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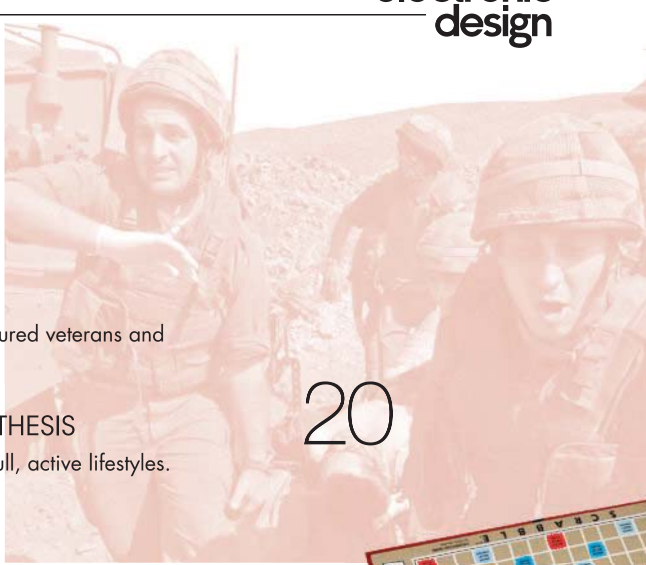

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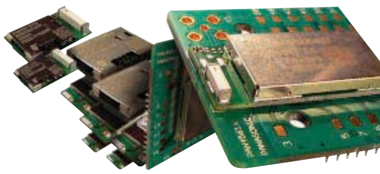

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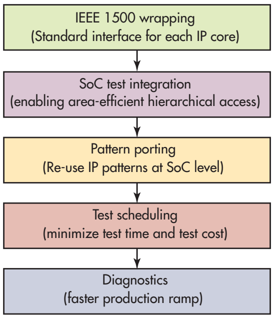

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EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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

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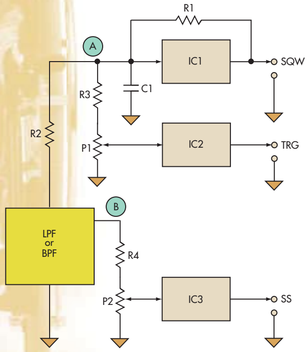

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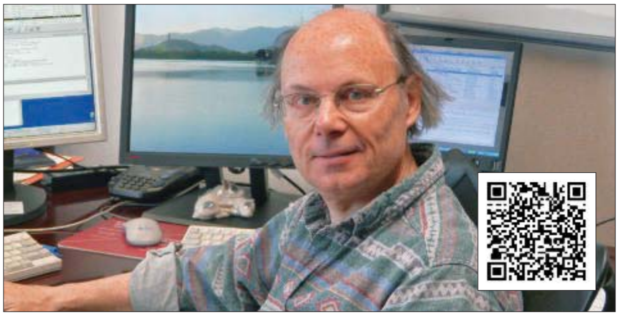
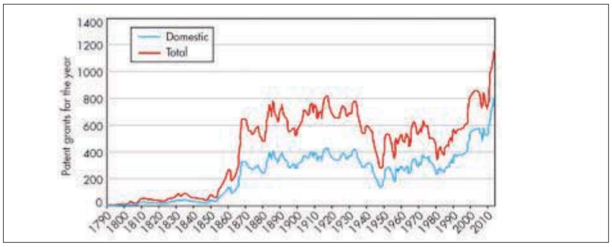


BJARNE STROUSTRUP TALKS ABOUT C++14

A Q&A with Bjarne Stroustrup, the well-known creator of C++ and a 2013 inductee to the Electronic Design Engineering Hall of Fame in 2013.



MISUNDERSTANDING THE PATENT SYSTEM

Based on misconceptions about patents, bad decisions are being made.

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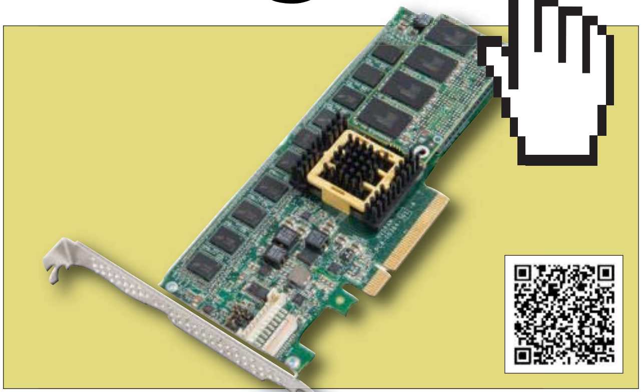

FLASHTEC DRIVES COMBINE FLASH AND DRAM

PMC's Flashtec PMC drives add another high-speed layer to the storage hierarchy. It combines DRAM and flash onto to a PCI Express adapter.

E3'S PIEP SUPPORTS MODULAR DEVELOPMENT

E3 Embedded Systems turns to Kickstarter to see if the embedded community can take advantage of a modular prototyping system.

WATCHING ROBOTS GIVING A HAND

Robots are showing up in more places from bomb disposal to drones. Getting robots to take on more tasks often requires using a better hand.

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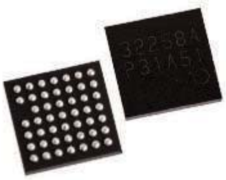

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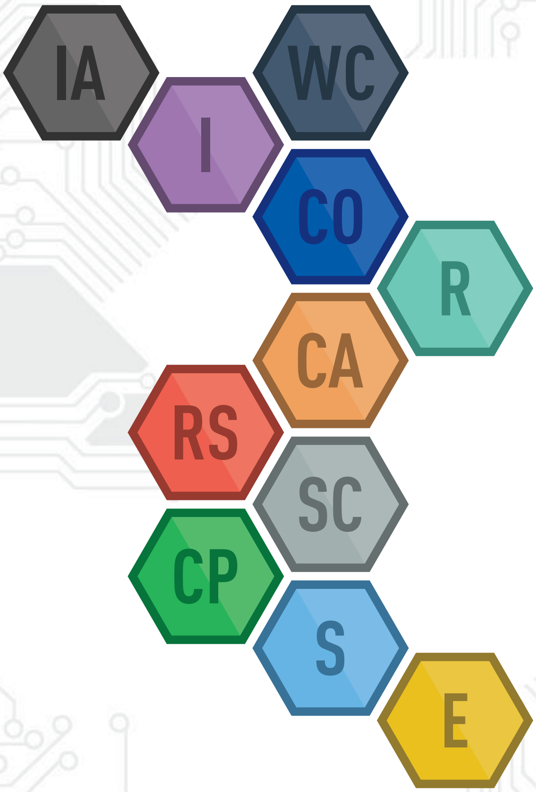

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electronic design
A Penton® Publication
SEPTEMBER 2014

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Technology Gives Back

Last month marked the 100th anniversary of the outbreak of World War I. Thanks to advances in surgery, that war saw more injured soldiers return home than any previous conflict. To help these men regain their mobility and potentially return to work in some capacity, research and development was quickly devoted to prosthetics. According to Thomas Schlich, author of "The 'bionic men' of World War I" (www.cnn.com), "Virtually every device produced today to replace lost body function of soldiers returning from our modern wars—as well as accident victims, or victims of criminal acts, such as the Boston Marathon bombings—has its roots in the technological advances that emerged from World War I."

Given the advances in computing, manufacturing, materials, networking, and more since World War I, such a statement is very surprising. Yet it makes sense in that the goal of prosthetics has always been to replace a body part with one that at least partially restores function and/or appearance. With today's technical advances, of course, prosthetic development is moving toward serving as a complete replacement or even an improved enhancement. It is this rapid evolution--combined with the need to help so many returning soldiers—that inspired us to delve into the engineering achievements behind today's cutting-edge prosthetics.

As Penton's Design Engineering & Sourcing Group, our staff of technical experts has researched and covered this topic from a variety of specialized engineering disciplines. The results can be seen in articles, interviews, image galleries, and other multimedia efforts on the *Electronic Design*, *Hydraulics & Pneumatics*, *Microwaves & RF*, and *Machine Design* sites. In each special section, the editors pinpointed and detailed the leading edge in prosthetics development—whether that edge was in wireless networking, sensors, multiprocessing, motors and motor control, or fluid power and hydraulics.

As exciting as these developments are technically, we were especially proud to cover them because you, our engineering audience, have had so much impact on the lives of our returning soldiers. With two wars abroad, many of our men and women are coming home physically injured and with intense mental trauma. If technology can help them restore some of their physical capabilities, the hope is that they may be put on a road to greater healing.

The Design Engineering & Sourcing Group would like to thank all of the researchers, designers, investors, and others that make these latest prosthetic advances possible. In addition to healing our heroes, you are heroes yourselves, given the recovery that you're enabling. Please join me also in thanking our team for their work on this very special project: Bill Wong and Don Tuite, Ken Korane, Stephen Mraz, and Jean-Jacques DeLisle. Don't forget to visit our "Healing Heroes" hub on our websites to see the cross-brand and multimedia coverage of this topic.

Nancy Friedrich
Executive Director of Content & User Engagement
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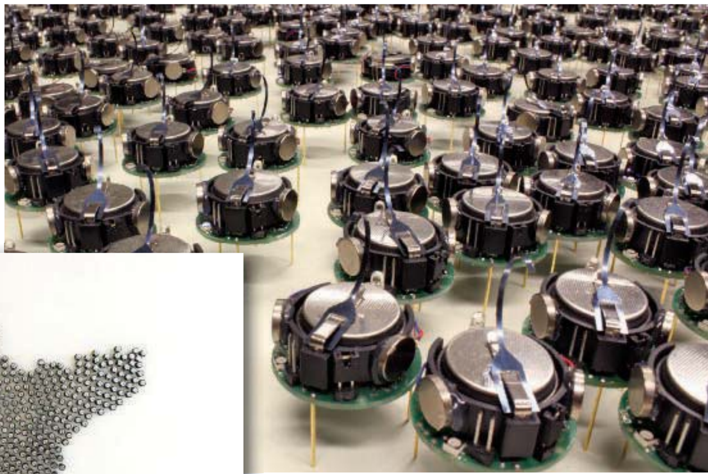
IR SIGNALS HELP HUGE ROBOT "SWARM" Localize, Form Complex Shapes



Staying true to the prefix "kilo," Harvard's Self-Organizing Systems Research Group upped the swarm ante by building a thousand of their "Kilobots"—well, 1024 to be exact. First introduced in 2011, the Kilobots are small and cheap, move around by vibrating their legs, and communicate with their fellow robots using infrared (IR) transmitters and receivers. The researchers are now working to develop specific algorithms so that the massive number of Kilobots can self-assemble into complex shapes.

At the heart of the Kilobot is an Atmel ATmega 328 microcontroller (MCU) packing 32 kbytes of flash and 1 kbyte of EEPROM for storing calibration values *(see "Kilobot Swarms" at electronicdesign.com)*. The algorithm used to create the Kilobot swarm shapes mimics biological organism maneuvers like that of, say, a school of fish. This enables three main capabilities: edge following (where a robot can move along the edge of a group by measuring distances from robots on the edge); gradient formation (where a source robot generates a gradient value message that increments as it propagates through the swarm); and localization (where the robots form a local coordinate system by communicating and measuring distances with their closest neighbors.)

Out of these three capabilities, the researchers found that localization is the most difficult to pull off—but it is also the most important. Although the robots can sense the distance between them and other robots by measuring the brightness of the IR light that each bounces off they're operating on, they have no information on the light's source. In order to localize, an initial group of "seed" robots must define the origin of the system. From there, the subsequent robots can localize based on the IR pulses coming from the previous set.

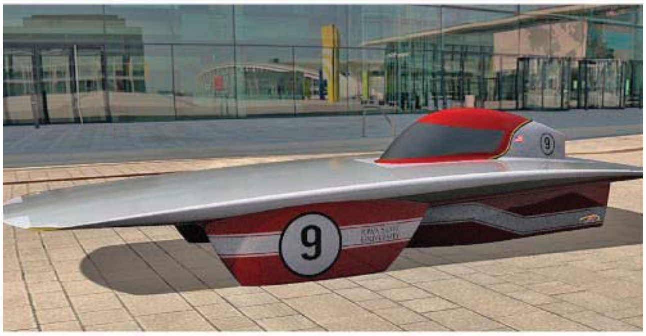
Once the robots localize, forming an arbitrary shape becomes the "easy" part of the process. The robots move around the perimeter of the swarm until they detect that they're in the shape-formation area. The robots continue to move around that edge until they're about to exit the shape or they bump into another, and continue to follow that chain until the shape is created. Working with so many robots at once essentially means that each individual Kilobot is inconsequential—one can screw up or break down and not wreck the entire system. However, when they operate together, the swarm becomes greater than the sum of its parts. ■

UNIVERSITY OF MICHIGAN Dominates Solar Car Races

WHILE HYBRID AND electric cars grab a greater share of the automotive market, we're still a long ways from seeing solar-powered cars on our highways. Universities around the globe, though, are working on innovations that may bring them to your local showroom someday.

They came together this past July at the Cockrell School of Engineering at the University of Texas at Austin to participate in the nation's two biggest collegiate solar-car races: the Formula Sun Grand Prix (FSGP) and the American Solar Challenge (ASC). The competitions feature cars that can reach 40 to 50 mph using only 1200 W, or about two-thirds the power it takes to run a hair dryer.

1. The University of Michigan's Quantum took first place in both the Formula Sun Grand Prix in Austin, Texas, and the 1700-plus-mile American Solar Challenge race. *(Courtesy of UMSolar)*



2. Iowa State University's Phaeton represents the team's 12th solar racecar. The team's car recorded the fastest lap in the Formula Sun Grand Prix and finished third in the American Solar Challenge.

Of the 20 teams that arrived, 17 eventually passed the rigorous "scrutineering" inspections and were able to get onto the Circuit of The America (COTA) track for the FSGP qualifier race, powered by Austin Energy. Heavy cloud cover, a steep hill up to turn one, and a battery fire that delayed the final day of racing created extra challenges for the races.

Iowa State set the fast lap around the track with an average speed of 44.8 mph. The overall top three spots belonged to the University of Michigan (completion of 174 laps, 596 miles), Oregon State (124 laps, 425 miles), and a tie between University of Minnesota and Western Michigan University (110 laps, 377 miles).

Only four registered teams met official lap qualification requirements for the 1700-plus-mile, cross-country ASC race—the University of Michigan, Oregon State, Iowa State, and QIAU HAVIN from Iran. Six other teams were granted provisional qualification (although one eventually withdrew, and another couldn't meet a qualification requirement and thus had to withdraw).

The eight eligible entrants were able to finish the race, which stretched from Austin, Texas to Minneapolis, Minnesota, despite encountering a number of cloudy days. In fact, the top six teams never had to trailer their vehicles. The top three finishers were the University of Michigan (time was 41:27:29), University of Minnesota (45:19:09), and Iowa State University (50:18:46).

"During the team's various testing events and competitions, our solar car is the star. As it drives by, other drivers rubberneck, pedestrians point, and cameras flash," said Ian Sullivan of the University of Michigan. The team's Quantum weighs 145 kg and is powered by a 1500-W SunPower Mono-Si array with a 5-kWh lithium-ion (Li-ion) battery pack and a 1.8-kW CSIRO motor *(Fig. 1)*.

"I've been working with the team ever since the first week of school. They pull you right in and you really just learn by experience. You can learn everything you need to do," said Neal Dylan Neal, who designs parts for the PrISUm team from Iowa State. PrISUm's Phaeton weighs 180 kg and is powered by a 1200-W SunPower Moni-Si with a 4-kWh Li-ion battery pack and a 7.5-kW NGM SCM150 motor *(Fig. 2)*. ■

TEMPORARY TATTOO Sensors Create Sweat-Fueled Biobatteries

POSTDOCTORAL STUDENTS, INCLUDING WENZHAO Jia, at the University of California at San Diego imprinted a flexible lactate sensor onto temporary tattoo paper containing an enzyme that removes electrons from lactate, producing a weak electrical current. The sensor simplifies the measurement of lactate, which is naturally present in sweat and an important indicator of how one is performing during exercise.

The tattoo sensor led the team on a quest to create a perspiration-powered biobattery. The battery's "anode" contains the enzyme that removes electrons from lactate, and the "cathode" contains a molecule that accepts the electrons.

The new approach was announced at the 248th National Meeting & Exposition of the American Chemical Society (ACS), the world's largest scientific society, held Aug. 12-14 in San Francisco, Calif. Using renewable sources (in this case, sweat), the biobatteries are certainly safer than traditional batteries, which can explode or leak toxic chemicals.

For testing, 15 volunteers wore the biobattery as they exercised on a stationary bike. Less-fit people produced a greater amount of power than those who were moderately or very fit. The team determined that less-fit people became fatigued sooner, causing glycolysis (a producer of energy and lactate) to kick in earlier and form more lactate. ■

The lactate levels produced during exercise are detected by a tattoo biosensor.

RFID TAGS TRACK Bee Behavior

RADIO-FREQUENCY IDENTIFICATION (RFID) tags for tracking the activity of honeybees in the hive revealed that about 20% of the foraging bees brought home more than half of the nectar and pollen gathered to feed the hive. When these overachievers are removed, though, the less active foragers improved their output by a factor of five within 24 hours to make up the difference.

Scientists at the University of Illinois Institute for Genomic Biology tagged the bees with laser-light-activated "p-Chip" PharmaSeq microtransponders, or tags. PharmaSeq laser readers connected via a USB cable to a computer detected the tags, each carrying a unique ID number. When lit by a reader's red laser beam, photocells on each tag's upper surface activate the chip to transmit its ID at of up to 10 mm to a pickup coil in the head of the reader.

