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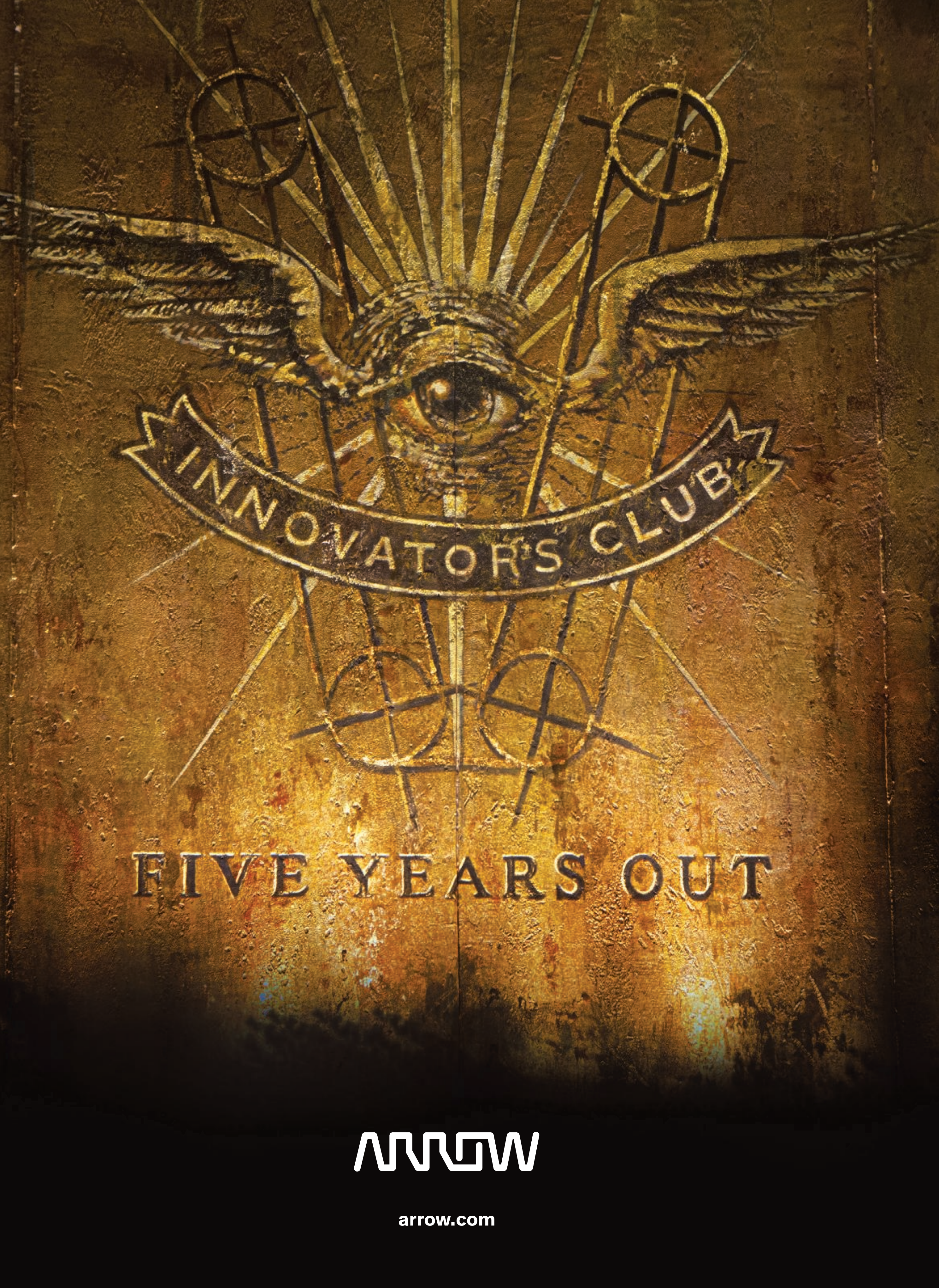
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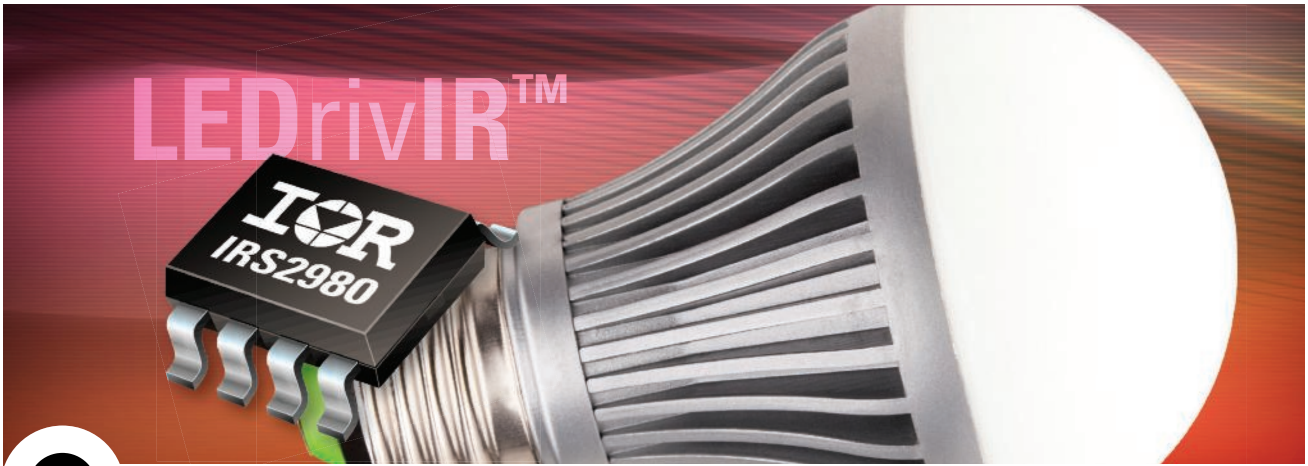
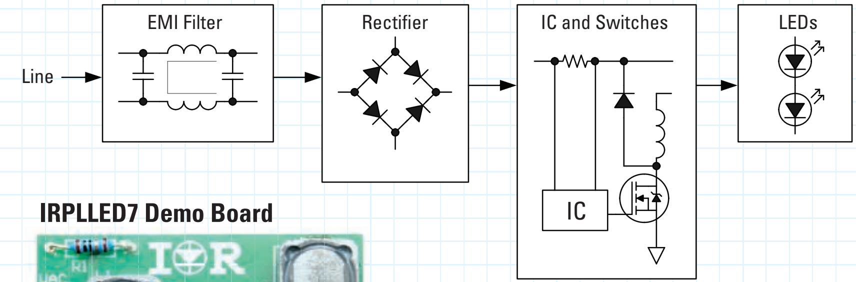
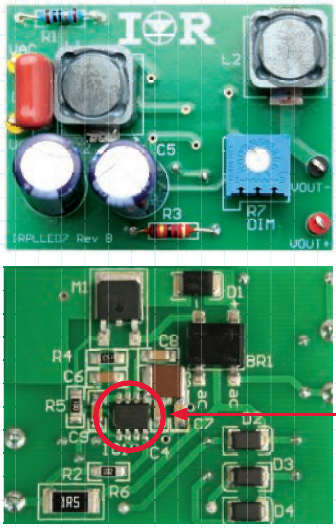


High-Voltage Buck Control ICs for Constant LED Current Regulation

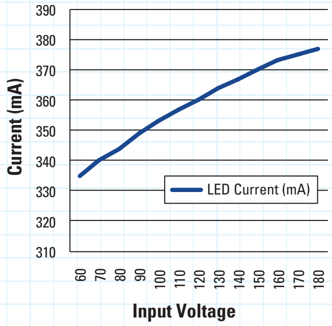


IRPLLED7 Demo Board



LEDrivIR™
IRS2980

IRPLLED7 Demo Board
LED Current vs Input Voltage



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- Internal high voltage regulator
- Hysteretic current control
- High side current sensing
- PWM dimming with analog or PWM control input
- Free running frequency with maximum limiting (150kHz)

IRS2980 Benefits

- Low component count
- Off-line operation
- Very simple design
- Inherent stability
- Inherent short circuit protection

Demo Board Specifications

- Input Voltage 70V to 250V (AC)
- Output Voltage 0V to 50V (DC)
- Regulated Output Current: 350mA
- Power Factor > 0.9
- Low component count
- Dimmable 0 to 100%
- Non-isolated Buck regulator

Part Number	Package	Voltage	Gate Drive Current	Startup Current	Frequency
IRS2980S	SO-8	450V	+180 / -260 mA	<250 µA	<150 kHz
IRS25401S	SO-8	200V	+500 / -700 mA	<500 µA	<500 kHz
IRS25411S	SO-8	600V	+500 / -700 mA	<500 µA	<500 kHz

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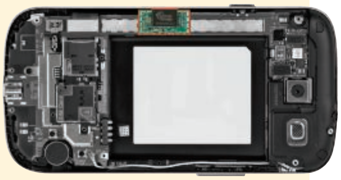

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To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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

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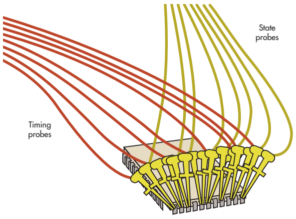

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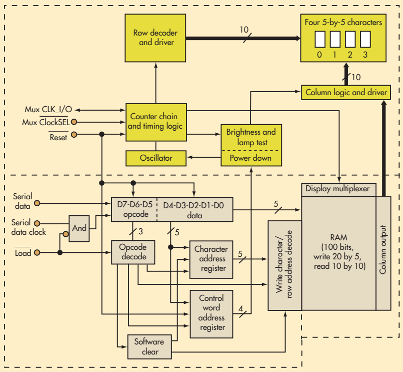

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Electronic Design Products

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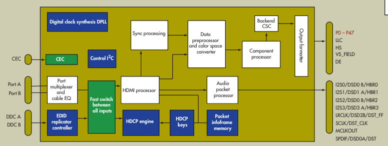

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Embedded World in Nuremberg, Germany, is one of the biggest shows on the European event calendar, and Sally Ward-Foxton was there to report on its hottest innovations.

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JOE DESPOSITO | EDITOR-IN-CHIEF joe.desposito@penton.com

Wind Turbines Play In Paradise, But Not In Falmouth

I RECENTLY RETURNED from a visit to my stepdaughter and family, who live in Hawaii on the island of Oahu. She has been living there for a few years, so my wife and I have visited her a few times now. She lives in a town called Haleiwa, which is on the North Shore of Oahu. The view of the hills to the south of the island is as beautiful as ever. However, the view of the hills to the north has changed.

Back in November, a company called First Wind completed construction of Hawaii's largest wind farm, the Kawailoa Wind project. So when you look north from Haleiwa, you can see a bevy of wind turbines methodically turning in the steady Hawaiian breeze. I was kind of shocked to see these turbines—there are 30 of them—but was also delighted to see this marvelous example of the use of green energy.

The 69-MW wind farm is built on land owned by Kamehameha Schools near Haleiwa and is expected to generate enough electricity to power the equivalent of 14,500 homes on Oahu, and at full output it could meet as much as 10% of Oahu's annual power needs, according to Boston-based First Wind. The wind farm uses Siemens 2.3-MW wind turbines.

I asked if there had been any backlash on the island from people who might be upset with the change in view, but it seems not. I also searched for news stories about Hawaiians protesting the turbines. Again, I couldn't find anything. Apparently, the project was developed with extensive input from the local community.

I asked my wife what she thought. "I think they're great," she said. "Haven't windmills been dotting landscapes for a very long time?" Absolutely, I replied.

This wind energy project is not the first for Oahu. It's actually the second and the seventh for Hawaii overall, which I had not realized.

TROUBLE IN THE WINDS AT FALMOUTH

Coincidentally, while watching TV during my trip, I caught a news segment about wind turbines that had been erected in Falmouth, Mass., in 2010. According to the report, the town had been in discussions about this installation since 2002.

It took so long to deploy not because of opposition to the project, but because the community wanted to take advantage of state and federal grants and incentive programs to make this energy source economically viable. While the community initially approved the project, now it wants to take the turbines down—at a considerable cost.

There are two main complaints, noise and health—not the change in a very scenic view. The Falmouth project, unlike the one in Hawaii, uses only two turbines. According to reports, they are Vestas V 82 1.65-MW commercial wind turbines. The Vestas Web site *(www.vestas.com)* no longer lists this model, but similar models are available.

With regards to noise, tests conducted by the Massachusetts Department of Environmental Protection revealed that sound levels from one of the two turbines exceeded the 10-dBA threshold that MassDEP defines as unacceptable under both high and low wind conditions.

The noise is not a constant sound, but more of an impulse sound like a swoosh. There's also an inaudible low-frequency sound, called infrasound. Reported health issues have included headaches, vertigo, sleep interruptions, and ringing in the ears.

ADD FIRE TO THE MIX

While researching this piece and learning about the other wind turbine installations in Hawaii, I found that one of them is having problems that have nothing to do with health, noise, or scenic beauty. The other wind farm on Oahu, at Kahuku, experienced a fire last August, which was the second one in two years.

The fire occurred in a 10,000-square-foot battery warehouse, also a First Wind facility, where electricity is stored from the farm's dozen wind turbines. The cost to rebuild is estimated at $8 million. As of the end of February, this wind farm had not resumed operations. ed

RICHARD ZARR | CONTRIBUTING TECHNICAL EXPERT ti_rickzarr@list.ti.com

The Quest For Zero Power Logic

WHAT IF A logic state was distinguished not by the flow of electrons, but by their individual positions? It's not science fiction. It's an area of research that's known as quantum cellular automata (QCA), which is part of a quest to find the successor to the aging field effect transistor (FET) as well as a solution to the density versus power dissipation problem that occurs at molecular geometries. In fact, this technology may be the next revolutionary change in the semiconductor industry.

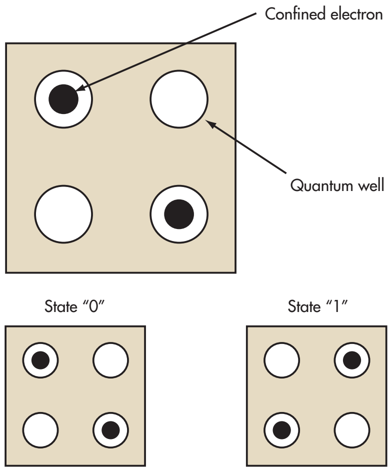
BACKGROUND

The humble and well-known FET has been the workhorse of the modern semiconductor industry for applications in computing as well as high-performance analog and mixed-signal devices. Moore's law has predicted that the number of transistors that are integrated on a single device would double roughly every two years.

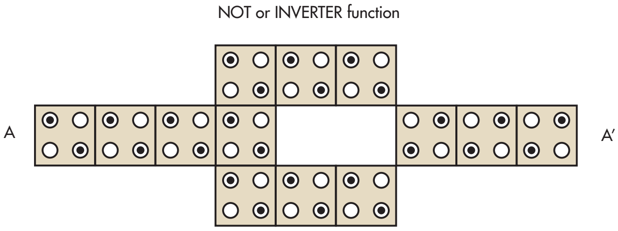
Intel and other semiconductor manufacturers have developed CMOS processes that continue to meet or even exceed Moore's predicted improvements in integration and fabrication. However, building a smaller transistor is only part of the overall problem. A power density relationship ultimately will halt the reduction in size of FETs unrelated to the ability to fabricate them.

Developments such as the FinFET, now used on the Ivy Bridge family of Intel processors, have continued to improve the density of transistors found on modern digital ICs. However, the power each transistor dissipates is based on several factors. In general, complementary transistors found in modern CMOS dissipate power while switching states, but also "leak" current while in a static state due to short channel effects and electron tunneling.

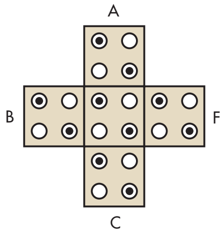
In the recent past, this leakage was minimal. But when scaling to geometries below 45 nm where the density of transistors dramatically increases, the leakage current rivals the dynamic power of the device. Scaling further continues to place more transistors in the same physical area, increasing both the dynamic and static leakage power density. It is believed this power dissipation versus density will limit the scaling before the fabrication process limits are reached.



1. A QCA cell comprises four quantum dots. The quantum dots do not scale with the cell.



Majority gate



A	B	C	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

2. There are two basic logic elements: the inverter or NOT gate (top), and the majority gate (bottom). This layout forms both gates along with the truth table of the majority gate.

ALTERNATIVE STRUCTURES

With this impending limit, the quest for a replacement for FET-based logic has been the Holy Grail of the semiconductor industry. Several single-electron candidates such as resonant tunneling diodes (RTD) and tunneling phase logic (TPL) offer advantages over traditional FET structures. One area of research in single-electron structures based on an old concept that reaches back to the first part of the 20th century called cellular automata (CA), though, has great promise in the computing world.

A CA is a state machine made from a grid of cells where each cell can only exist in a finite number of states. The cells affect each other based on either a physical law or programmatic rules that are fixed in time. In other words, the rules do not change. As an input cell changes state, it affects the state of adjacent cells, which propagates through the system. Basic CA is familiar to many of us in the form of software programs such as the computer program "Game of Life," written by John Horton Conway in 1970.

Stanislaw Ulam developed the concept of CA in the 1940s while he was employed at Los Alamos National Laboratory. Further study continued throughout the 1950s and 1960s, but it wasn't until Conway's game that interest in the field expanded outside of government institutions and universities. CA can be manifested in any finite number of dimensions, although two dimensions (planar) such as Conway's game are most applicable to logic. In the two-dimensional form, CA is a regular grid of cells. The grid typically is square, but it also can be hexagonal, like a honeycomb.

QUANTUM DOT CELLULAR AUTOMATA

As I alluded to earlier, one area of CA showing great promise is called quantum dot cellular automata (QDCA), or simply quantum cellular automata (QCA). QCA is not a new idea. It has been around since the early 1990s, when a group of researchers proposed using quantum dots to form the cells. A quantum dot can confine a single electron. A cell comprising four quantum dots is arranged in a square. After it's charged with two electrons, the cell will settle into one of two states *(Fig. 1)*. By arranging cells into patterns, gates can be created.

Solid-state QCAs have been prototyped using e-beam lithography and have dimensions on the order of 20 nm—not far from the gate length of standard FETs found in CMOS. However, they don't require a drain or source to operate. They simply need to be arranged into the correct pattern to form the logic.

QCA cells can be arranged to create logic "gates" by placing them near each other in a pattern. There are two fundamental gate structures in QCA. One is an inverter, and the other is called a "majority gate" *(Fig. 2)*.

