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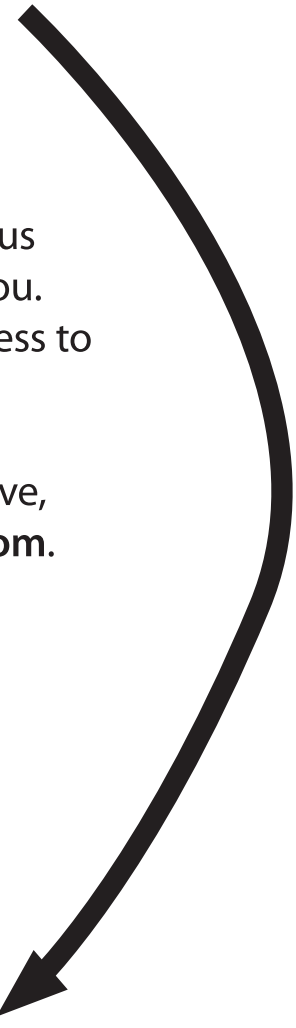

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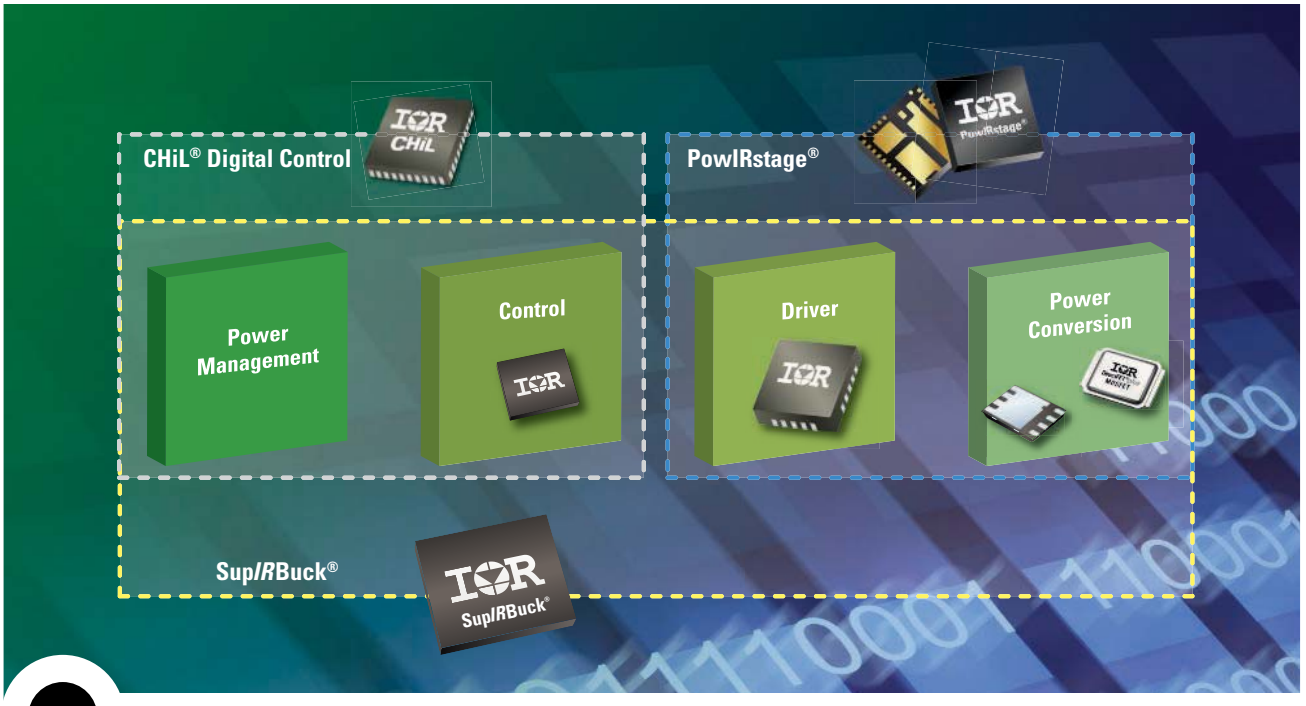

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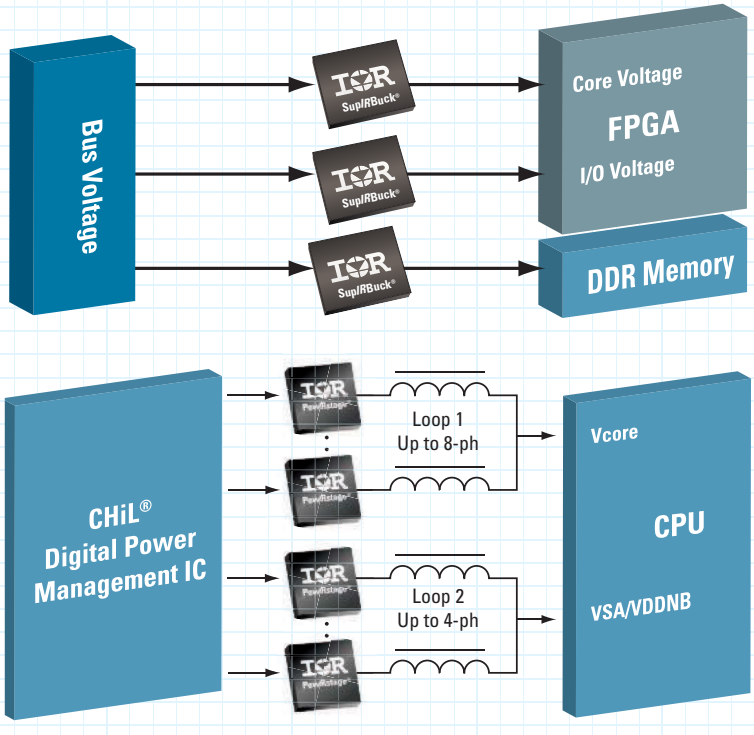

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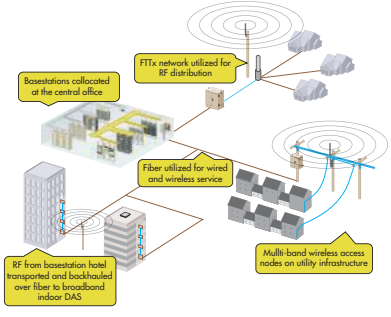

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To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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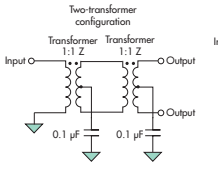

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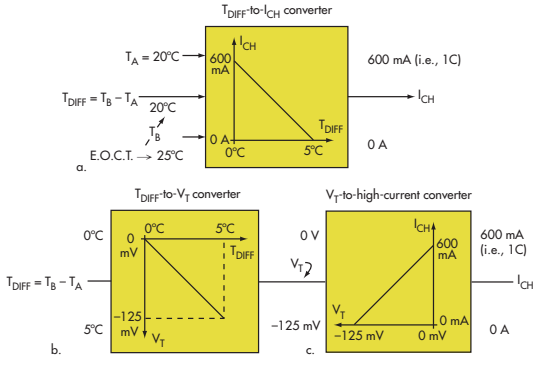

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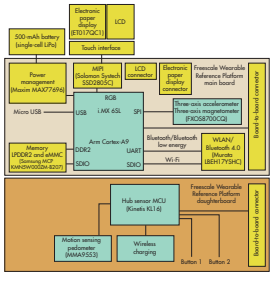

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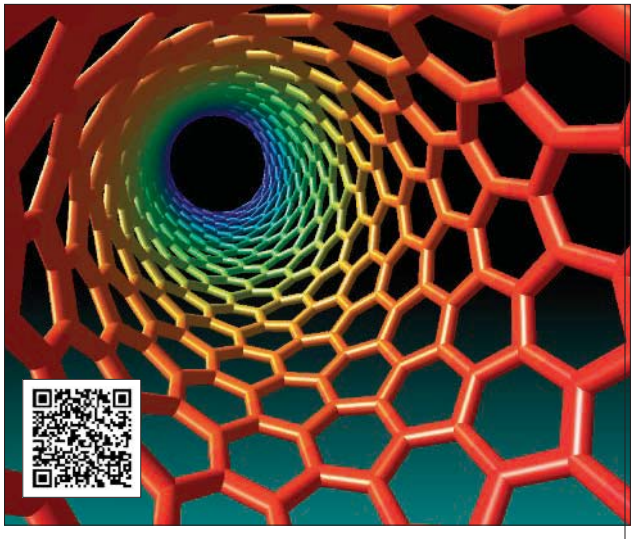

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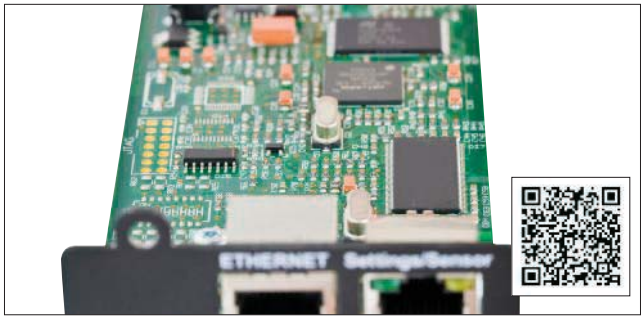

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Robots And 3D
Take The International CES Beyond Big Screens

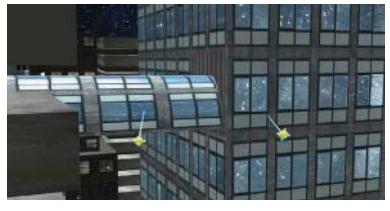
The 2014 International CES was chock full of 4K Ultra HD televisions, of course, including curved, glassless 3D and organic LED (OLED) versions. There were lots of 2-in-1 convertible computers and a plethora of smartphones and tablets as well. Yet a couple of unique items particularly piqued my interest—the $59.95 Ozobot and Sixense's MakeVR.

The Ozobot is a tiny, autonomous robot that doubles as an intelligent game piece *(Fig. 1)*. Measuring 2.5 cm, it has five sensors in a V shape on its bottom that can detect lines. The Ozobot uses these sensors to follow lines and determine their color as it interprets these color sequences as different commands. A multicolor LED on top displays the line and color recognition as well as the commands that the Ozobot rolls over. A micro-USB connector charges the lithium-polymer battery, which provides 40 minutes of continuous operation.

1. The Ozobot is a tiny, autonomous robot that doubles as an intelligent game piece.

A single button turns Ozobot on and off. It also calibrates the system. Place Ozobot on a surface and its two wheels move it as it looks for a line to follow. It works on almost any flat surface including tablets, where line-oriented games can use one or more Ozobot game pieces. The robot can detect ambient light and supports a range of skins. Developers and hobbyists may have access to the system in the future.

MakeVR is an easy-to-use 3D design system that takes advantage of two of the company's STEM System 3D controllers with six degrees of freedom (6DOF) that utilize Sixense's magnetic position sensing technology. MakeVR initially targeted the creation of 3D objects for 3D printers, but its applications also include architectural walkthroughs and manipulating virtual reality *(Fig. 2)*.



2. Sixense's MakeVR is an easy-to-use 3D design system that takes advantage of two STEM System 3D controllers.

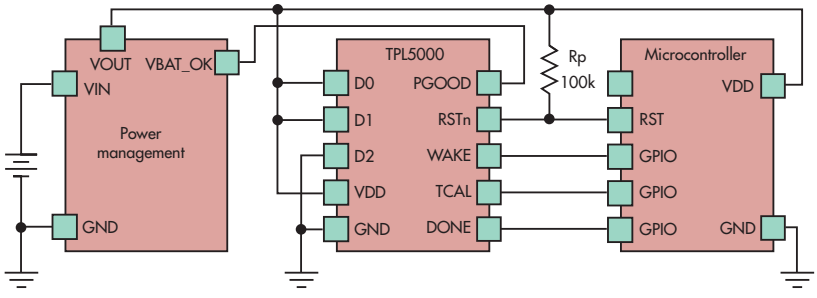
The two controllers map to a pair of 3D cursors that can be used to move, rotate, and scale using gestures that are very natural. Buttons on the controllers allow quick access to frequent actions such as copying and cutting.

Most designers start using MakeVR for freeform design building with existing objects, from simple cylinders to complex objects. MakeVR also is capable of precise construction including the use of grids and other alignment mechanisms as well as numeric scaling. Object definitions can be exported or uploaded to 3D printing services. ed

Energy Zarr
RICK ZARR | Contributing Technical Expert
ti_rickzarr@list.ti.com

Save Power In Building Automation Systems

Many of today's modern building automation systems depend on wireless connectivity to ease installation and allow fast modifications or expansion. But in the process of removing wires, designers must rely on batteries as a power source, which affects the total system cost by adding maintenance to periodically replace cells. The challenge in these systems is to build highly efficient power management schemes that, in addition to saving battery life, ensure proper operation in life-safety applications.



A nano-power programmable timer implementing a low-power microcontroller-based device also can satisfy certain standards such as EN50271, which requires a watchdog function to reset the processor in the event of a low-battery condition to prevent erratic behavior.

INTRODUCTION

According to a 2013 "Markets and Markets" forecast[1] as well as other sources, the global building automation market will grow to almost $50 billion by 2018. This growth is fueled by the ever-increasing need to make our work and living spaces safer, more comfortable, and efficient.

The expansion of this market is partly due to the introduction of wireless sensors, which allow easy installation, expansion, or modification. A large portion of the installation cost is labor associated with cabling along with rising copper prices. Wireless automation infrastructures can reduce these costs dramatically, though they introduce a long-term cost of ownership—without wires, systems must run on batteries.

Battery replacement costs vary, but it can be labor-intensive, based on the location of the sensor. For instance, the sensor could be mounted on a 20-foot ceiling or another hard-to-reach location. In an ideal world, the battery would never be replaced in the useful life of the sensor. However, that is often unrealistic due to the aging of cell chemistry or the sensor's power drain. For most wireless building automation systems, a five-year cell life is a minimum, and 10 to 15 years is advantageous.

MITIGATING ENERGY LOSS

Designers can focus on several areas to help extend the period between battery replacements. The first is to understand the RF environment where a sensor will be required to operate. In most cases, it will be in a network with other sensors. The nodes can be arranged as a "mesh" network where some sensors are an end-point or function as repeaters.

This configuration is very energy-efficient due to reduced RF transmit power, which can be the largest consumer of energy in the sensor. By lowering the transmit power and allowing routers to repeat messages, an extremely low-power network can be formed. This topology often is used in wireless networks based on IEEE 802.15.4, such as ZigBee or 6LoWPAN.

An issue with mesh networks is synchronization, as seen with ZigBee. Router nodes must be available at all times. So if a node originates a message or a message is sent to a node, then the message is forwarded or stored and forwarded when the node is available.

For ultra-low-power devices, power is greatly reduced during a "sleep" cycle where most of the device is powered down, including the RF receiver. In this scenario, the router nodes must be powered (for example, ac power) to monitor for messages from the sleeping nodes when they are awake. Here, power consumption is highly asymmetrical. Sensor nodes are extremely low-power and sleep for long periods, and router nodes (which also could be sensors) are powered continuously and have their receivers active.

A complete ultra-low-power network without routers that are line-powered requires very precise timing, which can lead to increased cost and complexity in each node. The entire network wakes within a tight window, communicates, and then

sleeps again. The longer the duration between cycles, the tighter the timing requirements. If a node loses synchronization with the network, then it needs to stay awake until the next waking cycle to resynchronize—something to be avoided in a battery-powered network.

In most practical wireless networks, the router is powered continuously from some constant source such as line power or more likely power over Ethernet (PoE). In this case, the nodes have the burden of being as efficient as possible with their battery power. Typically a microcontroller powers down the radio and anything non-essential. In the case of a sensor, all of the analog front-end (AFE) electronics are powered down as well. Then the microcontroller enters a low-power mode using a timer to periodically wake up, power up the system, send any appropriate messages, and then reenter sleep mode.

The duty cycle of these sleep and wake cycles determines the power that's consumed. The equation shows the power calculation for estimating battery life based on the sleep and wake power consumption:

$$T = \frac{E_A}{P} = \frac{C\left(\frac{V_S + V_E}{2}\right) \bullet \alpha \bullet \text{eff}}{D(P_W) + (1 - D)(P_S)}$$

Run time (T) in hours is based on duty-cycled power states. It is calculated as the ratio of available energy (EA) in watt-hours to the power consumed (P) in watts. This can be further expanded.

Capacity (C) is in amp-hours (Ah), V_S and V_E are the starting and ending voltages respectively during discharge, P_W and P_S are power consumed in watts during wake and sleep cycles respectively, and D is the duty cycle (0 to 1) of the waking period. A de-rating factor (α) is used to adjust the battery for a loss in capacity in applications with an extended service life (greater than five years). The efficiency (eff) of the power converter stage is also taken into account since it degrades performance. Typical efficiencies range between 80% (eff = 0.8) to 95% (eff = 0.95).

Part of this design is selecting a power source that will last 10 to 20 years without significant degradation and a power converter (for example, switching regulator) that is extremely efficient at low power. The first problem can be addressed by a battery chemistry of lithium thionyl chloride ($Li/SOCl_2$). This chemistry has been around since the 1970s and has an extremely long service life (10 to over 25 years). $Li/SOCl_2$ has been used successfully in remote meters and other battery-powered wireless systems.

Cells have a typical voltage of 3.6 V and exhibit an excellent operating temperature range (–55°C to 125°C).

When using a single lithium-based cell, a sensor-node design may boost the 3.0- to 3.6-V output to 5.0 V or use a buck-boost converter like the TPS63001, which has a fixed output of 3.3 V and can deliver up to 800 mA in all conditions (buck or boost). This is key during the active state since RF transmitters may require significant instantaneous current. More importantly, the converter is mostly unloaded during the sleep cycle and must be able to automatically enter a pulse frequency mode (PFM) or some other pulse-skipping technique to conserve power.

Another source of energy loss is keeping the microcontroller active during the sleep cycle, even in low-power mode. At a minimum, a timer must be running with the main core shut down to conserve energy, but even this configuration may draw several microamps. Even state-of-the-art, low-power microcontrollers such as the MSP430 hover around 0.3 µA of current while in standby mode.

One novel solution is to use timer devices specifically designed for long sleep periods. The TPL5000 from Texas Instruments has programmable dividers to provide wakeup pulses with periods up to 64 seconds. It also has an extremely low power consumption of only 30 nA while running. With extremely long sleep cycles, this can add as much as two years to the service life of a battery-powered wireless sensor *(see the figure)*.

CONCLUSION

With the proliferation of battery-powered wireless networks, installers and owners are looking for longer battery life—some with requirements for never replacing the battery during the entire network life (25 years or longer). Battery chemistries such as Li/$SOCl_2$, high-efficiency PFM converters, and novel nano-power long-period timers consume extremely low power during device sleep cycles, resulting in wireless building automation systems that rival their wired counterparts.

Reference

Building Automation & Controls Market (2013 – 2018): By Product (Lighting, Security & Access, HVAC, Entertainment, Outdoor, Elevator Controls, Building Management Systems (BMS)), Application & Geography (Americas, Europe, APAC, And ROW), marketsandmarkets.com, February 2013, Report Code: SE 1625.

RICHARD ZARR is a technologist at Texas Instruments focused on high-speed signal and data path technology. He is a member of the IEEE and holds a BSEE from the University of South Florida.

News & Analysis

Rescue Robots
Roll Toward A $2 Million Prize

Tartan Rescue, the team hailing from Carnegie Mellon University, put its robot CHIMP through its paces connecting a fire hose to a wall spigot, among other tasks, as it took third place overall in the event.

As disasters and other emergencies get more dangerous, first responders are looking to robotic solutions that can save lives without putting personnel in danger. In an effort to encourage innovation, the Defense Advanced Research Projects Agency (DARPA) invited teams from academia and the industry alike to participate in its DARPA Robotics Challenge (DRC) Trials.

SOLAR CAR CRUISES INTO INTERNATIONAL CES

FORD'S C-MAX SOLAR Energi debuted at January's International CES. The concept car's 1.5-m^2 solar panel works with a canopy outfitted with a Fresnel lens that tracks the sun during the day, improving sunlight collection by a factor of eight, to draw an 8-kW charge. According to Ford, the sun could power up to 75% of all trips made by an average driver in a solar hybrid vehicle.■

Held in December at the Homestead Speedway in Homestead, Fla., the competition simulated what robots might have to do to safely enter and effectively work inside a disaster zone while their operators stay out of harm's way. Sixteen teams participated in the event, which consisted of eight tasks including walking across rough terrain, opening doors, locating and closing leaking valves, and even driving and exiting a vehicle.

"At the start of the event, I said that I would be thrilled if even one team scored half the points available," said Gill Pratt, DARPA program manager for the DRC. "The event exceeded my expectations multiple, multiple times over, with the top teams each scoring half or more."

After two days of competition, DARPA chose eight teams to receive up to $1 million in funding to continue their work. SCHAFT Inc. of Tokyo took first place, followed by IHMC Robotics, Tartan Rescue of Carnegie Mellon University, Team MIT, RoboSimian of the NASA Jet Propulsion Laboratory, TRACLabs Inc., the WPI Robotics Engineering C-Squad of Worcester Polytechnic Institute, and Team Trooper of Lockheed Martin Advanced Technology Laboratories.

"The DRC Trials demonstrated the difficulty of having robots conduct seemingly simple tasks in real-world situations, and the participation of the first-responder community provided an important illustration of how technology can save lives," said Brad Tousley, director of DARPA's Tactical Technology Office. "This event was yet another example why challenges work to attract new ideas and help quickly advance technology to solve a focused need."

The teams now will prepare for the DRC Finals sometime in the next 12 to 18 months. The Finals will be an opportunity for the 16 teams to continue their efforts next to new teams to vie for the DRC's $2 million prize. And already, Pratt has identified three initial goals for the next competition.

