Two Camera Kits" on electronicdesign.com)*. The Cortex-M0 is used as a peripheral controller capturing data from the camera. It performs some limited post-processing before passing the data to the Cortex-M4, which handles the image analysis. The analyzed image data, which can include colored object size and position, is then passed on to the host via USB or a serial port.



2. The Ineda Systems Dhanush Wearable Processing Unit (WPU) family has up to three MIPS-compatible cores. Higher-end units support external DRAM that can be turned off to conserve power with the host using only on-chip SRAM.

The Ineda Systems Dhanush Wearable Processing Unit (WPU) family *(Fig. 2)* has up to three MIPS-compatible cores *(see "Hierarchical Processors Target Wearable Tech" on electronicdesign.com)*. It starts with a single-core system based on the MIPS microAptiv UC core *(see "MIPS Aptiv Family Brings Consolidation And Raises Performance Bar" at electronicdesign.com)*. At the high end, the third core is an interAptiv.

The WPU is designed for power-constrained environments. The cores can operate individually or in concert. The lowest active power operation would utilize the smallest core and SRAM, as well as some peripherals.

These microcontrollers have advantages and disadvantages from a programming standpoint. Hardware partitioning provides more effective software partitioning, though at the added cost of software complexity. Power management tradeoffs are more complex because multiple cores and subsystems are involved. However, hardware partitioning provides better control of the system and its power utilization.

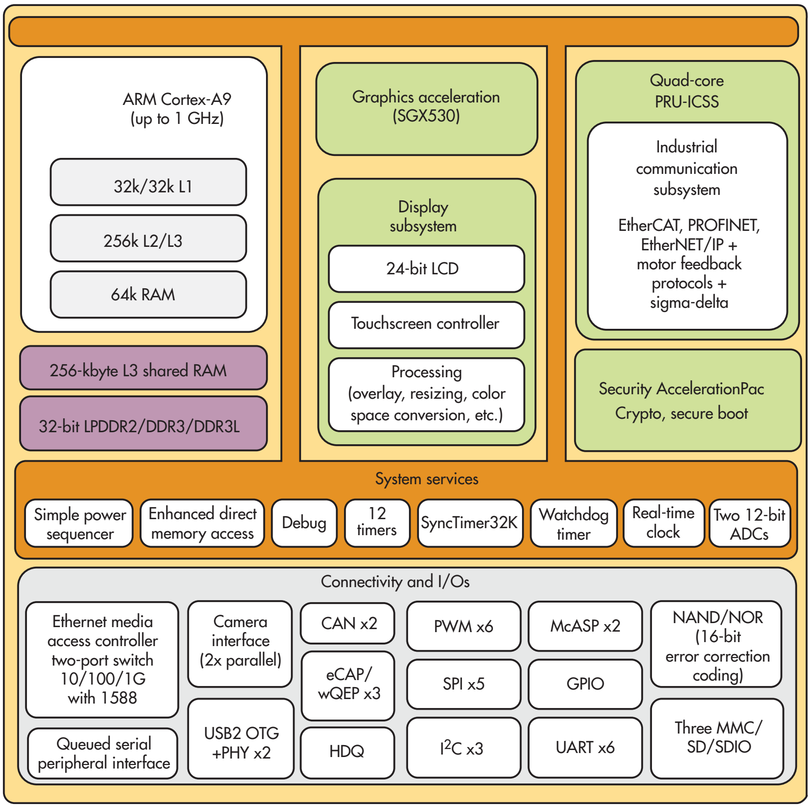
SPECIALIZED PERIPHERAL CONTROLLERS

Other AMP configurations include platforms that incorporate specialized peripheral controllers; these have some degree of programmability but tend to be less functional than the main CPU core. For example, the Texas Instruments Sitara AM437x has a single ARM Cortex-A9 core *(Fig. 3)*. It also has four Programmable Real-time Unit and Industrial Communication Sub-System (PRU-ICSS) cores.

The PRU-ICSS core is a simple 32-bit RISC processor that keeps code and data in SRAM. It is programmed in assembler. The instruction set has only about 40 instructions. Like the other AMP systems, these cores can operate while the main core is shut down. The programmable system provides significantly more functionality compared to smart peripherals or advanced direct memory access (DMA) subsystems.

Also, the PRU-ICSS can provide higher-level protocol support on communication links or advanced motor control. Each core has its own program memory. This produces a deterministic execution environment that is independent of all other cores within the system. Shared memory offers interprocess communication support.

Of course, the challenge is to balance the complexity of a multicore system against a faster, more powerful processor. Multicore has been a requirement at the high end because of power and frequency limitations, but they have a different impact with microcontrollers. ed



3. The Texas Instruments Sitara AM437x has a single ARM Cortex-A9 core plus four Programmable Real-time Unit and Industrial Communication Sub-System (PRU-ICSS) cores.

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Modeling Amp Output Impedance: A New Approach

A novel impedance module can be modeled with poles and zeros.

When used with other blocks and modules, a new approach to modeling operational-amplifier output impedance behavior can provide a more realistic overall behavioral model. Simulating the behavior of a part or system prior to fabrication or building a system with behavioral models to optimize performance is an essential part of the design process. In addition, engineers can benefit from evaluating the part's performance as a standalone device or in a system.

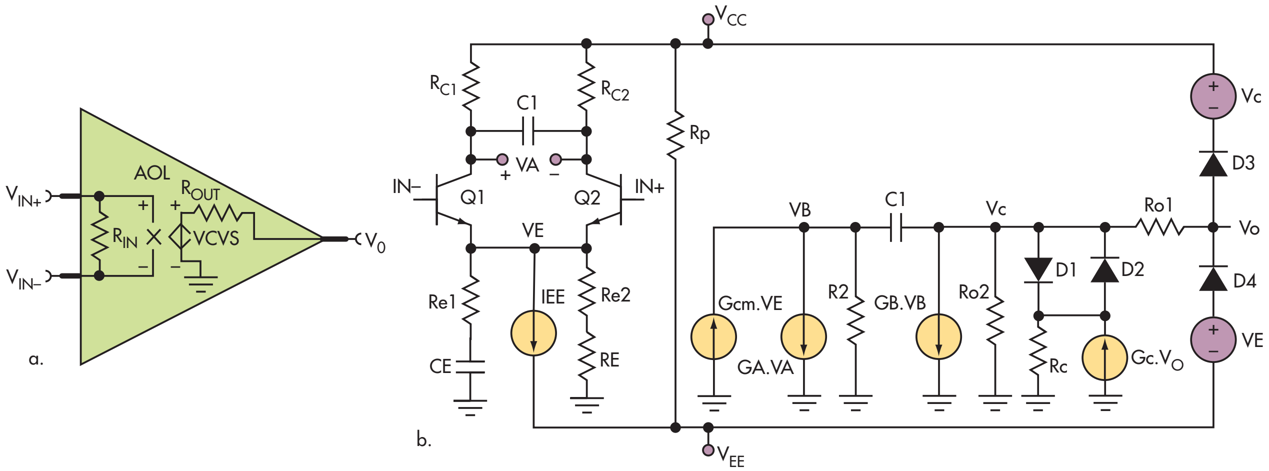
MODEL EVOLUTION

The Boyle model was the first comprehensive and most famous op-amp model.[1] It was introduced in the 1970s and still is being widely used today. While in many aspects the Boyle model is very primitive, it has proved itself to be useful in many different applications.

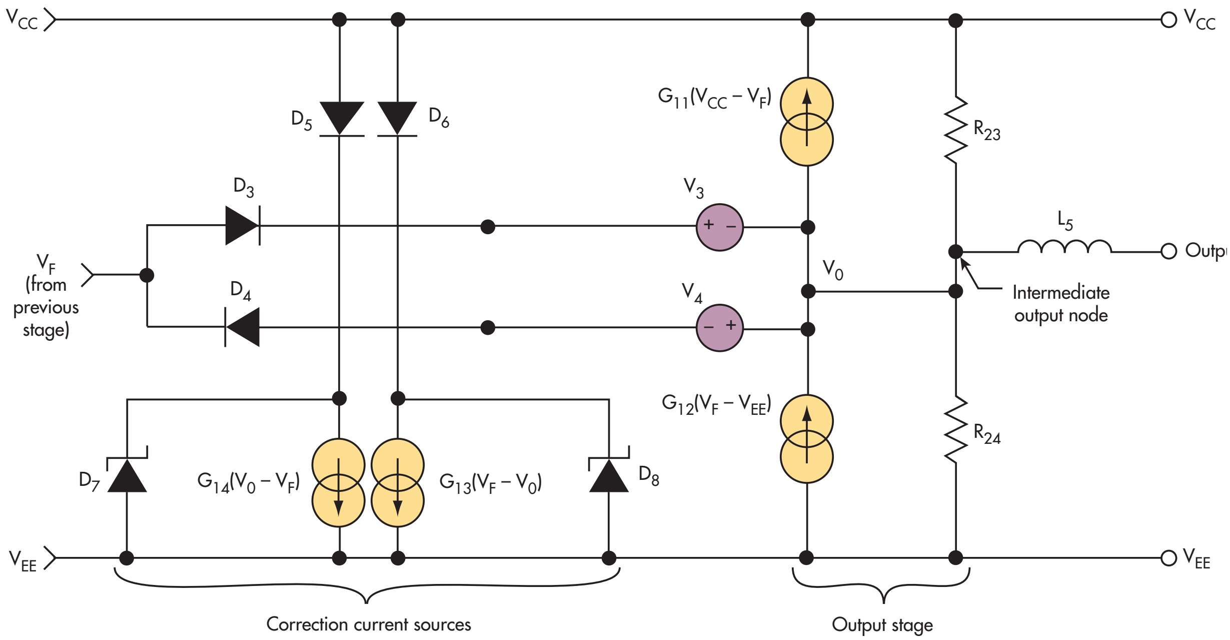
In the Boyle model, a resistor represents the output impedance, which cannot depict a frequency response. Other modeling methods introduced a filter of sorts to shape the output impedance frequency response. However, a new model for output impedance can reproduce the frequency behavior of output impedance with basic ideal components.

The simplest op amp comprises a few basic components: the input resistance, a gain element, and output resistance *(Fig. 1a)*. The input resistance is between two input terminals and is connected to a voltage-control-voltage-source (VCVS). The gain of VCVS sets the op amp's open loop gain. The output resistance is represented by a resistor connected in series from VCVS to the output node.

This model simply provides the coarse representation of dc gain and input and output impedance, which is barely adequate for most circuits or systems. If a pair resistor and capacitor is added as a low-pass filter to the gain stage, the op



1. Boyle's original model suffers from one main issue. Everything is referenced to ground, which is not valid for most real op amps. Among other limitations, this model has a limited number of poles and lacks zero in the gain stage.



2. The output portion of Alexander & Bower's model provides output current limit, supply current correction, and output impedance. The output impedance can be calculated from $R_{OUT} = R_O + sL_O$. L_O and R_O are the output inductor and resistor at the output stage, respectively.

amp's bandwidth can be introduced to model and shape its frequency response.

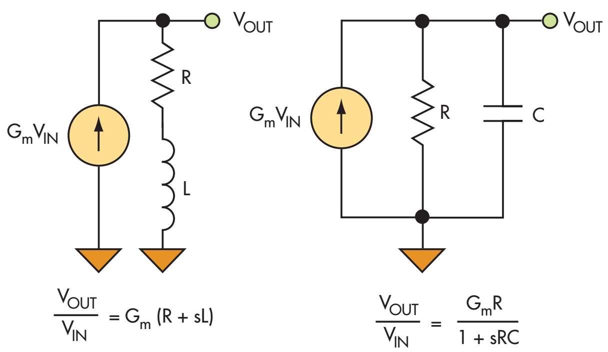
Boyle then introduced a more complete model capable of introducing a few more parameters such as current limit, slew rate, and output clamp *(Fig. 1b)*. In 1990, Alexander & Bowers came up with a new model for op amps.[2] It was based on Boyle's original model with improvements that introduced new parameters *(Fig. 2)*. The input to every stage came from the previous stage while it was being referenced to an internal reference point (V_{REF}), which was calculated based on the supply voltages:

$$V_{REF} = (V_{DD} - |V_{SS}|)/2$$

A NEW APPROACH

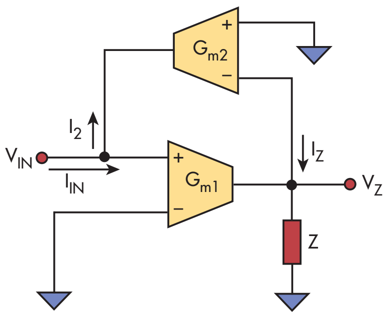
Up to this point, no models could provide a dynamic and robust production of output impedance. They were limited to either the dc representation of the output impedance or to the frequency shaper that's used for output impedance, which could not adapt to a more complicated variation of output impedance.

Alternative approaches can provide more output impedance control. One model introduces multiple poles and zeros to output impedance. Much like the approach used in gain stage, capacitors, inductors, and resistors can be added to introduce the desired number of poles and zeros in the frequency response of output impedance.

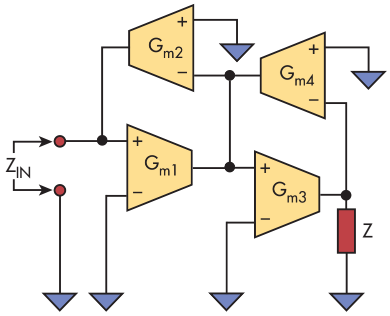


4. The common drain output stage exhibits an inductive behavior (left). The common source output stage exhibits a capacitive, frequency decaying response (right).

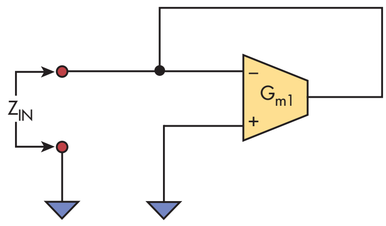
3. The new model, developed and employed at Texas Instruments, starts with a black-box approach.



5. The behavior of OTAs in feedback can be analyzed using Equations 3 through 10.



6. This impedance multiplier is based on two cascaded gyrators.



7. The OTA model can be reduced to a voltage-controlled resistor.

Similarly, one can introduce a module with a series of low-pass and high-pass filters in a negative feedback to achieve the same result. These methods control how the impedance is shaped very well and can closely match the output impedance response to the behavior of the actual part. While these approaches are superior to those previously mentioned, introducing additional knobs to control or adjust the behavior is difficult.

One of the main goals during development of the output impedance block was modularity. The output impedance module must be easily adjustable and easily inserted into or removed from the main amplifier block. By creating a module that could be plugged in or removed, a wider variety of amplifiers and applications can be covered.

In amplifier macromodels, the gain and frequency shaping stages are placed prior to the output impedance. Given the location of the output impedance block, it should not attenuate or amplify the input signal. For example, it should exhibit unity gain from input to output. To tackle modularity, a two-port network approach is utilized as the starting point *(Fig. 3)*.

Based on these constraints and goals, the impedance module must satisfy two basic conditions. First, looking into the module from C, it should exhibit controllable impedance and frequency dependency. Second, the gain from A to C is unity. For this purpose we start from basic building blocks, continue with the impedance gyration concept, and conclude with implementation.

SYSTEM COMPONENT VALUES		
Component	Value	Units
g_{m1}	2	mA/V
g_{m2}	2	mA/V
R1	1	kΩ
R2	110	Ω
C3	1.4	µF
g_{my}	1	mA/V
R_{Large}	10,000	kΩ

FREQUENCY-DEPENDENT RESISTOR

Generally, the amplifier's open-loop output impedance can be modeled as a resistor with some frequency dependency:

$$Z(s) = R^*(Z(s)/P(s)) \quad (1)$$

The precise characteristics of impedance across the desired range of frequency depend on the amplifier's output stage under test. The scope of this project was to create an impedance module that could be modeled with poles and zeros, created using either of two circuits *(Fig. 4)*.

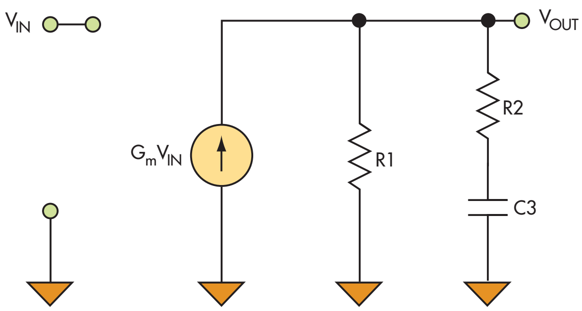
One thing to consider, though, is that a bare "zero stage" requires the use of an ideal inductor. An ideal inductor can generate infinite voltage when the current through it changes instantaneously, creating convergence issues in Spice. To avoid convergence issues caused by the non-causal zero stage, various circuit combinations can generate pole/zero or zero/pole pairs, which are more desirable for implementation.

THE OTA

Before delving deeper into the inner workings of the impedance block, it is important to understand the basic building block used to create the model: the operational transconductance amplifier, or OTA *(Fig. 5)*. In an ideal OTA, the output current is a linear function of the differential input voltage, calculated as:

$$I_{OUT} = (V_{IN+} - V_{IN-})g_m \quad (2)$$

where V_{IN+} and V_{IN-} are the voltages at the non-inverting and inverting inputs and g_m is the transconductance of the amplifier. OTAs are very useful building blocks and can be found in



8. A pole/zero pair adds the required frequency dependence.

a wide variety of applications in circuit designs, from filters to the differential input pair of an op amp.

Assuming that the input impedance of the OTA is infinite, or that there are no current flows into the V_+ or V_- terminals, these expressions can be drawn:

$$I_Z = g_{m1}V_{IN} \quad (3)$$

$$V_Z = I_ZZ \quad (4)$$

Thus:

$$V_Z = g_{m1}ZV_{IN} \quad (5)$$

Now:

$$I_2 = g_{m2}V_Z \quad (6)$$

Substituting Equation 5 in Equation 6 yields:

$$I_2 = g_m1g_{m2}ZV_{IN} \quad (7)$$

Since for an ideal OTA:

$$I_2 = I_{IN} \quad (8)$$

Substituting Equation 6 in Equation 7 gives:

$$I_{IN} = g_{m1}g_{m2}ZV_{IN} \quad (9)$$

Rearranging:

$$\frac{V_{IN}}{I_{IN}} = Z_{IN} = \frac{1}{g_{m1} \cdot g_{m2} \cdot Z} \quad (10)$$

Looking closely at Equation 10, notice that the impedance Z has been "inverted" into an admittance multiplied by a scaling factor of $1/g_{m1}g_{m2}$. The impedance inverter or gyrator can be used to invert a capacitive load and emulate a relatively large inductive load. This is very useful when passive inductors are not practical due to size or cost.

CASCADED GYRATORS

Based on the principle explained earlier, gyrators can be cascaded to build what is known as the impedance multiplier *(Fig. 6)*:

$$Z_{IN} = \frac{g_{m3} \cdot g_{m4}}{g_{m1} \cdot g_{m2}} R \quad (11)$$

Equation 11 resembles Equation 1, but it doesn't have any frequency-dependent terms. However, these can be easily incorporated by adding poles to the g_{m1} and g_{m3} terms. For example, let g_{m1} be in the form of:

$$g_{m1}(s) = g_{m1}\frac{1}{P_1(s)} \quad (12a)$$

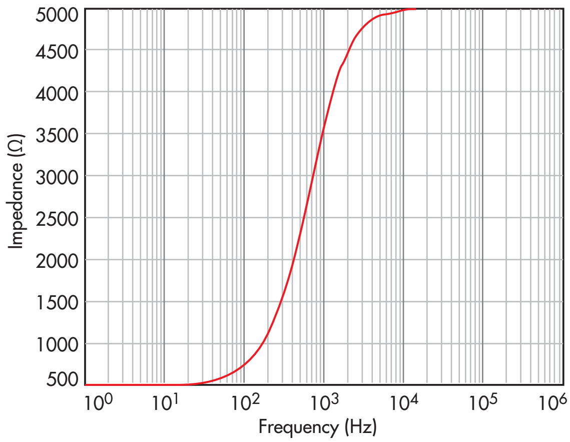
Similarly, let g_{m3} be in the form of:

$$g_{m3}(s) = g_{m3}\frac{1}{P_3(s)} \quad (12b)$$

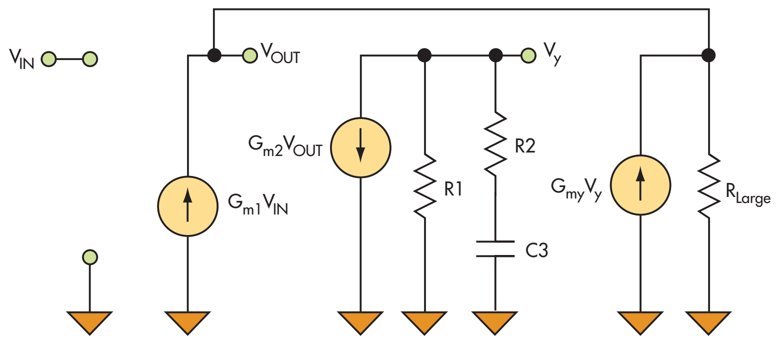
Then Equation 11 becomes:

$$Z_{IN} = \frac{g_{m3} \cdot g_{m4}}{g_{m1} \cdot g_{m2}} R \frac{P_1(s)}{P_3(s)} \quad (13)$$

Letting $g_{m1} = g_{m2} = g_{m3} = g_{m4}$, Equation 13 can be rewritten as:



9. The target open loop output impedance (in Ω) looks like this. The dc value of the resistance is about 500 Ω. It increases by 1.4 (700 Ω) or 3 dB around 100 Hz, and it reaches 70% (3500 Ω) or –3 dB of the final value around 1 KHz.