Due to the laser beam's 1.5-mm diameter, researchers could attach two tags to each bee to increase the likelihood of detection *(see the figure)*. Each tag measures 500 by 500 by 100 µm and weighs 90 µg. Two tags fit easily on each bee's thorax. The researchers believe that the tags did not impair the natural foraging behavior. At a cost of $1.35 per tag, they considered the tags disposable and eschewed retrieving them from the bees.

To read the tagged bees, a plastic tube walkway was attached to the hive entrance. Two laser readers were projected into the top of the tube. Bees passed under each reader as they entered and exited the hive. The order of detection by each reader inferred the direction of travel. After detecting a bee, the reader passed the ID and reader number to a connected PC, which issued a time stamp. ■

Researchers at the University of Illinois used RFID tags to track honeybee behavior. They determined that 20% of the bees are overachievers, responsible for more than half of the hive's pollen and nectar. *(courtesy of Tom Newman, Robinson Bee Laboratory)*

HEALING HEROES

ENGINEERING FEATURE

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ELECTROMECHANICAL MEDICAL

Advances in human augmentation are providing prosthetics for injured veterans as well as tools for workers so they can handle more difficult jobs.

MARVELS

Recent electromechanical breakthroughs are helping the injured to walk and eat. They also are giving workers tools that allow them to do more. For example, exoskeletons are helping injured veterans learn to walk by providing just enough support to make movement possible. They also are helping to strengthen muscles with enough exercise without overwhelming the patient. Amputees are now living and working thanks to prosthetic devices and exoskeletons. Or, disabled veterans may have limbs that aren't capable of normal use without augmentation. Finally, these tools can provide people with superhuman strength, longer reach, and more durability, allowing them to complete tasks that a person could never perform alone.

AUGMENTING THE HAND

Have you ever wished you had an extra hand or an extra finger or two? Developed at the Massachusetts Institute of Technology, "supernumerary robotic fingers" might be what you need (*Fig. 1*).

Many devices simply mimic human capability so users can move normally. Others provide more features so jobs and tasks that were once impossible can be performed easily.

1. Faye Wu, a graduate student in mechanical engineering at MIT, demonstrates the "supernumerary robotic fingers" device. *(photo by Melanie Gonick).*

Photo: © (David Furst) Getty Images

In this case, MIT's Department of Mechanical Engineering added two large fingers to a glove. It lets users do things like hold an object with a couple of fingers while using the others to perform another job such as adding salt to a cup of liquid or opening the top of a jar.

Faye Wu, a graduate student at MIT, tracked how the hand and robotic joints moved to perform various tasks. She found that the various grasps could be defined by a combination of two or three general patterns using the seven fingers. The system uses an algorithm that essentially teaches the robotic components to move based on human hand movements.

The system is attuned to the user since grasping and control gestures will differ between people. The device needs to work naturally with each user. This adaptive nature is similar to voice recognition systems that can improve their usefulness over time. Future research will address the positioning of the robotic fingers as well as the amount of force being used, which would allow delicate or forceful work.

GETTING A GRIP WITH ROBOGLOVE

Sometimes 10 fingers are enough, but they can get tired doing hard or repetitive jobs. This is true on Earth as well as in space. No surprise then that NASA is where RoboGlove (*Fig. 2*) came into being. Developed in conjunction with General Motors, it uses technology initially developed for the Robonaught 2 (R2) robotics project (see "These Robots Are No Danger, Will Robinson" on electronicdesign.com). In particular, R2 has an articulated hand with a complex feedback mechanism.

RoboGlove is essentially a wearable exoskeleton gripping tool. A person typically can grip or hold an object for a few seconds, but it becomes more difficult as the weight and time increase. Odd positions only exacerbate the problems. Repetitive stress syndrome (RSS) is often an issue, and RoboGlove can address it by reducing the amount of stress involved in an action or process.

The device would be very handy on the assembly line, especially where large or heavy items need to be held. Use cases include the ability to pick up an item and then lock the fingers so the user's hand provides minimal force. RoboGlove can provide a peak force of 50 pounds and a continuous force of 15 to 20 pounds.

RoboGlove uses the same Tendon Driven Finger Actuation System technology employed by R2. Unlike the R2 hand, RoboGlove is just assisting so it uses a single tendon instead of the four or five tendons used by R2. The linear actuators are in the forearm along with the control electronics. An FPGA handles sensor feedback.

2. RoboGlove is designed to augment a person's grip. It can add force or maintain a grip while the user relaxes.

PROJECT DANIEL

Mike Ebeling, CEO and founder of Not Impossible Labs, gave an inspiring presentation at the 2014 Intel International Science and Engineering Fair talking about projects the organization has worked on (see "Not Impossible Labs Inspires Intel ISEF Students" on electronicdesign.com). Not Impossible Labs' open, collaborative approach to solving problems resulted in its Eyewriter and Project Daniel efforts.

Eyewriter is a low-cost system that allows patients with a debilitating disease like amyotrophic lateral sclerosis (ALS, also known as Lou Gehrig's Disease) to use their eyes to communicate with others. It was initially built around a pair of cheap sunglasses and a camera that tracks eye movement. The project was launched to provide Tempt One, a noted Los Angeles graffiti artist with ALS, a way to communicate again. The open-source technology is available for others as well.

Project Daniel uses a similar approach. It started as a way to give a child a new set of arms. Daniel lives in South Sudan in the war-torn Nuba Mountains where many people have lost multiple limbs. Conventional prosthetics are expensive and unavailable to local doctors.

Not Impossible Labs used a Makerbot Replicator 2 3D printer to create custom prosthetics for people like Daniel. The results may be crude compared to commercial solutions but the cost is considerably lower, making it practical for third-world countries.

The initial prosthetic was based on the Robohand designed by Richard van As. It can be found on MakerBot's Thingverse. The prosthetics are much more advanced. It takes about $100 worth of plastic filament plus some medical orthoplastic and metal parts to make an arm.

Power, a laptop, and a 3D prin er are the major items that are needed to make the prosthetics. Dr. Tom Catena helped train others to use the equipment so they could create new limbs for others. After the initial training, they created two more arms by the time the project team had returned home.

NASA EXOSKELETON

NASA's 57-pound X1 is a lower-extremity exoskeleton developed in conjunction with the Florida Institute for Human and Machine Cognition (IHMC). It provides mobility assistance for abled and disabled users.

The X1 is essentially a robot that detects the user's movements and augments them. The suite features torque-controllable, powered actuators at the hip flexion/extension and knee flexion/extension. The hip joints are passive. The exoskeleton is adjustable so it can fit a variety of body sizes. The powered joints are co-located with the user's joint. The anthropomorphic structure is created using an adjustable harness. The harness also goes up the back and around the shoulders.

The X1 has 10 degrees of freedom (DOF). The four powered joints at the knees and hips are capable of variable impedance, ranging from zero impedance for transparent mode to high impedance for stiff position control.

The exoskeleton can be used for different purposes. In space, it could be used as an exercise device since an astronaut's body needs exercise in low gravity or it deteriorates. Astronauts on long-term missions typically have an exercise regimen and, sometimes, special equipment. The X1 could provide similar resistance exercises as well as freedom of movement. A suit has built-in sensors so telemetry could provide a record of an astronaut's activity. Think of it as a very advanced pedometer.

The X1 technology also could provide assistance in space, especially when used with a spacesuit. Pressurized spacesuits are an extra burden to astronauts, and an exoskeleton could reduce the effort to use them.

Exoskeletons are useful now and continue to improve. There are still challenges from improving sensing and feedback mechanisms as well as enhancing power supplies and incorporating regenerative power systems. ed

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BEHIND THE ENGINEERING THAT GOES INTO A LEG PROSTHESIS

In 1919, after World War I, a German prosthetist named Otto Bock set out to improve the functionality of the artificial limbs that wounded soldiers and civilians needed to carry on their lives. His first innovation was to make the production of artificial limbs into a production-line operation, rather than a custom process for each amputee, as it had been in the past. Needless to say, the rest of the 20th century provided more than ample opportunity to refine and innovate the mass-produced, fittable, artificial limb.

Mr. Bock died in 1960. Today, Otto Bock Healthcare, the company named after him, is a global organization, headquartered in Duderstadt, Germany, with engineering facilities worldwide, including Minneapolis.

The company is known, among other things, for its “C-Leg” a microprocessor-controlled above-the-knee prosthesis *(Fig. 1)*. Numerous videos on the Web show men and women who wear the leg riding bicycles, enjoying strenuous sports, and otherwise living full lives.

1. An active, microprocessor-controlled, artificial limb, Otto Bock Healthcare’s C-Leg enables many amputees to ride bicycles, kick soccer balls, and traverse stairs and uneven terrain.

RE-CLOSING THE FEEDBACK LOOP

Our human, upright-stance, two-legged locomotion is a constant battle against gravity, based on sensors located from our ears to our limbs to our toes. A request for a movement is initiated by the brain, which sends impulses through the spinal cord and nerves to the muscles, particularly, the calf muscle. For most of us, muscle activity and nerve stimulation are constantly interacting at about 20 times a second.

To attempt to duplicate at least part of this control system, in the C-Leg, pressure sensors in the leg’s knee and ankle supply information to a microprocessor. Based on this information, a program running on an RTOS in the C-Leg’s microprocessor controls a system of hydraulics in the leg.

In the software, walking is divided into a “stance” phase and a “swing” phase. During the stance phase, the primary task is to stabilize the leg, so that it can support the body weight when the user is not yet in motion.

The swing phase, when the user is in motion, places a greater load on the microcontroller. The prosthetic lower leg must be controlled as it comes off the ground, swings through its arc, at the pace set by the user, and is then slowed down in preparation for the next step.

In the stance phase, a C-Leg employs hydraulic damping to provide stability. It exits this state and enters the swing state when simultaneously meeting two criteria: first, the knee must be fully extended, and second, approximately 70% of the body weight of the prosthesis wearer must be supported by the natural leg.

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IT'S ALL ABOUT THE KNEES

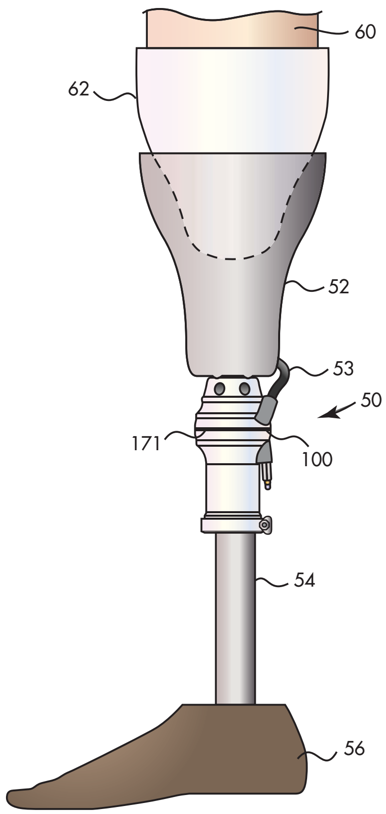
The C-Leg's microprocessor-controlled knees function much like those in a human leg. When the software in the microprocessor receives the sensor information, it has sufficient information to determine exactly where the knee is in the walking or gait cycle. The algorithm is based on data analyzing the walking techniques of literally thousands of people. Reducing the data to an algorithm, the microprocessor can anticipate what the leg needs to do each moment. This was a breakthrough by Otto Bock Healthcare. It made the prostheses proactive, rather than reactive. For example, in a sound leg, at the end of a swing phase, just before the heel scrapes the ground, the quadriceps and hamstrings simultaneously contract and prepare for loading that will occur at heel-strike.This prevents the knee from collapsing and allows it to act as a shock absorber while also creating a smooth, efficient gait. The software and pneumatic system in the artificial leg is able to emulate this.

In finer detail, what happens is this: There are two sensors in the prosthesis, one near the ankle and one at the knee joint. They provide the microcontroller with a constant stream of information, updated 50 times a second, about the user's gait and environment. The algorithm in effect enables the C-Leg to anticipate the demands about to be placed on the system and adjust resistance to leg flexion and extension.

Mechanically, it's more complicated: Based on information from the sensors, the microprocessor-controlled servomotors open and close valves in the hydraulic channels, increasing or reducing resistance in the knee. These channels can be engaged alone or simultaneously, similar to the large muscles of the leg, to create the appropriate resistance no matter where the user is in the gait cycle. Because each C-Leg user is unique, the practitioner will use Otto Bock software designed for the C-Leg to set special resistance parameters. The company's BionicLink system exploits Bluetooth technology, so that the user or a prosthetist can set semi-permanent system parameters tuned to the wearer's physical characteristics. The various parameters allow the C-Leg to "predict" where the user will be, moment to moment, and enable it to function proactively. The link also allows wearers to switch among parameters dynamically to adapt to terrain or various physical activities.

Based on sensor information, during the swing phase, the microprocessor anticipates when the leg is about to make heel contact, enabling it to calculate the resistance parameters that will be needed for stance-phase security. With that calculation, it can instantaneously adjust the knee's flexion valve to adjust resistance in a way that conforms to the user's gait pattern and the current environment.

Then, at the end of each stance phase, the microprocessor recognizes forefoot pressure in conjunction with a straight knee and opens the flexion valve to prepare for swing phase. The sophistication of the gate cycle part of the algorithm even allows for "stance flexion," or the natural flexing of the knee that normally occurs after heel contact in a sound leg.



2. All of the sophistication of the knee joint would be lost if the C-Leg were painful to wear or unstable. Illustration 1 from Otto Bock Healthcare's patent (shown here) shows the parts of battery-powered vacuum pump system that allows for long periods of wear.

MORE MODES

That's a basic description of the primary mode of operation. For special situations, a second mode can be programmed by C-Leg practitioners. This could create a free-swinging leg for bicycle riding, for instance, or higher resistance for standing, such as during long surgical procedures.

While afoot, users can switch between modes in two ways. There is a handheld remote control that toggles the switch. But for more intuitive operation, the user can bounce on the toe three times. For those more comfortable with the C-Leg, the remote control allows for incremental adjustments to swing-phase dynamics. Finally, there's a "standing" mode, something no other artificial limb offers. This mode sets the knee at any flexion angle between 7 and 70 degrees to allow the user to shift weight so the prosthesis can relax their sound limb.

MAKING IT FIT

The C-Leg is more than its microprocessor-controlled knee joint. It's also engineered for comfortable, reliable fit, and long periods of wear *(Fig. 2)*. C-Legs provide a socket for the limb, with a plastic liner. A battery-powered pump creates a vacuum that forces the residuum of the user's leg down against a fluid-filled, donut-shaped, soft plastic piece. When a vacuum is applied, it forces fluid out of the donut through a two-way valve and into a flexible reservoir. The valve arrangement allows dynamic cushioning between the residuum of the leg and the socket as the user walks without breaking the suction that secures the prosthesis to the user. ed

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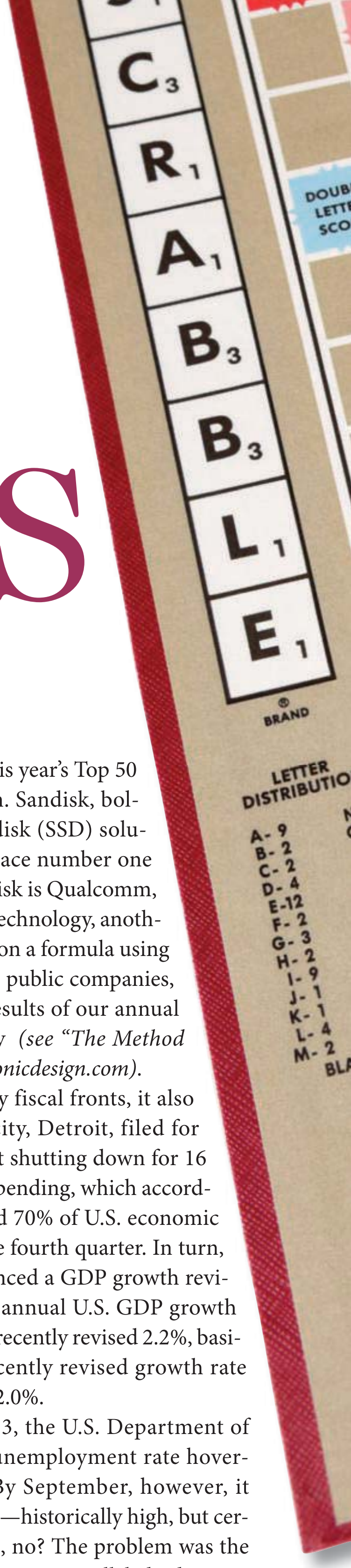
TOP 50 EMPLOYERS In Electronic Design

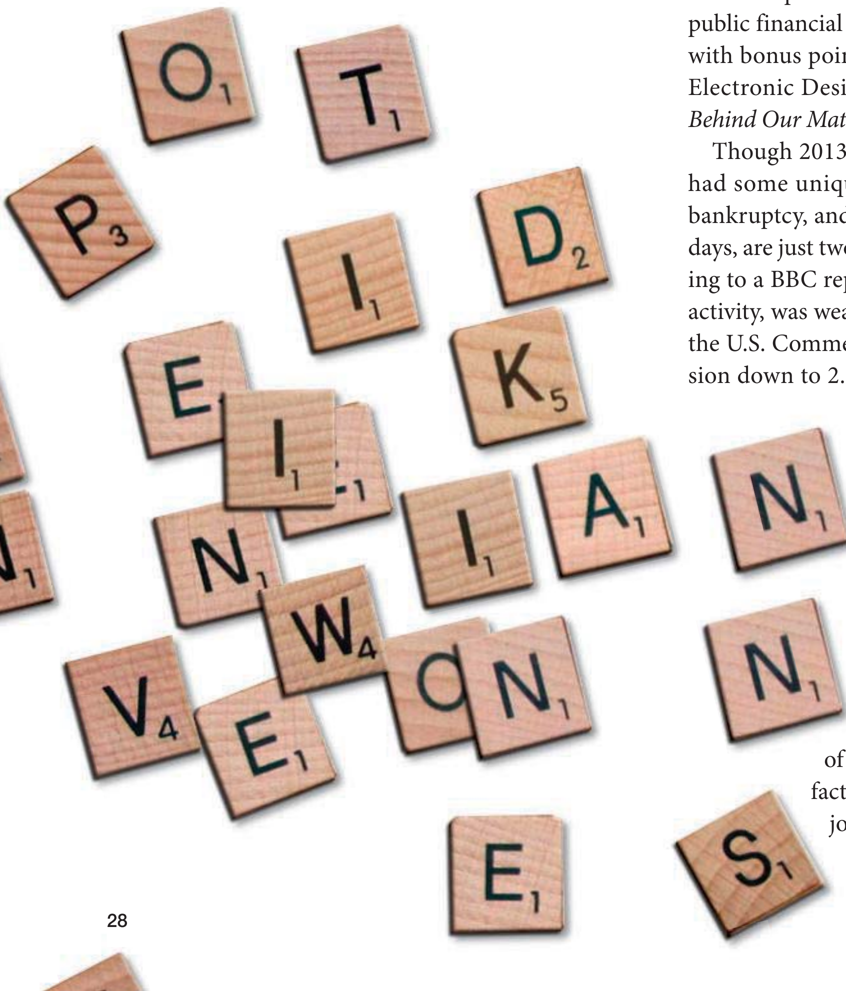


Some companies took risks to put pieces in the right places—and in the end they spelled success.

