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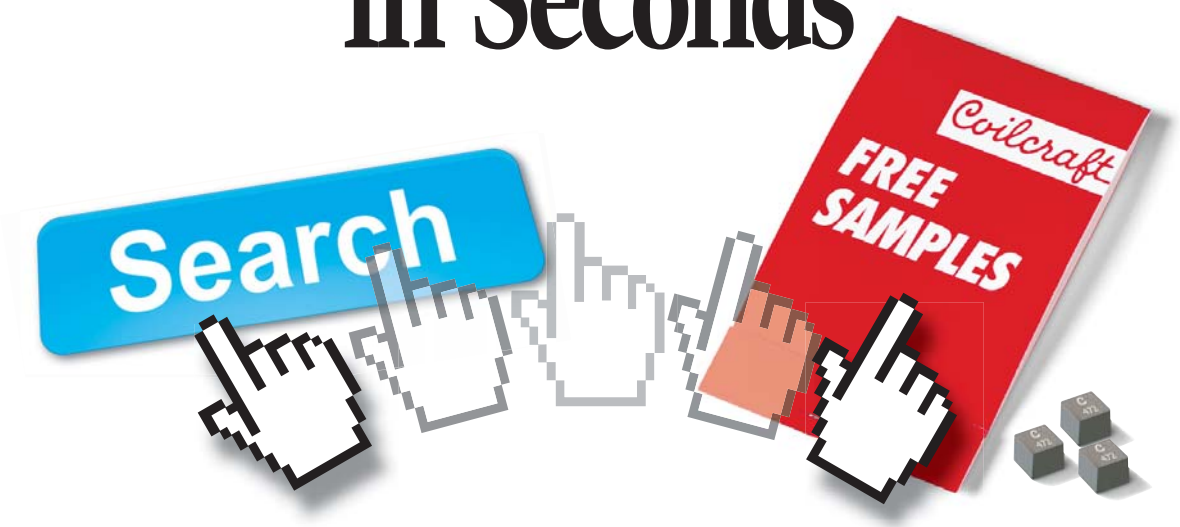

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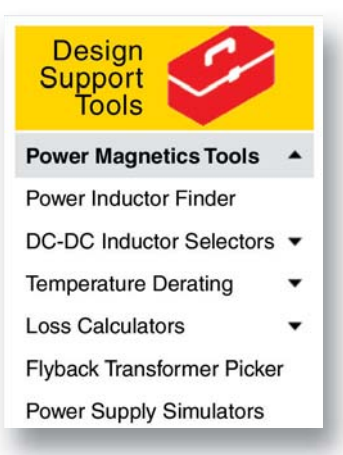

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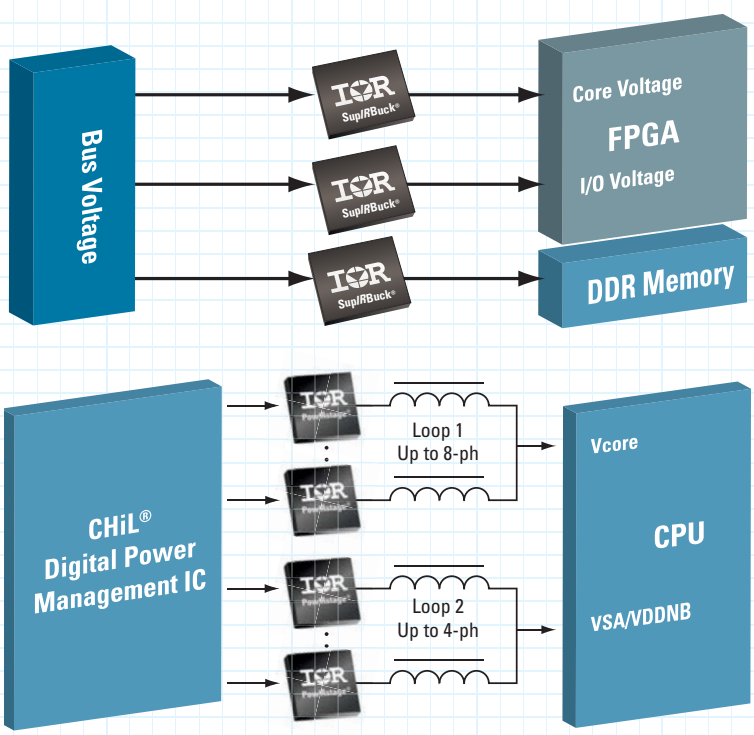

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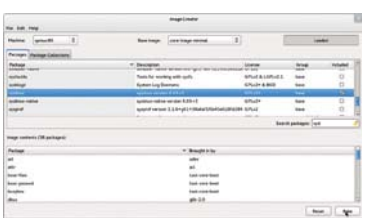

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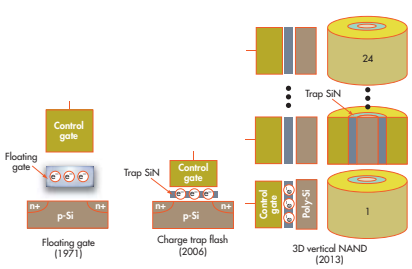

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EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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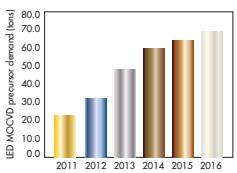

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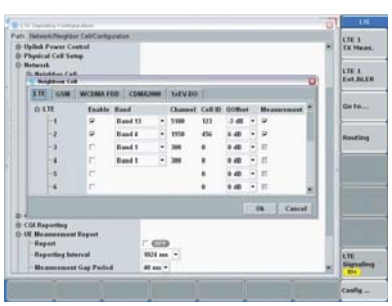

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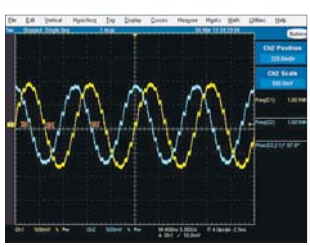

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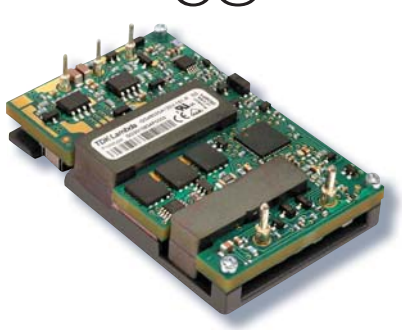

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on electronicdesign.com

ROLLING ROBOTS INTERACT WITH PEOPLE AT AUVSI 2013

While flying drones grab the headlines, robots with wheels offered plenty of innovations too at AUVSI's Unmanned Systems 2013 show in Washington, D.C.

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PAUL WHYTOCK
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- Why Does EV-Phobia Plague Most British Drivers?

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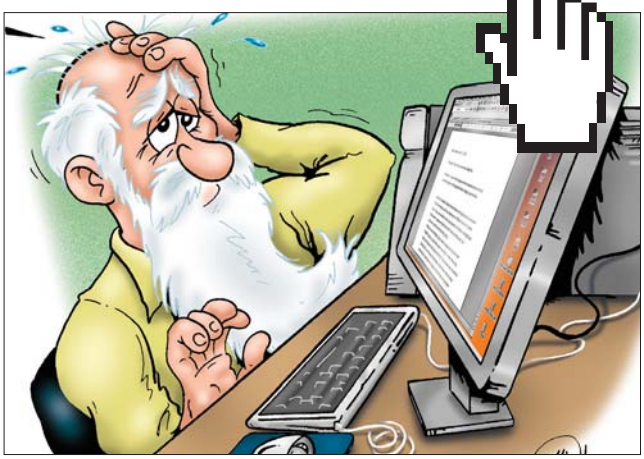

WHAT'S ALL THIS SOLENOID DRIVER STUFF, ANYHOW?

Paul Rako recalls an exchange with the late Bob Pease about a solenoid driver he found on the Web. Of course, Bob had plenty of criticism and advice as he drew up his own version of the circuit.

THE WIND TURBINE OF THE FUTURE

How can power electronics and machine innovation impact wind turbines? The yaw actuators, blade pitch actuators, and prime mover seem like fertile ground for improvement if we look at the rotating machines.

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Dongles Watch Your Driving

You've probably seen the insurance commercials. Just plug in a free dongle so the insurance company can track how you drive your car. You might save some money on your insurance bill. Then again, you might not. It depends on how, where, and what you drive.

The dongle plugs into the OBD-II diagnostic socket, which has a power and a controller-area network (CAN) connection to the rest of the car. The socket can be found in every car made after 1996. It provides access to data about the car and its operation. The dongle adds a micro, a GPS receiver, and a cellular interface.

I wasn't too fond of the idea of letting my insurance company track me, but I did think that it might be a good idea if I could get that information myself. As it turns out, we all can, for a price.

Audiovox's Car Connection (CC), which has an OBD-II dongle with GPS and cellular support, is now plugged into my 2010 Toyota Prius *(see the figure)*. It tracks my car's every move. I can find my car in a parking lot using the Android app on my smart phone. My wife can see where the car is too. I don't have one on her car yet.

The location information would be handier if my kids weren't off and married. CC lets you set up Safety Zones and texts you if the car goes outside of them. It is handy for tracking older or younger drivers who might have limits set on their driving.

What I have found more useful is the driving information. Of course, it says I should slow down to get better gas mileage. I did chuckle at its hint not to let the car idle, though. The Prius doesn't run when it's sitting still.

The system is supposed to provide diagnostic details if the car alerts you to a problem. I wish the app would provide this info anytime. Engineers and car buffs would love that, but it would probably just confuse the average consumer. The system will track and notify you about regular maintenance, but I had to set up the schedule myself. It would have been nice if the software did this itself, since it knows the make and model of the car.

There ain't no such thing as a free lunch (TANSTAAFL). There is an upfront cost and a reasonable annual subscription for CC. That insurance dongle might appear to be free, but it ain't. Even a lower insurance rate will cover its cost in the long run.

In theory, the tracking and automotive information that CC generates will only be available to me. That may be cold comfort these days with the likes of the National Security Agency looking over everyone's Internet shoulder. In the meantime, I'll keep a closer eye on my Prius using my smart phone. ed

(a)

(b)

Audiovox's Car Connection dongle (a) plugs into a socket found under the dash (b).

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BOB ZOLLO | Contributing Technical Expert
bob_zollo@agilent.com

Capacitor Challenges In Modulating DC Power

Engineers often face conflicting design goals. Take a design that requires an input capacitor to stabilize the bias voltage and present clean dc power to the device's circuits. During test, the device needs to be subjected to transients to see if it can tolerate disturbances on the dc input voltage.

You have to rapidly move the dc bias voltage to simulate noise or a dc disturbance. But with that large input capacitor on the device under test (DUT), rapidly changing the voltage will be hard. That capacitor was supposed to prevent rapid changes in voltage. Hence the conflict—how do you change the voltage during test when the capacitor is keeping that from happening?

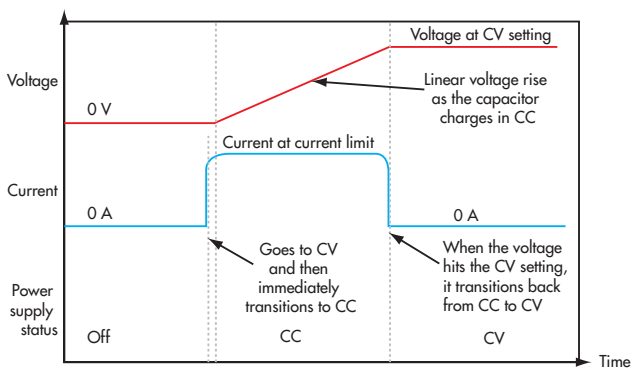
THE RIGHT POWER SUPPLY

To test under transient conditions, you turn to a power supply that can rapidly change its output voltage. The table's first column lists the key specifications. But unless the transient condition is only up in voltage, you need to consider how fast the power supply can change its voltage in the downward direction, too.

To quickly change voltage downward, you need a power supply that can sink current back into the power supply to discharge that large input capacitor on the DUT to bring the capacitor voltage down to the desired voltage. You need a power supply with a down-programmer circuit, or a power supply with two-quadrant operation (source current and sink current) or even a four-quadrant supply.

POWER SUPPLY SPEED SPECIFICATIONS

Column 1: Look for one of these specifications to determine how fast your power supply can change upward from a lower voltage to a higher voltage	Column 2: Look for one of these specifications to determine how fast your power supply can change downward from a higher voltage to a lower voltage
Power supply programming speed	Power supply down-programming speed
Power supply settling time	Power supply down-programming settling time
Power supply up-programming speed	Power supply fall time
Power supply up-programming settling time	
Power supply rise time	



When charging a capacitor with a CV/CC supply, the supply will transition from CV to CC and then charge the capacitor with a constant current. The voltage on the capacitor will climb linearly until its voltage hits the CV voltage setting of the power supply. The supply will then cross over back into CV and the expected operation will continue.

The four-quadrant supply's voltage can swing from plus to minus, but that doesn't enable it to go fast. Instead, its ability to sink current (i.e., operate in the quadrant with positive voltage and negative current) allows it to rapidly pull the voltage down on the DUT's input capacitor. To determine if your power supply will be fast in the downward direction, look for the specifications called out in the second column of the table.

Once you have a fast power supply that can charge and discharge the input capacitor on the DUT, there are still other factors to consider. The voltage on the capacitor is governed by:

$$I = C * dV/dt$$

To rapidly change voltage at the required rate of volts per second (dV/dt), you need current. If you want to change the voltage faster, dV/dt gets larger, so the required current gets larger. And as the capacitor gets bigger, the current grows more. With the required current equal to the product of C and dV/dt, it can grow rapidly if you want to quickly change current across a large capacitor. Let's look at some examples.

CASE 1: CHARGING AN EMPTY CAPACITOR

When you first apply the dc bias power to charge a big, empty capacitor, it looks like a dead short. The power supply won't be able to instantaneously drive the voltage to the desired value. (Instantaneously means dV/dt is infinite so the required current is infinite.) So, the supply will go into current limit.

Assuming this is a constant voltage/constant current (CV/CC) supply, it will transition from CV to CC and charge the capacitor with a constant current. The voltage on the capacitor will climb linearly until its voltage hits the CV voltage setting of the power supply. The supply will then cross over back into CV and the expected operation will continue *(see the figure)*.

This may happen so quickly, you never notice the supply went from CV to CC, charged the capacitor, and then back into CV. If you want to see this, set your supply's current limit low and use a big capacitor. You'll be able to watch the CV to CC to CV state changes and see the linear charging on the capacitor

CASE 2: MODULATING DC

The capacitor has been charged and is sitting at its final dc voltage. Now you want to modulate the dc bias voltage on the DUT. Let's say the desired modulation is to put a sine wave riding on top of the dc. In the automotive world, this test is called alternator whine, where a small sine wave rides on the 12-V dc nominal voltage. The sine-wave amplitude could be 0.5 V p-p, and the frequency is swept up to 20 kHz.

The required current is I = C * dV/dt. If the frequency is 20 kHz, and the voltage swing is 0.5 V, then the approximate dV/dt is 0.5 V/(1/(2 * 20,000 Hz)) = 20,000 volts per second. With C of 1000 µF, it would take 20 A (= C * dV/dt = 1000 uF * 20,000 volts per second). While 20 A is not a large number, it is not related at all to the nominal dc current.

Even if the DUT only required 1 A nominal, the dc source would still need to be able to source and sink 20 A just to drive the capacitor up and down by 0.5 V at 20 kHz. If you wanted to put 1 MHz of noise instead, the current would soar to 1000 A.

SUMMARY

When changing the voltage on capacitors, you need to consider how much current will be required. And that current can grow quite large as the capacitor gets large or as the desired rate of change of voltage gets large.

BOB ZOLLO is a product planner with the Power and Energy Division, Electronic Measurements Group at Agilent Technologies. He holds an EE degree from Stevens Institute of Technology.

News & Analysis

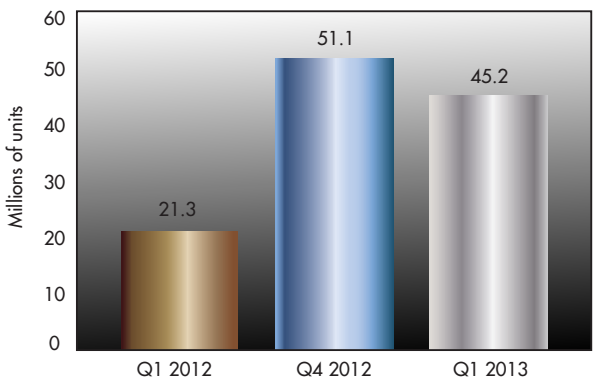
Tablet Display Market Doubles In Q1

Shipments of panels used in media tablets more than doubled in the first quarter of 2013 as consumer demand for low-priced products in the 7- to 8-in. range continues to rise, according to IHS. The information and analytics provider notes that global shipments of capacitive touchscreen displays for media tablets totaled 45.2 million in the first quarter *(see the figure)*.

This growth represents a 111.9% increase over the same period in the previous year and more than doubles the 2012 first quarter total of 21.3 million. Shipments declined by 13% from the fourth quarter of 2012 into the first quarter of 2013, but that seasonal decline is typical for electronics, IHS says.

"These tablets are inexpensive, with pricing at $199, making them popular among consumers. With the level of competition increasing in both the tablet and panel markets, pricing is expected to continue to decline, boosting shipments of displays and end products in this size range," said Duke Yi, senior manager for display components and materials at IHS.

As the number of panel makers increases, the average selling price of tablet PC touch-panel modules is rapidly falling. In the first quarter of 2013, average pricing for 7.0-in. tablet touch panels fell to $15.60, down 16% from $18.60 in the first quarter of 2012. Pricing for 7.0-in. touch panels dropped by 7.5% from $15.60 in the fourth quarter, the largest sequential percentage decrease of any size.

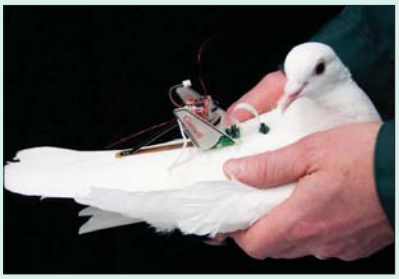


Global shipments of capacitive touch-panel displays for media tablets doubled from 21.3 million units in the first quarter of 2012 to 45.2 million units in the first quarter of 2013, according to IHS.

At the end of the first quarter of 2013, TPK commanded the tablet touchscreen market with a 29% share because of its strong client list, which includes Apple, Amazon, Barnes & Noble, Microsoft, and Asus, including the Nexus 7. This roster vaulted the company to the lead in the tablet touch-panel market in terms of unit shipments. Iljin Display, GIS, Wintek, and O-Film rounded out the top five suppliers. ■

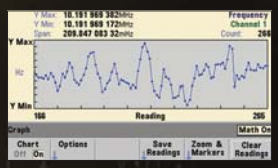
***ELECTRONIC DESIGN* STAFF**

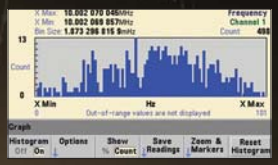
ENERGY HARVESTER POWERS BIRD BACKPACKS



RESEARCHERS ARE STUDYING climate change through bird migration, requiring sensors that birds can wear. Batteries are too heavy to power these packages, so Cornell University's Laboratory for Intelligent Machine Systems has developed an energy harvesting system that converts the bird's motion into electrical power. Each backpack comprises a microcontroller, an accelerometer, a memory module, a wireless receiver, and a piezoelectric device that handles the energy harvesting. *(courtesy of Cornell University)*

It's more than a frequency counter. It's a high-speed answer tool.





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UPDATED ZIGBEE HOME AUTOMATION STANDARD VERSION 1.2 NOW AVAILABLE

THE LATEST UPDATE to the ZigBee Alliance's Home Automation standard is ready for product development. The standard is one of several ZigBee application standards that provide flexible frameworks for designers of specific uses of the ZigBee wireless technology.

The standard permits the setup of a home-area network of ZigBee-enabled devices to monitor power usage, turn appliances on or off, control lighting, and monitor and control home devices from anywhere via the Internet. It emphasizes easy DIY installation and uses ZigBee's mesh networking feature to make it easy to add or remove controlled or monitored items. ZigBee uses the unlicensed 2.4-GHz spectrum and coexists with Wi-Fi.

Version 1.2 improves battery life for security sensors to more than seven years, standardizes device pairing, and simplifies installation and maintenance for consumers and installers alike. It should have a major impact on operational and device costs to service providers and quality of service (QoS) to consumers. ■ **LOU FRENZEL**

FISHY TURBINES BOOST ENERGY PRODUCTION

INSPIRED BY THE pattern of spinning vortices left behind by swimming fish, Caltech professor John Dabiri is testing a set of 24 particularly placed wind turbines. Simulations so far show energy production increasing by a factor of 10. Standing just 30 feet tall, these vertical-axis wind turbines also are expected to decrease the cost, footprint, and environmental impact of wind farms. *(courtesy of Robert Whittlesey)*

ABB BUYS POWER-ONE FOR A BILLION BUCKS

POWER-ONE'S STOCKHOLDERS HAVE overwhelmingly approved the sale of the Camarillo, California-based energy-products company to ABB for $6.35 per share of common stock. Earlier in July, that worked out to roughly a billion dollars. The company will be integrated into ABB's Discrete Automation and Motion unit, which produces robots, motors, and drives.

Power-One created the Z-Bus, a technology for monitoring and control of power supplies implemented in the company's point-of-load (PoL) regulator ICs. Power-One's successful patent infringement lawsuit in 2005 knocked the wind out of the sails of other PoL companies until 2009, when a formula for royalty agreements became routine.

However, Power-One never limited itself to power management ICs, growing by acquisition and innovation into the power supply business and solar-power and wind-power inverters, as well as expanding its global sales reach.

ABB, headquartered in Zurich, was created by the 1988 merger of Sweden's ASEA and Switzerland's Brown, Boveri & Cie. It is a global leader in power and automation technologies for utility and industrial customers.

Last year, ABB bought Tropos Networks, which gave it a customized wide-area wireless broadband communications product line optimized for distribution grid management. Distribution is the part of the grid that takes electricity from power generation and transmission entities and sells it to the retailers who deal with end customers.

In 2010, ABB also acquired Ventyx, which provides utilities with distribution management and supervisory control and data acquisition (SCADA) software. In the U.S., ABB has invested $10 million on a "smart grid center of excellence," a testing lab and demo center in North Carolina.

