UBM Tech

EDN®

JUNE 2013
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Issue 6

Arduino Yún Wi-Fi board
Page 12

POWER TO THE PEOPLE

The democratization of engineering

Page 38

Counting squares: a method to quickly estimate PWB trace resistance
Page 31

10 tips for maximizing battery life
Page 47

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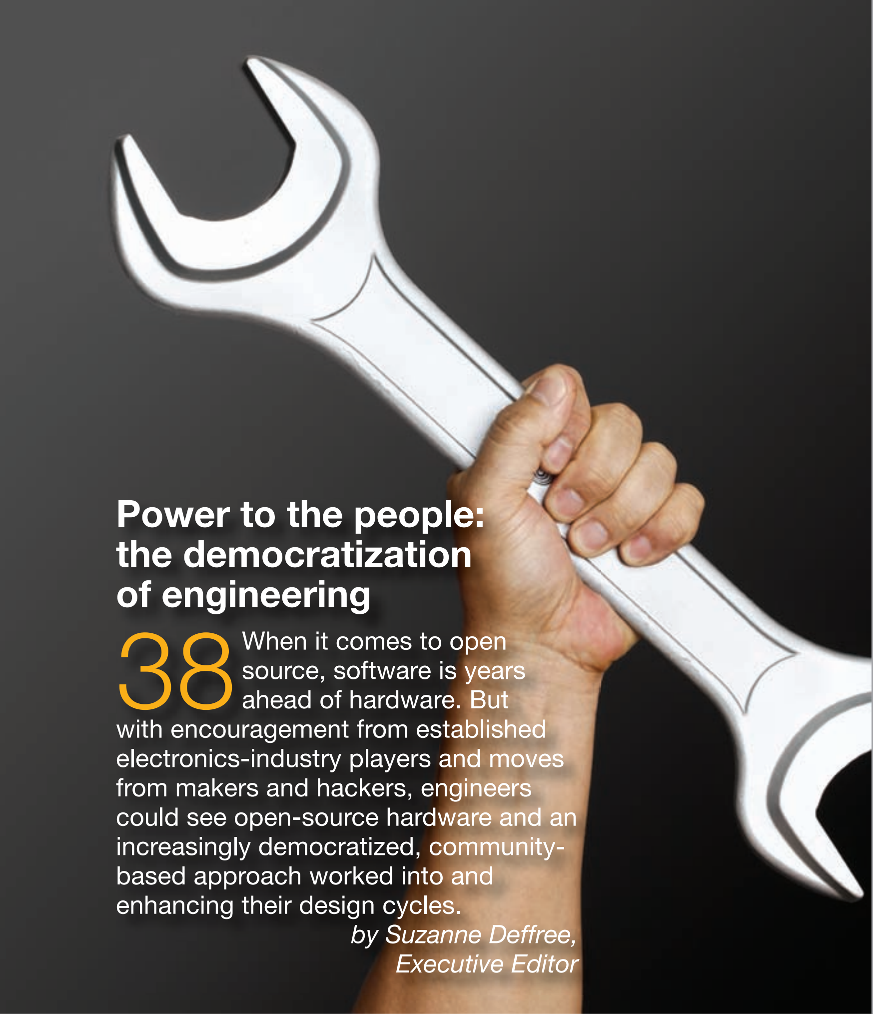
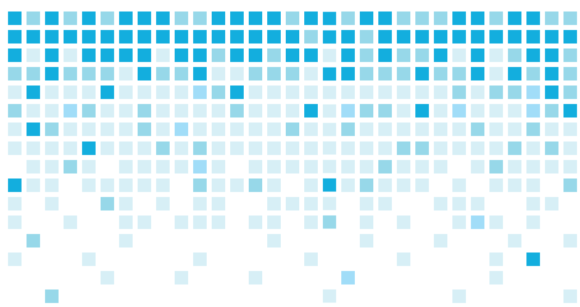
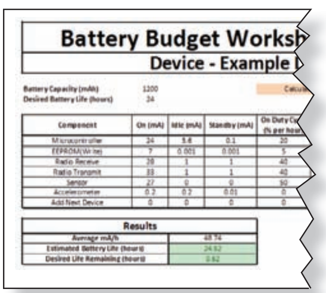
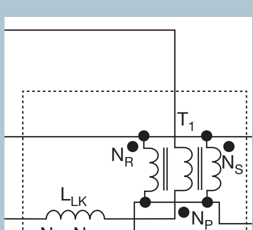