A majority gate is fundamentally a three-input gate with a single output. In this configuration, the electric field effects of the inputs are additive, resulting in an output based on the majority state of the inputs—ones or zeros. It also can be thought of as a programmable block where one input selects the function of the other two inputs to be either an "AND gate" or an "OR gate." All other logic functions can be made from these two structures.

Additionally, wires can be built by simply arranging cells in a line. There are also structures for converting traditional voltage inputs to QCA and outputs that convert the state of a QCA cell to a voltage for integration with existing digital technologies.

DIRECTIONALITY AND CLOCKING

An interesting architectural phenomenon in QCA is that the direction of data flow is reversible. That is, unlike conventional CMOS logic where there is distinctly an input side and an output driver side, QCA can work symmetrically. This is useful in applications such as serialization and deserialization (SERDES) where the function is completely reversible. However, data in pipeline logic generally needs a fixed direction of flow or chaos ensues. The other issue is the loss of energy during state transitions, so a method to add gain to the system also must be implemented.

Both issues can be addressed via a buried clock layer below the quantum cells. This conductive material sits below all cells within a given clock "domain" and controls the gating of state transitions by raising and lowering the tunneling barrier between dots. By placing adjacent clock domains in quadrature (for example, 90° out of phase), the direction of logic flow can be controlled.

FABRICATION OF QCA LOGIC

Initially, QCA logic will be built by following the traditional methods of silicon wafer fabrication. Today, QCA structures have been fabricated using electron beam lithography, which is slow and impractical for production volumes. However, extreme ultraviolet lithography and other nanolithographic techniques show promise in fabricating structures below 10 nm in production volumes.

One method called DNA tiling uses strands of DNA to self-assemble rafts containing tiles of QCA cells. Different patterns can be formed by using the various configurations of tiles, which contain the QCA cells in fixed positions. These rafts can then be "nudged" into trenches etched with more conventional methods to form circuits.

CONCLUSIONS

CMOS still has some life left, and for the near term it will continue to be the mainstay of high-performance logic designs. But due to power density and dissipation issues, CMOS will ultimately run out of scalability, pushing the industry to alternatives. QCA shows great promise in succeeding CMOS for logic used to fabricate digital integrated circuits. By 2025, it may be the primary means used to fabricate the engines of our electronic devices. ed

RICHARD ZARR is a technologist at Texas Instruments focused on high-speed signal and data path technology. He has more than 30 years of practical engineering experience and has published numerous papers and articles worldwide. He is a member of the IEEE and holds a BSEE from the University of South Florida as well as several patents in LED lighting and cryptography.

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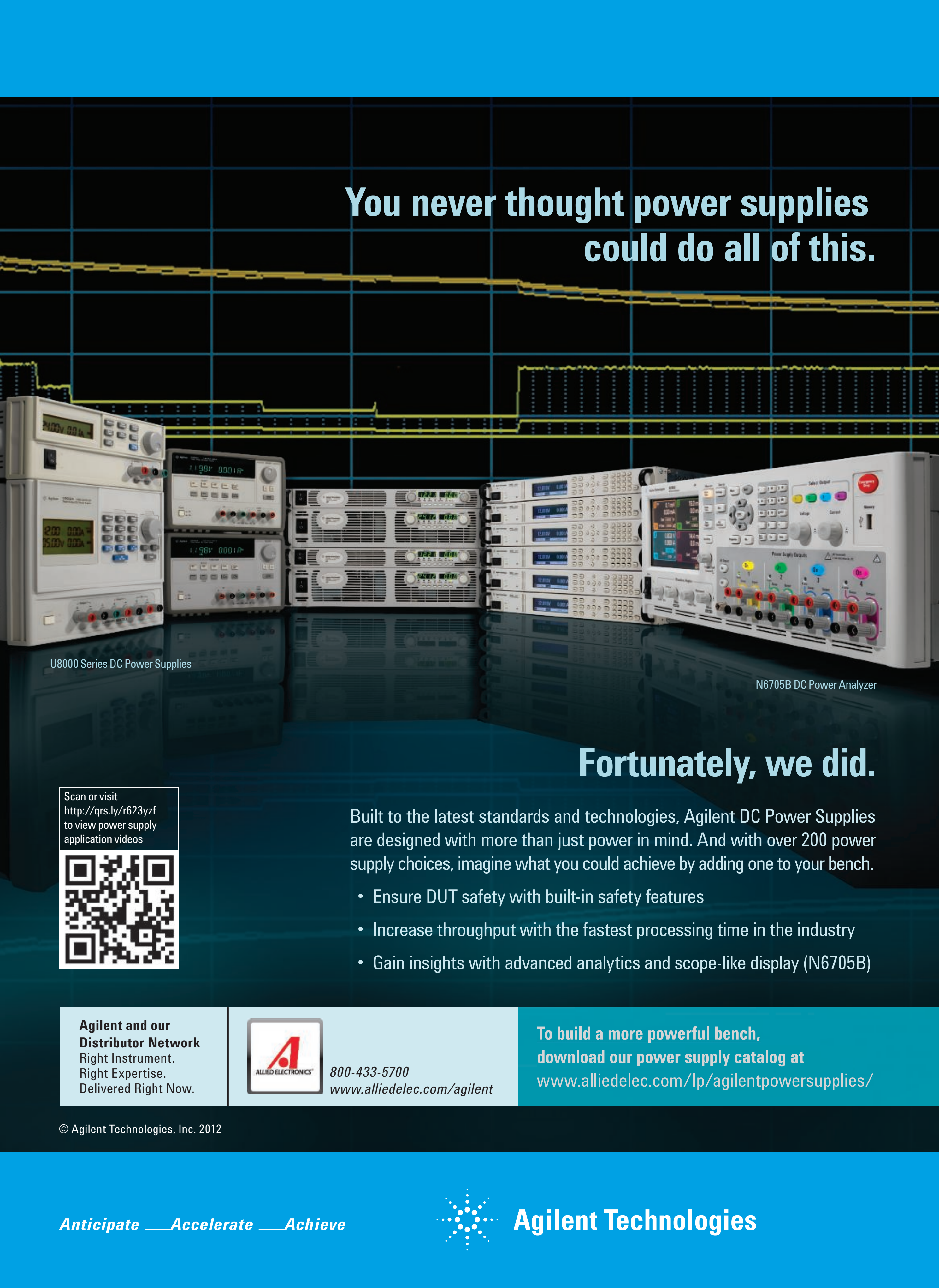

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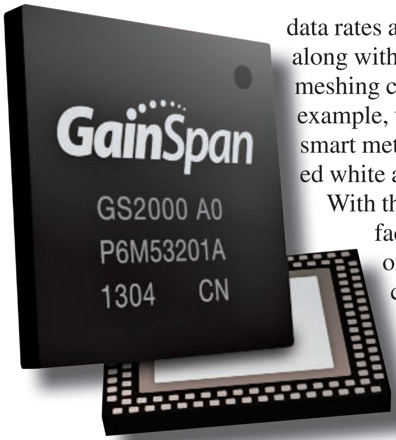
WI-FI/ZIGBEE CHIP EASES IoT IMPLEMENTATION

GainSpan's GS2000 multimode system-on-chip (SoC) implements Wi-Fi and 802.15.4/ZigBee radios in a single IC with an ARM microcontroller along with memory, multiple interfaces, and I/O capabilities. It targets the home automation market *(see the figure)*.

Home automation and energy management products rely on communications networks to provide expected monitoring and control functions. ZigBee has made some inroads with electric meter manufacturers. Other technologies like power-line communications, Wi-Fi, and Z-Wave have also seen some action.

Now, two trends are pushing the home automation movement toward a singular solution. First, the Internet of Things (IoT) is leading manufacturers to adopt Internet protocol (IP) addressing schemes that some wireless devices do not support. Second, appliance manufacturers seem to have settled on Wi-Fi as the communications link for future refrigerators, washers, driers, and other white goods.



GainSpan's GS2000 incorporates Wi-Fi and ZigBee/802.15.4 radios, enabling a single-chip solution that talks to electric meters and a wide variety of appliances and other devices in a home-area network.

Given these trends and Wi-Fi's use in many homes for Internet access, it makes sense to choose Wi-Fi as the anchor for new home automation implementations. However, devices still need to be flexible enough to implement all the technologies that are likely to appear in future home networks.

The GS2000 fully integrates multi-standard RF as well as both 802.11b/g/n and 802.15.4 physical layer/media access controller (PHY/MAC) functionality, dual ARM Cortex M3 CPUs, a networking stack and services, and a large memory to support various application profiles. The 802.15.4/ZigBee feature talks to the electric meter and any other ZigBee-enabled devices, while the Wi-Fi 802.11 radio talks to the appliances, the home router, and other Wi-Fi devices.

A dual-mode IPv4/IPv6 TCP/UDP networking stack with additional networking services enables a complete networking solution for embedded MCU-based applications. It supports the Wi-Fi wireless local-area network (WLAN) software and networking features, ZigBee IP (which is based upon 6LoWPAN), and IP-based addressing and methods over the 802.11 and 802.15.4 wireless standards.

By incorporating the only two wireless IP-based home-area network (HAN) standards while supporting dual-stack IPv4 and/or IPv6 devices, the GS2000 extends Internet connectivity wherever there's a Wi-Fi access point or hotspot and leverages the key benefits of each technology—the high data rates and widespread availability of Wi-Fi along with ZigBee IP's small channelization and meshing capability. In residential applications, for example, the solution will bridge the gap between smart meters using ZigBee and the new connected white appliances, all integrating Wi-Fi.

With the GS2000, device and appliance manufacturers no longer will have to design for one protocol or the other. Instead, they can use the same SoC to support ZigBee IP and/or Wi-Fi, with IPv4 or IPv6, all in the same product.

The GS2000's flexible dual-core architecture is based upon the popular, low-power ARM Cortex M3 CPU and is fabricated in TSMC's low-power, low-leakage, 65-nm process technology. Its mixed-signal peripherals and significant memory resources create a powerful and flexible solution for low-power and line-powered IoT applications, including smart energy. Other key features include:

- Complete Wi-Fi (IEEE 802.11b/g/n with Space Time Block Coding) and ZigBee IP (IEEE 802.15.4) on a single silicon die; the RF section is shared between 802.11 and 802.15.4 for concurrent operation
- Support for Station/Client Mode, Limited Access Point for easy provisioning or connecting to smart phones, Wi-Fi Direct, and Wi-Fi Direct with concurrent mode, allowing a device to act simultaneously as an access point station as well as an access point for other devices
- Multi-megabit/s throughput for high-definition video and audio applications
- Low idle power consumption with fast wakeup performance from idle state to extend battery life for Wi-Fi devices
- High receiver sensitivity for extended-range operation
- Personal and enterprise security, embedded DHCP, DNS and HTTP(S) clients and servers, XML parser, service and device discovery, easy provisioning, over-the-air firmware updates, and more
- Support for SEP2.0, OpenADR, and ECHONET Lite for Smart Energy Applications

The GS2000 and associated modules are sampling now with full production later this year. **LOUIS E. FRENZEL**

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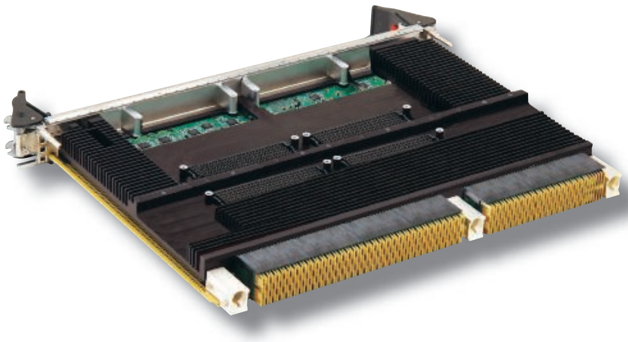

Curtiss-Wright's CHAMP-WB-DRFM runs a Xilinx Virtex-7 FPGA and has a special, dual FMC site for the Tektronix TADF-4300 FMC module.

DELIVER FAST ANALOG USING VPX AND FMC

The FPGA Mezzanine Card (FMC) standard has been widely adopted to provide a way to customize FPGA boards using third-party modules. Its high-speed interface can handle bandwidths needed by the latest FPGAs, but sometimes applications push even those limits.

Curtiss-Wright Controls and Tektronix have combined to exceed these limits starting with Curtiss-Wright's CHAMP-WB-DRFM *(see the figure)* and Tektronix's TADF-4300 FMC module. But the TADF-4300 FMC is not a typical FMC module. It covers two FMC sites and adds proprietary expansion sockets to utilize the full bandwidth of the digital-to-analog converters (DACs) and analog-to-digital converters (ADCs) on the FMC module and provide data to the host Xilinx Virtex-7 FPGA.

The additional sockets support 20 serializers/deserializaers (SERDES) that can operate at speeds up to 10.3 Gbits/s. There are 16 low-voltage differential signaling (LVDS) pairs on the socket in addition to the standard interface on the regular FMC sockets.

The 6U OpenVPX (VITA 65) board can handle the 12.5-Gsample/s data stream from the FMC module. Backplane communication includes Gen 2 Serial RapidIO (SRIO) support, but the Virtex-7 can be programmed to handle other fabrics as well.

The board is available with an X690T or X980T Virtex-7 FPGA that has access to 8 Gbytes of dual banked DDR3L SDRAM. The system supports Xilinx ChipScope Pro and JTAG debug interfaces. The board has thermal and power monitoring support. The VITA67.2 coax backplane option is available.

The combination targets demanding, rugged applications such as electronic warfare, radar, signal intelligence, and electronic countermeasures. The FMC can handle dual-channel, 8-bit ADC and 10-bit DAC operation at 6.25 Gsamples/s.

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ROBOTICS *MOVES* TO THE MAINSTREAM

Robots soon will be everywhere, including at home and at work. But first, designers must ensure safety and resolve other practical issues.

Don't look now, but an autonomous robot might be around the corner cleaning the floor, delivering medical supplies, or performing some other useful job. You literally could bump into a robot while it's trying to complete its chores for its human overlords. You might even be one of those overlords.

Robots have been improving for decades, but what started in a university lab is now available at the hardware store, like iRobot's Roomba floor cleaner. If you've ever visited the University of Maryland Medical Center (UMMC), you may have seen the Aethon TUG delivering everything from medicines to meals.

Robots are used in assembly lines to create everything from cars to cookies, but they're typically isolated from people or put inside a cage for safety. Sensing systems such as light curtains make environments that are more open possible, shutting down the robot if an object or a person crosses the curtain.

1. The Baxter from Rethink Robotics is a behavior-based robot that can be easily trained to perform assembly tasks.

2. Hundreds of Aethon TUGs are being deployed in hospitals to deliver everything from medicine to meals.

Sometimes robots are segregated because the environments are dangerous. Sometimes, they're segregated because they can't identify people and could hurt them. However, some robots have to interact with people, making safety solutions much more difficult. Hardware and software improvements are helping with increased flexibility.

Technical improvements such as improved sensors and greater computing power also have influenced the design of robots that can work with and around people *(see "Safe Robots Rely On Sensors," p. 26)*. Robots now can determine when people and other objects are nearby and how they should react. The level of sophistication is still limited in most cases but usually sufficient for the target applications.

CHANGING THE ASSEMBLY LINE

Robots on the assembly line normally have been assigned simple, repetitive tasks that they can perform better than most people. Falling prices and improved performance make these robots more cost-effective in some areas.

But for complex products like cars, robots complement people who handle other tasks along the assembly line. A large robotic arm can easily lift a heavy car hood and place it on a car moving down an assembly line where it may have taken two people to do the same job.

Handling more intricate wiring or placing an object in a difficult to reach spot may be beyond a robot's capability, though. Robots and people usually are separated along these kinds of assembly lines. Likewise, the robots are normally programmed to do one task, and that programming tends to be precise.

Rethink Robotics is targeting its Baxter model at assembly environments where interaction with people is more common, including programming and operation *(Fig. 1)*. Baxter could sit in the corner and churn away at its task forever, but it's more likely to be tuned or re-tasked as necessary. It's also designed so whoever is re-tasking it doesn't need extensive technical training to handle most jobs. Baxter is designed to be human-friendly, too.

"Baxter is a totally new kind of robot. It is a robot with common sense, so it knows what you want and does what you expect," says Mitch Rosenberg, vice president of marketing and product management at Rethink Robotics.

"Baxter is aware of its surroundings and can adapt as needed. One particularly important example of its common sense is its awareness of and adaptation to humans in its environment. This makes it safe to work alongside humans," he adds.

Baxter's counter-weighted arm allows low-impact operation. When Baxter accidentally hits you, it hurts about as much as bumping into another person. If other robots typically found on an assembly line hit you, though, you're likely to get a fracture.

Baxter uses behavior-based programming, just like the Roomba, but Roomba works on a much simpler scale. Behaviors are rules that consider the current state of affairs including inputs from sensors as well as computer-based and user-based directives. If a rule is met, then an associated action is performed. Rules may be simple, such as "if a front sensor indicates an object then stop forward motion." Rules can be combined to perform complex functions and provide sophisticated behaviors from an external point of view.

It's possible to get down to this level of programming, but the system is designed to use the behaviors to implement a high-level programming environment including an interactive training system. In this case, it can be as simple as pressing the program button on an arm, positioning the arm by holding the hand and moving it, pressing the program button again to let the hand grab an object, lifting the arm and moving to a new location, and pressing the program button again. The arm can then repeat this process of picking up an object and moving it to a new location forever.

Rethink Robotics provides a software development kit (SDK) for more complex or custom programming chores. The SDK can be used to augment the interactive programming system and provide ways for the robot to interact with other devices within its environment.