On its Web site, Power-One claims that it is the second largest manufacturer of solar power inverters globally and states that it has recently opened manufacturing centers in Phoenix, Arizona, and Toronto, Canada.

Products comprise central and string inverters for photovoltaics. Central inverters are intended for large solar applications such as field installations, industrial facilities, and large buildings. Power-One's go up to 1.5 MW. String inverters are smaller scale, but Power-One's largest is still a three-phase unit, with a peak output of 5.8 kW. On the wind side, Power-One's inverters scale to 50 kW. ■

DON TUITE

design FAQs

Pseudo-SLC Flash Provides Design Flexibility

Bill Wong *Embedded/Systems/Software Editor*

FREQUENTLY ASKED QUESTIONS

Q: What types of NAND flash storage are available?

A: Most designers are familiar with single-level cell (SLC), multi-level cell (MLC), and triple-level cell (TLC) NAND flash storage designed to store 1, 2, or 3 bits in one cell. NAND flash technology is pushing towards 4 bits per cell.

SLC has the lowest capacity for a given cell size, but its write speed and durability are better. SLC flash was the first version developed. It is now used for applications where data is written often such as server database applications where cost may be less important than disk lifetime.

MLC has become the dominant NAND flash storage system because it provides twice the capacity of SLC. The tradeoff is cell lifetime, but it is sufficient for many applications including enterprise storage environments.

TLC is at the other end of the spectrum with higher capacity but an even shorter lifetime. It currently targets consumer applications where capacity trumps storage lifetime. It is good for applications where reads dominate.

A variant of MLC called pseudo-SLC (pSLC) brings SLC's speed and durability to MLC—almost.

Q: What is pSLC flash storage?

A: The basic differences between SLC, MLC, and TLC are the charge stored in the cell and the mechanisms used to write to the cell and to read its contents. SLC has a simple threshold while MLC and TLC need a more refined sampling mechanism. MLC has four distinct levels, while TLC has eight.

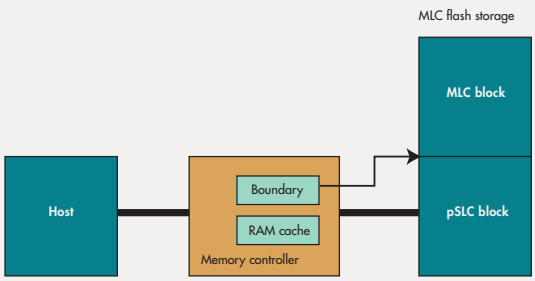
The lifetime of the MLC and TLC cells is reduced because the degradation of the cell after many writes affects how accurate the contents can be read and written for all values.

There is no real requirement that an MLC or TLC cell has to store multiple bits of information. It is just that high capacity tends to be more desirable. Of course, there is the significantly limited lifetime compared to SLC.

The pSLC only stores 1 bit per cell like SLC. The difference is that, from an MLC standpoint, the value will be 0 or 3. The read analog-to-digital converter (ADC) then can more readily discern the proper value. Likewise, the degradation due to many writes has less effect over time just like an SLC implementation.

Q: Why not use pSLC flash storage instead of SLC all the time?

A: SLC and pSLC are similar, but they aren't the same thing. SLC has been designed for single-bit operation while MLC flash has been designed for storing 2 bits. The performance characteristics of pSLC are much better than MLC but less than SLC. The actual numbers vary depending upon the vendor and implementation, but typical write endurance is about half of SLC's 60,000 compared to MLC's 3000.



A system can employ pSLC and MLC flash using the same controller. The controller typically splits the memory array into two sections, providing a high-reliability section and a high-capacity section.

Also, pSLC has improved read and write speeds compared to MLC. The estimated 19-nm speed is 100 Mbytes/s. So pSLC won't be replacing SLC anytime soon, but it does have some benefits when paired with MLC.

Q: Does pSLC require a special MLC flash architecture?

A: Not usually. It can typically use the same storage array and interface as MLC. The approach can also be applied to higher-density flash such as TLC.

The advantage of pSLC is that it does not require any changes to the MLC memory controller. It is already set up to read and write the cells. The only difference is how the data is presented to the outside world. Obviously the controller needs twice as many cells for the same amount of data, but it simply needs to process twice as many cells to deliver the same amount of data for each memory transaction.

Q: What does a typical pSLC flash storage system look like?

A: A single controller normally can handle an MLC array *(see the figure)*. Typically it splits the array so some is used for pSLC and the rest for MLC. Important information such as boot code, keys, or data that changes more often is stored in the pSLC partition. The rest is stored in the more dense MLC partition.

The partition size is normally fixed for a particular application when it runs the first time. Dynamically changing the partition size would be very challenging because of a range of issues from wear leveling to over provisioning.

This generally isn't an issue since embedded designers control the system

design. It lets designers use one device to provide two types of storage while providing the flexibility to determine how much of each is available.

The split can easily change between new system designs. This may be more difficult for in-field updates, but it should not be an issue for initial deployments.

Q: Does pSLC work better with an integrated controller?

A: It may be possible to use an MLC as a pSLC when dealing with raw storage media, but an integrated controller can offer key advantages. The biggest advantage is a unified interface to memory that only differs by the write endurance and read/write characteristics. Normally the controller handles error correction and wear-leveling as well. This still needs to be done with both partitions.

Q: Can an MLC/pSLC system be dynamically partitioned?

A: In theory, a system can be reconfigured as needed, but designers typically set the partition once since they normally know the amount of pSLC storage required for the application. In general, the entire array should be erased when the partition is created so the system can be placed into a known state. Likewise, the hidden sectors for wear-leveling need to be adjusted accordingly.

Q: Where can I find pSLC flash storage?

A: Different vendors use different descriptions for this technology. For example, Toshiba's SmartNAND has a pSLC mode called Reliable Mode. Normal Mode is used to refer to the section of flash storage that operates in MLC mode. Most platforms that support pSLC can operate in pSLC or MLC mode.

The pSLC approach works best with integrated controllers where the controller hides the complexity of managing two different storage areas. It is possible to do this with most NAND controllers, but software-based solutions need to keep in mind the dual nature of the system. That is not as easy as it sounds.

Q: What markets does pSLC/MLC flash storage target?

A: This combination works best in embedded applications where designers can get the best features of both types in a single package and where they can be apportioned before deployment. ■

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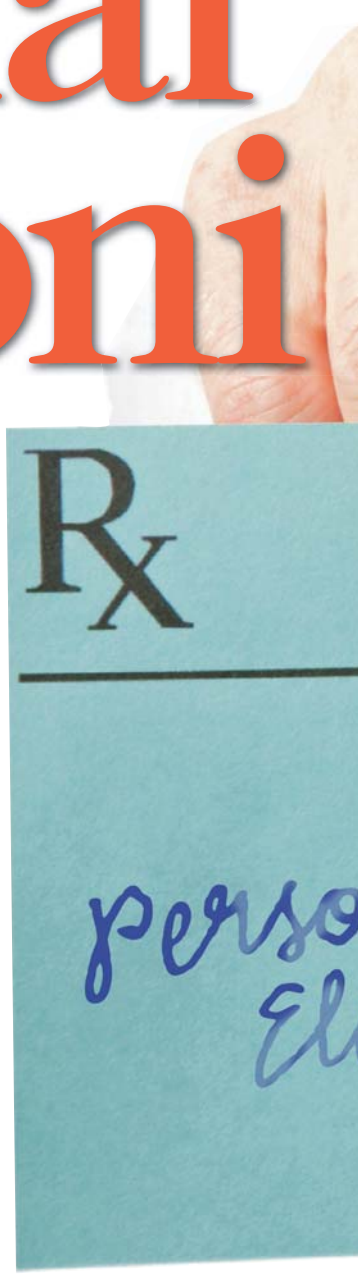
GET YOUR PRESCRIP Personal Electroni



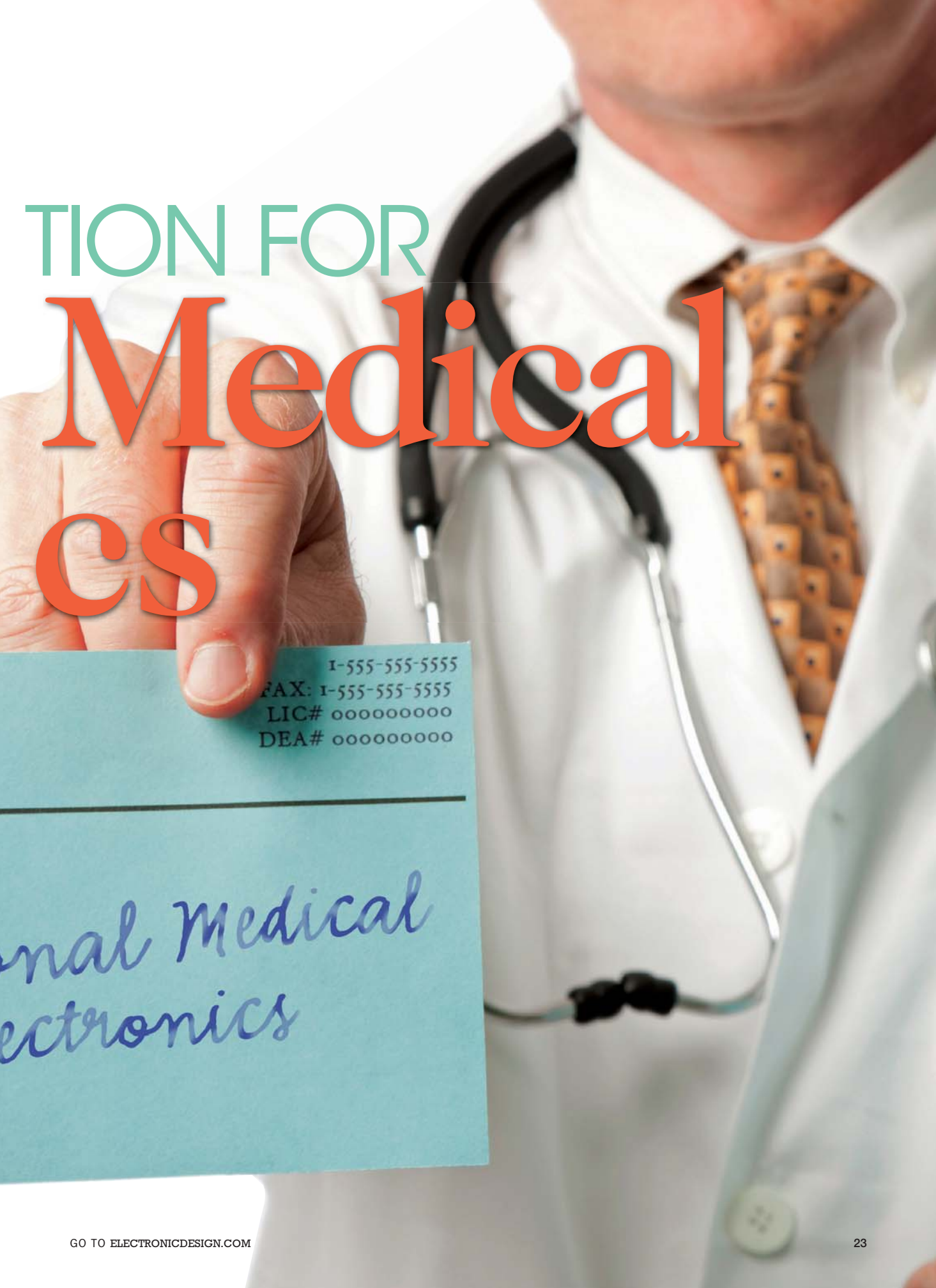
Leading-edge technologies coming together promise to revolutionize healthcare by focusing on the patient, reducing costs, accelerating diagnostics and therapeutics, and improving delivery.

The convergence of four pervasive technologies—ubiquitous sensing, wireless connectivity via smart phones and tablets, cloud computing, and social networking—is rapidly driving the development of "personal" medical electronics for diagnostics, monitoring, and therapeutics. Some call it digital health, e-health, electronically enhanced medicine, m-health (mobile health), or personalized healthcare, emerging as the next generation in healthcare diagnostics and preventive medicine that will be independent of time and place of treatment.

THE ROLE OF SENSORS

Personal medical care will depend on a host of sensors embedded in a wearable device or even implanted within the body that will send the patient's medical information wirelessly to the doctor or healthcare facility. The result will be lower costs, better quality, more convenience, and faster results. Major companies like Apple, Google, and Microsoft are getting into the wearable computing business for wellbeing and healthcare applications.

Speaking at the Microelectronics Packaging and Test Council meeting in San Jose in May, microelectromechanical systems (MEMS) pioneer Janusz Bryzek, vice president of development for MEMS and sensing solutions at Fairchild Semiconductor Corp., predicted the implementation of e-health in a broad scale of sensing and actuating medical



TION FOR Medical cs

devices such as out-of-body ultrasound and X-ray scanners, dialysis machines, on-the-body wearable devices to monitor health and wellness, in-the-body infusion pumps, and blood glucose sensors.

More than a dozen startups offering wearable devices aimed at fitness and healthcare applications have emerged. Many of these devices are used for personal fitness monitoring, but they also have potential in personalized medical monitoring and diagnostics. For example, the Nike+ FuelBand from Nike Inc. uses wearable sensors and low-power ARM-based cores to track and display what the company calls NikeFuel by counting the wearer's daily activities *(Fig. 1)*.

1. The Nike+ FuelBand from Nike Inc. tracks and displays what the company calls NikeFuel, which counts the wearer's daily activities.

Soaring costs of healthcare expenditures worldwide are driving personal, portable, and wireless healthcare innovations. On a gross domestic product (GDP) per capita basis, the U.S. spends about twice the amount of developed countries. According to the Office of the Actuary of the U.S. Center for Medicare & Medicaid Services, the U.S. spent about $2.6 trillion in 2010, which is projected to surpass $4.5 trillion by 2020 *(Fig. 2)*.

To empower the development of mobile and wireless healthcare for consumers, Qualcomm formed the $10 million Tricorder XPRIZE competition. The aim is to come up with a tool capable of non-invasively capturing health metrics and diagnosing a set of 15 diseases using the latest advances in wireless sensing, imaging, and portability technologies to replace costlier and bulkier laboratory equipment.

The Tricorder XPRIZE began in late 2010. That's when Peter H. Diamond, CEO of the XPRIZE Foundation, met with Don Jones, vice president of global strategy and market development at Qualcomm's Wireless Health Group (now Qualcomm Life Inc.), and Paul E. Jacobs, CEO and chairman of Qualcomm and the Qualcomm Foundation, to kick off the program.

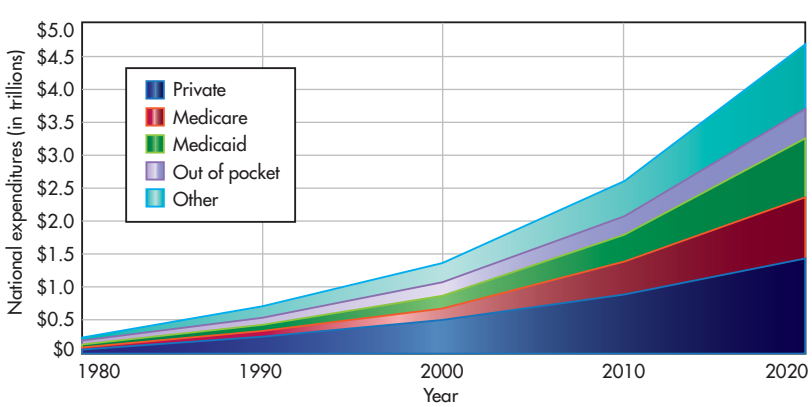
Mobile phone maker Nokia has joined the Qualcomm competition with its own $2.25 million XCHALLENGE, which encourages teams to build sensing technologies for use in identifying and diagnosing diseases. Judges for the competition have chosen 12 innovative hardware and software sensing technologies to advance as finalists in the first challenge, based on technology trustworthiness, privacy and security, standardization, and interoperability.

Wireless and portable medical diagnostics have already been proven in the field. In 2011, the U.S. Food and Drug Administration (FDA) gave its approval to Telcare Inc. to market the first cellular-enabled and portable blood glucose meter, the BGM, which connects diabetes patients with their healthcare providers and families. The BGM works with an FDA-cleared database called Telserve to aid patients in the management of diabetes.

Portable and wireless phones can also be used to monitor adherence to prescribed drugs and compliance with dosage directions. "Technology is at the heart of what we do," says Aunia Grogan, CEO of Atlantis Healthcare. The company develops and executes interventions to address treatment adherence, which Grogan sees as a rising cost caused largely by patients' belief in the effectiveness of their medications and the severity of their illnesses. "The strategic use of technology is critical to effectively deliver mass personalization, ensuring the right person receives the right message at the right time and in the right way."

One of these technology tools is the Raisin system from Proteus Biomedical. According to the company, patients don't take 30% to 50% of their prescribed medications, and the costs of hospitalization due to non-adherence are very high. The Raisin system uses a swallowable pill that marries medicine and mobile computing technologies to solve this problem.

Sensors send wireless signals through the body to a receiver that records the type of drug taken, the dose, and the place of manufacture. The system also measures heart rate, body activity, and respiratory rate. Thin-film MEMS layers on each ingestion event maker (IEM) are activated and powered using stomach electrolytes. The system modulates and pulses the current flow to encode information stored in it. It then communicates this data through the body tissue, where a receiver worn on the patient's skin detects an electric field.



2. The U.S. spent about $2.6 trillion on healthcare in 2010, and that will grow to over $4.5 trillion by 2020. *(courtesy of the Office of the Actuary of the U.S. Center for Medicare & Medicaid Services)*

SENSING AND POWER CHALLENGES

According to Phillipe Kahn, founder of Fullpower Technologies Inc., makers of wearable medical products must overcome three main challenges before their products see greater acceptability in mobile health. They'll need to be more innovative, create smaller and more accurate sensors, and improve battery performance in terms of smaller size, longer lifetimes, and suitability for wearable medical products. Kahn created the first camera phone in 1997 and is a pioneer in wearable electronics.

3. The BodyMedia FIT wearable calorie-counting healthcare monitor delivers reading accuracies greater than 90%, the best outside of a laboratory. Four sensors provide the right size, cost, and functional relevance.

Kahn says that his company's MotionX mobile sensing technology platform, which is embedded in products from Nike, Jawbone, Pioneer, and JVC, is the result of innovative thinking from Fullpower Technologies. "We have a strong focus on breakthrough algorithmic power management that is above and beyond other solutions on the market," he explains. "This applies to wearable computing applications as well as smart phones."

Kahn also says that many health and fitness wearable mobile medical products can provide readings that are within the 15% to 20% range in accuracy, which paints the wrong picture of a patient's medical data. He says that levels of 5% accuracy or better are needed. Accuracy can be crucial, for example, in diagnosing lower back pain and gout during a long gait.

BodyMedia claims to have the highest accuracy for a wearable fitness monitor in its FIT calorie counter, with accuracies greater than 90% *(Fig. 3)*. Its on-body multi-sensor platform meets FDA Class II category regulations and conforms to the ISO 13485 standard. More than 150 clinical studies verified this accuracy claim, claims BodyMedia.

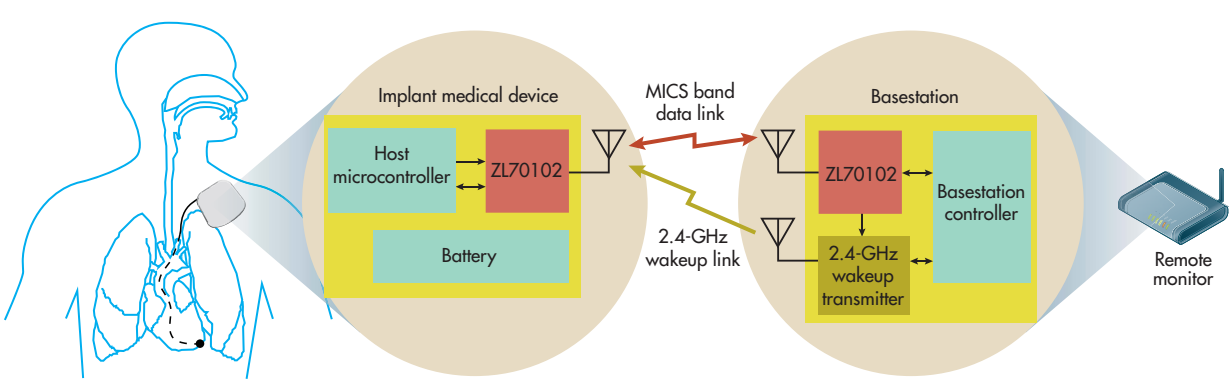
Unlike other wearable body monitoring devices, the FIT includes four sensors that provide the right size, cost, and functional relevance working together to predict the most accurate calorie burn information outside of a laboratory. One sensor measures galvanic skin response due to sweating. A three-axis accelerometer measures motion and the number of steps taken. A temperature sensor measures body heat. And, a heat flux sensor measures the rate heat is dissipated from the body.

Samsung Electronics has embarked on a forward-looking vision that is bound to dramatically change wireless mobile health and define the next decade of medical technology. Speaking at this year's MobileBeat Conference, Samsung's president and chief strategy officer Young Sohn showed a video demonstrating a foldable form factor for large displays, photonic crystal reflective lighting that requires no backlighting, and RF wave sensors integrated within worn patches that check and transmit a patient's health data.

Sensors don't need to be integrated into a wearable device, Samsung demonstrated. Instead, they simply can be used as connected add-on accessories. The folded display form factor allows the expansion of the display screen without drawing additional battery power.

Wearable e-health portable devices require a certain degree of sensor fusion that intelligently combines and processes data streams from multiple sensors, producing an output whose sum is greater than the individual inputs combined. Many sensor fusion products are available in hardware and software packages that are often proprietary to a specific ven-

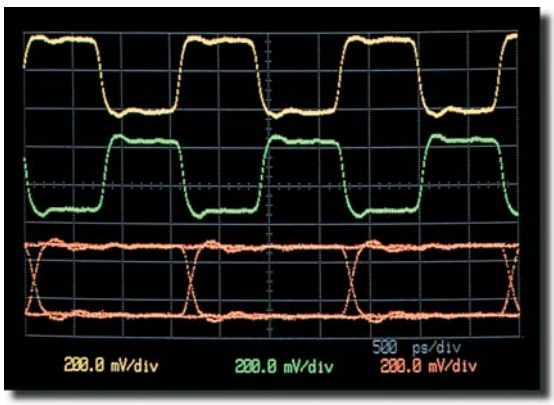
4. Medical implants such as insulin infusion pumps, cardiac pacemakers and defibrillators, drug pumps, and neuro-stimulators all depend on Microsemi's ultra-low-power medical implantable communication service (MICS). It connects the ZL70102 wireless RF transceiver chip in a module implanted in a patient's body to a module within an external monitoring basestation.