COVER IMAGE: SHUTTERSTOCK

DESIGNIDEAS



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contents June 2013

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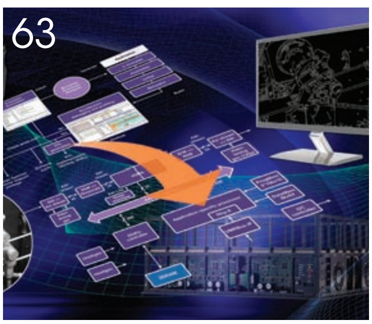
DEPARTMENTS & COLUMNS



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	IR3841	IR3865	IR3475	IR3865	
	IR3841W				
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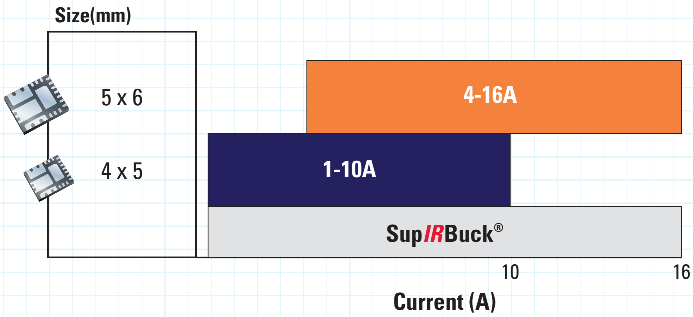

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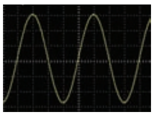
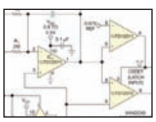


In response to "Top 10 challenges for analog," a blog post by *EDN*'s Steve Taranovich at www.edn.com/4415122, Alan60 commented:

"Analog field programmable arrays are still not worth writing home about. If it is fast enough (GBW, slew) then it is not accurate enough (Vis, Vcm); if accurate enough then wrong supply range; if right supply range then wrong common mode input range; if good common mode input range then wrong output range, etc ad nauseam. Even with '... never needing more than 640K ...' in mind, it will be a long time until analog PGAs are as useful and ubiquitous as digital FPGAs."

In response to "On-board diagnostics not just for racing anymore," a blog post by Pallab Chatterjee at www.edn.com/4413449, D Feucht commented:

"Vehicle telemetry is another example of how technology is a two-edged sword. While the many good uses of it are outlined in the article, misuse (and I would not limit it to 'potential' misuse) exists in how insurance companies—and sooner if not later, institutions of coercion (that is, governments)—could respond to such data were it made available to them. The power to observe is the power to control."



In response to the Design Idea "Gnat-power sawtooth oscillator works on low supply voltages" at www.edn.com/4414514, WKetel commented:

"This circuit design is a simple and elegant improvement on the more common version. Good work, and thanks for publishing this potentially very useful design tip."

EDN *invites all of its readers to constructively and creatively comment on our content. You'll find the opportunity to do so at the bottom of each article and blog post.*

CONTENT

Can't-miss content on EDN.com

THE TOP 5 FASTEST SUPERCOMPUTERS AND THEIR POWER MANAGEMENT CHALLENGES

It's tough to keep up with who has the fastest supercomputer nowadays. More speed means more power demanded from the power supply, not to mention redundancy back-up power and the need to deal with all the heat dissipation from such a beast.

www.edn.com/4415242

CHECK THAT CONFIGURATION

DANIEL VASCONCELLOS

In this online-exclusive Tales from the Cube entry, an engineer struggles to locate a mysterious fault, only to finally find it buried in a configuration page.

www.edn.com/4414943

ENGINEERING COMMUNITY

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Do you know your tech history?

Which president was issued a patent? Who gave the first public demonstration of radio? What innovation capped off the "Miracle Month" in 1947? Think you know your history? Take our tech-history quiz—based on the popular *EDN* Moments blog, which looks back at important moments in history and how they pertain to engineering—and see if you know your stuff!