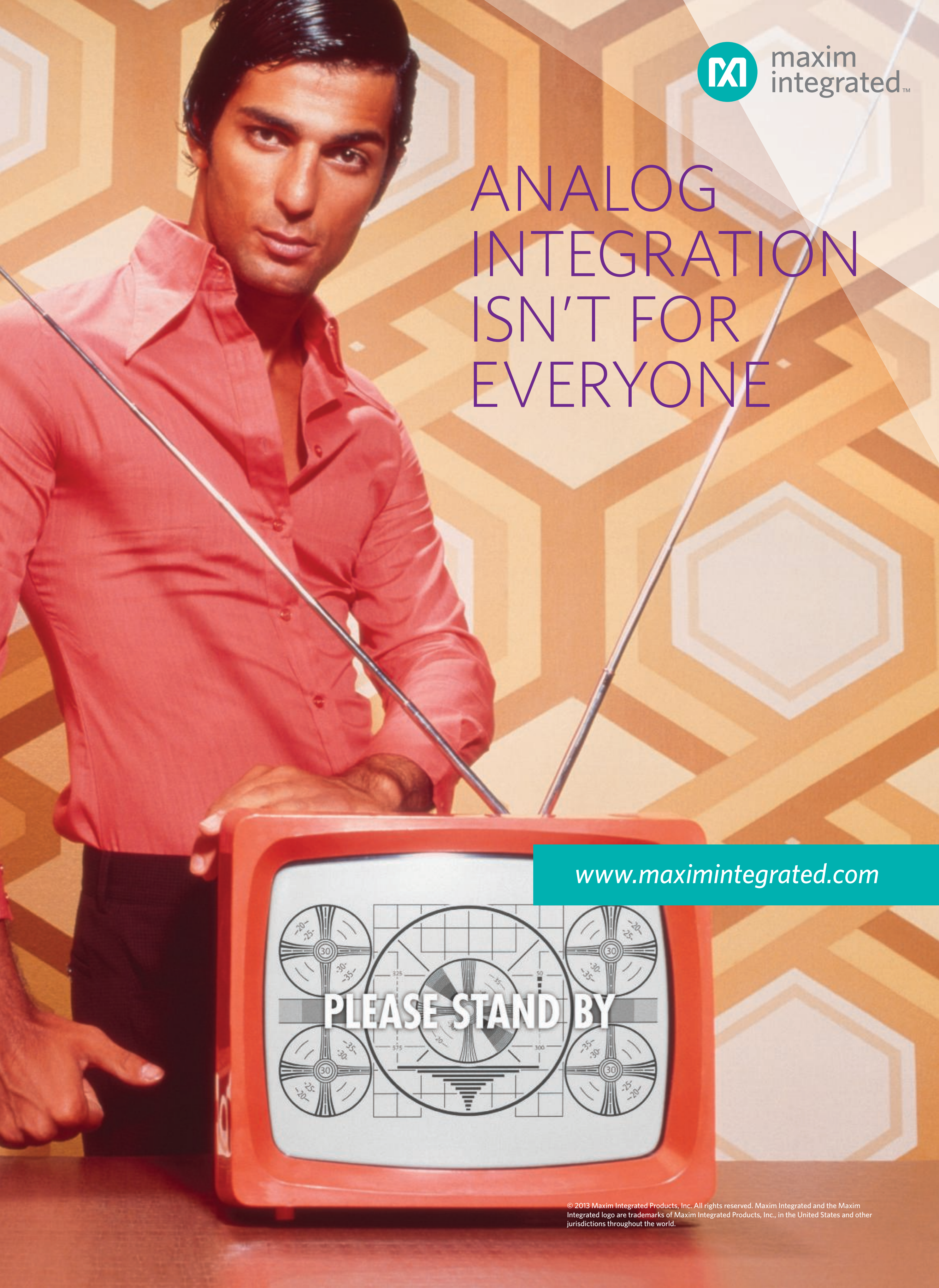
Pick-and-place applications are common in assembly line jobs, though these applications don't take advantage of Baxter's other capabilities. For example, the hand can have a camera that can recognize the shape and orientation of an object so it doesn't have to be found in a fixed location, which pick-and-place robots require.

In more complex applications, Baxter could perform different actions depending on the type, color, and orientation of an object. It could sort red objects into one bin and green into another, for instance.

Baxter's behaviors also address collisions between its two arms. If one arm is programmed to move objects from point A to point B and the other is programmed to move objects from point B to point C, then Baxter knows not to have both arms at point B at the same time. It's also impossible to move the two arms so they touch when you're programming Baxter.

Baxter isn't designed for heavy loads. Its typical hand payload is five pounds. It moves about 2 feet/s under load and 3.3 feet/s without. The arms have seven degrees of freedom, which is on par with a human being's range of motion.

Its hands, also called end-effectors, are a bit more flexible than a human hand. They accept easily interchangeable devices from clamps to vacuum cups. The hands and arms have force feedback for safety and more precise operation.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SAFE ROBOTS RELY ON SENSORS

The PR2 from Willow Garage includes a variety of stereo cameras in its movable head and hides a Hokuyo UTM-30LX laser scanner in the neck. Microsoft Kinects have been seen to sprout from the top of the head.

As more robots operate near people, they must be built so they don't cause any injuries—and that requires all of the computational and sensor technology we can muster. The first mobile robots often used a single ultrasonic or infrared sensor mounted on a servo for a wide range. Today, even small robots are ringed with these sensors as well as image sensors. Multiple sensors also are common for robots like the PR2 from Willow Garage, because a single sensor type won't provide a full range of capabilities *(see the figure)*.

Robotics has benefited from other markets such as smart phones and tablets that have made motion and image sensors smaller and cheaper as volumes have grown tremendously. Lower costs and smaller, high-performance computing packages can change the way robots are designed. For example, robots often used movable heads to reorient their image sensors because moving those heads to cover wider areas was cheaper and easier than including additional sensors. Now, robots may have multiple cameras and multiple microprocessors.

FORCE SENSORS

Touch or bump sensors are the simplest. They normally are a switch attached to a surface or lever that moves. They're popular because they're easy to incorporate and the interface is trivial. Force sensors, though, provide a more graduated response. They are more complicated and come in a range of form factors with different response characteristics. Analog versions are connected to an analog-to-digital converter (ADC), so the host needs to do more work to track the effects.

Touch sensors have become popular for multitouch screens and even buttons and controls. Touch-sensor controller chips do most of the heavy lifting and often have built-in microcontrollers. Robots also can use them. Resistive and capacitive systems are the most popular. Capacitive systems can provide proximity information and can cover a large area as well.

Force feedback systems also are useful. They often can acquire data without any additional hardware when sensorless or sensor-based electric motor control is used. In this case, force feedback occurs when part of the robot is being moved and it meets an obstacle like a person. The amount of force needed to move the robot goes up as contact is made.

RANGE SENSORS

Sensors that provide range information are useful for robotics because they allow the robot to detect objects before they come in contact with them. Most range-based sensing systems are active, employing a light or sound transmitter. Proximity sensors can use ambient light but are typically limited in range, accuracy, and precision.

Ultrasonic sensors consist of a transmitter and receiver. The echo delay from sound emitted by the transmitter and recognized by the receiver provides range information. Ultrasonic sound is uncommon, so noise is less of an issue. These sensors are rated to provide range information within a sensing cone centered on the sensor. Problems can occur because of the audio reflectivity of some materials.

Infrared sensors are like ultrasonic sensors and work in the same fashion with a transmitter/receiver pair. Interference from the outside world is also greater since infrared light is common. Most infrared sensors base the range on the intensity of the incoming light rather than the time taken for a round trip.

Laser range finders are similar to infrared sensors, but they normally determine the travel time of reflected light between the transmitter and receiver. They require faster, more sensitive hardware, though they also provide faster, very accurate range information. The precision and accuracy come at a higher price.

Radar also fits into this category, but its use with robots tends to be limited to specialized environments due to cost. Automotive radar systems are starting to become more common in high-end cars, and this technology may eventually find its way into robotics.

LIDAR (light detection and ranging) takes a laser or radar sensor and scans 2D as well as 3D areas. It provides a very accurate 2D or 3D map, but the sensing system must move accurately, at a greater expense. A rotating mirror often keeps the transmitter and receiver fixed.

IMAGE SENSORS

LIDAR used to be the holy grail for robot designers because imaging was even more computationally complex and costs were high. Now, image systems are small, cheap, and highly accurate. Sensors like the Microsoft Kinect based on Primesense technology provide 3D range information and color images.

Basic image sensing uses a single camera. The resolution, precision, depth of field, and other factors all come into play in object identification and tracking. The cameras used with robots range from the tiny ones found in smart phones to ones that incorporate a zoom lens system. One challenge with all video-based systems is lighting since ambient light is typically used.

A single camera can provide object tracking and even range information if the object or camera is moving, but these functions require significant amounts of computational power that goes up as the frame rate, resolution, and precision of the system increases. A camera also provides a video stream that can be useful in general. Two cameras can provide stereo vision and make it easier to extract depth information. The tradeoff is a second camera that used to be expensive.

Primesense made a major difference in the gaming and robotic markets when it provided the technology behind the Microsoft Kinect. The system consists of three main components including two cameras. An infrared transmitter throws a pattern instead of a single dot, so no scanning is involved. An infrared camera detects the change of the pattern, providing the depth information. A color camera provides a conventional image. An ASIC analyzes the depth at 30 frames/s.

Additional cameras, sonar sensors, and a flat-panel display are where a head might be. The cameras and sonar can identify objects around the robot, whereas the hand cameras are used for identifying items below or in front of the hand.

Baxter is intended for assembly chores that might change on a regular basis, such as short production runs or handling different objects in a specific manner. These changes would be impractical with a conventional assembly line robotic system, but Baxter excels in these environments.

Baxter is an articulated robot but not mobile. It is designed to sit in front of an assembly area. Mobile robots with arms are commonly used in military applications and even police and rescue applications, but they tend to be semi-autonomous teleoperated robots like unmanned aerial vehicles (UAVs) and explosive device removal robots. At this point, the robots that you might encounter couldn't give you an actual hand.

ROBOTS HELP HOSPITALS

Aethon has quite a few TUGs that have found work in hospitals *(Fig. 2)*. They shuttle carts throughout the hospital, picking up and delivering everything from linens to food and medicine. The TUGs and carts tend to be optimized to specific tasks, but their operation and interaction with people is identical.

The TUGs have a different challenge than Baxter but many of the same concerns. Safety and flexibility are at the top of the list, and improved sensors and computing power have made safe and efficient operation possible.

The TUG is an electric robot that can pull a cart. Its four sealed lead-acid batteries support a pair of electric motors for about 10 hours. The drive wheels have a patented ultra-accurate odometer system. The system has a 31.7-in. turning radius and a top speed of 225 feet/minute. And, the TUG can handle a 10% grade and a load up to 1000 pounds.

The robot has overlapping laser, sonar, and infrared sensors. Wi-Fi provides communication with the central management system, which tracks the location of all the robots. The wireless link is also used to control other devices such as doors and elevators.

The TUG operates in the hospital using the same doors and corridors as people. It is polite and makes way for people and other robots. The robot uses its own elevators in some hospitals, but more for efficiency, not because it needs to be isolated. Charging systems are normally deployed where TUGs can congregate when they aren't active.

TUGs move their cargo as necessary, such as picking up meals at the cafeteria and then stopping at the appropriate rooms or stations, where a person will remove the meals for final delivery to a patient. TUGs also are used to return the dirty dishes. The same operation occurs for linens and medicine, with different destinations.

The carts are a bit different. Medicines require a locking system that would be programmed so they are dispensed to the correct patients. Likewise, people interacting with a TUG at a designated location will need to indicate if anything was removed or added to the cart because the TUG might not have sensors that could register these changes. The UMMC deployment uses the MedEx tracking system and radio-frequency identification (RFID) plus biometric scans to create an electronic chain of custody. This approach reduces paperwork, increases security, and complies with medical practices and laws.

3. Bossa Nova's mObi telepresence robot balances itself on a ball for omnidirectional movement.

The system's user interface normally is limited to large buttons and some audio visual feedback. It's easy for any of the hospital staff to work with, but patients and visitors wouldn't use it. The hospital management system keeps track of all the robots and their loads so personnel know when and where they will be. For example, nurses could receive a text indicating a robot will be delivering lunch in a couple of minutes.

Unlike Baxter, Aethon is involved in site design since the TUGs do have some operational requirements. Most hospitals are already designed to meet these requirements, though. For example, electric doors are common throughout hospitals. The system also must fit the hospital's existing methodology. This means studying the current flow and determining how the TUGs would integrate with that environment. Even simple optimizations can result in significant savings.

In their first year at UMMC, TUGs reduced cycle time for deliveries from 74 minutes to 30 minutes. The robots are available 24/7 so even the time of day doesn't affect them. Hospital personnel are more efficient since they don't have to track deliveries, allowing them to spend more time with patients.

ROBOTS TAKE YOUR PLACE

You're also likely to run into telepresence robots like Bossa Nova's mObi *(Fig. 3)*. These robots can move in and around people. They also typically have a flat-panel display where the remote operator can be seen and a camera to show the operator what the robot sees. Audio support completes the design.

The robots tend to be about four or five feet tall, bringing the camera and display near an adult's eye level. They have an array of sensors to detect people and other objects so they can move about without colliding with them.

From a safety point of view, these robots tend to be on par with the vacuum cleaning robots. They are small and light enough not to pose a major threat to people, although they could be a problem around small children. Usually the collision avoidance is designed to keep the robot from getting hurt.

These robots tend to look different, but the main differences really are in the drive system. Bossa Nova's mObi rides on top of a ball, taking the balancing act of the Segway Human Transporter to the next level. The inverted pendulum is simply on a ball and sensors, and the drive motors are placed accordingly.

Like the Segway, the mObi requires very little power to stay balanced. It also tends to be efficient in moving. It has the advantage in omnidirectional movement and recovery that other telepresence robots lack. Bump into the mObi, and it will move. Bump into another telepresence robot, and it might not.

The mObi has a lot of competition, from Anybot's QB to the VGo from VGo Communications. Suitable Tech's Beam is going to be used to remotely direct an animated film called *The Tower Of The Dragon*. The telepresence robot provides a mobile viewing platform, but the digital recording of the movie enhances the telepresence approach since it delivers an additional view.

Telepresence robots are teleoperated by definition, but they're normally semi-autonomous. Operators often can take over full control, but they're more likely to specify waypoints with the

LOUIS E. FRENZEL | COMMUNICATIONS EDITOR lou.frenzel@penton.com

MILLIMETER WAVES WILL EXPAND THE WIRELESS FUTURE

Technology finally makes millimeter waves practical to use, enabling the continued growth of wireless communications before we run out of spectrum.

The Silicon Image UltraGig 6400 60-GHz transceiver is small enough to fit in the modern smart phone for video connectivity.

Millimeter waves occupy the frequency spectrum from 30 GHz to 300 GHz. They're found in the spectrum between microwaves (1 GHz to 30 GHz) and infrared (IR) waves, which is sometimes known as extremely high frequency (EHF). The wavelength (λ) is in the 1-mm to 10-mm range. At one time this part of the spectrum was essentially unused simply because few if any electronic components could generate or receive millimeter waves.

All that has changed in the past decade or so. Millimeter waves are now practical and affordable, and they're finding all sorts of new uses. Best of all, they take the pressure off the lower frequencies and truly expand wireless communications into the outer limits of radio technology. If we go any higher in frequency, we will be using light.

THE PROS AND CONS

Millimeter waves open up more spectrum. Today, the spectrum from dc through microwave (30 GHz) is just about used up. Government agencies worldwide have allocated all of the "good" spectrum. There are spectrum shortages and conflicts. The expansion of cellular services with 4G technologies like LTE depends on the availability of the right sort of spectrum. The problem is that there isn't enough of it to go around.

As a result, spectrum is like prime real estate—it's expensive, and "location, location, location" is apt. Millimeter waves partially solve the problem by providing more room for expansion. You can take all of the useful spectrum we now use from dc to 30 GHz and drop it into the lower end of the millimeter-wave region and still have 240 GHz left over.

Millimeter waves also permit high digital data rates. Wireless data rates in microwave frequencies and below are now limited to about 1 Gbit/s. In the millimeter-wave range, data rates can reach 10 Gbits/s and more.

The bad news is that while this spectrum gives us some expansion room, it isn't useful for all types of wireless applications. It has its limitations. Overcoming those shortcomings has been the challenge of making millimeter waves practical and affordable. That time has come.

One of the key limitations of millimeter waves is the limited range. The laws of physics say that the shorter the wavelength, the shorter the transmission range for a given power. At reasonable power levels, this limitation restrains the range to less than 10 meters in many cases.

The free space loss in dB is calculated with:

$$L = 92.4 + 20\log(f) + 20\log(R)$$

R is the line-of-sight (LOS) distance between transmit and receive antennas in kilometers, and f is the frequency in gigahertz. For example, the loss at 10 meters at 60 GHz is:

$$L = 92.4 + 35.6 - 40 = 88 \text{ dB}$$

Designers can overcome this loss with good receiver sensitivity, high transmit power, and high antenna gains.

Also, the atmosphere absorbs millimeter waves, restricting their range. Rain, fog, and any moisture in the air makes signal attenuation very high, reducing transmission distances. Oxygen (O_2) absorption is especially high at 60 GHz *(Fig. 1)*. Water (H_2O) absorption is responsible for the other peaks. Selecting frequencies within the curve valleys minimizes the loss. Additionally, high-gain antenna arrays can boost the effective radiated power (ERP), significantly increasing range.

Short range can be a benefit. For example, it cuts down on interference from other nearby radios. High-gain antennas, which are highly directional, also mitigate interference. Such narrow beam antennas increase power and range as well. And, they provide security that prevents signals from being intercepted.

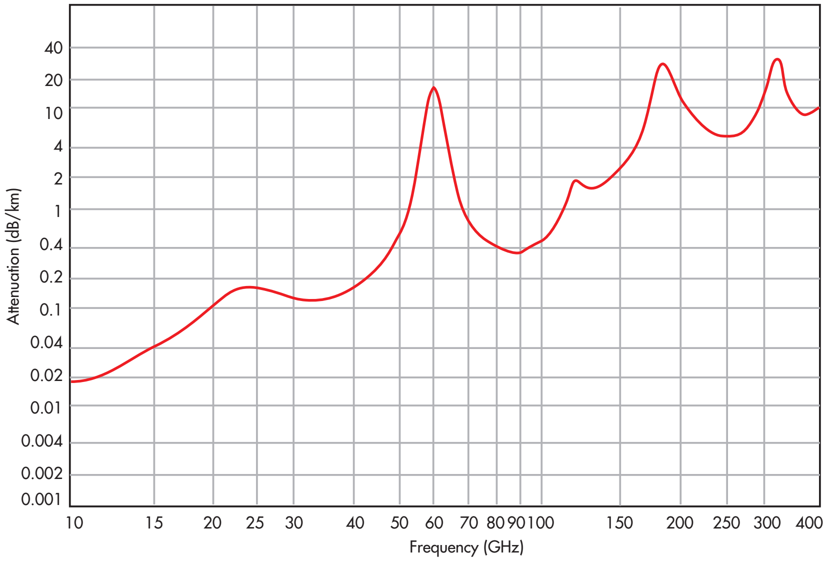
Small size is another major advantage of millimeter-wave equipment. While ICs keep the circuitry small, the high frequency makes very small antennas necessary and possible. A typical half-wave dipole at a cellular frequency like 900 MHz is six inches long, but at 60 GHz one half-wave is only about 2.5 mm in free space and even less when it's made on a dielectric substrate. This means the entire structure of a radio including the antenna can be very small. It's easy to make multiple-element phased arrays on a substrate chip that can steer and focus the energy for greater gain, power, and range.