"First, we'd like the robots to be more stable so they don't fall, and if they do fall, be more robust so they won't break," he said. "Second, have the robots work without their tethers by using wireless communication and more efficient, self-contained power systems. Finally, we'd like the robots to use more task-level autonomy in unstructured environments such as those found in real disasters." ■

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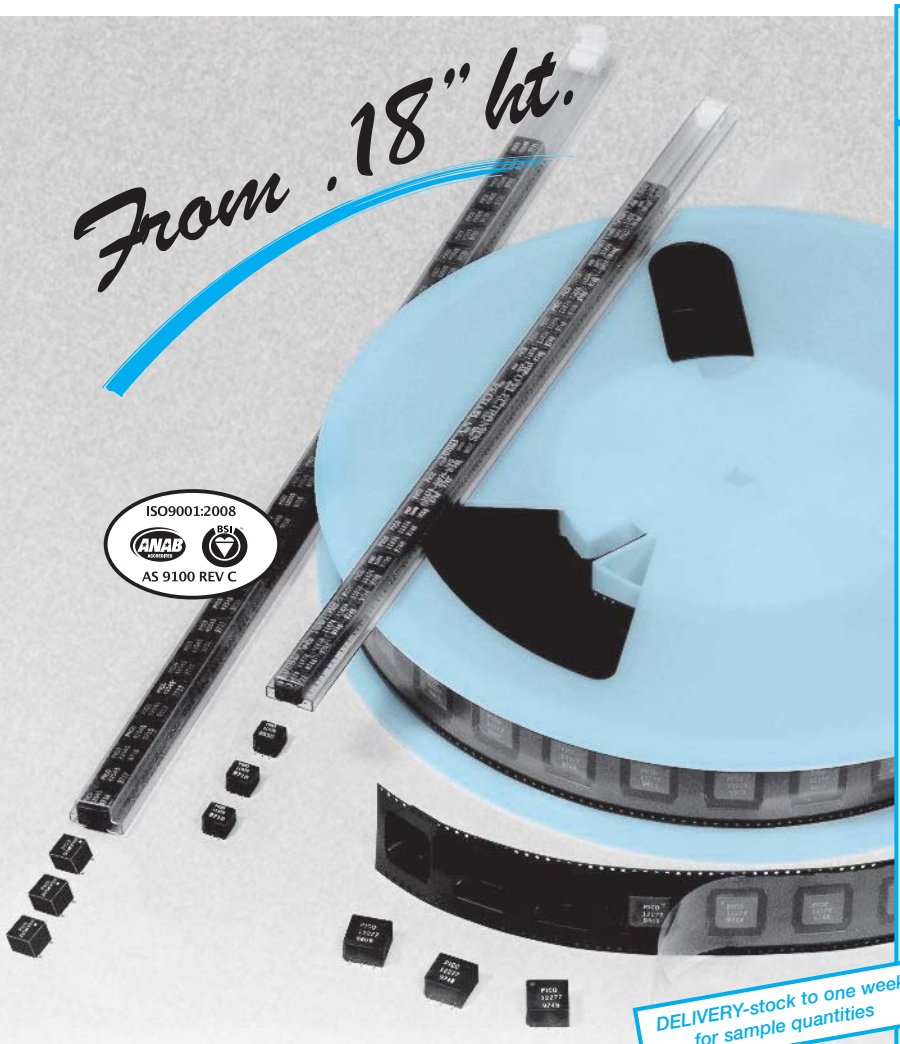

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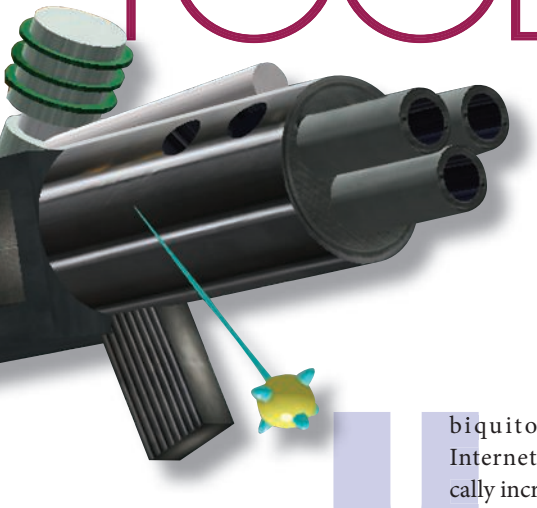
Sixense's MakeVR can be used to design 3D figures like this with users collaborating on the design in real time via the cloud.

DEVELOPMENT TOOLS Move To The Cloud



You can find just about anything in the cloud these days, including development tools, but not all of their advantages benefit developers.

Ubiquitous high-speed Internet access has radically increased the number of cloud-based apps available for smartphones, tablets, and PCs. Most of these apps are relatively simple compared to development tools, but tools have migrated to the cloud too. This approach offers many advantages and disadvantages for developers and vendors alike, ranging in importance from insignificant to essential.

For developers, setup and software updates are automatic. The interface often is browser-based, allowing the application to work on almost any platform. The interface also is amenable to mobile users. Developers who must maintain multiple versions of an application will appreciate having multiple tool versions available to them, assuming the vendor provides this capability.

Software distribution also often is part of a vendor's service, especially for app development tools. This support frequently includes billing services in addition to customization for different targets.

Performance can be enhanced when using cloud-based solutions since vendors generally can provide more powerful support clusters that can speed compiles and other chores. The downside is that active users share these clusters, so support may depend on the number of users and what kinds of operations they are working on at the time.

For vendors, there can be a significant reduction in support calls, especially those relating to setup and upgrades of software or tools. Calls that require a support technician to examine the state of the tool are now easier since the technician can access a user's tool, data, and screen. The technician can provide immediate feedback to users.

Support personnel also can provide users with more sophisticated collaboration tools. Collaboration features have been added to many standalone platforms, but implementing and managing them can be difficult when users have to configure and manage them.

Vendors benefit from regular access to users as well. They can track the kinds of operations that are being performed and track what versions of their tools are being used. New goods and services can be advertised, especially when "free" services are provided. Users will need to read any contracts closely to determine whether vendors are using their "data" for other purposes.

Another issue for vendors that can be very important is protection of intellectual property (IP)—not their users' IP, but the IP within their tools. Competitors can utilize the tools and see how they operate, but they would not have access to the code to reverse engineer the tools.

There are disadvantages, though. In general, an Internet connection is required. Some applications can operate offline, but typically with more limited functionality. Data also must be

local, making usage impractical on many platforms like smartphones and tablets.

For developers, posting work on the Web may violate company or project security requirements. Vendor lock-in is significantly easier to force using Web-based tools since the user cannot use the tools without Internet access.

Uptime also can be an issue. The inability to access a cloud-based service can be caused by problems on the user's device, the connection via the Internet, or the vendor's cloud service. Debugging this kind of problem can range from simple to complex depending on the diagnostic tools and the type of problem.

As noted, vendors may provide access to multiple versions of tools and runtime libraries. But this can be an issue if they do not guarantee configurations that can be locked down on a per-user basis. This can be important for users who maintain their applications.

Long-term support also can be an issue since the ability to generate and support an application could be lost if a vendor's status changes or the user stops buying a subscription to use the tools. Free online services are vendor-dependent as well, and a shutdown likely will eliminate access to user data.

For vendors, maintaining a service can be a challenge, especially for a large user base that may be using many versions of their applications. Vendors often buy cloud-based platform services to deploy their offerings. This minimizes their infrastructure costs, but there can be issues related to the scaling and reliability of those services.

Vendors usually provide standalone, thick-client, thin-client, or browser-based applications. The standalone applications encompass development tools such as the typical integrated development environment (IDE). Each of these delivery mechanisms has advantages and disadvantages, such as the ability to use a range of local resources. Graphics-oriented applications generally need access to hardware acceleration. Browser-based solutions benefit from HTML5 and WebGL, which provide access to 3D hardware acceleration.

STANDARD NETWORK-BASED TOOLS

Developers are already familiar with network-based collaborative tools that are easily hosted in the cloud, including applications like source code revision management, bug tracking, and help forums. Most IDEs like Eclipse, Microsoft's Visual Studio, Apple's Xcode, and Oracle's NetBeans support one or more third-party platforms for these types of applications, often via the plug-in mechanism that each supports.

For example, there are many source code management tools including the open source Concurrent Version System (CVS), Git, and Subversion. There are vendor-specific solutions as well, often integrated with application lifecycle management (ALM) tools like Microsoft's Visual Studio Team Foundation Server, now known as Visual Studio Online. Visual Studio Online is integrated with popular third-party IDEs like Eclipse and Xcode.

Source code management is just the tip of the iceberg when it comes to collaboration. Integration with bug tracking, code coverage, and other tools can be found in many solutions such as Microsoft's latest version of Visual Studio. The Code Lens support adds an extra line above portions of a code listing such as the start of a function definition. This heads-up type of display includes details like the number of code references, the number of bugs, and the number of code reviews. It even hooks into Microsoft's Lync messaging support, making it easy to contact people working on those details.

Platforms like Visual Studio are examples of standalone solutions that have been augmented with cloud-based support. The server services can be hosted locally, or users can take advantage of Internet-based services.

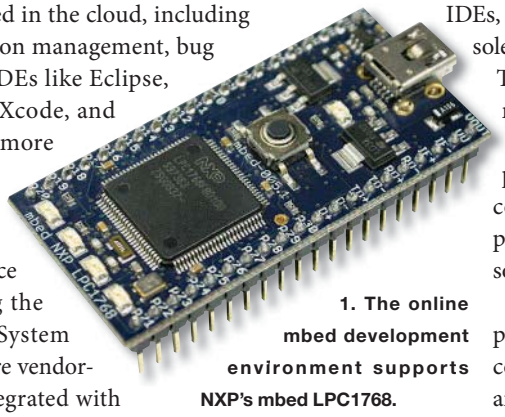
DEVELOPING EMBEDDED SOFTWARE IN THE CLOUD

The free, online mbed development platform targets Arm microcontrollers. It started with the mbed LPC1768 module from NXP, but it has expanded to include a range of modules including Freescale's latest Freedom FRDM-KL46Z *(Fig. 1)*.

A lightweight, browser-based IDE is used to edit projects that are hosted on the website *(Fig. 2)*. The mbed C/C++ compiler and linker are mbed cloud services. The source code is also on the site, so the compiler can take advantage of the cloud host, which may be more powerful than the average developer PC. The binary is downloaded to a target where the application then can be debugged locally.

The mbed SDK (software development kit) includes a number of runtime libraries that provide access to the standard peripherals available on the target platforms. The SDK also includes a real-time operating system (RTOS).

The mbed approach may be unique since it targets a range of third-party hardware. Arm, NXP, and other sponsors essentially provide support for the site designed to generate applications that will utilize Arm platforms. The SDK suits use with other IDEs, although applications can be developed solely using the mbed environment.



1. The online mbed development environment supports NXP's mbed LPC1768.

The mbed site provides easy startup and management of embedded applications for Arm microcontrollers. But this provides convenience as the compiler computational requirements for most projects are relatively small compared to some compute-heavy chores.

Plunify addresses FPGA design support. FPGA development encompasses computationally heavy work like layout and verification. Large, complex FPGA

designs can take days to process for a single configuration. Optimizing the designs frequently takes multiple iterations.

The cloud approach provides access to cloud-based computational services that are often built on platform services from cloud computation and storage providers like Amazon and Verizon. These computational services are provided on demand and can be run at off-peak times to reduce costs or increase computing resources.

The challenge with this approach for an individual user is the complexity of setting up this type of support and then using and managing it. Companies like Plunify have done all this work and provide the services with an easy-to-use interface and simplified billing that takes advantage of the on-demand cloud support.

Just about any development tool that requires sophisticated setup or large amounts of computing power is a target for cloud-style development delivery. These days, system-on-chip (SoC) design includes extensive simulation that could be done in the cloud. As with FPGA development, a designer usually needs these services for a fraction of the development cycle, so investing in a lot of hardware to address the peak needs can be more expensive than using cloud-based services.

For software development, testing is ripe for cloud support. Regression testing can be time consuming, and having large amounts of storage and compute power on tap is what the cloud is best at. Many tools can already take advantage of local shared clusters, and utilizing the cloud is a natural progression.

COLLABORATING IN THE CLOUD

Integrating collaboration tools like instant messaging and shared whiteboards is common with communication services like Skype or Microsoft's Lync. Real-time collaboration has significant advantages in a range of development applications including chores such as code reviews and mechanical design.

MakeVR is a 3D mechanical modeling tool that utilizes a pair of Sixense's magnetic-based STEM controllers *(Fig. 3)*. Each user has an individual viewpoint that can be changed independently. Users also can manipulate the environment simultaneously. MakeVR is a PC-based tool with cloud connections. The application must be running on all hosts.

SpaceClaim Engineer 2014 is another 3D modeling tool that provides real-time collaboration *(Fig. 4)*. Its browser-based Connect feature allows access from any suitable Web browser. 3D applications like this tend to have more hardware integration and performance requirements than simply displaying text or an image. This is comparable to flash-type requirements for displaying streaming media. Of course, HTML5 standards and higher-performance mobile devices make this more practical for a wider range of devices.

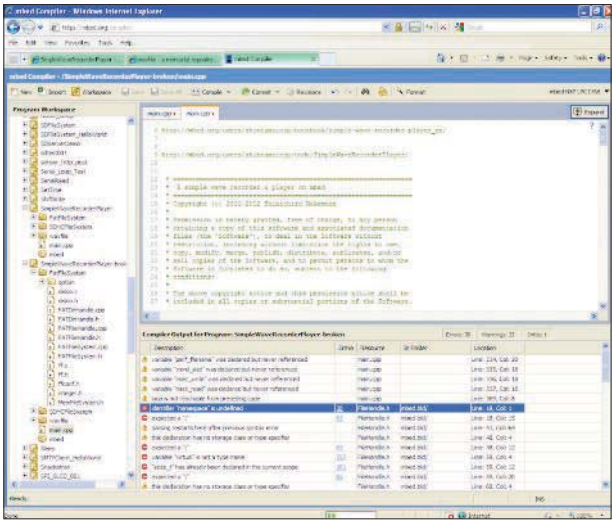
Still, the heavy lifting is handled in the cloud where more performance power is available. The approach is already used for cloud-based voice recognition like Apple's Siri. Latency and bandwidth tend to be the challenge with these types of applications, but this is also an area where massive multiplayer online (MMO) gaming operates with quite a bit of success.

PCB DESIGN IN THE CLOUD

Companies like ExpressPCB and Sunstone Circuits can deliver custom printed-circuit boards (PCBs) quickly. They provide free PCB design tools, or developers can create PCB designs using third-party tools like Altium Designer, Cadence Allegro PCB Designer, and Mentor Graphics Xpedition xPCB Layout.

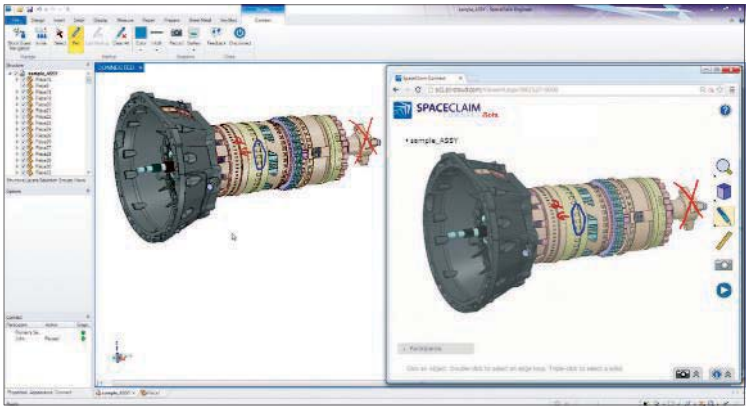
Boards normally are uploaded and ordered using standards-based file formats and a Web browser. More of this process is being integrated into the design tools, simplifying the process and reducing errors. Sunstone Circuits' PCB123 provides this type of functionality.

Gumstix's Geppetto moves the design tool to the cloud. The browser-based interface provides drag-and-drop layout of carrier boards designed to hold Gumstix processor modules. The components are laid out in a CAD fashion without



2. The mbed IDE is a lightweight, browser-based solution. Projects are hosted on mbed.org.

3. Sixense's MakeVR 3D CAD design tool allows remote collaboration. Each user has a pair of 3D cursors to manipulate the virtual world.



4. SpaceClaim Engineer 2014 provides 3D CAD collaboration using a Web browser.

concern for interconnect routing. Designers only need to create logical connections between components. The design tool handles dependencies, so a board design is only complete when all required connections have been made.

The end deliverable is a completely populated board that then can be ordered in any quantity. There are initial startup costs in addition to a per-board cost, but they tend to be significantly lower than a custom design. The designs can even be shared on the Gumstix site.

Geppetto designs are typically for prototypes and small to midrange production numbers. Gumstix has also made it easier to share open source hardware designs via Kickstarter. As with most PCB quickturn services, the cost per board goes down as the volume increases. The Kickstarter approach allows the initial number of boards to be based on demand, usually with a threshold for a target cost.

A CHANGING APPROACH

Standalone development tools will continue to be preferred by many developers, but cloud-based solutions are on the rise. Many solutions are exclusively cloud-based, especially those from new vendors. Vendors with established products need to keep their current customers happy even while they begin offering integrated cloud-based support.

Customers must determine what types of tools they will need and where they can afford to have their data and designs processed and stored. As companies get leaner, many functions have moved to the cloud or third-party services. Development is no different. In the end, it will be a tradeoff between the available tools and the customer's requirements. ed

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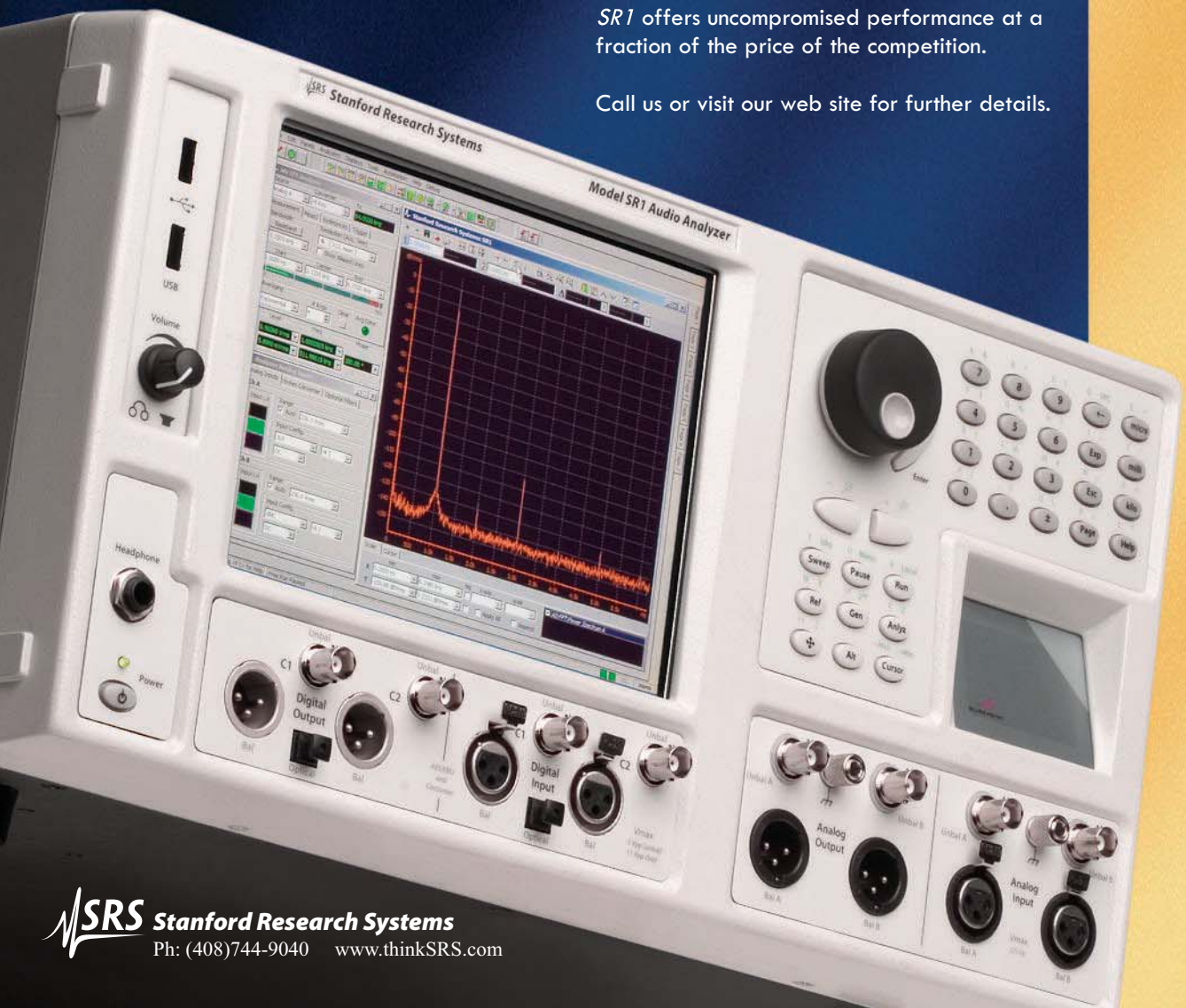

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TODAY'S OSCI
Tackle Evolving Commu

Oscilloscopes have grown beyond basic time-domain tools and are now available with many automatic functions to speed and simplify a wider range of measurements, with an eye on the growing range of wireless specifications.