There's a new game in town for this year's Top 50 Employers in Electronic Design. Sandisk, bolstered by a shift to solid-state-disk (SSD) solutions, vaulted up 60 places to place number one on this year's Top 50 list. Following Sandisk is Qualcomm, last year's top company, and Microchip Technology, another new Top 50 member. The list is based on a formula using public financial data from a "pool" of 97 public companies, with bonus points awarded using the results of our annual Electronic Design Reader Profile Study *(see "The Method Behind Our Mathematics, 2014" at electronicdesign.com).*

Though 2013 mirrored 2012 on many fiscal fronts, it also had some unique moments: A major city, Detroit, filed for bankruptcy, and the federal government shutting down for 16 days, are just two examples. Consumer spending, which according to a BBC report accounts for around 70% of U.S. economic activity, was weaker than expected in the fourth quarter. In turn, the U.S. Commerce Department announced a GDP growth revision down to 2.4% from 3.2%. Overall, annual U.S. GDP growth was slow but stable at a recently revised 2.2%, basically matching the recently revised growth rate from 2011 to 2013 of 2.0%.

At the start of 2013, the U.S. Department of Labor revealed an unemployment rate hovering around 7.9%. By September, however, it dropped to around 7.2%—historically high, but certainly an improvement, no? The problem was the unemployment-rate decrease paralleled a decrease in the number of newly added jobs, suggesting that more Americans were simply dropping out of the labor force (a familiar phenomenon by now). In fact, the number of people working or actively seeking a job hit a 35-year low in September 2013.



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Jobs were added at a rate of 207,000 per month in the first quarter of 2013, slowing down to 182,000 a month in the second quarter, and finally 143,000 a month in the third quarter. Of course, the standoff in Congress centered primarily around the Affordable Care Act that led to the government shutdown on October 1, certainly didn't help. As global stock markets tumbled on September 30, the partial shutdown left about 800,000 federal workers unemployed. When the shutdown ended on October 16, according to the AP, economists estimated that the government shutdown erased $24 billion from the economy.

BETTER NEWS FOR 2014

The Department of Commerce says the economy is expected to grow above a 3% rate for the rest of 2014 into 2015. However, with severe weather triggering a 2.1% decline in the first quarter, followed by second-quarter growth of around 4%, 2014 will likely grow at a rate similar to every year since 2011—around 2.1%.

The good news is that real disposable income jumped 4% for the first half of 2014, fueled by renewed consumer confidence that's at its highest level since before the recession. Retail sales have rebounded and auto sales in June reached their highest levels in eight years. Hiring seems to be increasing, evidenced by the few initial unemployment claims since May. The Index of Manufacturing Purchasing Managers also points to increased output.

After a terrible first quarter, some of it again weather-related, both building starts and sales of new and existing homes are expected to rise during the second half of 2014. As for retail sales, growth should be slightly higher during the second half, averaging around 4% for the year (a nudge up from last year's 3.5%).

According to the U.S. Department of Labor, 244,000 jobs per month have been added since February, compared to a monthly average of 187,000 over the last three years. By the end of 2014, 2.8 million workers should be added to payrolls, with growth spread fairly broadly across all industries. The unemployment rate, on the other hand, will most likely not see better numbers. That's because those who stopped looking for jobs and start actively searching again would still count as officially unemployed. It's estimated to come out to approximately 6.1% by year's end.

Improving non-supervisory worker wage should reach a 2.5% annual growth rate by year's end, and continue to accelerate in 2015 and 2016. This group makes up over 80% of the workforce, which will ultimately help push consumer demand and economic growth.

According to the U.S. Census Bureau, the slumbering business investment segment shows signs of awakening. Capital spending is projected to increase around 4.5%—not great, but an improvement over the 1.5% spent in 2013. The first-quarter decrease in GDP was the largest since the recession hit five years ago, but companies are cautiously starting to add capacity.

That said, success for companies on the list typically results from multiple factors. Below are snapshots of the top three companies on our list:

1 SANDISK

THIS YEAR'S TOP company, SanDisk, didn't even break into last year's Top 50 Employers list. Its meteoric rise revolves around the company's expertise in always-accessible digital storage, particularly solid-state drives (SSDs).

In corporate data centers and in the cloud, flash technology has begun replacing mechanical hard drives for storing and accessing mission critical data. As far as computing, the company's SSDs offer a more efficient, compact, and durable alternative to mechanical hard drives for desktops, laptops, and today's ultra-thin PCs. With respect to mobile, the company delivers high-performance flash storage to manufacturers of smartphones, tablets, and other mobile devices. Finally, in terms of consumer electronics, SanDisk technology finds homes in multiple platforms, including digital cameras, mp3 players, flash drives, and storage cards.

For the second fiscal quarter of 2014, the company reported record revenues and net income, illustrating further progress in its strategic shift to SSD solutions. SSDs, both client and enterprise, now account for 29% of revenue and are on track to exceed 2014 revenue mix goals. In fact, SSD revenue has doubled year over year and grown 30% sequentially (quarter to quarter), driven by increases in both SATA (Serial ATA) and SaaS ("Software as a Service" is a software delivery method that provides access to software and functions remotely as a Web-based service) products.

According to research firm IHS iSuppli, SSD shipments jumped 82% (57 million units) while hard-drive shipments declined 7% year-over-year in 2013. IHS iSuppli estimates SSD shipments to grow 50% this year and reach 190 million units by 2017, which is close to half the size of the HDD market of 397 million. The real opportunity, however, comes in the form of enterprise SSDs.

The company's portfolio of innovative enterprise flash solutions positions them as a preferred partner to those customers ramping up use of flash to optimize their workloads. CloudSpeed and other SATA SSD products are now qualified at multiple large-scale customers. On the SaaS SSD front, SanDisk is now in production at a Tier 1 storage OEM for its all-flash array offering, headed by the 2-Tbyte Optimus Eco SSD.

During the second quarter, SanDisk introduced the Lightning 12-Gbit SaaS and 4-Tbyte Optimus MAX SaaS SSDs. Also, the new 4-Tbyte MAX SaaS SSD received lots of customer interest for replacing legacy 15k and even 10k release-to-manufacturing (RTM) hard-disk drives in mission-critical storage and data-center applications.

In June, SanDisk signed a definitive agreement to acquire Fusion-io, a market leader in enterprise PCI Express (PCIe) hardware and software solutions. Fusion-io develops flash-based PCIe hardware and software solutions to boost application performance in enterprise and hyperscale data centers. This acquisition should help further enhance the transformation into a value-added solutions provider and improve

TOP 50 EMPLOYERS IN ELECTRONIC DESIGN		
No.	Company	Fiscal 2013 Rank
1	SANDISK CORP.	1
2	QUALCOMM INC.	2
3	MICROCHIP TECHNOLOGY INC.	3
4	EATON CORP.	4
5	WHIRLPOOL CORP.	5
6	3MCOMPANY	6
7	UNITED TECHNOLOGIES CORP.	7
8	SYNOPSYS, INC.	7
9	FORD MOTOR CO.	9
10	GENERAL ELECTRIC CO.	10
11	INTERNATIONAL GAME TECHNOLOGY	11
12	AT&T INC.	11
13	JOHNSON CONTROLS, INC.	11
14	CISCO SYSTEMS, INC.	11
15	HONEYWELL INTERNATIONAL INC.	15
16	VERIZON COMMUNICATIONS INC.	16
17	ROCKWELL AUTOMATION, INC.	16
18	THE BOEING COMPANY	16
19	MICRON TECHNOLOGY INC.	19
20	INTEL CORP.	19
21	LOCKHEED MARTIN CORP.	19
22	MICROSOFT CORP.	19
23	MENTOR GRAPHICS CORP.	19
24	CADENCE DESIGN SYSTEMS, INC.	19
25	APPLE INC.	25
26	JUNIPER NETWORKS, INC.	26
27	GENERAL MOTORS CO.	27
28	LAM RESEARCH CORP.	27
29	ANALOG DEVICES, INC.	27
30	EMC CORP.	27
31	ROCKWELL COLLINS, INC.	31
32	NATIONAL INSTRUMENTS CORP.	32
33	NCR CORP.	33
34	VISTEON CORP.	34
35	TEXAS INSTRUMENTS INC.	34
36	APPLIED MATERIALS INC.	36
37	XILINX INC.	36
38	ADVANCED MICRO DEVICES INC.	38
39	DANAHER CORP.	38
40	WESTERN DIGITAL CORP.	38
41	GENERAL DYNAMICS CORP.	41
42	BOSTON SCIENTIFIC CORP.	41
43	RF MICRO DEVICES, INC.	41
44	BROADCOM CORP.	41
45	HEWLETT-PACKARD CO.	45
46	TRW AUTOMOTIVE HOLDINGS CORP.	45
47	MOLEX INC.	45
48	THERMO FISHER SCIENTIFIC INC.	45
49	ITT CORP.	45
50	NETAPP, INC.	50
51	MEDTRONIC, INC.	50
52	RAYTHEON CO.	50

capabilities with various new solutions, channels, customers, and go-to market expertise.

Record quarterly revenue also was achieved for client SSDs. The company's portfolio of SATA and PCIe client SSD solutions serves a multitude of personal-computer OEMs, and its making rapid progress toward qualifying 1Y nanometer client SSDs (19 nm) at many of these OEMs.

The SanDisk Extreme PRO also debuted during the second quarter. The client SSD features up to 1-Tbyte class capacity that, SanDisk says, is the first to come with a 10-year warranty. Moreover, the company will start to ship its X3-based client SSDs in the retail and distribution channels, as well as initiate qualifications with OEM customers, in the third quarter. The company is buoyed by the increasing attach rate of SSDs to notebook computers, particularly in corporate PC platforms.

Overall revenue for embedded solutions grew slightly from the prior quarter. Though solid growth was seen in terms of sales of custom embedded solutions, iNAND sales declined (embedded flash drives for mobile devices), primarily stemming from some weakness at certain high-end smartphone customers and the timing of 1Y product transitions.

Partnerships with China-based mobile-device manufacturers resulted in solid revenue growth. Moreover, the company expanded mobile offerings for mid- and entry-level smartphones and tablets with the launch of the iNAND Standard, which is an X3-based embedded offering. Customer qualifications of X3-based embedded solutions are proceeding as planned, which should boost revenues in the third quarter and the rest of 2014.

For retail markets, SanDisk offers a mix of high-performance, ultra, and extreme products. Key market trends such as ultra-high-definition video and high-resolution imaging features in various consumer devices fuel a greater need for high-performance, high-capacity removable storage solutions. This plays to the company's retail strength, brand recognition, performance-based product segmentation, and broad global reach.

In terms of fab output in the second quarter, its 1Y (19 nm) technology mix represented approximately 60% of total bit output and should remain at approximately this level for the remainder of 2014. OEM customer demands for 19-nm technology nodes grow louder by the day. Greater success with OEM and enterprise accounts means the trend of longer product lifecycles on older technology generations becomes more pronounced as customers look for supply continuity. The company expects 5% wafer capacity growth in 2014, and given OEM and enterprise demand for 19-nm supplies, it expects supply bit growth to be closer to 25%. Estimates for industry supply bit growth remain at approximately 40%.

With a projected healthy industry demand/supply environment for the remainder of the year, the company expects to be somewhat supply-constrained during the second half of the year. As such, its revenue mix will primarily focus on strategic priorities and customer relationships.

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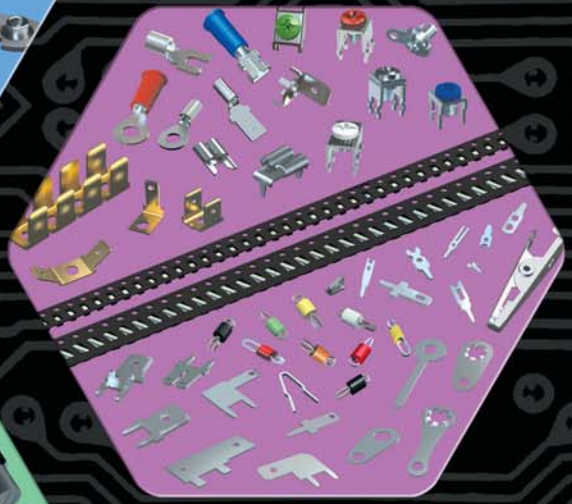
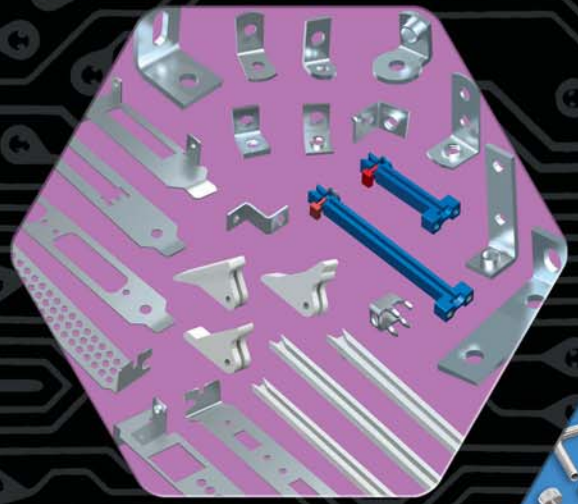


Terminals & Test Points

Spacers & Standoffs

PC Board Hardware

Pins, Plugs, Jacks & Sockets



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STAMPING, MACHINING & ASSEMBLY. Our engineering and design specialists utilize the most advanced design/production capabilities such as CAD/CAM, 3D modeling and printing.

SanDisk will begin installation and qualification of equipment for technology transition in phase two of its Fab 5 in the third quarter of 2014. Phase II of Fab 5 is not expected to contribute any meaningful incremental wafer capacity during this calendar year.

Strong progress with 15-nm technology development should lead to a ramp-up of production toward the end 2014, with meaningful contribution to product shipments in the first quarter of 2015. Progress also marches on with 3D NAND technology development; pilot production is expected to begin in the second half of 2015, with target production in 2016.

2 QUALCOMM

COMMUNICATIONS TECHNOLOGY IS the backbone of Qualcomm, the second-ranked company in the Top 50 Employers list. Its singular goal is to push the envelope on mobile technology, evidenced by the company's hardware showing up in hundreds of smartphones (as opposed to the few that use Intel technology). Qualcomm also dominates the emerging LTE cellular baseband processor market, holding a 66% market share according to Strategy Analytics.

Its success in part is attributed to the $14 billion poured into R&D over a four-year period. Such massive R&D investments were made possible by the cash flow generated by its 3G technology licensing. Because Qualcomm owns the IP, it produces licensing fees of 3-5% of a 3G phone's wholesale price.

INDUSTRY GAINS IN KEY AREAS

Category	Fiscal 2013 versus 2012	Fiscal 2012 versus 2011
Employee growth	0.0%	2.6%
Sales growth	2.3%	3.5%
Pretax income growth	40.6%	–17.2%
Pretax margin improvement	3.9 pts.	–2.6 pts.
Debt to equity ratio improvement	0.0 pts.	5.6 pts.
Research & development expense	5.4%	6.1%
Electronic Design Reader Profile Survey respondents	512	480

PERCENTAGE OF COMPANIES THAT SAW GROWTH IN KEY AREAS

Category	Fiscal 2013 versus 2012	Fiscal 2012 versus 2011
Sales growth	53%	48%
Pretax income	39%	45%
Employee growth	45%	60%
R&D	63%	69%

GSMA Intelligence estimates approximately 8.5 billion global cellular connections by 2017, 4.5 billion of which will still be 3G. If so, Qualcomm looks to retain a strong licensing revenue position at least up until then, even with most of the growth coming in emerging markets with cheaper handsets, thus lowering average licensing fees. Keep in mind that tablets, smart watches, automobiles, and whatever else comes along will require these connections.

Qualcomm is making progress in striking 4G deals with LG, Nokia, Samsung, and ZTE, but it's nowhere near as dominant as in the 3G arena. While China Mobile chose to develop its own proprietary 3G network, it decided not to pursue the 4G area—a potential opportunity for Qualcomm.

For the third quarter of 2014, the company produced record revenue and earnings results, driven by broad demand for its 3G and multimode 3G/4G chipsets. Shipments totaling 225 million mobile-station-modem (MSM) chipsets were driven by strength in emerging market regions, which spiked 17% quarter to quarter and 31% year over year.