Another challenge is developing circuitry that works at millimeter-wave frequencies. With semiconductor materials like silicon germanium (SiGe), gallium arsenide (GaAs), indium phosphide (InP), and gallium nitride (GaN) and new processes, though, transistors built at submicron sizes like 40 nm or less that work at these frequencies are possible.

APPLICATIONS

Video signals demand the greatest bandwidth and, accordingly, a higher data rate. Speeds of many gigabits per second are needed to transmit 1080p high definition (HD) video. That data rate can be reduced if video compression techniques are used prior to transmission. Then, data rates of several hundred meagbits per second can get the job done, but usually at the expense of the video quality.

Compression techniques invariably diminish the quality to allow available wireless standards like Wi-Fi 802.11n to be used. Standards like 802.11ac that use greater bandwidth in the 5-GHz band are now available to achieve gigabit data rates. Millimeter-wave technologies make gigabit rates common-



1. The plot of signal attenuation at sea level and 20°C versus log frequency shows how oxygen (at 60 GHz) and water at the other peaks in the atmosphere significantly increase signal attenuation.

place and relatively easy to achieve, making uncompressed video a reality.

Applications include video transmission from a set-top box (STB) to an HDTV set or transmission between a DVD player and the TV set or from a game player to the TV set. Video also can be sent wirelessly from a PC or laptop to a video monitor or docking station. Transmitting signals from a laptop or tablet directly to the HDTV screen is popular as well. Other applications include wireless HD projectors and video cameras. Millimeter-wave technologies allow the wireless transmission of popular video interfaces such as HDMI 1.3 or DisplayPort 1.2. A wireless version of PCI Express is also available.

There is now considerable interest in implementing a wireless version of USB 3.0. It is becoming the interface of choice not only on PCs and tablets but also TV sets and other consumer gear. USB 3.0 specifies a maximum rate of 5 Gbits/s with about 80% of that rate being achieved in a real application. A 10-Gbit/s USB version could be in the works as well. Wouldn't it be nice to have a millimeter-wave dongle that could achieve those rates?

Other applications for millimeter-wave equipment include backhaul for wireless basestations, short-range radar, and airport body scanners. One interesting potential use is PCB-to-PCB (printed-circuit board) or chip-to-chip wireless links. At millimeter-wave frequencies, cables, connectors, and even short PCB runs add attenuation. A short (inches or less) wireless link eliminates the problem.

The 60-GHz unlicensed industrial-scientific-medical (ISM) band from 57 to 64 GHz is getting lots of attention. It is already being used for wireless backhaul, and greater use is expected. Two short-range wireless technologies are also addressing this band's potential: IEEE 802.11ad and WirelessHD.

2. Incorporating the 802.11n chip from Qualcomm Atheros and the 60-GHz chip from Wilocity, this three-band module suits hot spots, routers, and other WLAN products.

IEEE 802.11AD WIGIG

The designation 802.11ad is an extension of the IEEE's popular 802.11 family of wireless local-area network (LAN) standards generally known as Wi-Fi. The 11ad version is designed for the 60-GHz band. It is backward compatible with all previous versions including 11a/b/g/n/ac, as the media access control (MAC) layers of the protocol are similar. The 11ad version is also known by its trade name WiGig. The Wireless Gigabit (WiGig) Alliance supports and promotes 11ad, and it recently announced plans to consolidate with the Wi-Fi Alliance under the Wi-Fi Alliance banner.

WiGig uses the unlicensed ISM 60-GHz band from 57 to 64 GHz, divided into four 2.16-GHz bands. The primary modulation scheme, orthogonal frequency division multiplexing (OFDM), can support a data rate up to 7 Gbits/s, making it one of the fastest wireless technologies available. The standard also defines a single carrier mode that uses less power and is a better fit for some portable handheld devices. The single carrier mode can deliver a data rate up to 4.6 Gbits/s. Both speeds permit the transmission of uncompressed video. The WiGig specification also provides security in the form of the Advanced Encryption Standard (AES).

Because of the small antenna size at 60 GHz, gain antennas are normally used to boost signal power and range. The maximum typical range is 10 meters. WiGig products use antenna arrays that can provide beamforming. This adaptive beamforming permits beam tracking between the transmitter and receiver to avoid obstacles and maximize speed even under changing environmental conditions.

One clever feature of the WiGig standard is its use of a protocol adaptation layer (PAL). This software structure talks to the MAC layer and allows simplified wireless implementation of other fast standard interfaces like USB, HDMI, DisplayPort, and PCI Express.

Wilocity, which is the primary source of WiGig radios, makes a single-chip 60-GHz transceiver. Its most common use is in conjunction with a standard 802.11n implementation. Qualcomm Atheros packages its AR9642 802.11n transceiver with the Wilocity 60-GHz chip, forming a module that covers the three main Wi-Fi bands of 2.4, 5, and 60 GHz *(Fig. 2)*. Wilocity also has an arrangement to package its device with Marvell's Wi-Fi transceivers. Look for more combinations as wireless LANs (WLANs), routers, and hot spots begin adopting a three-band strategy that may include 11ac.

WIRELESSHD

WirelessHD is based on the 60-GHz technology originally developed by SiBEAM, which Silicon Image acquired in 2011. The original specification became WirelessHD. It is maintained and promoted by the WirelessHD Consortium, a special interest group that includes dozens of semiconductor and consumer electronics companies.

The latest WirelessHD specification, version 1.1, can stream uncompressed video (and related audio) up to 1080p 24-bit color at a 60-Hz refresh rate. It also can deliver compressed video in all EIA 861 video formats. The maximum general data rate exceeds 3 Gbits/s, but 10 to 28 Gbits/s are possible under special conditions. Operation is in the 57- to 64-GHz unlicensed band that's available in the United States. Sub-bands are also available in Japan and South Korea with the potential for a European Union band in the near future.

A key part of the specification is smart antenna technology, which includes beamforming and beam tracking that allows non-LOS operation to avoid obstacles while extending range. The beamforming feature uses a phased array to provide very high gain, permitting a maximum of 10 W of effective isotropic radiated power (EIRP). This gives WirelessHD its range of up to 10 meters. The beam-tracking feature enables the transmitter and receiver to stay aligned with one another as the equipment moves or as obstacles appear or disappear.

WirelessHD defines both high and low data-rate modes. Both use OFDM. The high data-rate mode uses 1.76 GHz of bandwidth in one of four non-overlapping 2.16-GHz bands in the 57- to 64-GHz band. This includes 512 subcarriers with a spacing of 4.957 MHz, of which 336 subcarriers handle the data.

Modulation may be quadrature phase-shift keying (QPSK) or 16-phase quadrature amplitude modulation (16QAM). The rate for QPSK is 1.9 Gbits/s, while the rate for 16QAM is 3.8 Gbits/s. The low data-rate mode uses 128-subcarrier OFDM in a 92-MHz bandwidth. The data rate with binary phase shift keying (BPSK) modulation can vary from about 2.5 to 40 Mbits/s with different coding rates and beam-forming options.

WirelessHD radios are available from Silicon Image, which developed the HDMI, MHL, and DVI video interface standards. The company licenses the technology and provides IC products for these interfaces. Its UltraGig 6400 single-chip transceiver incorporates an embedded beamforming and steerable antenna array and all baseband processing *(see the opening figure)*.

Its small size (10 by 7 mm) makes it possible to integrate it into laptops and tablets to transmit video to a nearby large-screen HDTV using a WirelessHD dongle. Latency is less than 5 ms, and power consumption is 500 mW.

The WiGig and WirelessHD standards are very close to one another in technology, functionality, and target markets. Video transmission is the primary application. Both offer gigabit data speeds with steerable antennas and beamforming with a maximum range of about 10 meters. Both are suitable for both fixed and portable devices.

The primary advantage goes to WiGig for its PAL, which lets it be adapted to a wide range of other interfaces. WiGig is also backward compatible with other 802.11 standards, making it a companion for multiple-band operation with other devices. For video transport, the two technologies seem on par with one another. The advantage goes to WirelessHD for consumer video applications.

Building 60-GHz applications continues to get easier because of ICs like those from Hittite Microwave Corp. Its HMC6000LP711E transmitter and HMC6001LP711E receiver ICs both operate in the 57- to 64-GHz ISM band. They are ideal for building single-carrier modulation WiGig devices and data communications equipment like backhaul, as well as for HD video transmission.

Both devices support the IEEE channel plan of 2.16-GHz bands with a 1.8-GHz modulation bandwidth. The transmitter has an output power of 16 dBm. The receiver has a noise figure of 7 dB and a variable gain to 67 dB. Both transmitter and receiver have on-chip antenna arrays with a gain of 7.5 dBi. And, both come in a 7- by 11-mm surface-mount (SMT) package.

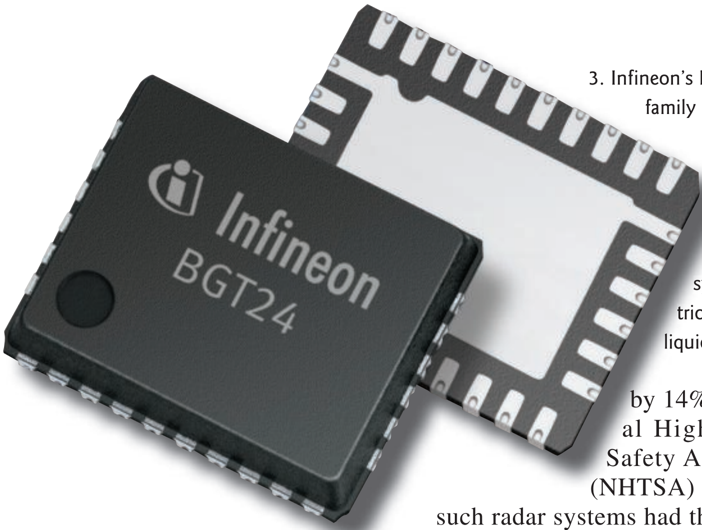
RADAR ON A CHIP

Semiconductor technology now routinely allows millimeter-wave circuits to be packaged into ICs. Today we have single-chip radar chips just looking for new applications. Millimeter-wave radars have been around for years in military service, but that technology has not been widely deployed in commercial or consumer applications because of its expense. With today's SiGe heterojunction bipolar transistor (HBT) or BiCMOS single-chip radars, though, many new applications are being found.

Infineon's BGT24MTR11 24-GHz single-chip radar operates over the 24- to 24.25-GHz ISM band. Both the receiver and transmitter are on one chip using a standard QFN-style (quad flat no-lead) IC package. The device is easy to use since no RF matching or transmission lines are required on the PCB. The device has a maximum range of 160 meters.

The BGT24MTR11 uses the continuous-wave Doppler radar technique, which is being deployed in a variety of applications, such as liquid-level measurement in tanks *(Fig. 3)*. Other uses include street lighting, motion detection, door openers, intrusion alarms, police speed meters, and collision avoidance on industrial vehicles.

One key advantage of millimeter-wave radar is its fine resolution in detecting



3. Infineon's BGT24MTxxx family of single-chip radars can make tank and silo level metering systems more accurate as the system is not tricked by splashing liquid or dust.

small objects and movements. Millimeter precision is possible in determining location. A two-receiver version of the Infineon device permits even finer precision in detecting objects and at a wider angle. That's pretty good for a $16 chip.

Perhaps the most widespread use of millimeter-wave radar is in automotive safety devices, including adaptive cruise control, automatic braking, collision warning, blind spot detection, lane departure warning, and backup object detection. These radars use the 76- to 81-GHz ISM band.

Freescale Semiconductor's automotive radar solution is a 77-GHz radar chipset comprising the PRDTX11101 transmitter and a customized multichannel receiver designed for the application plus one 32-bit MCU. This combination can be adapted to any of the most common automotive applications with detection ranges from 20 meters to 200 meters.

Such radar accessories are common in high-end luxury cars. Like video backup cameras, radar is gradually finding its way into lower-priced vehicles as the industry and consumers learn about their great safety benefits.

For example, DENSO Corporation's 77-GHz radar is now deployed in the new Mazda 6. It has a detection range of 205 meters and a detection radius of ±18°, making it increasingly useful in lane intrusion applications.

According to a recent study by the Highway Loss Data Institute, with the use of forward collision detection and automatic braking in Acura and Mercedes vehicles, insurance claims dropped by 14%. The National Highway Traffic Safety Administration (NHTSA) projected that such radar systems had the potential to reduce rear-end crashes by 15%. While more research is planned by the NHTSA, the government could mandate such systems in all cars in the near future.

IDEAL BACKHAUL

Backhaul is generally defined as any point-to-point (P2P) communications link between remotely connected sites. It can be wired or wireless. In telecommunications, both fiber and microwave backhaul are common. Cellular basestation sites are connected to the main switching office by backhaul. While fiber probably dominates the backhaul space because of its high-speed capacity, microwave and millimeter-wave backhaul are becoming more widespread.

Millimeter-wave backhaul is particularly attractive for the new small-cell movement. Smaller basestations called picocells, microcells, and metro cells are projected to be widespread in rolling out LTE 4G cellular services in high-density areas. It appears that the best way to connect these cells to the main office is millimeter-wave links.

The typical microwave backhaul bands are 6, 11, 18, 23, and 38 GHz. Unlicensed 60-GHz backhaul equipment is inexpensive but offers limited range due to its high oxygen absorption levels. Some 80-GHz backhaul units are also available. The most popular new millimeter band is the E-band, which covers 71 to 76 GHz, 81 to 86 GHz, and 92 to 95 GHz.

These bands require a Federal Communications Commission (FCC) license. They aren't afflicted with the high-water and other atmospheric loss effects of 60

GHz, though. The millimeter bands also offer very high data rates from 1 Gbit/s to over 10 Gbits/s in some cases. While the communications range is short, they offer excellent privacy, security, and frequency reuse. The protocol of choice is Ethernet.

The Siklu Etherhaul-1200T small-cell backhaul unit operates in the 71- to 76-GHz E-band *(Fig. 4a)*. It offers a data rate to 1 Gbit/s using adaptive coding and modulation. Features include carrier Ethernet bandwidth-aware quality of service (QoS), service management, and operations administration and maintenance (OAM) as well as advanced timing over packet handling with SyncE or IEEE 1588.

Ceragon's FibeAir IP-20C advanced backhaul unit is available in any of the standard backhaul frequencies from 6 to 38 GHz *(Fig. 4b)*. It provides guaranteed 1-Gbit/s rates in a 28/30-MHz channel or a guaranteed 2 Gbits/s in a 56-MHz channel. It uses up to 2048QAM and provides 4x4 multiple-input multiple-output (MIMO) techniques to ensure high throughput.

These and similar units from BridgeWave, DragonWave, and others offer the benefits of lower cost connectivity than fiber. Fiber backhaul installations can run $25,000 to $100,000 per mile—not to mention the need to hang cable on poles or excavate the ground. Microwave and millimeter-wave backhaul runs less than $20,000 per mile, and installation only takes days compared to months for fiber.

IS MILLIMETER 5G NEXT?

LTE and 4G cellular technology rollouts are limited by spectrum availability. LTE uses lots of bandwidth, and carriers only have so much spectrum. The cost of buying new spectrum is high, and the amount of spectrum is limited. Carriers are resorting to all sorts of maneuvers to get the spectrum to build LTE capacity and revenue.

One solution is to go to a TD-LTE (time division duplex) format that uses only half the spectrum of FDD-LTE (frequency division duplex). That doesn't seem to be on the roadmap for many carriers, however. Small cells are a more popular solution. Microcells, picocells,

4. Small-cell backhaul units are very compact and mounted next to the small-cell structure on a light pole or other facility. Siklu's Etherhaul 1200T operates in the 71- to 76-GHz E band and provides up to 1-Gbit/s data rates (a). Ceragon's IP-20C is available in models operating from 6 to 38 GHz (b). Data rates to 2 Gbits/s are possible using MIMO techniques.

and femtocells are limited-range basestations that are being deployed to fill in the gaps in macro basestation coverage. With their limited range, these small cells will adopt frequency reuse techniques in order to provide more efficient use of the spectrum available.

The small-cell movement, also known as heterogeneous networks or HetNets, may eventually become the fifth generation (5G) of cellular systems. But that's not all. The small cells may use the millimeter-wave bands to provide that precious coveted spectrum needed for expansion. Recent research at New York University (NYU) has shown that the millimeter-wave bands can be used for cellular connections.

Using the 28-GHz and 38-GHz bands, NYU has demonstrated that even in a difficult urban environment like New York City, operation is possible. Highly directional antennas with automatic positioning and beamforming can make millimeter-wave frequencies work for cellular phones that demand great link reliability. Watch for more developments in this area.

TERAHERTZ AND BEYOND

While research has produced transistors that function beyond 100 GHz, their usefulness dies around 300 GHz or so because of excessive transit time through the device. If that's the case, what devices can be used to generate and detect waves into and above 1 THz? Strangely enough, there are semiconductor devices that do work in the optical spectrum above the terahertz zone.

Infrared extends from roughly 700 nm to 2000 nm or 430 THz to 150 THz. Visible light extends from about 400 nm (violet) to 700 nm (red) or about 750 THz to 430 THz. Ultraviolet light is beyond 740 THz. Lasers and LEDs can generate these waves and photodiodes can detect them, but they don't work at the lower terahertz frequencies. There is a dead zone from roughly 300 GHz to 100 THz where few if any practical devices exist.

Schottky diodes have been shown to work as mixers in this range, but we need a good terahertz oscillator or equivalent. Papers in IEEE's relatively new *Transactions on Terahertz Science and Technology* describe the research efforts around the United States. The major applications for terahertz waves remain to be seen, and they may not be communications. ed

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THE ESSENTIALS OF LOW-COST DESIGN

Designers need to keep seven key factors in mind if they want to rein in the costs of their next project and still meet their performance specifications.

How do you create low-cost designs? Companies that ask this question usually want to build thousands or millions of products, and cost certainly is one of the factors. But cost isn't always the main driver of the design. In some cases, it's the second or third driver, usually behind performance or low noise.

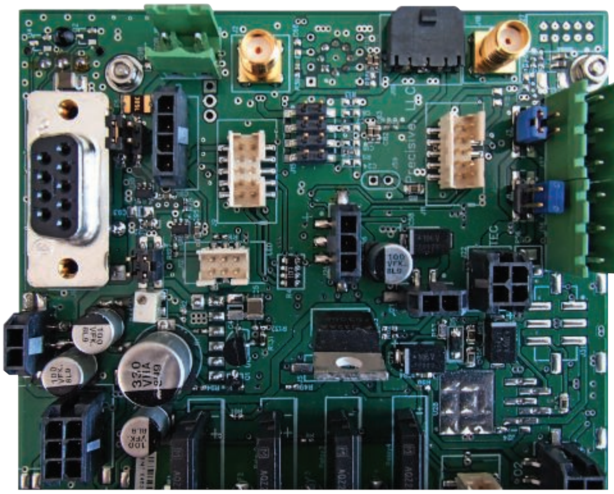
So how do you produce a low-cost design and still meet the performance specs that may be even more important than cost? Seven elements most affect product cost: interconnects and materials, components and manufacturers, printed-circuit board (PCB) and assembly, board implementation and integration, equipment layout and enclosure, serviceability and the final user, and certifications.