2 GHz Clock Generator

CG635...$2995 *(U.S. list)*

- ***Square wave clocks from DC to 2.05 GHz***
- ***Random jitter <1 ps (rms)***
- ***80 ps rise and fall times***
- ***16-digit frequency resolution***
- ***CMOS, LVDS, ECL, PECL, RS-485***
- ***Phase adjustment & time modulation***



Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

The CG635 generates clock signals—flawlessly. The clock signals are fast, clean and accurate, and can be set to standard logic levels.

How fast? Frequency to 2.05 GHz with rise and fall times as short as 80 ps.

How clean? Jitter is less than 1 ps and phase noise is better than –90 dBc/Hz (100 Hz offset) at 622.08 MHz.

How accurate? Using the optional rubidium timebase, aging is better than 0.0005 ppm/year, and temperature stability is better than 0.0001 ppm.

You would expect an instrument this good to be expensive, but it isn't. You no longer have to buy an rf synthesizer to generate clock signals. The CG635 does the job better—at a fraction of the cost.

Stanford Research Systems

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dor, usually tied to that vendor's sensor offerings.

Researchers now are looking at data fusion rather than just sensor fusion. Many experts consider this approach the key to enabling more intelligent applications, which will be needed in e-health devices.

HONING COMMUNICATIONS CHIPS

Semiconductor IC manufacturers have long been serving the medical community with highly integrated, low-power, and accurate devices, attributes required in portable and wearable wireless communications products. Renesas Electronics is collaborating with Belgium's IMEC to advance wireless communications with the first multi-standard RF receiver and an analog-to-digital converter (ADC) CMOS IC manufactured on a 28-nm process. The devices target LTE-Advanced and next-generation Wi-Fi communications.

"Using a 28-nm CMOS process allows us to offer high levels of integration and low power levels, increasingly important parameters for the latest and future wireless communications devices," explains Renesas' Nelson Quintana, director of marketing. "We've been supplying extremely low-power and highly accurate devices to the medical community such as our RX100 32-bit entry level microcontroller (MCU)."

Silicon Laboratories is acquiring Norway's Energy Micro AS, one of the first companies to develop 32-bit MCUs based on a licensed ARM-Cortex-M3 core with an emphasis on low-power and battery operated applications. Silicon Laboratories is trying to develop a critical mass in its pursuit of the wireless and embedded Internet of Things (IoT) market, which includes portable medical electronics.

Bluetooth low energy (BLE) is serving as a good connectivity model for e-health devices. It suits applications that send limited data and need to operate from very low power levels, like blood pressure monitors and pulse oximeters. Such e-health devices are more likely to operate at home or in a doctor's office. But hospital and clinical settings involve larger volumes of data, and medical devices generally operate from larger batteries or an ac power source. That's also the case for implantable devices like infusion pumps for delivering insulin to the pancreas. Here, Bluetooth is the correct communications choice.

It should be noted that the Bluetooth Smart communications protocol supports BLE but not the classic Bluetooth. The Bluetooth Smart Ready protocol is available to communicate with both BLE and classic Bluetooth, and it is already in use in many smart phones and tablets.

"Our research has shown and all the information is indicating that BLE is the predominant one in the market now. Using BLE components adds a new level of functionality that enhances their power-saving capability," says Chuck Parker, executive director of the Continua Alliance, a non-profit, open industry organization of more than 200 healthcare and technology companies worldwide collaborating to improve the quality of personal healthcare.

Parker also sees ZigBee as another communications protocol that offers designers some capabilities in meshing networks. "It allows us to follow an individual through a home or through a relatively large-square-foot setting. Bluetooth simply can't accomplish that. It's got a 33-foot limit, whereas with ZigBee, with its meshing points, we can basically monitor the entire facility, whether it's on a single floor or multiple floors," he says.

Medical implants are omnipresent, and many are linked to home networks. According to Janus Bryzek, 600,000 of the 2.5 million medical implants such as pacemakers that are already deployed are linked via home networks for remote sensing and monitoring.

Medical implants such as insulin infusion pumps, cardiac pacemakers and defibrillators, drug pumps, and neuro-

stimulators all can use Microsemi's ultra-low-power medical implantable communication service (MICS). It connects the ZL70102 wireless RF transceiver chip in a module implanted in a patient's body to a module within an external monitoring basestation *(Fig. 4)*.

MICS operates in the 402-MHz to 405-MHz band and consumes less than 6 mA in the transmit/receive modes, 290 nA in the listen before transmitting mode, and just 10 nA in the sleep mode. Micosemi's ZL70321 implantable radio module works with the ZL70102 and has an integrated matching network, a surface acoustic-wave (SAW) filter for unwanted blockers, and an extra low-noise amplifier for maximized receiver sensitivity.

Researchers at Switzerland's Centre Suisse d'Electronique et de Microtechnique (CSEM) are working on the WISERBAN project for much smaller implantable medical devices that will feature smarter communications and consume less power.

This project will develop an ultra-miniature wireless body area network (BAN) comprising a 2.4-GHz radio, a microprocessor for sensor data processing, and RF MEMS devices for improved radio performance, all within a 4- by 4- by 1-mm system-in-package (SiP) housing, and consuming just a few milliwatts. According to Vincent Peiris, section head of CSEM's analog and IC design section and the project's coordinator, the group is developing devices that are 50 times smaller and require 20 times less power than existing consumer products. ed

MORE MEDICAL TECHNOLOGY

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LOOK INSIDE PROGR MEMS Clock

Piezoelectric quartz may cost less, but it can't be as small or as versatile.

In the beginning, clocking digital electronics was simple. You started with a basic Pierce oscillator, controlled by a piezoelectric quartz crystal, clipped the tops off the resulting sine waves, filtered out the noise, and divided-down the pulses to a usable clock rate. There was even programmability of a sort. Makers of semiconductor clock devices offered resistor-selectable divide-down rates. Later, some "silicon oscillators" used R-C multivibrators in lieu of quartz. They were less expensive, but offered less temperature stability.

That was the situation in the late 20th century and the early 21st. In 2006, SpectraLinear began offering greater programmability. The company's EPro clock family incorporated up to four programmable phase-locked loops (PLLs) that allowed users to fine-tune output impedance (which in effect controlled drive strength), output skew, operating frequency, and spread-spectrum profile. Also, clock outputs often could be programmed to be in-phase or be 180° out of phase *(see "Bulletproof Your System Timing With Programmable Clocks" at electronicdesign.com)*.

When Silicon Labs acquired SpectraLinear, it gained additional expertise in clock programmability. That capability has more recently grown with a new CMOS-MEMS technology developed inside Silicon Labs. This technology is a late addition, however. SiTime, an independent startup, offered the first devices based on silicon microelectromechanical-systems (MEMS) clock resonators in 2006. In 2007, Discera announced products based on its PureSilicon MEMS technology. The company has not discussed PureSilicon's details in the media, though.

Complementing its acquisition of SpectraLinear last June, Silicon Labs introduced what it characterized as the industry's first single-die MEMS oscillator, meaning that its MEMS structures are built directly on top of the same CMOS wafers that incorporate its analog circuitry. (SiTime uses separate die.) Silicon Labs designates the products "CMEMS oscillators" and says the process supports wafer probing of complete oscillator systems for quality and process control *(see "Inside Silicon Labs' CMEMS Resonators," p. 34)*. More concretely, Silicon Labs guarantees that the products will meet their datasheet performance specs for frequency stability relative to solder shift, load pulling, V_{DD} variation, operating temperature range, vibration, and shock for at least 10 years.

Similarly in 2010, IDT acquired Mobius, a startup founded by Michael McCorquodale that made silicon MEMS oscillators. But the following year, McCorquodale left and IDT announced pMEMS (piezo-MEMS) devices, pMEMS being an internally developed technology that uses quartz MEMS *(Fig. 1)*. Subsequently, in 2012 and 2013, IDT introduced advanced pMEMS products with multiple outputs and reduced jitter *(see "pMEMS Oscillators Make Waves Without The Crystal" at electronicdesign.com)*.

MEMS VS. PIEZOELECTRIC QUARTZ

SiTime might be considered the grandfather of the business. Since shipping its first products in 2006, it has moved 160 million units to more than 800 customers, with 40 to 50 programmable devices yielding about 200,000 part numbers. It also commands 80% of the MEMS timing market.

AMMABLE Chips

The company was founded on the expectation that resonators based on silicon MEMS technology, unlike piezoelectric quartz crystal resonators, could utilize the economies of the silicon foundry infrastructure to make inroads into quartz dominance.

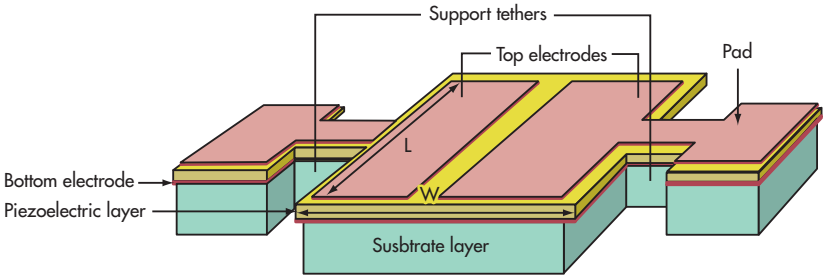
Before the dawn of MEMS-based timing devices, piezoelectric quartz-based suppliers included IDT, Texas Instruments, Analog Devices, Silicon Labs, and Microsemi making analog semiconductor-based chips. Epson, Kyocera, NDK, and Webtron had the quartz crystal technology. Quartz-based suppliers could buy analog ICs from the semiconductor companies and the semiconductor suppliers could offer timing devices, using an external quartz device as a reference. There was no successful unified solution until SiTime integrated MEMS regulators with its own electronics.

"The quartz guys had a lock on their expertise in precision machining of quartz crystals. They could take a quartz crystal and cut it and do all kinds of things to it to make sure that it operated at a standard frequency and stayed that way for 15 or 20 years. And they made a fabulous job of it," says Piyush Sevalia, vice president of marketing at SiTime.

Meanwhile, the semiconductor-clock companies didn't have the expertise in the special kind of packaging that quartz crystals require. Quartz needs vacuum-sealed ceramic packaging to ensure that the resonator's Q remains high. The need for separate packaging of resonator and analog electronics had several drawbacks, not least that in consumer products, a lot of board space was taken up with clocks, limiting opportunities for miniaturization. In those days, a device put out

one clock output, and designers had to accommodate that.

SiTime was the first to successfully resolve the various problems, probably because its founders' backgrounds embraced both analog and silicon MEMS resonator expertise. Building the resonator out of silicon and packaging it with the clock's analog circuitry made it possible to provide multiple clock outputs from a single, compact semiconductor package, providing product designers with greater versatility in their own packaging *(Fig. 2)*.



1. IDT's pMEMS resonator combines a piezoelectric material with monolithic silicon. The piezoelectric layer and electrodes are stacked on top of the silicon layer. When an electrical stimulus is applied to one of the top electrodes, a transverse piezoelectric coefficient generates a bulk acoustic wave in the entire device. The resonator then vibrates laterally, and the other top electrode senses the vibration.

For example, one of SiTimes' MEMS wafers may look like any other semiconductor wafer. Yet it can hold from 30,000 to 50,000 or more MEMS die that are vacuum-sealed as part of the wafer processing. For an animation, see *www.sitime.com/videos/mems-first.html*.

MEMS MARKETS

Today, these products have become essential for the latest digital cameras, tablets, camcorders, e-readers, set-top boxes, and consumer entertainment equipment. On the communications side, they go into switches, routers, basestations, solid-state drives, and cloud storage.

The ability to use a conventional 0.18-µm silicon-foundry process and back-end technology was of some advantage, but it still left quartz a competitive edge when price was a buyer's only criterion. However, silicon made inroads because of its supply chain advantages, reliability, and robustness.

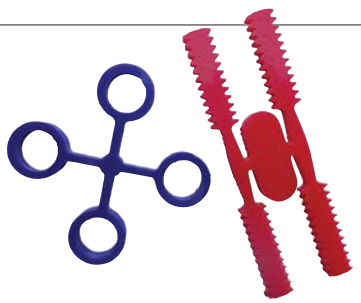
INSIDE SITIMES' RESONATORS

SITIMES OFFERS TWO kinds of silicon resonators (see the figure). One is a double-cantilever-beam low-power structure used for 32-kHz clocks for timekeeping applications such as watches. The other is a quadruple-ring structure used for 48-MHz data-clocking chips.

Essentially, the two cantilever elements in the 32-kHz devices behave like a pair of coupled vibrating beams, back-to-back. The rings have a more complex vibration mode, which can be described as something akin to the way the mouth of a bell vibrates.

In both cases, the devices were built with multiple resonators to increase the signal-to-noise ratio of the raw input to the clock chip's internal electronics. The multiple resonators also were center-anchored to reduce power consumption and to minimize the effects of external shock and vibration by reducing the coupling.

The core of the analog portion of SiTimes' clock devices is a fractional-N phase-locked loop (PLL), in which the reference frequency is divided by an integer multiple before it is input to the phase comparator. This allows the synthesis of frequencies that are N/M times the reference frequency, where M would be the multiplication factor of a conventional PLL. The analog electronics inside the clock devices also filter out shock and vibration artifacts, along with their basic function of driving the resonators.



SiTime used 3D printing to illustrate the shapes of its high-frequency and low-frequency resonators in plastic models.

Getting the internal resonators just right is non-trivial. Companies must develop their own simulation software to predict and analyze the behavior of new designs across a range of operating parameters. It's classic mechanical engineering, done at a nano scale. (SiTime's actual die size is 0.4 by 0.4 mm.)

At the scale of these structures, silicon tends to become a perfectly elastic material. In addition, due to the scale, the maximum deformation forces that a resonator structure sees are orders of magnitude less than the stress failure point of the material. That's a useful point in selling against quartz crystal clock devices, which have decades of reliability data to support their claims of robustness.

On the analog side, most of SiTime's catalog is based on 0.18-µm CMOS. The company uses TSMC as a foundry. On the MEMS side, SiTime uses TowerJazz and Bosch, which has been connected to SiTime since its founding. ■

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"Because it's silicon, we can get fully configured devices shipped in production in three to four weeks. With quartz, it might take eight to 10 weeks to get that. We can also be 10 times more reliable and 10 or 20 times more robust in terms of resistance to shock and vibration," Sevalia says, also noting that market penetration has accelerated as products for end users get smaller.

"Smart phones typically did not use MEMS timing components until we came out with a tiny 32-kHz device," he says. "This could be a breakthrough, the proverbial hockey stick, that can drive revenues for the MEMS-timing companies dramatically. The industry, as a whole, could benefit."

For instance, wearable electronics such as the Fitbit personal health monitor use SiTime's 32-kHz devices. Additionally, another set of new applications for silicon clocks is keeping networking systems synchronized.

"Your cell phone tells time. It's got a local clock for that. But that local clock must be synchronized to a global central clock. In femtocells, they're talking about synchronizing to GPS, among other options. The way to do that would be to have a local clock plus some algorithms and software to do the synchronizing function," Sevalia says.

"In general, we think the synchronization trend is going to go towards greater precision, which implies that frequency stability must similarly get better and better. If a clock's frequency is not precise, the window of uncertainty expands and you can't get the level of performance required," he says.

Particularly in mobile technologies, the emphasis on precision is a recent trend.

"Jitter performance will have to get better over time," he says, "because jitter reduces the window of uncertainty during which a clock and data can be synchronized."

ADDING FEATURES

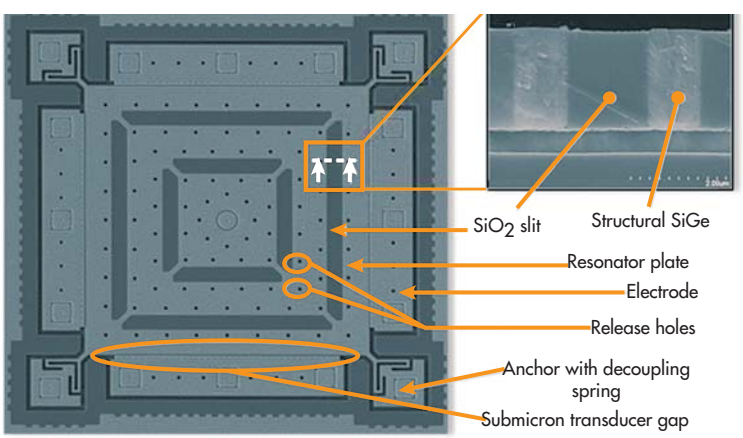
Exclusive of MEMS resonators, programmability has been an important part of all of these companies' positioning. Silicon Labs and SiTime each have a programmer that allows them to program these devices and have samples within a matter of seconds. For its communications customers, SiTime has additionally focused on high-temperature (125°C) operation. Most communications equipment runs in outdoor environments, so it needs to be able to withstand the 40°C to 45°C temperatures that are common in hot places. They can offer oscillators with guaranteed operation up to 125°C.

INSIDE SILICON LABS' CMEMS RESONATORS

SILICON LABS' PROCESS starts with standard, passivated, and planarized CMOS wafers. Polycrystalline silicon-germanium (Poly-SiGe) and pure germanium (Ge) are surface micro-machined to create integrated MEMS devices on top of the CMOS circuitry.

Silicon Labs isn't saying how its process technology can create microstructures without destroying the CMOS IC. But the company will show photos of the resonator structure (see the figure). What one sees is a square plate with slits of silicon dioxide. Those slits are a key component of Silicon Labs' intellectual property. The company says the technique avoids the temperature sensitivity of other companies' processes.

Silicon Labs says this comes about because the CMEMS resonator is fabricated from both polymorphous SiGe and silicon dioxide (SiO_2). The temperature coefficient of the SiO_2 compensates for the temperature coefficient of the SiGe, and the resulting resonator temperature coefficient is in single-digit ppms/°C. As with any semiconductor clock, these MEMS oscillators use this passively compensated resonator for a reference frequency with which to drive a cost-optimized, power-efficient digital frequency-locked loop (FLL).



1. Silicon Labs took an entirely different approach in its resonator, a flat plate made of silicon germanium and silicon dioxide.

The FLL uses the MEMS reference frequency along with a divided signal from an on-chip voltage-controlled oscillator to drive a frequency comparator that generates frequency error values and feeds them to the FLL's digital loop filter. The FLL also handles temperature compensation, using an on-chip sensor. For more, see "CMEMS Oscillator Architecture" at www.silabs.com/Support%20Documents/TechnicalDocs/cmems-oscillator-architecture.pdf. ■

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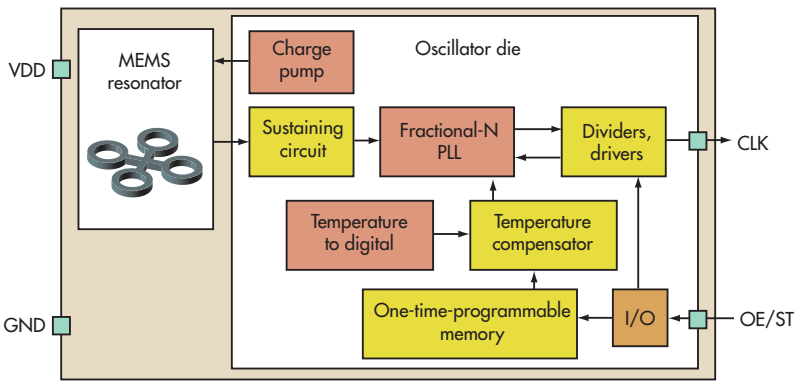

2. SiTime successfully combined MEMS and analog electronics on a single die, resolving the need to package the resonator and analog electronics separately.

Each device provides temperature compensation to cancel out the frequency drift as temperature changes affect the resonator. Then, you have the output drivers and one-time programmable memory. SiTime has been able to design kilohertz devices with jitter as low as 500 fs, stability as low as 0.1 ppm, and very low (700 nA) power consumption.

Programmable parameters include drive strength; rise and fall times to reduce electromagnetic interference (EMI), improve jitter, or drive large/small loads; frequency to six decimals of accuracy; and stability, temperature, and signaling level (LVPECL or LVDS). For long traces, designers can make the drive stronger. If the trace is short, they can make the drive strength weaker and reduce EMI.

For a standard 15-pf load, standard drive strengths will result in a typical square wave. If designers wanted to drive a softer load, they would get pulses with fast leading edges. If they want to drive a harder load, they would get a softer leading edge. There is a significant difference in EMI between the two. So if designers are looking to their clock source to reduce EMI, a soft edge can help

LATEST SITIME PRODUCTS

SiTime's recent 32-kHz SiT15xx family can be further divided into SiT153x devices that operate from a 1.2- to 3.63-V regulated supply and SiT154x devices that operate from an unregulated 2.7- to 4.5-V power source. Both come in chip-scale packaging. The former are aimed at smart phones that

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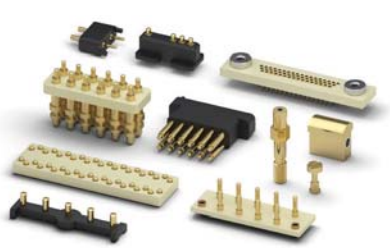

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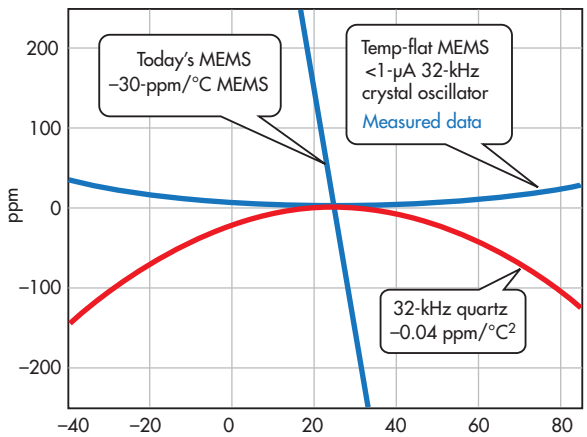

3. Until SiTimes' TempFlat announcement in July, the strongest arguments in favor of quartz resonators were their low price and predictable temperature stability (red arc). A MEMS resonator characteristic is typified by the nearly vertical line. Dealing with that required compensation circuitry inside the device. The nearly flat blue line represents actual measurements on a TempFlat crystal-oscillator-replacement device.

use coin-cell or supercap battery backup. The latter are for devices that use lithium-ion batteries.