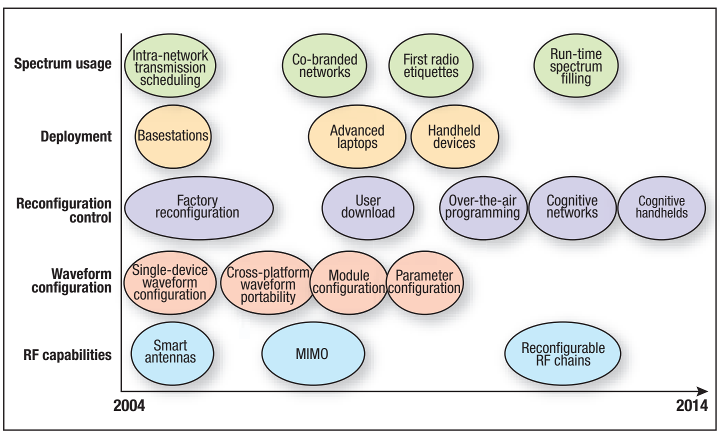
www.edn.com/4415918

BY PATRICK MANNION, BRAND DIRECTOR

Cognitive radio arrives, all by itself!

A scant 10 years ago, it seemed that the ultimate in cognitive-radio concepts was considered to be so far out there that it would always be a pipe dream without massive government expenditure on research and infrastructure. So how did it just "happen"?

It was Joseph Mitola III who coined the term *cognitive radio* and defined it as radio that is "self-aware, user-aware, [and] RF-aware" and that incorporates elements of "language technology and machine vision." Back in 2004, in conversations I had with Mitola, then working at Mitre, and Bruce Fette, then with General Dynamics, it seemed the foundations of cognitive radio were just beginning to be put into place.



In 2004, the prediction was that we'd have cognitive handsets by 2014, yet the path was a bit murky. Then came the unpredictable: multisensory iPhones/iOS and Android devices backed by a connected apps ecosystem, and we've arrived a year early. Almost.

Software-defined radios that could adapt to multiple wireless baseband processing and modulation/demodulation schemes were afire, fed in part by the emergence of new multicore processing architectures with less and less power consumption. At the front end, higher levels of CMOS integration offered by the emergence of direct-conversion radios and other techniques made flexible front ends seem likely to match the flexible processing architectures. Even the Federal Communications Commission was cooperating, opening up more spectrum and looking for ideas on how to mitigate in-band interference with the licensed radios operating regionally.

Everything seemed to be coming together, but there were some really important issues that needed to be addressed to fully realize the potential of a handset that, in Fette's words, could not just avoid being an interferer and adapt to multiple bands but also be cognizant enough to remind you when you were approaching a pothole you hit last time you went a certain route in your car.

In 2004, the intelligence, processing power, and contextual location-awareness requirements for the latter were just not doable. So it remained a pipe dream. For the former, there was talk of using RF MEMS as the foundation for programmable bandpass filters that could tune to any band, without the need for multiple RF front ends. The signal would go from antenna, to filter, to digital. But RF MEMS were still too nascent.

At that time, I also spoke with a fellow by the name of Gerald Q Maguire, a professor at the KTH Royal Institute of Technology (Stockholm, Sweden), who made a very important connection between advances in wireless and ever cheaper memory. In fact, he considered it critical. I agreed. But store that thought for a second.

Fast forward to 2013, and look at what has happened. Starting with the iPhone and its multisensory, multiband, location-aware capabilities with increasing amounts of memory coupled with an ecosystem of software (app) developers, and suddenly you have what no government, no one group, and no organization could have conceived or enabled: fully aware handsets that can adapt to multiple bands and tell you everything about where you are and where you've been. (Ask the NSA.) And voilà! Cognitive radio has arrived. All by itself.

That part about flexible RF front ends is still a bit of an issue, but this week (June 4) I was encouraged by the announcement by Cavendish Kinetics that it was sampling tunable RF capacitors based on the company's "patented breakthrough RF MEMS technology." I hope it works, but either way I was inspired enough to reflect upon how far we've come in 10 years.

I look at my kids sometimes and I literally can't imagine what's next, what world they'll live in. Can you? **EDN**

Contact me at patrick.mannion@ubm.com.

pulse

INNOVATIONS & INNOVATORS

Wi-Fi board combines Arduino with Linux for easy M2M use

Arduino Yún is the first member of a new line of Wi-Fi products combining the power of Linux with the ease of use of Arduino. *Yún* means "cloud" in the Chinese language, as the purpose of this board is to make it simple to connect to complex Web services directly from Arduino.

The Arduino Yún is the combination of a classic Arduino Leonardo (based on the Atmega32U4 processor) with a Wi-Fi system on a chip running Linino (a MIPS GNU/Linux based on OpenWRT).