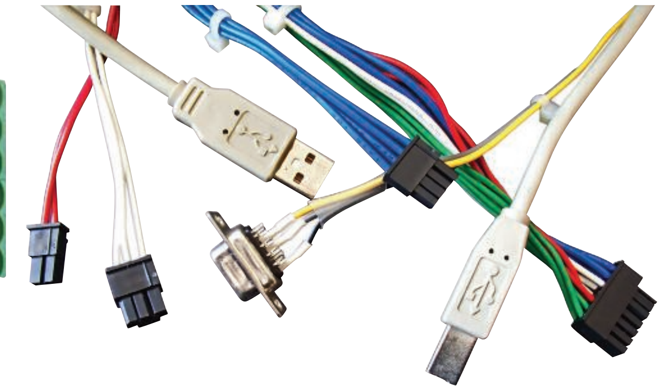
INTERCONNECTS AND MATERIALS

The physical interconnect typically is the most expensive element, accounting for anywhere from 5% to 20% of your electronic bill of materials (BOM), depending on the particular equipment. This is because of three factors.

First, high-quality interconnects such as gold platings are pricey. Second, the quality and complexity (or simplicity) of the product layout might significantly impact manufacturing, serviceability, and product longevity. And third, low-quality interconnects might be fragile (or sensitive to aging) or corrode when mixed materials are used. This is a particularly tricky issue that won't show up until several weeks after field operation when the material will show signs of degradation.

In that sense, the best strategy is to develop a careful physical layout that optimizes the product geometry from the over-





1. Multiple connector styles are common in a design, but they represent a variety of parts that have to be inventoried. Different connector styles also require different cable harnesses, but they minimize the assembly error.

all system point of view and use standard (low-cost) connectors *(Fig. 1)*. You should also account for the environmental conditions that your product will be subjected to because they might dictate whether stainless steel parts are required rather than cheaper materials. For example, an office product doesn't have the same stringent requirements as outdoor field equipment.

2. Some cases require special heatsinks. In other cases, heatsinking to the chassis is possible.

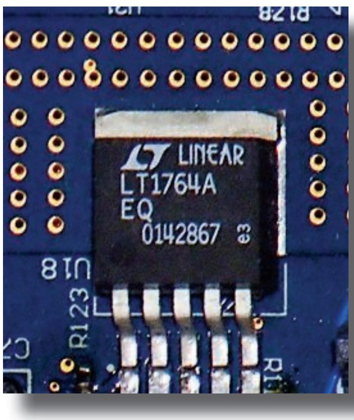
COMPONENTS AND MANUFACTURERS

There is no easy path to minimize the total number of components, but you can minimize costs by maximizing the use of the same component type and value. Standardizing all the resistors, capacitors, ICs, and other components to a single type and value as much as possible will help to consolidate parts in your system. (Standardizing the connectors to a few types could help minimize cost.)

Furthermore, you can forge a better alliance if you use components from a single vendor instead of components from multiple manufacturers. This is not truly visible until you realize how the inventory of all the parts and the procurement process behind it impact the product cost. The product cost is associated with the entire company and its processes.

Also, minimize "custom components," but this is easier said than done. If your design calls for a particular transformer, it is up to you to evaluate if that particular approach is better or if you should be evaluating a different configuration. Potentially, you can significantly reduce a design BOM by using generic components that are available off-the-shelf. (Notice that some custom components might require an additional certification.)

On the other hand, you should leverage your company's capabilities, including all the component libraries and the inventory. Your company could be using that transformer everywhere in its designs, and maybe it has the assembly line to assemble the transformer itself. If this were the case, then take advantage of your custom company components.



3. Heatsinking to the PCB is possible in some cases, saving on additional components, but they require more PCB real estate.

There also might be alternative parts that are cheaper for a particular application. This is not an easy path to take since some components might provide a better performance than others. So here the tradeoffs start—what's more important, performance or cost? Also, some components might be significantly more reliable. Then the tradeoff is between product lifetime versus cost, which isn't an easy equation.

Obviously, the most mature components might be cheaper than the new advanced components, but sometimes you don't care. There is no reason why the LM741 can't be used in new designs if they meet the required functionalities and achieve the performance that's required. By using a more expensive component, you might be over-designing your product. (But obviously you won't try to use the LM741 as the first stage of a thermocouple measuring circuit.)

Depending on your product volume, you might prefer to deal directly with the manufacturer or try to deal with components that are available from your favorite online distributor. Make sure you check the component status because it might be difficult to deal with a design where critical parts are obsolete or don't comply with the certification process. Certain types of components might be special due to their size or performance, and it might be better to establish a partnership with those manufacturers. In this case, the business and management team must contribute to making the deal.

PCB AND ASSEMBLY

The number of layers and vias on the PCB as well as its shape also can drive low cost. Obviously, you shouldn't use buried vias if they aren't dictated by the design, and you should optimize the number of different hole sizes used in the design. Some PCB manufacturers might charge an additional fee depending on the number of holes per square inch. It's also a good practice to standardize the number of hole sizes (and get in touch with your PCB manufacturer to validate the range of sizes) and then implement these changes all the way back to the component footprint of through holes and via library in your PCB software.

The PCB is just a very small fraction of the BOM cost. If you have components on a single side, then you minimize the assembly cost. If this goes against the "minimize the size/footprint" guidelines of your product, though, then you have another issue at hand where you might have to compromise. For example, only through holes or some component types may be allowed on the solder side.

If your board targets some certifications, then make sure it complies with their clearance, creepage, and other requirements. Make sure traces are adequate to the current they are going to support, and don't forget to validate for the need for trace impedance or line balance in the case of high-speed signals.

Certain special manufacturing processes might be required in products like hybrid circuits, microelectromechanical systems (MEMS), wafers, and flexible PCBs, and it might be better to identify several companies that can achieve that level of complexity.

The manufacturing team must work on this line to leverage the company manufacturing process.

BOARD IMPLEMENTATION AND INTEGRATION

Interconnects are a big deal in most designs, but other elements besides the cable harness and other peripherals are significant too, including the heatsink, keypads, and LCDs. These additional components affect your product design and system integration. If you need to connect to an external sensor through a watertight connector, it might be more expensive than if the sensor is designed to be wired directly to the PCB. It all depends on your system configuration, field operation, and additional specifications.

Some components can be heatsinked to the PCB up to a certain power operation, while others would require an additional external heatsink, which adds cost in terms of assembly and inventory. It's important to provide adequate space for all the additional components like heatsinks and enable room for their assembly.

In some cases, power electronics can heatsink to the same equipment chassis *(Fig. 2)*. Some surface-mount (SMT) components can be heatsinked to the PCB when adequate copper area is allocated, but this is also a function of the layer thickness and the thermal vias used *(Fig. 3)*.

Most simulation software allows you to perform Monte Carlo simulations or worst-case analysis that will go through a sweep of the component tolerances. This way, you can screen the components that truly affect your performance or critical variables and then use cheaper components (with wider tolerances) where they are not truly required.

Low cost is also related to time-to-market. To reduce the time-to-market in some cases, some designs use modules that are fully tested and functional, but they cost a premium like dc-dc power supply modules, solid-state relays (SSRs), and RF modules. If the imperative of low cost is more important, then a discrete design can replace those modules. But be aware that this approach adds design complexity and will require more time for validation and testing! Some modules are pre-certified, shortening the development time. The overall design cycle impacts the product cost.

4. Custom enclosures add cost to the product, but they also are differentiators that might appeal to customers. Strategically placing the connectors in the PCB minimizes the need for cable harnesses.

EQUIPMENT LAYOUT AND ENCLOSURES

If your product requires an enclosure, whether it's a custom design or a standard off-the-shelf box, the geometry of all the elements inside plays a role in its cost *(Fig. 4)*. If you have an LED on your board, does it need to be visible?

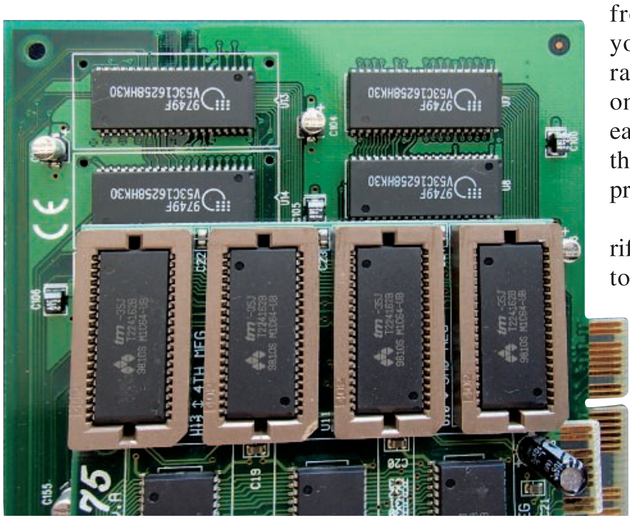
I've seen clever optical geometries just to allow a cheap LED to be seen outside the product enclosure, whereas a more integrated design team potentially could have come up with a different design strategy to locate the LED in a different location to allow for a better visualization. Again, the overall team has to take part in the system layout, and all the specifications should be evaluated. Cost is in the overall design!

Also, look beyond the PCB. If you have solenoids valves, relays, sensors, heaters, fans, and other components, make sure you implement the most adequate connectors to service each of them. Wire routing (and connectors) can play a significant role in lowering the integration cost of your product. Therefore, the location of all the peripherals is important.

SERVICEABILITY AND THE END USER

Low cost also is associated with your technical support, from the manufacturing line to your quality assurance and warranty service *(Fig. 5)*. Planning on the right checkpoints and the easy access to them in the product, then, might be significant for the product's overall low cost.

The low-cost goal cannot sacrifice the end user either. If a custom enclosure adds value to the product and shining LEDs are an indication of your product performance, then take the time to add them. This is where your business group, customer attention, and even technical service (or repair group) might provide some feedback to enhance the product features and reputation. Will this effort reduce the



5. Sockets are great for designs that require some future upgrade. Otherwise, they're just an additional cost.

6. Some components are fully certified. You should make sure they have the certifications for your intended market.

cost? No! But what is the benefit of designing a low-cost product that no one is interested in buying? After all, you always have a competitor.

CERTIFICATIONS

If the equipment must be certified, then it's better to start using parts and components that are also certified to the standard that the equipment must meet. Some parts that are CE certified might have to be qualified again if the system is targeted to the UL market. If you have a broader market, perhaps including other countries, then look for parts that are also qualified to those standards.

Certifications are usually required on parts that are going to interface with the external world, such as connectors, protection components, and relays. Talk to your company certification guru if you have one. Non-certified components will add cost to your product and could delay its launch.

You might count on voltage adapters that are certified for your market and then design the rest of your system around the availability of those certified parts *(Fig. 6)*. Make sure to have second sources for all the components. Otherwise, if they become your critical point (a single source), then they might also become the expensive component.

OTHER CONSIDERATIONS

It's important to establish a good relationship with your vendor. A partnership with a large volume distributor like Allied, Arrow, Avnet, Digikey, Mouser, or Newark might take you a long way in terms of product inventory prediction and low-cost component availability. These vendors also provide insight on components nearing their end of life cycle as well as alternatives that you can start evaluating before you get to a crisis level.

Finally, the product cost will depend on your volumes, development time, and what exactly your market is. Everything is interconnected, and the entire company has to work in a synchronized way to achieve the noble goal of a low-cost design. ed

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DISTRIBUTORS HOME IN ON DEFENSE MARKETS

Distributors sharpen their focus on key segments of the military and aerospace market with acquisitions and value-added services.

Slowing growth in the defense market is no deterrent to distributors committed to the segment, as two recent industry acquisitions demonstrate. Avnet's purchase of defense-focused USI Electronics in December and this year's news that New York-based Astrex bought California-based connector specialist TIM-CO sharpened both companies' focus on the defense and aerospace business even as macro-economic conditions threatened a slowdown among some of those customers this year. Executives from Astrex and Avnet point to slowing growth in defense markets as an important reason to further develop their expertise so they can better penetrate the market moving forward.

"I think we have peaked in the decade-long cycles that defense goes through," says Bryan Brady, vice president, defense and aerospace, for

Avnet Electronics Marketing, pointing to the drawdown in the wars in Iraq and Afghanistan and the larger fiscal pressures affecting the U.S. economy. In many ways, he adds, a rising tide has lifted all boats in the last 10 years and now it's time for distributors to work harder to earn their share of defense and aerospace spending.

"We remain very focused on this market segment," Brady says. "Regardless of the ebb and flow of the [Department of Defense budgets] and the concerns in Washington, we remain committed to this marketplace."

Brady says the USI acquisition shows that commitment by deepening Avnet's specialization in defense and aerospace, especially in discrete semiconductor, passive, and electromechanical components for those customers. Avnet USI is a separate business unit within Avnet Electronics Marketing, continuing a single focus on the defense/aerospace segment.

Smaller distributors such as Astrex have similar strategies. The TIM-CO acquisition adds complementary products and services and gives Astrex a West Coast presence it didn't have before. Company president and CEO Mike McGuire points to TIM-CO's engineering capabilities and its focus on radio frequency (RF) cable assemblies as key points, too.

"Being a connector specialist, we want to stay a specialist, but we also want to have a little more within our niche to offer our customers," says McGuire. "[The TIM-CO] acquisition gives us more services in the cable assembly world and some additional product lines we didn't have before. The third piece of the puzzle is that it gives us a footprint in California that we didn't have."

As of early March, McGuire said Astrex hadn't been affected by the sequestration or other defense budget cuts, but noted he was concerned about the doubt such issues cast on the market in general, particularly since distributors are often the first to feel the effects of uncertainty in the marketplace. On the upside, McGuire and others point to the growing amount of electronic content in defense and aerospace systems as a big positive for companies specializing in serving a wide range of mil/aero customers.

"We are always looking to fill any gaps in our line card when it comes to the [high-reliability] connector market," says Mike McGuire, Astrex president and CEO. "Right now we're working on the integration of TIM-CO, but we are still an acquisitive company."

FOCUSED ON GROWTH

Astrex is coming off of a solid 2012, and McGuire says he's optimistic about business this year, especially with the addition of TIM-CO to the Astrex family. Astrex sells to a wide variety of customers in defense and aerospace, so unless there's an across-the-board downturn, McGuire says the company is diversified enough to weather any storm. He says bookings in 2012 were up 18%, with the space segment driving that growth. Integrating TIM-CO and staying on the lookout for more strategic acquisitions are a focus for 2013.

"We are always looking to fill any gaps in our line card when it comes to the [high-reliability] connector market," McGuire explains. "Right now we're working on the integration of TIM-CO, but we are still an acquisitive company."

With the acquisition, Astrex has 65 employees and two locations, and it is projecting 2013 sales of roughly $40 million. The new product and service package will help the company better penetrate its customer base, but McGuire says product availability is still the top priority when it comes to serving this market.

"Because mil/aero tends to be a low-volume, high-mix business, it always falls back to having inventory on hand to compensate for long connector lead times," says McGuire. "Overall, it's always been about being able to inventory parts. That hasn't changed."

Brady points to cost reduction as another important customer concern. As customers look to make the most of their supply chains, they are seeking cost-cutting strategies that take advantage of existing, successful distributor relationships, putting vendor reduction at the top of the to-do list as well.

Also, Brady notes the growing electronic content in systems and commercial aircraft as harbingers of a solid outlook ahead despite the slowing conditions. He cites strong demand in foreign military sales and commercial avionics in particular.

DISTRIBUTORS ADD SYSTEM-LEVEL TRAINING TO THEIR SERVICES

Training and education are becoming increasingly important elements of the services that distributors provide, especially as design engineers demand more software and systems-based training. Today's trend toward system-on-chip (SoC) design is a pointed example, and distributors are partnering with their suppliers to meet the growing demand for new information about the various programs that are available to engineers.

Avnet Electronics Marketing launched a series of three-day workshops based on the Xilinx Zynq-7000 All Programmable SoC Architecture this year, for instance, and has had to increase its number of locations for the in-person workshops from an initially planned 22 to more than 100. Avnet EM's Tim Barber, senior vice president, design chain business development, says it is increasingly important to help customers integrate these new technologies in a hands-on environment.

Barber says the Xilinx SpeedWay Design Workshop series grew out of the distributor's 2012 XFest training program, which trained more than 6000 customers worldwide. Also run in conjunction with Xilinx, XFest is a one-day training event for FPGA, DSP, and embedded system developers that takes place every other year. Avnet's SpeedWay Workshops run

from one to three days depending on the subject and are held in cities around the world.

"By the time they're all done, we'll train over 2500 customers in a hands-on environment, with boards, PCs, and Avnet instructors," says Barber. "When we wrote out these Zynq SpeedWays, we only planned 22 locations. As of [February 25], we're at well over 100 due to customer demand."

He doesn't see the demand for such programs and services slowing down, either.

"I honestly think that one of the most important value-adds for us will be in the area of education," Barber says.

Electronic Design asked Barber to weigh in on these and other trends in customer training in late February. The following are excerpts from our conversation.

ELECTRONIC DESIGN: What trends are you seeing in customer training needs today? What kinds of programs are customers looking for?

BARBER: It's interesting how things have changed over time. We see customers looking more for systems-level training. When we do [training] programs, we can train them on the FPGA, but also on how to interface the data converter [and] how you bring that up on the Xilinx solution, for example. What we really focus on is how those products work in a system-level solution. [We focus on] all the key technologies the customer needs to enable their design.

ELECTRONIC DESIGN: Do you find that customers are driving the new trends in training or that you, as a distributor, are doing so?

"One of the things we're seeing is that software is becoming such a bigger part [of the equation]," says Tim Barber, senior vice president of design chain business development with Avnet Electronics Marketing. "With the mix between hardware and software designers—there's more of the latter now—we see a lot of requests [to help] customers get training so they can develop these products in a software environment.

BARBER: It's really a combination. Any time we talk to a supplier today about a new product introduction they will always want to talk to us about what [we can] do to train customers. We have over 1000 FAEs [field application engineers] worldwide to tell us where customers are struggling. We can then create the training to suit the market needs.

ELECTRONIC DESIGN: Do you find that customers are looking for training and education in a particular technology or discipline? Or perhaps in a particular product group?