10. The complete system, based on the modeling, looks like this.

$$Z_{IN} = R\frac{Z(s)}{P(s)} \quad (14)$$

As a result, a frequency-dependent resistor is achieved by using only OTAs and capacitors. Taking a closer look at Equation 12a, it becomes clear that if poles and zeros are considered, then it can be rewritten as:

$$g_{m1}(s) = g_{m1}\frac{Z_1(s)}{P_1(s)} \quad (15)$$

Since an OTA is a voltage-controlled current source, feedback can be used to transform this conductance into a resistance, also known as the source absorption theorem—the same principle used in diode-connected transistors. By applying feedback, the whole circuit can be reduced to a voltage-controlled resistor circuit where:

$$Z_{IN} = \frac{1}{g_{m1}}\frac{P_1(s)}{Z_1(s)} \quad (16)$$

The system in Figure 7 was used for final implementation due to its simplicity. A pole/zero pair can be implemented as in Figure 8, where:

$$\text{Gain} = g_m R_1$$
$$R_2 = \frac{R_1}{\frac{f_z}{f_p} - 1} \quad (A)$$
$$C_3 = \frac{1}{2 \cdot \pi \cdot f_p \cdot R_1}$$

UNITY FORWARD TRANSMISSION

So how is the frequency-dependent resistor used in a circuit? Since our model represents a grounded resistor, it is convenient to drive this module with a current source. Given the input to the module is voltage, an OTA can be used to drive the Z_{OUT} module. Therefore, the gain from input to output can be written as:

$$\frac{V_{OUT}}{V_{IN}} = \frac{g_{m1}}{g_{m2}}\frac{P_2(s)}{Z_2(s)} \quad (17)$$

where g_{m1} is the g_m of the driver stage and g_{m2} is that of the frequency-dependent resistor. To obtain unity gain at dc $V_{OUT}/V_{IN} = 1$:

$$g_{m1} = g_{m2} \quad (18)$$

To illustrate the use of the output impedance module, assume the output impedance module needs to display a behavior as in Figure 9. Reducing the behavior in Figure 9 to model parameters, the following assumptions can be made:

- The value of R = 500 Ω, thus g_{m2} = 2 ms
- There is a zero at F = 100 Hz
- There is a pole at F = 1 kHz

Moving to the driver stage:

$$g_{m1} = g_{m2} = 2 \text{ ms}$$

The complete system, based on the modeling, looks like Figure 10. The table lists the component values.

SIMULATION

To simulate the output impedance, simply ground the inputs and connect an ac current source to the output node. Note that $Z_{OUT} = V_{OUT}/I_{OUT}$. Since I_{OUT} = 1 (ac source), the magnitude of the output voltage corresponds to the output impedance. By plotting the frequency response, the output impedance can be analyzed. ed

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AUGUST 2014

Complexity Drives Need for Training Programs

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Two electronics distributors are tackling the ongoing challenge of internal and external stakeholder education.

BRIDGET McCREA | CONTRIBUTING EDITOR

THE DAYS WHEN it was enough for electronics distributors simply to sell and support products are long gone. Advances in technology, growing application complexity, changing customer requirements, and myriad other forces have driven distributors to provide training and education in ways they've never offered in the past. Here is a look at how two different companies approach the task, the challenges that they face in this realm, and the benefits that come from keeping both internal sales teams and external customers up-to-date and knowledgeable about the goods being sold.

LEVERAGING THE EDUCATIONAL COMPONENT

For Future Electronics of Quebec, Canada, providing customers with the highest level of continuity of supply and outstanding service are business mainstays.

"We have a unique value proposition in how we go to market," explains Lindsley Ruth, executive vice president. "We have all of the capabilities and differentiators, and everything that we need behind the scenes to achieve those two goals, but it takes people to implement those programs and processes with our customers."

That's where the educational component, both internally for the Future Electronics' sales team and externally for its customers, comes into play.

"We invest significantly in training on a global basis," says Ruth. "It's paramount to our success as a distributor." Exactly who administers that global training is also important to Future Electronics, which Ruth says relies on a pool of experts to present the associated programs and strategies. "We don't have trained teachers or professionals in the continuing education area conducting the training," he explains. "We have individuals who are actually experts in the subject matter."

The distributor crafts the educational content, delivers it, and offers resources such as role-playing, with the idea that attendees will go back to their respective roles and use

Continued on Page 36

Electronics Distributors on the Acquisition Trail

M&A activity picks up in the electronics distribution sector as TTI, Sager, RFMW, and Master Electronics all make key purchases.

THERE WAS A flurry of acquisitions in the electronics supply chain as summer began, with four of *Global Purchasing*'s Top 50 Electronics Distributors announcing new deals. TTI Inc., Sager Electronics, Master Electronics, and RFMW are all on the acquisition trail.

TTI BUYS ASTREX

Texas-based TTI Inc., which ranked sixth on the 2014 Top 50 Electronics Distributors report, announced in June its purchase of Plainview, N.Y.-based Astrex Electronics, also a Top 50 company, coming in at number 29 this year. TTI had sales of $1.68 billion and Astrex yielded $37.6 million in sales last year. Berkshire Hathaway owns TTI.

"Our team is very excited to be joining the esteemed TTI organization," says Astrex president Mike McGuire. "Joining an organization with such well-known commitment

Continued on Page 38

the information during the course of their jobs. Future Electronics also tracks and measures the results of its training efforts.

"We make sure that we have a closed-loop feedback process for all of the programs that we put in place and use," says Ruth. In terms of the content delivery, he says the company utilizes a combination of traditional classroom sessions, "lunch-and-learn" type meetings, and the Web.

In some instances, the distributor training lends itself to the online format, where attendees can learn at their own pace and on their own time. It works particularly well when the material itself is straightforward, according to Ruth, and when it requires little or no interaction with a "live" instructor. The group setting, on the other hand, features a high degree of personal interface both between students and the instructor and among the students themselves—something that the online format doesn't necessarily support.

"Attendees can get instant feedback," Ruth adds, "and have certain issues addressed live and in person."

Future Electronics' lunch-and-learn educational programs are used primarily with customers that need more information about advanced technology, new products, or broader topics such as introducing supply chain initiatives and mitigating supply chain risk. Ruth says the distributor's three-pronged approach to training allows it to flex and adapt to its users' needs.

"We've learned that there's no one-size-fits-all model when it comes to learning and development," he notes, "so we cover the bases in those three different ways."

Covering those bases isn't always easy for electronics distributors, which face a number of challenges on this front—not the least of which are the time and money spent bringing both internal and external stakeholders up to speed in a rapidly changing business environment. Ruth says one of Future Electronics' biggest hurdles is bringing people in for a week for training and then watching them go back to their job and continue doing things the way they've always been done.

"Effectively putting people through a kind of 'mental car wash' and re-programming is challenging and requires repetitive follow-up," says Ruth. "It also requires practice in the areas that we're training them on, be it engineering, sales, marketing, or another discipline." Changing the mindsets or habits of industry veterans, for example, can be particularly onerous.

"Someone may have 20 or 25 years of experience on paper, but in reality it's just one year of experience relived 20 or 25 times," says Ruth. "He or she learns it all in one year and then just keeps doing the same things over and over again."

"When we fail to service or support a customer with distribution in general, it gives the overall distribution market a black eye," says Lindsley Ruth, executive vice president, Future Electronics.

"When we go in and train customers, we have to make sure we're dealing with the latest revision from our supplier partners, so that they can go out and start designing and using those tools right away," says Avnet's Tim Barber.

FULFILLING KEY REQUIREMENTS

When Avnet Electronics Marketing in Phoenix started selling a new Artix FPGA IC this year, the distributor focused both on the product side of the equation and on the solutions and services related to that new product.

"When we work with our partners to develop new products and take them to market," says Tim Barber, senior vice president, design chain business development, "we know that our customers are interested not only in the products themselves, but also in the complete design associated with those products."

Customers also need to know how to power up their products, hook them up to data converters, connect them to memory interfaces, and take the many other steps necessary to get up and running. When rolling out the Artix FPGA, for example, the distributor tapped into the training content, reference content, and reference designs developed by the manufacturer itself to gain a greater understanding of the item and how it will work in the real-world environment. Concurrently, the distributor examined the training needs of its customers and developed the hands-on training (typically in the form of a workshop) to support it.

For its internal sales team, Avnet first trains its field application engineers (FAEs) on the fine points of using the new product. Then, those FAEs train the distributor's sales team.

"We provide a brief tutorial or 'lobby pitch' that the sales team can use when sitting down with customers to discuss the new product," Barber says. In other instances, Avnet pairs up with semiconductor or software-defined radio manufacturers to develop key training sessions in specific cities nationwide.

"Customers fly in and attend the training," says Barber, "which is presented in a 'live' workshop environment." In June, for example, the company announced the X-fest series of free, full-day, how-to training seminars for systems designers on Xilinx All Programmable products. The X-fest program features 12 technical courses based on the devices.

Right now, Barber says Avnet is exploring various Web-based training options—a delivery mechanism that the distributor has already used successfully for several educational offerings. Currently, for example, the company offers a number of 16-tract software classes (with labs) online.

"For those classes, we're signing up anywhere from 20 to 30 customers daily," says Barber. "Over time, we've moved from the hands-on educational environment, which we will continue to offer, to a 'live' environment online, where we've found that customers really learn better."

NO BLACK EYES, PLEASE

Avnet also has faced challenges on the educational front, where matching up the right content for the correct application and class isn't always easy. Keeping up with rapid advances in design tools, Barber adds, is another obstacle.

"When we go in and train customers, we have to make sure we're dealing with the latest revision from our supplier partners," he explains, "so that they can go out and start designing and using those tools right away."

Managing customer demand for education, information, and knowledge is also difficult at times, says Barber. "According to our FAEs, a lot of customers want access to our training," he notes, "so we're always looking for new ways to deliver the content in an effective manner. It's something that just continues to evolve."

To distributors looking to beef up their educational offerings or launch a new program, Ruth says, don't give up, and remember what's most important—ensuring all distributors work together to promote the value of distribution.

"We can't forget that distribution is here to hold inventory, help service customers, and deal with the mass market and the long trail of customers that exists out there," says Ruth. "When we fail to service or support a customer with distribution in general, it gives the overall distribution market a black eye." ■

On the Acquisition Trail Continued from Page 35

to connector products, customer service, technical expertise, and resources will allow us to provide our customers with an even higher level of service. "

Astrex will operate independently of the TTI organization until system integration is complete, according to TTI.

SAGER BUYS POWERGATE LLC

Sager Electronics—owned by TTI—has announced it would buy PowerGate LLC, a North American power specialist distributor. The deal expands Sager's position in the power market. Sager Electronics ranked 13th on the 2014 Top 50 Electronics Distributors report.

"PowerGate is a recognized power specialist with concentration in select North American markets," says Sager president Frank Flynn. "This acquisition advances one of our growth strategies and strengthens our position in the market as a power specialist. Sager Electronics will preserve and build upon PowerGate's specialization by making significant investments in additional key markets and inventory in order to accelerate growth."

PowerGate president Paul Christiansen will become Sager Electronics' vice president of supplier marketing and product management for power. Ed Kramar, who is PowerGate's current vice president, will remain with the organization in an advisory capacity, according to Sager.

"We are thrilled to become part of an organization that values and understands our business model," Christiansen explains. "My team and I are excited to join the Sager Electronics organization and have the opportunity to service more customers in power with leading-edge technologies, technical sales expertise, and field application engineering."

RFMW BUYS AXOMIC PTE. LTD.

California-based electronic components distributor RFMW Ltd., which came in at number 25 on this year's Top 50 report, has acquired Axomic Pte. Ltd., a specialty distributor of radio frequency (RF) and microwave components based in Southeast Asia. The deal expands RFMW's global footprint and enhances its position as an RF-focused, technically proficient distributor serving high-tech customers and suppliers.

"We've followed the growth of Axomic for quite a while," says Joel Levine, president and CEO of RFMW Ltd. "We appreciate their focus on customer service, supplier relationships, and business strategy. The fact that their company's mission and philosophy closely match that of RFMW made the acquisition an easy decision."

Levine said this spring that RFMW would spend the next few months integrating Axomic into the RFMW network. Axomic will become RFMW Asia.

MASTER ELECTRONICS BUYS ELECTRO SONIC

In yet another merger of two Top 50 companies, number 15-ranked Master Electronics purchased number 28, Electro Sonic, which has served customers across Canada for more than 60 years. Electro Sonic will continue to do business under its existing name, according to leaders at Master.

"We are very pleased to have E-Sonic as part of the Master family," says Jamil Nizam, Master Electronics president. "A company with such a long and rich history is hard to come by. Electro Sonic's reputation of customer focus and deep supplier relationships is something we will be proud to carry on. I am confident that with our resources and commitment to inventory, Electro Sonic will carry on as one of the premier Canadian electronic component distributors."

Electro Sonic serves Canada's OEM, maintenance, repair, and operations (MRO), and contract manufacturer markets with sales contacts across the country, including Toronto, Montréal, Calgary, Winnipeg, Ottawa, Edmonton, and Québec City. ■


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TE Connectivity's Egbert Stellinga Discusses USB 3.1

USB 3.0 is found on most new motherboards and mobile devices. It provides significantly higher throughput and more functionality than USB 2. Also, USB 3 provides backward compatibility with USB 2.0 in terms of connectors, though it hides additional connections. There have been new USB 3 connectors as well, but they tend to be larger than the USB 2 connectors.

The USB 3.1 connector supports this higher-speed interface, and TE Connectivity (TE) is supplying devices in this new format. Egbert Stellinga, product manager with TE Consumer Devices, has been with the company for almost 20 years.

WONG: Why is there a new USB 3.1 connector?

STELLINGA: We see a few trends in mobile devices: increased data speed, increased charging power even beyond 5 A, and integration of video capabilities into the device. Other than USB 3.1 standard connectors, the HSMIO (high-speed multi-I/O) connector from TE can combine all of these features in one connector *(see the figure)*. In addition, the USB 3.1 standard connector is designed similar to what we call the sidecar connector. It is a double-size connector with two plugs next to each other. TE's innovation drove a solution that captures all of the above into a micro USB 2.0-sized connector. The ultimate result provides USB 3.1 data speed and power charging plus video in a micro USB 2.0-sized connector.

TE Connectivity's new HSMIO connector provides USB 3.1 performance in a Micro USB 2.0 form factor.

WONG: What advantages does the HSMIO connector have over existing connectors?

STELLINGA: Our product is one of the industry's first high-speed multi-I/O connectors that transfers USB 3.1 signals in a micro USB 2.0 form factor. It handles data up to 10 Gbits/s supporting USB 3.1 Super-Speed and 3-A power delivery, but all in a smaller, micro USB 2.0-sized interface. Because of this ability to maintain high performance in this smaller size, our new product addresses the growing demand for mobile devices to have more increased functionality, higher speed, and larger screens that require high-power battery consumption. Meanwhile, the connector's small size, compatibility, durability, and improved electromagnetic interference (EMI) performance also present key advantages for use in small-size, battery-operated portable devices such as mobile phones, tablets, digital cameras, navigation devices, media players, and wearable devices.

WONG: What challenges or issues did TE encounter when designing the connectors, and how were they addressed?

STELLINGA: In particular, the high-speed design and protection against EMI (electromagnetic interference) challenged our engineering team. Supporting the USB 3.1 standard requirement of 10 Gbits/s required extensive simulation and testing. Also, the EMI leakage of the USB signals required a particular construction of the shells in the cable assembly.

WONG: What advantages does TE's solution provide?

STELLINGA: TE is committed to delivering extraordinary customer experiences. We strive to deliver miniaturization solutions that will help mobile device manufacturers create smaller, thinner, and lighter products. With an extensive global manufacturing footprint and product breadth, TE has a full range of the latest technologies to support consumer electronics applications. A prime example is the newly launched HSMIO connector. For details, see www.te.com/en/product-launch/slim-solution.html. ed

14.2mm Wide Creepage and Clearance Optocouplers for High Voltage Applications

Market	Bus Voltage	Creepage and Clearance*
$690V_{AC}$ Drives	1200V	>12mm
Wind Inverter	1200V	12mm
Medical ($480V_{AC}$)	1200V	>12mm
Central Inverter	1700V	>14mm
Solar Inverter (Multi-Level SiC	1000V	8mm

* Depend on factors such as working voltage, insulation type, pollution degree, and insulation material group

Table 1. Market segments with wide creepage and clearance trend

Introduction

The ACNT family of wide optocouplers offers 14.2mm creepage and clearance for high voltage applications. These optocouplers are able to achieve 2,262 V_{PEAK} insulation working voltage in a stretched compact SO-8 package. To address the needs for a comprehensive isolation solution in high voltage and noisy environment, the ACNT family consists of three products: the ACNT-H313, a high efficiency gate drive optocoupler for driving IGBTs; the ACNT-H61L, a low power 10MBd digital optocoupler for system control and data communications isolation; and the ACNT-H790, a high linearity isolation amplifier for current and voltage sensing applications.

Creepage and Clearance Requirements

Today high-voltage power systems require chip-level components to support well insulated and noise-immune large signals to minimize copper wiring costs while maintaining optimal power efficiency. In the drives systems, the benefits of using 690 VAC line voltage are power efficiency with power increases without current increases and lesser copper losses. This saves overall system costs in term of cable size, transformer size and installation cost.

According to the adjustable speed electrical power drive system safety IEC 61800-5-1 (ref IEC 60664-1), to determine the creepage requirements for a working voltage of the drive, design engineers need to consider several factors such as insulation type (basic or reinforced), pollution degree, and insulation material group. The factors of impulse voltage, working voltage and altitudes dictate multiplication factor and requirement for clearance.

Table 1 shows various market segments with the required creepage and clearance distance needed for pre-determined bus and working voltages. For example, a working voltage 630 VAC drive system with DC bus voltage 1200 V, pollution degree 2 and insulation material group III, requires 12.6mm minimum creepage for reinforced insulation.

Revision in the regulatory standards can call for wider optocouplers need. For example, from 2016, the harmonization of international standard bodies UL and IEC transits UL 508C to IEC 61800-5-1 will mean more stringent creepage and clearance requirements for new drive model while maintaining the same rating specifications. The ACNT family suits well to meet this revision and implementation.

It is Not Just About Creepage and Clearance

In other market segments, high insulation voltage or transient overvoltage capabilities is more critical in choosing a good isolation solution. An example is the medical devices - The new 4th edition medical standard IEC 60601-1-2 calls for higher levels 8 kV contact and 15 kV air between the sensing circuitry with direct patient or user contact to the control MCU board of patient monitoring device (Figure 1). Avago 14.2mm optocouplers with an internal clearance of 0.5mm, high transient overvoltage of 12 kV and its compact package meet this. The stretched wide package also improves the isolation gap and protection against electric arc discharge.

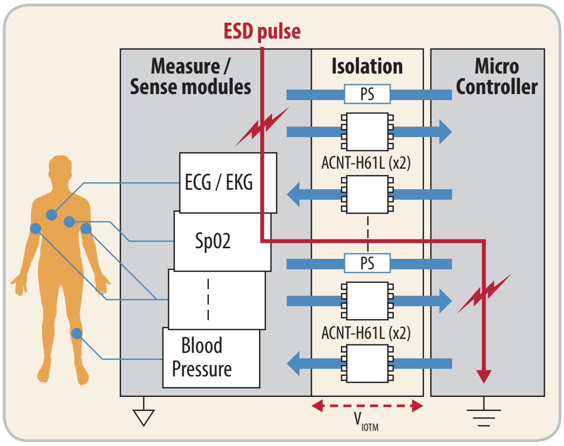

Figure 1: ACNT-H61L in patient monitoring device

The Avago ACNT family provides a complete isolation solution of a motor control system as shown in Figure 2. To isolate the low voltage "brain" or MCU and the high voltage power electronics, the ACNT-H313 2.5A gate driver suits driving power IGBTs and MOSFETs with excellent common-mode rejection noise performance of 40 kV/µs at 2000 V_{CM}. For the isolated motor phase current and voltage measurements, the ACNT-H790 isolation amplifier offers ±3% gain tolerance with excellent linearity and dynamic performance of 60 dB SNR. Its specifications of 200 kHz bandwidth and 1.6 µs fast response time allow capture transients in short circuit and overload conditions.