Oscilloscopes come in many shapes and sizes, with functionality ranging from simple signal capture to complex time-domain signal analysis. Recently, oscilloscope manufacturers have heeded user requests by enhancing the automated capabilities of their instruments so operators can achieve faster, more accurate measurements for increased productivity. In many cases, these automated measurements address high-speed serial communications parameters, with the aid of add-on personal-computer (PC) software.

But as modern oscilloscopes incorporate more capabilities, such as built-in logic analyzers and waveform generators, operators are exploring parameter measurements for communications-standards-based equipment, including Wi-Fi wireless local-area networks (WLANs) and Long-Term Evolution (LTE) cellular communications components. In many cases, newer oscilloscopes offer real values in terms of performance and measurement capabilities.

NOW AVAILABLE

The range of oscilloscopes on the market is quite wide, in performance and price. Typically, an oscilloscope is specified according to the measurement requirements of a device under test (DUT). Quite simply, an oscilloscope displays voltage as a function of time, and it can do so for any type of signal it can process. By knowing the bounds of a DUT's electromagnetic (EM) parameters, it is usually possible to find an oscilloscope to show the DUT's EM performance. Most oscilloscope specifiers start with a handful of performance specifications for comparison, including bandwidth and sampling rate.

For high-frequency signals or signals with fast rise times, bandwidth is critical for analysis. An oscilloscope's bandwidth indicates the frequency range across which it can make accurate measurements and across which signals are attenuated by no less than 3 dB in amplitude. Different components offer different guidance on seeking bandwidth for an oscilloscope, such as the "three-times rule" or the "five-times rule."

For the latter, the bandwidth of the oscilloscope should be five times the highest-frequency component of a DUT's signal of interest. The former rule refers to using the third-harmonic component of a DUT's signal of interest to set the bandwidth requirement for an oscilloscope. Similarly, the faster an oscilloscope's rise time, the more accurate will be its measurement and display of a DUT's signal rise time.

Bandwidth is associated with price, with greater oscilloscope bandwidths translating into higher prices, so most specifiers are careful about the instrument and amount of bandwidth that they select. While the upper-frequency limit of an oscilloscope does determine price, the lower-frequency limit is also worth noting since it can affect the instrument's effectiveness for some measurements. Some measurements, such as electromagnetic-interference (EMI) testing, require a measurement range that extends well into the audio-frequency range or even with dc measurement capability.

In contrast, sampling rate, which defines digital oscilloscope performance, has become more affordable so even lower-costing oscilloscopes are now available with impressive digital sampling circuitry with typical gigabit/s sampling rates. Sampling rate is often tied to bandwidth (with some company guidelines calling for a sampling rate that is at least 2.5 times the bandwidth). However, some lower-bandwidth instruments also feature impressively high sampling rates and the corresponding ability to capture rapidly changing signal events and features. As sampling rate increases, the amount of memory required to store the data increases, with demand increased by the number of oscilloscope channels as well.

In sorting through oscilloscopes, it is important to recognize the many types now in use and how they differ. Although

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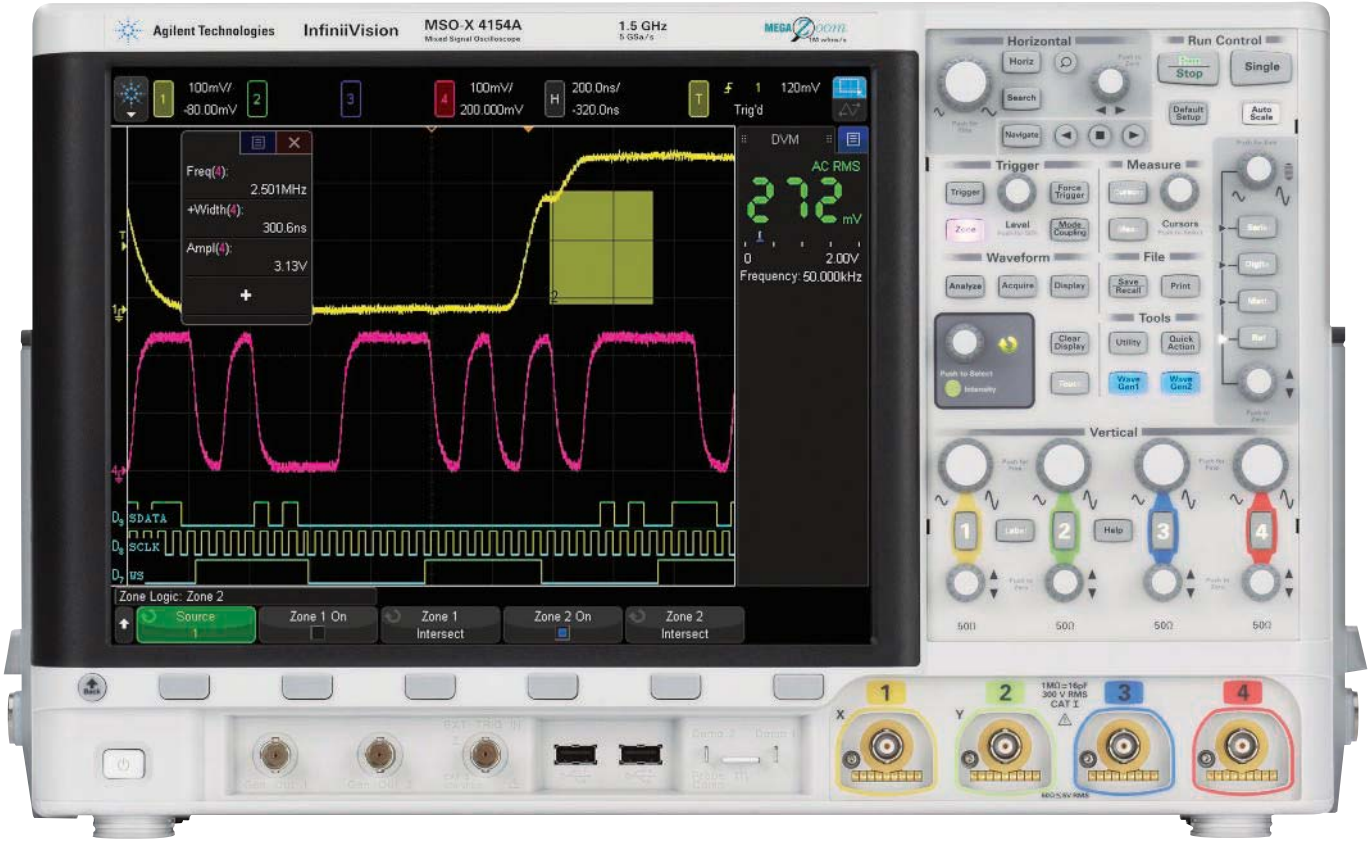

1. Agilent's Infiniium 4000 X-Series 4154A model oscilloscope includes four other handy instruments.

a vanishing breed, analog oscilloscopes are still used, based on analog input and signal-processing electronics and usually a CRT display screen to show measured signals. More common are the many types of digital oscilloscopes, which can be used to analyze analog and digital signals.

A digital storage oscilloscope (DSO) transforms analog input signals on a test channel to digital form by means of a high-speed analog-to-digital converter (ADC). By means of a microprocessor and digital signal processing (DSP), the waveform data is sent to the oscilloscope's display screen, often an LCD, for viewing.

2. By combining oscilloscopes with spectrum analyzers, the Tektronix MDO4000B series instruments are ideal for WLAN testing.

Software within an oscilloscope enables automatic computation of key waveform parameters, such as rise time, fall time, amplitude, and pulse width. At one time, these instruments relied on the memory within a data converter or microprocessor to store captured waveform data. Ready availability of high-speed memory, though, makes it possible to store and process more data and greater amounts of waveform information per channel in a DSO.

Digital oscilloscopes are available based on different triggering methods. For example, a digital sampling oscilloscope can measure a waveform once per trigger, such as a point on the rise time of a pulse, when working in single-shot (or real time) mode. It also can operate in repetitive sampling modes, using multiple samples to capture different portions of a high-speed or high-frequency waveform and then assembling an image of the waveform on the oscilloscope's display screen.

In this repetitive sampling mode, the performance and response of a digital sampling oscilloscope greatly depends upon the frequency response of the sampler used in the oscilloscope, but such an oscilloscope is effective at analyzing repetitive high-speed, high-frequency signals that are higher than the sampling rate of the oscilloscope.

A mixed-signal oscilloscope (MSO) combines a number of analog input channels with usually a greater number of digital input channels, providing synchronized measurements of the multiple inputs using a single time base and showing test results on a single display. While they may lack the large number of analysis channels of a dedicated logic analyzer, MSOs can provide great insight with a combination of oscilloscopes and logic analyzers.

A mixed-domain oscilloscope (MDO) provides measurement capabilities in both the time and frequency domains. Some oscilloscope manufacturers have integrated basic spectrum-analysis functions within their digital oscilloscopes to allow displays of both voltage versus time and signal amplitude versus frequency—in essence, creating a miniature automated test system within the housing of the oscilloscope. Although the bandwidth of the spectrum analyzer is typically limited compared to that of the digital oscilloscope, the additional functionality can be quite useful when examining such signal characteristics as phase noise and stability.

TRENDS IN SCOPES

This incorporation of multiple measurement tools within an oscilloscope, in both benchtop and portable versions, represents a growing and positive trend for oscilloscope users. The multiple measurement channels can be triggered in synchronization, without the need to fine-tune complex external clock arrangements.

An example can be found in the InfiniiVision 4000X series of oscilloscopes from Agilent Technologies, with bandwidths as wide as 1.5 GHz and sampling rates to 5 Gsamples/s for the analog channels (somewhat less for digital inputs). The InfiniiVision MSO-X 4154A packs a multiple-channel oscilloscope, a logic analyzer, a three-digital digital voltmeter (DVM), a dual-channel function-generator/arbitrary waveform generator (AWG), and a serial protocol analyzer into the enclosure once used for just an oscilloscope *(Fig. 1)*.

All five functions, including the oscilloscope and its bandwidth, can be upgraded for changing measurement requirements. To assist in creating waveforms with the 20-MHz AWG, the firm offers a free copy of the BenchLink Waveform Builder Basic software on its website (at *www.agilent.com/find/33503*). With its two channels, the AWG can produce modulated and differential signals.

As with other members of the InfiniiVision 4000X series, the MSO-X 4154A shows captured signals on a 12.1-in. capacitive touchscreen, updating the display at rates to 1 million waveforms/s. The display screen even helps with triggering on portions of a waveform—by drawing borders around a portion of interest on a displayed signal, that part of the signal will be triggered for future measurements.

The screen provides 8-bit standard vertical resolution and a high-resolution display mode with 12-bit effective vertical resolution. For those not enamored of the touchscreen, its functionality can be shut off and the MSO-X 4154A can operate like a traditional display screen with the push of a button.

Agilent, with a portfolio of oscilloscopes ranging from 20 MHz to 90 GHz, is offering a discount for customers seeking additional bandwidth from its 1000A, 1000B, 2000X, 3000X, or 4000X series oscilloscopes, as part of the "Supercharge Your Oscilloscope Bandwidth" promotion (through March 31). Oscilloscope customers can choose a model with a higher

bandwidth than they would normally afford, paying the price of the selected model to the next lower bandwidth with the same family and with the same number of channels.

Tektronix made noise several years ago by adding spectrum-analysis measurement capabilities to its MDO4000B series of MDOs, capabilities that it recently enhanced further late last year *(Fig. 2)*. The multiple-function capabilities of the MDO4000B instruments transform them into hybrid measurement systems capable of performing time- and frequency-domain measurements.

When equipped with the Live Link option and the company's SignalVu-PC vector-signal-analysis (VSA) software, the hardware and software can provide the analysis functions of an RF/microwave VSA. Options for the software enable analysis of IEEE 802.11 a/b/g/j/n/p/ac Wi-Fi signal quality, pulse quality for radar systems, general-purpose digital modulation, amplitude modulation (AM), frequency modulation (FM), and pulse modulation (PM) quality.

Tektronix reports that the oscilloscope series has gained in popularity as engineers face a growing number of communications interfaces with integrated RF/microwave circuitry, including Wi-Fi, ZigBee, and radio-frequency identification (RFID). According to Fanny Mlinarsky, president and CTO of wireless test services provider octoScope, "The MDO4000B with SignalVu-PC delivers the right capabilities at the right price point to enable embedded and WLAN module designers to rapidly debug systems without a steep learning curve."

The enhancements to the spectrum-analysis capabilities include spurious-free dynamic range (SFDR) of –60 dBc guaranteed and typically –65 dBc (an improvement from levels of –55 and –60 dBc in earlier models) and an improvement of as much as 20 dB in spectrum-analyzer phase-noise performance for greater confidence in evaluating spurious and low-level signals. In addition, the integral spectrum analyzer's lower-frequency limit has dropped to 9 kHz (formerly 50 kHz) for improved EMI diagnostics while the maximum RF/microwave acquisition time has essentially doubled, increasing from 79 ms to a current capacity of 158 ms.

These improved spectrum-analysis capabilities, when used with the SignalVu-PC software, support advanced modulation analysis of wireless standards such as the various configurations of IEEE 802.11. In addition to characterizing WLANs, the software/oscilloscope combination is a powerful tool for testing wideband radar systems, frequency-agile communications systems, and satellite-communications (satcom) equipment.

3. The right software equips Agilent's 4000 X-Series oscilloscopes for testing the MIL-STD 1553 and ARINC 429 avionics buses.

An important feature in newer oscilloscopes, such as the MDO4000B line, is signal integrity (SI) testing, since SI more and more is being used to characterize the quality of modern communications systems. SI can be degraded by analog and digital causes, including crosstalk from signal traces in close proximity, ground bounce, signal reflections, jitter, and circuit layout problems.

Oscilloscopes with sufficient bandwidth and eye diagram capability can help spot SI problems, since such diagrams can reveal serial data and logic transitions in a single view. The number of high-performance oscilloscopes that include eye diagrams and, ideally, simplify matters with one-button eye-diagram measurements is growing.

In terms of future developments, Tektronix announced last year that it would base its next line of high-performance real-time oscilloscopes on silicon-germanium (SiGe) semiconductors from IBM. Using that firm's 9HP SiGe process, which yields devices at transition frequencies to 350 GHz, Tektronix expects to achieve instruments with real-time bandwidths to 70 GHz in support of high-speed data communications.

"The advanced 9HP SiGe BiCMOS technology provides the faster switching speeds, high integration levels, and low noise our next generation of performance instrumentation requires to meet customer requirements," said Kevin Ilcisin, chief technology officer (CTO) of Tektronix. The next-generation oscilloscopes will also leverage asynchronous-time-interleaving technology for improved signal-to-noise performance.

As part of the company's efforts to enhance instrument performance, the R&S RTO series oscilloscopes from Rohde & Schwarz include a unit with measurement bandwidth to 4 GHz, the R&S RTO1044. With sampling rates of 10 Gsamples/s for four-channel operation and 20 Gsamples/s for two-channel use, it provides 8-bit vertical resolution and as many as 600,000 waveforms/s with 100-ps rise/fall time resolution. It shows results on a 10.4-in. liquid-crystal thin-film transistor (TFT) color display with touchscreen functionality.

As with the other digital oscilloscopes in the RTO series, the R&S RTO1044 offers full math functions and full fast Fourier transform (FFT) spectrum analysis per user-defined parameters, such as center frequency and Gaussian bandwidth. As with many newer high-resolution digital oscilloscopes, it can work with PC-based software to provide automated measurements per high-speed serial communications standards and even to some of the requirements of Wi-Fi and LTE standards.

Of course, standards testing with modern oscilloscopes is not reserved for commercial communications sys-

tems, and the military has been a longtime user of high-speed oscilloscopes for this purpose. As an example, the MIL-STD 1553 serial bus is largely used in avionics systems for control. It relies on three-level signaling and required dual-level triggering on the test equipment (an oscilloscope) for proper testing. Similarly, the ARINC 429 serial bus is used to interconnect avionics equipment in civilian aircraft. The DSO4XAERO A/D Serial Triggering and Analysis software for the 4000 X-Series oscilloscopes from Agilent Technologies provides eye-diagram masks for both interconnect standards to speed and simplify testing using one of the oscilloscopes *(Fig. 3)*.

In terms of bandwidth and sampling rate, few can match Teledyne LeCroy and its LabMaster 10 Zi series of modular real-time oscilloscopes. Available with four channels at 36 GHz or two channels at 65 GHz, or as many as 80 channels at 36 GHz with additional modules, these oscilloscopes operate at an impressive 160-Gsample/s sampling rate. The LabMaster ChannelSync oscilloscope architecture is built with high-frequency, high-speed SiGe chipsets and timing clocks with extremely low jitter. The sample clock exhibits low jitter of 50 fs RMS while the jitter among measurement channels is held to 130 fs RMS or less.

For those more comfortable with a traditional oscilloscope format, the firm also offers the two- and four-channel HDO4000-MS and HDO6000-MS high-definition oscilloscopes in bandwidths from 200 MHz to 1 GHz *(Fig. 4)*. Rather than plug into external monitors like the LabMaster ChannelSync oscilloscopes, the HDO models incorporate 12.1-in. touchscreen displays to show signal information captured with a 12-bit ADC architecture.

4. Teledyne LeCroy's two- and four-channel models HDO4000-MS and HDO6000-MS oscilloscopes are available in bandwidths from 200 MHz to 1 GHz.

These compact oscilloscopes run at 2.5 Gsamples/s with as much as 25 Mpoints/channel of memory (50 Mpoints/channel when interleaved). They also feature automatic measurements, waveform math, logic-gate emulation, and digital timing measurements. As with many new oscilloscopes, each HDO model is available with a software package that transforms the instrument into a spectrum analyzer, even converting its controls to spectrum-analysis functions. In addition, an optional Power Analysis software package allows an HDO instrument to measure and analyze the operation of power-conversion devices over time.

This trend in adding measurement functions even applies to portable, handheld oscilloscopes such as the 2512 from BK Precision *(Fig. 5)*. The dual-channel, 100-MHz-bandwidth device features a built-in digital multimeter (DMM) for fast voltage measurements. It also provides a wide range of recording functions, with 3.5 Mpoints of memory per channel or 7 Mpoints of memory for a single channel. The little oscilloscope runs at 1 Gsample/s and shows results on a bright 5.7-in. color display screen. It boasts 32 automatic measurements, including an FFT to make frequency-domain conversions.

5. This dual-channel, 100-MHz-bandwidth miniature oscilloscope from BK Prevision features a built-in digital multimeter (DMM).

Some oscilloscopes are available as PC-based instruments, like the PicoScope 9300 series from Picotech. The 9321 integrates a 20-GHz sampling oscilloscope with a 9.5-GHz optical-to-electrical converter for testing optical communications and other equipment with bit rates to 11 Gbits/s and higher.

The instruments' 20-GHz bandwidths are aimed at testing high-speed data signals, such as 10 Gb Ethernet, SONET/SDH STM64 and FEC1071, 10x Fibre Channel, InfiniBand, and PCI Express. They offer dual 16-bit ADCs with 60-dB dynamic range, 14-GHz trigger bandwidth, and low trigger jitter of 1.8 ps RMS. They rely on updated Pico-Sample software in 32- and 64-bit versions for use with Microsoft Windows XP through Windows 8 and enable 138 automatic measurements and 167 communications standards masks.

In at least one case, a portable oscilloscope is using Wi-Fi to make the test, rather than as the subject of the test. The CarScope PRO PC-based automotive oscilloscope from Ditex Co. is a four-channel wireless automotive diagnostic instrument designed for professional automotive technicians. Developed for software running on Windows-based PCs, it is connected to an automobile but transfers test data to its controller, a remote computer, by means of Wi-Fi IEEE 802.11b/g (from 2.412 to 2.484 GHz). It serves as an engine analyzer for any vehicle and can operate on a wide range of power sources (8 to 36 V dc).

A high-speed oscilloscope may at times be preferred to a frequency-domain instrument such as a spectrum analyzer for complex communications signals, as is the case with Wi-Fi and LTE signals, but also for signals in possibly emerging ultra-wideband (UWB) communications systems. Such systems, with frequencies allocated from 3.1 to 10.6 GHz and data rates reaching 1024 Mbits/s, will support short-range communications with complex, self-synchronizing, packetized, half-duplex signals. ed

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Analog Experts Note The Toward Targ

The most conspicuous trend in both pure analog and mixed-signal ICs is the replacement of ad-hoc analog signal-conditioning circuitry in new designs with targeted analog front ends (AFEs) aimed at specific kinds of applications including medical, automotive, and industrial control contexts.

Traditionally, analog signal acquisition and processing was accomplished with chains of amplifiers and data converters created by the engineers at the companies that were designing the final product. IC companies competed on the basis of data-sheet specs and pricing, and their design support was limited to application notes and contributed articles in magazines such as *Electronic Design*—though even that support is now changing *(see "Analog Chip Companies Provide Higher Levels Of Design Support" at electronicdesign.com)*.

These days, most new product announcements concern highly integrated, narrowly targeted devices that encompass the entire analog signal chain from the first stage after the sensors themselves to the interface to an FPGA or microcontroller. Examples in applications range from electrocardiography and ultrasound to managing the charge and discharge of traction-motor batteries in electric vehicles.

Executives at Linear Technology recently met to discuss these trends. The roundtable included Robert Dobkin, chief technology officer; Erik Soule, vice president of signal-conditioning products; and vice presidents Don Paulus and Steve Pietkiewicz, who essentially split power-management products, Linear's largest product line, between them.

DON TUITE: How does Linear manage discrete and integrated solutions?

ERIC SOULE: We do both. We're making the turnkey micro modules and we're making great standard products too that could be used in ways that we may not predict.

TUITE: Who is buying the standard products? Is there anybody typical?

STEVE PIETKOWITZ: I think the guy that tends to buy the standard product is the guy that's pushing the performance barrier. So almost by definition, there is no integrated or ready-made solution for him because he has the best box on the planet.