BARBER: One of the things we're seeing is that software is becoming such a bigger part [of the equation]. With the mix between hardware and software designers—there's more of the latter now—we see a lot of requests [to help] customers get training so they can develop these products in a software environment.

ELECTRONIC DESIGN: What other trends and issues are you dealing with when it comes to training and education?

BARBER: System-on-chip and all the software enablement around that will be interesting trends to watch…. We're also looking at how we operate globally. How do we deal with some of the language issues around training, for example? The speed of the Internet in some areas is an issue for us, too. For example, China's Internet is so slow. Some of this on-demand training [we offer] is quite large, so the training experience for that customer in China will be different from what it will be in Munich. Those are technology issues we'll have to think about as we roll out these training programs. ■

TOOLS AND TRAINING COMPLEMENT ENERGY-EFFICIENT MCUs

Freescale Semiconductor's Kinetis L series MCUs combine the energy efficiency and ease-of-use of the ARM Cortex-M0 processor with the performance and scalability of the company's Kinetis 32-bit MCU family. Top electronics distributors are putting these capailities front and center with new tools and training solutions.

In March, for example, North American distributor Newark element14 announced the availability of a new board for evaluating Kinetis KL05Z MCUs. With the new platform, design engineers can use the latest 32-bit technology with lower energy and higher performance in a cost-effective package.

Future Electronics is getting involved in training, offering in-person demonstrations on the L series for engineers designing energy-efficient portable devices. One of Future's advanced engineers travels to the customer site for a two-hour training session that includes design best practices for low-power applications; hardware and software development tools that support the new Kinetis L series MCUs; and a Kinetis L series Freedom development platform.

The industry's two largest distributors, Arrow and Avnet, are also promoting L series programs. Arrow Electronics is touting its Cloud Connect program, a free online tool chain for building Internet of Things applications on the ARM Cortex-M0+ platform. With it, designers can write, compile, and program code to their Freedom Development Platform without purchasing expensive software programs.

Earlier this year, Avnet Electronics Marketing launched its Wi-Go Challenge, inviting design engineers to show off the most creative ways to take advantage of advanced wireless connectivity, sensors, and Freescale microcontrollers. The contest runs through June 30, and the grand-prize winner will receive an 11-inch Apple MacBook Air. ■


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GET THE MOST OUT OF YOUR LOGIC ANALYZER

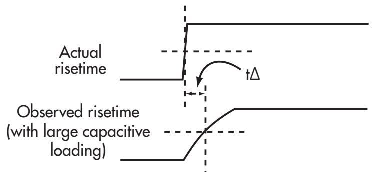
For many applications, a modern logic analyzer will reveal the root cause of troublesome bugs in less time than alternative instruments.

THE LOGIC ANALYZER is a versatile tool that can help engineers with digital hardware debug, design verification, and embedded software debug. Yet many engineers turn to a digital oscilloscope when they should be turning to a logic analyzer, often because they're more familiar with oscilloscopes. But logic analyzers have come a long way over the last few years, and for many applications they will help reveal the root cause of troublesome bugs in less time than alternative instruments.

DIGITAL OSCILLOSCOPES VS. LOGIC ANALYZERS

There are similarities between oscilloscopes and logic analyzers, but there are also important differences. To better understand how the two instruments can address your particular needs, it is useful to start with a comparative look at their individual capabilities.

The digital oscilloscope is the fundamental tool for general-purpose signal viewing. Its high sample rate and bandwidth enable it to capture many data points over a span of time, measuring signal transitions (edges), transient events, and small time increments. While the oscilloscope is certainly able to look at the same digital signals as a logic analyzer, it is typically used for analog measurements such as rise times and fall times, peak amplitudes, and the elapsed time between edges.



1. The impedance of the logic analyzer's probe can affect signal rise times and measurements of timing relationships.

Oscilloscopes generally have up to four input channels. But what if you need to measure five digital signals simultaneously—or have a digital system with a 32-bit data bus and a 64-bit address bus? You then need a tool with many more inputs. Logic analyzers typically have between 34 and 136 channels. Each channel inputs one digital signal. Some complex system designs require thousands of input channels. Appropriately scaled logic analyzers are available for those tasks as well.

Unlike an oscilloscope, a logic analyzer doesn't measure analog details. Instead, it detects logic threshold levels. A logic analyzer looks for just two logic levels. When the input is above the threshold voltage (Vth), the level is said to be "high" or "1." Conversely, the level below Vth is a "low" or "0." When a logic analyzer samples input, it stores a "1" or a "0" depending on the level of the signal relative to the voltage threshold.

A logic analyzer's waveform timing display is like a timing diagram found in a data sheet or produced by a simulator. All of the signals are time-correlated so setup-and-hold time, pulse width, extraneous, or missing data can be viewed. In addition to high channel count, logic analyzers offer important features that support digital design verification and debugging:

- Sophisticated triggering that lets you specify the conditions under which the logic analyzer acquires data.
- High-density probes and adapters that simplify connection to the system under test (SUT).
- Analysis capabilities that translate captured data into processor instructions and correlate it to source code.

Using a logic analyzer is like using other instruments. It involves four main steps: connect, setup, acquire, and analyze.

CONNECT TO THE SUT

Logic analyzer acquisition probes connect to the SUT. The probe's internal comparator is where the input voltage is compared against the Vth and where the decision about the signal's logic state (1 or 0) is made. The user sets the threshold value, ranging from transistor-transistor logic (TTL) levels to CMOS, emitter-coupled logic (ECL), and user-definable. Logic analyzer probes come in many physical forms.

General purpose probes with "flying lead sets" handle point-by-point troubleshooting. High-density, multi-channel probes that require dedicated connectors on the circuit board can acquire high-quality signals with minimal impact on the SUT. And, high-density compression probes that use a connector-less probe suit applications that require higher signal density or a connector-less probe attach mechanism for quick and reliable connections to the SUT.

The impedance of the logic analyzer's probes (capacitance, resistance, and inductance) becomes part of the overall load on the circuit being tested. All probes exhibit loading characteristics. The logic analyzer probe should introduce minimal loading on the SUT while providing an accurate signal to the logic analyzer.

Probe capacitance tends to "roll off" the edges of signal transitions. This roll off slows down the edge transition by an amount of time represented as "tΔ" in Figure 1. Why is this important? A slower edge crosses the logic threshold of the circuit later, introducing timing errors in the SUT. This is a problem that becomes more severe as clock rates increase.

DESIGN NOTES

High Voltage CMOS Amplifier Enables High Impedance Sensing with a Single IC – Design Note 513

Jon Munson

Introduction

Accurately measuring voltages requires minimizing the impact of the instrument connection to the tested circuit. Typical digital voltmeters (DVMs) use 10M resistor networks to keep loading effects to an inconspicuous level, but even this can introduce significant error, particularly in higher voltage circuits that involve high resistances.

The solution is to use high impedance amplifiers in an electrometer configuration, so only miniscule amplifier input current comes from the test node. To make the input current the lowest possible value, field-effect transistors (FETs) are traditionally employed at the inputs of these circuits. FETs are generally low voltage devices, and introduce voltage offset uncertainty that is difficult to eliminate. Monolithic amplifiers exist that incorporate FET inputs, but these are often very low voltage devices, especially those using typical CMOS fabrication methods, so their utility is limited in high voltage applications. Enter the LTC®6090, a CMOS amplifier that can handle over $140V_{P-P}$ signal swings with sub-mV precision, ideally suited to tackle the problem.

The LTC6090 Easily Solves High Voltage Sensing Problems

The LTC6090 combines a unique set of characteristics in a single device. Its CMOS design characteristics provide the ultimate in high input impedance and "rail-to-rail" output swing, but unlike typical CMOS parts that might be powered by 5V, the LTC6090 can operate with supplies up to ±70V. The device can hold its own in the small-signal regime as well, featuring typical V_{OS} under 500µV and voltage-noise density of $11nV/\sqrt{Hz}$, yielding a spectacular dynamic range. With the high voltage operation comes the possibility of significant power dissipation, so the LTC6090 is available in thermally-enhanced SOIC or TSSOP packages. It includes an overtemperature output flag and an output disable control that provide flexible protection measures without additional circuitry.

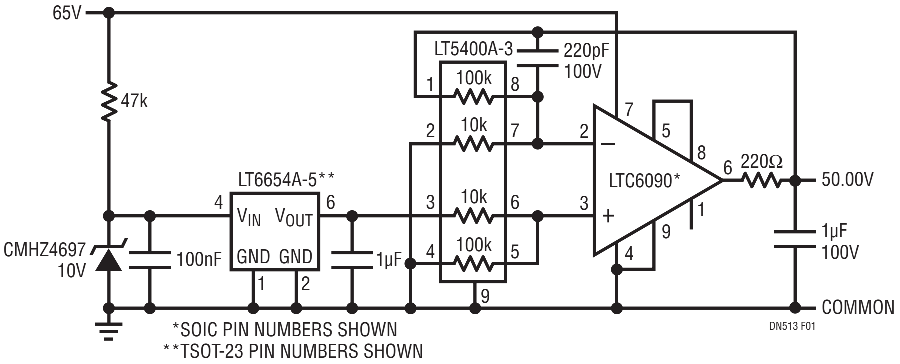


Figure 1. High Voltage Precision Reference

Accurate 50.00V Reference

The LTC6090 is capable of 140V output levels in single-supply operation, so amplifying a quality 5V reference is a simple matter of using accurate resistor networks to maintain precision. The LT®5400 precision resistor array handles voltages up to 80V, so utilizing the 10:1 ratio version for a gain of 10 is an easy way to produce an accurate 50V calibration source without any adjustments required. Figure 1 shows a circuit amplifying the LT6654A 5.000V reference to 50.00V with better than 0.1% accuracy. The circuit may be powered from 55V to 140V, with 65V being a useful supply voltage furnished from the optional portable supply shown as part of Figure 2.

The LTC6090 is set up with a 1μF output capacitance to provide excellent load-step response. The capacitance is isolated from the op amp with a resistance that forms an effective noise-reduction filter for frequencies above 700Hz. The precision LT5400A-3 resistor network provides 0.01% matched 10k/100k resistances that, along with the absence of loading by the high impedance CMOS op amp inputs, forms a highly accurate amplification factor. Input offset voltage of the LTC6090 contributes <0.03% error, while the LT6654A contributes <0.05%.

The entire circuit of Figure 1 draws about 4mA of quiescent current and can drive 10mA loads.

Simple Large-Signal Buffer

The LTC6090 behaves as an ordinary unity-gain-stable operational amplifier, so constructing an electrometer-grade buffer stage is simply a matter of providing 100% feedback with the classic unity-gain circuit. No discrete FETs or floating biasing supplies are needed.

As shown in Figure 2, the LTC6090 can easily be powered with a split supply, such as a small flyback converting battery source. This basic circuit can provide precision measurement of voltages in high impedance circuitry and accurately handle signal swings to within 3V of either supply rail (±62V in this case). With input leakage current typically below 5pA, circuit loading is essentially inconsequential (<V_{OS}) for source impedances approaching a gigaohm. The useful full-swing frequency response is over 20kHz.

Conclusion

The LTC6090 is a unique and versatile high voltage CMOS amplifier that enables simplified high impedance and/or large signal swing, very wide dynamic range amplification solutions.

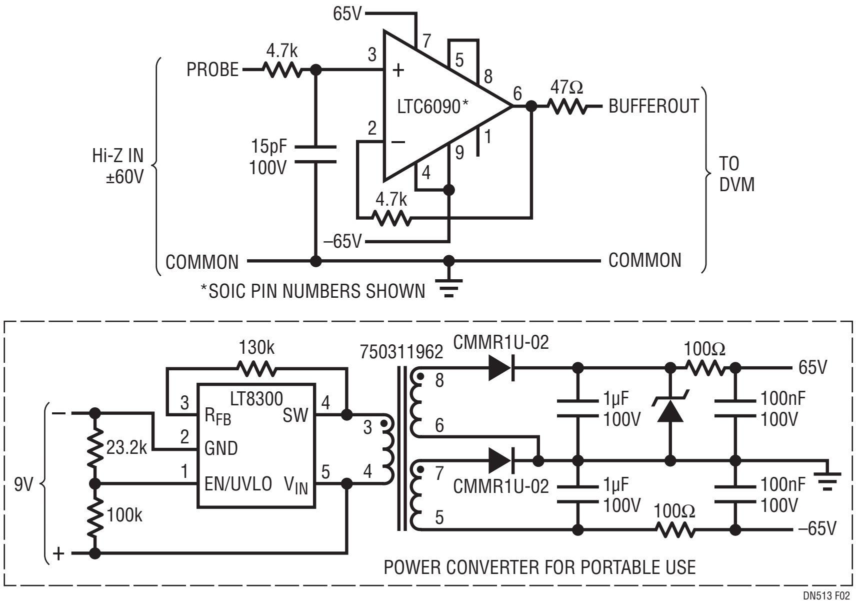


Figure 2. Buffered Probe for Digital Voltmeter

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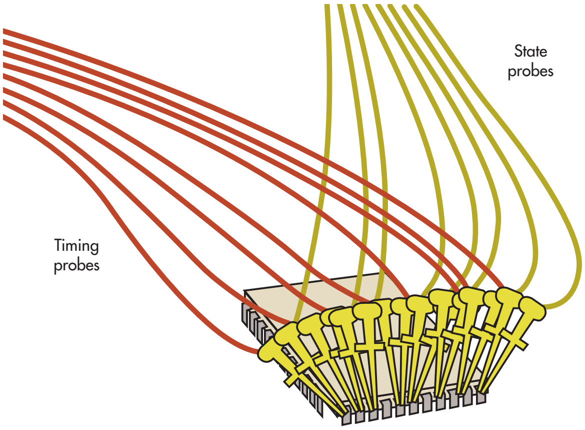


2. Double-probing requires two probes on each test point, decreasing the quality of the measurement.

In high-speed systems, excessive probe capacitance can potentially prevent the SUT from working. It's always critical to choose a probe with the lowest possible total capacitance. It's also important to note that probe clips and lead sets increase capacitive loading on the circuits they are connected to. Use a properly compensated adapter whenever possible.

SET UP THE LOGIC ANALYZER

Logic analyzers are designed to capture data from multi-pin devices and buses. The term "capture rate" refers to how often the inputs are sampled. It is the same function as the time base in an oscilloscope. Note the terms "sample," "acquire," and "capture" are often used interchangeably when describing logic analyzer operations. Also, there are two types of data acquisition or clock modes.

First, timing acquisition captures signal timing information. A clock internal to the logic analyzer is used to sample data. The faster data is sampled, the higher the resolution of the measurement will be. There is no fixed timing relationship between the target device and the data acquired by the logic analyzer. This acquisition mode is primarily used when the timing relationship between SUT signals is of primary importance.

Second, state acquisition is used to acquire the "state" of the SUT. A signal from the SUT defines the sample point (when and how often data will be acquired). The signal used to clock the acquisition may be the system clock, a control signal on the bus, or a signal that causes the SUT to change states. Data, which is sampled on the active edge, represents the condition of the SUT when the logic signals are stable. The logic analyzer samples when, and only when, the chosen signals are valid.

If you want to capture a long, contiguous record of timing details, then timing acquisition using the internal (or asynchronous) clock is right for the job. Alternatively, you may want to acquire data exactly as the SUT sees it. In this case, you would choose state (synchronous) acquisition. With state acquisition, each successive state of the SUT is displayed sequentially in a listing window. The external clock signal used for state acquisition may be any relevant signal.

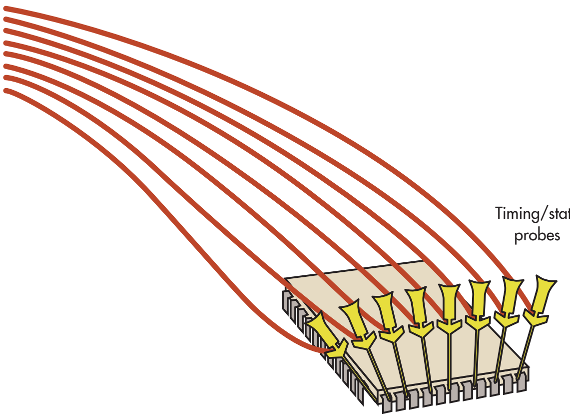
Triggering is another capability that differentiates the logic analyzer from an oscilloscope. Oscilloscopes have triggers, but they have relatively limited ability to respond to binary conditions. In contrast, a variety of logical (Boolean) conditions can be evaluated to determine when the logic analyzer triggers. The purpose of the trigger is to select which data the logic analyzer captures. The logic analyzer can track SUT logic states and trigger when a user-defined event occurs in the SUT.

When discussing logic analyzers, it's important to understand the term "event." It has several meanings. It may be a simple transition, intentional or otherwise, on a single signal line. If you are looking for a glitch, then that is the "event" of interest. Or, an event may be the defined logical condition that results from a combination of signal transitions across a whole bus. Note that in all instances, though, the event is something that appears when signals change from one cycle to the next.

ACQUIRE STATE AND TIMING DATA

During hardware and software debug (system integration), it's helpful to have correlated state and timing information. A problem may initially be detected as an invalid state on the bus. This may be caused by a problem such as a setup and hold timing violation. If the logic analyzer cannot capture both timing and state data simultaneously, isolating the problem becomes difficult and time consuming.

Some logic analyzers require connecting a separate timing probe to acquire the timing information and use separate acquisition hardware. These instruments require you to connect two types of probes to the SUT at once *(Fig. 2)*. One probe connects the SUT to a timing module, while a second probe connects the same test points to a state module. This is known



3. Simultaneous probing provides state and timing acquisition through the same probe for a simpler, cleaner measurement environment.

as "double-probing." It's an arrangement that can compromise the impedance environment of your signals. Using two probes at once will load down the signal, degrading the SUT's rise and fall times, amplitude, and noise performance.

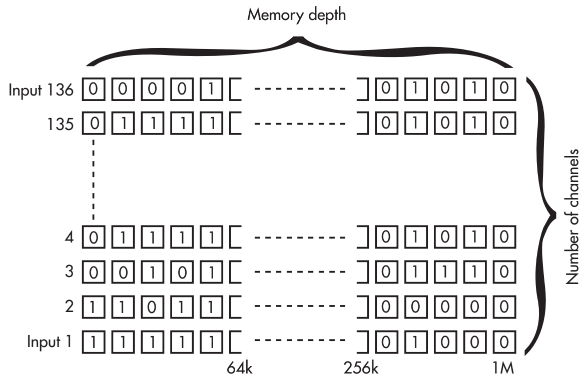
It is best to acquire timing and state data simultaneously, through the same probe at the same time *(Fig. 3)*. One connection, one setup, and one acquisition provide both timing and state data. This simplifies the mechanical connection of the probes and reduces problems. The single probe's effect on the circuit is lower, ensuring more accurate measurements and less impact on the circuit's operation.