Designed in collaboration with Dog Hunter, the board adopts the Linino distribution, which provides signed packages to ensure the authenticity of the software installed on the device. Historically, interfacing Arduino with complex Web services has been a challenge due to the limited memory available. Web services tend to use verbose text-based formats such as XML that require quite a lot of RAM to parse. On the Arduino Yún, the company has created the Bridge library, which delegates all network connections and processing of HTTP transactions to the Linux machine.

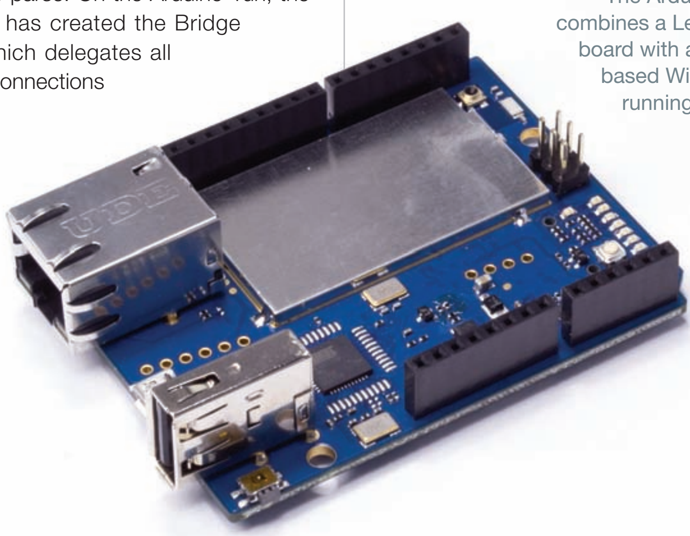
To make it even simpler to create complex applications, Dog Hunter partnered with the innovative start-up Temboo, which provides normalized access to 100+ APIs from a single point of contact, allowing developers to mix and match data coming from multiple platforms (for example, Twitter, Facebook, and Foursquare, as well as even FedEx or PayPal).

The board can be programmed with a USB cable in the classic Arduino way or through the Wi-Fi connection without the need to physically access the board. The new Arduino 1.5.x IDE has the ability to detect any Arduino Yún connected to the local network.

—by Julien Happich

▷**Arduino**, www.arduino.cc

▷**Dog Hunter**, www.doghunter.org



The Arduino Yún combines a Leonardo board with a MIPS-based Wi-Fi SoC running Linino.

TALKBACK

"A simple, elegant piece! I like the ball analogy, but as I read, I wondered how the analogy could be made to embrace the reflection at short circuits, which is about as severe as those caused at open circuits."

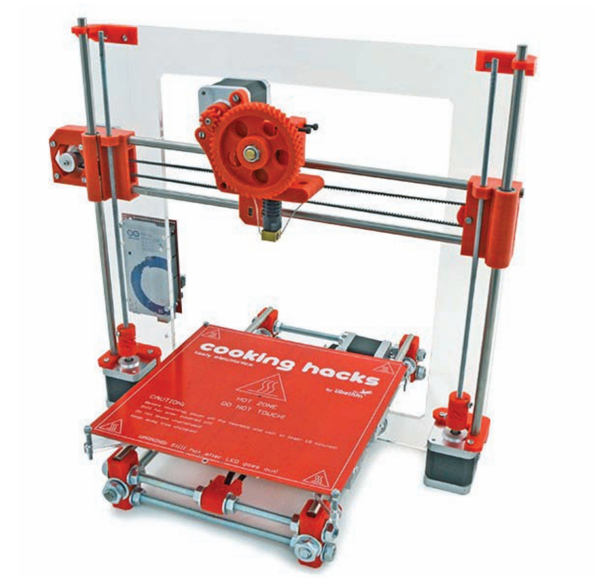
—Commenter Guru of Grounding, in response to "Why reflections happen," a post in Howard Johnson's Signal Integrity blog at www.edn.com/4414190. Join the conversation and add your own comment.

Inexpensive 3-D printer kit creates plastic components

Anyone with an idea for a new mechanical device can create it on his or her computer with 3-D solid-model software and e-mail it to a company that will "print" it and quickly return a prototype. Three-dimensional printers cost a lot of money, so the hacker and maker "communities" have embarked on their own projects to create low-cost 3-D printers.