The company is accelerating the transition from its current-generation Mirasol display technology to licensing of the next generation that focuses on wearable devices (although it will continue to make the current Mirasol displays). Mirasol is a trademarked name for its interferometric modulator display (IMOD) technology used in electronic visual displays. It consumes little power when not being addressed, and is visible in ambient light (*e.g.*, sunlight).

Qualcomm launched its first device based on its Snapdragon 805 processor and fourth-generation multimode 3G/4G modem, dubbed the Samsung Galaxy S5 broadband LTE-A. According to the company, the Snapdragon 805 is the first mobile processor to offer system-level Ultra HD support, 4K video capture and playback. Also, coupling the processor with the company's Gobi modems enables users to stream and watch 4K content over LTE.

Qualcomm CDMA Technologies (QCT) has seen strong design traction with emerging China customers. Success to date in China is based on chipsets launched last year. This quarter, the company plans to commercialize a new low-cost architecture with the Snapdragon 410.

Wi-Fi and RF360 solutions continue to ramp up, with overall Wi-Fi unit volumes on track to grow more than 40% this fiscal year, as their attach rate in mobile continues to extrapolate. Qualcomm has now launched, or is in design with, over 100 devices incorporating RF360, including the first to feature an envelope tracker, antenna tuner, and power amp. The RF360's singular design can be used to support the 40 and growing different global cellular bands.

The continued rollout and sustained growth of multimode 3G LTE presents a significant opportunity: According to the Global Mobile Suppliers Association (GSA), 300 operators have deployed, with 200 more committed to deploy, LTE. In addition, over 55 operators have or plan to deploy LTE Advanced services, including carrier aggregation. In this vein, Qualcomm will supply chipsets across multiple product tiers, leading with the launch later in 2014 of the Snapdragon 810, which is a premium-tier integrated system-on-a-chip (SoC) with Category 6 for smartphones.

To date, over 2000 multimode 3G LTE devices have been launched or are currently in design, based on Qualcomm chipset solutions. The LTE feature set continues to evolve, with features such as LTE Broadcast and LTE Direct.

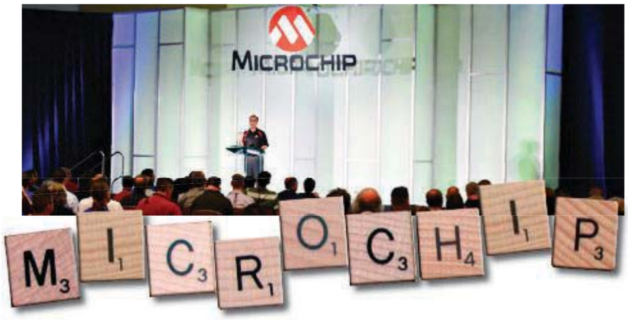
Commercialized in Korea and demonstrated in the U.S., Europe, and Australia, LTE Broadcast (eMBMS) provides single frequency network (SFN) broadcast capability to LTE. Thus, the same content can be sent to a large number of users at the same time, resulting in a more efficient use of network resources. LTE Broadcast can be used for distributing content such as live events and media to a wide audience, as well as for background file and software delivery and group information distribution.

LTE Direct is a device-to-device technology that offers privacy-sensitive and battery-efficient proximity-based discovery of friends, services, offers, and other relevant value in one's proximity. The company recently announced an LTE Direct trial in Germany in collaboration with Deutsche Telekom.

Although still early in the adoption cycle, opportunities in the automotive, healthcare, and wearable segments continue to take shape. The company's leadership in LTE brings an advantage to the automotive segment, with the move from 3G to multimode LTE in addition to General Motors' launch of OnStar LTE. In addition, new Android Wear devices were recently unveiled to bolster this segment. On top of that, Snapdragon 400 has turned into a key driver in various devices offered by Samsung and LG.

Also pushing the needle for Qualcomm were several key acquisitions.

First was Velocity, a leader in the development of 60-GHz chipsets based on the IEEE 802.11ad standard, also referred to as WiGig. The standard operates within the unlicensed 60-GHz frequency range and promises data transmission rates of up to 7 Gbits/s. The other acquisitions were Black Sand Technologies, which supplements its RF team and expands its RF360 roadmap, and digital still-camera technology developed by CSR.



3 MICROCHIP TECHNOLOGY

MICROCHIP TECHNOLOGY LANDED at number three on the Top 50 mainly due to always being under control—that is, embedded control. The company develops, manufactures, and sells specialized semiconductor products used by customers for a wide variety of embedded control applications.

Products include general-purpose and specialized 8-, 16-, and 32-bit microcontrollers; linear, mixed-signal, power-management, thermal-management, RF, safety, security, wired connectivity and wireless connectivity devices; serial EEPROMs (a type of volatile read only memory); serial flash memories; parallel flash memories; and serial static random-access memory (SRAM) memories. The company also licenses flash-IP solutions that are incorporated in a broad range of products.

The first quarter of 2014 produced record sales of $531 million, up 7.7% over the previous quarter. Record revenues were recorded in the microcontroller (MCU) and analog segments,

MOST IMPROVED COMPANIES, 2012-2013

Company	Rise in the ranks
SANDISK CORP.	60
MICROCHIP TECHNOLOGY INC.	58
ADVANCED MICRO DEVICES INC.	58
MICRON TECHNOLOGY INC.	54
INTERNATIONAL GAME TECHNOLOGY	50
GENERAL DYNAMICS CORP.	50

and geographically, revenues reached new highs in the Americas and Asia. Improved gross margins and strong expense control also shattered quarterly earnings marks.

MCUs, also occasionally referred to as "embedded controllers," represented 65% of Microchip's overall revenue in the quarter. Overall MCU revenue grew strongly at 5.3% sequentially in the quarter, and was up 14.5% versus the year-ago quarter, achieving a new revenue record. The 8-, 16-, and 32-bit MCU segments all experienced sequential growth, as well as record revenues, in the quarter.

Not only did 8-bit MCU revenue bump to a new high in the first quarter, cumulative revenue in the last four quarters was up 11.5% over the previous four-quarter stretch. While competitors have defocused in this arena, Microchip continues to expand its market share.

TOP 10 OEM EMPLOYERS

Company	Fiscal 2013 OEM rank	Fiscal 2013 overall rank	Category
QUALCOMM INC.	1	2	Communications
MICROCHIP TECHNOLOGY INC.	2	3	Components & subassemblies
EATON CORP.	3	4	Industrial Controls
3M COMPANY	4	6	Industrial Controls
SYNOPSYS INC.	5	7	Test equipment
ROCKWELL AUTOMATION INC.	6	16	Industrial Controls
MICRON TECHNOLOGY INC.	7	19	Components & subassemblies
INTEL CORP.	7	19	Components & subassemblies
MENTOR GRAPHICS CORP.	7	19	Test equipment
CADENCE DESIGN SYSTEMS INC.	7	18	Test equipment

In fact, it's reached the point where manufacturing can't keep pace with demand for Microchip's latest 8-bit MCU products. Its 8-bit PIC MCUs are finding their way into applications such as smartphones, audio accessories, video gaming peripherals, and advanced medical devices.

Conventional wisdom has been that 8-bit MCUs are slipping, and all customers simply want to convert to 32-bit MCUs. Bucking that trend, the company introduced a raft of new 8-bit products, including a high-efficiency 8-bit core and a family of core-based products that use C programming language, much like higher-end 16-/ 32-bit MCUs.

Microchip also introduced core-independent peripherals that allow customers to run the peripheral functions without the MCU core engine running or without consuming CPU power. As a result, customers can expand the use of 8-bit MCUs, leading to renewed popularity. Demand for this process technology is rising at a rate of 15% to 20% per quarter, starting from a fairly large base.

Its 16-bit MCU business was up 0.6% sequentially in the June quarter, achieving a new record, and up 26.5% versus the year-ago quarter. Records were reached for 32-bit MCUs, too, up 21.5% sequentially in the quarter, and 59.8% versus the year-ago quarter.

Including the acquisition of Supertex analog products (maker of high-voltage analog/mixed-signal integrated products), the analog business grew 18.9% sequentially in the quarter and was up 23.8% from the year-ago quarter. The analog sector represented around 24% of Microchip's overall revenue in the quarter, achieving over $500 million.

The memory business, which consists of the Serial E-squared and SuperFlash memory products, was sequentially up 0.7%. This high-profitability segment represented 6.3% of Microchip's overall revenue in the quarter.

In May, the company acquired Taiwan-based ISSC Technologies Corp., a fabless Bluetooth SoC design-house. It offers Bluetooth-compliant solutions for mono and stereo headsets, car kits, and MFi adjunct solutions (made for iPhone/iPod/iPad), among others.

End markets such as industrial, automotive, housing, consumer electronics, and personal computing are showing strong growth across the board for Microchip. For example, the strategy in automotive has been to focus on a broad range of auto applications as opposed to a single control item. If purchasing a new S Class Mercedes, one will find around 50 Microchip "chips" inside the car, with about 30 of them being MCUs.

To summarize, the economy's recovery from the 2008/2009 recession is slogging along at about half the rate from past recoveries since WWII. Thus, adding capacity and payroll is a riskier option than automated equipment to increase production and match variations in demand. Also, wage growth has averaged around 2% since the recession, so consumer demand simply doesn't merit large increases in capacity.

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Moving Bluetooth Low Energy Closer to the Mainstream

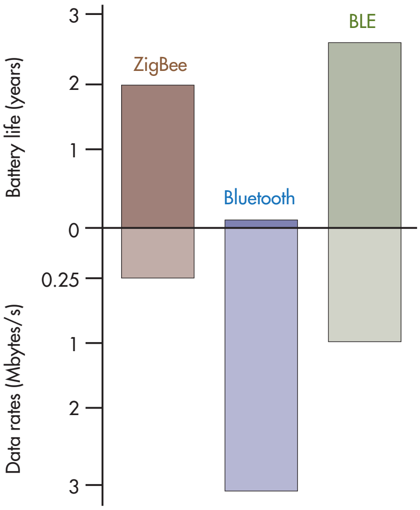
Revisions to the Bluetooth core specification and chip advances will increase the impact of this ultra-low-power RF technology.

Bluetooth Low Energy (BLE) may not be part of your electronic designs just yet, but chances are it will be soon. This wireless connectivity technology has experienced explosive growth over the last three years. Now, it provides low-power connectivity to millions of electronic devices, such as smart watches, fitness trackers, smartphone accessories, and medical monitors. Thanks to upcoming technical enhancements, BLE is poised to become even more pervasive in the next generation of consumer electronics and the emerging Internet of Things (IoT).

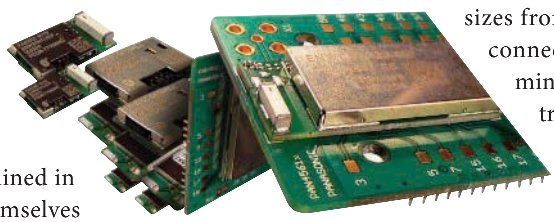
Many of these improvements have been incorporated in Bluetooth 4.1, a recent update to the core specification. These updates include support for more efficient bulk data transfers, greater flexibility in communications between devices, simultaneous dual-mode roles, and the first steps toward IP-based communications. Taken together, these technical improvements make BLE even more attractive from power consumption, performance, and cost standpoints *(Fig. 1)*.

In addition to the changes outlined in Bluetooth 4.1, the BLE chips themselves have been continuously improving as well. Thanks to efficiency improvements, transmission power consumption in the second generation of BLE will fall by about 66% with no loss of range or performance.

BLE isn't the only game in town when it comes to low-power wireless communications, though. ANT and ZigBee have capabilities that overlap with BLE, and both wireless standards have their place *(Fig. 2)*. However, BLE does have significant advantages when you consider its technical capabilities and the fact that it is an open protocol.



1. BLE offers longer battery life and greater data rates than ZigBee.



2. Modules based on Bluetooth 4.1 will be able to support more efficient bulk data transfers, greater flexibility in communications between devices, simultaneous dual-mode roles, and the first steps toward IP-based communications.

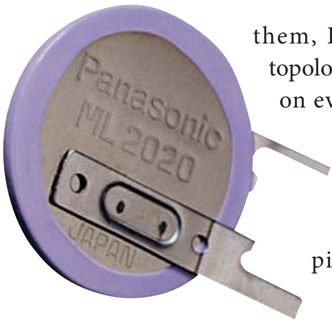
BLE BASICS

For wireless communication devices that have been optimized for low power consumption rather than maximum data transfer rates, BLE fits the bill perfectly. It consumes as little as one-hundredth the average power required by Bluetooth Classic. Also, BLE's peak current draw is as low as 15 mA, compared to 40 mA or more for Bluetooth Classic. With such thrifty current consumption, BLE can run on a single coin-cell battery for months or even years, depending on the application *(Fig. 3)*.

BLE achieves its low power consumption primarily by keeping its radio turned off most of the time. BLE scans only three advertising channels, and its radio awakens only to send or receive short bursts of data, with small packet sizes from 8 to 27 octets. BLE also sets up connections very quickly, which further minimizes the radio's on time. BLE can transmit authenticated data in as little as 3 ms, versus the 1000 ms typical for Bluetooth Classic.

Furthermore, BLE's maximum practical data rate is typically well under 100 kbits/s. So, it's not intended for the continuous data streaming applications possible with Bluetooth Classic, which offers data rates up to 3 Mbits/s.

BLE also has other technology differences with Bluetooth Classic. Chief among



3. Bluetooth Low Energy devices can run for years on a single coin-size battery.

them, BLE uses a star network topology and 32-bit access address on every packet for each slave, which in theory allows billions of devices to be connected at a given time. Bluetooth Classic's piconet topology, by contrast, allows only up to eight devices at a time.

Other BLE technical features include:

- **Optimized Gaussian frequency shift keying (GFSK) modulation:** Like Bluetooth Classic, BLE uses a GFSK modulation scheme. BLE, however, uses a higher modulation index and 2-MHz channels for lower bit error rates that translate to greater range.
- **Adaptive frequency hopping:** BLE technology uses the same adaptive frequency hopping scheme as Bluetooth Classic when devices are connected. Adaptive frequency hopping minimizes interference from other technologies in the 2.4-GHz industrial, scientific, and medical (ISM) band shared by the multitude of wireless devices operating in this spectrum.
- **Robustness:** BLE uses single 24-bit cyclic redundancy check (CRC) on each packet, allowing the header and data fields to detect odd number bit errors as well as 2- and 4-bit errors. The 24-bit CRC, versus 16- or 32-bit CRC, is optimized for BLE's data payload.
- **Tight security:** BLE encryption and authentication is implemented using 128-bit Advanced Encryption System (AES-128), developed by the U.S. government to safeguard data.

Another crucial aspect of Bluetooth 4.1 is its dual-mode capability. While devices such as sensors or phone accessories often use BLE by itself, smartphones and tablets frequently act as wireless hubs that communicate via both BLE and Bluetooth Classic. The Bluetooth core specification makes this dual-mode implementation possible. In essence, dual-mode modules combine the Classic and BLE communication stacks and permit a shared antenna. Single-mode and dual-mode devices are respectively designated as Bluetooth Smart and Bluetooth Smart Ready.

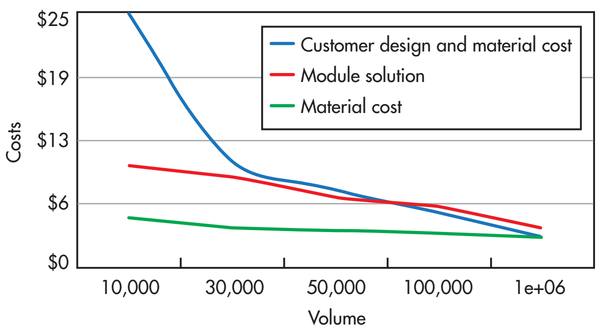
BLE IMPLEMENTATION STRATEGIES

After deciding your applications protocol, the next question is whether you're going to buy a BLE module or build your own discrete solution. Both approaches are viable, but three scenarios clearly favor modules:

- **Low production volumes:** At production volumes under 100,000 units, modules have a clear cost advantage over discrete components (*Fig. 4*). Tally up the development, manufacturing, RF certification, and testing costs of a chip-based BLE implementation, and you will find that the cost typically falls between $150,000 and $200,000. Amortize those costs over volumes under 100,000, and the cost of RF can be prohibitively expensive. At volumes from 100,000 to 150,000, either the module or chip solution can make sense from a total cost standpoint. Over 150,000 units, the balance swings back to discrete solutions.
- **Fast time-to-market objectives:** Modules also have an advantage when time-to-market considerations come into play. Discrete RF applications typically take experienced engineering teams three to six months to develop. By replacing much of the custom programming with an application programming interface (API) and text string command set, modules dramatically streamline the development process. Modules are also pre-certified, which eliminates the time and cost of the certification process. The bottom line is that modules can be dropped into a new product design in a matter of weeks, creating a significant time-to-market advantage.
- **Long lifecycles:** Modules can fight obsolescence in products that have lifecycles that may outlast their ICs. Module designs can incorporate new chips when needed without changes to the legacy pinouts, functionality, size, or firmware interface.

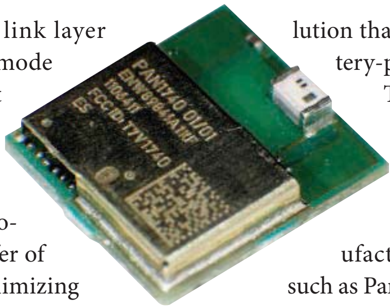
WHAT'S NEXT FOR BLE?