The logic analyzer's probing, triggering, and clocking systems exist to deliver data to the real-time acquisition memory. This memory is the heart of the instrument—the destination for all of the sampled data from the SUT, and the source for all of the instrument's analysis and display.

Logic analyzers have memory capable of storing data at the instrument's sample rate. This memory can be envisioned as a matrix with channel width and memory depth *(Fig. 4)*. The instrument accumulates a record of all signal activity until a trigger event or the user tells it to stop. The result is an acquisition, essentially a multi-channel waveform display that lets you view the interaction of all the signals you've acquired with a very high degree of timing precision.

Acquiring more samples (time) increases your chance of capturing both an error and the fault that caused the error. Logic analyzers continuously sample data, filling up the real-time acquisition memory, and discarding the overflow on a first-in, first-out basis. Thus, there is a constant flow of real-time data through the memory. When the trigger event occurs, the "halt" process begins, preserving the data in the memory.

The placement of a trigger in the memory is flexible, providing the ability to capture and examine events that occurred before, after, and around the trigger event. This is valuable for troubleshooting. If you trigger on a symptom, usually an error of some kind, you can set up the logic analyzer to store data



4. The logic analyzer stores acquisition data in deep memory with one full-depth channel supporting each digital input.

preceding the trigger (pre-trigger data) and capture the fault that caused the symptom. The logic analyzer can also be set to store a certain amount of data after the trigger (post-trigger data) to see what subsequent effects the error might have had.

The logic analyzer's main acquisition memory stores a long and comprehensive record of signal activity. Some logic analyzers can capture data at multi-gigahertz rates across hundreds of channels, accumulating the results in a long record length. Each displayed signal transition is understood to have occurred somewhere within the sample interval defined by the active clock rate. The captured edge may have occurred a few picoseconds after the preceding sample, a few picoseconds before the subsequent sample, or anywhere in between. The sample interval, then, determines the resolution of the instrument.

Evolving high-speed computing buses and communication devices are driving the need for better timing resolution in logic analyzers. The answer is a high-speed buffer memory that captures information at higher intervals around the trigger point. Here too, new samples constantly replace the oldest as the memory fills. Every channel has its own buffer memory. This type of acquisition keeps a dynamic, high-resolution record of transitions and events that may be invisible at the resolution underlying the main memory acquisitions.

ANALYZE AND DISPLAY RESULTS

The data in the real-time acquisition memory of the logic analyzer can be used in a variety of display and analysis modes. Once the information is stored, it can be viewed in formats ranging from timing waveforms to instruction mnemonics correlated to source code.

The waveform display is a multi-channel detailed view that lets the user see the time relationship of all the captured signals, much

LOGIC ANALYZER REQUIREMENTS FOR SIGNAL INTEGRITY TESTING

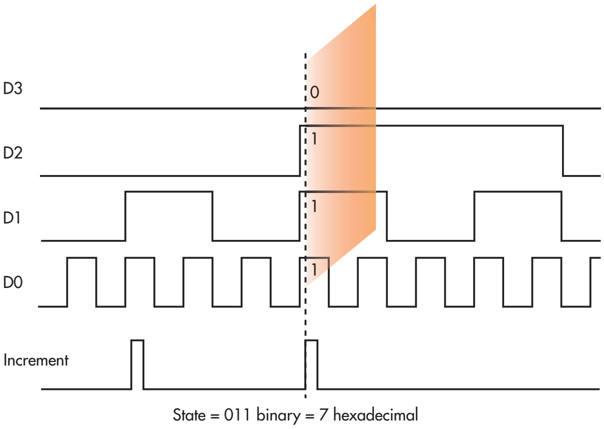
Logic analyzer feature	Recommended capability for signal integrity
Oscilloscope integration	Time-aligned oscilloscope traces on logic analyzer screen, multi-channel eye diagrams
Probing	Simultaneous timing, state, and analog acquisition through the same logic analyzer probe
Timing measurement resolution	20 ps (at 50-GHz clock rate)
State acquisition rate	Up to 1.4 GHz
Acquisition record length	Up to 256M
Triggering	Edge, glitch, logic, setup/hold, etc.
Analysis	Processor support packages and disassemblers
Display	Multiple displays

like an oscilloscope. Commonly used in timing analysis, it is ideal for diagnosing timing problems in SUT hardware. It also can be used to verify correct hardware operation by comparing the recorded results with simulator output or data sheet timing diagrams. And, it suits the measurement of hardware timing-related characteristics including race conditions, propagation delays, and the absence or presence of pulses.

The listing display provides state information in user-selectable alphanumeric form. The data values in the listing are developed from samples captured from an entire bus and can be represented in hexadecimal or other formats. Imagine taking a vertical "slice" through all the waveforms on a bus.

The slice through the four-bit bus represents a sample that is stored in the real-time acquisition memory. As Figure 5 shows, the numbers in the shaded slice are what the logic analyzer would display, typically in hexadecimal form. The intent of the listing display is to show the state of the SUT, allowing you to see the information flow exactly as the SUT sees it.

State data is displayed in several formats. The real-time instruction trace disassembles every bus transaction and determines exactly which instructions were read across the bus. It places the appropriate instruction mnemonic along with its associated address on the logic analyzer display.



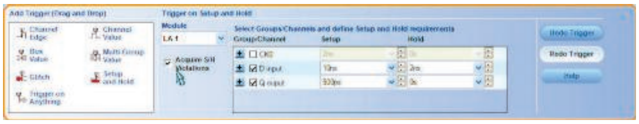
5. State acquisition captures a "slice" of data across a bus when the external clock signal enables an acquisition.

The source code debug display makes debug work more efficiently by correlating the source code to the instruction trace history. It provides instant visibility of what's going on when an instruction executes.

With the aid of processor-specific support packages, state analysis data can be displayed in mnemonic form. This makes it easier to debug software problems in the SUT. Armed with this knowledge, you can go to a lower-level state display (such as a hexadecimal display) or to a timing diagram display to track down the error's origin.

Automated measurements provide the ability to perform sophisticated measurements on logic analyzer acquisition data. Oscilloscope-like measurements can include frequency, period, pulse width, duty cycle, and edge count. The automated measurements deliver fast and thorough results by quickly providing measurement results on very large sample sizes.

Two use cases show how logic analyzers can be used to address common measurement problems.



6. Setup and hold timing violation event parameters can be defined to create a trigger.

CAPTURING SETUP OR HOLD VIOLATIONS

Setup time is defined as the minimum time input data must be valid and stable prior to the clock edge that shifts it into the device. Hold time is the minimum time the data must be valid and stable after the clock edge occurs. Digital device manufacturers specify setup and hold parameters, and engineers must take great care to ensure their designs do not violate the specifications.

But today's tighter tolerances and the widespread use of faster parts to drive more throughput are making setup and hold violations ever more common. In recent years, setup and hold requirements have narrowed to the point where it is difficult for most conventional general-purpose logic analyzers to detect and capture the events. The only real answer is a logic analyzer with sub-nanosecond sampling resolution.

The following example uses a synchronous acquisition mode that relies on an external clock signal to drive the sampling. Irrespective of the mode, the logic analyzer can provide a buffer of high-resolution sample data around the trigger point. In this case, the DUT is a "D" flip-flop with a single output, but the example is applicable to a device with hundreds of outputs.

In this example the DUT itself provides the external clock signal that controls the synchronous acquisitions. The logic analyzer drag-and-drop trigger capability can be used to create a setup and hold trigger. This mode offers the ability to define the setup and hold timing violation parameters *(Fig. 6)*. Additional submenus in the setup window are available to refine other aspects of the signal definition, including logic conditions and positive- or negative-going terms.

When the test runs, the logic analyzer actually evaluates every rising edge of the clock for a setup or hold timing violation. It monitors millions of events and captures only those that fail the setup or hold timing requirements.

SIGNAL INTEGRITY

Direct signal observations and measurements are the only way to discover the causes of signal integrity-related problems. Mostly, the same familiar instruments found in almost any electrical engineering lab measure signal integrity.

These instruments include the logic analyzer and the oscilloscope with probes and application software rounding out the basic toolkit. In addition, signal sources can be used to provide distorted signals for stress testing and evaluation of new devices and systems.

When troubleshooting digital signal integrity problems, especially in complex systems with numerous buses, inputs, and outputs, the logic analyzer is the first line of defense. It offers high channel count, deep memory, and advanced triggering to acquire digital information from many test points, and it then displays the information coherently. Because it is a digital instrument, the logic analyzer detects threshold crossings on the signals it is monitoring and then displays the logic signals as seen by logic ICs.

The resulting timing waveforms are clear and understandable, and they can easily be compared with expected data to confirm that things are working correctly. These timing waveforms are usually the starting point in the search for signal problems that compromise signal integrity.

These results can be further interpreted with the help of disassemblers and processor support packages, which allow the logic analyzer to correlate the real-time software trace (correlated to source code) with the low-level hardware activity. However, not every logic analyzer qualifies for signal integrity analysis at today's extremely high (and increasing) digital data rates.

The table provides some specification guidelines that should be considered when choosing a logic analyzer for advanced signal integrity troubleshooting. With all the emphasis on sample rates and memory capacities, it is easy to overlook the triggering features in a logic analyzer.

Yet triggers are often the quickest way to find a problem. After all, if a logic analyzer triggers on an error, it is proof that an error has occurred. Most current logic analyzers include triggers that detect certain events that compromise signal integrity—events such as glitches and setup and hold time violations. These trigger conditions can be applied across hundreds of channels at once—a unique strength of logic analyzers.

SUMMARY

Logic analyzers are indispensable for digital troubleshooting at all levels. As digital devices become faster and more complex, logic analyzers are keeping pace. They deliver the speed to capture the fastest and most fleeting anomalies in a design, the capacity to view all channels with high resolution, and the memory depth to untangle the relationships between tens, hundreds, or even thousands of signals over many cycles.

Triggering can confirm a suspected problem or discover an entirely unexpected error. Most importantly, triggering provides a diverse set of tools to test hypotheses about failures or locate intermittent events. A logic analyzer's range of triggering options is a hallmark of its versatility. Furthermore, high-resolution sampling architectures can reveal unseen details about signal behaviors.

Single-probe acquisition of both state and high-speed timing data is helping designers gather volumes of data about their devices and then analyze the relationship between the timing diagram and the higher-level state activity. Other characteristics such as acquisition memory, display and analysis features, integration with analog tools, and even modularity join forces to make logic analyzers the tool of choice to find digital problems fast and meet aggressive design schedules. ed

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SPI Eases Interfacing For 5-By-5 Dot-Matrix Display

WHEN DISCUSSING DISPLAYS, seven-segment displays and LCDs are among the first that come to mind. Each type has its pros and cons. But generally, seven-segment displays cannot display letters, and LCDs tend to be bulky. Recently, I came across a four-character 5-by-5 dot-matrix, serial-input display (the SCDV5542 from Osram) that has several advantages.

The display can display alphanumeric characters and measures 10.16 by 19.91 mm (0.400 by 0.784 in.) with 3.12-mm (0.123-in.) characters. It has a serial peripheral interface (SPI) and allows high-speed data input. It features eight levels of dimming, an internal/external clock capability, and decoders, multiplexers, and an LED driver.

The device consists of a CMOS IC with control logic and drivers for the four 5-by-5 characters *(Fig. 1)*. Each individual LED dot is addressable, so the user can create special characters. The device requires only four lines from a microcontroller. The IC accepts decoded serial data that is stored in internal RAM. Asynchronously, the RAM is read by the character multiplexer at the rate defined by the strobe.

The microcontroller supplies a string of bit-mapped characters *(Fig. 2a, b, and c)*. Each character consists of six 8-bit words. The first word is the character address. It's followed by the row data, which represents the on/off status of each LED in the column. Each bit of the 8-bit word consists of a 3-bit opcode (D7-D5) and 5 bits (D4-D0) of column data or character address or control word data.

To load data, bring the $\overline{\text{Load}}$ line low, which puts data in the serial register *(Fig. 2d)*. The shift action occurs on the low-to-high transition of the serial clock (SDCLK). The least significant bit (D0) is loaded first. After one word is transferred, the $\overline{\text{Load}}$ line is set to high for opcode decoding. The decoded opcode latches D4-D0 in the character address register. The time between loads must be at least 600 ns. The character address register bits (D0-D4) and row address register bits (D7-D5) direct the column data bits (D4-D0) to a specific RAM location.

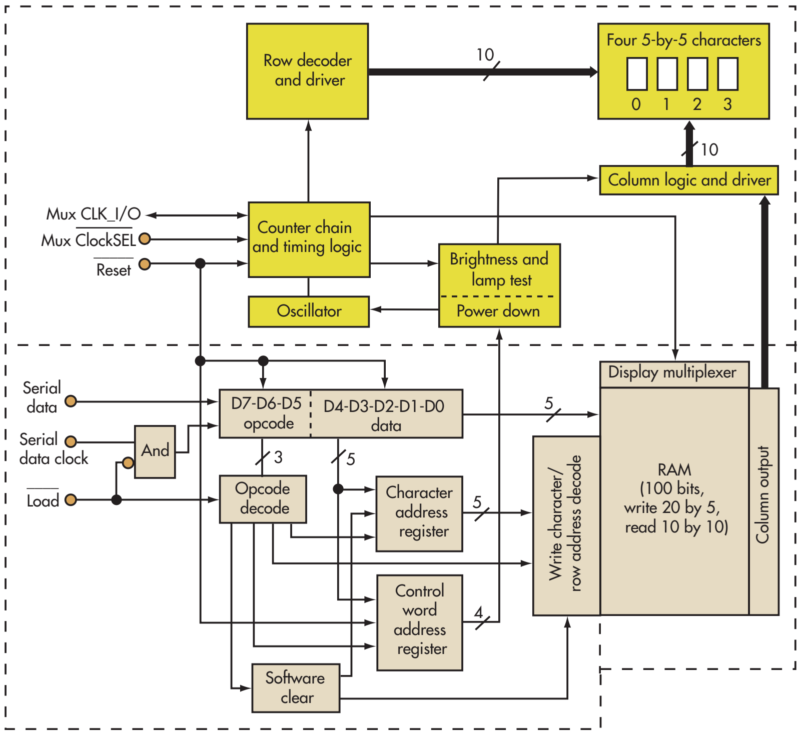
The load character address tells the display the location *(Table 1)*. The load column data controls the individual LED dot *(Table 2)*. This feature allows you to create your own special symbols.

The display has seven brightness levels, defined by the percentage of full brightness that can be achieved: 100% (0xF0), 53% (0xF1), 40% (0xF2), 27% (0xF3), 20% (0xF4), 13% (0xF5), and 6.6% (0xF7). To control the brightness level, change the duty factor of the strobe pulse. Table 3 shows an example line.

In the power-down mode, the display brightness is set to 0% and the clock to the internal multiplexer is stopped, reducing the quiescent current, I_{CC}, to 50 µA *(Table 4)*. The display is reactivated by loading a new brightness level control word into the display. During power-down mode, data can be written to RAM.

Table 5 illustrates the operation of the lamp test mode, which sets all the LEDs to 53% brightness. This operation can be cleared by loading a brightness level control word.

Finally, the software-clear mode clears the address register and the RAM *(Table 6)*. The



1. The SCDV5542 four-character 5-by-5 LED dot-matrix display stores decoded serial data in a 100-bit internal RAM. Users can address each dot individually so they can generate custom characters.

TABLE 1: LOAD CHARACTER ADDRESS									
Opcode			Character address					Hex	Operation load
D7	D6	D5	D4	D3	D2	D1	D0		
1	0	1	0	0	0	0	0	A0	Character 0
1	0	1	0	0	0	0	1	A1	Character 1
1	0	1	0	0	0	1	0	A2	Character 2
1	0	1	0	0	0	1	1	A3	Character 3

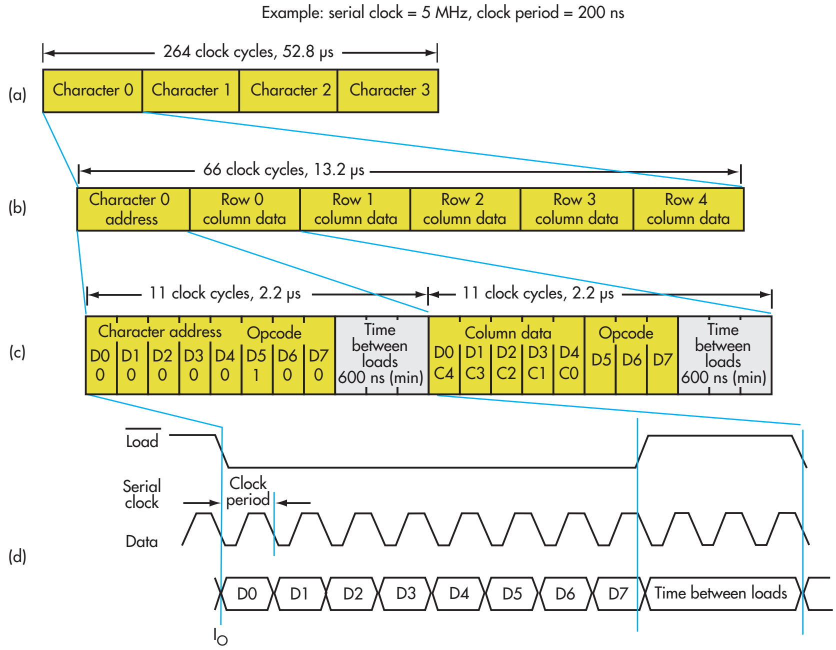
TABLE 2: LOAD COLUMN DATA								
Opcode			Column data					Operation load
D7	D6	D5	D4	D3	D2	D1	D0	
0	0	0	C0	C1	C2	C3	C4	Character 0
0	0	1	C0	C1	C2	C3	C4	Character 1
0	1	0	C0	C1	C2	C3	C4	Character 2
0	1	1	C0	C1	C2	C3	C4	Character 3

TABLE 3: DISPLAY BRIGHTNESS									
Opcode			Control word					Hex	Operation load
D7	D6	D5	D4	D3	D2	D1	D0		
1	1	1	1	0	0	0	1	F1	53%

TABLE 4: POWER DOWN									
Opcode			Control word					Hex	Operation Level
D7	D6	D5	D4	D3	D2	D1	D0		
1	1	1	1	1	1	1	1	FF	0% brightness

TABLE 5: LAMP TEST									
Opcode			Control word					Hex	Operation Level
D7	D6	D5	D4	D3	D2	D1	D0		
1	1	1	1	1	0	0	0	F8	Lamp test

TABLE 6: SOFTWARE CLEAR									
Opcode			Control word					Hex	Operation Level
D7	D6	D5	D4	D3	D2	D1	D0		
1	1	0	0	0	0	0	0	C0	Clear



2. The bit-mapped characters supplied by the microcontroller occur within certain timing specifications. The times in this example are based on the use of a 5-MHz clock (a period of 200 ns).

display is blanked and the character register address is set to character 0. The internal counter and control word register are unaffected.