Recently I learned about a 3-D printer kit from Cooking Hacks, available for about $850. Cooking Hacks operates as part of the Spanish company Libelium Comunicaciones Distribuidas SL. According to the Cooking Hacks Web site images and information, software to control four stepper motors and the plastic extruder runs on an Arduino single-board computer. Two steppers control Y-axis (up-down) movement of the printing head, which moves back and forth under control of another stepper. A fourth stepper positions the platform on which your component gets "built." The printer can create devices with maximum dimensions of 20×20×20 cm. I didn't find information about how long it takes to create different types of devices.

Most of the kit parts, such as gears, shafts, bearings, and hardware, look like standard components. Custom plastic parts connect the kit pieces, and an aluminum frame provides a sturdy and stable frame for the completed printer. (Illustrations on the Cooking Hacks Web site show a clear plastic frame, perhaps to make all portions of the mechanisms easy to see.)



The $850 3-D printer kit from Cooking Hacks includes software to control four stepper motors; the plastic extruder runs on an Arduino single-board computer.

Some of the custom pieces look as though they came from a 3-D printer, but perhaps the company used them to create a prototype and will supply injection-molded components in all kits. If you work at a small company that needs the capability to create plastic prototypes or you need many plastic parts for a hobby or for artistic uses, the Cooking Hacks 3-D printer deserves a look. It also might fit into public-school technology programs as a 3-D printer in design classes and also as a way to have students create parts needed for school projects, robot competitions, science fairs, and so on.

For more information, please visit the product page at http://bit.ly/18wKnmY. So that you can see what building a kit involves, view a complete tutorial here: http://bit.ly/18qCVMx. I found some of the instructions lacked details that most people would need to build this type of kit. One instruction notes, "Take your heated bed and solder two high current cables," but the nearby image doesn't show cables or where they should go.

Obviously you will need software to create a 3-D representation of the device you need to print. Commercial software can cost thousands of dollars, but I found a site that lists free 3-D stereolithography (STL) software: http://bit.ly/10xP3Hs.

> "The hacker and maker 'communities' have embarked on their own projects to create low-cost 3-D printers.

The software needed to drive the printer comes as part of the kit, but your 3-D design software must provide design files in the standard STL format. Check 3-D CAD software capabilities to ensure you can get an STL file for your printer. (Most 3-D printers require a design presented in STL-format files.)

I don't use enough mechanical parts to make a 3-D printer worthwhile. But I await the day when I can send a design to my local Kinkos or UPS Store and pick up my 3-D parts later the same day. That time will come sooner than we think. Meanwhile, this type of 3-D printer kit will give many people a head start. **—by Jon Titus**

▷**DEV-monkey blog**, www.edn.com/4415031

DILBERT By Scott Adams

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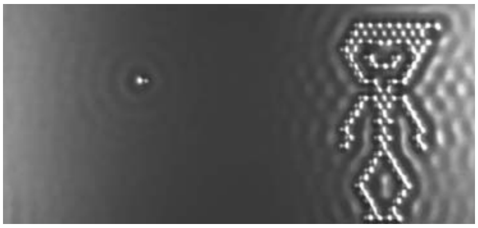
Now playing: the world's smallest movie (made with atoms)

Scientists at IBM have created the world's smallest movie—made with atoms—that can be viewed only when magnified by 100 million times. The 242-frame stop-motion production, named "A Boy and His Atom" (http://bit.ly/13XeT8A), was created using a scanning tunneling microscope to precisely capture and position thousands of carbon monoxide molecules.



IBM's 242-frame stop-motion video was created using a scanning tunneling microscope to precisely capture and position thousands of carbon monoxide molecules.

Researchers used the remotely operated IBM-designed microscope to control a super-sharp needle along a copper surface to "feel" for and attract atoms, and then pull them to a specific location on the surface. Critical to this process was the "scratchy" sound that moving atoms make (http://bit.ly/13XeLG7), which provided feedback on how many positions an atom had moved.

A behind-the-scenes look at how "A Boy and His Atom" was created is available at this link: http://bit.ly/143u0Kn. The video includes interviews with Christopher Lutz and Andreas Heinrich, both from IBM Research.

IBM sees the ability to move single atoms as crucial to its research in the field of atomic-scale memory. The ability to create ever-smaller memories promises to enable unprecedented levels of data storage in future computing applications.

> IBM sees the ability to move single atoms as crucial to its research in the field of atomic-scale memory.