Even as it stands today, BLE technology provides an exceptional solution for devices that require low-power wireless connectivity. But BLE is about to become even more power-efficient, and the enhancements contained in Bluetooth 4.1 will make it easier to design the next generation of wireless devices and the smart objects that will make up the IoT. These improvements to Bluetooth 4.1, which remains backwards compatible with legacy devices, include:



4. At production volumes under 100,000 units, modules have a clear cost advantage over discrete components.

- **Multiple role support:** Changes to the link layer and dual-mode topology will allow dual-mode devices to act simultaneously as Smart Ready hubs and Smart Devices.
- **Data exchange efficiency:** The addition of connection-oriented channels to the Logical Link Control and Adaptation Protocol (L2CAP) enables more efficient transfer of bulk data between BLE devices while minimizing overhead.
- **Connection improvements:** Engineers will have more flexibility in creating and maintaining Bluetooth connections, including automated reconnections.
- **IP-based connections:** Paving the way for the IoT, the new core specification builds the technical foundation for IPv6 communications by adding dedicated Logical Link Control and Adaptation Protocol (L2CAP) channels.



5. Panasonic's PAN1740 nanoPower single-mode Bluetooth Low Energy module consumes 5 mA in transmit or receive mode, enabling the use of coin-cell batteries and decreasing battery requirements by up to 50% compared to current BLE devices.

Look for the enhancements in Bluetooth 4.1 to start appearing in BLE and dual-mode chips and modules early in 2014. Looking further down the road, expect an ongoing BLE revolution that positively affects power budgets for battery-powered applications.

The beginning of this revolution can be seen in the new BLE discrete ICs and modules that are hitting the market. These devices are commonly known as ultra-low power BLE, although individual manufacturers have already adopted trade names such as Panasonic's nanoPower family.

The nanoPower devices reduce transmit and receive current consumption by more than 66% compared to the current generation of BLE devices and by nearly 90% compared to Bluetooth Classic devices (*Fig. 5*). These current reductions have been achieved without range reduction, without transmit power reduction, and without manipulation of the Bluetooth specification. ed

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IAN BEAVERS | CONTRIBUTING TECHNICAL EXPERT

Gigasample ADCs Promise
Direct RF Conversion

Designers working with ever-smaller geometry process nodes clamor for gigahertz ADCs to help simplify architectures and shrink design times.

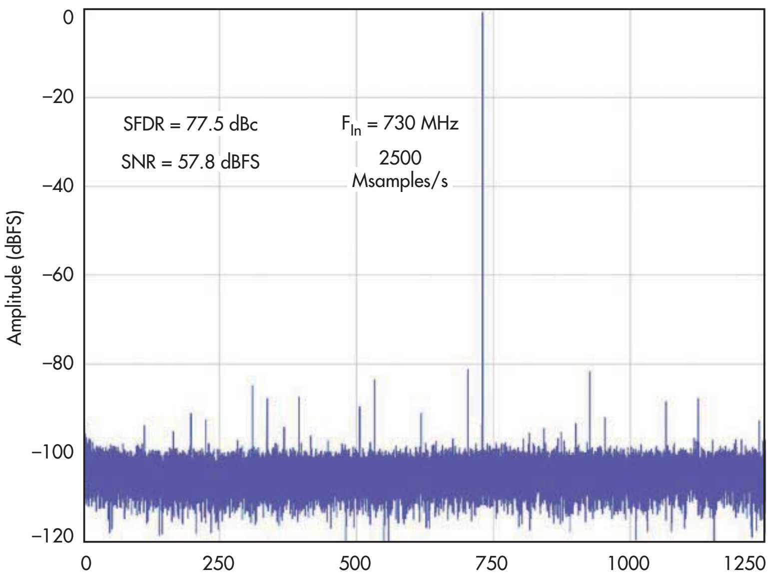
As analog-to-digital converter (ADC) designs and architectures continue to advance using smaller geometry process nodes, a new class of gigahertz ADC products has begun to emerge. ADCs that can directly RF sample at gigahertz rates and above, without the interleaving artifacts, provide new solutions to systems for direct RF digitization of communications systems, instrumentation, and radar applications.

Formerly, these solutions required multiple stages of filtering, synthesizers, and mixers to translate the input signal to a reference frequency that then could be digitized by an ADC at the 100-Msample/s conversion rate. Now, direct RF sampling is achievable with state-of-the-art wideband ADC technology.

Yet keep in mind that speed, although important, is not the only performance factor to consider in your designs. Equal consideration should be given to dynamic range and spectral noise. We will explore these performance dimensions in future articles.

Not too long ago, the only monolithic ADC architectures that could run at gigasample-per-second (Gsample/s) speeds were flash converters with 6 or 8 bits of resolution. They were power hungry and typically could not provide an effective number of bits (ENOB) beyond 7 bits due to the geometric size and power-constraint tradeoffs of flash architectures.

Thus, the only way to sample higher-dynamic-range analog input signals above 1 GHz was to interleave multiple high-speed ADC cores with a sampling clock that had a staggered phase to each core with precise accuracy, or duty cycle. The analog input needed to be split and multiplexed to each ADC, which provided an opportunity for new signal noise to enter the signal chain and reduce the input power. While this method may provide adequate results for some applications, the design was complex and yielded nasty unwanted interleaving artifacts in the output frequency domain that needed digital filtering.

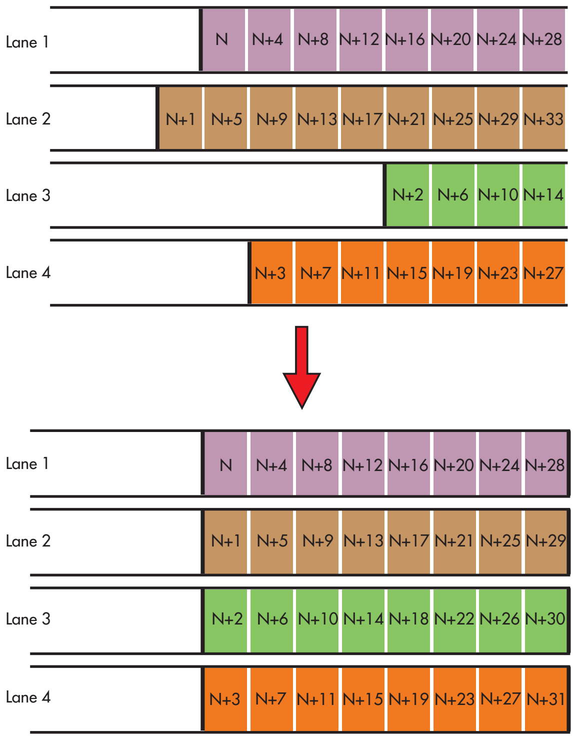


1. The FFT of a wideband 2.5-Gsample/s ADC shows that it's capable of high-performance SFDR without the interleaving artifacts that have historically been problematic in high-speed ADCs.

FAST OR HALF-FAST?

Interleaving "spurs" can be seen in the frequency response of a fast Fourier transform (FFT), where the input offset, gain, bandwidth, and sample timing are not exactly matched across each of the internal interleaved ADC cores. This creates additional planning complexity for the system engineer to pre-determine where interleaving artifacts will be seen in frequency and either avoid or remove them in digital post-processing.

Because each ADC core is discrete, the potential is high for manufacturing mismatching variance among these performance parameters during the life of a system in production. These mismatches cause



2. The JESD204B framing protocol permits significant timing skew between data lanes and within printed-circuit-board (PCB) routing. An FPGA can realign the data and samples with internal buffer delays.

imbalances in the periodicity of the incoming signal, and spurious frequencies are seen at the output of interleaved ADCs.

Proprietary ADC technology now can take advantage of advanced architectures and algorithms that prevent the issues seen in dual and quad interleaved ADCs. Instead of using two interleaved ADCs at half speed, with added artifacts, the performance now can be achieved in a single ADC at full speed without the interleaving spurs. Factory-trimmed algorithms and on-chip calibration ensure that each ADC operates to the expected high performance standards, as opposed to being exposed to the mismatch variances seen from multiple discrete interleaved cores.

When spurious frequencies are observed in an otherwise spectrally pure FFT, this reduces the available spurious free dynamic range (SFDR) of the carrier signal relative to other noise. To improve the SFDR of gigasample-per-second ADCs, new architectures and algorithms are now emerging beyond the use of interleaved cores. This removes the burden for system engineers to have dedicated ADC post-processing routines that must identify and remove unwanted interleaving spurs (*Fig. 1*).

SIMPLIFY THE ROUTING

Multi-gigasample converters with 10-, 12-, or 14-bit resolution generate lots of output data, and in a hurry. The use of low-voltage differential-swing (LVDS) data could require 30 parallel lanes of 1-Gbit/s data for a 2.5-Gsample/s, 12-bit ADC. Handling 30 differential LVDS pairs per ADC can be challenging to route and maintain matched lengths on a system layout. Equivalent data can be sent with only six or eight differential lanes using JESD204B, a high-speed serializer/deserializer (SERDES) standard designed specifically for converter interfaces.

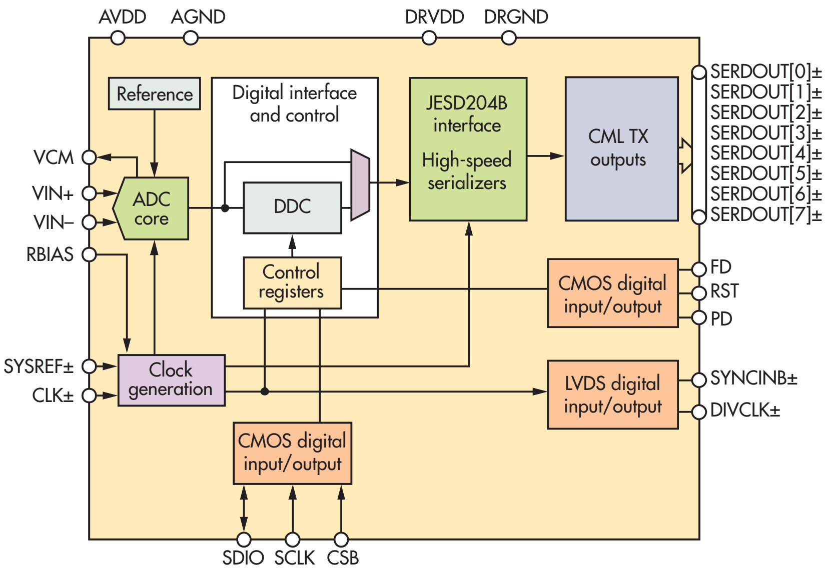
JESD204B provides a means to output data at high speeds on fewer data lines without the matched timing board complexities of many high-speed LVDS lanes. Since the data sent over JESD204B is framed, based on an embedded clock and control characters, the routing of the lower-count serial lanes is much more forgiving of timing skew than LVDS (*Fig. 2*). This removes the need to spend countless hours working to tweak output timing on every I/O of the system PCB.

Additionally, JESD204B offers informational "control bits" of auxiliary data that can be appended to each analog sample to help characterize the downstream processing. In this fashion, trigger time-stamping and over-range conditions can be tagged per sample so that a back-end FPGA can have further intelligence about data alignment and its validity.

OVER-RANGE DETECTION

Adaptive gain algorithms are important in terms of adjusting the amplitude of an analog input signal, since a saturated ADC input essentially makes the system blind in its ability to decipher signals. Ideally, the gain adaptation feedback loop should be as fast as possible. Whether the high-speed ADC output is LVDS-based or uses JESD204B, the added latency of this digital output often can be too long to wait to receive the saturated data, detect the issue, and react to the condition.

One solution to this issue is to use a variable-level comparison within the ADC core itself and directly send an immediate output flag upon occurrence of an over-range condition. This technique bypasses the latency of the longer back-end output stage, which shortens the feedback time to the



3. Analog Devices' AD9625-2.5 12-bit, 2.5-Gsample/s ADC offers better than –75-dBC SFDR performance across a wide bandwidth with a noise spectral density of 150 dBFS/Hz.

amplifier, allowing for a faster adaptive gain cycle. In addition to this "fast over-range detection" output, the over-range samples can be appended with alert bits, using the JESD204B interface, to let downstream system processing make appropriate decisions about the data.

TUNE, FILTER, AND DECIMATE: WHAT TO DO WITH THE DATA

A wideband ADC offers the benefits of broadband sampling, but also may provide more data than needed in some applications. For high-sample-rate systems that don't need to observe a large frequency spectrum, digital downconversion (DDC) allows a sub-sampling and filtering strategy for decimating the amount of data output from the gigasample-per-second ADC. Downstream processing then observes a smaller portion of the frequency spectrum.

DDCs are often implemented after the ADC in the signal chain. This not only consumes more resources in an FPGA, but it also requires the full bandwidth to be transmitted between the ADC and FPGA. Instead of transmitting and processing the sampled data in an FPGA, the DDC filtering can be done within the ADC to see just one-eighth or one-sixteenth of the total bandwidth.

When used in conjunction with a synthesized numerically controlled oscillator (NCO), the precise placement of the converter's DDC filter in the band can be tuned with accurate resolution. This permits a lower output rate and eliminates the need to move and process large amounts of unwanted data on an FPGA. When two DDCs are available, each with a unique NCO, they can alternately be stepped across the spectrum to sweep for expected signals, without loss of visibility. This is often typical in some radar applications.

The AD9625-2.5 12-bit, 2.5-Gsample/s ADC from Analog Devices offers greater than –75-dBC SFDR across a wide bandwidth with a noise spectral density of 150 dBFS/Hz (*Fig. 3*). Proprietary ADI technology achieves this performance without the interleaving artifacts typically seen with gigahertz ADCs that sample above 1.5 Gsamples/s. An optional dual-decimation downconversion filter path with wideband frequency tuners enables observation of only a one-eighth or one-sixteenth swath of full spectrum bandwidth, each with independent 10-bit NCO placement resolution.

The AD9625 uses up to eight lanes of the JESD204B output interface, which relaxes the need for a challenging layout of matched trace routing that's typical of LVDS pairs. In addition, designers can leverage the benefits of JESD204B, such as the low pin-count output, harmonic frame clocking, control bit information per sample, and deterministic latency.

CONCLUSION

The trend toward gigahertz ADC products and systems is being driven, in part, by smaller geometry process nodes that will only decrease in size over the next decade. This will create demand for more ADCs capable of direct RF conversion so architectures can be simplified and design times contained within reasonable limits. This combination of speed, simplified design, and other performance factors like dynamic range and low noise will push advanced wideband ADC technology to the next level and maybe beyond. ed

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PRASAD SAGGURTI | Product Marketing Manager, Synopsys

Apply IEEE 1500 to Integrate Multiple JTAG Chains in SoCs

A hierarchical DFT approach using a standard and unified interface facilitates testing of large designs without adding area or test costs.

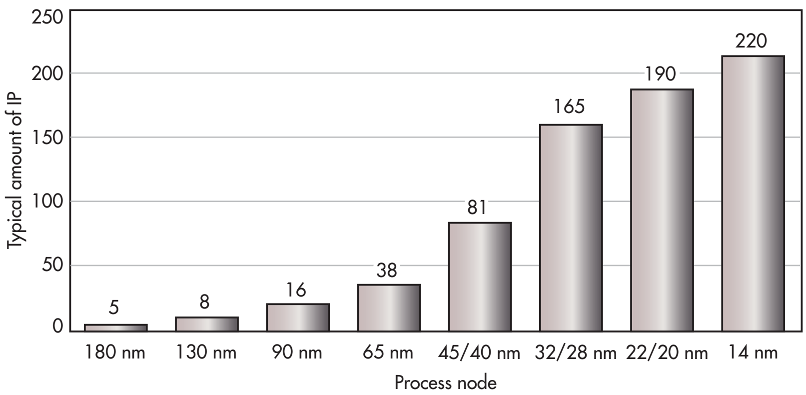
Today's systems-on-a-chip (SoCs) integrate large amounts and varieties of IP that come from multiple sources. Some are developed internally, while others come from one or more external suppliers. Integrating the JTAG chains of these varied IP and the related controllability create challenges for chip designers, which they either just accept, or try to address using ad hoc solutions (*Fig. 1*).

Even if a single chip-design company solely develops the high percentage of IP, there's the challenge of coordinating globally dispersed teams that each work on a piece of the design. Each element of this multitude of IP comes with its own BIST solution and own JTAG connection to the outside world. With I/Os at a premium, test ports are expensive to replicate in pad-limited designs. Designers make tradeoffs by dropping some other I/O, or sacrifice test coverage or controllability of IP. Alternatively, they invest engineering resources to combine these different test chains to conserve die area and reduce the number of JTAG ports.

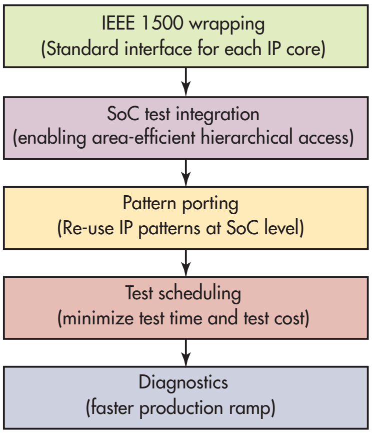
These ad hoc IP test integration approaches are based on in-house scripting and typically rely on direct access to I/Os. This may have been viable in the past when the average design had a small amount of IP whose I/Os could be brought out directly at the SoC level. However, with larger designs, more IP, and a limited number of I/Os, direct testing of the entire design is not an option. Standard top-down design-for-test (DFT) approaches using centralized test management or control add area while also increasing design time and test costs.

One possible solution is to use a hierarchical DFT approach with a standard and unified interface that enables efficient testing of large designs without adding area or additional test costs. Such an approach has the benefit of enabling sign-off at each design hierarchy for integration at the SoC level. As different teams across the world complete different design blocks or hierarchies, each can sign off on test in the same way they would sign off on timing or any physical aspect of the design. The blocks can then be integrated into a single, unified design.