For data bus communication isolation or simply provide isolation between low voltage control and high voltage power (eg. HVIC or IPM), the ACNT-H61L digital 10 MBd optocoupler offers the lowest power consumption (less than 20mW) 14.2mm optocouplers available in the market.

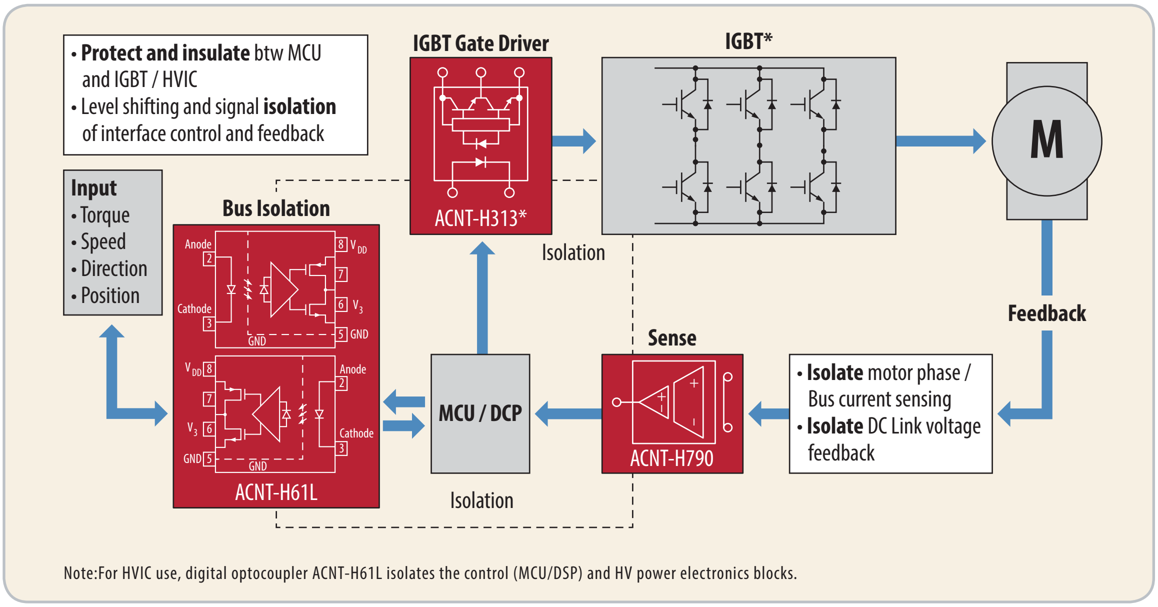

Figure 2: A complete isolation solution in the motor control system

ACNT Family Optocouplers Value Propositions:

Market	Bus Voltage
V_{IORM} = 2,262 V_{PEAK} V_{ISO} = 7,500 V_{RMS}	Market's highest insulation voltage 2262 V_{PEAK} optocouplers in 14mm creepage/clearance Certified high insulation voltage for robust, reliable and safe fail reinforced insulation
14.2mm Creepage and Clearance	Meets stringent system/equipment regulatory requirements
Low power <20mW	Market's lowest power consumption 10MBd optocoupler in 14mm creepage/clearance Energy efficient. (ACNT-H61L)
High noise immunity CMR (40kV@V_{CM}=2,000V)	Prevent erroneous driving IGBT in noisy environment (ACNT-H313)
Low gain drift -50ppm/°C and 0.05% linearity	Advanced Sigma-Delta A/D modulation technology and full differential isolation to enhance accuracy (ACNT-H790)

Contact us for your design needs at: **www.avagotech.com/acnt-family**

DesignSolution

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Use a Kernel In Your IoT Designs

In the Internet of Things, 80% of all devices will be deeply embedded and will require 32-bit processors for communication. The use of a kernel provides the required software architecture and efficiency.

I won't attempt to define the Internet of Things (IoT). Given its current state of development, many technologies and communication protocols still need to be defined. However, that's also why there is room for innovation and definition. We have enough of the building blocks today to make the IoT a reality, so no one should hesitate to start developing products or systems to capture a portion of this emerging market.

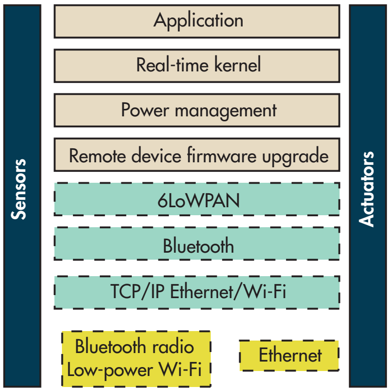
An IoT system comprises many components, including the thing itself (the embedded device), local networking (wired or wireless), the Internet, new IoT protocols, and, finally, some type of cloud-based subsystem. It's clear, though, that 32-bit processors will be prevalent for the embedded devices in IoT systems.

There still will be many 8-bit and 16-bit processors for low-power sensors and actuators. But because of the IoT's communication requirements, 32-bit processors will surpass any other processor architecture.

While many embedded systems manage well with single-threaded application, networked devices require more capable software. This means the software for an IoT device must be:

- Scalable, to accommodate a wide range of different classes of devices
- Modular, so you can choose only the components you need to meet tight RAM requirements
- Connected, so you can move data in and out of the device via Wi-Fi, Ethernet, USB, Bluetooth, or a wireless sensor networking technology
- Reliable, so your device can be certified for safety-critical applications

Developers can meet these requirements with the utilization of a kernel. In addition, a kernel allows the establishment of a modular software architecture, which facilitates development, troubleshooting, and product upgrades.



1. A typical low-power industrial IoT device may incorporate one or more wired or wireless network interfaces.

WHY NOT LINUX?

Linux is a robust, developer-friendly operating system (OS) that has been getting attention as a platform for IoT devices. It has matured into a mainstream embedded operating system for many applications. However, it has a key disadvantage compared to a real-time operating system (RTOS): memory footprint.

Linux can be trimmed down by removing tools and system services that aren't needed in embedded systems, yet it's still a large piece of software. It simply will not run on 8- or 16-bit MCUs, and many newer 32-bit MCUs don't have enough onboard RAM for the Linux kernel.

The ARM Cortex-M series is a good example. Hundreds of different MCUs that typically have only a few hundred kilobytes of onboard memory are based on the popular Cortex-M architecture.

Linux will certainly have many uses in embedded devices, particularly ones that provide graphically rich user interfaces. But there are thousands of applications for which Linux is ill suited.

INDUSTRIAL VS. CONSUMER IOT

The software requirements for industrial and consumer IoT devices can differ quite a bit. Although they might share a common kernel and low-level services, the middleware required by their applications can be radically different.

Figure 1 represents a software stack for an industrial IoT device, such as a wireless sensor node. This low-power, low-cost device may run entirely on a battery. Such a device might typically use a Cortex-M0 or Cortex-M3/M4 MCU. It would use a highly efficient network protocol such as 6LoWPAN to reduce transmission time and save power. It also would communicate over short distances wirelessly using Bluetooth or low-power Wi-Fi, or else use Ethernet when employed as an edge node.

Figure 2 conveys a software stack for a consumer IoT device. Clearly, the software requirements for this device are much greater. It might need a Java VM. It also may well use a vertical market protocol such as AllSeen, HomePlug/HomeGrid, Continua Alliance, or 2net. Such a device typically might use a Cortex-M3/M4 or a Cortex-A processor.

Ultimately, these requirements will drive your RTOS choice, so the platform choice shouldn't dictate a device's functionality. In fact, a flexible, scalable RTOS can help increase return on investment, cut development costs, and reduce time-to-market.

SCALABILITY

Although deeply embedded systems historically have been built entirely around 8- and 16-bit MCUs, the price of 32-bit MCUs has been dropping rapidly. As they have become commodity products, their popularity for embedded devices has skyrocketed.

A common engineering solution for networked sensor systems is to use two processors in the device. In this arrangement, an 8- or 16-bit MCU is used for the sensor or actuator, while a 32-bit processor is used for the network interface. That second processor runs a RTOS.

Sales of 32-bit MCUs have exploded in the last several years, and they have become the largest segment of the MCU market. The 32-bit MCU segment alone is expected to grow to $19.2 billion by 2017 *(Figures 3 and 4)*.

IoT devices will still include a mixture of small and large MCUs for years to come. A scalable RTOS that runs on a variety of 16- and 32-bit MCUs will meet tight memory requirements and reduce processor demands to save money.

MODULARITY

IoT devices also will require a modular OS that separates the core kernel from middleware, protocols, and applications. The OS will provide ease of development and minimize the software's memory footprint.

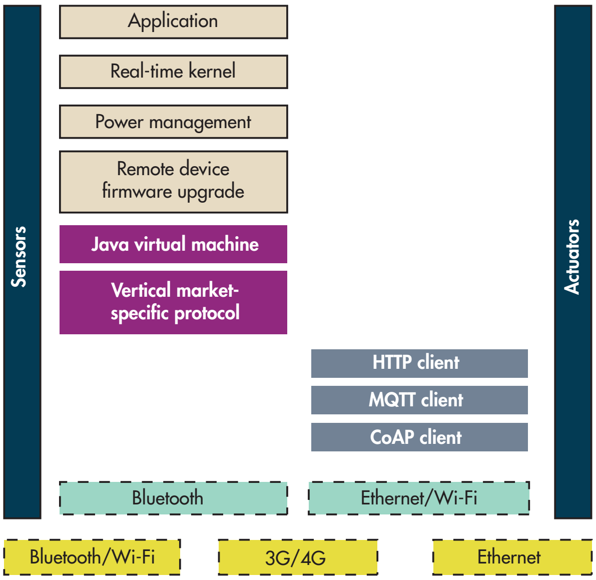
Using a modular RTOS simplifies the development process, especially when developing a family of devices with different capabilities. Relying on a common core allows the entire family of devices to share a common code base, while each device is customized with only the middleware and protocol stacks required by the application.

This approach also allows for a smaller memory footprint in the device. Unlike a monolithic operating system that bundles an entire suite of software together, a modular RTOS allows the embedded software to be tailored for the device, requiring less RAM and flash memory while reducing costs.

CONNECTIVITY

Network connectivity is essential to the IoT. Whether we are talking about wireless sensor nodes in a factory or networked medical devices in a hospital, the industry now expects embedded devices to be connected to each other and to communicate with corporate or public networks.

To achieve this connectivity, the RTOS needs to support communications standards and protocols such as IEEE 802.15.4, Wi-Fi, and Bluetooth. The device must be able to connect to



2. The software stacks for a consumer IoT device may incorporate one or more client profiles.

Internet Protocol (IP) networks using bandwidth-efficient protocols such as 6LoWPAN.

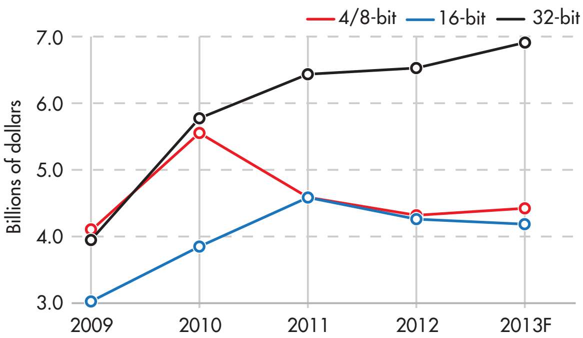
An RTOS will allow you to select the specific protocol stacks needed, which again means saving memory on the device and reducing cost. It also can help retrofit existing devices with new connectivity options without reworking the core of the embedded software.

RELIABILITY

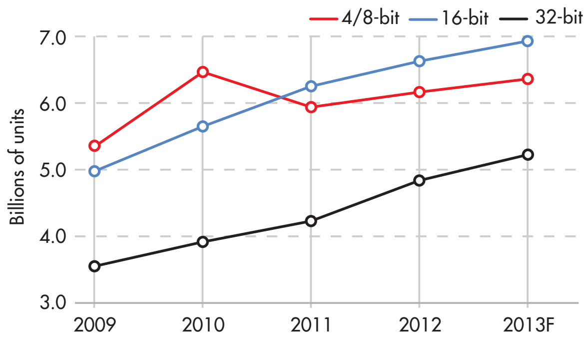
Many IoT systems will be deployed in safety-critical environments or in locations where repair and replacement are difficult. IoT devices, then, will need to be faultlessly reliable.

In these situations, an RTOS must have safety-critical certification. This is vital to demonstrate the device's reliability and safety. Certifications that may be required include:

- DO-178B for avionics systems



3. Sales of 32-bit MCUs continue to increase. (courtesy of IC Insights, April 25, 2013)



4. All MCU unit shipments are increasing. (courtesy of IC Insights, April 25 2013

- IEC 61508 for industrial control systems
- ISO 62304 for medical devices
- IEC SIL3/SIL4 for transportation and nuclear systems

When building products for use in a safety-critical environment, using software that is already certified can reduce certification time and costs. Every part of the device will require certification and extensive documentation. Validation suites and certification kits, typically available from third parties, provide thousands of pages of documentation that otherwise would have to be developed for each product.

Even if certification isn't required for the device, knowing that the OS running within it has been certified can provide confidence and peace of mind that your product will perform reliably.

CONCLUSION

Embedded devices used as things in the IoT will predominantly use 32-bit processors mainly because of the networking requirements. The use of a kernel, especially an RTOS, provides the software architecture and efficiency required for this type of embedded design.

An IoT system may use small sensor nodes running on low-power smaller processors up to large gateways running on application processors. Designers must invest in an RTOS that can run on these types of processors. And while RTOSs may have been seen as a commodity in the last decade, the IoT is giving a new life to them and to embedded systems in general. ed

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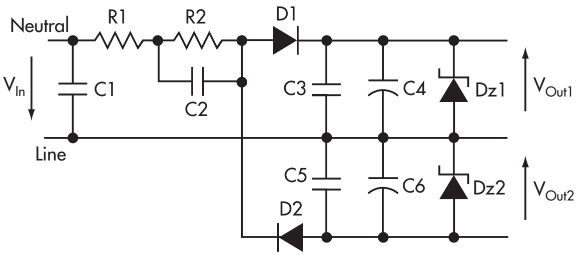
Topology Implements Updated Version Of Non-Isolated Capacitive Power Converter

ZBYNO BRUDNY | BEFRA/BEBRO ELECTRONIC GMBH brudny@befra.cz

LOW-VOLTAGE MICROCONTROLLERS GENERALLY HAVE been powered from a regulated supply, such as 1.8 to 3.6 V, and have very low current consumption, typically between 1 mA and 5 mA. Achieving an inexpensive, space-saving solution for effective conversion from line voltage as high as 230 V ac down to 3 V/20 mW is not a simple task, especially while meeting additional mandates such as those for electromagnetic compatibility (EMC) and standby power.

The non-isolated supply converter shown requires no inductor or switched-mode power (SMP) converter. It uses the "capacitive-dropper principle" enhanced with a new and specific connection of the Q-pump (a capacitor-based charge pump), which converts the power in the opposite direction, from minus node to plus node.

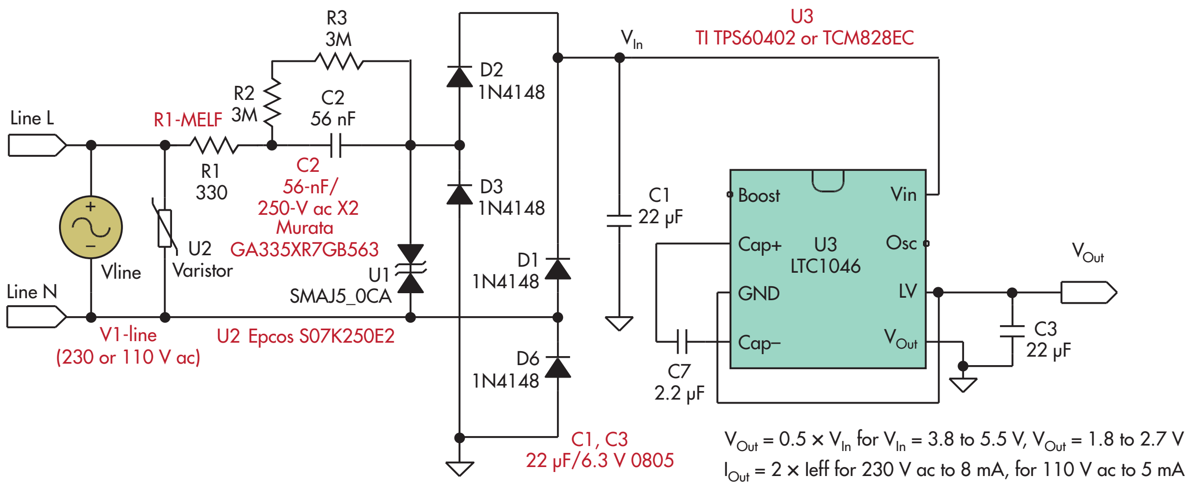
In the well-known design of a capacitive power supply, capacitor C2 accommodates the ac mains voltage to a voltage level suitable for the application, while R1 and R2 are connected to limit inrush currents due to the capacitors (*Fig. 1*). The voltage is then rectified by diodes D1 and D2 and regulated using Zener diodes Dz1 and Dz2 along with output capacitors C4 and C6. The amount of output current depends on the impedance of capacitors at 230 V/50 Hz or 110 V/60 Hz.



1. The basic capacitive converter uses a diode rectification, Zener diodes, and capacitors but has no regulation.

KEY OPERATIONAL PARAMETERS AT 184-, 230-, AND 260-V AC LINE VOLTAGES

$Line_{In}$ (V_{eff})	$Power_{In}$ (mW_{eff})	V_{Out} (V)	I_{Out} (mA)	$Power_{Out}$ (mW)	Efficiency (%)
184	25.2	2.07	4.4	11.88	47.1
230	40.2	2.57	5.20	13.36	33.3
260	43.1	2.62	5.26	13.78	32.0



2. The modified capacitive converter with bridge rectifier adds additional regulation and protection.

Capacitor C2 must be the X2 type to satisfy EN 60384-14. Resistor R2 builds a discharge path for C2, still meeting IEC61010-1 or UL1950 safety requirements. The output current of the converter is determined according to:

$$I_{out\_eff} = U_{line} \times 2\pi \times f_{line} \times C2$$

where U_{line} and f_{line} are the line voltage and frequency, respectively.

Recently, Murata introduced a very small and interesting monolithic ceramic chip capacitor, the SMD-X2. For a 230-V ac line, the output current with this capacitor is:

$$I_{out\_eff} = 230 \times 2\pi \times 50 \times 56 \times 10 - 9 = 4.0 \text{ mA}$$

For 110 V ac, it is:

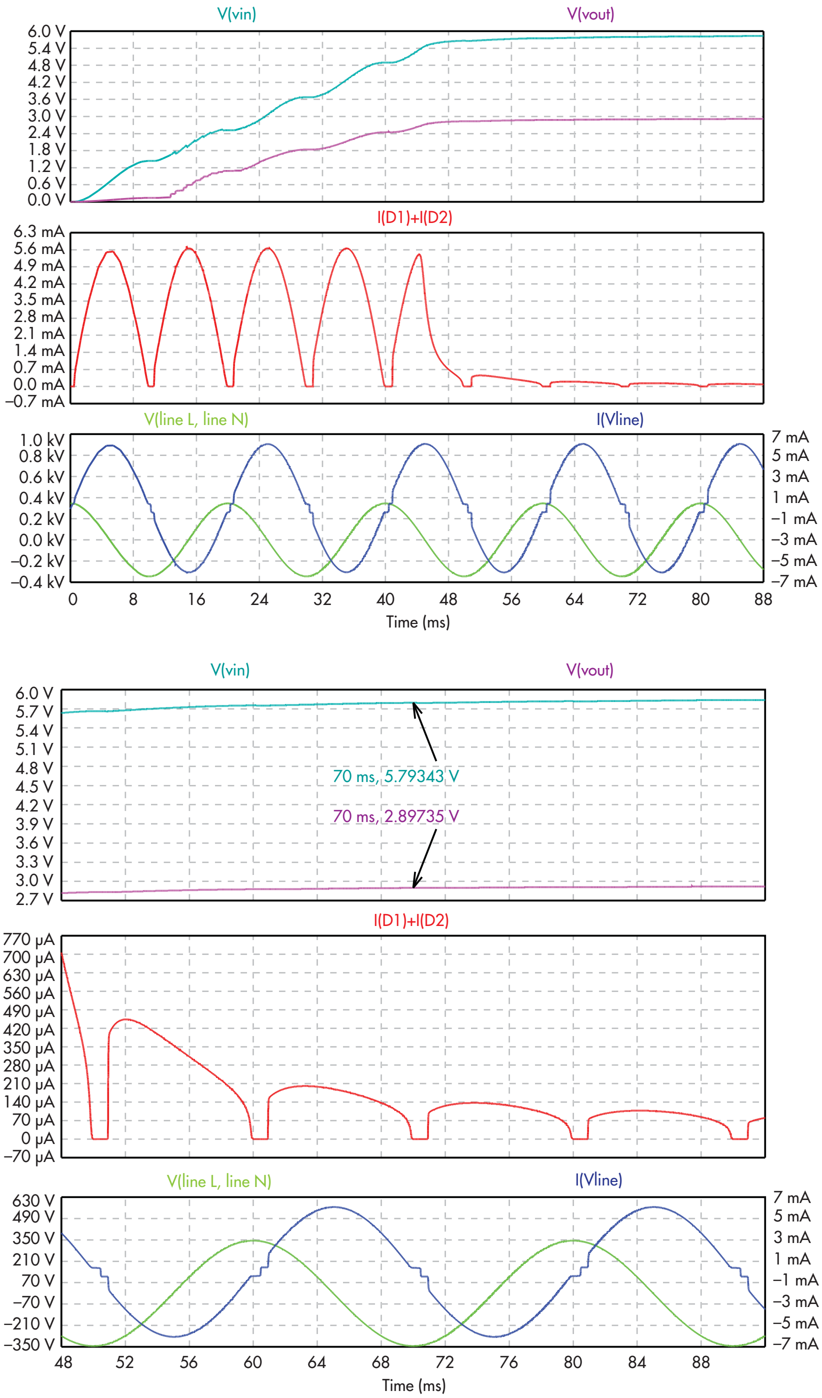
$$I_{out\_eff} = 2.3 \text{ mA}$$

While this might be enough current for many very low-power microcontroller applications, it wouldn't be sufficient for many of them. In the modified capacitive converter, diodes D1 and D2 have been replaced with a bridge comprising D1, D2, D3, and D6, which pumps current into capacitor C1 in every half-period of line voltage *(Fig. 2)*. Varistor U2 and suppressor U1 are added for immunity against 2-kV surge and the burst testing procedure of IEC61000-4-5.