For more on the movie, and IBM's atomic-scale research, see the company's related-article page (http://ibm.co/143ua4a). For more on IBM's scanning tunneling microscope, see the video "History of the scanning tunneling microscope" (http://bit.ly/1167Nuj). **—by Rich Pell**

▷**IBM**, www.ibm.com

Graphics chip recognizes nearby pedestrians and bicycles

Fujitsu Semiconductor Europe announced the development of the MB86R24, the company's third-generation graphic SoC for automotive applications. The device incorporates the Approaching Object Detection functionality—which notifies drivers of nearby people, bicycles, and other objects—into the 360° Wraparound View System that allows drivers to check their entire surroundings in 3-D from any angle.

The new chip also enables the development of integrated human machine interface (HMI) systems that consolidate and provide centralized control over a variety of onboard vehicle information. Until now, the display of such information on multiple screens has been controlled independently for each screen. The MB86R24 is expected to help in improving safety, comfort, and peace of mind for automobile drivers, as well as for home and industrial applications that are becoming increasingly important.

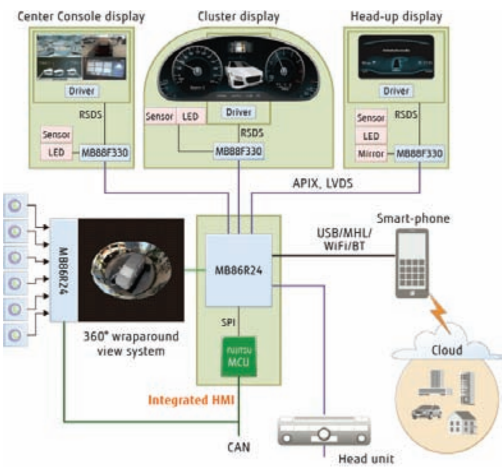
Equipped with six full HD input channels and three display output channels, the MB86R24 boasts roughly double the CPU performance and five times the GPU performance of its predecessor, delivering sharper images and the ability to view surroundings from any perspective.

In recent years, the amount of information shared between drivers, vehicles, and the outside world has been steadily growing. Such information includes battery information for electric vehicles, camera imagery, navigation information, and connectivity with smartphones and the cloud. Different kinds of information are displayed on different screens, such as central console displays, cluster displays, or heads-up displays, all of which require separate display control.

To provide such information in real time to drivers in an easy-to-understand manner, there is a need for technology that can collect information in a single location and centrally control how it is displayed, depending on the driving scenario. HMI systems can accomplish this, and MB86R24 is able to control each display to present information that suits the current driving scenario.

Moreover, the new SoC facilitates the development of modules and platforms for displays that can be incorporated into multiple models, rather than one-off development for each car model as in the past. This, in turn, enables a reduction in part counts for display systems, while also making it easy to reuse products in different car models. The CPU employs two ARM Cortex-9 cores along with the PowerVR SGX543 3-D graphics engine. The SoC also features Fujitsu Semiconductor's proprietary 2-D graphics engine. 3-D and 2-D graphics engines can run independently of one another for better graphics processing performance. **—by Christoph Hammerschmidt**

▷**Fujitsu Semiconductor**, www.fujitsu.com



The MB86R24 from Fujitsu Semiconductor processes the input of up to six cameras simultaneously, creating a 360° surround view of the vehicle.

Invisibility cloak hides objects from radio waves

Researchers at the University of Texas at Austin have built an "invisibility" cloak that can hide 3-D objects from microwaves. Unlike most previous cloaking techniques, which have used bulk metamaterials to bend incoming waves around an object, this latest approach uses a very thin, form-fitting "metascreen"—just microns thick—to cancel microwaves scattering off a 3-D object, making it invisible to microwave radiation.

The metascreen consists of strips of 66-µm-thick copper tape attached to a 100-µm-thick, flexible polycarbonate film in a fishnet design. In experiments it was able to hide a 7-inch-long rod from microwaves, with optimal functionality at 3.6 GHz.

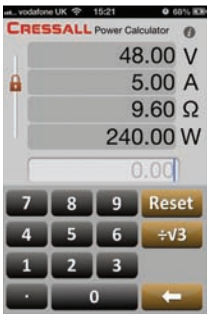
According to the researchers, such a "mantle cloaking" approach offers conformability, manufacturing, and bandwidth advantages over existing methods. In addition, it should be easier to realize at visible frequencies, although when applied to optical frequencies may be most efficient when used with micrometer-sized objects.