Announced in March, they are presently the smallest timing devices for 32-kHz timekeeping functions, with a total footprint fully 85% smaller than the closest competing devices. None of the devices in the family require external decoupling or load capacitors. (Quartz resonators typically require a load capacitor for excitation.) The small footprint makes the devices attractive for smart phones and tablets *(see "Inside SiTimes' Resonators," p. 32)*.

Originally, SiTime MEMS resonators exhibited a frequency-stability variation of 30 ppm/°C. Over a temperature range from –40°C to 85°C, there could be as much as a 4000-ppm variation before temperature compensation in the analog electronics brought the clock output variation down to as low as 0.1 ppm. Quartz devices achieve 0.4-ppm/°C stability.

In July, the company introduced TempFlat MEMS, intended for smart phones. These devices differ from previous MEMS oscillators that used compensation circuitry to stabilize the output frequency over temperature. They are the first MEMS resonators that are natively able to outperform quartz resonators without temperature compensation.

TempFlat MEMS offers several advantages. If it isn't necessary to compensate a resonator variation of 30 ppm/°C, for example, the circuit consumes less power, the die area is smaller, the circuit performs better, and system design is easier.

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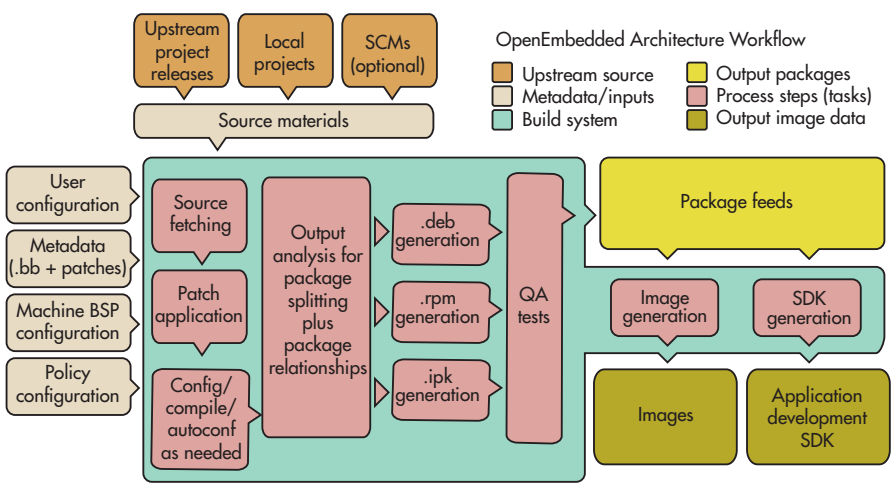
Industry Organizations Launch To Support Linux

The Yocto Project and the GENIVI Alliance deliver customized Linux platforms for embedded and automotive applications.

Cooperation is the hallmark of open-source projects, and Linux is one of the prime examples. It runs on most platforms capable of supporting it, and it is the basis for popular platforms such as Android.

Linus Torvalds manages the Linux kernel. The latest kernel can be found at www.kernel.org, but it is only the core of any version of Linux in use. It may be closer to a version of Linux used in embedded applications, but even a minimal system will have some additions to make it useful.



1. The Yocto Project uses the OpenEmbedded architecture to take BitBake recipes to generate custom Linux configurations.

Some projects target Linux specifically. The Linux Documentation Project delivers manual pages, how-to documents, and FAQs for core functions. The Linux Driver Project creates and maintains open-source kernel drivers. There are also organizations for user interfaces such as Gnome and KDE and programming frameworks like Qt *(see "Digia's Lars Knoll Discusses The Qt GUI Framework" at electronicdesign.com)*. Of course, numerous Linux distributions like Debian, Ubuntu, Fedora, and CentOS combine all of these types of components into a platform that can be installed and used immediately. They normally target PC or server platforms.

These Linux distributions often come in a minimal configuration, but they are typically more than what is required for an embedded application. They also tend to have a rather quick update sequence and lack the support necessary for embedded developers. In the long past, at least by computer standards, developers had to roll their own version of Linux. These days, embedded Linux developers normally turn to tool vendors to deliver and support their version of embedded Linux. This used to result in platforms that were very specific to the vendor, but things are changing.

The Linux Foundation supports collaborative projects built around Linux such as OpenMAMA (Open Middleware Agnostic Messaging API) and virtualization as part of the Xen Project. The Yocto Project, which has garnered an amazing amount of support, provides tools to create custom Linux-based systems *(see "Mike Woster Discusses The Yocto Project," p. 41)*. The Yocto Project kernel targets popular hardware platforms such as x86, ARM, MIPS, and Power (PC).

The GENIVI Alliance also utilizes the output of these tools *(see "Interview: Joel Hoffmann Discusses Infotainment And The GENIVI Alliance" at electronicdesign.com)*. It targets automo-

tive in-vehicle infotainment (IVI) environments. GENIVI Alliance platforms have a more limited development audience, but they may provide software platforms that can be used to deliver applications from a wide range of developers.

THE YOCTO PROJECT

Linux has grown into a number of diverse distributions such as Debian, Red Hat/Fedora, and Ubuntu. They target popular standard platforms like 32- and 64-bit x86 PCs, but they're just the tip of the iceberg. Distributions that target resource-constrained environments such as Arch Linux support a mix of package management systems, but they all build on the same Linux kernel.

The Yocto Project attempts to bring these elements together into a single environment for building Linux distributions. It primarily targets embedded developers who are interested in incorporating their own collection of features, applications, and drivers.

A developer may target a specific hardware platform, but the processes used by the Yocto Project tools allow the target to be part of the system specification. In theory, it makes porting to a different platform significantly easier. Further customization or support may still be necessary, but it can often be isolated to a device driver or application.

The Yocto Project's Poky reference system is based around the OpenEmbedded architecture *(Fig. 1)*. The project pro-

MIKE WOSTER DISCUSSES THE YACTO PROJECT

EVEN IF YOU use Linux or write applications for it, you may not know about the Yocto Project. It's essentially tools for making tools. Mike Woster, COO and vice president of the Linux Foundation, oversees Collaborative Projects such as Yocto.

WONG: How is Yocto associated with the Linux Foundation?

WOSTER: The Yocto Project is a Linux Foundation Collaborative Project. Linux Foundation Collaborative Projects are independently funded software projects that harness the power of collaborative development to fuel innovation across industries and ecosystems. We provide the infrastructure, guidance, and services needed to support a project, while participants can focus on innovation and results.

WONG: Does the Yocto Project target board support package (BSP) developers, embedded developers, or application developers?

WOSTER: Embedded system developers who are tasked with building a Linux operating-system stack will find with the Yocto Project all of the necessary tools to create a custom Linux distribution for their target device.

Board support package developers appreciate the Yocto Project providing a standardized platform for BSPs. That alleviates them from having to adapt their BSPs to different cross-development toolchains and build system environments. Consequently, for SoC (system-on-chip) vendors, the Yocto Project has become the de facto standard for SoC companies to support their BSPs, spanning all four major architecture families.

For application developers, the Yocto Project builds an Application Development Toolkit (ADT) that includes a cross-development toolchain and root file systems for hardware and emulated targets. Together with the available plugin for the popular Eclipse IDE (integrated development environment), the ADT provides a powerful roundtrip application development experience with remote target debugging and performance profiling from within a single developer's workbench.

WONG: What technologies and tools are provided by the project?

WOSTER: The Yocto Project is a collection of multiple open-source projects that are hosted and actively developed under one umbrella. The most prominent representative from this family is the Poky Build System, which is a self-contained build environment that creates custom Linux distributions all the way from source code to kernel and root file system images that boot on actual hardware as well as inside emulators. Poky includes multiple "blueprints" for creating Linux operating-system stacks. These blueprints allow system engineers to quickly ramp up building their own custom stacks by modifying and extending them.

WONG: How would I use the tools?

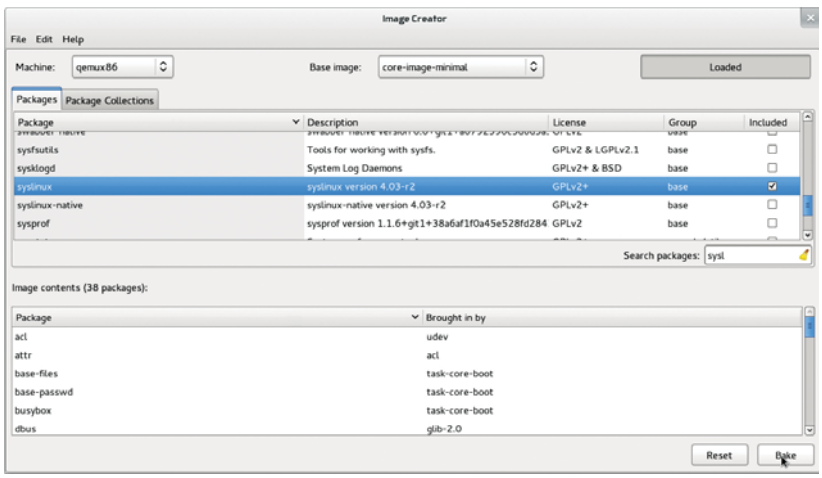
WOSTER: Anyone can start using these tools right now to build custom Linux-based embedded Linux products. You can participate in the community and/or download the tools at Yacto Project Web site. The easiest way is to download the build appliance and launch it in a virtual machine environment. That does not require the installation of any software on the test system. The test system does not even have to be a Linux system. Another option is to download the current Poky release right away, use the quickstart manual, and build your first custom Linux distro on your Linux build host.

WONG: How does the Yocto Project fit with embedded developers?

WOSTER: The Yocto Project is an embedded developer's dream, because it brings together the elements needed to make the difficult embedded Linux development process a lot easier. Also, because of the alignment with the OpenEmbedded community, developers have access to an integrated, common build framework for embedded Linux.

WONG: Is there commercial support?

WOSTER: You can see who is supporting the project today at the Yacto Project Ecosystem page: https://www.yoctoproject.org/ecosystem.



2. HOB is a graphical front end for configuring BitBake recipes.

vides open-source, high-quality templates, tools, and methods to allow anyone to create a Linux-based system for any supported hardware architecture. At the core is the BitBake build system and BitBake recipes/build files. BitBake can pull source code from Git, a distributed version control and source code management (SCM) system. Linus Torvalds initially developed Git for Linux kernel management.

Other components include:

- Autobuilder: a quality assurance (QA) automation environment built on BuildBot
- Build Appliance: a virtual machine image used to try out the Yocto Project
- EGLIBC: the embedded version of the GNU C Library
- Matchbox: an X Windows-based graphical reference user interface (UI) for embedded devices
- HOB: a graphical user interface for BitBake
- Application Development Toolkit (ADT): a development environment for user space applications to run on operating-system (OS) stacks built by Poky
- Eclipse IDE plugin: provides ADT integration
- Swabber and Pseudo: tools for cross-development integrated with Poky

Most of the Yocto Project tools are text and command line oriented. Developers can configure the system by editing text files or by using the HOB GUI *(Fig. 2)*. HOB provides basic configuration support, but it is sufficient for many developers who simply need to select and configure a basic set of features.

The Eclipse IDE plugin provides support for developers targeting Yocto-based platforms for the graphical, open-source, Eclipse development environment that is the basis for many third-party tool vendors such as Mentor Graphics' Sourcery CodeBench and Wind River's Workbench.

A typical scenario starts with the Yocto Project tools including a virtual build appliance that is a VMware virtual machine running Linux and equipped with all the necessary software to build a new Linux distribution. The developer simply needs to start with a recipe and select a target for the build process. Developers can subsequently customize a distribution by using HOB or editing the recipe files and rebuilding.

The virtual appliances do not contain the source code, only the tools to obtain it (Git) and build it (BitBake). Git will download the source code locally and then compile, link, and build the Linux image. The image then can be downloaded to the target or a simulated target.

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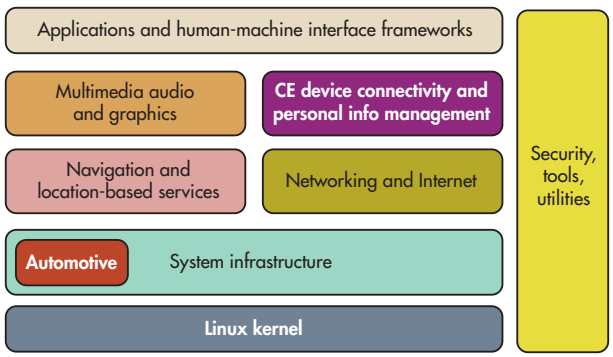

3. The GENIVI Alliance stack builds on Linux using standard frameworks on top of the Linux images while adding IVI-specific application programming interfaces (APIs).

An application for this custom distribution can be created using most any Linux development toolset, such as the Eclipse IDE, that can be equipped with the ADT plugin. This provides cross-platform toolchain support as well as QEMU (Quick EMUlator) support for simulating target hardware for test and debug purposes. It also includes many useful user space tools that run on the target.

The major embedded Linux vendors have embraced the Yocto Project. They all had their own tools in the past, and migration to the Yocto Project toolset isn't simply a matter of replacing a toolchain for cross-platform development. Likewise, many vendors had build systems that may have included more sophisticated features that they might want to incorporate into their offerings. Still, many are already delivering development environments that are based on the current Yocto Project output.

The advantages of a common framework from a developer's point of view are obvious. System designs and development tools can be shared. Software can be included simply by having the recipe and access to the source code repository on the Internet.

The advantage for vendors is less clear until one considers that they can now add their value on top of a more sophisticated system. The base software will be accessible and shared by their competition if they take the Yocto approach, but this approach simplifies building and supporting that base, leaving more resources for adding value in other areas.

GENIVI ALLIANCE

IVI is a big market and a significant selling point for new vehicles. Audio and radio solutions have grown into interactive navigation systems with Bluetooth and cellular connectivity. They still tend to be unique to an OEM and often to a particular car model or brand.

This was less of an issue before smart phones and third-party involvement in development of applications for OEMs and Tier 1 suppliers. At this point, any third-party applications on an IVI platform will be limited to a selection provided by the OEM. These applications were likely to be developed or customized specifically for the delivery platform.

The GENIVI Alliance is designed to provide a common base for IVI platforms. Joel Hoffmann, automotive strategist for Intel's Automotive Solutions Division and GENIVI Alliance spokesman, says that "the objective is to provide the industry a more competitive environment for faster innovation and lower cost of software development" *(see "Interview: Joel Hoffmann Discusses Infotainment And The GENIVI Alliance" at electronicdesign.com)*.

OEMs and Tier 1 vendors were already using or considering Linux, although other OSs and frameworks have been used in this space. Ford

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Motor Company's Sync is based on Microsoft's Windows technology *(see "Ford's Electronics Advances Aim To Reach Drivers On A More Personal Level" at electronicdesign.com)*.

Applications that interface with the driver and vehicle occupants are just part of the equation. Machine-to-machine (M2M) applications are also being linked to IVI systems and the infrastructure they utilize. A common application development environment would be useful regardless of whether additional applications are for M2M chores or for providing occupants with more information.

The GENIVI Alliance stack builds on Linux distributions from the Yocto Project *(Fig. 3)*. It also specifies standard frameworks on top of the Linux images while adding IVI-specific application programming interfaces (APIs).

The GENIVI system infrastructure provides automotive APIs for information about the car such as tire pressure. It also manages Internet access and local wired and wireless networking support. GPS and navigation support are moving from optional to standard fare, so it is not surprising that this is part of the mix as well.

The application and human-machine interface (HMI) frameworks are designed to abstract the hardware that will be available. It can range from touchscreen interfaces to voice recognition systems. CE device connectivity and personal info management should make linkage details between smart phones and tablets transparent to the developer. Multimedia audio and graphics support might seem simple, but it also needs to address hardware that will be found in a car such as the radio. Graphics support needs to be coordinated with the HMI support as well.

The baseline GENIVI system comprises more than 140 components and APIs. That is a significant chunk of software and a major amount of middleware that now has a standard interface. It would make the job of building an application for different vendors utilizing GENIVI much easier.

Security is part of the mix and one reason that GENIVI's framework may find limited third-party use compared to platforms like Android. GENIVI targets the IVI subsystem, but it is still close to the car's command and control infrastructure. The OEM may not want to allow the car's owner to arbitrarily select and install an application like one can on a smart phone. On the other hand, a common framework for applications will greatly simplify Tier 1 and Tier 2 suppliers' development chores. It also means that security-approved applications can be utilized on more hardware.

Linux supports virtual machines, but this technology has yet to find major deployment in the IVI automotive space. This could potentially isolate GENIVI-based applications.

One major difference between the Yocto Project and the GENIVI Alliance is compliance and testing. The GENIVI Alliance addresses both. Testing gives developers confidence that the platforms provide the facilities needed to run their application. Likewise, OEMs can provide a platform with known functionality. The OEMs and Tier 1 vendors manage compliance and testing.

Tool and OS vendors are delivering GENIVI-compliant platforms and tools. These products target the OEMs and Tier 1 developers plus the limited but growing group of application developers targeting GENIVI. I would not expect Android and iPhone application developers to be flocking to GENIVI yet.

The Yocto Project has widespread support and applicability. GENIVI is more focused, but both highlight how open source is changing how embedded applications are built and supported. They also show how cooperation is raising the level of the starting point for developers and vendors. ED

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Teresa Sanders Discusses TI Tech For Parkinson's Patients

According to the Parkinson's Disease Foundation, Parkinson's patients spend an average of $2500 a year on medication. As symptoms such as tremors and instability change, though, so does the need for that medication. Effective treatment depends on precise evaluation of those symptoms, but doctors can't continuously observe patients and make incremental adjustments.

Teresa Sanders, a Texas Instruments Fellow and PhD student at Georgia Tech, was working with Emory University Parkinson's disease specialists when she received an eZ430-Chronos watch from TI. She then realized that a watch with an accelerometer could measure limb tremors and be paired with other tools to provide information for accurately medicating Parkinson's patients, even at home.

The watch measures the patient's tremors and sends the data to a smart phone, which the patient also wears to track speed and stability. The phone processes the information and remotely transmits it to medical personnel for evaluation. We spoke with Sanders about the hardware and software behind the system.

ED: What makes the eZ430-Chronos watch a good fit for the system?
TS: Our primary application for the watch was using the accelerometer to monitor limb tremor. The eZ430 CC430 system, together with the USB-based CC1111 wireless interface (915 MHz), allowed our software to access and control the CC430 on-board three-axis accelerometer from either the PC (Python) or the Samsung Galaxy S3 smart phone (Java).

ED: How does the system use accelerometers to measure movement?
TS: The system uses the CMA3000-D01 low-power three-axis accelerometer for limb tremor measurement, while the Samsung S3 smart-phone accelerometer and gyroscope are used to measure the other signs of Parkinson's disease.

ED: How does the system distinguish between tremors caused by Parkinson's disease and natural arm movements?
TS: Parkinson's tremors have a distinctive frequency profile. After removing signal artifacts, we detect this profile from the watch accelerometer data using band-pass frequency filters. Since we simultaneously track body trunk movements using the smart-phone sensors, we can then isolate true Parkinsonian tremors that occur at rest from signals related to overall body movements.

ED: Did you need to develop new software to enable the watch and phone to monitor tremors?
TS: Yes, we had to create a smart-phone Java app to enable wirelessly controlling and reading from the watch (and saving the accelerometer data to the smart phone). A second app simultaneously collects data from the smart-phone onboard sensors to allow analysis of additional Parkinson's disease (PD) signs (other than tremor). We also created offline analysis algorithms and software (Matlab) for detecting the tremors and other PD signs from the saved data.

ED: What about smart-phone compatibility? Will it work with Apple, Android, and Windows devices?
TS: Our Java app should work in Android smart phones with USB host mode capability. However, so far, it has only been tested in the Galaxy S3. We have not yet created an app for Apple or Windows mobile devices.

ED: How did you develop the user interface so patients can easily use it?
TS: The data collection apps use standard Android user interfaces. However, the system is currently designed for medical professionals to set up. The system should then run continuously without patient intervention (although the patient can, of course, remove the smart phone and watch as needed). We have plans for an eventual doctor/patient data interface tool.

ED: Could the system be adapted for use with patients who have other neurological disorders that affect motor functions?
TS: Yes, the system could be adapted to detect motor signs related to other disorders such as multiple sclerosis (e.g., loss of balance, postural and/or intention tremors) or ALS (e.g., twitching, reduced movement/weakness on one side of the body).

ED: Do you have a timetable for when you expect to begin clinical trials?
TS: Our on-site IRB (institutional review board) approval allowed us to collect preliminary data in our lab. We have been talking with a potential physician partner for pre-clinical trials and hope to begin these soon. ed

TERESA SANDERS spent several years in industry designing, simulating, prototyping, and field-testing infrared and radar missile systems after obtaining a master's degree in electrical engineering from UCLA. In 2008, she returned to graduate school for a PhD in bioengineering at the Georgia Institute of Technology. She has authored numerous papers, holds one signal processing patent with another patent pending, and is the recipient of both Texas Instruments Leadership University and NSF Teaching Fellowships.

Georgia Tech PhD student and TI Fellow Teresa Sanders has developed a system that uses an eZ430-Chronos watch and a smart phone to monitor and report tremors in patients with Parkinson's disease. The watch houses a 3D accelerometer, a pressure and altitude sensor, a temperature sensor, a voltage and battery sensor, a CR2032 battery, a CC430F6137 MCU, a 96-segment LCD, a buzzer, and two-wire JTAG access. Its wireless development kit includes an eZ430 programmer, an RF access point, and a Chronos disassembly tool as well.

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SEPTEMBER 5, 2013

Global Distribution Asia: 5 Trends To Watch

Despite some re-shoring activity and slowing growth, Asia remains the world's low-cost manufacturing center and a key business target for electronics distributors.