We have one category of parts. Call them high-performance widgets. Whether it's a switching power supply or an amplifier, it tends to be a building block. In the RF world, these are mixers or modulators, the kind of fundamental squares and triangles on your schematic that have really the best features or the best combinations of specs that you can get. The guy that knows his end product can cobble those things together in unique ways that allow him to differentiate.

DON PAULUS: Like Steve said, the answer is it's both. We're doing these reference designs, the integrated modules, the ASSPs (application-specific standard parts)—those tend to be more, I think, application-specific, where we do all the hard stuff and build it inside. And then I think there are guys who go the complete opposite direction and take the widgets and do things with them.

Trend eted Apps

Linear Technology CTO Robert Dobkin and other executives describe how the company is handling the industry's shift away from general building blocks and to products designed for specific end uses.

TUITE: What is it about the guys who have the really trailblazing state-of-the-art end products—where do they find their customers? Where do they come from? Are they older people who have spun off from larger companies with a specialty?

SOULE: No, they're established companies. I think of these industrial, European, family-owned companies having been around for generations and generations. They're not startups. They know what they're doing. They're leaders in whatever box they make. We see it in Europe. We see it in Asia and Japan. We see it here. These are companies that have been around for a long time. They make the best of whatever it is. They compete hard with whomever they compete against, and they tend to buy a lot of our products.

PAULUS: But I think the guys are interested in more of a system-level solution being provided. And from my perspective, that's a growing piece of our customer base, and it has become more of a focus inside LTC, certainly for certain products in my business.

"We're a high-performance supplier, and we continue to think of new higher-performance devices that people need," said Robert Dobkin, CTO of Linear Technology. "And then we go and enhance them to make them more useful to the engineering community, and we can get an advantage over the competing parts. We can charge money so it's not a free-for-all on price, and we've got better products to go out there."

The battery management system in general is probably the best example that I can think of, because these are very sophisticated systems. These days, the balancers have to interact with the battery management system. And in order to use a balancer effectively, you need to develop an algorithm that will allow you to effectively balance the charge in both discharging or charging. The demonstration capability—the reference design, if you will—is an entire system including the algorithmic smarts to know how to use this thing effectively. That kind of a system-level approach to market is relatively new for the company.

PIETKIEWICZ: That's a really interesting example because that market didn't exist 10 years ago. We used lithium-ion battery monitoring. And yet we were in a unique position because we had the data converter, the filtering, the references, the right type of logic and high voltage capability to put all those things together. But that was an example where because we had a lot of the discrete parts, we could make the

ASSP. That thing is very application-specific. So that one was a market that was right for integration and we went after it. I wouldn't say all markets are like that. Some of them remain discrete and probably will forever be discrete.

PAULUS: But markets that are like that. They want us to do the hard stuff.

SOULE: That's right.

PAULUS: So providing system-level algorithms and demonstration capabilities...

SOULE: Software, yeah.

PAULUS: That includes software and full battery emulators and so on. That's a pretty new concept that I think is going to become more and more useful.

SOULE: That's where growth is. Growth is a derivative, right? And if you look at what the business levels are in various pieces of Linear's business, that's not a huge number. It's growing. There's lots of interest. Lots of articles get written about it. But this broad industrial base, these old-line companies, is a much bigger piece of our business.

ROBERT DOBKIN: And it's still a growing piece of the business. There are only so many ASSPs that we can undertake to do where we know we're going to have a return on it. Some of these things are 15 to 30 man-years in development, for development of a product plus the software to support it plus the application support. That better have a return. And it ought to be pretty clear to us that we can have a technical advantage in the marketplace that'll make people turn to us. If we don't have an advantage in the marketplace, then it's a free-for-all on price.

So we looked at these things pretty carefully. We're a high-performance supplier, and we continue to think of new higher-performance devices that people need. And then we go and enhance them to make them more useful to the engineering community, and we can get an advantage over the competing parts. We can charge money so it's not a free-for-all on price, and we've got better products to go out there.

TUITE: So you've got the highest-performance discrete parts. But we're also talking about custom parts for battery management. And so there's a certain kind of smarts that a company has to have to do one and another kind of smarts that you have to have to do the other, because you weren't born knowing about battery management.

DOBKIN: We're not doing customs. They're ASSPs. The difference is, the customer comes to you and says, "Make this." In our case, we set up the specs, we set up the timetable, and we make the part for the market, rather than having a customer come to us.

"Our customers ask us to solve more of their problems," said Erik Soule, who oversees signal-conditioning products at Linear Technology. "And we've known for some years that a big problem is EMI. And earlier this year we brought out the kind of technology we call silent switcher, which drops the radiated EMI down by 20 or 25 dB compared to our own previous designs. And that's gotten a lot of attention because it makes our customer's life easier. He doesn't have to spend a week at the EMI lab."

PAULUS: But the application is very specific.

PIETKIEWICZ: Well, I guess you want to look for a long-term trend on who's doing the design essentially.

TUITE: That's another part of it. It's the companies that you're talking about. The old-line guys who really know what they're doing are one set of customers. There's another set of people who are popping up with maybe ideas that the CTO has had in his head for a long time, but they just never had the opportunity to get a crew together to make that into a reality. That's one class of customer. The old guys that you were talking about are another class. And I'm trying to get an idea of whether there are any other types of customers.

PIETKIEWICZ: I think the biggest trend is people [companies] that can't afford to have a bunch of analog people on staff like the big guys, outsource their work. I was just at conference where half of the potential customers had good analog guys, and the other half didn't. The ones that outsource it come to LTC and say, "Look, you guys are the experts, and you figure out what the end product is." They say, "We just want it done."

There are actually customers who would be very happy to have us do the complete design for them, which we do a lot thanks to our FAEs [field application engineers]. And there are other people who like to buy the whole thing. And that's what Eric is now doing.

When we bought Dust [Dust Networks, a maker of wireless-sensor mesh networks that complements Pietkiewicz's energy-harvesting product line], which is a mesh network hardware and software technology, it was complete. It's software; it's an algorithm; it's IP. It [Dust Networks] is an IT company. Customers expect an IT company to deliver the whole bill of goods, including the silicon.

TUITE: Some of my friends have been chip designers, circuit designers, who could make a pretty good living bouncing around from small company to small company doing that custom kind of stuff. Now they're all crying about the way the situation has developed where they can't find business. And part of that may be because the smarter ones have found their way into companies like LTC. Does that make sense?

PAULUS: On the chip design side, that's probably the case, at least in the analog business, I think.

DOBKIN: We've had a couple of chip design companies that wanted us to buy them.

PIETKIEWICZ: Definitely the long-term trend for a handful of my businesses has been that the customer is expecting the whole thing to be done. It used to be that they come in and they buy an integrated circuit from us. And now they're coming in and saying, "Solve my problem for me." And the integrated circuit, you have to have the best one to start with. That's what gives us an edge. But in order to tip the sale over in our favor, sometimes you have to provide more. I have more software guys on staff now than I ever had in the past. I have more digital guys.

So, there's a lot of digital content that we're doing. The performance that we get rewarded for is still on the analog side, but digital is required. You have to have software guys in the lab who are debugging stuff. In fact, one of the strengths of our power system management is the software that talks to this whole product portfolio that we have.

TUITE: The battery management stuff requires you to learn a great deal about battery technology. It's not somebody coming to you asking specifically for that, but you finding that market. So, give me an idea how that works.

DOBKIN: With the battery technology, we do have people coming to us. They want us to do the measurement. They want us to do some of the controls. But the big ones, they want to use their algorithm to control the battery. They don't want us controlling the battery. So they're talking to the battery manufacturer and they're finding out what the battery manufacturer wants. Then they come to us and they say, "We need to do these measurements and these controls. Will your system do it?" And it will, and it'll talk to their processor.

PIETKIEWICZ: So that was kind of an interesting scenario, the battery. We were already working with one of the large tier 1 suppliers in Japan, and they were using a lot of our discreet building blocks. (That's "tier 1" like in automotive speak.) So you have your OEM, the car companies' tier 1, which is your equivalent of the Delphi type guys, and then you have independent design houses. I usually think about it in those three tiers.

And this was like the guy in the middle who classically in the automotive world has been responsible for bringing in the next generation of ABS or fuel injection drive or whatever it is. So he was putting together a battery management system, making the switch from nickel metal hydride to lithium, and he ran into a host of problems.

And I remember one day staring at this thing and going, "Wow, there's a lot of things we could do if we roll up this all together." It was like one of those conversations: "Well, what are you really trying to do?" And the conversation gets more interesting. So that's how that went. It was because of the relationship we had.

But let me follow along with that idea, since you're asking a lot of questions about what types of customers there are and where they are. With the electrification of the car,

there are more and more subsystems that never existed even five years ago. We've seen that kind of food chain move around a little bit, and all the new technologies are not necessarily coming in through the tier 1 suppliers. For instance, a lot of them lately are becoming equivalent to the new engine of the car, so they're more strategic. Now you see this drift away from the design houses and the tier 1 suppliers to the OEMs. The car companies are basically specifying what everybody's going to have to do. So our sales team is scrambling because we're trying to figure out, "Well, whom do I talk to?"

We joke that we have to win a design contest five times because you have to win over the car company; you have to win over the tier 1; and there are two design houses competing for the business. So it's pretty dynamic, I would say, at least in the automotive environment. Who is the customer, and who actually originated the concept and is going to carry the design through to production?

PAULUS: Especially in battery management.

PIETKIEWICZ: Yeah, I'm just talking about battery management.

PAULUS: For hybrid electric and electric vehicles.

PIETKIEWICZ: Well, I think you could make the same argument around something like collision-avoidance radar. The milliwave radar is becoming much more strategic because of lane departure, automatic cruise control, and backup sensors. So, we actually saw a lot of tier 1 guys who used to specify that, and there are car companies now that are basically dictating the critical components to their tier 1 suppliers.

DOBKIN: In terms of us supplying more than the parts, we have a 20-bit analog-to-digital converter. And that requires a lot of hand-holding and a lot of development on our part because if you just put that in, you'll find out that your resistors are not 20-bit linear. And you'll find that the nano-amp of leakage you have is going to mess up your 20 bits. So getting all the bits out is going through your mind. It requires a lot of hand-holding, a lot of expertise from us, because nobody's had to go through that before, except maybe the makers of eight-digit volt meters. And it takes a lot of work on our part.

PAULUS: It's in the land of switching regulators, the venerable buck regulator, which there are just dozens or hundreds of in every car. Our customers ask us to solve more of their problems. And we've known for some years that a big problem is EMI [electromagnetic interference]. And earlier this year we brought out the kind of technology we call silent switcher, which drops the radiated EMI down by 20 or 25 dB compared to our

"Customers would love it if they could get a field application engineer in a box, that you go to the website and you type in what you want and there's some type of expert system that then gives you the bill of materials and the schematic that you just lay out," said Don Paulus, who manages power management products at Linear Technology. "It'd be even great if it does layout. The problem is that actually getting that, with all the subtleties involved, is just impossible. You'll never replace an FAE."

own previous designs. And that's gotten a lot of attention because it makes our customer's life easier. He doesn't have to spend a week at the EMI lab.

Getting type approval—which is a pretty tough thing to do if you don't do it right from the beginning—it's hard to take something that fails and turn it into something that passes. So we've developed a lot of expertise in EMI, which is RF. We've got a bunch of parts, and we want to get the most RF possible out of them, and in my switching regulators I wanted to get the least RF possible out of them. And it turns out that the techniques are very similar. You get a lot of something and you get none of something. You have to know what's going on.

DOBKIN: From a manufacturer's viewpoint, commodity managers are a real problem because we're selling more than the part. But the commodity manager just wants the cheapest price on the part. Well, on a lot of these sophisticated systems, that doesn't get your system working and running. But he's only compensated on how much money he saves. And some of the parts that we make, we've been selling for 30 years. We can't give them a 10% reduction for 30 years. It just doesn't work that way. So we are fighting a war against commodity managers who don't understand their own systems requirements and don't understand that there is more to the system than just the chip they buy.

I think one of the things you can see from any of the companies is that the analog IC is just not the chip. It's the system. Because we're getting more complex, our competitors are getting more complex. The components or the systems are getting more complex. And, people don't want to spend six months learning how to do it. They want to get their product out, so they're going to rely more on the manufacturers.

PAULUS: And as you pointed out earlier, you can't get the performance the chips will offer unless you solve the system level problem—so, hence, the burden on the component guys.

DOBKIN: So I think the market is seeing a shift to higher-performance analog requiring a lot more support.

PAULUS: You can't fiddle with it. In my opinion, customers would love it if they could get a field application engineer in a box, that you go to the website and you type in what you want and there's some type of expert system that then gives you the bill of materials (BOM) and the schematic that you just lay out. It would even be great if it does layout. The problem is that actually getting that, with all the subtleties that are involved, is just impossible. You'll never replace an FAE.

"We have one category of parts. Call them high-performance widgets," said Steve Pietkiewicz, who manages power management products at Linear Technology. "Whether it's a switching power supply or an amplifier, it tends to be a building block. In the RF world, these are mixers or modulators, the kind of fundamental squares and triangles on your schematic that have really the best features or the best combinations of specs that you can get. The guy that knows his end product can cobble those things together in unique ways that allow him to differentiate."

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Forging A Stronger Design-Supply Link

As manufacturers seek continuous improvement, distributors respond with services aimed at bridging the gap between design and production needs.

THE "CONTINUOUS IMPROVEMENT" MANTRA still echoes throughout the supply chain. As 2014 gets underway, many distributors are responding by reaching beyond their traditional customer base for growth. A pointed example is the tightening of the design and supply chain as companies seek to forge stronger relationships from the design phase on through to production. The trend is an extension of the drive for continuous process improvement in all kinds of manufacturing operations, and it highlights some of the changes taking place in manufacturing today.

"Continuous improvement is alive and well in manufacturing. For most companies, it has become a way of life," according to a recent manufacturing industry outlook survey from Minneapolis-based accounting firm Clifton-LarsonAllen. The firm interviewed executives from U.S. manufacturing and distribution organizations in late 2013 to uncover trends, issues, and challenges facing the industry as we head into 2014. Finding new ways to reduce costs and improve quality remains a top industry goal, the firm found.

"Sixty percent of respondents indicated that their continuous improvement efforts target market pressures like costs, quality, and on-time delivery; 19 percent aim to increase capacity; and just 7 percent said they are targeting inventory reduction," the survey said. Other efforts to achieve these goals include workforce training, lean manufacturing, and factory automation.

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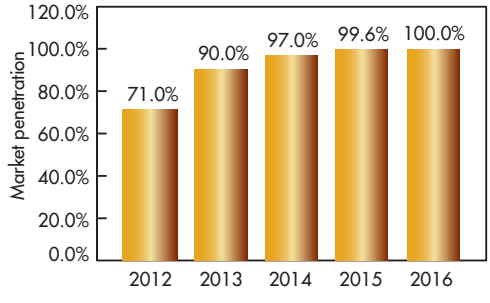
Demand For LED Technology Gains Steam

The residential market represents the next big opportunity for makers and sellers of packaged LEDs, new reports show.

WITH THE MARKET FOR LED backlighting stabilizing, sellers of LED technology are looking to new lighting markets for growth over the next few years. LED lighting in general is a bright spot on the economic horizon, but industry researchers point to the market for packaged LEDs in residential lighting as a particularly hot area over the next three years.

"Amid falling prices and rising consumer acceptance, light-emitting diode (LED) technology is taking over the lighting business, spurring a 96% increase in packaged LED revenue in the market from 2013 through 2016," according to a late 2013 report from market researcher IHS Inc. A packaged LED is an LED die that has a protective covering with contacts that allow it to be directly soldered to an electrical circuit.

IHS predicts global revenue for packaged LEDs used in lighting applications to reach



LED backlighting reached 90% of the global LCD TV market in 2013, with 100% penetration expected by 2016. *(courtesy of IHS Inc.)*

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Design Supply

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The trend is opening the door for new business to distributors that can drive such changes through supply chain management programs. For some electronics distributors, this means extending their reach to serve a wider range of customers' needs, beginning with the design phase and then moving with customers as they navigate through the production cycle.

Large distributor Digi-Key Corp. is a case in point. With more than 40 years serving design engineers and other electronic component buyers, the distributor has been investing in building its business on the production side since 2000. Vice president of supply chain solutions Steve Vecchiarelli describes the business as an important extension of Digi-Key's capabilities—and one that takes perseverance and a new mindset.

Vecchiarelli recently sat down with *Global Purchasing/Electronic Design* to discuss how design and production businesses can work together to expand distributors' business opportunities while helping manufacturing customers achieve some of the cost reduction and efficiency goals they've set in recent years. Here are some excerpts from our conversation:

GLOBAL PURCHASING: What steps did Digi-Key take to develop this hybrid distribution model, serving both design engineers and production customers?

STEVE VECCHIARELLI: Digi-Key started its production business division in the 1999-2000 timeframe. Customers elected to give us more business and they said "we like you, your pricing is better, but you know you've got to do some other things service-wise to be competitive with other companies." So, we went from the Stone Age to the Space Age in about eight months, putting the tools and systems in place that would get us into the game [of serving high-mix, low-volume production customers]. Since then we have refined things, and it's been about eight years in the actual managing of material for customers.

Now, when we go to talk to young startup companies in particular, we try to sell them on a "prototype to production" basis. We actually trademarked that phrase [in 2013]. We have what we think is a unique ability to do that—to supply products from the early design phase, and as they move through the lifecycle of an idea, we build a supply chain so that there is product at every phase of the operation.

"Now, when we go to talk to young startup companies in particular, we try to sell them on a 'prototype to production' basis," said Steve Vecchiarelli, vice president of supply chain solutions at Digi-Key. "We have what we think is a unique ability to do that—to supply products from the early design phase, and as they move through the lifecycle of an idea, we build a supply chain so that there is product at every phase of the operation."

GLOBAL PURCHASING: Does this model work better for particular customer segments?

VECCHIARELLI: It does depend on the customer type. If they are more of a contract manufacturing customer, they may not be as interested in it because they have multiple customers and they do different things for those customers. But for an OEM—and one that builds its own products—there is considerable interest. We had a customer recently in Texas who came to us [for this kind of solution]. The customer was using one contract manufacturer for its production work and a smaller contract manufacturer for prototype, with different suppliers supporting each. They wanted one supplier who could work with the engineer all the way through to the contract manufacturer.

We had another customer in California looking for the same type of thing. They were both looking for a bridge between the prototype stage and production, and they asked us to handle a set of products [to that end]. So, it all depends on the customer, but more of them are absolutely coming to [distributors that] straddle both sides of the fence.

GLOBAL PURCHASING: What are the challenges of doing business this way, particularly when it comes to meeting customers' cost reduction goals?

VECCHIARELLI: I think technology on the customer's end is certainly a challenge. A lot of customers have grand ideas but don't have the resources or technology to achieve them right away. I used to say they read the book from Toyota or Apple and they're all charged up—and they should be, because no matter what level you're at you can drive cost savings with [supply chain management programs]. But they don't realize that they buy in a year what Apple or Toyota buys in a month. That can be a frustration for them. The solution is to do a lot of discovery about their capabilities and design a program that works best for them.

GLOBAL PURCHASING: So customization is important.

VECCHIARELLI: Yes. We realize that the only thing that's the same about all of these programs is that they're different. We have to be flexible and innovative with almost every single customer we deal with, and we can do that because of the many tools we've put in place. We

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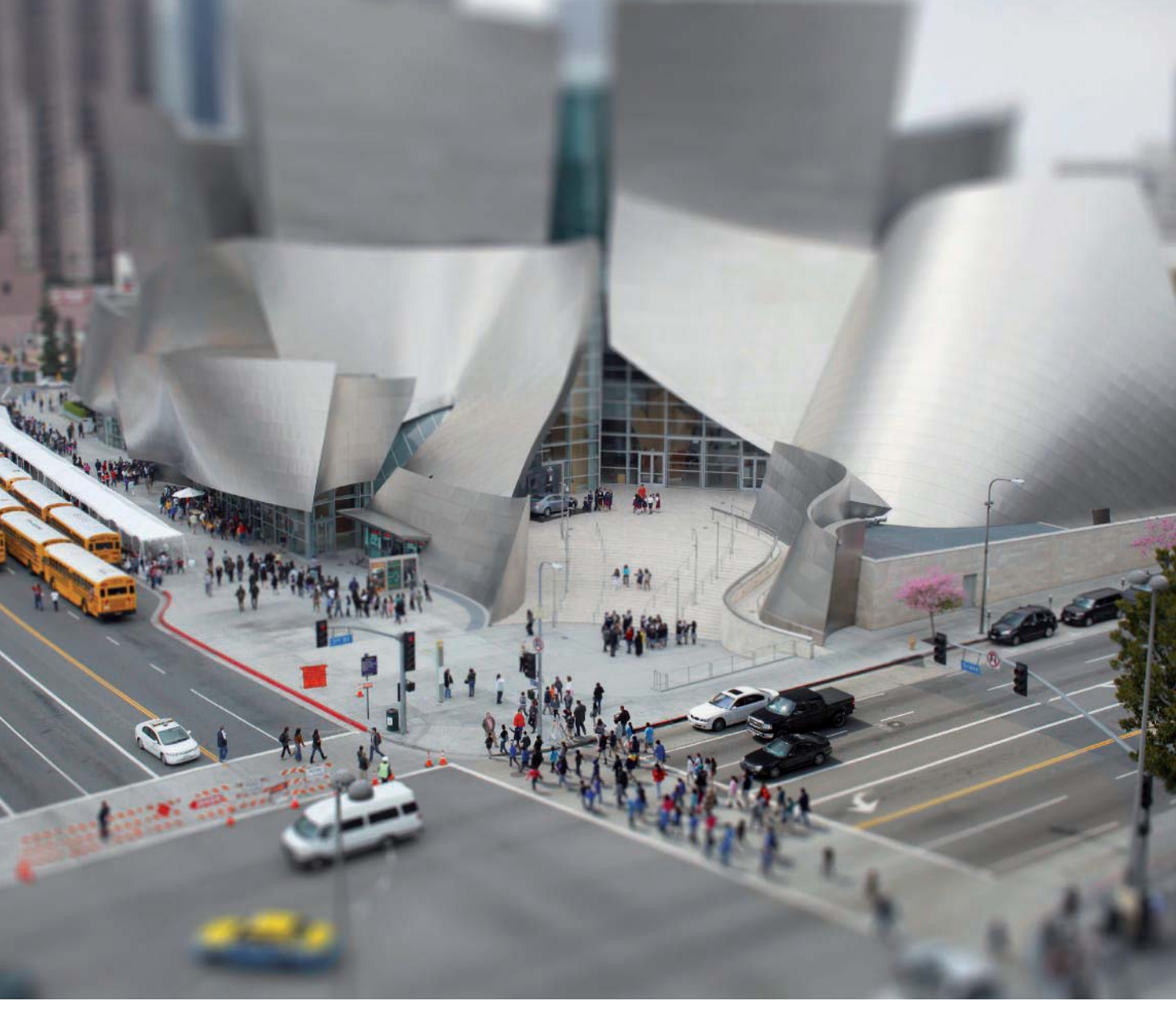

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LED Technology

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$7 billion in 2016, up from approximately $3 billion last year.