Possible applications for the latest technology include the next generation of optical nanodevices, and for optical computing, switching, biomarkers, and energy absorbers, as well as for possibly realizing optimal sensors that receive signals without affecting measurements. For more information, see the original paper, "Demonstration of an ultralow profile cloak for scattering suppression of a finite-length rod in free space," http://bit.ly/13WTJau.—by Rich Pell

▶**University of Texas at Austin**, www.utexas.edu

Ohm's Law iPhone app helps engineers back-solve electrical power calculations

Cressall Resistors is usually associated with heavy engineering, but the company also has software engineering expertise in-house, the first fruit of which is an iPhone app for solving Ohm's Law. The app has already been downloaded more than 1000 times in less than a month, an impressive total for a technical app and far in excess of the company's own targets.



The iPhone app from Cressall Resistors allows users to input any two of the key variables of volts, amps, ohms, and power, and calculates the other two.

Ohm's Law is the essential mathematical model that engineers use for mentally mapping out electrical circuits. The brainchild of Peter Duncan, who retired as managing director of Cressall Resistors at the end of 2012, the iPhone app originated as a routine for solving Ohm's Law on his handheld HP programmable scientific calculator. Duncan was using it daily and thought it would be useful to other electrical engineers because it allows them to input any two of the key variables of volts, amps, ohms, and power, and calculates the other two.

Once the first calculation is solved, an engineer can then change the value of any of the resulting variables, and the app will back-solve all of the other variables automatically.

"There are several Ohm's Law calculators in the Apple app store at the moment," says Chris Johnson of Cressall Resistors, "but they clear their data after each operation and you're forced to recalculate every time. With our app you can change any parameter value and keep playing around with it until you come to a satisfactory solution. If you're in any doubt about what you're doing, you can call up a power triangle diagram.

"The Android version is in development now and being ported over. We will extend the language options available, too, in partnership with our international agents who have volunteered to give us translations for their home markets. We are expecting to launch German, French, and Swedish versions soon."

The next release on the drawing board for the app is a star-delta calculator for three-phase electric motors. Every revision and new language will be offered free as an upgrade. Following the port to Android, Johnson anticipates one to Windows phones, written in Microsoft's own C# programming language. The app can be downloaded for free from iTunes.

—by Julien Happich

▷**Cressall Resistors**, www.cressall.com

VOICES

NI's Eric Starkloff: inspired by engineering ingenuity

Sixteen years ago, Eric Starkloff joined National Instruments (NI) as an applications engineer after earning a bachelor's degree from the University of Virginia. Now, as the company's senior VP of marketing, he presides over conferences, including NI Week, visits with customers, and explains the drive behind NI's progress. Starkloff was willing to take a few moments and reflect on his career so far. Read more of his conversation with *EDN* senior editor Janine Love at www.edn.com/4412937.

How did you get involved with test?

A In school, I focused on communication system design in terms of my EE concentration, but then got involved in a research project doing digital design with computer architectures. I was basically an ASIC developer and learned VHDL and digital layout "on the job." The work was very interesting, and unlike many university research projects, we were well funded and had some pretty cool toys. I remember getting to spend $65k on a new workstation in the mid-1990s—a quad-processor Sun with 1 Gbyte of RAM, which was outrageous at that time. I always think of that purchase when I buy a new tablet or smartphone, which at this point probably has more processing power than that workstation!

What has surprised you most about your career?

A I am constantly impressed by the incredible spectrum of challenges in society that engineers are addressing and the pace at which technology has changed in a fraction of a lifetime. At NI, our business touches virtually every discipline of engineering, and I've been fortunate enough to work on applications [including] the latest life-saving medical technologies, the coolest mobile devices, new alternative-energy systems, and even new frontiers in basic science. The ingenuity that engineers are bringing to each of these areas is inspiring to me. And this is true of test in general. As a test engineer, you get to touch so many different aspects of technology and engineering disciplines. There is never a dull day.

What frustrates you about the "standards" process? How could we do it better?

A Standards are necessary in our industry and can ultimately be a tide that raises all the ships of both vendors and customers. They work best when the line is clear between necessary precompetitive infrastructure we all need and the areas where vendors will differentiate and compete. This is critical

because our customers want multivendor compatibility, and they also don't want us all to reinvent the wheel each time; of course, they also benefit from competition and the innovation that it inevitably drives.

What makes your job fun?

A I get to visit with our customers throughout the world, and I enjoy learning not only about different applications but also about different cultures. I also enjoy the variety of challenges I get exposed to; I have a short attention span, so this suits me well!

What are the next biggest challenges for the T&M industry?