AMERICAN MANUFACTURERS AND DISTRIBUTORS are still betting on Asia to remain the world's leading low-cost manufacturing center despite slowing growth in the region and industry talk about the "re-shoring" of projects back to North America. Supply chain companies continue to invest in Asia, seeking new opportunities and expanding existing operations—particularly in China, which analysts predict will continue to see the lion's share of the region's manufacturing activity.

Electronics distributors are making the most of these opportunities with enhanced services, new locations to better serve customers in the region, and a focus on developing more nimble global supply chains. Market leaders say that focus is especially crucial as manufacturers place increasing importance on the "design anywhere, build anywhere" philosophy, which benefits those suppliers that can serve them in multiple locations around the world. Still, whether they have served customers globally for years or

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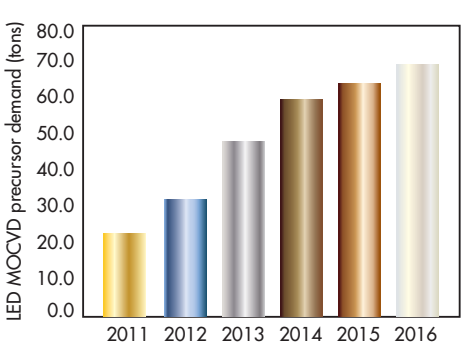
LED Demand Remains Strong

Increased use spells a bright future for component manufacturers and distributors of light-emitting diode technology.

LEDS ARE ENJOYING WIDESPREAD adoption across industrial, commercial, and residential settings, causing component makers and distributors to step up when it comes to building and introducing the newest solutions for lighting manufacturers. Distributors such as Digi-Key Corp. are keeping up by pairing new products with design services to help those manufacturers speed their time-to-market.

"We view Digi-Key's role as helping [customers] get to market faster," explains Robbie Paul, Digi-Key's director of lighting sales. "The traditional development cycle in lighting is 12 to 18 months, but the LED cycle is much faster. That's something new and different for lighting OEMs. They're not used to developing and evolving their products as quickly as they do now."

Demand for key raw material used in manufacturing LEDs is set to more than double by 2016, reflecting growing demand for solid-state lighting. *(courtesy of IHS)*



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Global Distribution

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are just starting to build an international presence, distributors selling in Asia are observing five key trends that are shaping the local business landscape.

1. SLOWING BUT STILL GROWING

Distributors doing business in Asia say growth is slowing, but they still point to the region as a good long-term source of business for those supplying the range of manufacturing operations there, especially contract manufacturers. IHS senior analyst Jeffrey Wu concurs, pointing to a slowdown across the entire outsourced manufacturing business in Asia since the 2008-2009 recession.

"What we see happening in Asia is [that] growth has slowed down compared to five years ago," says Wu. "Then, [you had] 5% compound annual growth. Now, between 2012 and 2017, the compound annual growth rate really is somewhere in the 1.5% to 2% ballpark depending on the region."

Wu points to rising labor rates, government efforts to update infrastructure, the expiration of certain tax benefits, and efforts to impose stricter environmental regulations as some reasons for the slower growth. But he adds that those conditions are not enough to keep Asia, and especially China, from maintaining its status as the world's leading low-cost manufacturing center.

"Does this mean that China won't be the world's factory anymore?" Wu says clients often ask. "Our answer is no."

Steve Martin, president of U.S.-based distributor Components Direct, agrees. Components Direct specializes in managing manufacturers' excess and obsolete components and does more than 50% of its business with customers in Asia. It has a warehouse in Hong Kong, with sales and service handled online through its e-commerce business.

"I think Asia is going to be a growing market," Martin says. "The facts and figures are that it's down and becoming more competitive, but I think that for a lot of companies—especially for a lot of North American companies—there's a lot of potential in the Asia market."

"You're going to see a much more robust supply chain infrastructure built in those areas of the world to take advantage of the optimized supply chain and, just as importantly, to mitigate risk," says Alex Iuorio, senor vice president of supplier marketing for Avnet Electronics Marketing. "What we do is couple the design chain with our supply chain so customers can design anywhere and build anywhere."

2. CHINA MAINTAINS ITS LEAD

For companies looking for a low-cost manufacturing strategy, Asia is still the place to go, with China at the top of the list. Aside from the cost benefits that can be realized on many projects, the region's now well-established manufacturing and supply chain centers are business attractors as well.

"It's really about design anywhere and build anywhere, [and the trend] happens to be Asia today," says Alex Iuorio, senior vice president of supplier marketing for Avnet Electronics Marketing. Iuorio emphasizes the region's importance by pointing to the migration of manufacturing work within Asia, specifically the movement away from coastal regions to inland China and some movement to other countries such as Malaysia and Vietnam.

"[It's about] what makes the most sense for a particular customer," Iuorio explains, noting that other trends such as regionalized manufacturing—in which companies build products closer to where they will be consumed—and local market demand are additionally coming into play.

IHS's Wu agrees, emphasizing domestic demand as a key to the region's ongoing strength.

"[In the last five years], products being built in China are being driven by an ever-increasing demand in the domestic market," he explains. "Ten years ago, the majority of product output was used for export. We don't have exact figures, but we're seeing that Chinese market demand is driving production in China to a much more significant degree than it did five to 10 years ago."

Julie Yuan, managing director of California-based small specialty distributor Amidon, agrees that China will remain the region's top low-cost manufacturing center for some time. Although she says there are projects that are going to Vietnam and Thailand, she notes that there has not been a mass exodus of work to other countries.

"It's not enough to disrupt the flow of contract manufacturing to China," she says, adding that she also sees a growing contract manufacturing base that does specialized work due to better, more consistent quality in the region. Amidon supports customers in government, medical, consumer electronics, and similar industries and is expanding its business in Southern China by opening an office in Hong Kong this fall.

3. MIGRATION TO INLAND CHINA

As Avnet's Iuorio points out, more manufacturers are moving to inland China, and that will create new infrastructure and supply chain challenges over the next few years.

"You get there because of the low-cost workforce, and now you have an inherent problem—roads, transportation [and so forth]," says Iuorio. "That will drive infrastructure, which will in turn drive supply chain processes. It makes

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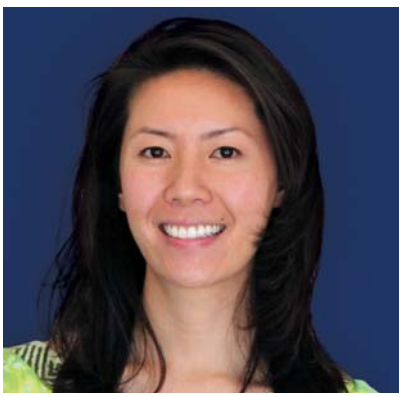

"Through the years of dealing with our customer base [in Asia], we've found that there may be more of a need for our services," says Julie Yuan, managing director of California-based distributor Amidon. Asia currently represents about 8% of Amidon's overall sales now, and the company aims to build on that.

sense to me that the biggest changes [ahead] will be around supply chain services as it relates to global customers moving their manufacturing to Asia."

Wu agrees, adding that the migration will result in new manufacturing clusters in China, which should also help drive growth.

"What's happening now is… there are a few distinct clusters in China. [As] they move production inland, there are newer hubs," Wu says, pointing to local supply chains that have developed in China over the last 15 to 20 years that make it difficult for manufacturers to move elsewhere, especially to higher-cost countries under the guise of "re-shoring."

"We still believe that a shift to the U.S. is symbolic," adds Wu, pointing to companies such as Apple and Motorola who have announced that they will build or assemble some products back on U.S. soil. "Despite program shifts back to the U.S., we do not see that kind of formation of manufacturing clusters or supply chain clusters all over again in the U.S."

4. OPTIMIZED SUPPLY CHAINS ARE A MUST

Avnet's Iuorio points to supply chain optimization as a key issue, especially as it relates to the "design anywhere, build anywhere" strategy. He says much of the world's design work is still done in the West, and as production moves East, the situation begs for an optimized supply chain—one in which manufacturers, distributors, and customers have the technology, logistics, and infrastructure in place to serve customers efficiently, anywhere in the world.

"You're going to see a much more robust supply chain infrastructure built in those areas of the world to take advantage of the optimized supply chain and, just as importantly, to mitigate risk," says Iuorio, pointing to Avnet's 300 locations in 70 countries. "What we do is couple the design chain with our supply chain so customers can design anywhere and build anywhere."

Hand in hand with that, manufacturers are paying closer attention to their "real and total" costs these days, which is affecting their decisions to manufacture some products in regions close to where they will be consumed.

"We're seeing more of a discerning view of what the real and total costs are and what makes sense for an individual customer," says Iuorio. "There is no question that we're seeing many, many [companies] manufacture in the Asia-Pacific region closer to where they think end demand will be."

5. GROWING DEMAND FOR SPECIALTY SERVICES

As customers move production to China, many distributors are moving to Asia. As Yuan explains, Amidon's move to Hong Kong this fall is a result of careful research among existing customers in the region and management's belief that there is a growing need for the specialized services Amidon provides. Amidon is a specialty distributor of ferrites, iron powder cores, and custom inductors/transformers focusing on small-quantities, typically working with purchase orders that range from $50 and up.

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LED Demand

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It's especially new and different for smaller lighting OEMs that have little experience in developing LED solutions, Paul explains. But he says distributors are seeing more interest from that part of the market as LED adoption grows.

"The question is how do more of the 2000 small and mid-size lighting OEMs participate in this market?" Paul asks. "This is new to them, so it's a key place for us to help."

Distributors have long been on the front lines of new product introductions, and most have been building their service offerings recently, especially online. Reference design libraries, micro-sites, and other lighting-focused online resources are a few examples.

But traditional component manufacturers are finding an even more pressing need to broaden their offerings in the LED department. Paul points to increasing customer demand for integrated solutions such as pre-configured boards designed for LED applications.

"Many small to mid-sized [lighting] companies don't have adequate resources to tackle the electronic challenges [involved in LED design]," explains Paul,

"The traditional development cycle in lighting is 12 to 18 months, but the LED cycle is much faster," says Robbie Paul, Digi-Key's director of lighting sales.

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Industrial Outlook Mixed

Demand is picking up in some sectors of the industrial economy, but the sequestration and sluggish energy markets are still trouble spots for some supply chain companies.

STABLE DEMAND AND SLOWLY improving business conditions characterized the manufacturing economy this summer, and supply chain companies—especially distributors—are cautiously optimistic that those conditions will hold.

In particular, distributors report some strength in industrial equipment, which fuels many of the manufacturing sectors they serve. Brian Ellison, president of America II Electronics, points to growth in the distributor's instrumentation and control business as a key example.

"That market segment seems to be rather robust now," says Ellison. "Demand is slowly ticking up and to the right. It's falling in line with [how the] electronics market as a whole has been performing since January."

Florida-based America II sells a wide range of electronic components, specializing in obsolete and end-of-life parts. The company focuses its instrumentation and control business on mining, automotive, semiconductor, and similar manufacturing industries. Ellison says buying activity in the sector has picked up over the past quarter, in particular.

"There was a lot of conservative buying in the 18 months prior to this past quarter," he explains. "Now we're seeing lead time orders from customers in that segment."

Ellison's observations match other reports. The Institute for Supply Management's Purchasing Manager's Index showed two straight months of growth in manufacturing in mid-summer, for instance, with June and July heading back into expansion mode following contraction in May *(see the table)*. The PMI, a key economic indicator, averaged 51.6 in the 12 months ending July 31, above the 50-point mark indicating growth in manufacturing.

Allied Electronics' Mark Simon says he's seeing some effects of the slow and steady improvement as well, particularly in the West, where business had been lagging. He points to medical and high-tech manufacturing in particular, adding that Allied is fielding more sales inquiries from semiconductor manufacturers recently, a hopeful harbinger of business to come.

Tool makers in the extreme Northwest were looking like another source of potential strength over the summer, Simon adds. He pointed to dwindling customer inventory—the PMI report showed that customer inventories fell 3.5 points in July, for example—as a key factor for high-service distributors such as Allied, across all markets.

"Overall, customer inventory is down," says Simon, Allied's vice president of sales. "We're a high-service distributor with millions of dollars in inventory, so that's good for us."

MINING, ENERGY STILL DOWN

Diversity is also good for Allied, which sells electronic components and electromechanical products to all segments of the industrial economy. Machinery and equipment crosses many of those areas, and Allied supports the sector in a variety of ways, selling to makers of industrial equipment as well as to users of the equipment on the factory floor. Allied sells to OEMs in the sector and supports machinery and equipment maintenance with its lines of test equipment and automation and control products.

Though he says the West is looking up and medical manufacturers are doing well everywhere, Simon also points to some trouble spots on the industrial horizon. He says makers of agricultural equipment are slowing down, the mining industry has not been good, and energy markets in the Southwest are spotty at best. Looking at energy in particular, Simon notes a decline that began a year ago but continues to be marked by some bright spots among makers of ancillary products for energy markets.

Sequestration, the series of automatic government budget cuts that began in March, is another source of concern.

"It's real," says Simon, pointing to the cuts that continue to threaten projects and programs nationwide. "There are customers that remind us of it all the time. They're worried about it. They may still be busy with previously contracted work, but it's not clear what will happen down the road. It's a continuous source of worry and concern [for many customers]. And that's a big part of our business as well."

Supply chain companies have warned of a trickle-down effect of sequestration, as many businesses that support government and military projects face potential losses due to budget shortfalls. ■

ISM PURCHASING MANAGER'S INDEX

Month	PMI	Month	PMI
July 2013	55.4	January 2013	53.1
June 2013	50.9	December 2012	50.2
May 2013	49.0	November 2012	49.9
April 2013	50.7	October 2012	51.7
March 2013	51.3	September 2012	51.6
February 2013	54.2	August 2012	50.7

Average for 12 months: 51.6
High: 55.4
Low: 49.0

Courtesy of the Institute for Supply Management

Global Distribution

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"We think there are more people out there that don't have an outlet for these small quantity [buys]," says Yuan, noting her existing contract manufacturing customers as well as potential customers in the region who may be missing out on smart buying opportunities because they simply don't have the staff or resources in the region to find them. Amidon can help not only by supporting smaller projects, but also by seeking opportunities that require a backup source of components.

"It's something we've noticed over time," says Yuan. "Through the years of dealing with our customer base there, we've found that there may be more of a need for our services."

Yuan will travel to Hong Kong in September to work on building Amidon's business. The company has office space and some staff in the region, mainly outside sales. Asia represents about 8% of Amidon's overall sales now. The move to expand internationally is aimed at helping this small company grow in what continues to be a challenging economic environment.

"We have really been struggling with the idea of whether to bring on more lines or find other avenues of expansion," she says. "This is one of many ideas we're hoping to execute." ■

LED Demand

Continued from Page 54

pointing to integrated devices that an OEM can take and connect into a system or design. "We're thinking and looking more towards the complete solutions base, all in the effort to get the customers to market faster."

SET FOR GROWTH

Digi-Key pegs the North American LED market for 15% to 20% growth this year, led by the West Coast where government regulations are driving a switch to more efficient lighting and energy solutions, Paul explains.

A recent report from IHS also points to LED market growth, noting a significant increase ahead in raw materials used to make LEDs. For instance, global demand for precursor, a material used in manufacturing LEDs, is set to more than double from 2012 to 2016 according to IHS's report titled "Precursor for LED MOCVD-Market and Industry Analysis," released in August. The market for precursor used in the metal-organic chemical vapor deposition (MOCVD) manufacturing process for making LEDs will rise to 69 tons in 2016, up 114% from 32 tons in 2012, the report says *(see the figure)*.

"The boom in the precursor market reflects the rising operating rate of MOCVD as the LED lighting market grows," explains Richard Son, senior LED analyst at IHS.

Precursor is a core material that ensures the optimal light efficiency for each LED epi layer, according to IHS. It is used in the MOCVD process, the key process in manufacturing LED chips. Major precursors include trimethylgallium (TMGa), trimethylindium (TMIn), trimethyl aluminum (TMA), triethylgallium (TEGa), and biscyclopentadienyl magnesium (C2Mg2). Among these, TMGa is the most widely used and commands about 94% of total demand. Global shipments of MOCVD equipment are also on the rise, with shipments expected to climb by 17% in 2013, IHS says.

Paul points to related growth across all end markets, with commercial and industrial leading the way. On the commercial side of the business in particular, he sees rising demand for full-fledged LED fixtures, reflected in growing sales among lighting manufacturers designing those types of solutions. On the residential side, demand is still concentrated in replacement lamps, a trend he expects to continue for the next few years. But Paul emphasizes that sales of LEDs and associated components are enjoying rapid sales growth in general.

"So that's a positive trend for us," he says.

Paul also points to lighting controls as a big growth area.

"Companies that make dimmers and other controls that go along with LED lighting are experiencing even greater sales growth than the LED manufacturers," he says, adding that controls and sensors generally are becoming a more important part of the solid-state lighting market. ■

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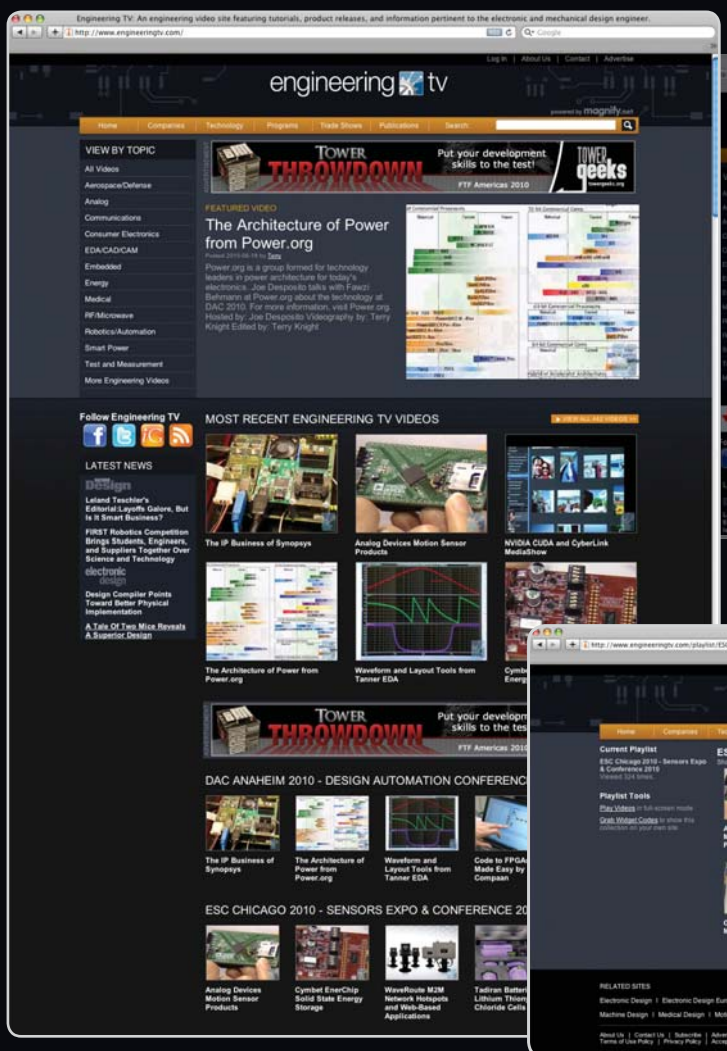

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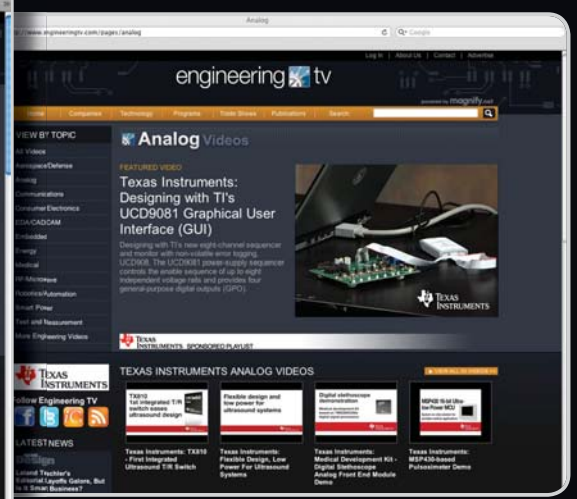

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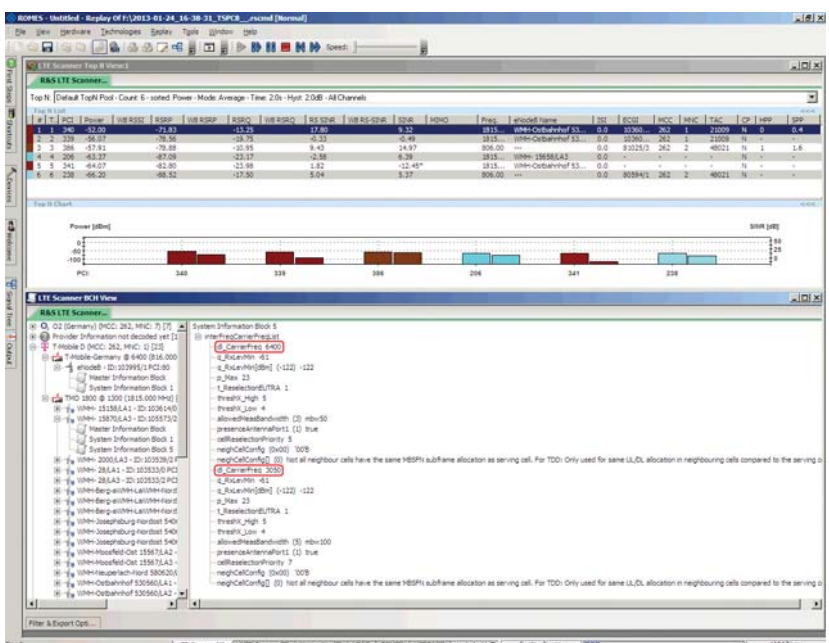
Test ANR Functionality
On Your LTE Devices

With the planned progression of networks towards LTE-Advanced and heterogeneous networks, automatic neighbor relation (ANR) is becoming more important, and so is testing the functionality on an LTE-capable, multi-mode wireless device.

With 97 networks launched in 2012 and 145 networks commercially "on air" today in 66 countries, LTE has achieved the fastest adoption rate ever for any mobile communication technology. Besides the new OFDM-based (orthogonal frequency division multiplexing) air interface and an all-IP-based (Internet protocol), simple, and flat core network architecture, LTE is the first cellular standard to take advantage of self-organizing network (SON) functionality.