As design size increases, both the test pattern development time and the amount of time required to test the entire SoC grow significantly. Therefore, it is not uncommon for designs to exceed 100 million gates, requiring several weeks to develop chip-level test patterns. In such scenarios, it is useful to be able to reuse the test patterns at the IP or block level, then automatically port those patterns to the SoC level and ultimately test the entire SoC.



1. The amount of IP used in a design expands significantly with each technology node, requiring an efficient solution to integrate and test at the SoC level.



2: IEEE 1500 explains the key steps in an effective hierarchical SoC test solution.

A HIERARCHICAL APPROACH TO SoC TEST

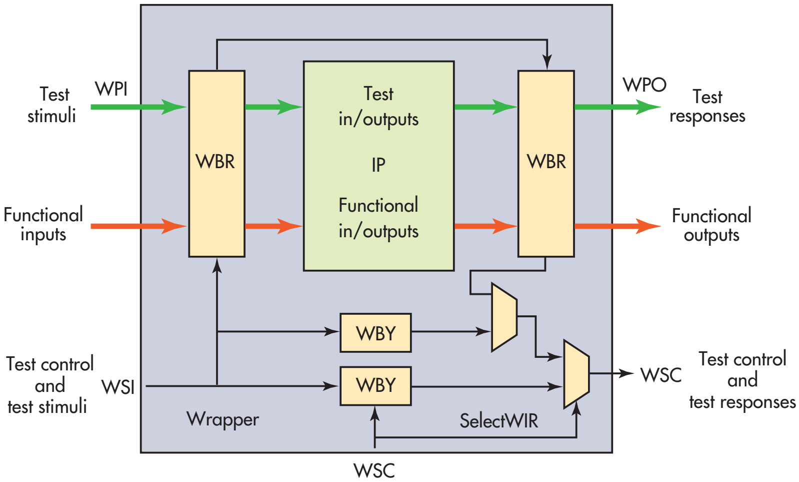
An effective hierarchical test solution should provide an area-efficient and unified framework to control and observe the many IP blocks. It should also enable IP and block-level test-pattern portability to the SoC level, eliminating the need to re-create them. And it should use a well-understood standard as the interface to the IP to enable an ecosystem of support from both IP suppliers as well as test solution providers.

IEEE 1500 is just such a standard. This industry-defined scalable standard architecture enables test reuse and integration for embedded cores and associated circuitry. When used with the widely popular 1149.1 JTAG standard, it provides a convenient solution to the challenge of hierarchical SoC test.

IEEE 1500, "Standard Testability Method for Embedded Core-Based Integrated Circuits," includes serial and parallel test access mechanisms (TAMs), along with a rich set of instructions suitable for testing cores, SoC interconnect, and circuitry. Core test language (CTL) is the official mechanism for describing IEEE 1500 wrappers and test data associated with cores.

While it claims to forego addressing analog circuits and focuses on facilitating efficient test of digital aspects of SoCs, it can be used to interface with analog/mixed-signal IP. Using a standard like IEEE 1500 gives users the flexibility to utilize it in test and debug environments throughout the design lifecycle. By leveraging IP or block-level diagnostics and providing SoC-level diagnostics, it can pinpoint the test that failed and where it occurred, which helps reduce the overall design and production ramp-up time.

There are many steps in implementing a hierarchical SoC test solution. They include IP accessibility, SoC test integration of all the blocks, pattern cre-



3. Within the IEEE 1500 standard interface, WSI and WSO are the wrapper serial input and wrapper serial output from the IP block under test. The WBY is a way to bypass the underlying IP and route the data from WSI directly to WSO or wrapper parallel output (WPO).

ation, test scheduling, and post-silicon diagnostics (*Fig. 2*). The IEEE 1500 standard is the de-facto standard for IP- or core-based test and provides a flexible means of interacting with each of the individual IP and digital logic blocks. Wrapping each IP block with a module that has an IEEE 1500 interface is the first step toward improving accessibility and observability. Since it is an industry standard, a solution that leverages existing IEEE 1500 interfaces also enables a standard communication channel with all IP and blocks from the SoC level.

It's important to have a test solution that can create these interfaces with optional wrapper boundary registers (WBRs) for IP and blocks that don't already have them. SoC designers could potentially create these wrapper modules with WBR registers that capture all states of the underlying IP. However, this could lead to an unnecessary increase in area and power. As with many DFT-related choices, there's a need to optimally balance observability and area/power. In addition to the WBR registers, Wrapper Instruction Registers (WIRs) and Wrapper Bypass Registers (WBY) form a complete test interface to the IP block (*Fig. 3*).

Increasingly, many IP modules come with these IEEE 1500 interface wrapper blocks pre-packaged. Those that don't have available wrapper modules require an automated method of creating these wrappers. This can be done by including a standard description of the IP block, which contains port and pre-stitched chain information, plus the required physical order of the test ports in the wrapper. Once available, an IEEE 1500-compliant wrapper module can be created with appropriate RTL.

Along with this greatly enhanced observability comes the question of whether the SoC designer wishes to grant access to this wrapper—a question of security. So any automated way of building these wrappers should also provide a post-silicon mechanism for summarily shutting off the access.

Much research has been published on ways to build these wrappers. However, there's still the challenge of easily connecting the typically large number of wrappers without negatively impacting the die area or test time. The ideal solution will create an efficient hierarchical IEEE 1500 network to integrate the individually wrapped IP blocks, and provide hierarchical control using modular test access control blocks.

While some have proposed a binary-tree-like hierarchy of connections, often a ring or daisy-chain style

LINEAR TECHNOLOGY

DESIGN NOTES

Increasing Output Voltage and Current Range Using Series-Connected Isolated µModule Converters – Design Note 530

Jesus Rosales and Willie Chan

Linear Technology's isolated µModule® converters are compact solutions for breaking ground loops. These converters employ a flyback architecture whose maximum output current varies with input voltage and output voltage. Although their output voltage range is limited to a maximum of 12V, one can increase the output voltage or the output current range. The solution simply involves connecting the secondary side of two or more isolated µModule converters in series.

The LTM®8057 and LTM8058 UL60950-recognized 2kV AC isolated µModule converters will be used to demonstrate this design approach, which can also be applied to the LTM8046, LTM8047 and LTM8048. Let's assume an output of 10V at 300mA is desired from a 20V input. Reviewing the maximum output current curve from Figure 1, we notice that a single LTM8057 is insufficient to meet the output current requirement under these conditions.

However, upon noticing that a single LTM8057 can deliver 300mA at 5V from a 20V input, a solution becomes apparent. Since the output voltage is isolated from the input, the outputs of two LTM8057s set at 5V can be connected in series to achieve a 10V output at 300mA (Figure 2).

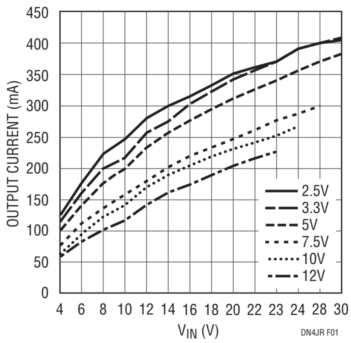


Figure 1. Typical Maximum Output Current vs Input Voltage

The same circuit in Figure 2 can also be used to increase the output voltage range when more than 12V is needed. By adjusting the feedback resistors to provide a 7.5V nominal output voltage, the combined output voltage has increased to 15V. The output current capability for the 15V is the same as that of the individual 7.5V modules (Figure 3).

The circuit shown in Figure 2 supports a third option: providing positive and negative outputs with a common return. The return node for both outputs is the common connection in the middle of the output stack. With this approach the circuit in Figure 2 would have 5V and –5V outputs. Each output can be of different magnitude, since the output voltages for each converter are determined independently.

Low Output Noise Series-Connected Converters

The low output spectrum noise advantage of the LTM8058 with its integrated LDO post regulator can still be maintained with series-connected outputs. Figure 4 shows the schematic for two LTM8058s with V_{OUT2}, the output of the LDO connected in series for $10V_{OUT}$. Figures 5 and 6, respectively, show the output noise spectrum of the LTM8058 under a 100mA load at 10V with the LDO outputs connected in series (Figure 4 schematic) and the flyback outputs connected in series.

Linear Technology's isolated µModule converters provide a simple and compact solution for isolated power at regulated output voltages. The LTM8057 and LTM8058 successfully demonstrate that the output capabilities of isolated µModule converters can be increased by adding one or more isolated modules with the outputs tied in series while still preserving the output noise characteristics.

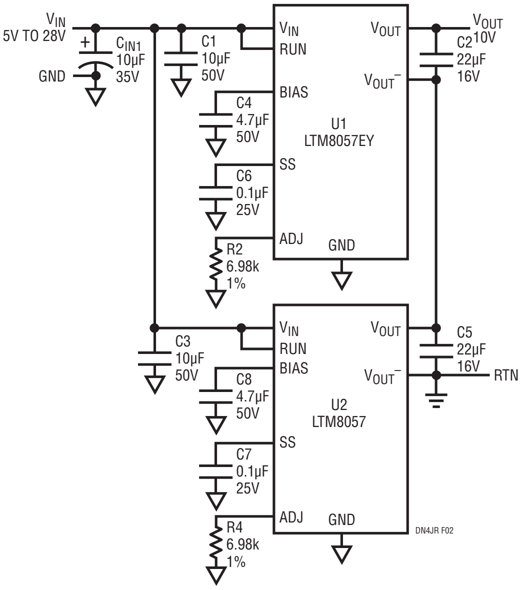


Figure 2. Two LTM8057 Modules with Outputs Connected in Series, Supporting a 10V, 300mA Output Application from $20V_{IN}$

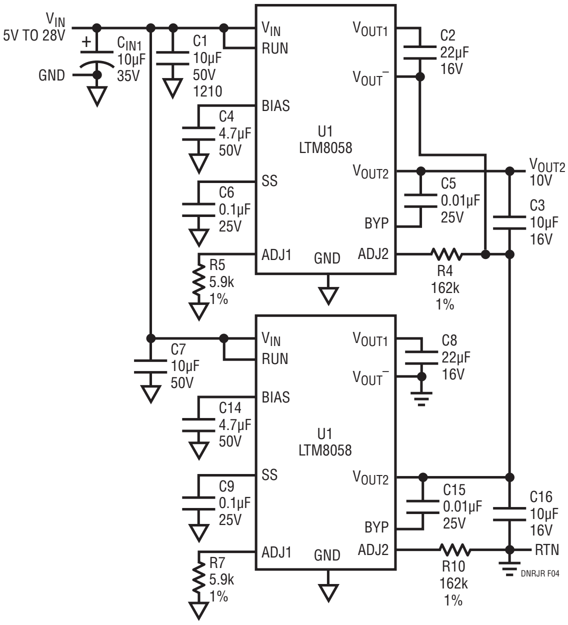


Figure 4. Two LTM8058 Modules Connected with V_{OUT2} in Series for $10V_{OUT}$

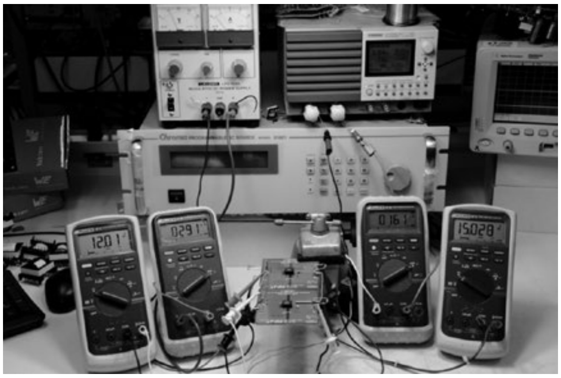


Figure 3. Two LTM8057 Modules with Outputs Connected in Series Deliver More Than 160mA at $15V_{OUT}$ from $12V_{IN}$

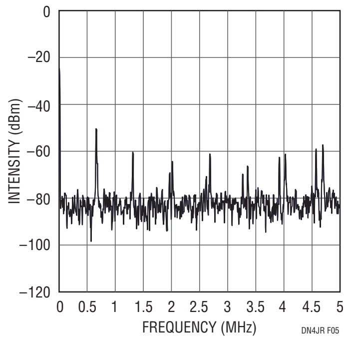


Figure 5. Noise Spectrum for Two LTM8058s with the LDO Outputs Connected in Series Under a 100mA, $10V_{OUT}$ Load

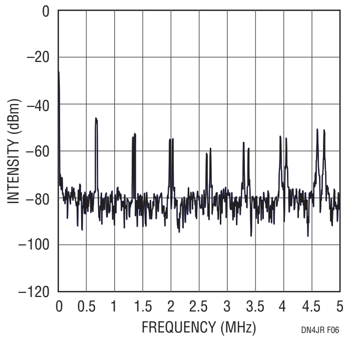


Figure 6. Noise Spectrum for Two LTM8058s with the Flyback Outputs Connected in Series Under a 100mA, $10V_{OUT}$ Load

Data Sheet Download

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of connections between the wrapper modules creates the most efficient connectivity scheme. By using a ring or daisy-chain architecture combined with modular test access control, the design hierarchies can have a single IEEE 1500 interface instead of an interface for every IP at each design hierarchy level, which minimizes top-level routing and congestion.

There's also a question of whether to integrate these wrappers at the RTL or at the gate level. Integrating at the RTL level provides greater flexibility and is easier to maintain. It's also important to automate this integration, rather than use manual, error-prone, ad hoc customized makefiles.

After assembling the SoC, creating the test infrastructure, and integrating all IP blocks, it's time to create SoC-level test patterns. A solution that allows porting of IP test patterns from the block level eliminates the need to create new patterns at the SoC level. In such an approach, the test patterns with the IP would be ported to the sub-chip or design block hierarchy with the help of the IEEE 1500 network and modular test access control.

Similarly, when integrating the sub-chip within the SoC environment, those sub-chip level patterns are ported to the top level. This allows test engineers to reuse the IP-level patterns, verify the patterns, and do a test signoff at each of the design hierarchies at which they are working. Automatically porting the patterns to the SoC level, where they can be directly applied to the tester, saves development time and resources. In addition, the increased controllability and observability at the periphery of the IP and logic blocks with the IEEE 1500 wrapper significantly improves test QoR and diagnostics.

An effective hierarchical test solution should also be able to balance test time against power and pin count. Flexible test scheduling is fundamental to minimizing test cost. Poor scheduling could lead to either high power consumption during test or increased test time and cost. The ideal hierarchical solution would enable programming of any possible schedule to test different IP modules in any serial or parallel combination. Thus, designers could optimally balance test time and power consumption. A solution using less pins at the top-level—e.g., JTAG TAP—can help further reduce test time by enabling multi-site or concurrent testing of multiple die.

A common interface between the memory BIST solution, hierarchical test solution, and JTAG port greatly simplifies SoC-level test-pattern creation/scheduling. For easy portability between testers, these patterns should be generated in Standard Test Interface Language (STIL) or Waveform Generation Language (WGL) format. The Serial Vector Format (SVF) also has been used to transport boundary-scan vector information.

Enabling an interactive diagnostic solution allows chip designers to move from tester to laptop, and lets system architects conduct any software debug or system in a more convenient location. It's particularly important to use a prevalent standard interface, such as USB and JTAG, between the laptop and chip, due to the availability of USB-to-JTAG cables. ed

Offset Compensation Technique Improves Bridge-Configured Sensor Performance

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STRAIN GAGES AND pressure sensors usually are connected in a bridge configuration. These sensors have a typical full-scale sensitivity of 3.0 to 5.0 millivolts per volt (mV/V) of excitation, though some may be as low as 1.0 mV/V. This level is intended to improve linearity while minimizing mechanical stress in the sensor, but at the expense of the signal level.

One way to increase the signal level is to increase the excitation level. But if the system works from a single 3.3- or 5.0-V supply, this may not be an option. Usually, substantial gain must be added to get the signal into the range of a reasonable analog-to-digital converter (ADC).

Most systems digitize sensor data, then either display it or perform some control function. That means a microcontroller is available to control gains and connections. The op amps inside typical microcontrollers have input offset voltages that are higher than what can be used directly in some applications.

For example, with a 5.0-mV/V sensor and 5.0-V sensor drive, full scale is 25.0 mV. An instrumentation amplifier built using op amps with input offset of 3.0 mV uses up to 24% of the available range. Further, an offset drift of 15 µV/°C yields an error of 1.8% of full scale over as little as 30°C of range, even if you calibrate out the offset at startup.

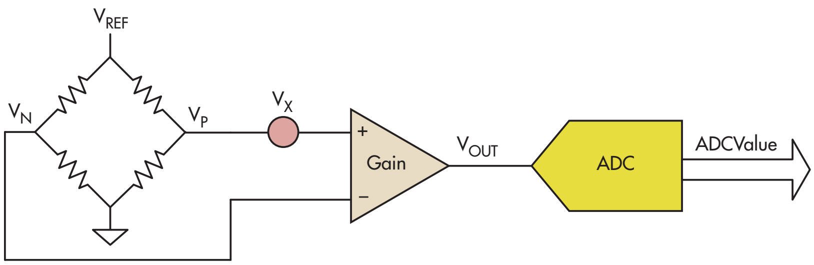
There is a solution to the offset, drift, and low-frequency noise problem by taking advantage of the switches on the microcontroller analog inputs to switch signals around to subtract the offset voltage. The Cypress PSoC, for example, has multiplexable inputs to differential and instrumentation amplifiers.