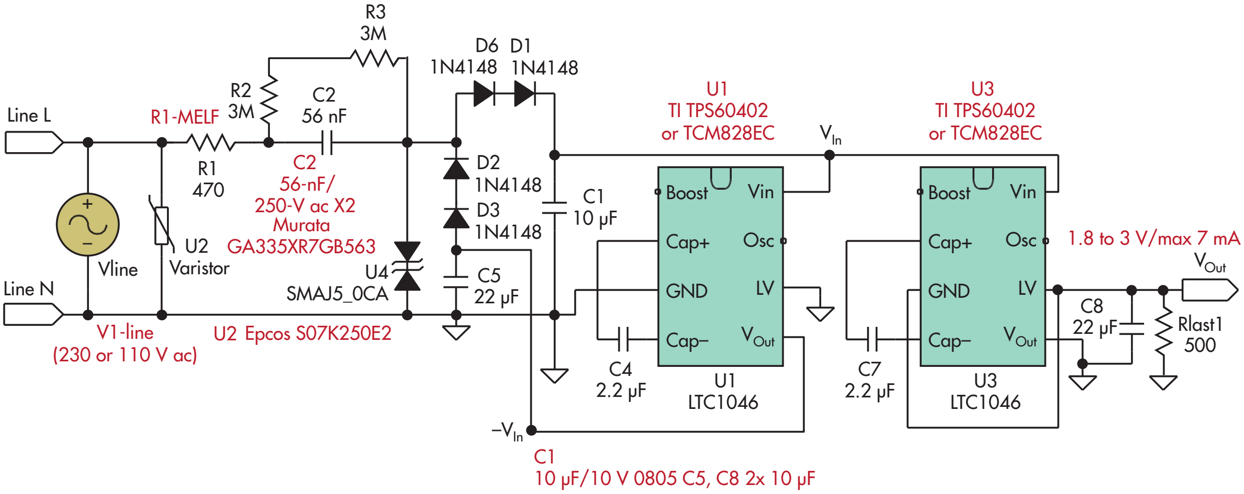
I used the LTC1046, which has a model in SW-LTspice, for the simulation of the circuits model of the Q-pump. However, it is too expensive for many situations, so you can use the TPS60402 or TMC828EC, which have the same functionality but are cheaper.

Therefore, there is only a very short time when the charge from C1 has to supply the rest of the circuit. The circuit has been simulated using LT-Spice version 4.19, as well as built and tested *(Fig. 3)*.

U3 is the capacitor-based charge pump, a very cheap, small (SOT23-6), and very efficient IC for small currents. In the step-down charge pump connection, it produces output voltage $V_{Out} = 0.5 \times V_{In}$ and corresponding output current $I_{Out} = 2 \times I_{In}$. With the same 56-nF X2 capacitor for C2, we get $I_{out\_eff} = 8.0$ mA for the 230-V ac line and $I_{out\_eff} = 4.6$ mA for the 110-V ac line. This



3. C1 has to supply the rest of the circuit of Figure 2 for very short periods.



4. The modified capacitive converter without bridge rectifier brings a fixed ground connection.

should be sufficient for most modern microcontrollers with a supply voltage range between 1.8 V and 2.7 V.

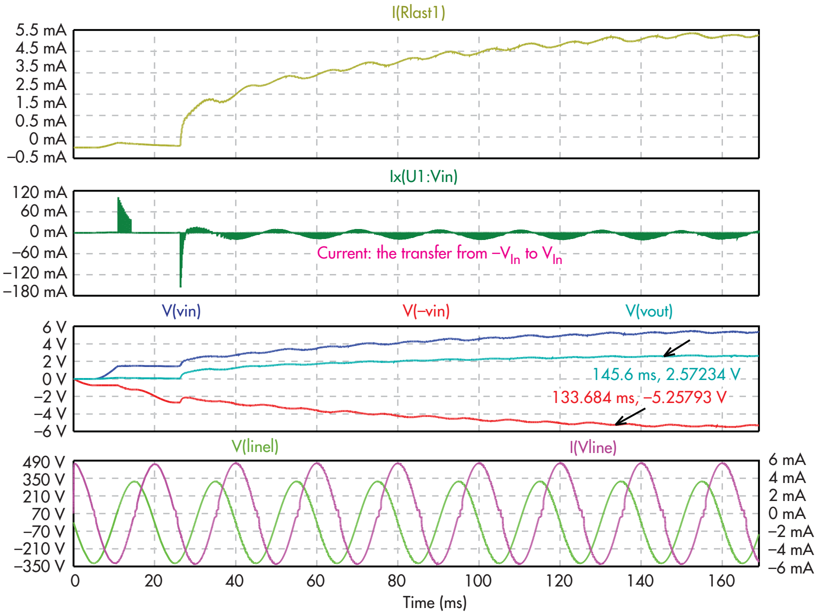
The "ground" of the converter is not connected with any side of ac-supply lines. Instead, it alternates between both line and neutral. As such, it could be unsuitable for many applications. To overcome this, the modified schematic uses the same arrangement of two-way rectification as the basic design in Figure 1, bringing a fixed connection of the ground supply node to one of the line wires *(Fig. 4)*.

The value of capacitor C5 for the negative rectification path is two to three times larger than the value of capacitor C1 for the positive path. As a result, the voltage on the positive path grows more quickly than it does on the negative path. The Q-pump-IC is designed to convert a positive supply into a negative one, using a bridge of four controlled-FET switches and a working capacitor. The opposite conversion of energy can be produced from the negative path of the supply to the positive path, due to the use of these FETs for switching.

This results in the same properties in this rectification circuit as with bidirectional rectification using a diode bridge. Figure 5 shows the simulated results and the change of current polarity of charge pump U1's V_{In} pin.

The circuit of Figure 5 has been simulated and tested at the worst-case line voltage of 230 V ac ±20% *(Fig. 6)*. All of the results meet the requirements for most modern MCUs with respect to 2013 ErP Standby Power Regulation *(see the table)*. There was a very small ripple in V_{Out} (<60 mV) for capacitor C5, 100 µF/10 V (Taiyo Yuden LMK-325BJ107MM), and C1, 22 µF/10 V (Murata GRM219B31A226MEA 0805). Furthermore:

- The less complicated circuit of Figure 2 can be used for applications that don't need a fixed connection to the power line (line or neutral).
- Two 56-nF, X2-type capacitors should

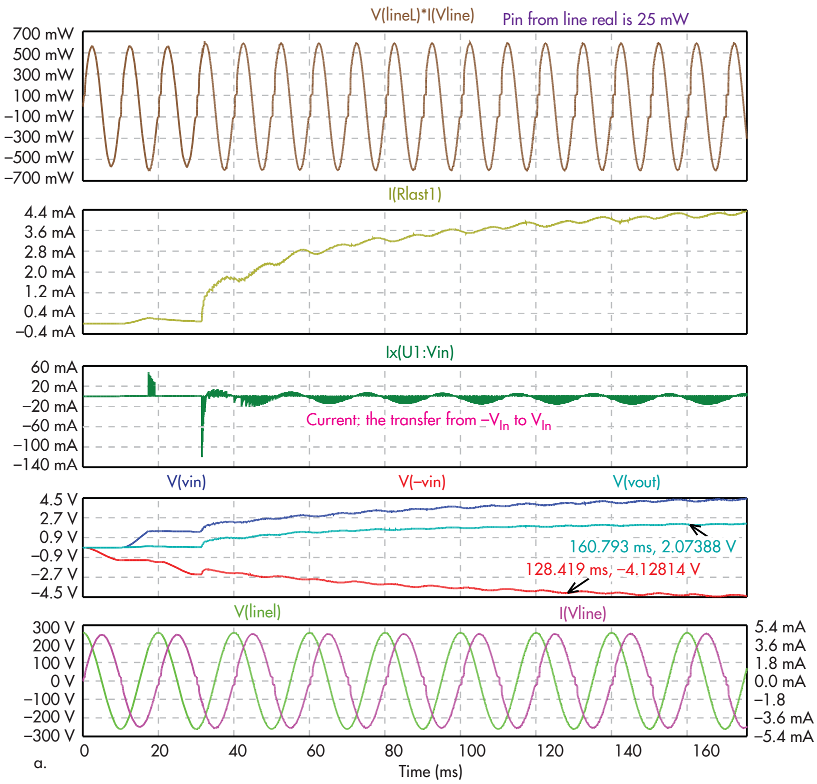


5. The startup and normal operation of the circuit at 230 V ac shows the change of current polarity on the V_{In} of charge pump U1 with a cycling period of 5 ms and 15 ms.

be used in parallel for applications with a line voltage of 110 V ac or universal input from 85 to 260 V ac.

- There is a minimum 12- by 12- by 8-mm space required for this design on a two-layer printed-circuit board.
- To stabilize the output voltage over line voltage 230 V ac ±20%, use consecutive low-dropout regulators such as the TLV70025.
- The Holystone SCC2825X563K202 56n X2 safety SMD capacitor also can be used.

ZBYNO BRUDNY is a development engineer with Befra/Bebro Electronic GmbH in Germany, working in new product definition and application circuit development. He graduated from the Brno University of Technology, the Czech Republic.



a.

DESIGN NOTES

Control the Voltage of a Remote Load Over Any Length of Copper Wire – Design Note 529

Philip Karantzalis

Introduction

A common problem in power distribution systems is loss of regulation due to the cable/wire voltage drop between the regulator and the load. Any increase in wire resistance, cable length or load current increases the voltage drop over the distribution wire, increasing the difference between actual voltage at the load and the voltage perceived by the regulator. One way to improve regulation over long cable runs is to measure voltage directly at the load via a 4-wire Kelvin connection between the regulator and the load. Unfortunately, this solution requires routing additional wires to the load as well as a Kelvin resistor placed near the load, impractical when the load is inaccessible for modification. Another method minimizes the voltage drop by employing large diameter wire, lowering the resistance from the regulator to the load. This is electrically simple, but can be mechanically complicated. Increasing the size of cable conductors can significantly increase space requirements and cost.

An alternative to additional wiring is to compensate for the voltage drop at the regulator with the LT®6110 cable/wire drop compensator without additional cabling/wiring between the regulator and load. This article shows how the LT6110 can improve regulation by compensating for a wide range of regulator-to-load voltage drops.

The LT6110 Cable/Wire Compensator

Figure 1 shows a 1-wire compensation block diagram. If the remote load circuit does not share the regulator's ground, two wires are required, one to the load and one ground return wire. The LT6110 high side amplifier senses the load current by measuring the voltage, V_{SENSE}, across the sense resistor, R_{SENSE}, and outputs a current, I_{IOUT} proportional to the load current, I_{LOAD}. I_{IOUT} is programmable with the R_{IN} resistor from 10µA to 1mA. Cable/wire voltage drop, V_{DROP} compensation is accomplished by sinking I_{IOUT} through the R_{FA} feedback resistor to increase the regulator's output by an amount equal to V_{DROP}. An LT6110 cable/wire voltage drop compensation design is simple: set the $I_{IOUT} \bullet R_{FA}$ product equal to the maximum cable/wire voltage drop.

The LT6110 includes an internal 20mΩ R_{SENSE}, suitable for load currents up to 3A; an external R_{SENSE} is required for I_{LOAD} greater than 3A. The external R_{SENSE} can be a sense resistor, the DC resistance of an inductor or a PCB trace resistor. In addition to the I_{IOUT} sink current, the LT6110 I_{MON} pin provides a sourcing current, I_{MON}, to compensate current-referenced linear regulators such as the LT3080.

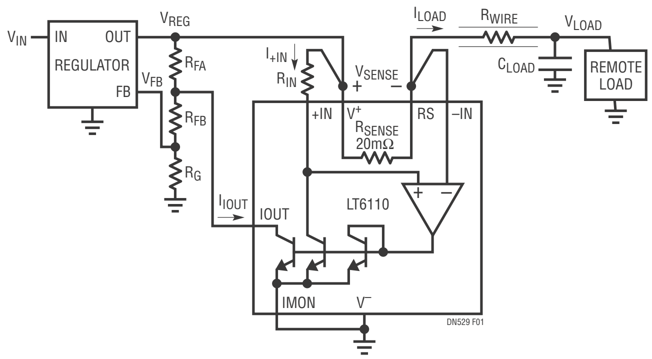


Figure 1. No Extra Wires Are Required to Compensate for Wire Voltage Drop to a Remote Load

Compensating Cable Voltage Drops for a Buck Regulator

Figure 2 shows a complete cable/wire voltage drop compensation system consisting of a 3.3V, 5A buck regulator and an LT6110, which regulates the voltage of a remote load connected through 20 feet of 18 AWG copper wire. The buck regulator's 5A output requires the use of an external R_{SENSE}.

The maximum 5A I_{LOAD} through the 140mΩ wire resistance and 25mΩ R_{SENSE} creates an 825mV voltage drop. To regulate the load voltage, V_{LOAD}, for $0A \le I_{LOAD} \le 5A$, $I_{IOUT} \bullet R_{FA}$ must equal 825mV. There are two design options: select I_{IOUT} and calculate the R_{FA} resistor, or design the regulator's feedback resistors for very low current and calculate the R_{IN} resistor to set I_{IOUT}. Typically I_{IOUT} is set to 100µA (the I_{IOUT} error is ±1% from 30µA to 300µA). In the Figure 2 circuit the feedback path current is 6µA (V_{FB}/200k), the R_{FA} resistor is 10k and the R_{IN} resistor must be calculated to set $I_{IOUT} \bullet R_{FA}$ = 825mV.

$I_{IOUT} = V_{SENSE}/R_{IN}$, $I_{IOUT} \bullet R_{FA} = V_{DROP}$

and

$$R_{IN} = R_{FA} \bullet \frac{R_{SENSE}}{R_{SENSE} \bullet R_{WIRE}}$$

and

for R_{FA} = 10k, R_{SENSE} = 25mΩ and R_{WIRE} = 140mΩ, R_{IN} = 1.5k.

Without cable/wire drop compensation the maximum change in load voltage, ΔV_{LOAD}, is 700mV (5•140mΩ), or an error of 21.2% for a 3.3V output. The LT6110 reduces ΔV_{LOAD} to only 50mV at 25°C, or an error of 1.5%. This is an order of magnitude improvement in load regulation.

Precision Load Regulation

A modest improvement in load regulation with the LT6110 does not require accurate R_{WIRE} estimation. The load regulation error is the product of two errors: error due to the wire/cable resistance and error due to the LT6110 compensation circuit. For example, using the Figure 2 circuit, even if the R_{SENSE} and R_{WIRE} calculation error is 25%, the LT6110 still reduces V_{LOAD} error to 6.25%.

For precise load regulation, an accurate estimate of the resistance between the power source and load is required. If R_{WIRE}, R_{SENSE} and the resistance of the cable connectors and PCB traces in series with the wire is accurately estimated, then the LT6110 can compensate for a wide range of voltage drops to a high degree of precision.

Using the LT6110, an accurate R_{WIRE} estimation and a precision R_{SENSE}, the ΔV_{LOAD} compensation error can be reduced to match the regulator's voltage error over any length of wire.

Conclusion

The LT6110 cable/wire voltage drop compensator improves the voltage regulation of remote loads, where high current, long cable runs and resistance would otherwise significantly affect regulation. Accurate regulation can be achieved without adding sense wires, buying Kelvin resistors, using more copper or implementing point-of-load regulators—common drawbacks of other solutions. In contrast, compensator solutions require little space while minimizing design complexity and component costs.

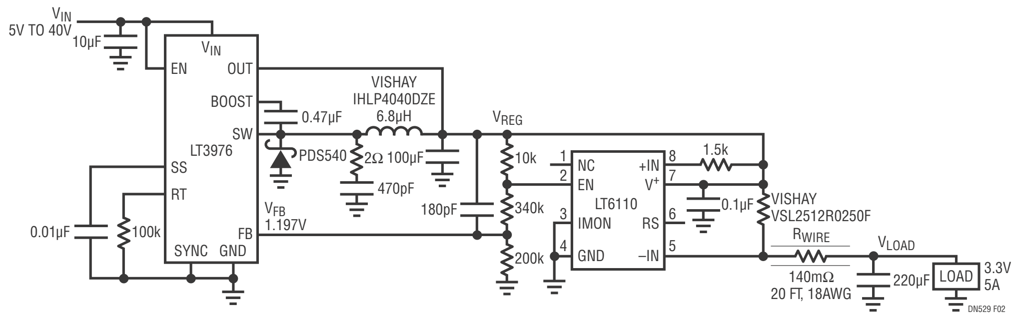


Figure 2. Example of a High Current Remote Load Regulation: A 3.3V, 5A Buck Regulator with LT6110 Cable/Wire Voltage Drop Compensation

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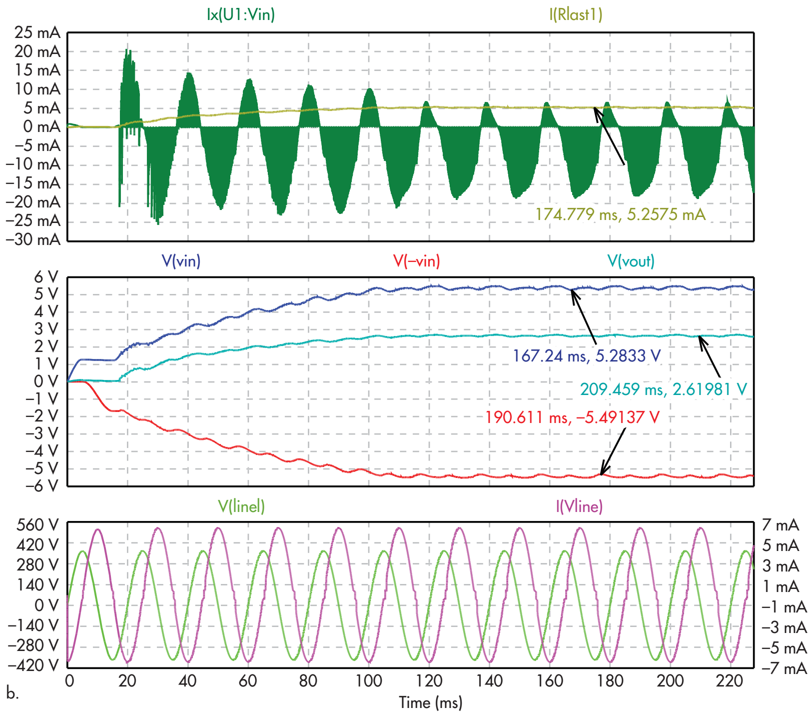

b.

6. The waveforms of critical circuit points at startup and during normal operation of the circuit at a low line-voltage of 184 V ac (a) and a high line-voltage of 260 V ac (b) show smooth power-on transition and subsequent regulation.

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Software Solution Secures DDS

Real-Time Innovations' (RTI) Connext DDS Secure brings policy-based security to the Data Distribution Service (DDS). The previous Connext DDS has been used in applications that span embedded to enterprise applications. The latest version implements a plug-in oriented architecture that provides policy-based security that scales across this range.

The current set of plug-ins includes authentication, access control, encryption, data tagging, and logging. The plug-in approach lets developers enhance plug-ins and provide plug-ins that can take advantage of resident hardware and software. For example, the encryption plug-in can use hardware-accelerated encryption support. Encryption can be applied at the field level, significantly reducing encryption overhead if only some data requires high security.