One of the first SON features to be defined was automatic neighbor relation (ANR). ANR functionality is in high demand by network operators worldwide. Its aim is to significantly reduce the interaction of the service provider with its network during the manual process of managing neighbor cell relations. Over the past few years, this has become a challenging and time consuming task not only because of new technology deployments such as LTE, but also due to provisioning 2G (GSM, CDMA) and 3G (WCDMA, HSPA, 1xEV-DO) cells.



1. R&S ROMES Drive Test Software can capture decoded System Information Block Type 5 (SIB Type 5), which contains all relevant neighbor cell information for inter-frequency cell reselection.

WHAT'S MY NAME?

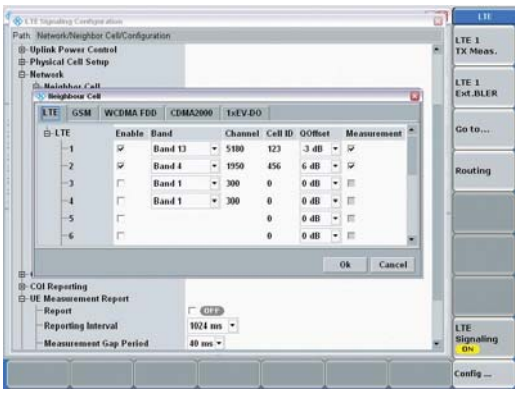
Before going into the details of ANR, it is important to get some clarity on the different but permanently assigned identities of an LTE basestation (enhanced Node B, eNode B, or eNB) during the network deployment process. The most obvious identity is the physical cell ID (PCI), which identifies a cell that is served by an eNB. The PCI is derived from the primary and secondary synchronization signal.

There are, in total, 504 unique PCIs being used throughout the entire LTE network. That relatively small number results in PCI reuse at some point, such as when the network is rolled out in a metropolitan area, not to mention the future plans of service providers worldwide to answer the forecasted capacity crunch with the deployment of small cells. The 3rd Generation Partnership Project (3GPP), the standardization body behind LTE, has specified additional identities to retain the ability to uniquely identify an eNB (and its associated cells) in an operator's LTE network.

The first is a cell identifier, better known as an E-UTRAN cell identifier (ECI), broadcast with System Information Block

Type 1 (SIB Type 1). The ECI, a 28-bit value, unambiguously identifies a radio cell within a public land mobile network (PLMN). The mobile country code (MCC) and mobile network code (MNC) form the PLMN identity.

In the U.S., one of the used country codes, for example, is 311. Two major carriers use the 311 MCC to identify their 4G LTE networks. The MNC is, of course, unique to each carrier and all other service providers. The PLMN and ECI form the E-UTRAN cell global identifier, or ECGI, which can be up to 52 bits long. While the PCI is supposed to be reused, the ECGI is a system-level parameter that must be unique.



2. The configuring neighbor cell list on the R&S CMW500 Wideband Radio Communication Tester for lab-based cell reselection test suits LTE-capable devices. Dependent on received signal quality measurements, the LTE device may decide to change the cell it is attached to by doing cell reselection.

All these identities—PCI, ECI, and ECGI—play an important role in the definition and execution of ANR functionality, as specified by 3GPP as part of Release 8 for all relevant technical specifications.

NETWORK OPERATORS DEMAND ANR

SON functionality is generally divided into three categories: self-configuration, self-optimization, and self-healing. ANR belongs to self-configuration. It relies on the device's (user equipment, or UE) capability to report cells that it has detected but are not part of the neighbor list.

What we are calling a neighbor list is actually information acquired while reading system information in the form of SIBs. For LTE, these SIBs are primarily Type 4 and 5. Other SIBs provide neighbor list information for legacy radio access technologies (RATs). SIB Type 4 lists the LTE intra-frequency neighbor cells—cells on the same carrier frequency, but with a different cell identity. SIB Type 5 provides neighboring LTE cells on a different frequency band (inter-frequency).

The SIB Type 5 inter-frequency list (recorded during network optimization measurements with the R&S ROMES drive test software) in Figure 1 shows two neighboring cells. Their downlink frequency is highlighted in red. First, there is a neighbor on channel number (EARFCN) 6400 that corresponds to 800 MHz, which is frequency band 20 used in Europe. The second cell on EARFCN 3050 is at 2.6 GHz, corresponding to frequency band 7.

This network operator uses three frequency bands for its LTE deployment. The decoded information, captured from a real network, can now be used in the lab for cell reselection tests on LTE-capable devices. The R&S CMW500 Wideband Radio Communication Tester can be used for this type of testing, where neighbor list and all other relevant parameters can be easily configured *(Fig. 2)*.

Traditionally, the initial list of cells provided by SIBs 4 and 5 are based on simulations performed with network planning tools. The coverage prediction models used by these software tools by nature simulate real-life conditions and therefore leave room for error, as conditions and the environment may change. However, a missing neighbor in the neighbor relation table (NRT) is a common reason for call and connection drops due to failed handovers. Handovers are network controlled—that is, the network decides about the target cell. An up-to-date NRT is therefore essential for successful handover.

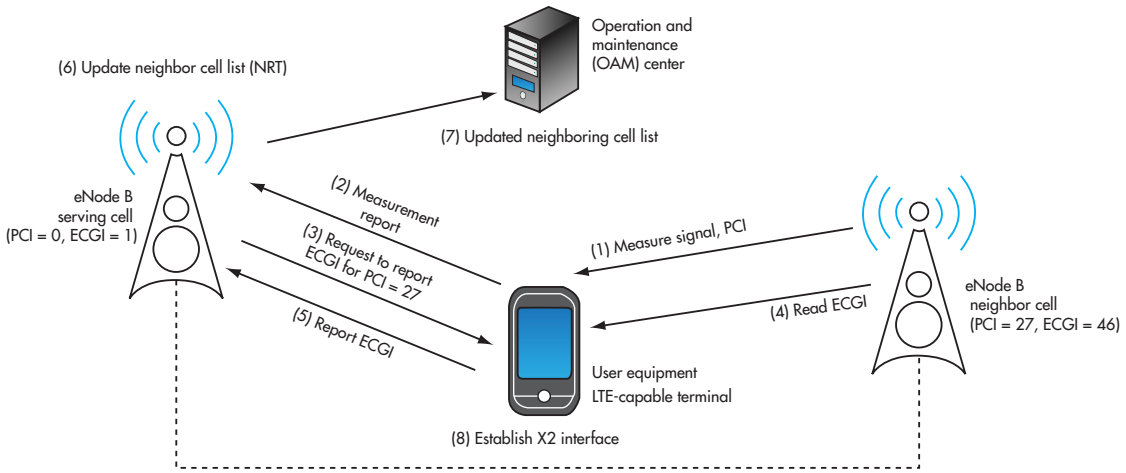
Carriers are required to perform drive tests to optimize neighbor lists manually for all technologies during the operational phase of a network. With the anticipated massive deployment of small cells, including picocells and femtocells, as part of heterogeneous networks (HetNets), this task will become even more challenging if not impossible. An automated way to determine neighbor relations is absolutely essential from an operational point of view, especially for LTE and LTE-Advanced.

ANR PROCEDURE AND DEVICE SUPPORT

In the general ANR procedure, the eNB instructs the LTE terminal to take quality measurements of neighboring cells on a periodic basis—on the same frequency, for instance *(Fig. 3)*. While doing so, the device may detect a PCI that is not listed in the neighbor list. When sending the measurement report to the network, the device uses the cell identity to indicate the cell it is reporting, including the newly detected cell with a PCI of 27.

After receiving the measurement report, the eNB instructs the terminal to report the ECGI, while reading the BCCH of that cell. In the next step, the UE reports the example ECGI of 46, which the eNB will use to update its neighbor relation table (NRT). This table contains for each cell the neighbor relation (NR), determined by the target cell identifier (TCI), which comprises ECGI and PCI.

For each TCI, three attributes will be set: no remove, no handover, and no X2. The first stipulates that the eNB shall not remove this cell from the NRT. The second stipulates that no handover shall be initiated to this cell, whereas attribute three excludes the establishment of the logical X2 interface to this



3. The ANR procedure is embedded into the overall measurement quality procedure of LTE, where a device would take periodic measurements based on certain events and triggers.

identified cell and its serving eNB. The operation and maintenance (OAM) center controls the listed attributes. It is the only authority that can delete entries from the NRT.

As indicated earlier, ANR enables intra-frequency and inter-frequency neighbor cell detection for LTE. For the latter, the network needs to inform the device about which frequencies to measure. It also requires the scheduling of measurement gaps, which enables the terminal to retune its receiver to the instructed frequencies and take the required signal quality measurements.

Feature group indicators (FGIs) indicate ANR support. The FGI for LTE as of 3GPP Release 8 is a 32-bit map, where each bit indicates the device's support of a specific feature. This bitmap is submitted to the network during the initial registration and attach procedure as part of the UE capability transfer.

The FGI bits of interest are bits 5, 17, 18, and 19. Bit 5 defines the support of the long discontinuous reception (DRX) cycle. DRX saves battery power by not continuously monitoring relevant downlink channels. The device transitions into a kind of "sleep mode" and only wakes after certain periods to read the physical downlink control channel (PDCCH).

The DRX cycle generally consists of an "on duration" and a sleep period *(Fig. 4)*. Both periods are under network control as maintained by the basestation and are configurable via several parameters and timers. An LTE-capable device always switches first to a short DRX cycle. If no data is sent during this period, the terminal will move to the long DRX cycle. For ANR, the "sleeping mode" may be used to retune the receiver to take, for instance, intra- or inter-frequency measurements for LTE or even for other RATs.

So why is the long DRX cycle so important and required for ANR? As described earlier, after the device reports the newly detected PCI, the network also will instruct it to report its ECGI. As previously noted, the ECGI consists of the ECI and the PLMN identity. Both IDs are transmitted within SIB Type 1, which has a fixed periodicity in LTE of 80 ms.

Standard measurement gaps do not provide enough time to successfully detect and decode SIB Type 1 for the newly detected cell. Only the long DRX cycle permits the device to derive the PLMN identity as well as the ECI, enabling the ECGI report back to the network.

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New CS53L30: Easy to Use, Ultra Low Power, Four-Channel Microphone A/D Converter

Highly integrated ADC makes it easy to add multiple microphones to enhance the quality of voice capture.

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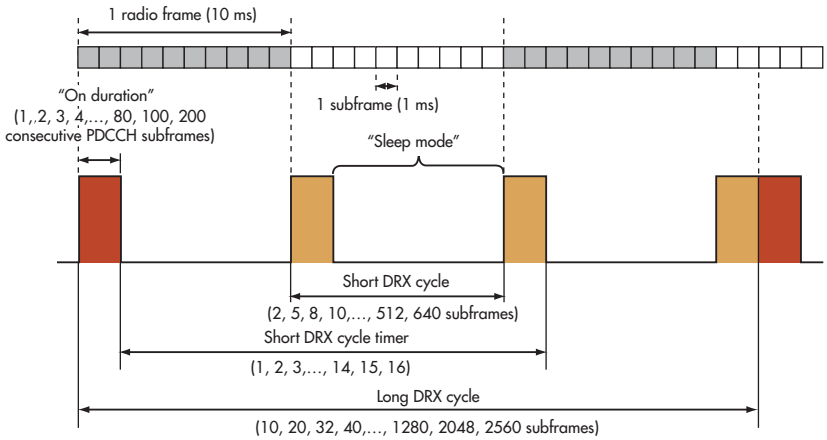


4. Short and long discontinuous reception (DRX) cycles are used in mobile communications, like LTE, to conserve the batteries of mobile devices.

Finally, bits 17 to 19 determine if the device can perform periodical measurements for intra-LTE (intra- and inter-frequency; bit 17, 18) or for inter-RAT (bit 19), i.e., 3G/WCDMA.

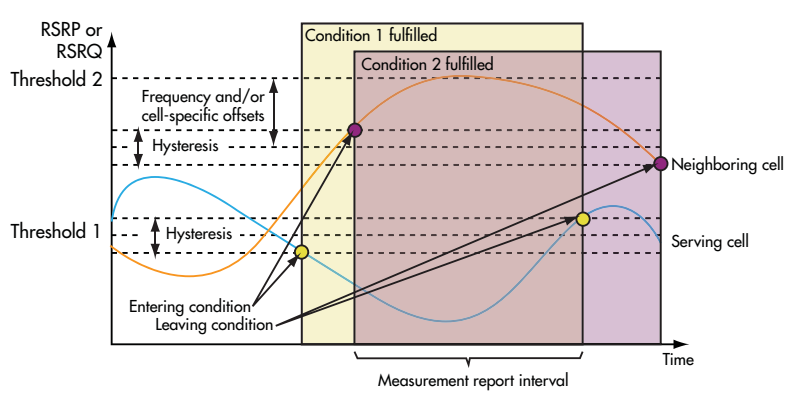
QUALITY MEASUREMENTS AND EVENT TRIGGER

Devices should not scan for neighbors continuously to find a cell that's not part of the neighbor list. The ANR procedure is well embedded within the overall quality measurements that a device would take independently of ANR. These quality measurements are based on conditions set for the LTE network that trigger certain actions. The relevant receive-signal quality measurements for LTE, which the mobile device takes, are reference signal received power (RSRP) and reference signal received quality (RSRQ).

RSRP is the average power level over all subcarriers within the signal bandwidth that carry the reference signal pattern, excluding noise and interference. A 10-MHz LTE signal, for example, consists of 600 subcarriers due to a subcarrier spacing of 15 kHz. Every sixth subcarrier (100 subcarriers in total) carries a reference symbol out of the reference signal pattern. Reference signals are used for detection and coherent demodulation by the receiver terminals and also for the quality measurements mentioned earlier.

RSRP is measured in idle as well as in connected mode, i.e., during both a pas-

5. During event A5, the serving cell falls below threshold 1 and the neighbor cell exceeds threshold 2.



LINEAR TECHNOLOGY

DESIGN NOTES

36V Input, Low Output Noise, 5A µModule Regulator for Precision Data Acquisition Systems – Design Note 518

Jaino Parasseril

Introduction

Low output noise, fast transient response and high efficiency are just a few of the stringent power supply demands made by applications featuring high data rate FPGA I/O channels and high bit count data converters. The power supply designer faces the difficult task of meeting all of these requirements with as few components as possible, since no single topology easily meets all three.

For instance, high performance linear regulators achieve the required low output noise and fast transient response, but tend to dissipate more power than a switching topology, resulting in thermal issues. Switching regulators, on the other hand, are generally more efficient and run cooler than linear regulators, but generate significantly more output noise and cannot respond as quickly to transients. Power supply designers often resort to combining the two topologies, using a switching regulator to efficiently step down a relatively high bus voltage, followed by a linear post regulator to produce a low noise output. Although it is possible to produce a low noise supply in this way, it requires careful design to achieve high efficiency and fast transient response.

An easier way to reap the benefits of both a linear regulator and a switching regulator is to use the LTM®8028, which achieves low noise, fast transient response and high efficiency by combining both regulators into a single part.

Integrated Switching and Linear Regulators

The LTM8028 is a 36V_{IN}, 5A µModule® regulator that combines a synchronous switching converter and low noise linear regulator in a 15mm × 15mm × 4.92mm BGA package. It operates from an input range of 6V to 36V with an output voltage that can be programmed between 0.8V and 1.8V. The combination of the two converters results in tight tolerance of line and load regulation over the –40°C to 125°C temperature range.

The switching frequency can be adjusted between 200kHz and 1MHz with the RT resistor, or the SYNC pin can synchronize the internal oscillator to an external clock. The 5A current limit can be reduced by utilizing the IMAX pin. The PGOOD pin can be used to detect when the output voltage is within 10% of the target value.

PCB Trace Voltage Compensation Using SENSEP

The resistance of PCB traces between the µModule regulator and the load can result in voltage drops that cause a load regulation error at the point of load. As the output current increases, the voltage drop increases accordingly. To eliminate this voltage error, the LTM8028's SENSEP pin can be connected directly to the load point.

Programmable Output Voltage

The output voltage can be digitally programmed in 50mV increments by controlling the LTM8028's 3-state inputs: VO0, VO1 and VO2. Additionally, the MARGA pin can be used for output margining via analog control that adjusts the output voltage by up to ±10%.

DC1738A Highlights the LTM8028 Capabilities

A 1.8V output application is shown in Figure 1. The LTM8028 comes in a 15mm × 15mm × 4.92mm BGA package and is featured in the demonstration circuit DC1738A, shown in Figure 2.

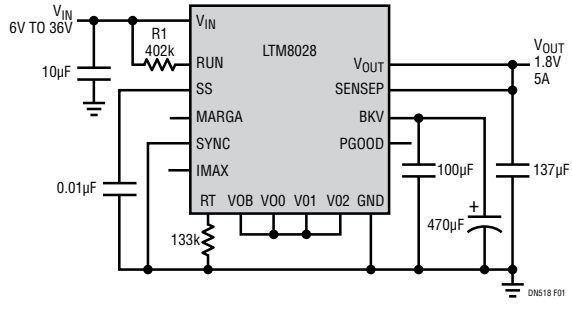


Figure 1. µModule Regulator Takes a Wide Ranging 6V to 36V Input and Produces a Low Noise 1.8V Output with Up to 5A Output Current

Noise Test Comparison Using LTC2185 ADC

When powering high speed analog-to-digital converters (ADCs), it is important to use a power supply that is as clean as possible. Any switching spurs that are present on the power supply rail will translate into AM modulation in the ADC output spectrum. The noise performance of the LTC®2185, a 16-bit ADC, was evaluated to see the difference between using (1) a typical LDO, (2) a typical switching regulator, and (3) the LTM8028 low noise µModule regulator. A simplified schematic of the test is shown in Figure 3, where the DUT is represented by either of the configurations.

Figure 4 shows the FFT plots using the three different methods of powering the LTC2185 when sampling a 70MHz tone at 100Msps. The LDO provides a clean power supply, achieving a SINAD of 76.22dB. However, when powered by a typical 250kHz switching regulator, there are spurs around the fundamental with an offset frequency of 250kHz. These are switching regulator spurs that are AM modulated around the carrier frequency. The sampling process produces 250kHz spurs at baseband. As a result, the SINAD drops to 71.84dB, around 4dB compared to an LDO. This reduces the LTC2185 to nearly 12-bit performance. In demanding applications where tenths of dBs are significant, losing 4dB of SINAD because of a noisy regulator is unacceptable. In addition to degrading the SINAD of the ADC, these spurs may land on neighboring channels or on other signals of interest, making it impossible to receive meaningful data from those channels. With the LTM8028, only a few extraneous spurs exist near the desired frequency and the SINAD performance is only 0.03dB worse than the LDO baseline. The spurious content that was very pronounced in the spectrum of the switching regulator is virtually eliminated. As a result, there will not be any performance degradation of the LTC2185 when using a LTM8028 regulator.

Conclusion

The LTM8028 µModule regulator combines a linear regulator and a switching regulator to form a DC/DC converter with minimal power loss, low noise and UltraFast™ transient response, all in a 15mm × 15mm × 4.92mm BGA package.

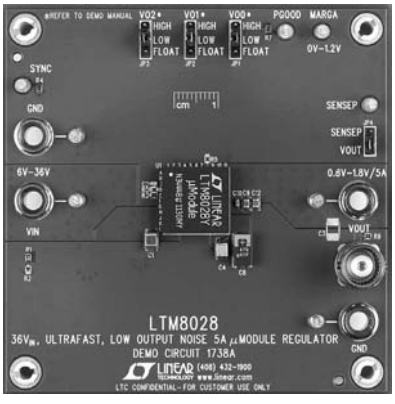


Figure 2. The LTM8028 Makes It Possible to Build a Minimal Component-Count Regulator That Meets Stringent Noise, Efficiency and Transient Response Requirements

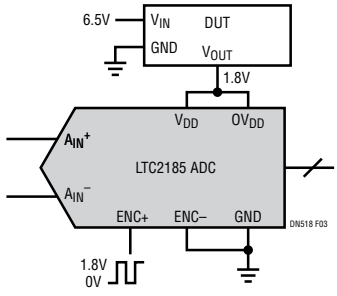


Figure 3. Noise Test Schematic Using Different Supplies to Power 16-Bit LTC2185 ADC

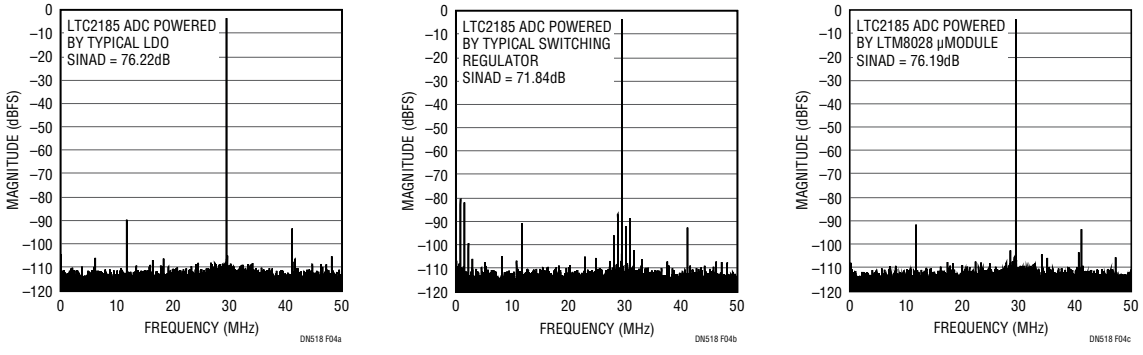


Figure 4. 32k-Point FFT, f_{IN} = 70.3MHz, –1dBFs, 100Msps, Using CMOS Clock Drive

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sive and an active connection with the network. In contrast, RSRQ is only measured in connected mode. In legacy technologies such as GSM, WCDMA, or CDMA2000 1xRTT, this metric would refer to the received signal strength indicator (RSSI). In fact, RSRQ is the ratio of RSRP over RSSI, impacted by the measurement bandwidth. Therefore, it is a quality measurement that accounts for all types of interference and noise that is degrading the received signal.

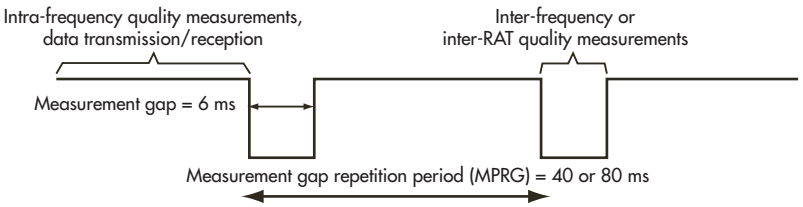
The reporting of these two quality measurements is event driven. Once certain thresholds are met or exceeded, the device starts measuring and reporting. Based on the measurement report, the basestation makes its mobility decisions. There are several event triggers for LTE-only, and there are others relating to inter-RAT to expedite handovers to legacy technologies.