In recent years, growth in packaged LEDs was centered on the market for LCD backlighting, in applications such as mobile phones, notebook computers, and televisions. Those applications have completed their transition to LED technology for the most part, stabilizing demand and limiting growth to single-digit percentages, IHS says. In a separate 2013 report, the researcher said LED backlighting was set to reach 90% penetration in LCD TVs in 2013, for example *(see the figure)*.

Such changes open the market to more general lighting applications, which IHS predicts will "provide the next wave of explosive growth for packaged LEDs."

"In 2012, the lighting sector became the largest end application for the packaged LED market, having finally overtaken the TV backlighting market," the researcher reports. "Market saturation for LED backlighting has resulted in a number of leading suppliers shifting their focus and development resources toward the lighting industry."

COMPETITION HEATS UP

Many companies focused on LCD backlighting have already begun their shift to lighting.

"LED suppliers that are focused on lighting are predicted to gain market share," says Jamie Fox, principal analyst for LEDs at IHS. "Some of the companies that have a large market share in LED backlighting, such as Seoul Semiconductor and Samsung, have already managed to shift much of their business to lighting and have done very well in this area, winning market share in recent years."

Increased competition will result, which researchers say will drive down prices in the LED market over the next four years. IHS forecasts average selling prices for packaged LEDs in lighting to fall to $0.19 in 2018, down from $0.25 in 2016 and $0.41 in 2013, for instance.

Residential lighting applications represent the greatest growth opportunity ahead, IHS says, predicting packaged LED revenue in that sector to grow to nearly $2.7 billion in 2016, up from roughly $850 million last year. Retail and hospitality markets have led LED lighting adoption in recent years, at approximately 6% penetration. Comparatively, the residential market is at about 1% penetration—but primed for growth. Geographically, IHS says Japan saw the largest adoption of LED lamps in 2013. ■

NEWS

Manufacturers And Distributors Optimistic, Survey Shows

ACCOUNTING FIRM CLIFTONLARSONALLEN'S third annual survey of U.S. manufacturers and distributors shows that many organizations are on the road to a positive future despite the slow economic recovery. Survey results point to healthy and sustainable organizations by using what the firm calls "The Value Triangle," which focuses on four dimensions: financial, growth, execution, and leadership.

"The attitude and mindset of the leaders we surveyed focuses on capturing opportunities instead of dwelling on things that cannot be controlled," said Eric Skie, manufacturing and distribution managing principal with CliftonLarsonAllen. "The industry has moved beyond the Great Recession and is now shaping its own future."

Of the respondents, 75% were privately held and family ownership businesses, 54% had two to five owners, and 27% were one-owner organizations.

The financial dimension yielded positive responses, with 70% of respondents at or above pre-recession profitability levels. Forty percent reported that the average age of accounts has increased, while about the same number said they have stayed the same. In addition, those surveyed say that working capital requirements (including inventory) and the availability of credit have not caused problems with growth in the past two years. Sixty-three percent said they are exporting, while 27% are not and do not plan to do so in the next two years. The survey also asked about management of revenue concentrations, with most respondents having an industry concentration that accounts for more than 50% of their revenue base.

Continuous improvement is alive in manufacturing: 60% of respondents said that their improvements target pressures such as costs, quality, and on-time delivery; 19% hope to increase capacity; and 7% plan to reduce inventory. There also is a shortage of skilled workers, so most organizations are implementing workforce training, lean manufacturing, and automation. Leadership is also important, with 35% of respondents expecting an ownership transition in the next five years.

"The need for skilled workers coincides with an expansion in manufacturing, but the inability to fill skilled positions could ultimately hold manufacturers back from their full growth potential," Skie said, adding that the resiliency that has brought companies through the Great Recession shows they will move forward. ■

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Wearable Electronics Drive Consumer Market

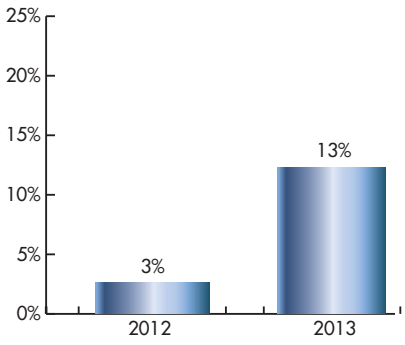
Demand for health- and fitness-related wearable devices leads the trend, as consumer interest in monitors, fitness apps, and fitness video games grows.

WEARABLE TECHNOLOGY IS all the rage in consumer electronics circles these days. This is especially true on the health-and-fitness front, as interest in purchasing wearable electronic fitness devices over the next 12 months has quadrupled in the last year, according to the Consumer Electronics Association (CEA).

In a mid-December report, the CEA said consumer interest in purchasing dedicated wearable fitness devices in the next 12 months grew to 13% in 2013, up from just 3% in 2012. This is the largest year-over-year increase for any category of fitness device, the group said in its new study *Understanding the Market for Wearable Health and Fitness Devices*. What's more, ownership of dedicated wearable fitness devices tripled in 2013, reaching 9% compared to 3% in 2012.

"CEA projects that the market for dedicated wearable fitness devices like body monitors and pedometers will continue to expand for the foreseeable future as more consumers become aware of these devices and an array of new products enters the market," Kevin Tillmann, senior research analyst for CEA, said in announcing the study's findings in December.

Consumers list motivation and the ability to monitor both fitness goals and their physical activity levels or intensity as key reasons for driving their interest in wearable fitness devices. Seventy-five percent of U.S. consumers say they own a fitness technology product, up from 61% in 2012. Pedometers are the most popular product, followed by fitness video games and portable blood-pressure monitors. Looking ahead, CEA says dedicated wearable fitness devices, fitness apps, fitness video games, and calorie trackers will be most in demand.



Consumer interest in purchasing a dedicated wearable fitness device over the next 12 months increased from 3% in 2012 to 13% in 2013. *(courtesy of the Consumer Electronics Association)*

And as demand grows, sales of fitness and activity-tracking devices are expected to exceed $1 billion this year—a nearly 40% increase over 2013.

"Fitness technology owners indicate they are seeing personal progress in their overall health and/or on specific goals, such as losing weight or lowering blood pressure, using their devices as much or even more than they originally expected," Tillmann says. "Not only are these fitness technology products catching on in the marketplace and experiencing strong growth in sales, consumers indicate they are experiencing positive results as well."

Gartner Research predicts similar growth in wearable fitness devices over the next few years. Worldwide revenue from wearable electronic devices, apps, and services for fitness and personal health was expected to reach $1.6 billion in 2013 on the way to $5 billion by 2016, according to Gartner's research director Angela McIntyre. In a December outlook on wearable technology, McIntyre predicted ongoing strength in the wearable electronics market for fitness and health, noting that it's part of a larger social trend.

"Wearables support the 'quantified self' trend of people tracking their vital signs, activities, and capturing images of what they experience during the day," McIntyre explains. "The fun of wearing and using gadgets to track fitness and health is appealing, and so is using their apps and services. Gamification enables wearers to compete against themselves or others and rewards wearers. Online communities provide camaraderie with those having similar goals. Wearable electronics provide new motivation to consumers for improving fitness and health." ■

Design Supply

Continued from Page 40

mix and match to whatever the situation is, and it's PFEP—plan for every part. We take a look at how many times they use it, what's the best way to manage it, how much they use.

GLOBAL PURCHASING: Where do you see this trend headed?

VECCHIARELLI: Something that we've seen for the last [several years] is that customers are looking for better, cheaper, faster. Fortunately, with today's technology, I think we're there. So, I think the better, cheaper, faster demand will be around for a long time. In terms of services, it's all about "what are you doing for me now?" That's what customers are asking. As a result, none of us can afford to sit on our hands. [In response], we're adding resources internationally on the production side—in-country resources covering all of Europe and Asia, all focused on the production business side of the company. ■

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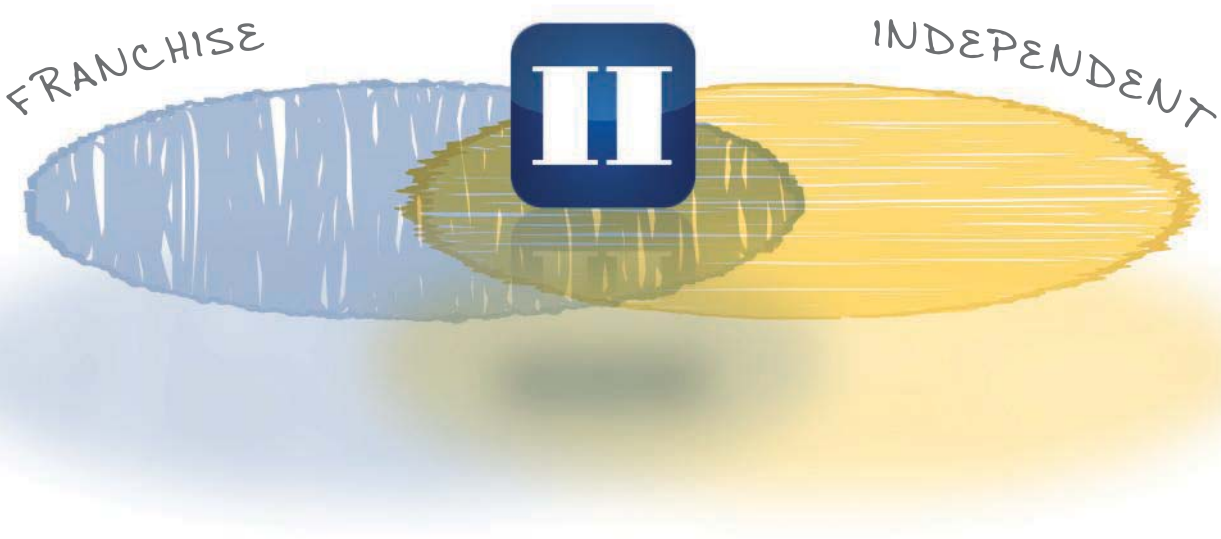

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Everyone Must Enlist In The Fight Against Counterfeiting

Most buyers think they can tell the difference between a counterfeit and an authentic product, but they can't.

By TOM GRACE, EATON, TomAGrace@eaton.com

COUNTERFEIT ELECTRICAL AND ELECTRONIC components continue to have real implications on our economy, our jobs, and even our health and safety.[1] These unsafe lookalikes exist for almost every product that is profitable, from components to mission-critical equipment.

For example, counterfeit circuit breakers can result in product malfunctions or failures, causing serious bodily injury including electric shock, electrocution, and even death. They also are capable of significant property damage, as they are designed to provide circuit protection for power distribution systems and to safeguard people and equipment.

A breaker failure means the loss of production, possible equipment damage necessitating costly system analysis and replacement, and the increased risk of worker injury at the time of failure or during maintenance. The financial liability of such an incident will fall on those who participated in the supply and distribution of the counterfeit products.

Despite recognizing the dangers of counterfeit electrical products and committing to avoid them, most purchasers do not realize the sophistication of modern counterfeiting techniques and think they can tell the difference between a counterfeit and an authentic product.

As part of its efforts to bring this serious issue to light, Eaton has worked over the past few years to present hundreds of professionals with two circuit breakers—one counterfeit and one authentic. After professionals take a few minutes to inspect the breakers, they come to the common realization that they never would have thought it was counterfeit *(see the figure)*.

This issue is compounded by the production, sales, and importation of counterfeit electrical goods, which is soaring at an alarming rate. According to the Department of Homeland Security, more than 3400 seizures of "Consumer Safety and Critical Technology" products accounted for a street value of more than $146 million in 2012, which is a 143% increase from 2011.

By looking at the two circuit breakers above, would you know the one on the left is counterfeit?

HOW TO WIN THE BATTLE

Stopping the sale of counterfeit products is everyone's responsibility. This includes manufacturers, distributors, resellers (authorized and unauthorized), governments, and customers alike.

Supply chain managers hold an important role in combating counterfeiting. By educating buyers and managers on how to identify a counterfeit electrical product and avoid purchasing it, they raise awareness of the issue and help ensure the purchase of authentic parts, preventing counterfeits from entering the supply chain and decreasing the demand for such products. Fortunately, companies can use three easy strategies to identify and avoid counterfeit electrical products:

- First, buy authentic. The best way to avoid counterfeit electrical products is to purchase products from the manufacturer's authorized distributors or resellers. There is a higher risk of counterfeits if one cannot trace the path of commerce to the original manufacturer.
- Second, scrutinize labels and packaging. When purchasing a product, check for certification marks from organizations that certify the quality and performance of electrical products. Be leery of additional markings or labeling not applied by the original manufacturer. As counterfeiters become more sophisticated, counterfeit products become even more difficult to detect this way, creating an increasing need for additional scrutiny.

  Some testing organizations have online product registries that enable you to look up a particular product or control number to verify the certification. For example, Eaton's Circuit Breaker Authentication tool *(www.eaton.com/counterfeit)* enables customers to detect if Eaton circuit breakers are counterfeit. Once the bar code, part number, and date code found on the circuit breaker are entered, the authentication tool can immediately verify authentication.
- And third, avoid "bargains." When shopping for products, don't be tempted by incredible deals. Compare the price of that product to a similar product at a different retailer. If it seems too good to be true, the odds are it is. ■

REFERENCE

"Counterfeit Electronic Components Survey," Global Purchasing, http://globalpurchasing.com/counterfeit/counterfeit-electronic-components-survey

TOM GRACE is brand protection manager for Eaton's Electrical Sector Americas.

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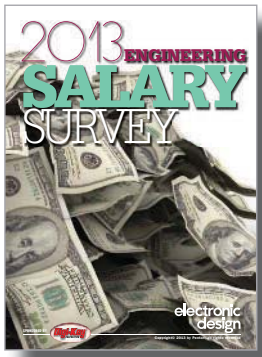

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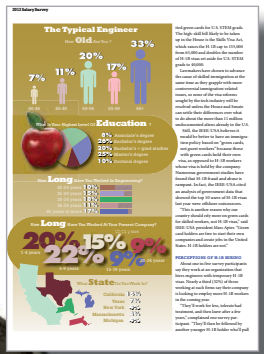

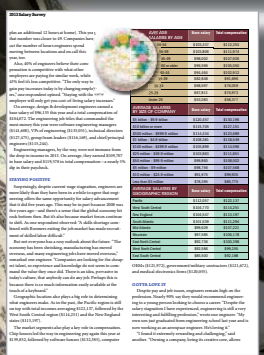

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Safe and Accurate Isolated Current Sensing in Motor Control using Optically Isolated Sigma-Delta Modulators

Introduction

In Industrial motor or servo control applications, accurate current measurement is a critical as part of the control loop. Not only has the current measurement need to be as accurate as possible, it also needs to be safe and reliable. Industrial Motor or servo control systems usually contains high voltages and in fault events like over-current or short circuits, these conditions need to be detected and rectified quickly to prevent catastrophic systems failures or in the worst case, human injury. Not only does optocouplers help to provide isolation in breaking ground loops, rejecting common mode noise and transients, it provide the necessary insulation to meet the required safety standards and regulatory requirements.

Optically Isolated Modulator Architecture

The inputs of an isolated modulator used in current measurements are usually connected to a small shunt resistor, which converts the current passing through it to a small voltage, usually about ±200mV, so as to limit the power dissipation in the shunt resistor. The sigma delta modulator then oversamples the analog input signal into a single high speed bitstream before transmission across the optical isolation barrier. The modulator data received on the isolated side is then sent to a processor for further processing. A Sinc3 decimation filter can then be easily implemented on an FPGA or microprocessor to recover the desired signal. The decimation filter averages or decimates the high speed oversampled bitstream to a lower rate by a factor, commonly known as as decimation ratio. Figure 1 shows the block diagram of an isolated sigma delta acquisition system.

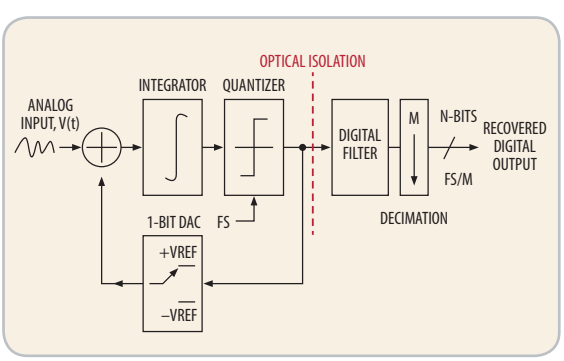

Figure 1. Optically Isolated Sigma Delta Modulator block diagram

There are a couple of advantages with such approach. Firstly, an isolation barrier can be easily placed on a single channel immediately after the modulator output. Secondly, any errors in the received bitstream that could be caused by common mode transients would have been averaged out by the decimation filter. The result is a very robust isolation scheme which provides good common mode rejection between primary and secondary or transient immunity in highly noisy environments like motor control. Being optical in nature, the device is also immune to magnetic interference unlike conventional Hall Effect sensors. Figure 2 shows a block diagram of the new Avago ACPL-798J externally clocked optically isolated Sigma-Delta Modulator with LVDS interface. The LVDS interface furthers improves the connection between the sensor and the processor as compared to the usual single ended LVTTL interface, allowing system designers to have a robust interface. The ACPL-798J also offers good gain accuracy of ±1% and 75dB of Signal to noise ratio equivalent to 12bits effective number of bits (ENOB).

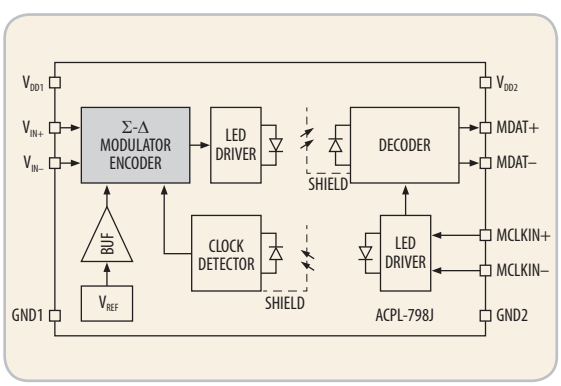

Figure 2. ACPL-798J block Diagram

Types of Optically Isolated Modulators

There are 2 types of optically isolated sigma delta modulators, internally clocked and externally clocked. An externally clocked type has certain advantages over internally clocked type. For example, externally clocked type typically has a higher clock speed. Externally clocked type also allows having a common master clock for easier data recovery and channel to channel synchronization, for example simultaneous measurements of phase currents.

Table 1. Decimation ratio vs. filter delay time illustration & ENOB

Decimation Ratio (R)	Fs = 20MHz			Fs = 10MHz		
	Throughput Rate (Fs/R) KHz	Effective Number of Bits (ENOB)	Filter Delay (µs)	Throughput Rate (Fs/R) KHz	Effective Number of Bits (ENOB)	Filter Delay (µs)
256	78.1	12	12.8	39.1	12	25.6
128	156.2	11	6.4	78.1	11	12.8
64	312.5	11	3.2	156.2	11	6.4
32	625	10	1.6	312.5	10	3.2

Speed and Precision

In motor or servo control, the motor loads being driven are inductive loads. From the inductor impedance equation below, one can deduce that voltage is dependent on the rate of change of the current flowing through the inductor.

$$V_L(t) = L\frac{di_L(t)}{dt}$$

Thus, fault conditions like phase to phase shorts or ground shorts need to be detected and rectified as quickly as possible before dangerous voltage levels develop on the motor which could lead to catastrophic failures as well as human injury. Typical reaction time required for the motor controller to react to such fault is usually less than 10µs. One common approach is to have separate filters with decimation ratios running in parallel (figure 3).

A filter can be configured with a smaller decimation ratio to provide the fast response required to track and react to fault conditions while having another filter in parallel with higher decimation ratio for better resolution during the normal control loop operation. By partitioning a system in such a way, it is possible to sense and react quickly to rectify any fault conditions. Table1 shows the tradeoff between resolution and speed by selecting the appropriate decimation ratio.