A model shows the standard connection with the offsets summed into a single voltage source, followed by a differential (or instrumentation) amplifier and the ADC *(Fig. 1)*. For this system, the output voltage is:

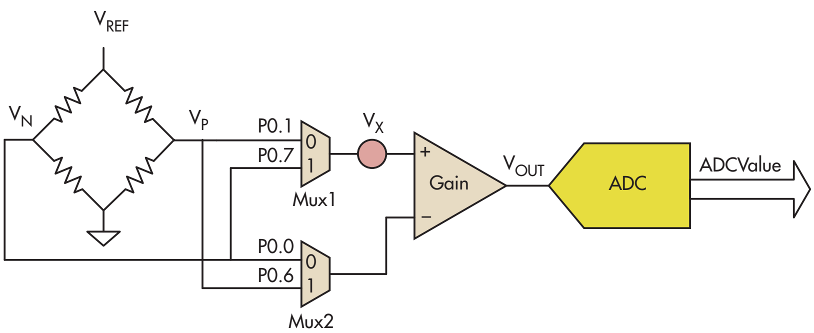
$$V_{Out} = Gain(V_P + V_X - V_N)$$
$$ADCValue = \frac{V_{Out}}{V_{Ref}} 2^n \quad (1)$$

where n is the bit resolution of the converter. A differential multiplexer is next added between the strain gage and the amplifier input *(Fig. 2)*. The input pairs are reversed, but the offset voltage stays at the same place in the loop.

When Mux1and Mux2 are set to input 0, the instrument amp and ADC outputs are:



1. The standard bridge-to-ADC model sums the offsets into a single voltage source. The signal plus offset goes through a differential/instrumentation amplifier prior to digitization.



2. The addition of a multiplexer allows for eventual cancellation of the offset voltage error by reversing the differential input signal but not the associated offset voltage.

$$V_{Out0} = Gain(V_P + V_X - V_N)$$
$$ADCValue0 = \frac{Gain(V_P + V_X - V_N)}{V_{Ref}} 2^n \quad (2)$$

When Mux1 and Mux2 are set to input 1, the instrument amp and converter outputs are:

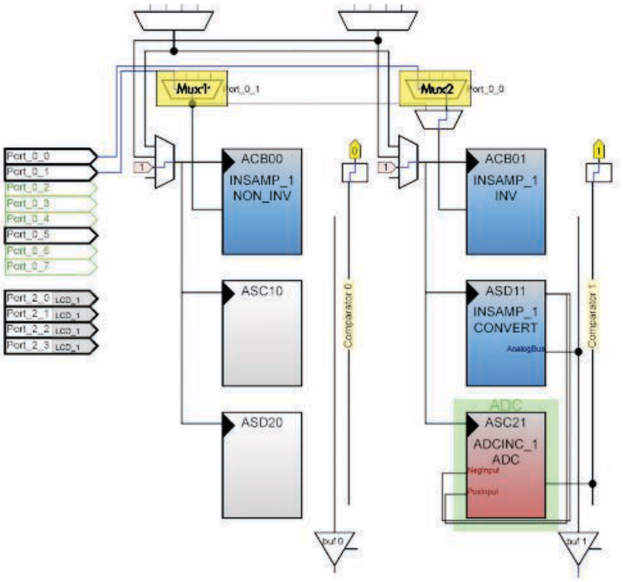
$$V_{Out1} = Gain(V_N + V_X - V_P)$$
$$ADCValue0 = \frac{Gain(V_N + V_X - V_P)}{V_{Ref}} 2^n \quad (3)$$

When output 1 is subtracted from output 0 (in software), the result is:

$$ADCValueDiff = \frac{Gain(V_P + V_X - V_N - (V_N + V_X - V_P))}{V_{Ref}} 2^n$$
$$ADCValueDiff = \frac{2 * Gain(V_P - V_N)}{V_{Ref}} 2^n \quad (4)$$

As a result, the offset voltage is subtracted out, and the sensitivity is doubled. If the offset voltage drifts, it is still cancelled out. Adding a low-pass filter reduces the low-frequency noise by the ratio of the filter bandwidth to the sample rate.

The filter can be one of several: a decimating-average type using a finite impulse response (FIR), a running-average type using an FIR, or a running-average type using an infinite impulse response (IIR). The decimating average uses the least RAM, but has the slowest update rate. The running average FIR yields a clean signal but uses a lot of RAM. The IIR is more computationally complex but yields a lot of filter roll-off for minimal amount of RAM.



3. With the PSoC design tool, you can set up the necessary circuit elements in the required configuration to implement the offset-cancellation scheme.

Chopper-stabilized op amps are available with very low offset voltages, but they don't eliminate any offset error from the ADC. The circuit performs the functions of a chopper-stabilized amplifier—namely, high gain and very low offset. It includes the ADC as well, resulting in a low-offset system where the offset of the ADC is cancelled out at the same time as the offset of the instrumentation amplifier.

This circuit can be implemented with low-cost op amps, a multiple-channel two-input multiplexer (e.g., CD4053), a suitable ADC, and a few resistors. More easily, it drops into a Cypress PSoC1 part such as the CY8C24423, which has the multiplexers, an instrumentation amplifier, and an ADC (either an incremental or a delta-sigma). The PSoC1 design requires no external parts. PSoC's design tool, PSoC Designer, shows the implementation *(Fig. 3)*.

The positive bridge output is connected to P0.1 for mux_1 and P0.0 for mux_2. The negative bridge output is connected to P0.7 for mux_0 and P0.0 for mux_1. The muxes are switched in software using the user modules' standard application programming interfaces (APIs). It takes about 20 lines of C code to control the muxes and get data, and a few more to display or send it. The instrumentation amplifier is brought out on P0.5 so you can see the amplified input toggling between its normal and inverting values.

To convince yourself that it works, short the inputs together at some mid-range value. Then, in software, average and stream out the V_P value (the value of the differential amplifier's input offset voltage) and the difference value. The ADCValueDiff is the offset-cancelled version.

Unless you got lucky and happened to pick op amps with super-low offset voltage, the difference will be clear. A quick test on four CY8C24423 chips showed that the instrumentation amplifier offset averaged 1.82 mV, which is well within the device spec. With the offset cancellation in place, the system offset was less than 6.0 µV. This is an offset reduction of a factor of 300, done with cheap parts and easy connections.

This circuit also works well with PSoC3, PSoC5, and PSoC4 series parts. The differential amplifier is constructed out of back-to-back programmable gain amplifiers (PGAs) in PSoC3 and PSoC5. PSoC4 requires resistors to set the gain in the differential amplifier. The differential amplifier outputs in these designs feed a differential ADC, eliminating the need for the third op amp in an instrument amp and a single-ended ADC.

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Audio Function Generator Provides Three Simultaneous Square, Triangle, Sine Waveforms

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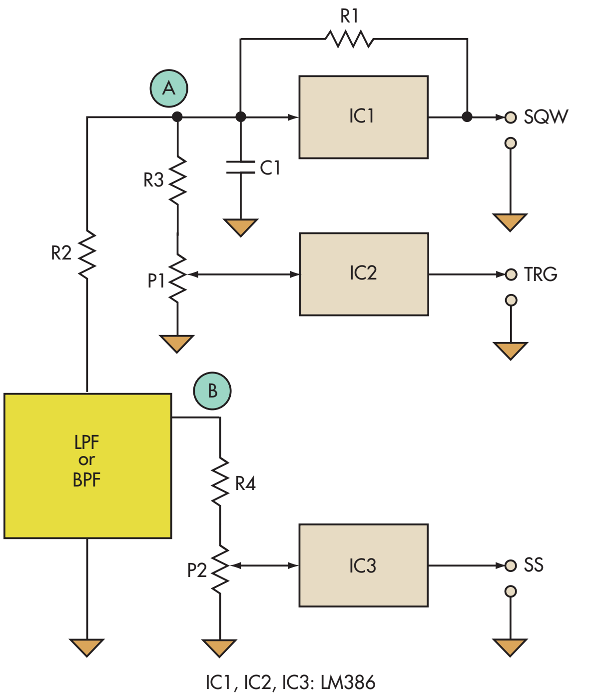
THIS SIMPLE, ROBUST, and low-cost signal generator, based on the LM386 power amplifier IC, provides a trio of audio-band signals with three different simultaneous outputs at the same frequency: square/rectangle (SQW), triangle (TRG), and sine (SS).

Each output can drive loads such as long cables, transformers, auto-transformers, audio couplers, or active loudspeakers. The amplitude of each output can be adjusted independently. The outputs can be connected to ground, the power supply, or between them for short time without damage.

The generator is useful for checking electrical or audio installations, audio or mains transformers, and similar components. The suggested maximum load for each output is 8 Ω, but lower-impedance loads also can be handled with some reduction in output. As a further convenience, the user can switch the output triplet between two frequencies.

The simplified block circuit shows IC1 operating as a square-wave generator with frequency determined mainly by R1 and C1 *(Fig. 1)*. The signal in point A is approximately triangular with amplitude of about 0.35 V p-p and a supply rail of +9 V.



1. The block diagram shows how three low-power audio amplifiers (LM386) are configured to implement a triple-waveform generator at one of two selectable frequencies.

The triangular signal goes to amplifier IC2 via potentiometer P1. It is also routed to the low-pass filter (LPF) or a band-pass filter (BPF). The quality of that filter determines the quality of the sinusoidal signal, which IC3 amplifies.

The 3-dB frequency of the LPF should be equal to or lower than the frequency of the triangular signal at point A. With a BPF, the central frequency or the resonant frequency should be approximately equal to that of the signal at the same point. In the simplest case, these can be second-order low-pass RC, RC band-pass, LC band-pass, or LC low-pass filters. IC3 amplifies the sinusoidal signal at point B, after potentiometer P2.

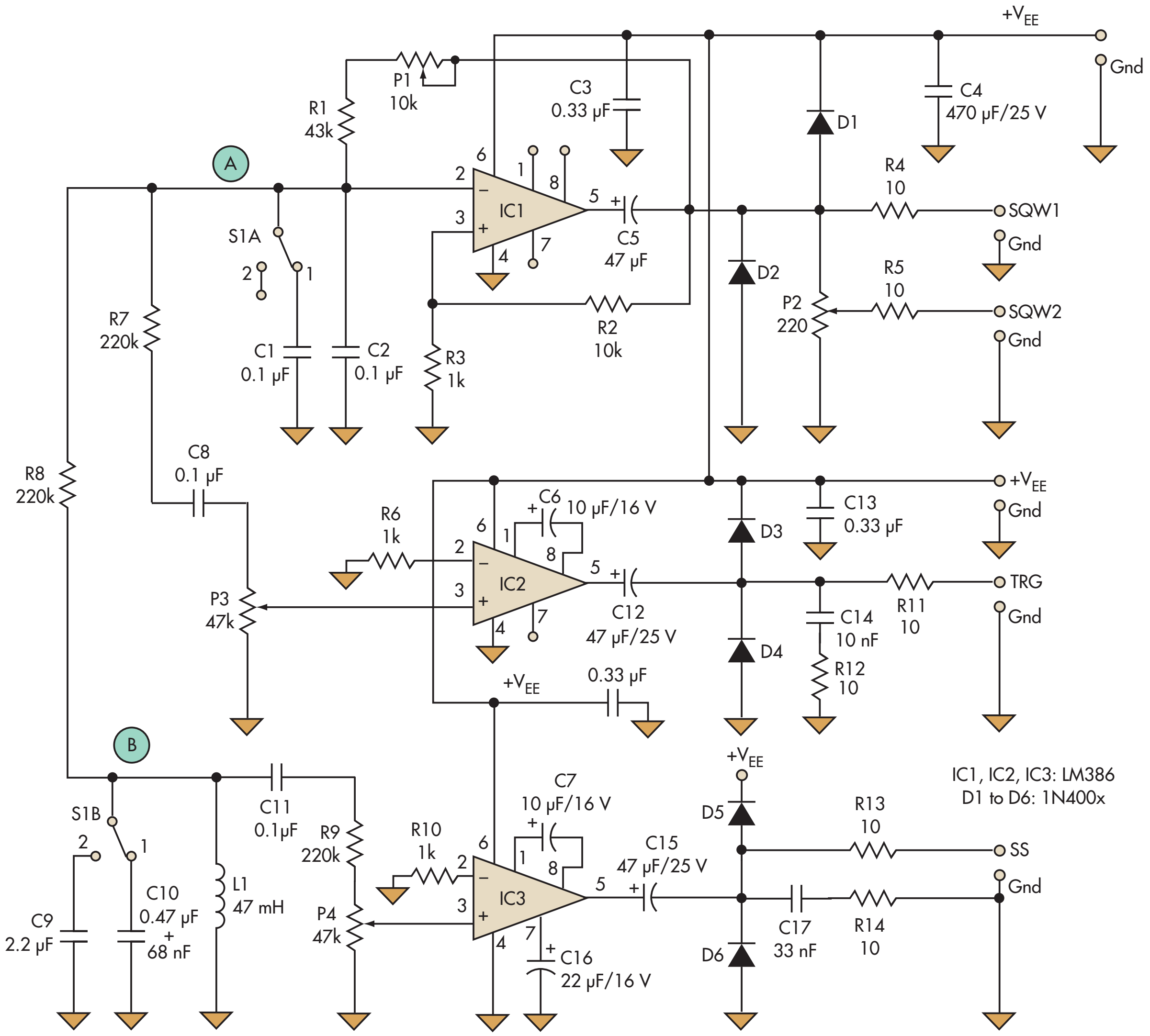
IC2 and IC3 are used with a gain of 200. This may result in trapezoidal-like signals at outputs TRG and SS when the input signals are too large and the amplifiers are saturated. If this is a problem, then the gains of IC2 and IC3 can be set to approximately 50 as described in the IC data sheet.

The actual circuit of the generator is built with three LM386 ICs. It produces two frequencies, selectable via double-pole double-throw (DPDT) switch S1 *(Fig. 2)*. When the switch is in position 1, the frequency is 1 kHz. In position 2, it is 500 Hz. Trimmer potentiometer P1 is used to fine-adjust the nominal 1-kHz frequency, while the 500-Hz output is not adjustable, for simplicity.

IC2 amplifies the triangular signal from point A via potentiometer P3. It also goes to the band-pass LC filter built with C9 (or C10) and L1. The resonant frequency of L1/C9 is around 500 Hz, while the resonant frequency of L1/C10 is 1 kHz, with C10 implemented as two capacitors in parallel (0.47 µF + 68 nF). The resonant frequency F of the LC tank can be approximated using the standard formula $F = 1/(2\pi \sqrt{LC})$.

Depending on the position of the wiper of the P3, output TRG will be triangular or trapezoidal, with the maximum amplitude limited by the power supply. The square-wave signal is available at the outputs SQW1 (non-adjustable amplitude) and SQW2 (adjustable amplitude with the potentiometer P2). The sinusoidal signal at point B is connected via potentiometer P4 to be amplified by IC3. The amplified signal is available as output SS.

The internal noise of the chosen LM386 may not specified, so its gain should be minimized. The values of R1, R7, R8, R9, P3, and P4 also should be minimized to minimize



2. The frequency of the simultaneous square, triangle, and sine waveforms can be switched between two values (here, 500 Hz and 1 kHz) via DPDT switch S1, which selects the capacitor for the resonant LC tank.

noise. The LM386 amplifier is available from different sources with some variations in specifications, such as an operating supply range from 4 to 12 V or 5 to 18 V. Typical and maximum output power is a function of the LM386 chosen, as well as operating voltage and load impedance.

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A Supply Chain That Improves Damaged Lives

Makers of prosthetics for military applications demand high-quality products and specialized solutions from supplier partners.

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR
JOE NOWLAN | CONTRIBUTING EDITOR

MICHAEL FILLAUER LOOKS FOR suppliers that can deliver the quality materials and electronic components his company needs in the small quantities his industry demands. Fillauer is president of Fillauer LLC, a manufacturer of orthotics and prosthetic devices, many of which are designed to help wounded soldiers who have lost limbs in combat. The wars in Iraq and Afghanistan have produced thousands of such injuries; helping those soldiers live more normal lives has become a key mission for companies such as Fillauer LLC and its supply-chain partners. Whether that means supplying the materials and parts that go into the devices, researching and developing the best new products, or bringing those end solutions to customers, the supply line for supporting today's military is made up of a series of specialized companies.

According to a recent Associated Press article detailing the high survival rate from battlefield injuries in the U.S. military today, "about 50,000 military personnel have been injured in the conflicts in Iraq and Afghanistan, with 16,000 hurt so severely that they likely would not have survived previous conflicts." Innovations and advancements in new prosthetic devices are giving those wounded warriors a better chance at a near-normal life than ever before, Fillauer explains, pointing to new materials and advancing technology that are driving the industry forward.

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For Mouser, Mexico and Brazil Lead the Way in Latin America

U.S. electronics distributor still growing in Latin America despite slowing economic conditions.

THOUGH BUSINESS CONDITIONS IN Latin America have slowed recently, some U.S.-based distributors are continuing along the growth path they have developed there in the last few years. Mouser Electronics, for instance, expects to see substantial growth in the region this year and is expanding its presence with more refined marketing programs

"My forecast for Latin America is that we'll continue on the track we're on and finish up total growth at over 35% for the year," says Mouser Electronics' Steve Newland, senior vice president of Americas sales and global sales operations.

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"We certainly see a lot of demand for the high-activity, carbon-fiber, dynamic-response feet that will allow individuals with amputations to be able to run, to do outdoor activities, to work out," explains Fillauer, who is a Certified Prosthetist and Orthotist (CPO). "And for some soldiers, even to return to active duty."

Depending on their age and the extent of their injuries, many returning veterans want to do more than just walk. This increases the demand for the more sophisticated and durable prosthetics Fillauer points to.

"People see these examples of individuals who return to active duty or they return to their sport after amputation," he says. "So they want that same technology."

A COLLABORATIVE EFFORT

Developing that technology is a continual and collaborative process, Fillauer adds, pointing to the supply-chain partners Fillauer LLC works with, including distributors of electromechanical and electronic components. He says Fillauer LLC relies on such companies—especially some of its newer suppliers—for component and material recommendations when enhancing or developing new products. This is on top of more routine demands for high-quality products, on-time delivery, and the ability to meet small-quantity needs.