DDS provides a publish/subscribe environment. Connext DDS lets the environment incorporate the cloud through Internet of Things (IoT) devices. Data can flow from a publisher through the network to any number of subscribers based on their needs. It handles quality of service, replication, and a host of other features that make the data transfers and communication links transparent to applications. Connext DDS complies with the Open Management Group's (OMG) DDS specification as well.

Data tagging allows metadata to be added to DDS data, which can be used to enhance access control. For example, access to a particular piece of data may be limited by an application. Added metadata permits the application to determine what policy to apply.

The modular Connext DDS support can provide more limited support on low-end, embedded clients as well as more sophisticated support on more powerful platforms. It does not have a single point of failure, and it can deal with a range of communication networks and protocols. It also can utilize low-bandwidth, limited-connectivity links and manage high-speed networks with multicast support.

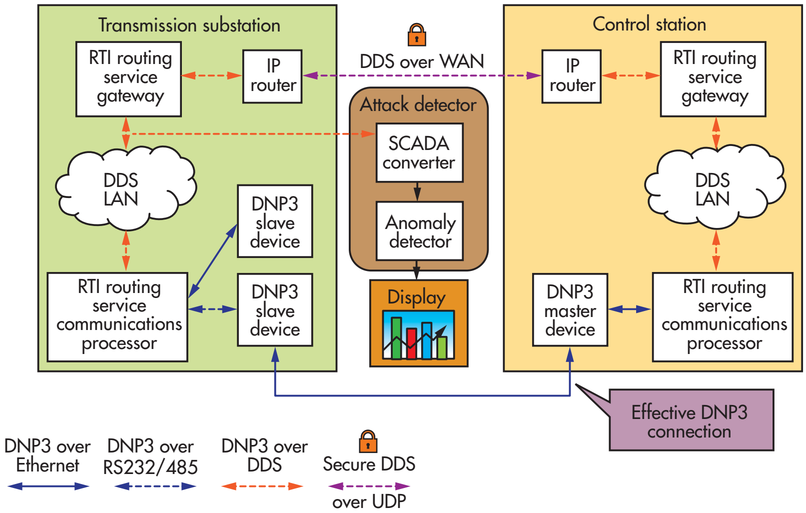
Connext DDS can be used for DDS applications without modification. Policies can be applied at a level above applications, or applications can take more control over their security using Connext DDS interfaces. Furthermore, it can be tailored to support legacy applications that may employ other communication methods.

THE APPLICATIONS

The Pacific Northwest National Laboratory (PNNL) worked with RTI to provide a better, more secure communication system for its Supervisory Control and Data Acquisition (SCADA) applications *(see the figure)*. SCADA is used in a variety of industrial control systems like those used by electric utilities. In this instance, PNNL's SCADA system used the standard Distributed Network Protocol 3 (DNP3). Unfortunately, DNP3 is point-to-point, and it isn't very secure. This can make security and reliable communication more difficult.

RTI and PNNL created a DNP3 routing service interface. Now, the SCADA applications can use Connext DDS's communication system, which can be more secure and reliable. Policies can be used to control access to the SCADA data that now flows only through Connext DDS. Also, the implementation provides access to the SCADA data via DDS in addition to replacing the DNP3 support that the system was intended to secure.

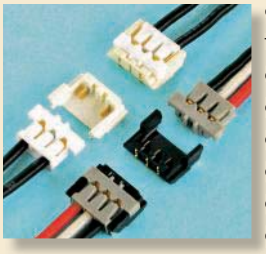
Connext DDS Secure can be used in any Connext DDS environment to improve security. Connext DDS Secure and Connext DDS work with most operating systems such as Windows, Linux, iOS, and many real-time operating systems. ed



Real-Time Innovations used Connext DDS Secure to retrofit the Pacific Northwest National Laboratory's SCADA system with more secure communications.

Wire-To-Board Subminiature Connectors Tackle High-Density LED Apps

WITH A mated height of 1.9 mm and a design for maximum printed-circuit-board (PCB) flexibility, the JST Corp. ADH series of wire-to-board, crimp-style, disconnectable connectors will find homes in a multitude of high-density LED light applications. The 1.2-mm pitch, side-entry, surface-mount connectors are polarized and maintain secure friction locking when mated. The design features a socket half that's mated with the header from the vertical direction while wires extend out of the socket horizontally, which allows the header to be placed anywhere on the PCB. Three circuits make up the series, all with a 3.0-A (ac-dc) rating using a 26 AWG wire at 50-V ac-dc. They can accommodate wire sizes AWG #28 to #26. Operating temperature ranges from –25°C to 85°C, including temperature rise when applying electrical current. Headers, molded of RoHS-compliant (Restrictions on Hazardous Substances) 94V-0 polybutylene terephthalate (PBT) material, incorporate insertion guides to facilitate mating. Contacts consist of gold-plated over nickel undercoated copper-alloy base material.



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Mini Connectors Meet High-Contact-Density Needs

ANSWERING THE call for ever-smaller connectors with increased contact density, Lemo extended its M series of plugs and cable-mount sockets with the ultra-compact MM connectors. The MM connectors come with three or four contacts and feature the company's ratchet-coupling shells. The lightweight MMs, some of the smallest IP68 connectors offered by Lemo, will specifically find homes in the automotive, racing, and aerospace markets. They're suitable for cable diameters ranging from 2 to 27 mm and contact configurations from two to 114 contacts. Application areas also include commercial off-the-shelf (COTS) military, security, aerospace, and other harsh environments that require robust performance in a lightweight, compact size.

LEMO

www.LEMO.com

ATCA System Boasts 600-W-Per-Blade Capability

WITH POWER and cooling for up to 600 W per blade, Artesyn's Centellis 8000 series AdvancedTCA (ATCA) system can accommodate full payloads of high-performance ATCA blades. It supports the company's System Services Framework (SSF) software, a centralized management software suite that configures and monitors software and hardware components in a single shelf or multiple ATCA shelves. The system also supports the company's FlowPilot software for advanced load balancing and packet classification, directing traffic flow to individual payload processors for further processing. Designed for standard 19-in. rack mounting, the 18U-high (798 mm) system features a 40-Gigabit Ethernet dual-star fabric interface and 14 blade slots. Among the 14 are two switching slots that can integrate Artesyn's 40G ATCA-F140 switching and system-management blade. A pre-certified range of application-ready configurations of the Centellis 8000 series for NEBS Level 3 helps save development time and cost.

ARTESYN EMBEDDED TECHNOLOGIES

www.artesyn.com

CompactPCI Serial Backplanes Perform Symmetrical Serial Processing

ELMA BUSTRONIC CompactPCI Serial (CPCI 5.0) backplanes feature a point-to-point star topology to deliver fast serial data transfers and transmission frequencies of over 12 Gbits/s. The 3U backplanes come in three-, five-, and nine-slot options. The three-slot backplane features one CPCI-5.0 system (CPU) slot and two CPCI-5.0 peripheral slots. The five-slot version has one system slot and four peripheral slots. The nine-slot version has one system slot and eight peripheral slots. All slots are connected to each other through a ful-mesh Ethernet topology. Also available is an eight-slot CompactPCI PlusIO backplane. System slots support serial interfaces such as PCI Express, SATA, USB2, and USB3. Applications include railway, avionics, transportation, and shipboard systems.

ELMA BUSTRONIC CORP.

www.elma.com/en/elma-bustronic

40-Gbit AdvancedTCA Switch Blade Satisfies Bandwidth-Hungry Telecom Apps

ADLINK TECHNOLOGY'S aTCA-3710 40-Gbit AdvancedTCA (ATCA) switch blade offers 14 10-Gigabit Ethernet (GbE) SFP+ uplink ports and supports 640-Gbit/s bandwidth for use in 14-slot, 40-Gbit ATCA shelves. The switch blade features a Broadcom BCM56846 10/40-GbE fabric interface switch and BCM56334 24-port GbE base interface switch, as well as a Freescale QorIQ P2041 quad-core local management processor. The hot-swappable aTCA-3710 complies with PICMG3.0 R3.0 and PICMG 3.1 R2.0 standards. It's positioned as a high-performance server switch. Along with CPU/NPU blades and Adlink Software for Networks (ADSN), it can form a 40-Gbit Application Ready Intelligent Platform (ARIP) for next-generation applications. ADSN middleware facilitates configuration, management, and monitoring of switch status. Next-gen 4G/LTE telecom applications include network monitoring and security, access-point controllers, video streaming, and deep package inspection.

ADLINK TECHNOLOGY INC.

www.adlinktech.com/aTCA/

IP56-Rated AC, DC Axial Fans Withstand Harsh Environments

QUALTEK'S HPLC ac and dc axial fans meet international standard IEC 60529 for dust, moisture, and direct water exposure. They also are certified to IP56's harsh-environment standards as well as IP54 and IP55. The FDA2 series of FPLC ac fans, which range in size from 172 to 280 mm, incorporates a thermal-protected external rotor capacitor-run induction-motor, two-ball-bearing system with an available 100,000-hour bearing option. Other features include an aluminum alloy frame, one-piece forged-steel impeller, and optional UL94V-0 plastic impeller for increased airflow. The FDD1 series HPLC dc fans integrate an IC-protected, brushless dc, two-ball-bearing system with an available 100,000-hour bearing option. Also featuring an aluminum alloy frame, one-piece forged-steel impeller, and optional plastic impeller, the dc fans come with alarm, tachometer, and pulse-width-modulation (PWM) configurations.

QUALTEK ELECTRONICS CORP.

http://qualtekusa.com

USB μModule Isolator With Power Protects Hubs, Peripheral Ports

COMBINING USB data communications and USB power, the LTM2884 USB μModule (micromodule) isolator guards against ground-to-ground differentials and large common-mode transients. It separates grounds by isolating a pair of USB signal transceivers using internal inductive signal isolation. Thus, the ruggedized device provides 2500-V rms isolation and common-mode transient rejection of less than 30 kV/μs. An integrated, low-EMI (electromagnetic interference), external or bus-powered dc-dc converter that powers the isolated transceiver delivers up to 2.5 W of isolated power for USB peripherals or hub/host controllers. Implementation of an automated bus speed-detection feature allows the LTM2884 to be used in hub/host/bus isolation applications. Integrated downstream-facing pull-down resistors and upstream-facing pull-up resistors are automatically configured to match the speed of the downstream devices, making it possible to monitor and report bus speeds to the host.

LINEAR TECHNOLOGY CORP.

www.linear.com/isolator

Monoblock Inserts Extend Connector Capabilities

DEDICATED, HIGH-DENSITY monoblock inserts developed by the Harting Technology Group expand the functionality of two of the company's top modular connector series: the Han Eco and Han Yellock. The inserts enable both series connectors to replace a larger connector or multiple units to save layout space for a device or control cabinet. The Han Eco monoblock E inserts, with screw termination, are designed as snap-in modules that foster faster, tool-free assembly. The monoblocks, with a rated voltage of 500 V and 16-A current, feature a pre-leading PE contact (ground) resulting in contact numbers of 10, 14, 20, and 28 plus PE for all four Han Eco housing sizes. They can be combined with modules from the Han Modular series in any Han Eco housing to mix transmission media. Han Yellock monoblocks offer 25 or 48 contacts with crimp terminations for 30 and 60 housing sizes, respectively. Han Eco connectors consist of glass-fiber-reinforced, high-performance plastics. Han Yellock is distinguished by an internal lock mechanism that works like a seat belt, which accelerates locking and pushbutton release, and incorporation of multiplying potentials (eliminating the need for terminal blocks inside a machine).

HARTING TECHNOLOGY GROUP

www.harting-usa.com

Spring Pin Socket for Kelvin Resistance Measurement

Power management devices need to be measured precisely for resistance values. Kelvin technique allows precise resistance measurement of devices using BGA or QFN socket over a wide temperature range with Ironwood Electronics' Kelvin socket technology. BGA and QFN GHz bandwidth Sockets for pitches down to 0.4 mm pitch and bandwidth to 40 GHz, with industry's smallest footprint simplifies development cycle.

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ED 09/14 ISSUE PREVIEW

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

Running Ada 2012 On the Cortex-M4

I like to think I write good code, and I've used C and C++ almost since their inception. I admit to incorporating more than one unwanted bug into C applications that were eliminated after sometimes tedious diagnostic sessions. Almost every new microcontroller released has a free C/C++ compiler toolchain associated with it.

Unfortunately, C is very unforgiving, and C++ is only a little better. But they are the mainstay for embedded programmers these days. That's one reason why I have been waiting for AdaCore's delivery of its Ada 2012 toolchain for Arm's Cortex-M platform. It is a free download at libre.adacore.com.

The Cortex-M is the main low-end, 32-bit microcontroller utilized by almost all major microcontroller vendors that have adopted the Arm architecture. Vendors like Green Hills Software, Atego, and Adacore have supported the Cortex platform in the past but with earlier Ada standards. Ada 2012 includes a range of new features including contracts.

ROLLING UP MY SLEEVES

I had already tried out a version of AdaCore's GNAT Programming Studio (GPS). It generated applications that would run on Linux on the BeagleBone based on the Texas Instruments Cortex-A8 platform. The new toolchain targets bare metal, which is needed for many applications.

Setup was easy since GPS was already installed. Setting up the ST-Link debug interface to the STM32 board actually took more time. It was then a matter of running through the flashing LED demo. I included a snippet of code from a flashing LED program to highlight some of the advantages that Ada 2012 provides *(see the listing)*.

Even if you haven't used Ada, you should be able to get an idea of what's going on. In particular, the task body definition highlights the built-in multitasking support. Also note the use of the "modular" (unsigned) data type for Index that limits the addressing of the Pattern array. Unlike C, there is no need to check the result of Next_LED when it is updated. Additionally, I prefer the more verbose if/then/else conditional expression of Ada to the C/C++ ?: combination. I have programmed in APL, and its one-liners were neat but typically indecipherable. C and C++ code can get this way too.

Ada has several benefits over C and C++ . But it has drawbacks as well, such as availability. For ARM Cortex microcontrollers, this is no longer an issue. Developers can take advantage of all the Ada 2012 features, from generics to multitasking.

I would encourage anyone wanting to write bulletproof code for embedded applications to check out the AdaCore/STM32 combination. It is inexpensive and very functional. The ST-Link support also allows it to work with platforms like the STM32F401 Nucleo. I tried it on my Nucleo as well.

The Heartbleed bug is just one of many reminders of how one range check error can wreak havoc. C does not do it, but Ada does check—and not just on array access, by default. Ada will not eliminate all bugs from your code, but it does make it a lot harder to create them. ed

```
with LEDs;        use LEDs;
with Button;      use Button;
with Ada.Real_Time; use Ada.Real_Time;
package body Driver is
  type Index is mod 4;
  Pattern : constant array (Index) of User_LED := (Orange, Red, Blue, Green);
  task body Controller is
    Period     : constant Time_Span := Milliseconds (75);  -- arbitrary
    Next_Start : Time := Clock;
    Next_LED   : Index := 0;
  begin
    loop
      Off (Pattern (Next_LED));
      Next_LED := Next_LED +
        (if Button.Current_Direction = Counterclockwise then -1 else 1);
      On (Pattern (Next_LED));
      Next_Start := Next_Start + Period;
      delay until Next_Start;
    end loop;
  end Controller;
end Driver;
```

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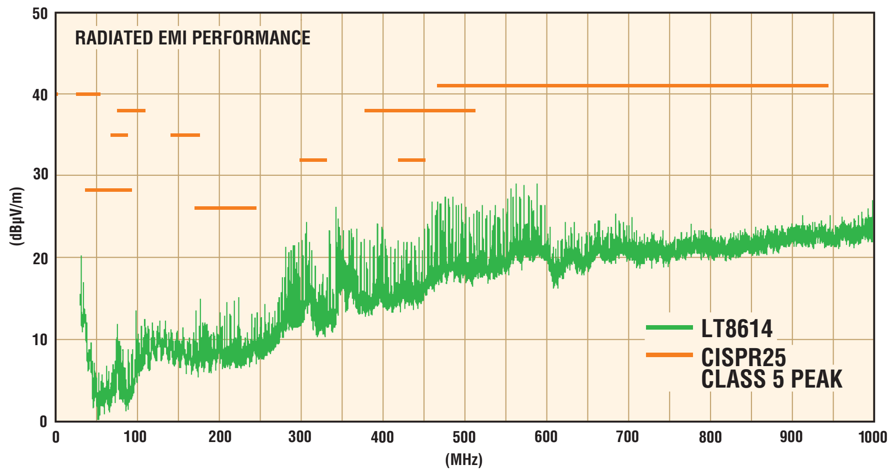

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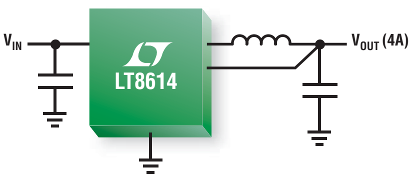
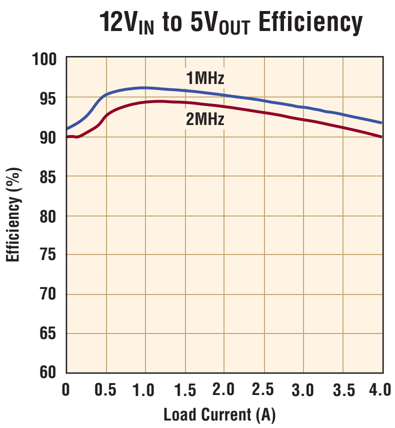
LT8612	42V Input, 6A I_{OUT}, 2.5µA I_Q
LT8614	42V Input, 4A I_{OUT}, 2.5µA I_Q, Ultralow EMC/EMI
LT8640*	42V Input, 6A I_{OUT}, 3µA I_Q, Ultralow EMC/EMI
LT8620	65V Input, 2A I_{OUT}, 2.5µA I_Q
LT8616*	42V Input, Dual Output 2.5A/1.5A, 5µA I_Q

* Future product





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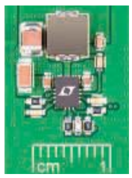

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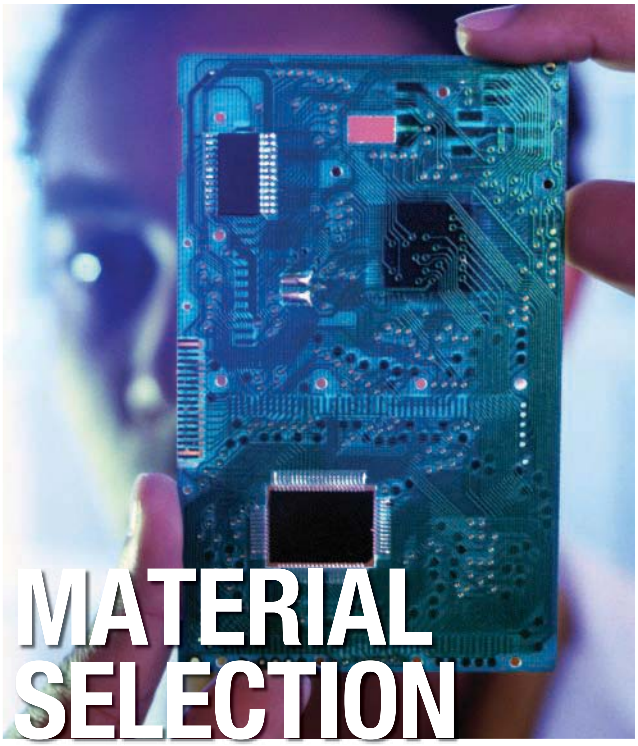

MATERIAL SELECTION Makes a Difference

JACK BROWNE | Technical Contributor

CHOOSING THE BEST MATERIAL FIT FOR AN APPLICATION, PARTICULARLY FOR A PRINTED-CIRCUIT BOARD (PCB), CAN DETERMINE IF A SYSTEM'S PERFORMANCE EXPECTATIONS CAN BE MET.

DEFENSE SYSTEMS rely heavily on different electronic materials, whether they happen to be used for circuits, shielding, or packaging. And whether intended for applications on the ground, at sea, or in the air, demands on these electronic materials can be quite extreme. A hasty or improper choice in electronic materials—such as printed-circuit-board (PCB) materials, electromagnetic (EM) shielding materials, or packaging materials—can lead to system failures, often at the worst times. Knowing key features for these different electronic

(continued on p. S22)

FIBER-OPTIC SYSTEM Supplies 3D Navigation

KVH INDUSTRIES (www.kvh.com) recently introduced an accurate inertial navigation system at the Eurosatory 2104 show in Paris for use on battlefield vehicles. The TACNAV 3D system provides full 3D navigation capabilities and an embedded Global Navigation Satellite System (GNSS) receiver. It can be used as a standalone inertial navigation solution or as the core of an expandable, multi-functional battlefield management system on light, medium, and heavy armored vehicles.