Events B1 and B2 are used for inter-RAT. Events A3 and A5 are the most important for LTE and ANR. Event A3 is defined so a neighbor cell becomes better than an offset relative to the serving cell. Event A5, which is more complex, requires two criteria to be fulfilled *(Fig. 5)*. First, the serving cell needs to fall below a certain threshold. Second, the neighboring cell needs to exceed another threshold. These thresholds are based on RSRP or RSRQ.

A network operator can set its event criteria on a parameter that provides more coverage and sensitivity (RSRP) or on a parameter for interference and noise handling criteria (RSRQ). This could be different from cell to cell. For RSRP, the value is within a range of 0 to 97. Whatever value is set in the information element provided by higher layers to the device, this value minus –140 dBm/15 kHz defines the actual threshold. If RSRQ is selected as the determining threshold, the range is 0 to 34. Whatever value has been defined, this value minus 40 and divided by 2 in dB defines the actual threshold.

TESTING ANR ON A WIRELESS DEVICE

The testing of ANR functionality requires a basestation emulator, such as the R&S CMW500 Wideband Radio Communication Tester from Rohde & Schwarz, that can simulate several radio cells, e.g., for LTE and additional RATs, such as 3G/WCDMA. More complex ANR test scenarios require the simulation of multiple cells of different RATs, all in parallel. The R&S CMW500 also supports this simulation with the so-called Multi-CMW Setup. To test under more realistic conditions, including fading, an R&S AMU200A Baseband Signal Generator and Fading Simulator should be added to the setup.



6. Measurement gaps in LTE allow the retuning of the receiver to do signal quality measurements for inter-frequency LTE or other RATs.

A network operator's ANR test strategy greatly depends on its LTE network configuration. Does the network operator use just one or multiple frequency bands for LTE? What are the supported legacy technologies for 3G? For simplicity, let's assume the LTE network utilizes two frequency bands and not concern ourselves about which legacy technologies our virtual network operator uses.

In our example, the service provider shall use a low and high band combination for LTE, where the lower frequency band, 800 MHz for example, is used to provide coverage and smaller cells use the higher frequencies (e.g., at 2 GHz) to increase capacity in hotspot areas. To verify ANR support on a mobile terminal, a radio communication tester such as the R&S CMW500 can simulate a LTE cell in the lower frequency band, where the mobile registers attach to the cell.

During the establishment of the EPS default bearer, the terminal provides its capabilities as part of the UE capability transfer procedure, including the FGI. The test set has to check to see if bits 5, 17, and 18 are set to 1. As discussed above, these bits are required to perform intra-frequency and inter-frequency ANR measurements.

By sending an RRC connection reconfiguration message, the instrument configures the device to perform ANR measurements. It could use event A3 as trigger point, where the trigger threshold is set to be based on RSRP, for instance. The test set waits for the device to acknowledge this by receiving the RRC connection reconfiguration-complete message.

Next, the same basestation emulator would enable a second cell within the same frequency band but with a different cell identity (PCI). This PCI is not part of the actual neighbor list provided to the device by system information. The reference signal power set for this cell must meet or exceed the A3 trigger event threshold. The device under test (DUT) is expected to report this cell identity to the tester.

Based on the reported new PCI, the instrument would have to configure the DUT to provide a measurement report for this cell while again using the RRC connection reconfiguration message that includes the cell to be measured, its frequency, the report quantity, and interval. While the DUT acknowledges this reconfiguration, the tester will verify in the next step the correct reporting, which may also include the cell's ECGI. This ends the first part of the example test case, which is verifying intra-frequency ANR measurements.

For the second part of our test scenario, we reconfigure the DUT to take inter-frequency ANR measurements. Therefore, an LTE cell needs to be emulated on a different frequency band, i.e., at the previously mentioned 2 GHz. The trigger event for this cell shall be A5 and the threshold is based on RSRQ, instead of RSRP. As the device has to retune its receiver to take quality measurements, measurement gaps have to be defined, including one of the two possible measurement gap repetition periods (MGRPs) *(Fig. 6)*.

The DUT is now expected to report the identity of this new cell and, while reconfiguring the device to take periodic qual-

ity measurement on this cell, the identity of the ECGI within the next measurement report. At the end of this test scenario, the radio communication tester would have to release the connection and transfer the device back into idle mode.

Running such a simple test case would be possible with a correspondingly configured R&S CMW500 Wideband Radio Communication Tester. To test under realistic conditions, the RF signal has to be faded while running the test case. This can be done with the R&S AMU200A Baseband Signal Generator and Fading Simulator.

The test will produce a log file, which is displayed with the Message Analyzer, a software tool provided by Rohde & Schwarz used for protocol test case analysis and debugging. The measurement report from the DUT reports the ECGI for the detected cell while performing intra-frequency ANR measurements.

3GPP has defined a number of test cases that directly or indirectly test ANR functionality. These test cases are defined in section 8.3.3 and 8.7 of 3GPP Technical Specification (TS) 36.523 Part 1 for UE Protocol Conformance. In addition, several network operators worldwide define their own test scenarios, similar to the one described above, to verify ANR functionality on devices intended for their LTE networks.

SUMMARY

ANR is the first SON feature used in today's LTE networks. With the planned upgrading of these networks toward LTE-Advanced and HetNets, it will become even more important as deployment scenarios use a mix of macrocells, picocells, femtocells, and relays to overcome forecasted capacity demands.

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Circuit Generates High-Frequency Sine/Cosine Waves From Square-Wave Input

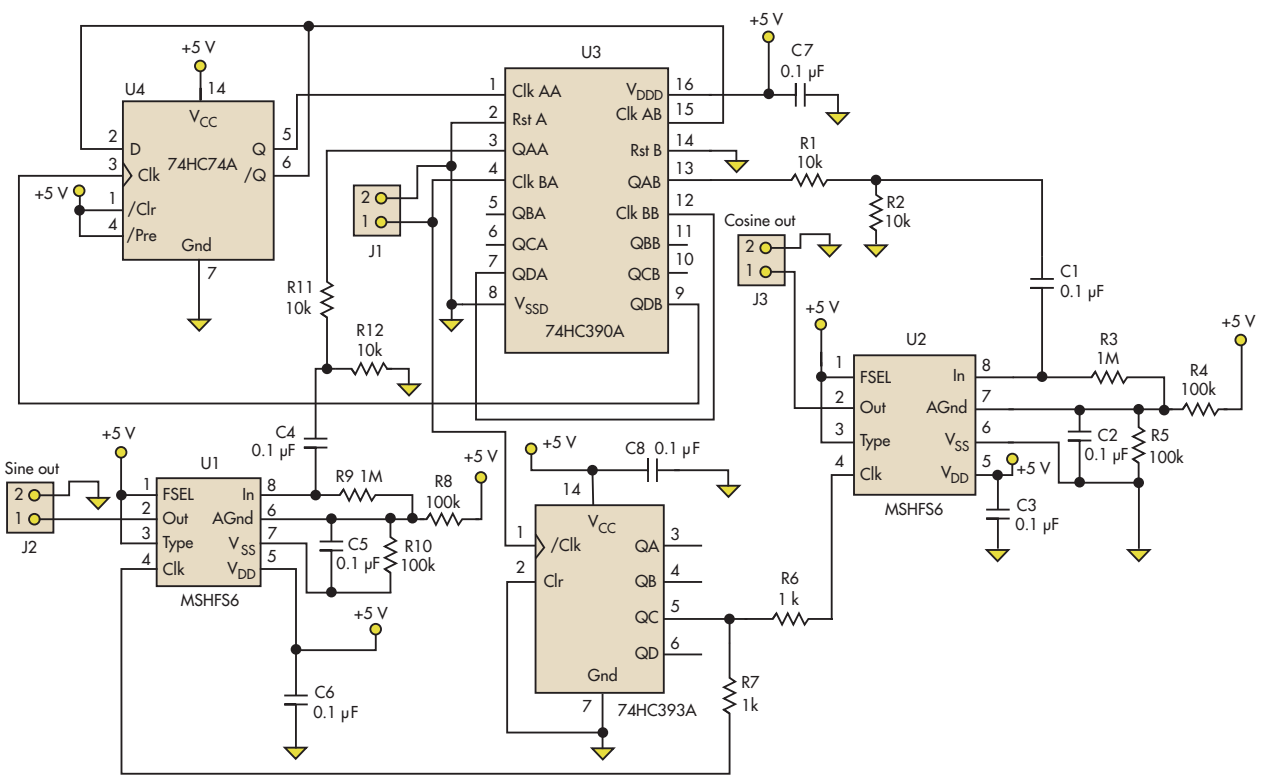
JOHN R. AMBROSE | MIXED SIGNAL INTEGRATION CORP. john@mix-sig.com

ALTHOUGH QUITE A FEW direct digital synthesis (DDS) ICs can generate high-frequency sine waves, their complexity excludes them from many designs. However, designers can use simple high-frequency CMOS logic and two switched-capacitor filters to create a sine/cosine generator. With newer filters, a 1-MHz output at 1.7 V p-p is possible.

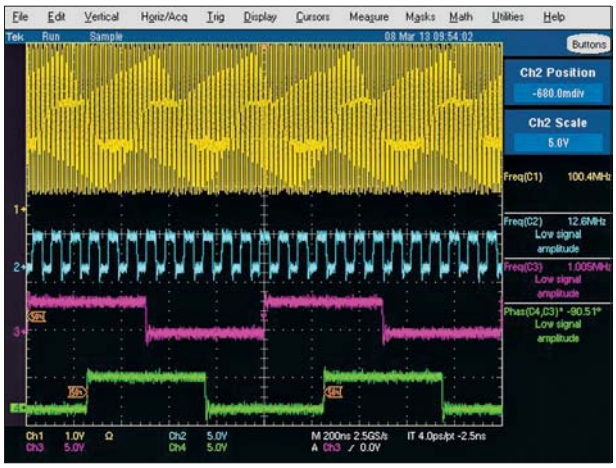
The example circuit uses an MSHFS6 5-V, low-power 12.5:1 switched-capacitor filter with selectable Butterworth, Bessel, or elliptic filters in the lowpass mode and full-, 1/3-, or 1/6-octave filters in the bandpass mode. Since the lowpass mode would cause a 3-dB loss of the signal output, the circuit uses the 1/6-octave bandpass filter, which is selected by tying pins 1 and 3 high on the MSHFS6 *(Fig. 1)*.

Two separate divider circuits are used. The 74HC393A divides the 50-MHz clock to 12.5 MHz. The 74HC390A is a dual divide-by-2 and divide-by-5 device. By combining the 74HC390 with the 74HC74A dual flip-flop, the 50-MHz clock can be divided to 500 kHz.

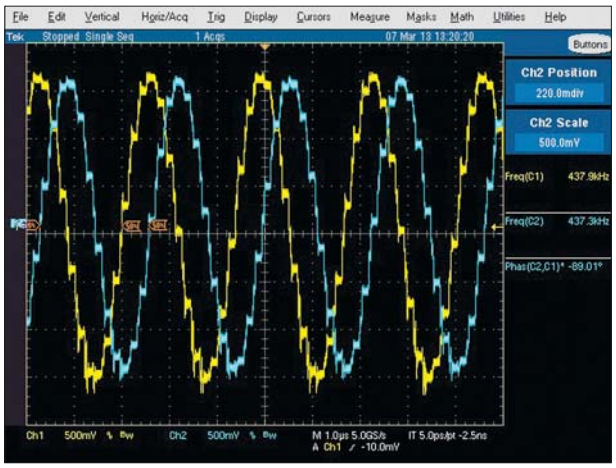
The 74HC74A provides a Q and /Q output at half the frequency of the divide-by-25 output of the 74HC390A. Dividing the 74HC74A output by 2 with the divide-by-2 blocks in the 74HC390A creates two square waves –90° apart. Figure 2 shows a 100-MHz square-wave input, a 12.5-MHz output for the filter clock, and 1-MHz sine and –cosine square-wave output before the dividers. Resistor-divider circuits reduce the amplitude from rail to rail to prevent generation of distor-



1. Instead of a DDS IC, the sine/cosine generator uses simple CMOS logic and two switched-capacitor filters to provide a 1-MHz output at 3.0 V dc.



2. The 1-MHz sine and –cosine outputs of the generator (channels 3 and 4) result from the 100-MHz square-wave input (channel 1).



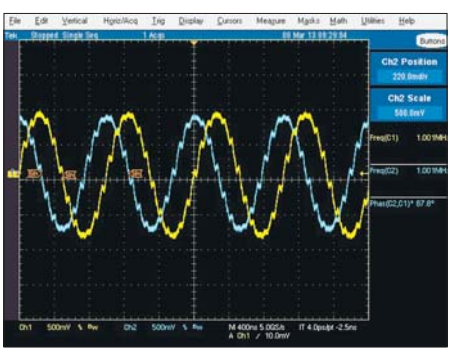
3. Channels 1 and 2 show the outputs of the two switched-filter capacitors with an input clock of nearly 50 MHz.

tion in the filters. The use of ac coupling at the MSHFS6 filter inputs ensures smoothed square waves centered around the filters' analog ground.

Figure 3 shows the output of the two filters with an input clock of nearly 50 MHz. If the inverted cosine is not acceptable, an op amp at the cosine filter output or the inverter at pin 13 of the 74HC390A can correct it.

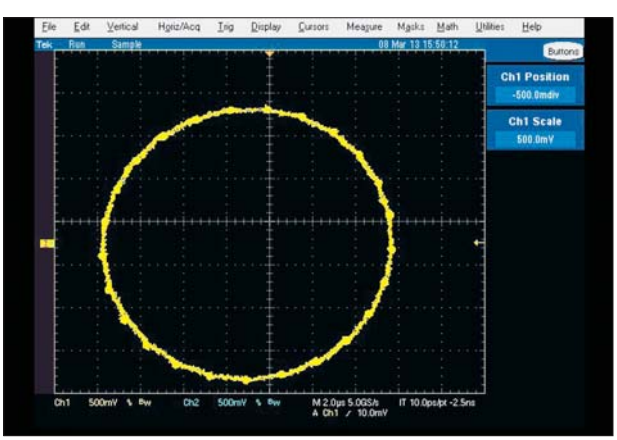
The Lissajous curve for the two outputs *(Fig. 4)* indicates that the phase circle matches the 89.1° reading in Figure 3. Using a Krohn-Hite 6900B distortion analyzer and a 1-MHz Krohn Hite lowpass filter (to remove the clock), the circuit's total harmonic distortion on the sine output was only 0.1%. Although the 74HC390A and 74HC393A have a guaranteed maximum operating frequency of 50 MHz at 6 V, Mixed Signal Integration Corp. and other companies have found that spec to be very conservative.

In this application, a 100-MHz input clock achieved the desired divide-by-4 and divide-by-100 needed to operate the newer MSVHFS6 switched-capacitor filter at 3.3 V. The only change needed was to reduce V_{DD} to 3.3 V and replace the 5-V MSHFS6 filters with the 3.3-V MSVHFS6. The input clock was increased to 100 MHz. Figures 5 and 6 show the filter outputs' phase relationship in time and as a Lissajous curve.



5. The original circuit used the MSHFS6 switched capacitor, but it also works with the newer MSVHFS6 version, which runs on 3.3 V rather than 5.0 V. This screen shows the two outputs' phase relationship in time.

JOHN R. AMRBOSE is the vice president of applications and system engineering at Mixed Signal Integration Corp.



4. The Lissajous curve for the circuit's two outputs shows that the phase circle matches the 89.1° found in Figure 3.

6. The Lissajous curve for the circuit using the MSVHFS6 3.3-V filters shows the outputs' phase relationship.

Determine Equivalent ESR, Ripple Voltage, And Currents For Unequal Capacitors In Parallel

ALEXANDER ASINOVSKI | MURATA POWER SOLUTIONS, MANSFIELD, MASS. aasinovski@murata.com

CAPACITORS OFTEN ARE CONNECTED in parallel in power electronics to decrease high-frequency ripples, current stress, power dissipation, and operating temperature, as well as to shape frequency response and boost reliability. Yet designers have three critical questions about this technique:

- What are the equivalent values of capacitance C_{se} and equivalent series resistance (ESR) R_{se}?
- What is the high-frequency ripple voltage?
- What are the individual RMS currents?

If all N capacitors in the parallel connection are identical *(Fig. 1)*, with equal capacitance values $C_{sk} = C$ and equal ESR values $R_{sk} = R_s$, then for k = 1, 2, . . . N the answers are clear:

- C_{se} is directly proportional to the number of capacitors N: $C_{se} = NC$, and R_{se} is inversely proportional to N: $R_{se} = R_s/N$.
- Ripple voltage V (RMS value) is:

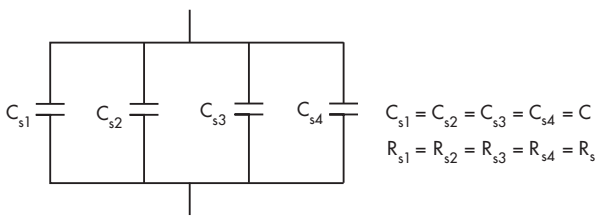
$$V = I\sqrt{R_{se}^2 + X_{se}^2} \qquad (1)$$

for a sinusoidal current excitation $i(t) = I\sqrt{2}\sin(2\pi ft)$ with frequency f, where $X_{se} = 1/(2\pi fC_{se})$ is the reactance of the equivalent capacitor C_{se} and RMS value I, and individual RMS currents in the capacitors are identical: $I_k = I/N$.

When the capacitors in the parallel connection aren't identical, with different capacitance C_{sk} and ESR R_{sk} values, the solution to the problem isn't trivial. The direct approach is to obtain an analytical expression for the input impedance of the parallel connection in the algebraic form $Z = \text{Re } Z - j\,\text{Im}Z = Z_{se}\,Z$ and use the formulas $R_{se} = \text{Re } Z$, $X_{se} = \text{Im } Z$, and $C_{se} = 1/(2\pi f X_{se})$.

A less complicated approach is based on the conversion of series C_{sk}, R_{sk} connections to equivalent parallel C_{pk}, R_{pk} connections. To obtain relationships between R_{pk} and R_{sk}, and also between C_{pk} and C_{sk}, set the admittance Y_{pk} of the parallel C_{pk}, R_{pk} pair and admittance Y_{sk} of the series C_{sk}, R_{sk} pair connections equal to each other: $Y_{pk} = Y_{sk}$, $\text{Re}(Y_{pk}) = \text{Re}(Y_{sk})$, and $\text{Im}(Y_{pk}) = \text{Im}(Y_{sk})$. Then:

$$C_{pk} = \frac{C_{sk}}{1 + \left(\frac{R_{sk}}{X_{sk}}\right)^2} \qquad (2)$$



1. For an array of N identical capacitors in parallel, determining the total equivalent capacitance and ESR values is straightforward. For unequal capacitors, the calculation can be difficult.

$$R_{pk} = \frac{R_{sk}^2 + X_{sk}^2}{R_{sk}} \qquad (3)$$

where:

$$X_{sk} = \frac{1}{2\pi fC_{sk}} \qquad (4)$$

is the reactance of the individual capacitor.

After individual parallel capacitances C_{pk} and resistances R_{pk} are calculated according to Equations 2 and 3, equivalent parallel capacitance C_{pe} can be easily found as the sum of C_{pk}:

$$C_{pe} = \sum_{k=1}^{N} C_{pk} \qquad (5)$$

The real part of equivalent admittance can be found as the sum of admittances $1/R_{pk}$. R_{pe} can be obtained as a reverse value of that sum:

$$R_{pe} = \frac{1}{\sum_{k=1}^{N} \frac{1}{R_{pk}}} \qquad (6)$$

The system's equivalent series capacitance C_{se} and ESR R_{se} can be found by conversion of the parallel C_{pe}, R_{pe} connection to the equivalent series connection C_{se}, R_{se}. To obtain relationships between C_{se} and C_{pe} and also between R_{se} and R_{pe}, set impedance Z_{pe} of the parallel C_{pe}, R_{pe} and impedance Z_{se} of the series C_{se}, R_{se} connections equal to each other: $Z_{pe} = Z_{se}$, $\text{Re } Z_{pe} = \text{Re } Z_{se}$, $\text{Im } Z_{pe} = \text{Im } Z_{se}$. Then:

$$C_{se} = C_{pe}\left[1 + \left(\frac{X_{pe}}{R_{pe}}\right)^2\right] \qquad (7)$$

$$R_{se} = \frac{R_{pe}}{\left[1 + \left(\frac{R_{pe}}{X_{pe}}\right)^2\right]} \qquad (8)$$

where:

$$X_{pe} = \frac{1}{2\pi f C_{pe}} \qquad (9)$$

is the reactance of the equivalent parallel capacitor C_{pe} *(Equation 5)*.

Based on this analysis, the calculation procedure for equivalent series capacitance C_{se}, ESR R_{se}, voltage ripples V, and RMS currents I_k in the capacitors is:

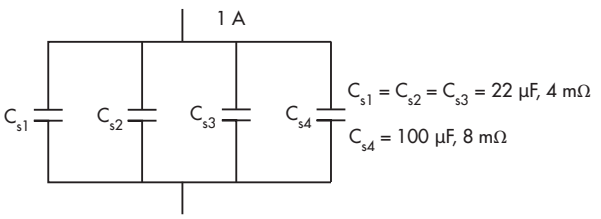
- Calculate reactances of individual capacitances according to Equation 4.
- Determine equivalent parallel parameters C_{pk}, R_{pk} of the capacitors based on Equations 2 and 3.
- Calculate equivalent parallel capacitance C_{pe} of the structure, its reactance X_{pe}, and equivalent parallel resistance R_{pe} according to Equations 5, 9, and 6.
- Calculate equivalent series capacitance C_{se} and ESR R_{se} of the structure according to Equations 7 and 8.
- Obtain RMS ripple voltage V using Equation 1.
- Calculate RMS currents I_k in the capacitors based on:

$$I_k = \frac{V}{\sqrt{R_{sk}^2 + X_{sk}^2}} \qquad (10)$$

Note that ESR values R_{sk} are strong functions of frequency. A designer should use ESR data specified by capacitor manufacturers at a given frequency of operation, such as the data for ceramic and polymer aluminum electrolytic capacitors from Murata Manufacturing Co. Ltd. (MMC) *(http://ds.murata.co.jp/software/simsurfing/en-us/index.html)*.