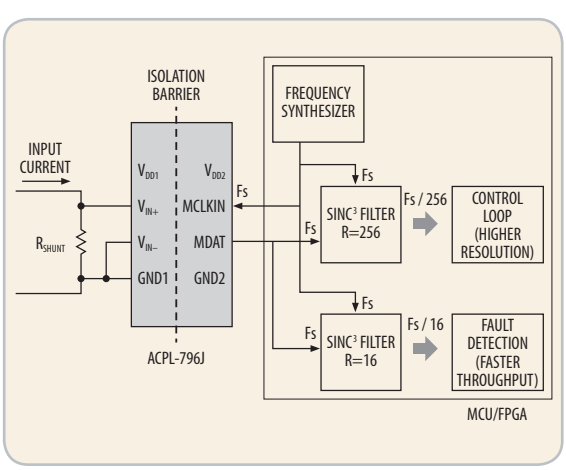

Figure 3: Decimation filters partitioning

Field Safety and Reliability

Avago optocouplers are certified to the IEC safety standard IEC60747-5-5 for Reinforced Insulation. This is a component safety standard designed to test the isolation construction, insulation material, aging mechanism of optocouplers and is applicable to only optocouplers and is not applicable to alternative isolators.

As a compromise, some test houses offer certified compliance for alternative isolators to the optocoupler standard DIN/EN 60747-5-2 but have only issued certification of BASIC insulation, which implies a partial compliance but not a full certification. That is because the quality and characteristics of such thin-film polyimide and CMOS insulation with respect to safe insulation application is not well understood yet.

Avago has been manufacturing and supplying in high volumes optically isolated modulators and isolation amplifiers to many motor control customers for over close to 2 decades. This track record is testament to the safety and reliability that optical isolation provides.

Summary

Current measurement using Optical isolated sigma delta modulators offers the flexibility to configure itself between precision and speed by choosing the appropriate filtering schemes. Only optocouplers are certified to the IEC Safety Standard IEC60747-5-5 for reinforced insulation. Avago optically isolated modulators provide a field proven method to measuring current in an accurate, safe and reliable way.

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TONY LEFEBVRE | TE Connectivity
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Understanding Distributed Antenna Systems

This measure of modulation quality may be a better predictor of wireless reliability than BER.

As cellular service providers seek to support more subscribers using data-intensive applications like video, small-cell networks are becoming essential for providing the requisite coverage and capacity. As part of their outdoor network plans, service providers are looking at distributed antenna systems (DASs) to create the small cells they need.

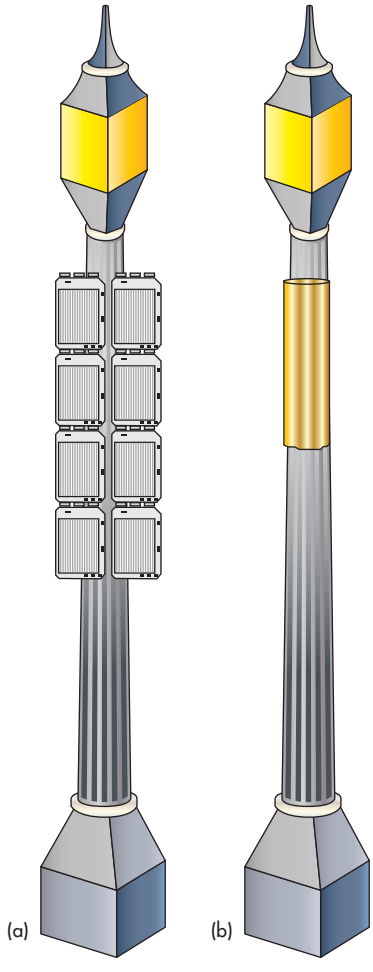
DAS technology has been around for more than 20 years. But now, the need to do more with fewer assets is driving innovation in DASs and optical networks. DAS solutions not only address the need for small-cell delivery, they also address efficient small-cell backhaul. Mobile operators are anxious to implement the latest DAS and fiber technologies to create leaner, more cost-effective deployments.

WHAT'S A DAS?

A DAS is a system of managed hubs and remote antennas that distributes a wireless signal to a series of connected indoor or outdoor multi-band, multi-technology radio heads. At the head-end of the DAS, service providers typically locate basestations to provide the cellular signal. A main hub takes that signal, digitizes it, and distributes it to other hubs and radio heads via a high-bandwidth fiber optic network. At the antenna, the radio converts the signals from digital to RF and RF to digital.

By digitizing the signal on the fiber, the DAS can transport the mobile signal at full strength to any remote antenna connected, no matter how far away it is from the main hub and basestation. This is in contrast to older, analog systems that transported RF signals over coaxial cabling and whose performance diminished in proportion to the distance of the remote antenna from the main hub.

DASs are used in urban canyons, suburbs, airports, stadiums, office buildings, and other venues where service providers need to enhance their coverage or network capacity. By focusing a basestation's signal on a specific area through remote antennas, the DAS delivers higher capacity and consistent coverage over the area it serves. Some DAS projects extend for miles and support thousands of subscribers. And to keep the mobile network out-of-sight,



1. DAS remote antennas can be deployed on light poles, streamlining and minimizing the infrastructure compared to distributed radio units with antennas. They can be visible (a) or integrated into the pole (b).

DAS remote antennas can be housed on lampposts, telephone poles, street cabinets, or other street furniture (*Fig. 1*).

DASs often are evaluated against other small-cell technologies such as picocells and microcells that providers seek to address a coverage or capacity problem. But picocells and microcells, while cheap and easy to install, typically support only one service provider's frequency band, so they offer low capacity. In addition, a picocell supports only a couple of dozen simultaneous subscribers, so it serves a relatively small area and limited capacity. Finally, each picocell or microcell requires its own backhaul connection to the network, which multiplies costs. In an area where subscribers demand coverage for all major service providers, a DAS can support multiple frequency bands and service provider services with a single set of antennas and a single backhaul connection.

SOLUTIONS FOR FIBER EFFICIENCY

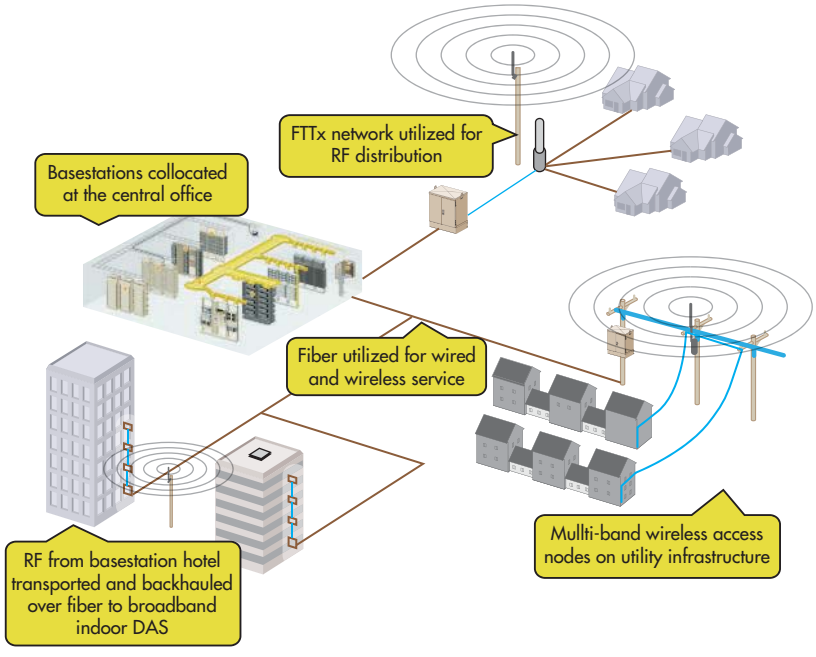
One of the key challenges in rolling out small-cell architecture is accessing the necessary fiber to make the backhaul connections. Potentially, a service provider would have to build a whole new fiber network to support a DAS or small-cell deployment. But there are several ways in which a DAS makes more efficient use of fiber than picocells or microcells.

First, the DAS requires only one backhaul connection for the entire DAS network. In contrast, each picocell or microcell requires its own backhaul connection. In the case of DAS, the fiber backhaul connection can serve thousands of subscribers, while a picocell or metrocell's fiber connection would serve only a relative handful of subscribers.

Second, the DAS provides a built-in aggregation point in the network. A modern DAS can do 8:1 aggregation out of the main hub, aggregating up to eight different frequency bands over a single fiber pair. In contrast, a service provider would have to deploy separate picocells or microcells to support each frequency band.

Several other fiber-saving technologies can be used as well. For example, DAS head-ends can aggregate the capacity from two or more basestations so the mobile operator can increase capacity by simply adding another basestation (no additional head-ends, antennas, or radio heads are required). In addition, advanced fiber solutions offer optional fiber-saving technologies:

- **ALL-DIGITAL TRANSPORT:** Digital DAS solutions transport RF signals in digital format from the head-end to the radio head or remote antenna unit. This means the signal does not attenuate between the head-end and antenna, and the head-end can simulcast the digital signal to all of the remote antennas in the system.
- **CAPACITY AGGREGATION:** Modern DAS solutions can simulcast the capacity from the connected basestation(s) to all of the remote antennas or radio heads in the system. Capacity aggregation saves on basestations and head-end units and simplifies network design and management.
- **FIBER-SAVING TECHNOLOGIES:** Several fiber-saving technologies can be used to minimize the amount of fiber that needs to be pulled and spliced. The first option is to use coarse wave division multiplexing (CWDM) or dense wave division multiplexing (DWDM) to expand the data-carrying capacity of individual fibers and fiber pairs by multiplexing eight (CWDM) or 80 (DWDM) wavelengths on a single fiber.



2. DAS networks can be overlaid on FTTx infrastructures by using the existing fiber infrastructure to widen the DAS coverage.

Another emerging option is cost-effective 10-Gbit/s transport solutions that slash the amount of fiber needed in a DAS network. A 10-Gbit/s transport can support up to 225 MHz of spectrum over a single fiber pair, which is more than three times the capacity of many baseband transport alternatives. This coupled with CWDM or DWDM offers significant capacity delivery over a single fiber.

A DAS is an efficient means for distributing RF spectrum from a common

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RF source, where the base transceiver station (BTS) signals are connected to a host, which then distributes the BTS's signal to multiple remote antenna locations via a fiber network.

DAS AND FTTX

To avoid having to build out a whole new fiber network for a DAS, service providers can partner with wireline carriers to piggyback DAS traffic on an existing fiber-to-the-x (FTTx) installation. Wireline carriers can participate in this model most easily by offering "a la carte" services to the wireless service provider that provide access to fiber, offer optical efficiencies, or provide leased physical space for the network infrastructure and gear.

DASs overlay nicely onto FTTx networks *(Fig. 2)*. The fiber in an FTTx network typically originates in a serving office with great access to necessary facilities to host or "hotel" BTS resources. Access to electrical, backhaul, HVAC, and, importantly, fiber to the remote nodes creates an environment where the wireline operator can lease space, eliminating the need for the wireless operator to develop a new site to locate the BTS resources. The wireline operator then has the fiber from this serving office running deep into the network serving its FTTx investment.

By either utilizing spare dark fibers or offering wavelength services from the FTTx plant, the wireline carrier can recognize recurring revenues leasing these fibers to the wireless operators for their use to distribute the BTS capacity to remote DAS nodes. In this scenario the wireline carrier has the opportunity to further monetize its investment while the wireless operator has a cost-effective and time-to-market efficient solution to deliver wireless services.

To overlay a DAS on an FTTx network, the wireline carrier can:

- Monetize spare or dark fibers that may be available as reserved for spares or expansion of the wireline network
- Use optical splitters that link the wireless signal from the basestation to the FTTx network for distribution to the remote units
- Offer wavelength services where dark fibers are not available
- Use a CWDM or DWDM to split out wavelengths for use in the DAS, minimizing fiber usage
- Speed time-to-market by using existing fiber assets to take advantage of zoning approvals already completed
- Utilize space within a central office, basement, enclosure, or hut to house wireless carrier basestations that will provide the signals for the DAS
- Utilize common backhaul, power, and HVAC to minimize cost and environmental impact
- Minimize time-to-service with easy-to-zone, non-aesthetically disruptive solutions overlaid on the existing infrastructure and real estate

CPRI AND DAS

Another of the enduring challenges in matching up a DAS with a mobile basestation has been the need to use RF as the method of interface, which adds complexity and cost to the deployment. But to date, DAS equipment has not been able to use the Common Public Radio Interface (CPRI), which has been defined for basestations. Now, DAS equipment that does use CPRI is emerging, solving several key problems.

CPRI defines the publicly available specification for the key internal interface of radio basestations between the radio equipment control (REC or basestation) and the radio equipment (RE, or radio head). The companies cooperating to define the CPRI specification now include Ericsson, Huawei, NEC, Nokia Siemens Networks, and Alcatel-Lucent. The CPRI specification has gone through several revisions, and today it is at version 5.0.

The idea behind CPRI was to create an open standard for interfacing basestations with radio heads. But in reality, CPRI is neither common nor public, as it is not truly an open standard. Instead, similar to what happened with the Integrated Services Digital Network (ISDN) for public branch exchanges (PBXs), each manufacturer developed its own flavor of CPRI that works only when interfacing its own basestations with its own radio heads.

Since the major basestation manufacturers don't make DAS equipment, DAS systems that have been supplied by third-party OEMs until now haven't been able to interface the DAS head-end equipment directly in the digital domain with basestations through CPRI because each BTS manufacturer's CPRI interface is unique.

Instead, the DAS head-end interfaces with basestations through the RF signal. This has been true since the inception of DAS more than 20 years ago. However, there is a significant power mismatch between basestations and DAS head-ends that must be accommodated for this interface to work. A typical basestation puts out about 40 W, and a DAS head-end takes in roughly 0.25 W. Feeding 40 W into a DAS will destroy the head-end. As a result, the basestation's power must be severely reduced before it can interface with the DAS.

There are several challenges with reducing basestation power output:

- **COMPLEXITY:** Basestation power is reduced with racks of passive equipment called attenuators. All of this external "plumbing" between the basestation (which can also include splitters, combiners, circulators, etc.) and the DAS adds to the size, complexity, and cost of the deployment.
- **SPACE:** Racks of attenuators take up floor space, making a DAS deployment much larger than it needs to be. In many cases, there may not be enough floor space at the intended facility to accommodate the entire deployment, so a separate,

off-site facility must be built. This added expense can be a deal-killer for many mobile operators.

- **HEAT:** RF attenuators generate a large amount of heat, making it necessary to spend more on air conditioning in DAS deployment areas.
- **COST:** The need for attenuators (and the rest of the aforementioned plumbing) and the need to invest manpower resources in designing and deploying all this RF plumbing adds capital and operating expenditures to the overall deployment, worsening the DAS business case for mobile operators.
- **INEFFICIENCY:** Mobile operators invest in large, hot, power-hungry amplifiers for their basestations, only to have their power substantially reduced in the actual deployment. Amplifiers are one of the biggest cost drivers in a basestation.

Interfacing directly with a basestation via CPRI instead of RF eliminates the need for all this plumbing, saving space, power, and cooling costs in the DAS deployment. All of these elements are critical when evaluating the practical and financial viability of DAS deployment. DAS manufacturers' ability to use CPRI interfaces versus traditional RF will greatly improve deployment time and the business cases for mobile operators, increasing DAS's market reach. Obviously, this will require direct cooperation from the basestation manufacturers, as custom CPRI interfaces will need to be developed to work with each major basestation manufacturer.

As we have seen, there are many advantages to be gained by deploying DAS with fiber networks. As mobile operators seek to provide robust and reliable services to their subscribers, DAS and fiber will play key roles in service rollouts. ed

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DesignSolution

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Design Wideband RF Front Ends For GSPS Converters

Passive front ends are best for ADCs operating at gigasamples per second in today's industrial applications.

As high-speed analog-to-digital converter (ADC) technology improves, so does the need to resolve very high intermediate frequencies (IFs) accurately at high speeds. This poses two challenges: the converter design itself and the front-end design that couples the signal content to the converter. Even if the converter's performance itself is excellent, the front end must be able to preserve the signal quality too.

High-frequency, high-speed converter designs exist in many applications today, with radar, wireless infrastructure, and instrumentation pushing these boundaries. These applications demand the use of high-speed gigasample-per-second (GSPS) converters with resolutions of 8 to 14 bits. But remember, many parameters must be met to satisfy the "match" for your particular application.

LAYING THE FOUNDATION

It is natural to gravitate to GSPS converters for applications such as radar, instrumentation, and communication observation because they offer a wider frequency spectrum or Nyquist band. Wideband, as defined here, is the use of signal bandwidths greater than 100 MHz and ranging into the +1- to 4-GHz frequencies. However, a wider frequency spectrum poses even more challenges on the front-end design.

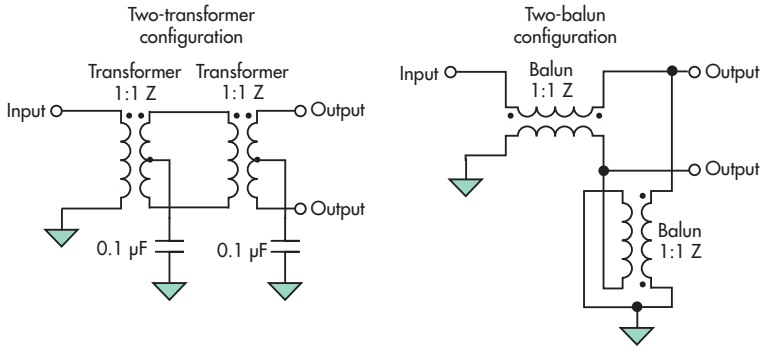
You can purchase a converter with a +1-GHz Nyquist, but you still have to wrap the right components around it and pay closer attention to the circuit's construction, i.e., its front end. Challenges escalate when the application calls for +1-GHz super-Nyquist sampling, where spectral information must be captured in the second, third, or fourth Nyquist zone.

QUICK NOTE ON BANDWIDTH

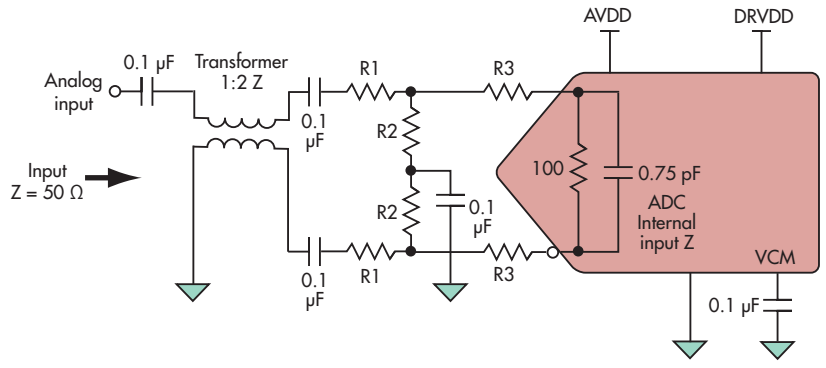
A converter's full-power bandwidth is different from converter "usable or sample" bandwidth. The converter needs full-power bandwidth to acquire signals accurately and for the internal front end to settle properly. Selecting an IF and using the converter out in this region is not a good idea since performance results will widely vary in the system.

Based on the rated resolution and performance stated in the converter's datasheet, the full-power bandwidth is much bigger than the sample bandwidth of the converter itself and possibly twice as big. The design is centered around the sample bandwidth. All designs should avoid using some or all of the highest-frequency portions of the rated full-power bandwidth or risk a de-rating in dynamic performance (SNR/SFDR).

To determine the sample bandwidth of the high-speed ADC, consult the datasheet or application support, since sometimes it isn't specially given. Typically, the datasheet has specified or even listed production-tested frequencies that guarantee delivered performance within the converter's sample bandwidth. However, better explanations about these bandwidth terms in the industry need to be specified and defined.



1. Double balun/transformer topologies can mitigate second harmonic problems related to phase imbalance issues.



2. Front-end networks can be optimized for bandwidth.

BALUN CHARACTERISTICS & IMBALANCE

Once the application bandwidth and high-speed ADC are known, choose the front-end topology: amplifier (active) or transformer (passive). The tradeoffs between the two are long and depend on the application.[2] This article will concentrate on transformer/balun coupled front-end designs.

The term "balun" will be used in the context that is referring to a transformer or balun. Even though there are differences between the two in their construction and topology, the assumption is that a passive device is used to couple and build the front end, which converts the incoming IF of interest from a single-ended signal to a differential one.

Baluns have different characteristics than amplifiers and should be considered when choosing the device. Voltage gain, impedance ratio, bandwidth and insertion loss, magnitude and phase imbalance, and return loss are some of these different characteristics. Other requirements may include power rating, type of configuration (such as balun or transformer), and center tap options.

Designing with baluns is not always straightforward. For example, balun characteristics change over frequency, complicating expectations. Some baluns are sensitive to grounding, layout, and center tap coupling.

It is wise not to fully expect the datasheet of the balun to be the sole basis for choosing it. Experience can play a huge role here as the balun takes on a new form when printed-circuit board (PCB) parasitics, external matching networks, and the converter's internal sample and hold circuit (i.e., load)[3] also become part of the equation.

Signal gain is ideally equal to the transformer's turns ratio. Although voltage gains found within a balun are inherently noise-free, utilizing a balun with voltage gain does gain the signal noise. There can be a significant tradeoff in bandwidth as well. Designers, then, should view a balun simplistically as a wideband passband filter with nominal gain. Therefore, the typical trend is the more signal gain in the balun, the less bandwidth.

Voltage gains with baluns can be highly variable, allowing for more significant ripple and roll-off to be obtained when it isn't wanted. Finding a 1:4 impedance ratio transformer with good gigahertz performance is difficult today. In summary, be wary. Plans to use 1:4, 1:8, and 1:16 impedance ratio baluns to improve or optimize the noise figure within the final signal chain stage should be well thought out and verified in the lab. Since bandwidth options become limited, as well as performance, the tradeoffs are significant, forcing the performance to be no better than a 1:1 or 1:2 impedance ratio design when designing in gigahertz regions.