The TACNAV 3D system is fitted with an Iridium transceiver to transmit and receive vehicle position, waypoint, and target location to or from a command center or other vehicles. It can also receive messages from the battlefield management system to pass on to the command center via the Iridium short duration burst message function.

"For military vehicles operating on the modern digital battlefield, this completely modular package is a vital component for effective battlefield management," says Dan Conway, KVH executive vice president for Guidance & Stabilization sales. "It is affordable, lightweight, and easy to integrate with any number of existing vehicles, both turreted and non-turreted. With a built-in communications option, TACNAV 3D is designed for short duration burst messaging, which can make a life-or-death difference to a soldier."

TACNAV 3D builds upon the success of KVH's TACNAV family of products, and incorporates the 1750 IMU, which combines 3 axes of KVH's compact high accuracy DSP-1750 fiber optic gyro (FOG), with 3 axes of high performance MEMS accelerometers. The TACNAV 3D system is designed to provide extremely accurate heading, dead reckoning, navigation, orientation, and 100% situational awareness in GNSS-denied environments.

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CONTRACTS

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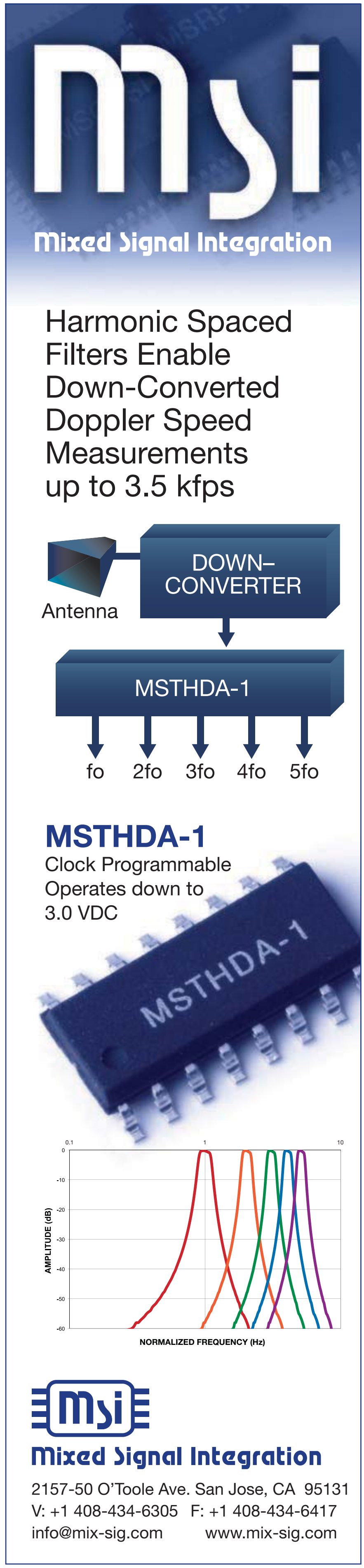


Specifying Well Beyond the Numbers

DEFENSE-RELATED APPLICATIONS have long been guided by challenging requirements, both mechanically and electrically. Whether for a ground-based system or for use in the air, at sea, or even in outer space, the "mil specs" for military systems have defined some rigorous requirements. They have detailed performance levels that must be maintained for a device, a component, or a system over wide temperature ranges—with shock, under vibration, and while encountering various other conditions.

For the most part, military-level specifications are well conceived. The devices and components that are designed and fabricated to meet these requirements generally do not fail when in those "impossible" operating environments, but provide the levels of performance that make radar, electronic-warfare, and other defense-related systems provide results.

Circuit materials and their electrical specifications are considerably different than the specifications that compare the performance levels of many of the components formed from those materials, such as filters. Most readers will probably admit that it has been a while (if ever) since the last time that they were performing measurements on different PCB materials for relative dielectric constant or coefficient of thermal expansion, or some of the other parameters that are only used to characterize PCB materials.

Although many RF/microwave engineers count on the results of such measurements to use those PCB materials in a component, circuit, or system, they could not recreate many of those PCB material measurements. The dielectric materials used in PCBs—as well as the materials used to package and protect a design—must be measured and specified. The accuracy of those measurements is absolutely essential to the next design step, which is using those numbers in a commercial computer-aided-engineering program to simulate a component, circuit, or system.

Fortunately, those who characterize the materials that serve as building blocks for this industry are quite good at what they do, and this editorial at least serves as a note of recognition for the difficult tasks they perform. The consistent quality of their measurements turns into published PCB material specifications that can be trusted and literally built upon. de

JACK BROWNE, *Technical Contributor*

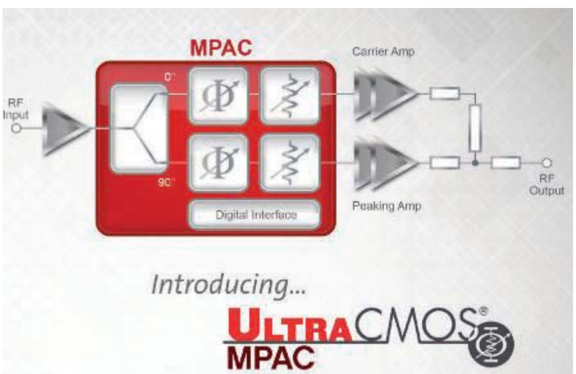
Boeing Recruits RC Receivers

BOEING CO. (www.boeing.com) has targeted Rockwell Collins (www.rockwellcollins.com) to provide the Global Positioning System (GPS) radios for its Combat Survivor Evader Locator (CSEL) radio system. The CSEL system offers search and rescue functions as part of the United States Department of Defense (DoD) Program of Record for Joint Search and Rescue. The radio system provides geoposition and navigation data, over-the-horizon communication relays, line-of-sight voice communications, and beacon capabilities.

"We've built a strong relationship with Boeing over the years and we believe our micro-GPS receivers will provide unmatched capability for the CSEL program," says Mike Jones, vice president and general manager of Communication and Navigation Products for Rockwell Collins. For its part of the program, Rockwell Collins is supplying its next-generation selective-availability anti-spoofing module (SAASM) GPS receiver, which allows decryption of precision GPS coordinates. It is a low-power subsystem that allows for the design of compact and efficient GPS subsystems for military applications around the world. ■

Pressurized Connectors Keep Things Simple

THE pSERIES of pressurized connectors from San-tron (www.santron.com) meets the requirements of the IP68 standard for critical applications using a simplified, three-piece design. The approach eliminates troublesome internal O-rings, gaskets, and silicone greases but still supports high-stability operation through 30 GHz at ±65 psi. Reliability problems with connectors employing internal O-ring seals for environmental control inspired the design of these simpler pressurized and sealed connectors.



As San-tron's director of engineering, Fred Hull, points out: "These RF-enhanced connectors have been specified on a number of programs, including 20 GHz ground-based satellite links, agricultural GPS systems, the London Underground, and space-borne systems." The pSeries pressurized connectors minimize losses and meet MIL-STD 202 Method 212, Condition D test conditions for leakage. They are claimed to provide five times the thermal stability of standard connector insulators based on polytetrafluoroethylene (PTFE) materials. The pressurized connectors are available in a variety of different connector types, including 2.92 mm, 3.5 mm, SMA, TNC, and Type-N series connectors. ■

Monolithic Approach Enhances Doherty Amps

PEREGRINE SEMICONDUCTOR Corp. (www.psemi.com) recently announced a line of monolithic phase and amplitude controllers (MPACs) based on its UltraCMOS semiconductor process that promise to optimize the performance of Doherty power amplifiers. Introduced at the recent 2014 IMS exhibition, the MPACs work through a digital serial peripheral interface (SPI) to enable alignment of the phase and amplitude of a Doherty amplifier's carrier and peaking signal paths.

Each highly integrated MPAC circuit includes two phase shifters, a 90-deg. hybrid splitter, two amplitude controllers, and a digital SPI. Mismatches in these signal paths result in amplifier performance degradation.

The controllers are nominally designed for use in wireless equipment, but can also provide benefits in a wide range of industries employing these power amplifiers.

As Duncan Pilgrim, Peregrine's vice

president of marketing, offers: "Doherty architectures have long been plagued by difficulties in optimizing performance, which leads to higher manufacturing and engineering costs."

He adds: "MPAC provides an ideal solution for this RF challenge and does so monolithically through intelligent integration—something gallium-arsenide (GaAs) technologies could never achieve."

The series of controllers offers amplifier designers an alternative to GaAs

technology approaches for many different applications.

While widely used in the wireless infrastructure industry, Doherty amplifiers require a considerable engineering investment to manually implement and optimize. Any mismatch or misalignment in phase and amplitude between the Doherty architecture's carrier and peaking paths can quickly contribute to higher costs and degradation of the system's overall performance. Even after optimizing with discrete components, the system remains inflexible to manufacturing variances from power amplifier assemblies. ■

Mini-Circuits Recognized by Raytheon

FOR THE fifth consecutive year, leading defense contractor Raytheon Co. (www.raytheon.com) has presented components, test, and subsystem supplier Mini-Circuits (www.minicircuits.com) of Brooklyn, N.Y., with its 4-Star Supplier Excellence Award at Raytheon's annual supplier conference. The award recognizes top supplier performance based on the overall quality of the products and on the on-time delivery of those products throughout each year.

According to Mini-Circuits' founder and president Harvey Kaylie, "This award is the result of a companywide team effort. It is very gratifying to see that our work has consistently merited recognition from Raytheon. We look forward to setting even higher standards next year." Mini-Circuits is a diversified supplier of active and passive RF/microwave components, such as amplifiers, couplers, filters, and power dividers, as well as test equipment and subsystems that can serve many of the functions of defense-related electronic systems (including transmitters and receivers).

Raytheon Co. (see p. S12) is a leading developer and supplier of radar and communications systems and other critical electronic systems for electronic-warfare (EW) and electronic-countermeasures (ECM) applications. The firm has a 92-year history of innovation and development of solutions for wartime and peacetime, including command, control, communications, and intelligence systems. ■

Rockwell Collins, NASA Seek UAS Air Safety

UNMANNED AIRCRAFT systems (UASs) are becoming a growing part of both tactical and peacetime airspaces, to the extent that communications-systems innovator Rockwell Collins (www.rockwellcollins.com) and the National Aeronautics and Space Administration (NASA) have scheduled risk-reduction tests to find ways to enhance the safety of UAS-based missions in U.S. airspace. Testing will be performed starting from the Rockwell Collins hangar at the Eastern Iowa Airport.

According to Troy Brunk, vice president and general manager of Airborne Solutions for Rockwell Collins, "Routine integration of sizable numbers of UASs into the national airspace system is a challenging task." He added that: "This technology will provide the critical communications link for UAS pilots on the ground to safely and securely operate their remotely piloted vehicles in flight even though they are many miles apart."

"Routine integration of sizable numbers of UASs into the national airspace system is a challenging task."

Serving as surrogates for unmanned aerial vehicles (UAVs) during these tests will be a NASA-owned Lockheed S-3 Viking aircraft and a Beechcraft Bonanza aircraft owned by the Operator Performance Laboratory of the University of Iowa. The first part of the test will involve the capability of an unmanned aircraft to hand off communications from one tower to the next. The second part of the test will evaluate how a single tower can communicate to multiple unmanned aircraft. The tests involve the use of experimental waveforms that support multiple communications channels from a single transmitter on the ground.

The project is co-funded by Rockwell Collins and is focusing on a nonproprietary data-link waveform that the firm is planning to release as a public resource. The company is hoping to help both the industry and the Federal Aviation Administration (FAA) to develop an appropriate set of rules and requirements to improve the safety of the growing number of unmanned flights in U.S. national airspace. ■

NuWaves to Supply C-Band Power for NASA

NUWAVES ENGINEERING (www.nuwaves.com) has been awarded a Phase I Small Business Innovation Research contract from NASA to research and develop a linear C-band power amplifier (PA) for unmanned aircraft systems (UASs).

In collaboration with Auriga Microwave (www.aurigamicrowave.com), NuWaves proposed an innovative method for reducing the size, weight, and power of a linear C-band PA for nonpayload command-and-control systems on UAS and unmanned aerial vehicle (UAV) applications; the protocol utilizes monolithic-microwave-integrated-circuit semiconductor devices.

It is hoped that the C-band PA provides adequate transmit power to overcome range limitations in data-link communications systems.

"NuWaves is pleased to team with Auriga Microwave to develop a new state-of-the-art linear C-band power amplifier solution in support of safe national airspace integration of unmanned systems," says Jeff Wells, the firm's president and CEO. "Our team has both the theoretical knowledge and applied expertise necessary to successfully develop and commercialize a new state-of-the-art PA solution for NASA." ■

Northrop Grumman to Counter Roadside IEDs

THE UNITED STATES MARINE CORPS is looking to Northrop Grumman (www.northropgrumman.com) to provide electronic jamming backpack systems to counter the threat of roadside improvised explosive devices (IEDs). The counter radio-controlled IED electronic warfare marine expeditionary unit special operation capable (CREW MEU SOC) contract is aimed at providing backpack systems capable of providing portable electronic jamming of a wide range of IEDs. They are intended to create a protective barrier around a Marine ground combat team and its equipment without disrupting friendly communications systems. The firm-fixed-price, indefinite-delivery, indefinite-quantity, multiple-award contract is $90 million over five years.

The CREW MEU SOC program is managed by the U.S. Naval Sea Systems Command. According to Mike Twyman, sector vice president and general manager, Northrop Grumman Information Systems, "Our troops face the IED threat around the world, and these Marine Expeditionary Units are the ones that go to the most dangerous places at a moment's notice. Northrop Grumman's Freedom 240 dismounted system is lightweight, powerful, and designed to keep up with these hard-fighting Marines." ■

Sotera Wins Prime Spot on DHS EAGLE II Contract

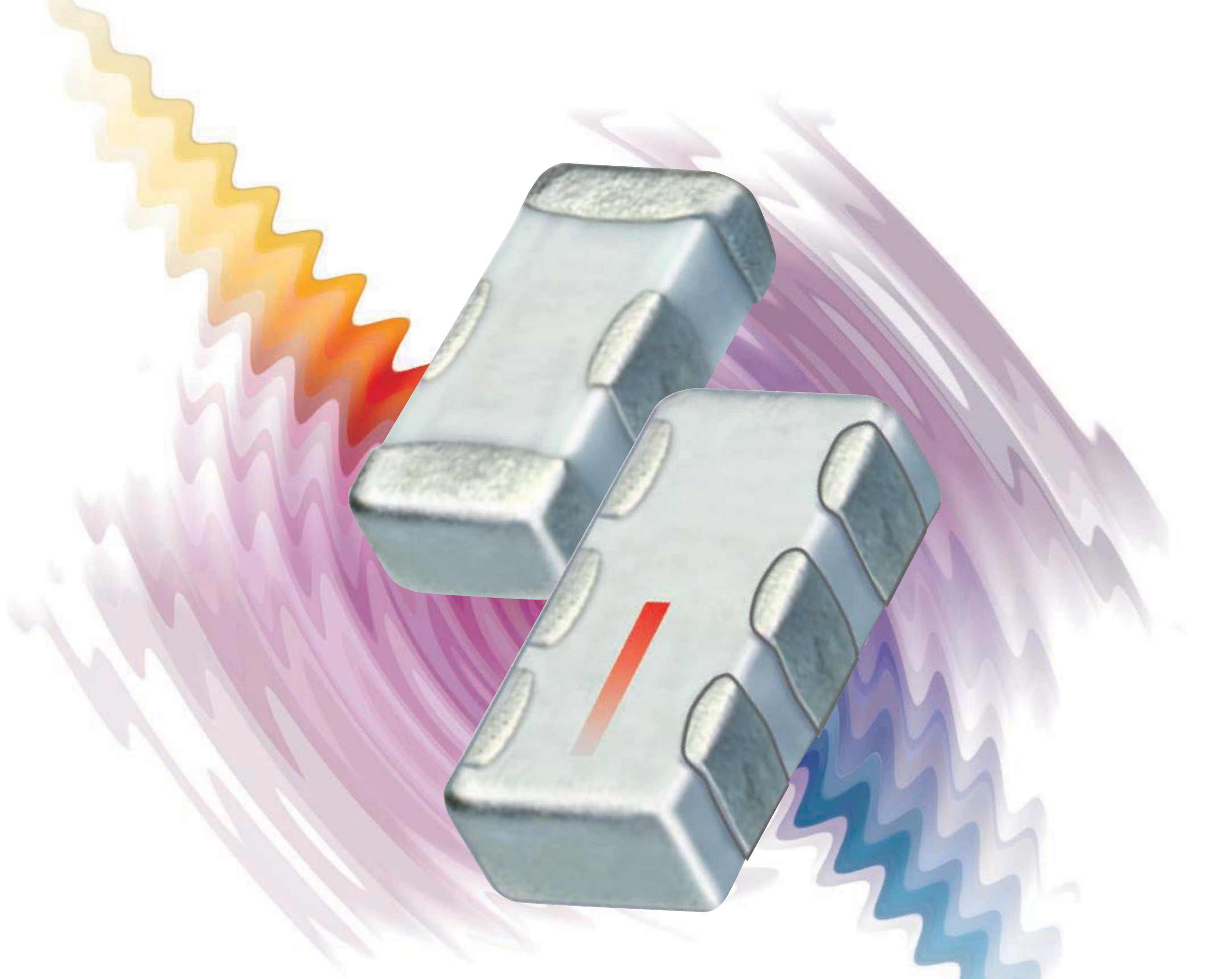
SOTERA DEFENSE SOLUTIONS (www.soteradefense.com) scored big on a contract from the U.S. Department of Homeland Security (DHS), winning a prime position on a sizable contract with the Enterprise Acquisition Gateway for Leading Edge Solutions II (EAGLE II) program. The indefinite-delivery, indefinite-quantity contract is for IT solutions through performance of a wide range of support services, including system design, development, implementation, and integration.

The seven-year deal has a $22-billion ceiling. According to Deb Alderson, president and CEO of Sotera, "This vehicle provides an excellent opportunity for Sotera and our teaming partners to deliver a wide range of mission-critical IT services and products to the DHS by providing increased flexibility over the course of the program." ■

Lockheed Martin Awarded Minuteman Reentry Job

LOCKHEED MARTIN (www.lockheedmartin.com) has been awarded a contract from the U.S. Air Force for sustainment of the reentry subsystem for the Minuteman III intercontinental ballistic missile (ICBM). The contract covers repair, modification, and testing of hardware and software components in the reentry system-reentry vehicle subsystem, as well as related support equipment. The contract—with an initial value of $109 million—is part of the Air Force's Future ICBM Sustainment and Acquisition Construct, which is designed to ensure a reliable Minuteman III weapon system through 2030.

As an example of the contract work, Lockheed Martin has developed a process for refurbishing the 25-year-old arming and fusing assemblies for the MK21 reentry vehicle at a fraction of the cost of producing new units. The procedure replaces or reconditions components for use on the Minuteman III through 2030. ■



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Looking Further with Modern Radar Systems

Radar systems are evolving into multiple-function platforms, some with communications and other capabilities, along with active signal switching and smaller, more efficient antennas.

RADAR TECHNOLOGY has grown a great deal over the last century. The principle of a radar system has not changed—sending out timed, pulsed signals and charting the direction and timing of their return reflections to learn more about what is causing those reflections—but the technology is now enhanced by advances in digital technology, in particular, modern data converters such as analog-to-digital converters and digital-to-analog converters. By digitizing and processing radar return signals, modern radar systems can perform any number of functions in support of different applications, including search, surveillance, target tracking, fire control, and weather monitoring.

By leveraging the signal processing possible with improved analog and digital components, modern radar receivers can increase sensitivity and overcome performance degradation from traditional problems such as clutter. As an example, the U.S. Navy is benefitting from a new multimode maritime surveillance radar on board the MQ-8B Fire Scout (*Fig. 1*), which is an unmanned helicopter developed by Northrop Grumman (www.northropgrumman.com). The improved radar system helps drastically improve the long-range imaging and search capabilities of these unmanned aerial vehicles (UAVs). According to George Vardoulakis, vice president for Medium Range Tactical Systems, Northrop Grumman Aerospace Systems, "This modernized radar complements Fire Scout's other sensors and systems to provide the Navy with increased visibility far beyond the horizon, while collecting vital imaging for maritime operations."

Essentially, Northrop Grumman modified an AN/ZPY-4 multi-mode maritime surveillance radar system from Telephonics Corp. (www.telephonics.com) that is normally used on manned aircraft and adapted it for effective use on the unmanned MQ-8B Fire Scout.

The MQ-8B Vertical Take-Off and Landing Tactical Unmanned Aerial Vehicle is part of the U.S. Navy's Fire Scout radar Rapid Deployment Capability program. On board an MQ-8B, the radar is configured for broad-area intelligence, surveillance, and reconnaissance missions and it is designed for remote control from the ground or at sea by Navy controllers. The MQ-8B has a range of about 110 nautical miles and is available in a larger version, the MQ-8C, with a slightly larger range of about 150 nautical miles and larger payload capacity. Both UAVs are based on a Bell 407 helicopter (www.bellhelicopter.com) certified by the Federal Aviation Administration (www.faa.gov) for such missions.