The example circuit uses a Cypress CY8C27443-24PXI programmable system-on-chip (PSoC) and a program written in C. I chose the PSoC because it enables designers to select individual hardware blocks. The serial interface to the display is straightforward and easy.

There are two ways to interface the display. The first is to connect a microcontroller via the serial port in mode 0. The serial port control register will be a simple shift register. Serial data enters and exits through the RXD pin, and the TXD pin outputs the clock.

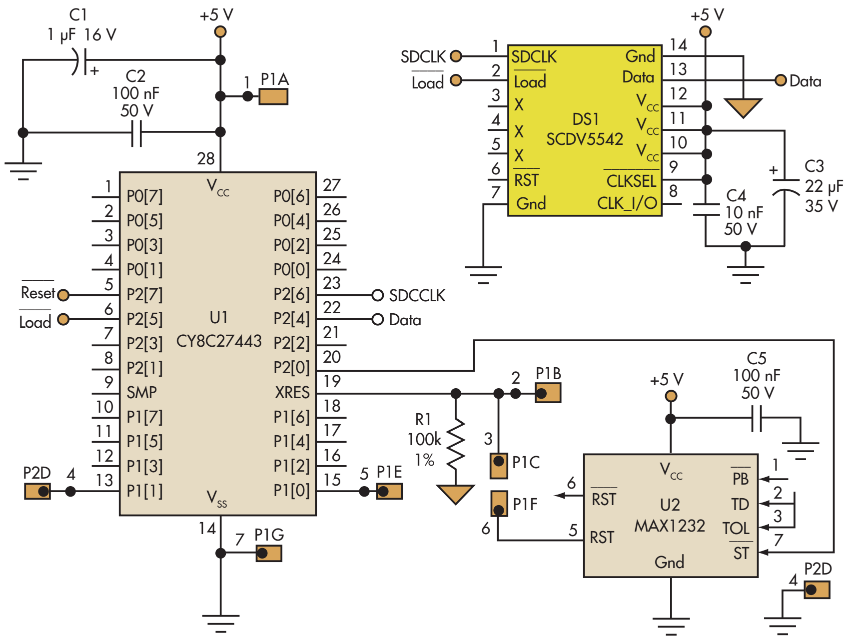
The second method interfaces the display via the SPI in mode 0. Besides MISO (master in slave out) and clock, the display needs Reset and Load control lines. I chose SPI for this project because of its inherent advantages over serial port *(Fig. 3)*. The circuit uses a MAX1232 as a reset controller, but you can choose any other method for properly resetting the microcontroller.

As noted, the PSoC enables you to choose your own hardware modules, which speeds development. For this project I opted for the SPI hardware instantiation to reduce firmware overhead. This choice also ensures the clock is stable and isn't influenced by other priority events.

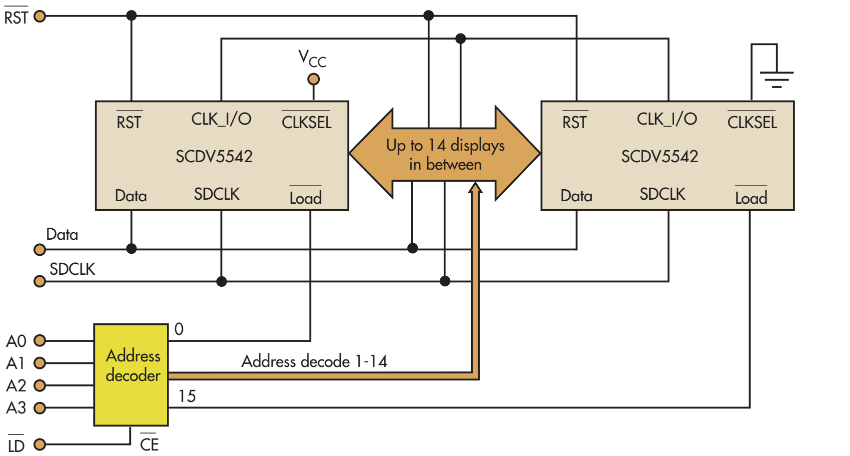
Instantiating SPI simplified the display's communication block. Below is the flow chart for firmware implementation. (The code for the demo project can be downloaded from the online version of this article at *electronicdesign.com*.)

- Power up the display.
- Bring Reset low (for at least 600 ns) to clear the multiplex counter, address register, control word register, user RAM, and data register. The display will be blank. The display brightness will be set to 100%.
- If different brightness is desired, load the proper display brightness control word from Table 4.
- Load the character address into the display *(Table 1)*.
- Load column data into the display *(Table 2)*.
- Repeat steps 4 and 5 for rest of the digits.

Finally, one display CLK_I/O line can drive 15 slave CLK_I/O lines, so you can cascade displays to increase the



3. The author opted to use a SPI instantiation for the display because it reduced the firmware overhead required.

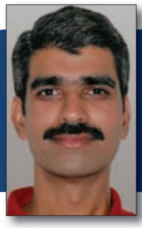


4. The display's CLK_I/O line can drive up to 15 slave CLK_I/O lines, so designers can easily cascade multiple units.

project's display capabilities. Figure 4 shows the block diagram for interfacing multiple displays.

SOURCES

1. Osram SCDV5542 display, catalog.osram-os.com/media/_en/Graphics/00034132_0.pdf
2. Cypress Semiconductor CY8C27443-24PXI, www.cypress.com/?mpn=CY8C27443-24PVXI
3. Cypress Semiconductor PSoC Designer, www.cypress.com/?id=2522
4. Maxim Integrated MAX1232, www.maximintegrated.com/datasheet/index.mvp/id/1286



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ANTENNAS

ULTRA-THIN NFC ANTENNA MEETS CONTACTLESS COMMERCE SPEC

Pulse Electronics says its new near-field-communications (NFC) ferrite-sheet antenna is 40% thinner than comparable antennas, yet still complies with EMVCo specifications. With it, mobile devices can read data from a distance of up to 40 mm, which lets them communicate with other wireless devices for payments, access and control, credential storage and exchange, and content consumption. The antenna, measuring 35 by 30 mm with minimum thickness of 0.185 mm and a pad size of 2 by 2 mm, sends and receives clear signals even when installed in a handset that's close to the battery or metal housing. It consists of a thin ferrite with one-sided flex and a thinner adhesive. Contacts within the antenna facilitate implementation and shrink the footprint.

PULSE ELECTRONICS CORP.

www.pulseelectronics.com/NFCFerriteAntenna

CABINETS, ENCLOSURES & BACKPLANES

SMALLER SIZES UPGRADE WEARABLE HANDHELD ENCLOSURE LINE

To keep pace with the ever-shrinking dimensions of many handhelds, OKW has added six smaller "XS" models to its family of ERGO-CASE wearable enclosure systems. Each ergonomically contoured XS case consists of a top, base, and intermediate ring (plain, or with one eyelet or two eyelets for fitting the device to a lanyard, or wrist strap or belt), assembled with two self-tapping screws. The top part has a recessed area for mounting a membrane keypad or product label. Screw pillars in the top and location pillars in the base are provided for fitting printed-circuit boards (PCBs) and battery assemblies. The enclosures externally measure 3.22 by 2.20 by 0.94 in. and are molded in ABS (UL 94 HB) in off-white or black. The intermediate ring consists of a gray soft-touch thermoplastic elastomer (TPE). Applications include personal handhelds such as medical and wellness equipment, security devices, and dosage detectors.

OKW ENCLOSURES INC.

www.okwenclosures.com/products/okw/ergo.htm

INTERCONNECTS

ZIF CONNECTOR BOOSTS FFC/FPC RETENTION FORCE

Targeting applications that use flexible printed circuit (FPC) or flexible flat cable (FFC), Hirose Electric has developed a halogen-free, 0.5-mm pitch, zero-force-insertion (ZIF) connector. The FH52's design increases the retention force on the FFC/FPC, up to 29.01 N, and facilitates the cable's positioning and insertion. Specifically, its mated height of 2 mm (from eight to 60 available positions) and an actuator opening simplifies the FPC/FFC insertion process by allowing the actuator to rotate up to 110°. A robust locking structure that delivers a firm and clear tactile click that verifies completion of the locking process enhances reliability and actuator retention. "Side catches" hold the tabbed FPC/FFC in place, increase the retention forces placed onto the FPC/FFC, provide a guide for positioning, and maintain a consistent connection. Applications include audio/video/recording devices, car navigation, notebook PCs, portable medical devices, industrial control units, LCD and digital TVs, peer-to-peer computers (PPCs), and plasma display panels (PDPs).

HIROSE ELECTRIC CO. LTD.
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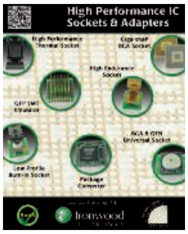
DROP-IN POE CONNECTOR SOLUTION EASES IMPLEMENTATION

A next-generation single-port controller integrates power-device (PD) controller circuitry and Power over Ethernet (PoE) functionality that saves up to 75% of space on printed-circuit boards (PCBs) compared to discrete solutions, says Molex Inc. In addition to the PoE plus power-device controller, the PDJack connector incorporates bridge rectifiers and combines them with gigabit magnetics. It supports functions of all PoE power-sourcing equipment as required for IEEE802.3at compliance, interoperability, thermal management, and electromagnetic interference (EMI) standards. Molex developed the connector with Microsemi, using its PD70200 PD controller, which meets all PD standards. The PDJack comes in Class 0, 1, 2, 3, and 4 and operates at 25.5 W at 37 to 57 V. Two output-power pins and standard signal pins provide Ethernet connectivity. Additional pins allow power-up of an external dc-dc converter. All communications are handled with the switch/router PoE controllers to negotiate power requirements and manage safe power-up and power-down.

MOLEX INC.
www.molex.com/product/poe.html

Catalog Literature Review

HIGH PERFORMANCE SOCKETS & ADAPTERS



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Ironwood Electronics

IR Enhances Online IGBT Product Selector and Performance Evaluator Tool to Further Simplify Device Selection and Optimization

IR has announced the enhancement of its Insulated Gate Bipolar Transistor (IGBT) selection tool that enables design optimization in a wide range of applications including motor drives, uninterruptable power supplies (UPS), solar inverters, and welding.

IR's enhanced IGBT selection tool evaluates application conditions including bus voltage, load current, switching frequency, short-circuit requirements, package and thermal system. New features include customizable thermal constraint setting and Current vs. Frequency output chart that conveniently compare devices over a range of operating conditions.

Located at http://mypower.irf.com/IGBT, the IGBT selection tool returns a shortlist of products that meet or exceed the application parameters entered by the user. The products are ranked by performance with losses and junction temperature for the specified operating condition to help facilitate the selection process.

IGBT selection requires evaluation of many parameters that cannot be simplified into a single metric, as switching losses can be traded for conduction losses. To address this problem, IR's product selection tool generates a Current vs. Frequency graph that provides a powerful indication of the relative performance of different IGBTs. With this information the designer can select the most cost-effective IGBT for the application.

More information is available on the **International Rectifier** website at
http://www.irf.com/whats-new/nr130307.html
For more information, contact Sian Cummins,
scummin1@irf.com. 310-252-7148.

High Endurance Socket for 0.4mm pitch QFP with E-pad

Ironwood Electronics has SS-QFE176SC-01 socket for 176QFP with E-pad has spring pins with 20g force per ball and 500,000 insertions. The self inductance of spring pin is 1.1 nH, insertion loss is < 1 dB at 11.5 GHz, capacitance is 0.58pF and current capacity is 1.5 amps. Socket temperature range is -40C to +120C. This socket can be used for hand test and burn-in applications with the most stringent requirements.

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BILL WONG | EMBEDDED/SYSTEMS/SOFTWARE EDITOR bill.wong@penton.com

The Year Of The Digital Pen

IT MIGHT BE a little late for predictions, but I think this year the digital pen will be mightier than the sword. The digital pens used with platforms like Samsung's Galaxy Note 2 work well for note taking, drawing, and other functions that finger painting doesn't do well.

The Galaxy Note 2 pen is based on technology from Wacom. It's the same technology found in the digitizing tablets that I use with PCs, except they don't have a display under the pen. Digital pens are pressure sensitive, so most don't feel like a ball point or a pencil when you use them, but they aren't bad.

PEN UNDER PRESSURE

I recently got to use N-trig's DuoSense Pen 2 with an HTC tablet *(Fig. 1)*. The pen does make a difference. Unlike other digital pens, the Pen 2 feels like a conventional ball-point pen on paper—smooth movement with a little drag—which was intentional *(see "N-trig DuoSense Digital Pen Offers True 'Pen-on-Paper' User Experience" at engineeringTV.com)*.

The Pen 2 comes with a set of removable tips to provide different kinds of feedback. It boasts better than 0.4-mm accuracy because the matching N-trig DuoSense capacitive controller detects the pen tip and senses 512 levels of tip pressure using an in-pen ASIC *(Fig. 2)*.

The controller can handle multiple finger touches and palm rejection, which was critical on the 7-in. tablet I was using because my palm then could rest on the screen without interfering with the finger or pen input. This was one of the biggest differences when working with an active surface. It isn't an issue with most digitizing tablets that only recognize the pen and not the hand or fingers.

The hover support was useful when applications took advantage of it. Popup menus would appear or buttons would be highlighted when the pen was above the surface.

But using the hover function can be a challenge depending on the application. For example, if the pen tip is close enough to the surface for the hover effect, then a slight, unintended movement can cause the pen to draw. On the plus side, the palm rejection makes a big difference for hover support since it is much easier to hold the tip close if the palm is helping to stabilize the hand.

PEN INCONSISTENCY

Generally, I have a problem with the plethora of use methodologies employed with pen-enabled applications. Simply giving programmers an application programming interface (API) will only lead to confusion.

Android tends to be wild and wooly. That's good for new ideas, but it leads to inconsistencies between applications. Every one of the applications I used with the Pen 2 had a slightly different way of selecting, erasing, and performing other functions.

Windows usually has a more rigid set of standards, but that runs contrary to letting new ideas emerge. Unfortunately, we are really at the beginning of the tablet/pen era, and most of the ideas being employed are sub-par and based on the limitations of the past.

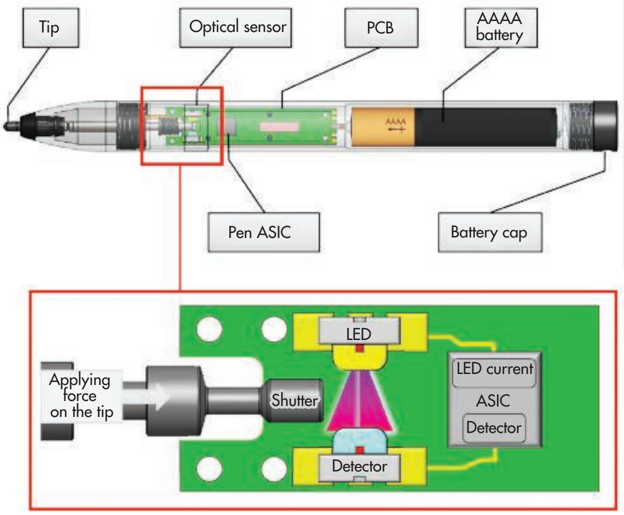
For example, the HTC platform I was using had four ways to enter text using a pen. That was nice, because not everyone uses script or prints well. The problem was that it was the pen or nothing. A virtual keyboard wasn't an option.

Features like the hover sensing also really need to become universal. Not all pens will have this capability, though, so what's an operating-system (OS) designer to do? Likewise, pen input needs to be more universal, which means adding to an application and providing transparency need to be easy. I'm thinking about annotations scribbled on the sides of pages.

Using the pen for input is a learning experience. I actually had good penmanship in grade school, but it has languished because of disuse. Even my printing tends to look more like scribbles. On the other hand, I am getting much better at using the pen with practice.

More changes will come. The Pen 2 that I used had a battery inside, but there likely will be a supercap version in the future that takes a wireless charge in seconds. ed

1. N-trig's DuoSense Pen 2 can be used with a range of tablets, phablets, laptops, and all-in-one desktop systems.



2. The touch sensor detects the Pen 2's tip. An ASIC in the pen captures the pressure information and transmits it along with button status information.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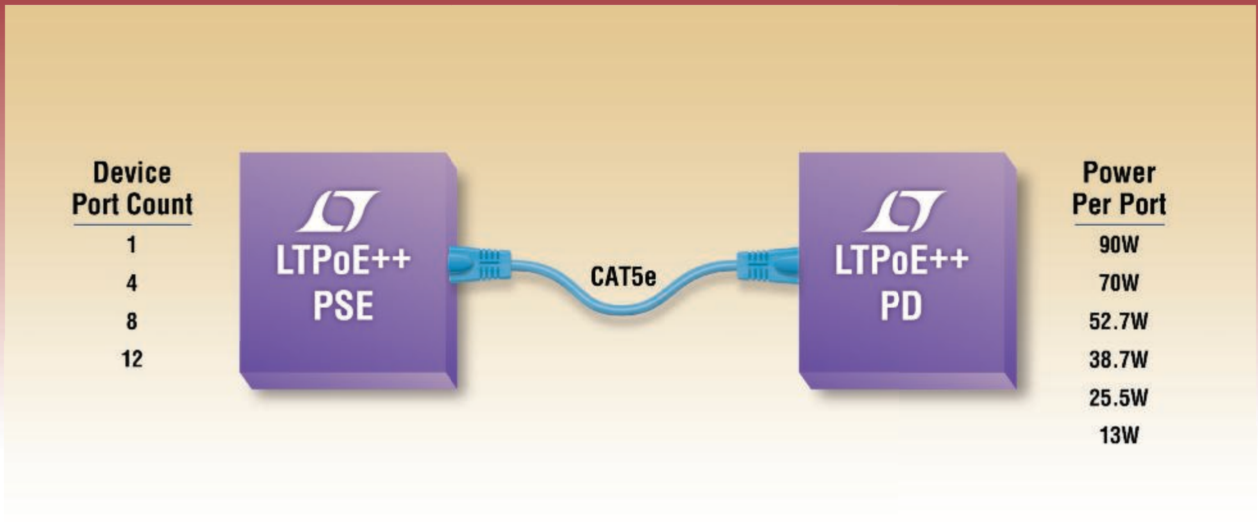

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