The balun's insertion loss is simply the loss over the specified frequency range and is the most common measurement specification found in any balun datasheet. This will change when implemented in the circuit. Typically you can expect half the frequency range specified in the datasheet. (Yes, that's right, half.) Some are worse, depending on the balun's topology and sensitivity to load parasitics, such as capacitance.

This is probably the most misunderstood parameter about baluns since they are optimized without load parasitics in an ideal impedance situation. In other words, they are characterized with a network analyzer.

Return loss is the balun's mismatch of the effective impedance of the secondary's termination as seen by the primary. For example, if the square of the ratio of secondary to primary turns is 4:1, one would expect a 50-Ω impedance to be reflected onto the primary when the secondary is terminated with 200 Ω. However, this relationship is not exact.[4]

To determine the reflected impedance on the primary changes with frequency, find the return loss at the center frequency specified for the design. This example uses 110 MHz. Zo is found not to be 50 Ω as assumed for an ideal transformer. It is lower, as found in Equation 3:

$$\text{Return loss (RL)} = -18.9 \text{ dB at 110 MHz} = 20*\log[(50 - Zo)/(50 + Zo)] \quad (1)$$

$$10\text{^}(-18.9/20) = (50 - Zo)/(50 + Zo) \quad (2)$$

$$Zo = 39.8\ \Omega \quad (3)$$

Next, ratio the primary Zo found in Equation 3 and secondary ideal impedance. Do the same for the primary ideal and solve for the real secondary impedance:

$$Z(\text{prim reflected})/Z(\text{sec Ideal}) = Z(\text{prim Ideal})/Z(\text{sec reflected}) \quad (4)$$

$$39.8/200 = 50/X \quad (5)$$

Solving for X:

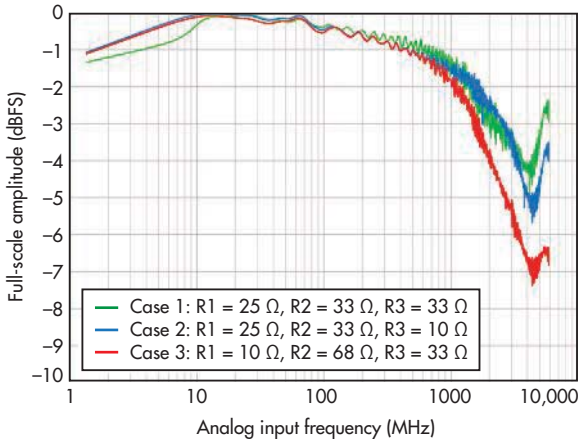
$$X = 251\ \Omega \quad (6)$$

This example proves a 251-Ω differential termination should be present on the secondary to reflect a 50-Ω load on the primary. Otherwise, the preceding stage in the signal chain ends up driving a heavier load (~40 Ω). This leads to more gain in the preceding stage.

More gain and misrepresented load conditions then lead to more distortion that the high-speed converter will "see," limiting the system's dynamic range. In general, as the impedance ratio goes up, so does the variability of the return loss. Keep this in mind when you're designing a "matched" front end with a balun.

Magnitude and phase imbalance are the most critical performance characteristics when considering a balun. These parameters provide a good measure of how each single-ended signal is off from the ideal: equal in magnitude and 180° out of phase. These two specifications give the designer a perspective on how much signal linearity is being delivered to the converter when a design calls for high (+1000 MHz) IF frequencies. In general, the more they deviate, the worse the degradation in performance can be expected.

Stick to those transformers or baluns that publish this information in the datasheet as a start. If the information is not present in the datasheet, it may not be a good choice for this high-frequency application. As frequency increases, the nonlinearities of the balun also increases, usually dominated by phase imbalance, which translates to worse even-order distortions (mainly second harmonic or H2) as seen by the high-speed converter. Even three degrees of phase imbalance can significantly degrade performance in spurious-free dynamic range (SFDR). Don't be quick to blame the converter. Look at the front-end design first if the expected datasheet spurious is way off, especially H2.



3. This plot of bandwidth matching shows the differences obtained with different front-end network values.

There are some solutions, though, to combat against second harmonic distortions. When using a balun at higher frequencies, try using multiple transformers or baluns in a cascaded fashion. Two or sometimes three baluns can be used to help convert the single-ended signal to differential adequately across high frequencies *(Fig. 1)*. The downside is space, cost, and insertion loss.[5]

The other suggestion is to try different baluns. Better single-solution baluns are out there from Anaren, Hyperlabs, Marki Microwave, Minicircuits, and Picosecond, to name a few. Their patented designs use special topologies allowing for extended bandwidth in the gigahertz region, providing a high level of balance that only employs a single device. In some cases, they're smaller than the standard ferrite footprints commonly used today.

Not all baluns are specified the same way by all manufacturers, and baluns with apparently similar specifications may perform differently in the same situation. The best way to select a balun for the design is to collect and understand the specs of all of the baluns being considered and request any key data items not stated on the manufacturer's datasheets. Alternatively, or in addition, it may be useful to measure their perfor-

MEASURED PERFORMANCE MATCHING VERSUS THREE FRONT-END CASE DESIGNS

Performance specs	Case 1: R1 = 25 Ω, R2 = 33 Ω, R3 = 33 Ω	Case 2: R1 = 25 Ω, R2 = 33 Ω, R3 = 10 Ω	Case 3: R1 = 10 Ω, R2 = 68 Ω, R3 = 33 Ω
Bandwidth (–3 dB)	3169 MHz	3169 MHz	1996 MHz
Pass-band flatness (2-GHz ripple)	2.34 dB	2.01 dB	3.07 dB
SNRFS at 1000 MHz	58.3 dBFS	58.0 dBFS	58.2 dBFS
SFDR at 1000 MHz	74.5 dBc	74.0 dBc	77.5 dBc
H2/H3 at 1000 MHz	–74.5 dBc/–83.1 dBc	–77.0 dBc/–74.0 dBc	–77.5 dBc/–85.6 dBc
Input impedance at 500 MHz	46 Ω	45.5 Ω	44.4 Ω
Input drive at 500 MHz	+15.0 dBm	+12.6 dBm	+10.7 dBm

LINEAR TECHNOLOGY

DESIGN NOTES

Inverting DC/DC Controller Converts a Positive Input to a Negative Output with a Single Inductor – Design Note 523

David Burgoon

There are several ways to produce a negative voltage from a positive voltage source, including using a transformer or two inductors and/or multiple switches. However, none are as easy as using the LTC®3863, which is elegant in its simplicity, has superior efficiency at light loads and reduces parts count compared to alternative solutions.

Advanced Controller Capabilities

The LTC3863 can produce a –0.4V to –150V negative output voltage from a positive input range of 3.5V to 60V. It uses a single-inductor topology with one active P-channel MOSFET switch and one diode. The high level of integration yields a simple, low parts-count solution.

The LTC3863 offers excellent light load efficiency, drawing only 70µA quiescent current in user-programmable Burst Mode® operation. Its peak current mode, constant frequency PWM architecture provides positive control of inductor current, easy loop compensation and superior loop dynamics. The switching frequency can be programmed from 50kHz to 850kHz with an external resistor and can be synchronized to an external clock from 75kHz to 750kHz. The LTC3863 offers programmable soft-start or output tracking. Safety features include overvoltage, overcurrent and short-circuit protection, including frequency foldback.

–5.2V, 1.7A Converter Operates from a 4.5V to 16V Source

The circuit shown in Figure 1 produces a –5.2V, 1.7A output from a 4.5V–16V input. Operation is similar to a flyback converter, storing energy in the inductor when the switch is on and releasing it through the diode to the output when the switch is off, except that with the LTC3863, no transformer is required. To prevent excessive current that can result from minimum on-time when the output is short-circuited, the controller folds back the switching frequency when the output is less than half of nominal.

The LTC3863 can be programmed to enter either high efficiency Burst Mode operation or pulse-skipping at light loads. In Burst Mode operation, the controller directs fewer, higher current pulses and then enters a low current quiescent state for a period of time depending on load. In pulse-skipping mode, the LTC3863 skips pulses at light loads. In this mode,

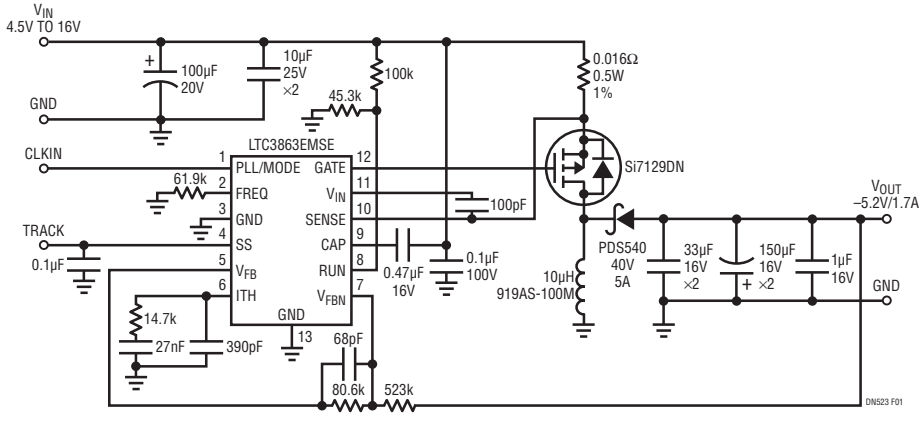


Figure 1. Inverting Converter Produces –5.2V at 1.7A from a 4.5V to 16V Source

the modulation comparator may remain tripped for several cycles and force the external MOSFET to stay off, thereby skipping pulses. This mode offers the benefits of smaller output ripple, lower audible noise and reduced RF interference, at the expense of lower efficiency compared to Burst Mode operation. This circuit fits in about 0.5in^2 (3.2cm^2) with components on both sides of the board.

Figure 2 shows the switch node voltage, inductor current and ripple waveforms at 5V input and –5.2V output at 1.7A. The inductor is charged (current rises) when the PMOSFET is on, and discharges through the diode to the output when the PMOS turns off. Figure 3 shows the same waveforms at 70mA out in pulse-skipping mode. Notice how the switch node rings out around 0V when the inductor current reaches zero. The effective period stops when the current reaches zero. Figure 4 shows the same load condition with Burst Mode operation enabled. Power dissipation drops by 31% at this operating point, and efficiency increases from 74% to 80.5%. At 12V input, the 45% reduction in dissipation is even more dramatic.

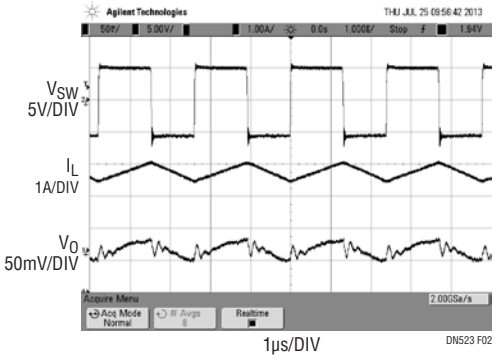


Figure 2. Switch Node Voltage, Inductor Current and Ripple Waveforms at 5V Input and –5.2V Output at 1.7A

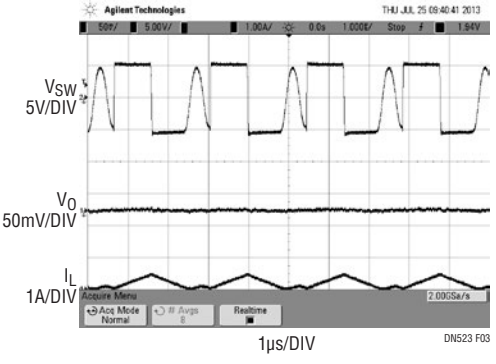


Figure 3. Switch Node Voltage, Inductor Current and Ripple Waveforms at 5V Input and –5.2V Output at 70mA in Pulse-Skipping Mode

High Efficiency

Figure 5 shows efficiency curves for both pulse-skipping and Burst Mode operation. Exceptional efficiency of 85.2% is achieved at 1.7A load and 12V input. Note how Burst Mode operation dramatically improves efficiency at loads less than 0.2A. Pulse-skipping efficiency at light loads is still much higher than that obtained from continuous conduction.

Conclusion

The LTC3863 simplifies the design of converters producing a negative output from a positive source. It is elegant in its simplicity, high in efficiency, and requires only a few inexpensive external components.

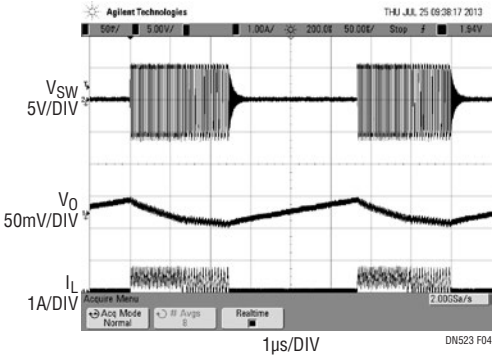


Figure 4. Switch Node Voltage, Inductor Current and Ripple Waveforms at 5V Input and –5.2V Output at 70mA in Burst Mode Operation

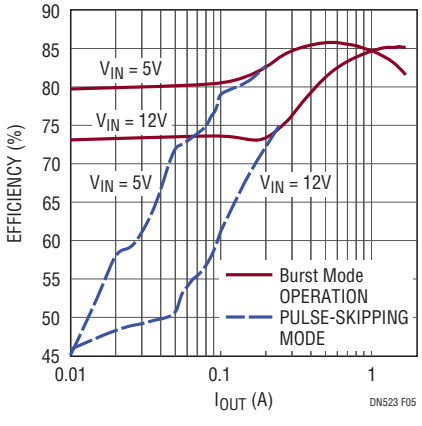


Figure 5. Efficiency In Normal Mode and Burst Mode Operation of the Circuit in Figure 1

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mance using a network analyzer or on the system board in front of the high-speed ADC.

Finally, when using a single-balun or multiple-balun topology, layout plays an equally important role in phase imbalance as well. Keeping performance optimized at higher frequencies means keeping the layout as symmetric as possible. Otherwise, slight mismatches in traces on the front-end designs that use a balun can be proven useless, including dynamic range limiting.

FRONT-END MATCH

First off, the word "match" is a term that should be used wisely. It is almost impossible to "match" a front end at every frequency today with 100-Msample/s converters, let alone over a band that's greater than 1000 MHz. The term match should be positioned to mean optimization yielding the best results given the front-end design. This would be an all-inclusive term where impedance, ac performance, signal drive strength and bandwidth, and pass-band flatness yield the best results for that particular application.

Each parameter, then, should have a particular weight of importance per the application. In some cases, for example, bandwidth (BW) might be the most important spec so other parameters are allowed to suffer a bit if the right amount of BW can be achieved. Figure 2 illustrates the input network for a GSPS converter. Each resistor in the network is like a variable. But as each of these resistor values is varied to create essentially the same input impedance, the performance parameters will change *(see the table)*.

The impedance matching network is roughly the same, but the yielded results between these three examples are different across the measured parameters needed to design the front-end network. The match here is the best result for all the parameters involved where in this case more than 2.5 GHz of BW was required. This narrows the choices down to Case 1 and 2 *(Fig. 3)*.

Case 2 would be more desirable for two reasons. First, the passband flatness only has 2 dB of ripple across the 2-GHz region. Second, the input drive is 3 dBm less than Case 1. This constrains the RF gain less further up the signal chain to achieve full scale of the high-speed converter on the primary of the balun. Case 2 appears to be the best "match" in this example.

SUMMARY

GSPS converters offer ease of use in theory when it comes to sampling wider bandwidth to cover multiple bands of interest or relieve a mix down-stage on the front-end RF strip. However, achieving bandwidth in the +1-GHz range can pose challenges to designing a high-performance converter front-end network.

Keep in mind the importance of specifying a balun where phase imbalance will become important in what the high-speed ADC understands as optimal second-order linearity, for example. Even when a balun is chosen, don't throw away its performance by using poor layout techniques, and be wary about matching the network properly. Many parameters must be met to satisfy the "match" for your particular application. ed

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ideas for design

Circuit Meets Challenges Of Fast, High-Current NiCd Charging

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BATTERIES BASED ON the nickel-metal-hydride (NiMH) and lithium-ion (Li-ion) chemistries have largely replaced the older nickel-cadmium (NiCd) battery in many of today's applications. Still, NiCds are the preferred choice when high discharge currents and a rapid recharge cycle (between one and two hours) are principal concerns.

Precautions must be taken, however, when you try to recharge a standard NiCd cell "fast" at current levels that approach or exceed the rated capacity of the battery (called its C-rating). As the battery becomes fully charged, these high-current levels (at 1C or higher) cause a rapid increase in electrochemical reaction (oxidation/reduction) within the cell, with a corresponding rapid increase in both internal cell pressure and temperature.

Therefore, as the cell approaches or exceeds 100% capacity, the high charging current must be reduced or the cell's overcharge safety vent may open, causing gasses to escape with a possible loss of electrolyte. Additionally, repeated overcharging could degrade the cell's life—the useful number of charge/discharge cycles—or even render it permanently useless.

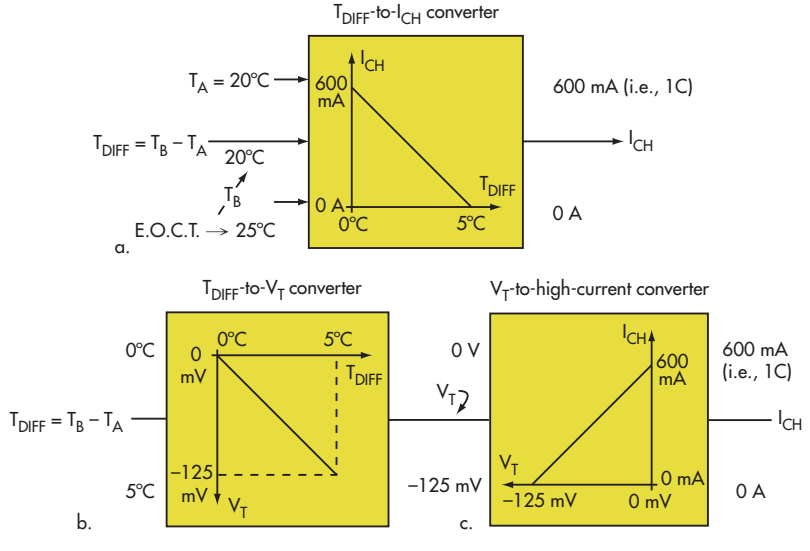
One way to avert the potential damage that can result from repeated cell overcharging at high currents is to monitor the differential temperature $T_{DIFF} = T_B - T_A$ between the battery's surface temperature (T_B) and ambient temperature (T_A) and proportionally reduce or "taper" the charging current I_{CH} as the differential temperature increases.

Consider a design that must convert a differential temperature rise (battery surface temperature above ambient) that ranges from 0°C to 5°C into a charging current that decreases proportionally from a maximum current level of 1C to 0 A. If the rated capacity of an AA cell equals 600 mAhr, then 1C equals 600 mA. Equation 1 describes this differential-temperature-to-charging-current system:

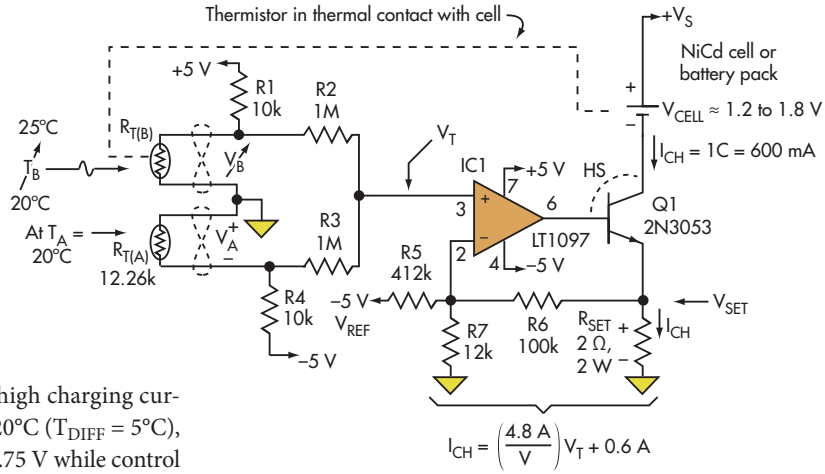
$$I_{CH} = \left(-120\frac{mA}{^{o}C}\right)T_{DIFF} + 600\,mA \quad (1)$$

Figure 1a represents the differential temperature-to-charging current system to be designed. Its main elements are a differential temperature-to-voltage converter and a voltage-to-high-current converter.

Temperatures T_B and T_A are monitored separately by standard negative-temperature-coefficient (NTC) thermistors (10 kΩ at 25°C) with corresponding resistance values of $R_{T(B)}$ and $R_{T(A)}$, respectively *(Fig. 2)*. Both sensor output voltages, V_B and V_A, are then applied to the inputs of a basic passive adder created by R2 and R3. At $T_B = T_A = 20°C$ (i.e., $T_{DIFF} = 0°C$) $V_B = +2.75$ V and $V_A = -2.75$ V, the passive adder's output voltage is



1. There are three critical equations and associated graphs for this design. Equation 1 shows the relationship between the differential temperature T_{DIFF} and the charging current I_{CH} (a), which leads to a single-ended control voltage (V_T) that is inversely proportional to T_{DIFF} as the output of the passive adder (b), and concludes with Equation 3, which relates I_{CH} to V_T (c).



2. The voltage outputs corresponding to thermistor resistances $R_{T(A)}$ and $R_{T(B)}$ are summed in passive adder IC1. This output difference varies from –125 mV to 0 V as the temperature rises from 0°C to 5°C.

given by single-ended control voltage $V_T = (V_A + V_B)/2 = (–2.75\ V + 2.75\ V)/2 = 0\ V$.