The Fire Scout provides the Navy with warning signals by means of conventional application of radar technology. But not all applications for radar are conventional, or through the air. The U.S. Army, for example, has been exploring new applications for ground-penetrating-radar (GPR) systems. GPR technology has been used by law-enforcement professionals to find hidden graves, while military professionals have long applied GPR systems for detection of mines, tunnels, and unexploded ordnance. The

1. The advanced maritime surveillance radar system onboard the Fire Scout unmanned aerial vehicle boosts the long-range imaging and search capabilities of these UAVs. (Photo courtesy of Northrop Grumman)

U.S. Army Contracting Command in Alexandria, Va., recently announced a $7.3 million contract to Non-Intrusive Technology (www.niitek.com) to develop a real-time version of the company's VISOR GPR system.

GPR systems usually operate with antennas in contact with the ground but can also operate with air-launched antennas above the ground. Higher frequencies do not penetrate as far through the ground as lower frequencies, but do provide better resolution. Good depth penetration is achieved in ice, where it can reach several hundred meters and is also possible in dry sandy soils. Good GPR depth penetration cannot be achieved in high-conductivity materials such as clay, where the radar pulses are dissipated as heat.

2. Compact radar function modules are enabling modern radar systems to achieve greater functionality in smaller sizes. (Photo courtesy of Mercury Systems.)

In addition to advances in digital technology, GPR systems are leveraging improvements in RF/microwave technology, such as a system developed by US Radar (www.usradar.com). The firm's Quantum Imager is said to be the world's first three-frequency GPR system. The use of three frequencies promises to improve imaging at increased ground penetration depths compared to single- and dual-frequency GPR systems. The firm's earlier GPR systems have developed excellent reputations for their capabilities in locating plastic land mines underground, so it would appear that applications for GPR systems are only beginning to spread.

Perhaps the best-known name in radar, Raytheon Co. (www.raytheon.com), has been exploring multiple capabilities for its radar systems for some time. The firm recently received an $8.5 million base contract from the U.S. Office of Naval Research (ONR) to design the Flexible Distributed Array Radar (FlexDAR), a multiple-mission system capable of numerous functions, including surveillance, communications, and electronic warfare (EW). The company hopes to apply digital beam forming among other techniques to support different applications from a common radar platform. As Paul Ferraro, vice president of Raytheon Integrated Defense Systems Advanced

Technology Programs, explains, "Migrating digital technologies closer to the front end of radars will allow for more reconfigurability and ultimately more flexible radars resulting in game-changing improvements." The FlexDAR system is being developed under ONR's Integrated Topside (InTop) Program to explore the use of novel technologies for the diversification of radar platforms.

Raytheon has long been an innovator in terms of applying new technologies. The firm has been using high-power gallium-nitride (GaN) semiconductor technology for more than 15 years, developing the technology in partnership with the U.S. Defense Advanced Research Projects Agency (DARPA). The company fabricates and studies GaN devices at its Radio Frequency Components Foundry in Andover, Mass. The GaN devices are capable of higher output-power levels than GaAs devices at microwave and even millimeter-wave frequencies, helping to extend the operating ranges of different radar systems and enabling them to function well even with smaller antenna arrays. As Ferraro observes, "We are charged with creating a pipeline of technologies to fuel business growth for years to come. GaN is the biggest winner we've delivered so far."

Somewhat smaller radar-developing companies such as Mercury Systems (www.mrcy.com) are contributing to steady advances in radar technology with their modules and their simulation tools (*Fig. 2*). The company recently received a \$8.8 million order from a leading defense prime contractor for signal-processing subsystems for a shipborne radar application. According to Didier Thibaud, president of Mercury's Commercial Electronics business unit, "Mercury's commitment to providing the most advanced and reliable high-performance signal processing subsystems has ensured our continued participation in this mission-critical defense program." The company's Radar Environmental Simulator tools have also proven to be reliable simulation and test tools for developing and evaluating radar systems (see the following story).

Mercury has been involved for some time in the improvement of synthetic aperture radar (SAR) techniques, such as circular SAR, to enhance the images created by different radar systems from the return signals they receive. Jon Lathrop, market segment director at Mercury, explains: "The processor-intense part of radar is image formation, which requires significant numbers crunching." These are computer- and processor-intensive applications that attempt to create high-resolution images from received return signals. Circular SAR involves flying a radar system around an area of interest and performing repetitive signal capture, collecting enough signal data to build a 3D image of the area based on successive layers of radar data.

Lockheed Martin (www.lockheedmartin.com) has developed its own version of a 3D radar system, its Three Dimensional Expeditionary Long-Range Radar (3DELRR) prototype system. The technology is intended for the U.S. Air Force's next-generation mobile, long-range surveillance and ballistic missile defense radar, providing 3D imaging in place of the existing AN/TPS-75 air surveillance radar system. The U.S. Marines also are evaluating the system as a replacement for its AN/TPS-59 ballistic missile defense radar system.

The system moves the radar beam rather than the antennas, by means of phased-array technology. By controlling the phase relationships of multiple beams from fixed scanning antennas, the system can switch the directions of tracking beams within microseconds. Historically, phased-array radar systems have suffered loss of imaging resolution when attempting to track multiple targets simultaneously. Lockheed Martin's efforts on the new system have included enhancements to allow tracking multiple targets at the same time without losing resolution, with each target followed by a dedicated tracking beam.

> "By leveraging the signal processing possible with improved analog and digital components, modern radar receivers can increase sensitivity and overcome performance degradation from traditional problems such as clutter."

The company is also developing its radar technology for the Space Fence program, meant to alter the way that the U.S. Air Force tracks and identifies objects in space. Space Fence is based on the use of ground-based S-band radars to provide uncued detection, tracking, and measurement of objects in outer space, mainly in low-earth orbit. Space Fence is being designed with specific placement of S-band systems to achieve detection of much smaller microsatellites and debris than current systems. The Space Fence system will allow operators to detect space events and debris that might pose problems for the International Space Station as well as GPS satellites. This new system, which will replace the VHF Fence currently in use since the 1960s for this purpose, is scheduled to come online by 2017.

MULTIFUNCTION RADAR

Major trends in new radar system designs include a steady replacement of multiple radar systems with fewer, multiple-function radar systems, and growing adoption of smaller antenna systems. The growing use of solid-state radar technology has allowed the use of active electronically steered radar arrays that enable multiple-purpose transmit/receive modules and multiple-function radar systems that represent cost savings for customers compared to contracting for multiple single-function radar systems.

Multiple-function radar systems can also save on system weight, space, and power by combining several stand-alone radars into a single system, in the process simplifying operator demands by combining the control of multiple systems into a single GUI. For example, Raytheon has put a great deal of effort in to the improved designs of its Spy 1 and Spy 3 dual-band shipboard radar systems, replacing as many as a dozen existing conventional radar antennas and greatly reducing the shipboard space requirements for radar antennas. Increased computer processing power and the use of digital-signal-processing (DSP) techniques enable these multiple-frequency-band, multiple-function radar systems to effectively separate wideband radar returns into different signal portions for separate applications.

For its part in solid-state radar development, Northrop Grumman has tied compact circuits and efficient devices into its TPS-703 radar system. With its 300-MHz bandwidth from 2.8 to 3.1 GHz, the compact radar system offers in-air tracking capacity of as many as 750 targets and maritime tracking capacity of as many as 500 targets. Based on the firm's active electronically scanned array technology, it has a detection range of 75 nautical miles and employs GPS time synchronization for improved accuracy. Claimed to have a setup time of only 30 minutes with four workers, it is built around air-cooled silicon-germanium (SiGe) active device technology for efficient generation and reception of multiple radar targets. Designed for low-cost supportability and high long-term reliability, the system eases use for its operators with highly visible, flat-panel color liquid-crystal displays.

Cassidian (www.cassidian.com), part of the Eurofighter consortium, has invested a great deal of time and effort into simulation of different radar approaches. The electronic-scanning technology on board the Eurofighter has been found to provide a great deal more efficiency than traditional mechanically tuned radar antennas. In fact, comparison studies of the two approaches have indicated that an e-scan radar onboard the Eurofighter can perform several tasks practically simultaneously. The transmit energy from the Eurofighter's radar system does not originate from a main transmitter but is produced by more than 1000 transmit/receive modules based on technology pioneered by Cassidian in Europe. de

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LZY-2+	500-1000	46	32	38	2195
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• ZHL-50W-52	50-500	50	40	63	1395
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Listed performance data typical, see minicircuits.com for more details.

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SIMULATORS
Help Train and Save

Simulators provide excellent starting points for the design and development of many different electronic-defense systems, including electronic-warfare and radar systems.

SIMULATORS FOR defense-based applications come in many forms and for many purposes. In many cases, they are quite similar in function to the systems they are meant to simulate, such as radar and electronic-warfare (EW) systems. With such similarities, many simulators make excellent training tools for soldiers needing to get a hands-on feel of a particular system. Of course, given the complexity of the systems they represent or exercise, these simulators are remarkable designs in themselves, with performance levels that can often reveal whether the radar or EW system they are simulating can handle the many variables waiting in the real world.

The Mercury Defense Systems (MDS) business unit of Mercury Systems (www.mc.com) has exercised a wide range of radar sensors with its Radar Environmental Simulator (RES) systems. In addition to producing the type of complex radar return signals needed to explore the capabilities of different fire-control, guidance, imaging, and surveillance radar systems, RES systems *(Fig. 1)* have been used to exercise EW and signal-intelligence (SIGINT) by means of a wide range of quantitative measurements. RES systems offer a low-cost alternative to full field trials for different radar systems, allowing them to be evaluated within secure and controlled environments.

RES systems are essentially active two-way transmit/receive (T/R) radar arrays based on digital-radio-frequency-memory (DRFM) radio architectures. They receive radar signals, digitize them, add targets, clutter, noise, and other environmental effects, and transmit back a low-latency signal for a system under test. The RES systems offer a great deal of test flexibility, and can be applied to production lines as well as to R&D applications. The system is supported by a modular Open System Architecture (OSA) so that its data and results remain exportable to other systems and affordable.

Some relatively large companies are involved in developing radar systems, and some develop simulators for use with their own radar systems, such as Rockwell Collins (www.rockwellcollins.com) and its Radar Simulation System (RSS). The firm's RSS has been used for a number of different airborne embedded training applications, with these simulators and their software integrated within a target aircraft to enhance the training value of each flight hour. The RSS features realistic environmental models of what a fighter pilot might face, including software representations of air-to-air and air-to-ground radar modes. The RSS has been used in simulations of fire-control radar systems as well as for search/navigation applications. In the area of simulators, the firm is also well known for its Joint Threat Emitter system, which is a mobile air defense threat simulator that can recreate the radar signals of surface-to-air and antiaircraft artillery radar systems for training and testing.

Any review of radar simulation tools would be incomplete without highlighting Raytheon Co. (www.raytheon.com) and the Raytheon Air and Missile Simulation (RAMS) tools. These software-based simulators *(Fig. 2)* employ collections of threat models, radar operations, battle management, and other applicable functions in a plug-and-play approach to training. The RAMS systems are modular in nature, which allows them to grow in complexity as the systems they are simulating are evolving. By changing modules and models, the RAMS systems can support simulations from early evaluations of design concepts through system-level, end-to-end performance assessments.

In terms of software, most of the RAMS system is implemented in Java, which is well suited for the modular architecture, although other programming languages are adopted where appropriate. For example, some detailed signal-processing routines are written in C for enhanced speed while some are implemented in Compute United Device Architecture (CUDA) code to make use of graphical processing units (GPUs) for additional speed. Legacy algorithms that might have been written in C, C++, or Fortran code can be reused by writing a Java wrapper around the legacy code for effective operation within the RAMS simulation infrastructure. The RAMS platform can also perform multithreading, running multiple simulation modules simultaneously on a multiprocessor computer platform to boost the execution speed.

1. The Radar Environmental Simulator systems can recreate the complex signals found in a wide range of different radar platforms, including fire-control, guidance, imaging, and surveillance radar systems. (Photo courtesy of the Mercury Defense Systems business unit of Mercury Systems.)

But RAMS is just one example of Raytheon's simulation capability. Its Communication System Engineering Toolset (COMSET) simulation environment is a powerful tool for creating complex RF/microwave signal environments. The COMSET simulation system, which is based on the MATLAB mathematical software from MathWorks (www.mathworks.com), is well suited for evaluating the interoperability performance of RF/microwave communications systems in dense and complex spectral environments. For example, the COMSET tools can predict the effectiveness of jammers on different targets and the expected performance levels of RF/microwave communications systems under a wide range of signal and operating conditions.

Many modern simulators address EW functions and platforms, some of these from quite sizable suppliers, such as the Combat Electromagnetic Environment SIMulator (CEESIM) from Northrop Grumman (www.northropgrumman.com). Developed by the company's Amherst Systems branch, CEESIM generates complex electromagnetic environments for direct-injection or free-space radiation into EW systems for testing. CEESIM's high-fidelity intrapulse modulation capability allows the simulation of a wide range of EW and communication, navigation, and identification signal environments with complex modulation and pulsed signal characteristics.

This is an elaborate simulation system that can perform complex pulse shaping, digital/analog signal modeling, control as many as 128 RF/microwave sources, and recreate spectral environments with more than 8000 emitters. CEESIM's advanced capabilities represent a cost-effective means of evaluating the performance of many different EW systems and their components. The system can recreate the type of signal effects faced by EW, ECM, and ESM receivers, including amplitude angle of arrival, time difference of arrival, and frequency difference of arrival effects using single-sideband, double-sideband AM and FM signals.

Northrop Grumman's Advanced Pulse Generation (APG) simulation technology is based on the use of high-speed direct-digital-synthesizer signal sources to provide high-speed frequency agility, tight control of pulsed output waveforms, and generation of advanced modulation formats. The practical integration of DDS technology has enabled

2. The Raytheon Air and Missile Simulation (RAMS) tools pack threat models and radar functionality into software-based simulators that are excellent for training. (Photo courtesy of Raytheon Co.)

the company to reduce the parts count in these APG-based simulation systems and, in the process, reduce the costs and increase the reliability of these systems.

The APG simulation technology is readily available to the CEESIM systems as an upgrade. It has already been integrated into various CEESIM system designs with the company's advanced angle-of-arrival modeling and sophisticated graphical-user-interface control capabilities to provide extremely practical and effective EW simulation tools.

For those willing to experiment with freeware to learn more about the nature of radar simulation software, the Flexible Extensible Radar Simulator (FERS) developed at the University of Cape Town, South Africa (www.uct.ac.za) is available free of charge from several websites, including SourceForge (www.sourceforge.net) and WinSite (www.winsite.com). The FERS software is written for use on a personal computer and supports both multistatic and monostatic radar systems and pulsed pulsed and continuous-wave signal formats.

Simulators are important tools for defense-based equipment developers, no matter which types of systems they are targeting. The great numbers of variables in the spectral environments for different types of EW, radar, and other types of tactical receivers often makes a simulator the most cost-effective approach to system design and then testing. Models can be saved and reused as needed, and modified to meet future needs. de


US ARMY photo

(continued from p. S1)
materials can help a great deal at the system-design level and contribute to the effective operating lifetime of the systems that rely upon them.

Choosing a PCB material for a defense-based application can be influenced by a variety of needs, with high reliability and consistent performance usually fairly standard requirements. For example, ground-based applications may be hindered by water or moisture absorption while minimizing weight may be a more important need for PCBs heading for satellites or missile-guidance systems.

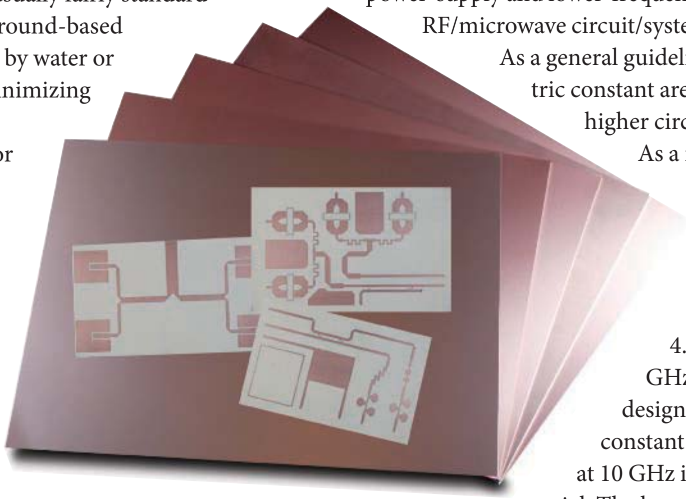
No one circuit material is ideal for all applications. Some materials may be better for portable use while others have traits that serve better in high-power circuits. Matching circuit materials to the requirements of different applications is a matter of finding the right combination of characteristics that will deliver the best performance and reliability—hopefully for the lowest cost.

Most PCB material selection starts with the material's relative dielectric constant, which is the ratio of the dielectric material's permittivity to the permittivity of a vacuum or air. It's an important circuit-design parameter that will be used in computer-aided-engineering (CAE) circuit design software to determine circuit dimensions for targeted circuit impedances, such as 50 Ω. A circuit material's relative dielectric constant is usually specified through the thickness (z-axis) of the material and at a standard test frequency of 10 GHz.

Perhaps as important as the value of the dielectric constant is its consistency across the PCB material. Especially for some larger circuit designs, such as antennas, variations in dielectric constant can result in changes of characteristic impedance for transmission lines. This can make it difficult to achieve consistent amplitude and phase responses across a wide temperature range.

Low-cost FR-4 circuit laminates have often served as "ground zero" for less-critical circuit designs; while low in cost, they can provide serviceable and respectable performance through frequencies of about 3 GHz (and even higher). These fiberglass-reinforced epoxy-based circuit materials have a typical relative dielectric constant of 4.8 in the z-direction at 10 GHz, with good strength-to-weight ratio and low water absorption. Unfortunately, FR-4 tends to suffer greater losses at higher (microwave) frequencies than circuit materials with lower dielectric constants and loss tangents, so copper-clad FR-4 circuit laminates tend to be used more for power-supply and lower-frequency circuit applications in RF/microwave circuit/system designs.

As a general guideline, lower values of dielectric constant are typically associated with higher circuit operating frequencies. As a result, circuit designers working at microwave frequencies and beyond typically look for PCB materials with dielectric constants of less than 4.8 in the z-direction at 10 GHz for RF/microwave circuit designs, often with dielectric-constant values around 3.0 or less at 10 GHz in the z-axis of the material. The lower the effective dielectric constant for a PCB material, the higher in operating frequency it can usually be used without unacceptable losses.



RT/duroid 6035HTC laminates exhibit extremely high thermal conductivity compared to standard PCB materials, permitting them to handle extremely high power levels. (Photo courtesy of Rogers Corp.)

Dielectric loss is one of the components of insertion loss for an RF/microwave circuit and it is usually related to the dissipation factor of the PCB material. This particular loss is due directly to the substrate material and not the conductor. The conductor material, such as copper, will also contribute to the insertion loss from a PCB, although often the roughness of a conductor can have as much to do with the loss of the PCB as the type of conductive material. Dielectric loss can be a concern for a PCB material when circuit losses must be minimized. Heat produced by circuit losses may also be a concern at higher signal levels.

Polytetrafluoroethylene (PTFE) has long been favored for use in RF/microwave PCBs for its low loss and low dielectric constant. Physically, it is considered a "soft" substrate and benefits from structural reinforcement. Many PTFE suppliers strengthen their PTFE-based PCBs with additional filler materials, such as woven fiberglass, glass fiber, or ceramic materials. Such fillers help the mechanical strength by controlling the PTFE expansion and contraction in a PCB's x and y dimensions (its length and width).

An important parameter for PTFE-based and other types of PCB materials is coefficient of thermal expansion (CTE). This is a measure of a material's physical change in length for a given change in temperature. It is measured and specified in all three dimensions for a PCB in percent or in units of ppm/°C. The goal is usually for the circuit-material's x and y (length and width) dimensions to have the same CTE values as the conductive metal, such as the 17 ppm/°C CTE of copper.

Although it is physically the smallest of a PCB's three dimensions, the material's z-axis can still suffer from the effects of material expansion and contraction with temperature and will also have a specified value for CTE. When plated through holes (PTHs) are formed through a PCB material, by drilling through the dielectric material and metal-plating the holes, conductive paths are formed from the circuit layer to the ground plane. Ideally, the CTE of the dielectric material in the z-direction would be minimal, especially when PTHs are used in the interconnection of different circuit layers in a multilayer assembly.

Significantly different CTE values for the metal plating and dielectric material can result in stress as the materials expand and contract with temperature. They may survive numerous cycles of expansion and contraction, but fatigue can affect the PTHs over time and cause loss of some of the ground connections. Changes in temperature take place regularly in hostile operating environments. However, they also occur due to normal PCB processing when creating and manufacturing a circuit, soldering components and connections, and other production steps.