"Because the prosthetics industry uses smaller quantities than what may be used in the automotive and aerospace industries, it is important that we partner with suppliers that are willing to sell to us in these quantities," Fillauer says.

He adds that improving quality and advancing the devices is the ultimate goal of the partnership.

"The challenge is always the need to make it lighter and smaller," Fillauer says of prosthetics, emphasizing an industry-wide trend. "For our myoelectric prosthetics [which use the existing muscles in the residual limb in order to control its different functions], the batteries need to last longer and the microprocessor needs to function just like the real hand. Technology has really played a pivotal role in the expectations for prosthetics."

Fillauer adds that patient testing is a critical part of the development process as well, and that Fillauer partners with practitioners at its own patient care facility and around the world before introducing a product to the market. And then there are the standards that must be met.

"All of our products, outside of tools and equipment, must be FDA approved and CE marked," he says. "Our equipment must meet UL and EU standards."

"Because the prosthetics industry uses smaller quantities than what may be used in the automotive and aerospace industries, it is important that we partner with suppliers that are willing to sell to us in these quantities," says Michael Fillauer, president of Fillauer LLC, a maker of prosthetics and orthotics.

APPLYING THE TECHNOLOGY

Fillauer LLC and its associated companies work directly with patients to deliver cutting-edge solutions. Other companies on the front lines of delivering such solutions include distributors of orthotics and prosthetics that specialize in finding the right solution to a patient's needs.

"For the active patient, like those returning from military service, we see a high utilization of prosthetic feet with carbon fiber that offer benefits like … vertical shock absorption and torque absorption," says J. Anna Avakian, with orthotics and prosthetics distributor SPS, Alpharetta, Ga. "Many patients want to return to activities above and beyond walking … [We]have technology to allow them to do that, much more than in generations past."

John Cronin concurs. Cronin is the sales and marketing manager at Cascade-USA, an independent orthotic and prosthetic distributor based in Chico, Calif.

"Carbon fiber has been the material of choice for feet," according to Cronin. "[And] composites are gaining ground also for feet. Titanium is the optimum for its components."

Once a prosthetic device leaves the factory or warehouse, it is still a long way before that device is successfully implemented.

"As a distributor, we are always working with suppliers to keep costs in check so our customers, the prosthetists who are working with the patients directly, can have quality components at the best possible price," Avakian adds.

Making sure the prosthesis fits comfortably and that the amputee learns how to walk, and maybe run, all over again is the goal of companies such as Medical Center O&P, located in Silver Spring, Md.

Ian Fothergill is clinical development manager at MCOP, which he describes as "a clinical provider. We work directly with amputees and provide them the care that they require," he explains. MCOP works with many amputees, including those at the Walter Reed National Military Medical Center in Washington, D.C.

The rehabilitation and prosthetic advances can create a challenge for prosthetists such as Fothergill who may have to temper rehabilitation expectations. While soldiers should set goals, they shouldn't plan on running marathons or climbing tall mountains in their first year of rehab.

"If they can use the prosthesis as a main mode of mobility during waking hours, we've succeeded," Fothergill says.

Visit *www.globalpurchasing.com* for more on this topic. ■

Mouser

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and additional staff focused on Mexico and Brazil, in particular.

"[Latin America] is still a small part of our business in the grand scheme of things, but it's fast-growing," says Mouser's Steve Newland, noting that the region still represents less than 1% of the distributor's global sales. "My forecast for Latin America is that we'll continue on the track we're on and finish up total growth at over 35% for the year."

Mouser serves the same design engineering and procurement customer base in the region that it serves elsewhere, focusing on delivering the newest technology in any quantity "really quick," says Newland, senior v.p. of Americas sales and global sales operations.

The company is building business with new customers in a wide range of industries, Newland adds, despite the many and varied challenges of doing business throughout the region. Newland and his colleague Mauro Salomao, the company's Latin America sales manager, point to the often-changing business rules and regulations in countries throughout Latin America combined with the need for cultural and language adaptation as two examples.

Those challenges have been exacerbated recently as Brazil's economy has slowed and following slower conditions in Mexico last year. The Manufacturers Alliance for Productivity and Innovation (MAPI), which represents global manufacturing companies, revised down its outlook for Brazil's economy this year and next, citing a struggling manufacturing sector. This year's World Cup events did not provide the boost MAPI had expected, with analysts predicting a manufacturing contraction in the second quarter of this year and a weak third quarter at best, according to Fernando D. Sedano, a MAPI economic consultant based in Argentina.

In Mexico, sluggish growth in 2013 has been followed by an uptick this year, led by the automotive sector, Sedano says. Mexico's outlook is rosier than Brazil, with growth in automotive, basic metals, and other areas along the industrial supply chain, Sedano adds.

Overall, MAPI forecasts Latin America's factories to expand output by 2% in 2014 and a "still shy" 2.1% in 2015. The fastest-growing segments will be motor vehicles, computing and electronic equipment, basic metals, and other transport equipment, the group says.

"Business conditions are challenging in all of the Latin American countries in different ways, but we don't seem to be constrained right now by [those economic challenges]," explains Newland. "We're picking up share in Latin America regardless of any economic tailwinds." ■

BILL WONG | Embedded/Systems/Software Editor
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PCI Express Mini Cards Provide Module Expansion

Stackable boards like PC/104 and its PCI Express variants offer developers a plethora of I/O expansion options. While compact, these boards are large compared to many module-based systems. These larger boards also often are overkill when it comes to peripheral expansion. Designers, then, have looked to deliver more compact expansion options like the PCI Express (PCIe) MiniCard (MiniPCIe).

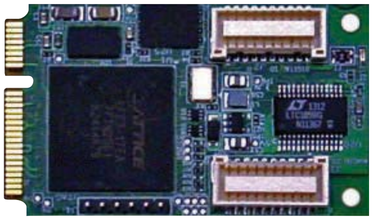
The MiniCard originally was designed for laptop expansion, but it has since been used in a variety of platforms. It comes in full-size and half-size form factors. Also, it has been hijacked to utilize other interfaces such as SATA for mSATA storage devices. The standard definition includes a single PCI Express lane, USB 2.0, and an I2C interface. The initial devices targeting laptops utilized the PCIe interface, but embedded solutions have taken advantage of the other interfaces as well.

One module/MiniCard combination, Versalogic's Falcon embedded processing unit (EPU), has a MiniCard socket on top (see "EPU Provides Smaller, Lighter Embedded System" on electronicdesign.com) that can handle cards like Versalogic's VL-MPEe-A1 eight-channel, 16-bit analog-to-digital converter (ADC). The PCIe interface easily handles the 100,000 samples/s from the tiny board. The EPU also can manage mSATA and USB-based MiniCards (*Fig. 1*).

Diamond Systems' line of MiniCard peripherals includes the DS-MPE-DAQ0804 (*Fig. 2*). This compact board has an eight-channel, 16-bit ADC with a 2048-sample FIFO. It also has four 16-bit analog outputs, 14 digital I/O pins, four 24-bit pulse-width modulation (PWM) timers, and eight 32-bit timers. This is the same peripheral complement that used to be available only on larger, PC/104-style boards.

MiniPCIe sockets also have been cropping up in standard-size motherboards, allowing expansion without resorting to larger PCI or PCI Express cards. For example, several of Super Micro Computers' (Supermicro) Mini-ITX form factor motherboards sport MiniPCIe sockets that handle mSATA

1. Versalogic's Falcon EPU hosts the VL-MPEe-A1 eight-channel, 16-bit ADC MiniPCIe card. The EPU also can handle mSATA and USB-based MiniCards.



2. Diamond Systems' DS-MPE-DAQ0804 has an eight-channel, 16-bit ADC with a 2048-sample FIFO. It also has four 16-bit analog outputs, 14 digital I/O pins, four 24-bit PWM timers, and eight 32-bit timers.

3. SuperMicro's X10SLV-Q Mini-ITX motherboard has a MiniPCIe socket in addition to a x16 PCI Express socket.

and MiniPCIe boards like the X10SLV-Q (*Fig. 3*).

Of course, the MiniCard is small enough to fit on other expansion cards like WinSystems' PXM-MiniPCIe. This SUMIT-ISM module has a MiniPCIe connector. The USB and PCI Express lane is connected to the SUMIT connector, which links the module to the host on the main motherboard. The board also has a pair of USB connectors and two RF antenna connectors linked to the MiniPCIe socket. VersaLogic's VL-EPM-P2 PC/104-Plus expansion board has two MiniPCIe sockets but without the other connectors found on the WinSystems board.

The MiniPCIe socket has been used for proprietary interface combinations as well. Cards based on these interfaces may look like other MiniPCIe modules, but they will only work on matching systems. ed

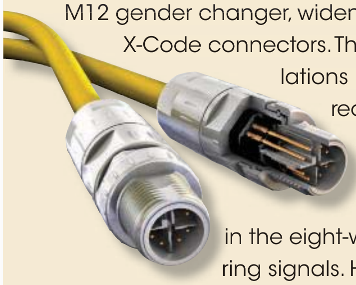
Fully Redundant 1U MicroTCA Chassis Delivers More Slots

BY LEVERAGING several design concepts, VadaTech's 1U MicroTCA chassis platform allows for more slots in a front-to-rear cooled solution while maintaining full redundancy. The VT840 combines the fan trays and power supplies on the rear of the chassis, enabling six Advanced Mezzanine Card (AMC) slots in a single module size. The six slots are divided among two sets of three slots for full-redundancy options with failover. Each set of slots has its own dedicated PCIe Fabric, Gigabit Ethernet (GbE), power module, clock structure, and management. The mezzanine approach of its dual integrated shelf managers make possible various front-panel I/O options in a compact, dedicated space.

VADATECH INC.

www.vadatech.com

Components Expand M12 X-Code Connector Deployment Capabilities



COMPLEMENTARY M12 X-Code components, including straight and angled printed-circuit-board (PCB) receptacles, M12-toRJ45 panel adaptors, and M12 gender changer, widen the range of HARTING's har-speed M12 X-Code connectors. The parts facilitate 6A Gigabit Ethernet installations in machine and plant automation—the receptacles and adaptors meet the requirements for Cat 6A and Performance Class EA with maximum transfer rates for 1/10 Gbits/s. As a result, they will find homes in the eight-wire Ethernet environment, or for transferring signals. HARTING's har-speed X-Code connectors and components enable deployment of an M12-cabling system conforming to IEC/PAS 61076-2-109.

HARTING TECHNOLOGY GROUP

www.harting.com

Synchronous Buck Battery Charger Accommodates Various Inputs with 40-V Operation

THE LTC4121 constant-current/constant-voltage 400-mA battery charger accepts a 4.4- to 40-V input. The charger, developed by Linear Tech, maintains a programmable 3.5-o 18-V battery charge voltage range with tight +1% accuracy, suiting it for battery chemistries such as lithium-ion, LiFePO4, and lead-acid. The LTC4121 can regulate its input voltage to a programmable percentage of the input open-circuit voltage to accommodate high-impedance input sources (*e.g.*, solar panels). If the input voltage falls below the user-defined percentage of the open-circuit voltage, it automatically reduces charge current. Programmable charge current ranges from 50 to 400 mA. A recharge function starts a new charging cycle if the battery voltage drops 2.2% below the programmed charge voltage.

LINEAR TECHNOLOGY CORP.

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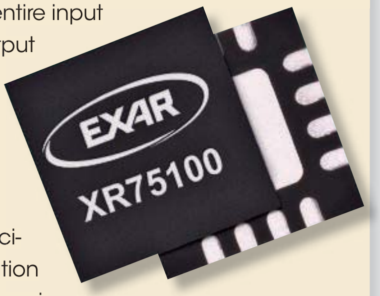
40-V COT Controller Delivers 0.008%/V Line Regulation

THE XR75100 40-V synchronous step-down controller, developed by Exar, supports point-of-load (POL) supplies from industrial 24-V dc and 24-V ac rectified sources. Its emulated current-mode constant-on-time (COT) control scheme offers the fast transient response of conventional COT controllers, but doesn't compromise other functionality. The device's 0.008%/V line regulation across the entire input voltage range (5 to 40 V) and 1% output accuracy over the full temperature range boosts headroom to facilitate design implementations. Adjustable output voltage ranges from 0.6 to 30 V. The COT control loop enables operation with ceramic output capacitors, thus eliminating loop compensation and reducing component count. Supervisory and protection features ensure proper sequencing, safe operation under abnormal conditions, and light load operation. The XR75100, which comes in a 16-pin, 3- by 3-mm QFN package, will deliver core voltage rails for ASICs, FPGAs, DSPs, and other processors in medical, automotive, instrumentation, and other industrial applications.



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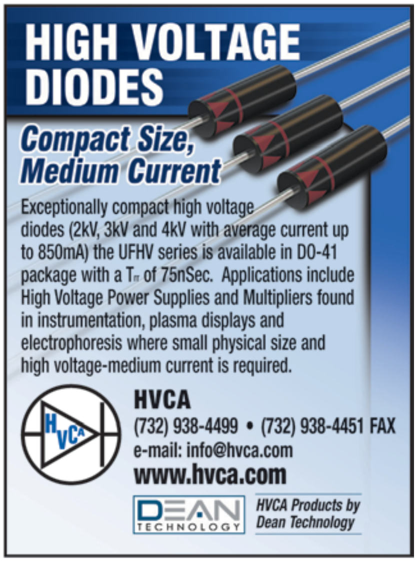
Mixed-Signal Scope Builds In Upgraded Memory Capabilities

YOKOGAWA'S DLM2000 mixed-signal oscilloscope increases acquisition memory up to 62.5 Mpoints for its standard unit and up to 250 Mpoints with the extended memory option. Thus, with the maximum memory installed (/M3 option), it can capture a 10-kHz signal lasting for more than one hour in single-shot mode. In addition, built-in flash memory capacity was increased from 0.1 to 0.33 Gbytes. Enhancements to the history memory function include an increase in the maximum number of history waveforms from 20,000 to 50,000. Together with a maximum continuous acquisition rate of 20,000 waveforms/s, which increases to approximately 450,000 in N single mode, the DLM2000's history memory enables capture of abnormal signals without needing to know what makes them different.

YOKOGOWA

www.yokogawa.com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Microcontroller Incorporates Hardware Scheduling and EtherCAT Support

Renesas' R-IN32M3-EC hardware scheduling and an augmented Ethernet controller make EtherCAT easy and efficient.

Most new microcontrollers offer faster clock speeds, more memory, and sometimes some interesting peripherals. But occasionally a micro stands out because of one or more new features.

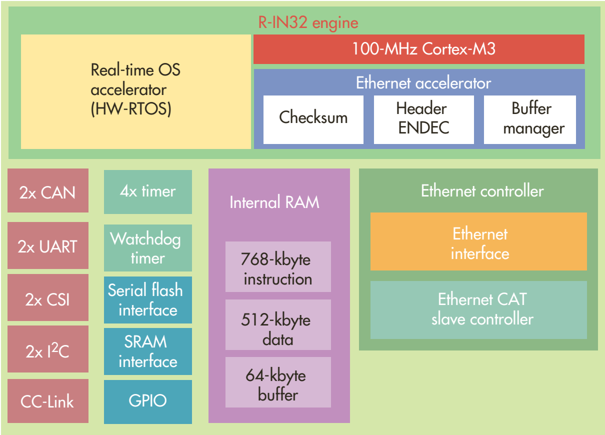
Based on ARM's Cortex-M3 microcontroller, Renesas' R-IN32M3 boasts hardware enhancements that reduce system overhead and, hence, power utilization. It also provides more headroom for user applications (*Fig. 1*). It will have a major impact on industrial automation by providing a very efficient, low-cost platform.

OS HARDWARE ACCELERATION

The R-IN32M3 is not the first platform to incorporate operating-system (OS) acceleration hardware or hardware-based scheduling, but the implementation level is very uncommon in this class of microcontrollers. The HW-RTOS block's more sophisticated interrupt service manager knows about task control blocks, semaphores, event flags, and mailboxes, which are implemented in hardware and tied to a hardware scheduler.

This works with the standard ARM nested vectored interrupt controller (NVIC). The big difference is that the hardware does much of the work typically performed in software to handle interrupts and task switching. This is faster, and many operations can be completed in parallel. Likewise, hardware alone can handle some operations, such as an interrupt setting a semaphore or deciding what task will be run next.

Micrium has customized a version of its µC/OS III to take advantage of the R-IN32M3. The main difference a programmer will see between a stock version and the enhanced version is that the tasks and priorities are more limited. Software tends to be limited by memory, while hardware is limited by what is implemented in hardware.



1. The Renesas R-IN32M3 includes hardware acceleration for the operating system and for EtherCAT support.

SLAVING OVER ETHERCAT

The R-IN32M3's dual Ethernet ports are designed to handle EtherCAT in hardware. Heavily used in industrial automation, EtherCAT always forms a logical ring and timestamps each packet (see "Industrial Automation Relies On Ethernet" on electronicdesign.com). The device also needs to process packets as they pass around the ring, so the amount of software overhead can be high unless there is hardware acceleration like that provided by the R-IN32M3. There are two Ethernet ports because EtherCAT slaves are designed for daisy-chain configurations that are popular in industrial control. They also can provide redundancy if the physical loop is closed.

Tessera designed the R-IN32M3-EC development board for Renesas (*Fig. 2*). This version of the chip uses external physical layers (PHYs) because the Ethernet ports can operate at speeds up to 1 Gbit/s. The R-IN32M3-CL has 10/100 ports but incorporates the PHYs on chip. Many applications only require the slower speeds. ed

2. The Tessera R-IN32M3-CL evaluation board includes a pair of RJ45 jacks for EtherCAT support.

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