When T_B rises to 25°C due to the initial high charging current of 600 mA and T_A remains constant at 20°C (T_{DIFF} = 5°C), the sensor voltage V_B = +2.50 V and V_A = –2.75 V while control voltage $V_T = (V_A + V_B)/2 = (–2.75\ V + 2.50\ V)/2 = -0.125\ V$. As a result, the output of the passive adder produces a value for V_T that is inversely proportional to T_{DIFF} *(Fig. 1b)*:

$$V_T = \left(\frac{-25\ mV}{^{\circ}C}\right)(T_B - T_A) \quad (2)$$

The voltage-to-high-current converter circuitry around IC1, whose output current is directly proportional to V_T, has both scale and offset capabilities and therefore can be designed to deliver the needed charging current I_{CH} to the battery *(Fig. 1c)*. Circuit performance is described analytically by:

$$I_{CH} = \left(\frac{4.8\ A}{V}\right)V_T + 600\ mA \quad (3)$$

Before proceeding, we can check the validity of this design by convolving Equation 2 with Equation 3 to reproduce Equation 1:

$$I_{CH} = \left(\frac{4.8\ A}{V}\right)\left[\frac{-25\ mV}{^{\circ}C}(T_{DIFF})\right] + 600\ mA = \left(-120\frac{mA}{^{\circ}C}\right)T_{DIFF} + 600\ mA \quad (1\text{-}3)$$

Begin the design implementation with T_{DIFF} at 0°C where V_T = 0 V. V_{SET} is chosen to equal 1.25 V, the maximum charging current is set at 600 mA, and the R_{SET} resistor value is determined by letting $R_{SET} = V_{SET}/I_{CH}$ = 1.25 V/600 mA = 2 Ω (2 W). When the differential temperature T_{DIFF} rises to 5°C and V_T = –125 mV, the value of V_{SET} will have linearly decreased to 0 V, causing I_{CH} to drop to approximately 0 A, terminating the high-current charge. The performance equation for this voltage-to-high-current converter is given by.

$$V_{SET} = \left(1 + \frac{R_6}{R_5} + \frac{R_6}{R_7}\right)V_T - \left(\frac{R_6}{R_5}\right)V_{REF} \quad (4a)$$

However, dividing both sides of the equation by R_{SET} yields the more useful form for design:

$$I_{CH} = \frac{V_{SET}}{R_{SET}} = \left(1 + \frac{R_6}{R_5} + \frac{R_6}{R_7}\right)\frac{V_T}{R_{SET}} - \left(\frac{R_6}{R_5}\right)\frac{V_{REF}}{R_{SET}} \quad (4b)$$

Final component selection for this converter is accomplished by comparing both offset and scale terms of the design equation *(Equation 3)* with the converter's corresponding performance equation terms in Equation 4b. Set feedback resistor R6 to 100 kΩ, 1% and equate offset terms in Equation 5. Then solve for the value of R5 by choosing –5 V for V_{REF}.

$$-\left(\frac{R_6}{R_5}\right)\frac{V_{REF}}{R_{SET}} = 600\ mA \quad (5)$$

The calculated value of R5 (416.67 kΩ) is approximated by choosing a standard 412-kΩ, 1% resistor. Finally, calculate the value of R7 by comparing scaling terms in.

$$\left(1 + \frac{R_6}{R_5} + \frac{R_6}{R_7}\right)\frac{1}{R_{SET}} = \left(\frac{4.8\ A}{V}\right) \quad (6)$$

The calculated value of R7 is 11.96 kΩ, which can be satisfied with a standard 12-kΩ, 5% resistor. Circuit performance was simulated and verified by laboratory measurement over multiple charge/discharge cycles.

REFERENCE

Villanucci, Robert S. and Diecidue, Joseph, "'Intelligent' NiCd Charger Avoids Battery Damage from High Currents," ***Electronic Design***, May 8, 2008, p. 51-54, http://electronicdesign.com/power/intelligent-nicd-charger-avoids-battery-damage-high-currents

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It Takes A WaRPed Mind
To Design Wearable Tech

Wearable tech was all the rage at this year's International CES. Smartwatches, wireless pedometers, and other gadgets all were integrating multiple functions into mobile devices. The fitness market led the way, but smart glasses like Google Glass have garnered more attention.

The plethora of low-power sensors and low-power, flexible displays opens up a wide range of design possibilities from medical sensors to augmented reality. The challenge for this type of design is that it is not easy to assemble the required components because of space and power constraints. So how does a designer turn an idea into a wearable device?

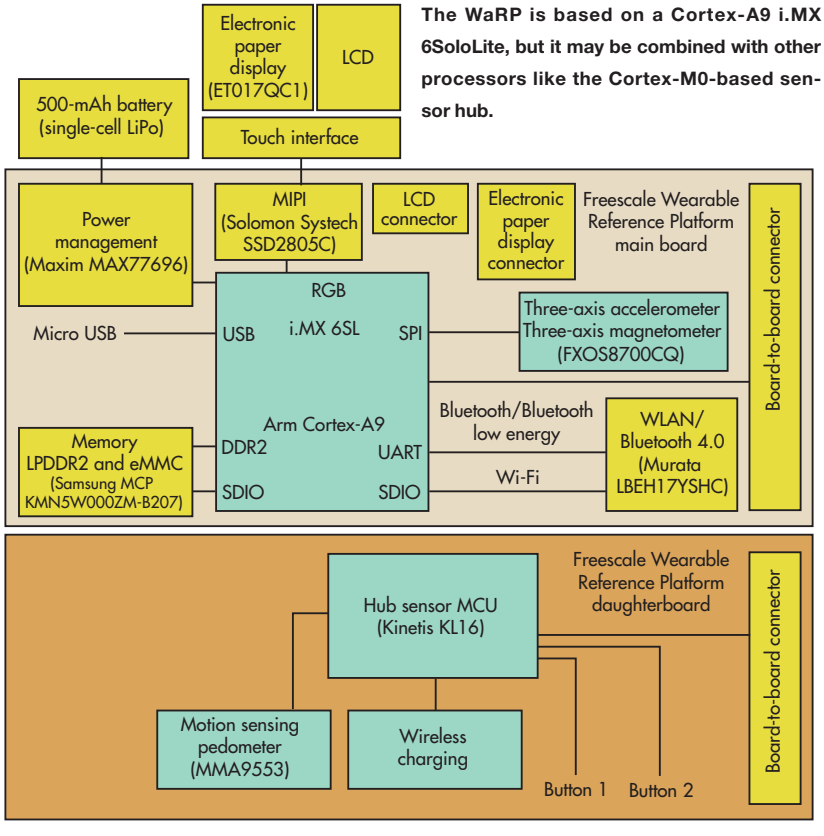
Freescale's 38-by 14-mm Wearable Reference Design (WaRP) application processor board (APB) allows designers to incorporate a 1-GHz i.MX 6SoloLite into a compact design. It includes the Cortex-A9 system-on-chip (SoC) plus Bluetooth and 802.11 Wi-Fi communication, a six-axis accelerometer and magnetic sensor, and a lithium-polymer (LiPo) battery charger. Its USB interface also can provide power. The module includes drivers for LCD or E-ink e-paper displays.

To keep the module small, Freescale takes advantage of a Samsung MCP that has 4 Gbytes of double-data-rate (DDR) memory plus flash memory. Combining multiple die into a single package like this is one way to keep wearable devices small. The system also runs Android, which provides a high level of functionality, though the hardware platform can handle a range of operating systems.

The WaRP module can plug into a daughterboard that provides additional peripherals, displays, and connectors. One of the first daughterboards incorporates Freescale's KL-16 sensor hub linked to a Freescale pedometer sensor and wireless charging system *(see the figure)*.

The module is not designed to be incorporated into a product. Rather, a typical design will have a custom board that would include many or all of the components in the APB. Freescale developed the platform with partners like Kynetics and Revolution Robotics. They provide rapid prototyping support and help create the WaRP hybrid design architecture.

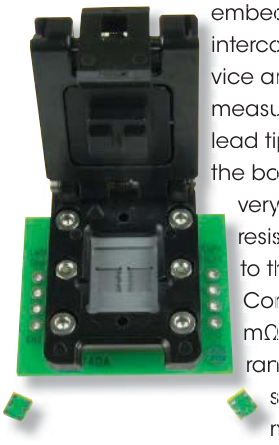
Wearable tech can be very small using tiny micros like Freescale's 1.9- by 2-mm KL02 Cortex-M0+ or even working directly with the silicon. Silicon Labs will even sell you die directly. This makes it possible for many applications to simply disappear inside clothes and jewelry.



The WaRP is based on a Cortex-A9 i.MX 6SoloLite, but it may be combined with other processors like the Cortex-M0-based sensor hub.

Elastomer Socket Targets High-Speed SOICs

OPERATING AT bandwidths up to 10 GHz with less than 1-dB insertion loss, Ironwood Electronics' SG-SOIC-3005 socket is intended for 0.5-mm-pitch, 10-pin small-outline integrated circuits (SOICs). It consists of low-inductance, gold-plated embedded wire on elastomer as an interconnect material between the device and printed-circuit board (PCB). It measures 3 by 3 by 1 mm, with a 5-mm lead tip to tip with an exposed pad on the bottom. Its small footprint allows for very close placement of inductors, resistors, and decoupling capacitors to the device for impedance tuning. Contact resistance is typically 20 mΩ per I/O. Operating temperature ranges from –35°C to 100°C. Pin self-inductance is 0.15 nH, with mutual inductance of 0.025 nH. Current capacity is 2 A per pin. The socket mounts onto the target PCB with supplied hardware. No soldering is required. ICs can be changed out quickly thanks to a swivel lid with compression screw.



IRONWOOD ELECTRONICS INC.

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Rugged Switch Solutions Shrink GbE Connectivity Costs

ACCORDING TO Curtiss-Wright Controls Defense Solutions, its SMS-652 Rugged Switchbox line-replaceable unit (LRU) and VPX3-652 Gigabit Ethernet (GbE) Switch line-replaceable-module (LRM) solutions significantly reduce the cost of adding network connectivity into new and legacy defense platforms. The 7.75- by 9.2- by 2.5-in. MS-652 is a fully MIL-qualified, standalone 16-port GbE switch LRU for size, weight, power, and cost (SWaP-C) constrained environments, targeting airborne communications systems, sensor data acquisition, and data-processing applications on limited-space platforms such as UAVs. Its switching fabric provides non-blocking wire-speed gigabit performance for 16 ports of 10-, 100-, or 1000-Mbit/s Ethernet connections. The VPX3-G52 offers up to 20 ports of copper Ethernet connectivity in a single 3U slot, and it includes IPMI functionality for system-level health management. Applications include space-constrained command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) and electronic warfare subsystems to support network communications within the subsystem, as well as connect externally to other subsystems within the platform.

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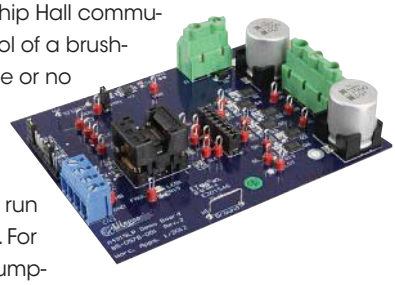
Three-Phase BLDC Motor-Driver Eval Kit Instantly Spins Motors

BY INCLUDING on-chip Hall commutation and an innovative SPEED control input, Allegro Microsystems' evaluation kit for its A4915 three-phase MOSFET controller IC makes it easier to "spin" a motor. The SPEED input takes an analog voltage and generates a pulse-width-modulated output with variable duty cycle. The combination of control interface with on-chip Hall commutation enables efficient control of a brushless dc (BLDC) motor with little or no microprocessing power. Six N-channel power MOSFETs mounted on the kit supply 30-A peak and 20-A nominal run current at room temperature. For larger loads, the A4915 has jumpers that disable the onboard bridge as well as connections to add an external bridge. An onboard 5-V regulator creates the secondary supply for logic inputs. The kit, targeted at the industrial and consumer markets, is available for the 28-pin thin-shrink small-outline package (TSSOP) with exposed thermal pad and 28-contact 5- by 5-mm quad flat no-lead (QFN) with exposed thermal pad.



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DSC Family Adds Higher Integration Levels For Motor Control

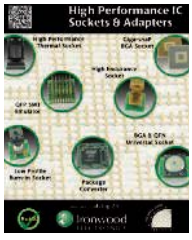
A NEW family of dsPIC33 digital signal controllers (DSCs) helps boost the efficiency of dual motor control by leveraging 12 motor-control pulse-width-modulation (PWM) channels (six pairs), dual 12-bit analog-to-digital converters (ADCs), multiple 32-bit quadrature encoder interfaces, and two controller area network (CAN) modules. With such integration, Microchip's dsPIC33EP512GM710 DSCs can independently control two motors with a single MCU. The devices also can serve as a communication hub for automotive or industrial applications to connect with multiple CAN buses. Each device supports 512 kbytes of flash, 48 kbytes of RAM, and four op amps. The two ADC modules can be configured as 10 bits, 1.1 Msamples/s with four sample-and-holds, or 12 bits, 500 ksamples/s with one sample-and-hold, supporting up to 49 channels. A peripheral trigger generator (PTG) schedules complex, high-speed peripheral operations, saving software cycles and reducing firmware complexity.

MICROCHIP TECHNOLOGY CORP.

www.microchip.com/get/V37V

Catalog Literature Review

HIGH PERFORMANCE SOCKETS & ADAPTERS



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IR's Highly Compact 10A AUIR08152S Gate Drive IC Shrinks Automotive High Current Switching Systems While Boosting Performance

IR announces the highly compact AUIR08152S automotive-qualified gate drive IC featuring high output current in excess of 10A that shrinks system size and boosts performance in automotive and industrial high-power switching applications.

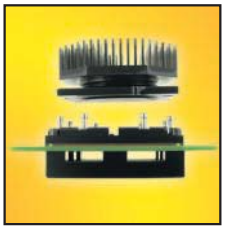
The AUIR08152S buffer gate driver enables the use of any standard low current gate driver, opto-coupler or CMOS isolator to drive large size IGBTs or MOSFETs in switching applications and efficiently boosts any low or under-powered gate drive into a high current drive system. Available in a compact SO8 package, the highly integrated buffer IC can replace up to 10 discrete components for simpler, smaller and more robust system design.

The new device's very low output impedance and power losses permit operation in harsh and high temperature environments. The AUIR08152S additionally features negative Vgs driving and continuous on-state capability as a result of an integrated PMOS output in parallel to the high-side pull-up NMOS. The OUTH and OUTL separated outputs allow selection of two different external resistors for charging and discharging the gate essential for controlling EMI and CdV/dT effect in high power motor driver and SMPS applications.

The device is qualified according to AEC-Q100 standards, housed in an industry standard SO-8 package that features an environmentally friendly, lead-free and RoHS compliant bill of materials and is part of IR's automotive quality initiative targeting zero defects.

More information is available on the **International Rectifier** website at
http://www.irf.com/whats-new/nr131205.html
For more information, contact Sian Cummins,
scummin1@irf.com, 310-252-7148.

High Performance - 10 GHz Socket Technology



SG-BGA-8019 is constructed with high performance and low inductance elastomer. The temperature range is -40 C to +100 C. The pin inductance is 0.15 nH. Capacitance to ground is 0.10 pF. Current capacity is 2A per pin. This elastomer socket technology, applicable for BGA pitches from 0.3 to 1.27mm, allows these pitch BGA's to operate to over 10 GHz without significant contactor loss.

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RoboCop Returns
With An Eye On Realism

RoboCop gets a reboot in 2014 with the new film directed by José Padilha and starring Joel Kinnaman as Alex Murphy, the man inside the machine *(Fig. 1)*. For those who missed the 1987 iteration starring Peter Weller, Alex Murphy is a policeman who is murdered and then revived by Omni Consumer Products (OCP), a rather malevolent mega-corporation. I've seen the original many times and look forward to the remake, set in 2028, because there are a few things I want to check out after talking with Martin Whist and Jamie Price.

1. The EM-208 RoboCop looks slick with a few internal sections removed from the armor by the special effects department.

MOVING CLOSER TO REALITY

As production designer, Whist was responsible for the overall feel of the movie. He has a long track record including films like the sci-fi hit *Super 8* directed by J.J. Abrams. He and his colleagues did a good bit of research into what is now on the drawing board for everything from super soldiers and police to what might be in the kitchen in 2028.

The challenge was to deliver something that was not only slick and compelling but also realistic since 2028 is right around the corner. Of course, this is a movie and presentation sometimes trumps realism. But the technology generally is on track, so engineers can enjoy the film even when they're viewing it with a technically critical eye. For example, graphene-based armor is being considered now because of its strength and light weight. There are production challenges when working with graphene, but they may be overcome by 2028.

Computer interfaces from 3D gesture recognition to transparent heads-up displays (HUDs) are in the mix as well in the new *RoboCop*. They are also in use now. At the 2014 International CES, Intel announced its RealSense including new 3D camera technology and an updated Perceptual Computing SDK. HUDs are creeping into high-end 2014 automobiles too.

Martin's job isn't easy since he must tie in all aspects of the environment, from motorcycles to kitchens, as well as monstrosities like a large robot that had to be virtualized.

ROBOCOP VIRTUALIZATION

Price was the VFX director for *RoboCop*. He led a team that turned Martin's and José's vision into the final film. This took a little bit of work when it came to the robots.

The ED-209 is a large robot in the film, so it was completely done using computer generated imagery (CGI) when it was moving *(Fig. 2)*. The challenge was in creating an "eerieness" that combines familiar human proportions and movement while retaining the sense of massiveness. The robots have a more convincing gait so they don't look like they would just fall over.

The producers created an aluminum bar as a stand-in for the ED-209 so the actors had something to look at. Animation replaced the bar in the final cut. VFX techniques have improved significantly, so the director was not as limited by the production technology.

2. The ED-209 was primarily a CGI creation that actors had to imagine, but viewers will see the final product.

The EM-208 robot was created using a spectrum of visual effect techniques. It always started with Kinnaman, but almost every shot has some augmentation of the suit. Typically, these additions to the shots included moving robotic parts or negative space in the joints. These enhancements are more akin to the robots we have today versus the space needed for a human elbow. Of course, implementing the action scenes also required a bit of creativity.

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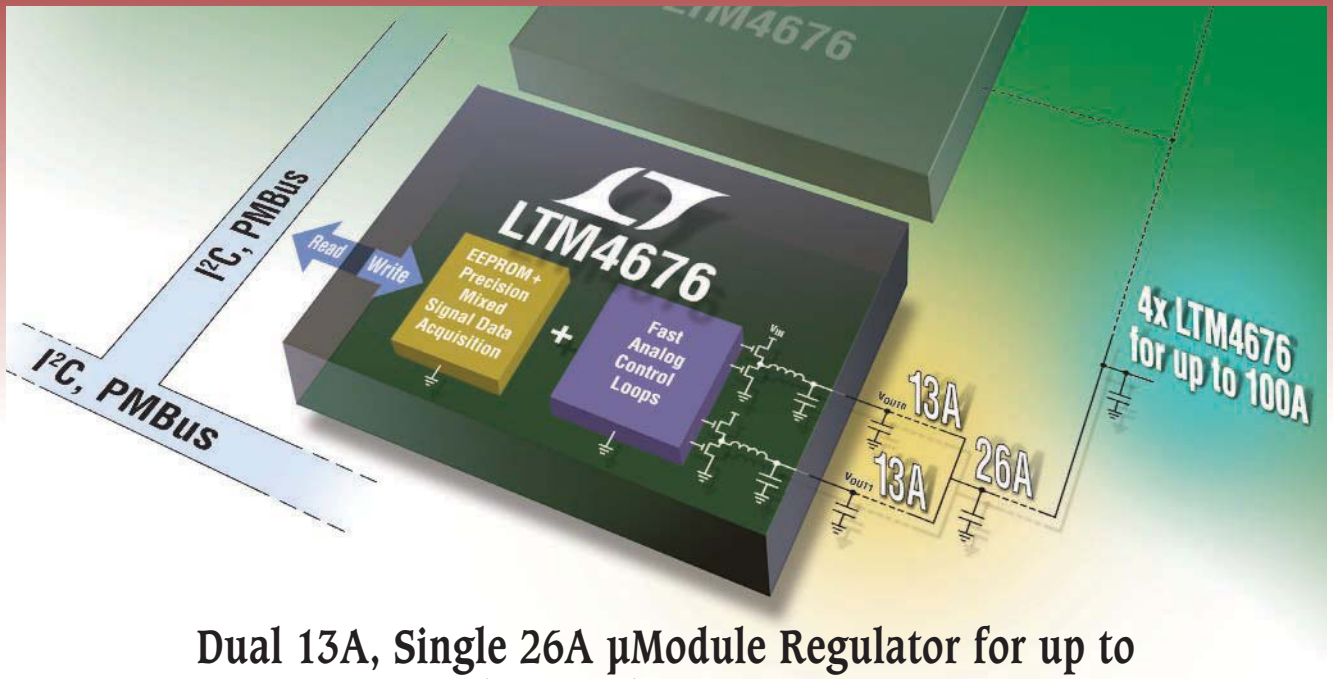

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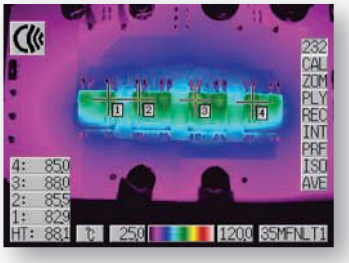

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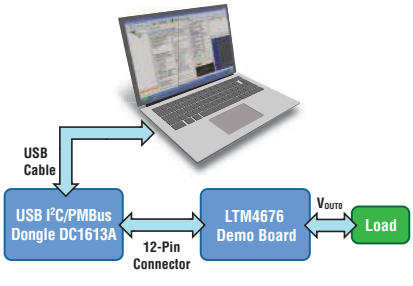

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