HANDLING HEAT

Since power and temperature are two variables that will inevitably impact PCBs in a defense-related system, another important parameter to consider when specifying materials for PCBs is thermal conductivity. It describes how power (in watts) is converted to temperature (in °K) across some physical distance through the z-axis of the material (W/m/K). The values of thermal conductivity differ quite widely across the industry, perhaps as widely as the values for effective dielectric constant, reflecting on choices of PCB materials with many different power-handling capabilities.

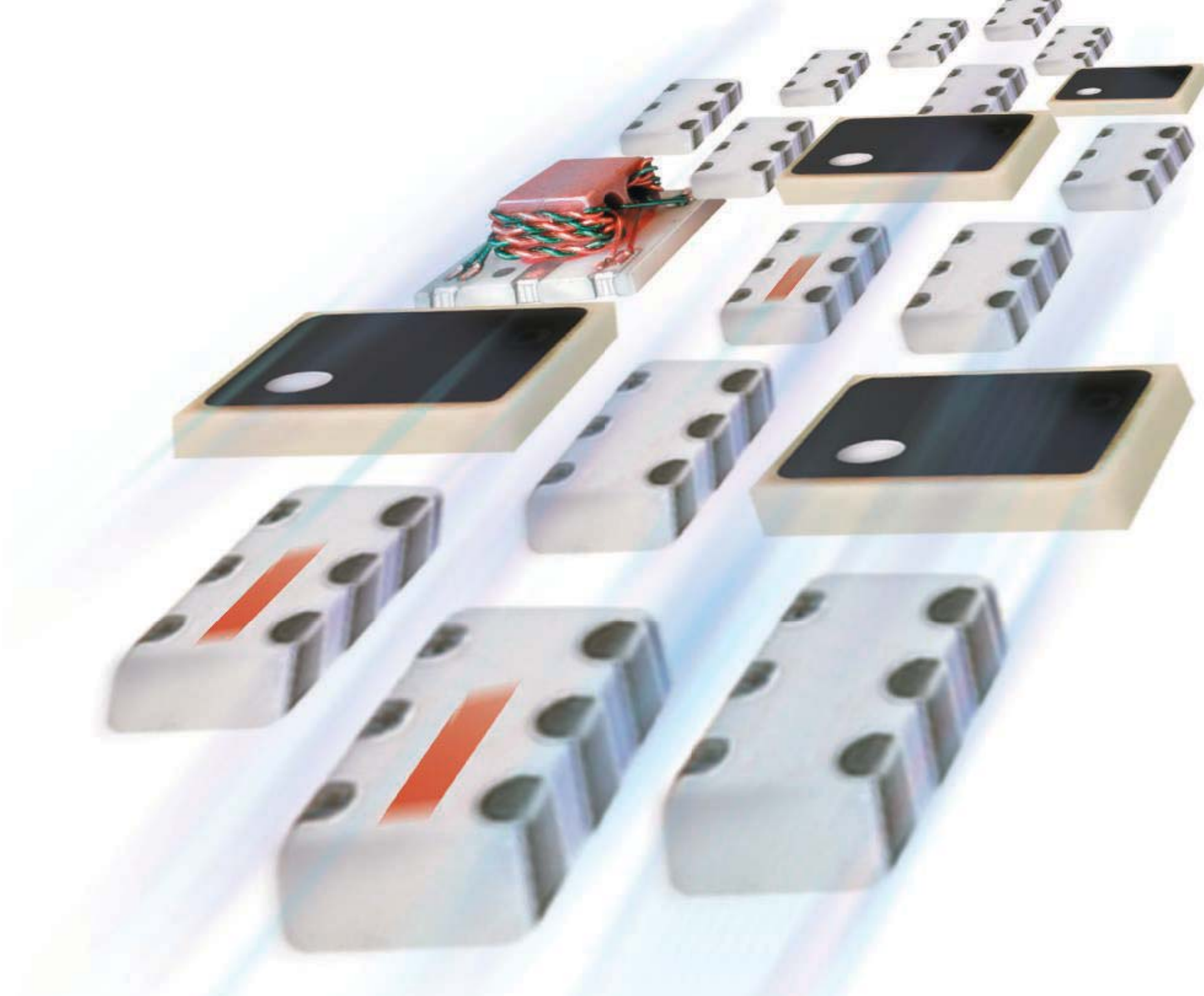
As an example, one of the PCB materials offered by supplier Rogers Corp. (www.rogerscorp.com), RT/duroid 5880 material, has been used in numerous communications, EW, and radar circuit designs for several years with good reliability results. It has a very low effective dielectric constant of 1.96 in the z-axis at 10 GHz for working with circuits through microwave and even millimeter-wave frequencies. It is a PTFE composite material reinforced with glass microfibers. The microfibers are randomly oriented to enhance the benefits of fiber reinforcement. This low dielectric constant makes this material a good choice for a wide range of broadband and high-frequency applications. However, it has a relatively low thermal conductivity of typically 0.20 W/m/K in the z-axis when measured at +80°C. This essentially means that only relatively low power levels are required to raise the temperature of the PCB material and that heat may become a concern at high-enough signal levels.

RT/duroid 5880 laminates are easily cut, sheared, and machined to shape, and resistant to all solvents and reagents normally used in etching printed circuits or plating edges and holes. RT/duroid 5870 and 5880 laminates have the lowest electrical loss of any reinforced PTFE material, boast low moisture absorption, are isotropic, and have uniform electrical properties over frequency.

In contrast, the same company's RT/duroid 6035HTC laminates have a much higher effective dielectric constant of 3.50 at 10 GHz through the z-axis of the material, which means that these laminates may not be as ideal or as low-loss in operation at higher microwave and millimeter-wave frequencies. But the RT/duroid 6035HTC laminates offer thermal conductivity of 1.44 W/m/K, which is more than twice the thermal conductivity capability of other circuit materials in the same company's RT/duroid 6000 product line. The RT/duroid 6035HTC laminates are ceramic-filled PTFE composite materials with excellent drillability for fashioning PTHs and multilayer circuits. In effect, they will exhibit lower operating temperatures for higher-power applications than the PCB materials with considerably lower thermal conductivity specifications.

MAKING THEM FIT

For military applications, a wide range of circuit-material suppliers are available, some with their own materials and some representing material manufacturers and providing additional services for producing and testing PCBs in various quantities. As an example, Amitron Corp. (www.amitroncorp.com) has been a supplier



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> "No one circuit material is ideal for all applications. Some materials may be better for portable use while others have traits that serve better in high-power circuits. Matching materials to different applications involves finding the right combination of characteristics."

of various types of PCBs, including aluminum- and copper-clad and single- and double-sided circuit boards, for aerospace, automotive consumer, medical, and military electronic applications.

Each application is driven by a set of desirable traits, such as light weight in some applications and high-power handling and good thermal dissipation in others. For defense-related circuit applications, it can be helpful to know which essential performance parameters should be compared when sorting through PCB materials, and how the different data-sheet specifications and parameters translate into different levels of performance and reliability.

Fortunately, circuit designers working with different PCB materials and perhaps in need of outside circuit fabricators can find a number of useful, low-cost tools to help them in the design and circuit-material-selection process. For example, Advanced Circuits (www.4pcb.com) offers PCB Artist, a free layout software for the PC with a library of more than 270,000 circuit elements and parts. Designers using the software and opening an account can receive an instant price quote when submitting a PCB layout design.

The software provides a list of circuit-design guidelines to minimize the cost of PCB fabrication, including guidance on the positioning of components on a board, the spacing between components, and the spacing between components and the edge of the PCB. The firm is a quick-turn PCB manufacturer for both prototype and production quantities. (In addition to the software, a free tutorial on using PCB Art-

MANAGING MATERIALS FOR EMI SHIELDING

ELECTRONIC MATERIALS IN defense systems serve many purposes, from housing a variety of functions to channeling different circuits. One of the more critical functions that is often overlooked until the second pass through a system design review is the electromagnetic-interference (EMI) and radio-frequency-interference (RFI) shielding. Because of the complex blend of analog, RF/microwave, and digital signals that can be found in many military systems, addition of suitable EMI/RFI shielding and shielding materials is often the only way to ensure proper operation of a defense-related system, since sensitive receivers may be positioned in close proximity to robust transmitters. EMI/RFI shielding materials can be quite effective in these circumstances, providing component-level isolation and minimizing crosstalk without having to totally redesign a system.

EMI/RFI shielding materials are often not very different in composition than the circuit materials they are protecting. The GS2100 Series of EMI shielding materials from W. L. Gore & Associates (www.gore.com), for example, which are approved for space-flight and military applications, consist of a carbon-filled PTFE matrix with a polyethylene terephthalate (PET) carrier film and a conductive pressure-sensitive adhesive material to bind together the PTFE and the PET layers. These EMI shielding materials are typically used to improve the shielding effectiveness (SE) of military and space systems by mounting to enclosures and even by wrapping around coaxial cables. The SE specification for materials with the adhesive is better than 45 dB at 1 GHz. These GS2100 EMI shielding materials, as well as many of the firm's EMI shielding gaskets and materials, are available in a variety of thicknesses, typically 0.25 to 2.00 mm in thickness.

SHIELDING SENSE

Selecting a shielding material for a particular design is a matter of combining a healthy number of mechanical and electrical requirements. For example, an EMI shielding material may be comprised of a conductive foam that can maintain full contact with a mating surface even with compression or movement of the mating surface, but can also lend mechanical strength to a structure. Minimizing gaps in the EMI shielding approach for a design will depend on the size and expenses of the EMI gasket materials.

The GS2100 EMI gasket materials undergo a great many different tests for use in military and space applications, including testing to DESC-92017 standards for EMI/RFI shielding, to MIL-G-8352 for EMI/RFI shielding, to MIL-STD-810 for environmental compatibility, and to MIL-STD-285 for attenuation measurements for use in enclosures. The EMI gasketing materials are also evaluated by Gore for British specifications and European Space Agency specifications and standards, and for performance against a wide range of conditions, including outgassing, corrosion resistance, electromagnetic pulse survivability, vibration resistance, and water seal.

This is just one of the firm's EMI shielding and gasketing materials that is applied for controlling EMI and RFI leakage and interference in military and aerospace circuit and system designs, but it has been engineered and testing with a great deal of attenation for many difist software is available from www.4pcb.com/media/PCBArtistLibraryTutorial.pdf.)

Many high-quality manufacturers offer circuit materials for designers seeking to start at the board level, including Arlon Materials for Electronics (www.arlon-med.com) and the Advanced Dielectric Division of Taconic Plastics (www.4taconic.com). For those who may prefer to transmit CAE files and let another company fabricate the circuits, a number of firms offer PCB manufacturing and test services, and can even help with custom design of circuit boards, including Advance Circuit Technology (www.advcircuit.com), Epec Engineered Technologies (www.epectec.com), E-TekNet (www.e-teknet.com), Just In Time Manufacturing Corp. (www.justintimemanufacturing.com), NexLogic (www.nexlogic.com), Printed Circuits (www.printedcircuits.com), Rush PCB (www.rushpcb.com), SF Circuits (www.sfcircuits.com), and Viasystems (www.viasystems.com). Many of these firms offer full prototyping and testing services for creating PCBs from computer files.

As for other types of materials, including EMI/RFI shielding, the list grows even longer and merits a separate, dedicated report (perhaps in the next issue). EMI/RFI shielding is an obvious concern for military applications, and must be treated at the system level, rather than at the component level, since every interface and interconnection is a potential weak point.

In addition to traditional EMI and electromagnetic-compatibility testing, the U.S. Army Research Laboratory (ARL; www.army.mil) is evaluating what it refers to as electromagnetic vulnerability (EMV), which is the possible degradation in an electronic system's performance or even its capability to perform its designed function as a result of exposure to a certain level of EM radiation. Testing is being performed in the ARL's Electromagnetic Vulnerability Assessment Facility (EMVAF) and covering a full spectrum of EM energy threats on the battlefield and in operations other than war. This testing determines the weaknesses of different weapon systems against RF directed-energy weapons, EW jamming, and unintentional interference.

Located at the White Sands Missile Range in New Mexico, the EMVAF houses two double-shielded anechoic chambers, each capable of precisely controlled measurements and with better than 100-dB isolation between shielded layers. The main seam-welded-steel shielded anechoic chamber is a Faraday cage that measures 100 × 70 × 40 ft. It includes a turntable capable of supporting test vehicles to 100 tons (the largest of its type in the U.S. Army). It is also well surrounded and shielded by radar absorbing material so that EM energy produced outside the chamber remains outside the chamber and EM energy generated within the shielded chamber can be precisely measured without reflections from the walls, and without interference from the outside world. de

ferent applications. The GS2100 materials are available with adhesives for an operating temperature range of –40 to +95°C and without adhesives for an operating temperature range of –200 to +200°C.

In addition to the GS2100 Series materials, the company's GS8000, GS52000 Series, and GS500 Series materials provide various levels of SE performance at low frequencies through 40 GHz. The shielding materials range from the moderately soft materials in the GS2100 line to thermally conductive materials in the GS5000 series to the soft conductive foam of the GS8000 series materials to provide shielding for everything from plastic housings to full-metal enclosures, as peel-and-stick gasket materials, to die-cut gaskets, to snap-together plated plastic shields.

Also, the company developed a unique board-level shielding solution known as the GORE snapSHOT EMI shields which consist of a metallized plastic material that can be thermoformed to almost any design. It features a patented attachment mechanism which employs individual solder spheres as snap-together mechanisms. The shield is metallized with tin on the outside, for reduced space between components and reduced thickness when compared to other shielding solutions for similar SE performance. For a thickness of 0.125 mm, this shielding material offers SE performance of typically 75 dB at microwave frequencies. It meets many rigorous requirements for mechanical shock and vibration, including MIL-STD-883CA for thermal shock, and can provide reasonable SE performance at frequencies to 7.5 GHz and beyond.

Fractional-N PLL Quiets 14-GHz VCOs

MODEL LMX2492 is a 14-GHz fractional-N phase-locked loop (PLL) with excellent noise performance and built-in advanced modulation. It supports a wide operating-frequency range of 500 MHz to 14 GHz. The unit is available in a variety of different grades for use in automotive, industrial, and military applications. Supplied in a 24-lead 4-×-4 mm WQFN housing, it supports to a +5.25-VDC charge pump and can operate from a single +3.3-VDC supply. The PLL produces simplified two-level frequency-shift-keying (FSK) and phase-shift-keying (PSK) modulation. It offers a phase detector frequency of 200 MHz and low PLL phase noise to generate low-noise output signals. A model LMX2492EVM evaluation module is available to help designers quickly understand the functionality and optimum use of the PLL. In addition, engineers can make use of TI's WEBENCH Clock Architect, which allows the simulation of phase noise and jitter to optimize a specific solution.

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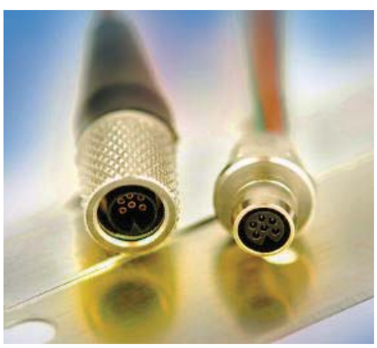
Connectors Trim Weight On UAVs

THE LATEST line of Metal Nano-Connectors from Omnetics Connector Corp. (www.omnetics.com) features high-density, multiple-position connectors with break-away or threaded metal housings, intended to form a positive lock and solid environmental seal. The connectors are designed to meet or exceed military specifications and are ideal for mission-critical applications where size and weight are important, such as in unmanned aerial vehicles (UAVs). They are constructed to handle operating temperatures exceeding +200°C and can be secured with locking screws to survive harsh UAV landings. Board-mounted versions of the connectors mate with prewired connector/cables for instrument wiring. The connectors are available in four shell sizes: 6, 11, 16, and 28 positions arranged on a 0.025-in. (0.64 mm) pitch; they can handle 1 A current per contact and be qualified to IP-68 waterproofing specifications.



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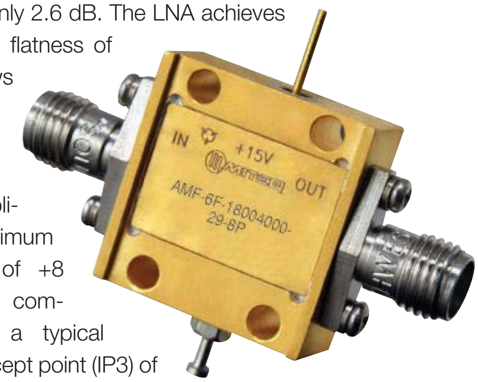
Amplifier Gains 18 To 40 GHz

MODEL AMF-6F-18004000-29-8P is a wideband, low-noise amplifier (LNA) for applications from 18 to 40 GHz. Across that frequency range, it generates more than 35-dB gain, with a maximum noise figure of 2.9 dB and a typical noise figure of only 2.6 dB. The LNA achieves worst-case gain flatness of ±3 dB and draws 275 mA current from a single +15-VDC supply. The amplifier provides minimum output power of +8 dBm at 1-dB compression, with a typical third-order intercept point (IP3) of +16 dBm. Supplied in a compact housing measuring only 0.38 × 0.75 in. with field-replaceable 2.93-mm connectors, the amplifier operates at temperatures from –40 to +75°C. Hermetic and RoHS-compliant versions are also available.



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A 6-B DIGITAL attenuator has been developed for controlling signals levels in broadband circuits and systems. Available in chip form as model MAAD-011021-DIE or in a 3-mm PQFN surface-mount package as model MAAD-011021, the attenuator operates from DC to 40 GHz in chip form and from DC to 30 GHz in the package. It is suitable for commercial military radios, radar systems, satellite-communications (satcom) systems, and test equipment. It provides as much as 31.5-dB attenuation in 0.5-dB steps with typically less than ±0.5-dB attenuation bit error. The digital attenuator integrates TTL digital control and is fully matched across the bandwidth of operation, offering switching speed of typically 45 ns with 4-deg. or less phase variations across the bandwidth.

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MODEL TGA2216-SM is a gallium-nitride (GaN) power amplifier (PA) that can handle commercial and military applications from 100 MHz to 3 GHz. It provides 10-W saturated output power from a 32-lead, 5-×-5 mm ceramic QFN housing when fed with a 0.5-W (+27-dBm) input signal. With large-signal gain of better than 13 dB and small-signal gain of 21 dB, the GaN amplifier operates with power-added efficiency of 50% at midband. It exhibits input return loss of better than 8 dB and output return loss of better than 11 dB. The amplifier draws 360 mA current from a +40-VDC supply. The amplifier is lead free and RoHS compliant.

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A NEW DATA gateway has been developed which provides a secure and simple means of exchanging tactical and positional information on the battlefield in real time. The gateway technology allows military forces using different communications networks to link and perform messaging in a secure manner. Developed by Mutualink, the Data Gateway requires less than five minutes of setup time. It enables unicast or multicast exchange of classified information between coalition armed forces. It is flexible enough to allow an end-user to transport classified information over almost any transport format—whether wired or wireless—such as Ethernet, satellite communications, or WiFi communications networks. For added security, it does not require a central server or switch. The system is currently being evaluated by the United States Marine Corps and NATO. The network can bidirectionally exchange messages between NATO Standard Agreement (STANAG) 4677 Joint Dismounted Soldier System (JDSS) XML (Extensible Markup Language) format; the Joint Variable Message Format (JVMF); and others.

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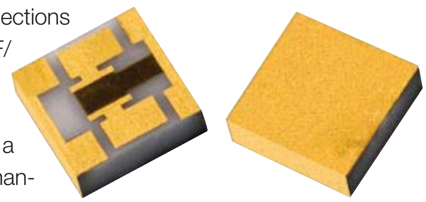
Attenuator Pads Are Steady To 50 GHz

FIXED ATTENUATOR pads from SemiGen can be produced in specific values for specialized applications. These attenuators make use of thin-film technology to achieve tightly controlled attenuation values from DC to 50 GHz. The attenuator pads have side wraps for surface-mount-technology (SMT) installations while top side contacts for input and output connections make them ideal for RF/microwave applications. The attenuation pads are available in a wide range of power-handling options, including medium- and high-power versions through 5 W CW power. Return loss is better than 18 dB through 14 GHz and better than 16 dB from 15 to 50 GHz. The attenuators exhibit a thermal coefficient of resistance (TCR) of less than 100 ppm and measure just 0.030 × 0.030 in. for most designs.



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Radio Tester Shoots For Analog Radios

THE R&S CMA180 radio test set was designed to simplify analog radio production and maintenance. It is well equipped for evaluating the performance of analog radios operating from 100 kHz to 3 GHz. The test set can generate signals to bandwidths of 20 MHz and process input power levels as high as 100 W for continuous power and 150 W for peak power levels. It includes an arbitrary waveform generator for producing complex test signals and includes a large touchscreen for ease of programming. With its functions and programmability, this tester is a good fit for evaluating software-defined radios (SDRs). Linear power sensors are available as options for use with the radio test set.

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