To illustrate the calculation procedure, let's determine equivalent parameters, voltage ripple, and current distribution for a parallel connection of three ceramic capacitors (GRM-21BR60J226ME39L) and one polymer capacitor (ESASD-40J107M015K00) from MMC *(Fig. 2)*. Using the data f = 200 kHz, $C_{s1} = C_{s2} = C_{s3} = 22$ µF, $R_{s1} = R_{s2} = R_{s3} = 4$ mΩ, $C_{s4} = 100$ µF, $R_{s4} = 8$ mΩ, I = 2 A, then:

- For reactance of each individual capacitance according to Equation 4, we have $X_{si} = X_{s2} = X_{s3} = 3.6$ mΩ, $X_{s4} = 0.8$ mΩ.
- Equivalent parallel parameters C_{pk}, R_{pk} of the capacitors based on Equations 2 and 3 are $C_{p1} = C_{p2} = C_{p3} = 21.7$ µF, $R_{p1} = R_{p2} = R_{p3} = 331$ mΩ, $C_{p4} = 49.7$ µF, $R_{p4} = 16$ mΩ.



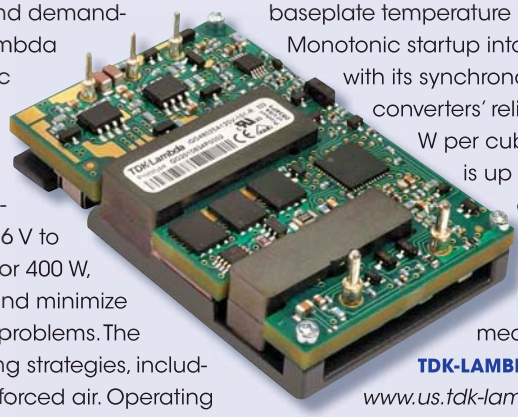
2. This example of four capacitors, with three identical and one different, illustrates how the computation scheme works in practice.

- For equivalent parallel capacitance C_{pe}, its reactance X_{pe} and equivalent parallel resistance R_{pe} of the structure according to Equations 5, 9, and 6, we calculate $C_{pe} = 115$ µF, $X_{pe} = 6.9$ mΩ, $R_{pe} = 13.9$ mΩ.
- According to Equations 7 and 8, the equivalent series capacitance C_{se} and ESR R_{se} are $C_{se} = 143.4$ µF, $R_{se} = 2.76$ mΩ.
- For RMS ripple voltage V based on Equation 1, we obtain V = 12.4 mV.
- RMS currents according to Equation 10 in ceramic and polymer capacitors are respectively: $I_1 = I_2 = I_3 = 341$ mA, $I_4 = 1.1$ A.

This shows the technique can easily determine the parameter values in each of the capacitors.

ALEXANDER ASINOVSKI is principal engineer at Murata Power Solutions Inc., Mansfield, Mass. He holds BSEE and MSEE degrees from State Technical University, St. Petersburg, Russia, and a PhD from the University of Telecommunications, St. Petersburg.

Low-Profile Quarter-Brick DC-DCs Up To 95% Efficient



TO HANDLE issues of tight space and demanding thermal environments, TDK-Lambda developed the iQG series of dc-dc converters, which measure a mere 0.52 in. high. The converters maintain a regulated 12-V dc output with 1500-V dc isolation, input to output. Input ranges from 36 V to 75 V dc. The models, rated at 300 or 400 W, feature efficiencies of up to 95% and minimize wasted heat and system cooling problems. The series is compatible with all cooling strategies, including conduction, convection, and forced air. Operating baseplate temperature ranges from –40°C to 125°C. Monotonic startup into a pre-bias output capability with its synchronous rectification enhances the converters' reliability. Power density equals 230 W per cubic inch. Usable output current is up to 33 A. The units suit intermediate or distributed bus power architectures for datacom/telecom, wireless/broadcast, robotics, industrial, and test and measurement applications.

TDK-LAMBDA AMERICAS
www.us.tdk-lambda.com

Constant-Voltage LED Driver Delivers 150 W

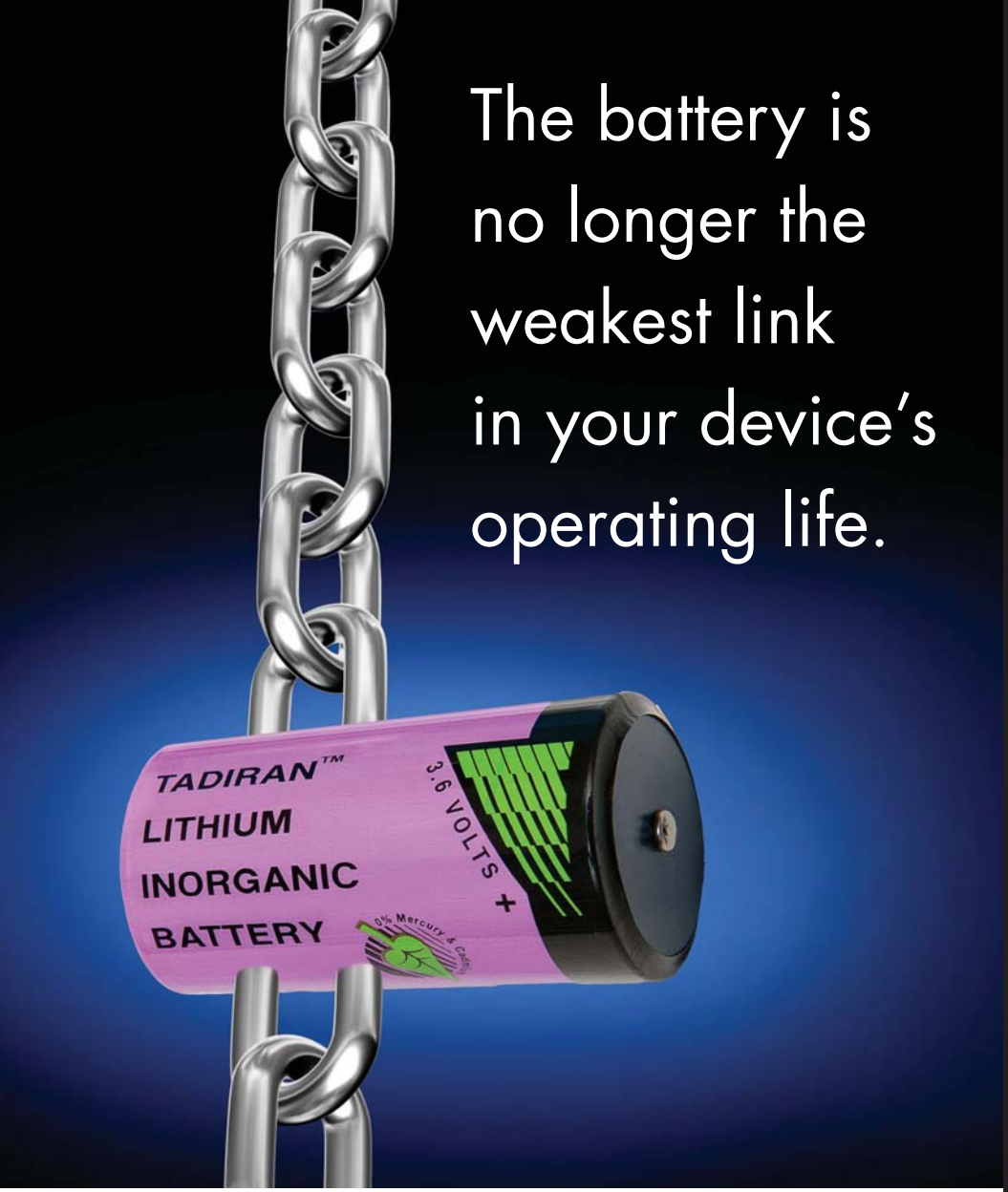
THE GLV-24-150 constant-voltage LED power supply, from Green Watt Power (a division of Calex Mfg. Co.), features a 100- to 277-V ac universal input range and a 24-V dc output voltage at 6.25 A. The input current at 110 V ac at full load is 1.8 A and 0.9 A at 220 V ac full load. Cold start inrush current at 220 V ac is 50 A maximum. The RoHS-compliant driver features 90% efficiency and 0.95 power-factor correction. Noise and ripple is 500 mV p-p. It has a 200-ms rise time with 2% load regulation. The GLV-24-150 comes in an IP67-rated, 8.98- by 2.83- by 1.73-in., fully encapsulated enclosure that has flanges to facilitate mounting. Flying leads are available, suiting the unit for various interconnect requirements. Overvoltage and overtemperature protection, as well as short-circuit protection with auto recovery, are included.

GREEN WATT POWER
www.greenwattpower.com

300-W AC-DC Supplies Have Medical Makeup

OPEN-FRAME PRINTED-CIRCUIT-BOARD (PCB) switching power supplies from PowerGate LLC feature a 300-W forced-air rating with 20 CFM and 200-W convection-cooled operation. The Mean Well RPS-300 medical power-supply series consists of five single-output models that include an active power-factor-correction (PFC) function. Output voltages range from 12 to 48 V dc. Input voltage extends from 90 to 264 V ac. Operating temperature ranges from –30°C to 70°C. A topology with synchronized rectification delivers efficiencies of up to 93%. Standard functions include a power-good signal, remote sense, and 12-V/0.5-A auxiliary output. The protection offered includes short circuit, overload, overvoltage, and overtemperature. "Green Mode" operation is enabled by remote on/off control and 5-V/1-A standby output to achieve no-load power consumption of less than 0.5 W. The supplies comply with international medical safety regulations (EN60601-1 3rd Edition/MOPP level) with low leakage current (≤300 µA at 264 V ac) and suit BF-rated, patient-contact equipment.

POWERGATE LLC
www.powergatellc.com



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Low-Noise AC-DC Linear Supply Meets Analog Objectives

THE MODEL 22-100 linear power supply developed by Calex Mfg. features a tightly regulated ±15-V output that provides ±100 mA of output current. With its low 2-mV rms output noise, the unit is tailored for powering sensitive analog circuitry. Output voltage accuracy is ±0.5%, and line and load regulation measures ±0.04% maximum. Input-voltage options include 100, 115, 220, 230, and 240 V ac, and ac input frequency ranges from 50 to 60 Hz. Isolation voltage is 1000 V rms, while isolation resistance tops out at 50 MΩ. The epoxy-encapsulated, 2- by 3- by 1-in. unit can be used in a variety of environments. Case operating temperature ranges from –25°C to 50°C. Temperature coefficient is ±0.01%/°C. Foldback current limiting protects all units.

CALEX MFG. CO. INC.
www.calex.com/pdf/submini.pdf

Wide-Input-Range DC-DCs Primed For Alternative Power Apps

EQUIPPED WITH a universal input range of 90 to 350 V dc, Absopulse Electronics' PFD 120 dc-dc converters are designed for a variety of solar and other alternative power-generation applications. Their wide input range offers solutions for 110-, 125-, 250-, and 300-V dc input requirements with a single unit. Also, their dual-conversion topology delivers up to 120-W output power. Available outputs, all tightly regulated and isolated, include 12, 24, 48, 110, and 125 V dc. A built-in redundancy diode enables parallel and N+1 operation or connection to a backup battery. Compact 114- by 51- by 201-mm chassis-mount enclosures feature robust mechanical construction and conformal coating of all printed circuits, ensuring immunity to shock, vibration, and moisture. Operating temperature ranges from 0°C to 50°C. Minimum full-load efficiency is 80%, depending on the I/O configuration. In addition to alternative power, the units suit rugged industrial environments.

ABSOPULSE ELECTRONICS LTD.
www.absopulse.com

Compact DC-DC Maintains 4:1 Input, Extended Temp Range

MINMAX'S MJWI10 series of dc-dc converters integrates tightly regulated single or dual outputs from a wide 4:1 input. The devices, within their 1- by 1-in. shielded metal package, provide 10 W. The series' 18 standard models range from 3.3 to 24 V dc in single-output configurations and ±5 to ±15 V dc in dual-output configurations. Input-to-output isolation is 1500 V dc. Up to 87% efficiency allows for a wide operating temperature range of –40°C to 80°C without derating. Remote on/off control comes standard. An optional heatsink can further expand the converters' thermal properties. The series is approved to UL60950-1 and EN60950-1 standards. Conducted electromagnetic interference (EMI) complies with EN55022, Class A and FCC level A. Applications include instrumentation, communications, electronics, and battery-operated equipment.

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rate in heat exchangers or filters, and usage in various test stand applications. The unit comes in ranges from 0-1 to 0-500 psid with standard 25% accuracy, or optional high accuracy of 0.1%. Five electrical connections are available. Amplified outputs include 0 to 5 V dc, 0 to 10 V dc, or 4 to 20 mA. Six different pressure ports simplify integration into most systems. Operating temperature ranges from –40°F to 240°F. Compensated temperature ranges from 40°F to 140°F. The transmitter's welded stainless-steel construction and safe 3X overload rating offer the ruggedness to handle demanding conditions.

TECSIS LP
www.tecsis.us

Dual-Tone Audio-Alert Transducer Offers Wide Input Range

DUE TO its operating voltage range of 6 to 48 V dc, Transducers USA's KPE637 dual-tone audio-alert transducer will find homes in a multitude of applications for on- or off-road needs. The transducer produces a sound output of over 100 dB in either a continuous or pulse output at 2500 Hz, ±500. Current consumption is 22 mA maximum, and operating temperature ranges from –30°C to 85°C. As a result, the device can handle all types of environmental conditions. Units are constructed of ABS-UL94 high-temperature plastic that comes with quick connect tabs or wire leads. For mounting, there's a two-hole footage mounting on a 32.5-mm circular body.

TRANSDUCERS USA
www.tusainc.com

Analog Output Augments Magnetic Positioning Sensor

A 4- TO 20-MA analog current and 0- to 10-V analog voltage ensure that the MPA magnetic positioning sensor delivers exceptional positioning performance, according to developer Sick Inc. The sensor's 107- to 1007-mm measuring lengths offer high-resolution and non-contact position measurement, which meet requirements of demanding automation tasks. A lower-cost alternative to potentiometers and other displacement sensors, the MPA suits applications concerning the detection of piston movements in pneumatic cylinders and positioning of pneumatic drives used for feeding, gripping, and measuring. Its IP 67-rated aluminum housing can be mounted on various cylinders, including T-slot, round, and tie rod. A teach pad, a four-color LED display, and several mounting accessories facilitate installation and commissioning.

SICK INC.
www.sickusa.com

MEMS Sensor Strengthens Shock Tolerance

DIVERSIFIED TECHNICAL Systems (DTS) enhanced its ARS PRO sensor to tolerate higher shock and vibration. Designed for high-rate angular velocity, the microelectromechanical systems (MEMS) sensor uses a resonating gyro to discern angular rates by measuring deflections in the sensing element that occur when rotational forces are applied. The device features dc response, low-power requirements, a compact form factor, and high reliability. All ARS PRO models are linear over the rated range, complying with SAE and ISO for frequency response. Full-scale ranges extend from ±300 to ±50,000 degrees/second. Bandwidths reach up to 2000 Hz. CFC 180, 600, and 1000 testing requirements are fully supported.

DIVERSIFIED TECHNICAL SYSTEMS INC. (DTS)
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Catalog Literature Review

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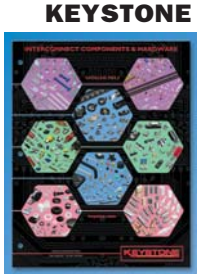

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IR's Innovative Power Block Devices Deliver Industry Leading Power Density for DC-DC Synchronous Buck Applications

IR announces the introduction of the IRFH4251D and IRFH4253D, the first of a family of innovative Power Block devices for DC-DC synchronous buck applications including advanced telecom and netcom equipment, servers, graphic cards, desktop, ultrabook and notebook computers.

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Optimized for 5V gate drive applications, the IRFH4251D and IRFH4253D work with any controller or driver to offer design flexibility while delivering higher current, efficiency and frequency capability in a small footprint compared to alternative approaches using two discrete 30V power MOSFETs.

More information is available on the **International Rectifier** website at
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The Changing Face Of Non-Volatile Storage

The Flash Memory Summit was host to a range of new technology, from LSI's SandForce flash memory controllers utilizing a multi-level low-density parity check (LDPC) to the Hybrid Memory Cube. The need for storage is insatiable. Three additional technologies look to address the issue: Samsung's 3D flash architecture, Crossbar's resistive RAM, and Diablo Technologies' TerraDIMM.

3D VERTICAL FLASH

Samsung's 3D V-NAND flash architecture increases capacity by layering 24 cells on top of each other *(see the figure)*. The technology improves reliability by a factor of two to 10 while delivering twice the write performance of conventional 10-nm-class floating-gate NAND flash memory.

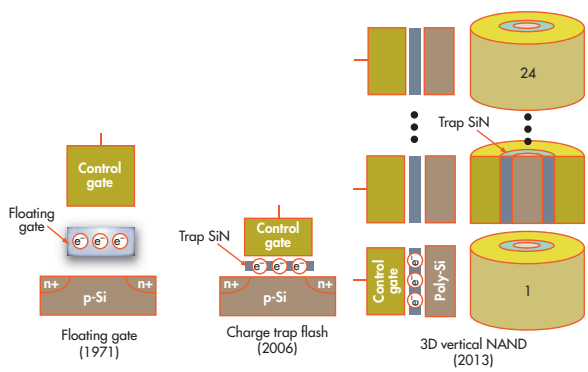
Samsung is delivering 128 Gbits in a single chip using V-NAND's 3D charge trap flash (CTF). The CTF architecture temporarily stores an electric charge in a non-conductive layer composed of silicon nitride (SiN) instead of a more conventional floating gate like most NAND technologies. A floating gate has more interference between cells as smaller geometries bring cells closer together.

Samsung uses a special etching technology to create the multilayer system. It punches holes through from the highest to the lowest layer of the chip. This is very difficult, but Samsung can now deliver chips on a regular basis.

RESISTIVE RAM IS NON-VOLATILE

Crossbar delivers non-volatile storage using a new resistive RAM (RRAM) technology that is compatible with existing CMOS technology. It beats NAND flash with performance increased by a factor of 20. It also cuts power requirements by a factor of 20. It has an efficient 4F2 cell layout as well. RRAM is comparable in performance and endurance with other non-volatile technologies like MRAM *(see "Magnetic DRAM Arrives" at electronicdesign.com)* and PCM (phase change memory), but with a lower power requirement.

Crossbar's announcement was about the technology versus chip delivery. It should scale well and even supports 3D stacking, but MRAM and PCM have yet to make a dent in flash except in niche markets. All three could give NAND flash a lot more competition in the future.



Samsung's 3D flash technology improves storage density by packing 24 layers of MLC storage cells on top of each other. It also improves reliability by a factor of two to 10.

DIMM FLASH

Diablo Technologies takes advantage of conventional MLC NAND flash but packs it onto a standard dual-inline memory module (DIMM). The TerraDIMM also includes the company's secret sauce in the form of a memory controller that handles the NAND flash and the DDR3 protocol.

A system can have a single TerraDIMM or multiple TerraDIMMs, and that's key to its performance edge. The TerraDIMM already has an edge by using the fastest interface to the processor, the memory controller. High-end processors sport multiple controllers, and multichip processor clusters share memory from all the controllers.

The TerraDIMM differs from Viking Technology's non-volatile DRAM, the ArxCis-NV. The ArxCis-NV mirrors conventional double-data-rate (DDR) memory in NAND flash between power cycles. The TerraDIMM works like conventional flash, so device drivers make this NAND look like a solid-state disk (SSD) to the operating system. The system can do more, but that requires operating-system changes. These changes may show up in the near future, offering interesting application advantages.

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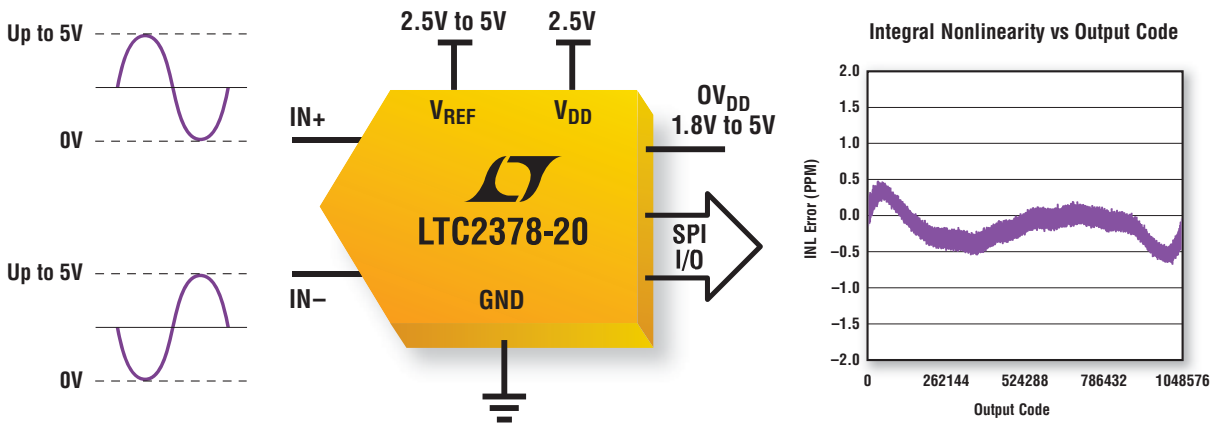

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Features

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- –125dB THD (Typ) at f_{IN} = 2kHz
- Low Power: 21mW at 1Msps, 21µW at 1ksps
- Fully Differential Input Range ±V_{REF}
- V_{REF} Input Range from 2.5V to 5.1V
- Digital Gain Compression Eliminates Need for Negative Rails
- –40°C to +85°C Guaranteed Temperature Range
- 16-pin MSOP and 4mm x 3mm DFN Packages

Complete 20-/18-/16-Bit Pin-Compatible SAR ADC Family

	250ksps	500ksps	1Msps	1.6Msps	2Msps
20-Bit 104dB SNR	2376-20	2377-20	2378-20		
18-Bit 101dB SNR	2376-18	2377-18	2378-18	2379-18	
16-Bit 96dB SNR	2376-16	2377-16	2378-16		2380-16

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