A I do believe we are facing some major disruptions. It starts with cost of test. The devices we are testing are getting more complex, and yet the cost to produce them is decreasing—both consequences of Moore's Law. Despite this, test hasn't kept pace and therefore continues to be a larger portion of the cost to invent and produce new technology. This has to change, and I believe software-defined modular systems, which also benefit from Moore's Law, are fundamental to bending this cost curve.

How has the role of the "test engineer" changed?

A Test engineers have had to become more proficient in software development as test systems have become more and more software centric. They have also had to learn new technologies at an increased pace. Take wireless test, for example. This used to be the domain of the specialist. We all know a guru microwave engineer. But, as wireless has permeated nearly every device, more and more test engineers have had to also learn to test wireless among numerous other functions on their device under test.

Would you consider yourself a "software" or "hardware" person? Or does that division even realistically exist anymore for test?

A I don't think it does. Software is increasingly important, but the need for good hardware design will never go away. I think some of the most interesting innovation happens at the intersection of the two.

Anything you would do differently if given the chance?

A I don't believe in regrets. However, I would do many things differently based on learning from mistakes I've made. That list is fairly long.

Any advice for new engineers?

A Get as many opportunities [as possible] to try new things early in your career. You might be surprised at what you love and where some hidden talents may lie. Also, don't be afraid to take risks. Our CEO, Dr Truchard, likes to say, "Even a turtle has to poke his head out every now and then."

BY HOWARD JOHNSON, PhD

Seek inspiration

1962: I was six, at my grandmother's house, eating pancakes and watching my favorite show on TV. Captain Kangaroo was talking to Mr. Moose about something not quite visible just off the right side of the screen. My grandmother entered the room. She looked at the big console television, tilted her head, and then tweaked the horizontal-position knob. The image shifted a bit to the left, revealing more at the right side. I sat in awe, jaw dropped, gaze transfixed.

When she left the room, I was all over that knob. If you turned it far enough, what would happen? Could you see off the edges of the set? Could you see the cameraman? Could you see yourself? My brain exploded with questions.

1972: I landed a summer job fixing TVs at the local Magnavox dealer. At night, I compared notes with my good friend Glen Collier, who was studying ham radio. Between the two of us, we came to a pretty good understanding of electronics. On the kind of brilliant Saturday afternoon when normal boys should be out-of-doors, Glen and I reversed the connections on the horizontal deflector coil of the new color TV in his family's living room, thus reversing the picture image, left to right. I still laugh when I recall the look on his mom's face, watching the news that evening, taking off her glasses and cleaning them, and putting them back on, vaguely aware that something was wrong with the TV but not sure what.

1982: Professor Martin Graham adopted me as his student. Marty was a rascal and a true genius. He spent the next 10 years passing along his understanding of high-speed electronics and computer architecture. Finding a mentor is one of the best career moves a young engineer can make. I know it sounds quaint, when YouTube and wiki-this and wiki-that can tell you everything you need to know in a minute, but a mentor fills the gap between knowledge and understanding, inspires you to learn more on your own, and opens doors that you never imagined existed.

1992: My experience in analog electronics, digital circuitry, and digital image processing led me to projects in voice mail, robotics, data transmission, video, and Ethernet. Each project taught me new lessons about ringing, crosstalk, ground bounce, and power system design—lessons I began communicating through my writings and public lectures. That kind of communication creates a whirling vortex of information. The more you communicate, the more people want to talk with you about their difficulties, and the more you learn.

2002: Ten years into the seminar business, I had gotten to know a lot of engineers. The successful ones all have something in common: They think of their career as a system, with inputs and outputs, and arrange the inputs to drive their career in the direction they want it to go. They realize that the more people you know, and the more varied your experience, the better your chances of landing a peach assignment (or surviving a major downturn). Therefore, they pick projects that introduce them to lots of other people and teach them new skills. They seek inspiration.

2012: Having lectured to 12,000 students in seminars all over the world, sold some 100,000 books, built up a program of high-speed digital engineering short courses at Oxford University, raised two wonderful daughters, and had the great pleasure of hearing from engineers like you the technical minutia of thousands of design issues, I began planning the end of my seminar business, and this, my last article for *EDN*. I do not know what the next phase of life will bring, but you can be sure that whenever some new electronic development comes forward, you will find me sitting in front of it, transfixed, gazing with the wonder of a small child. EDN

Howard Johnson will teach his last public seminar at the University of Oxford this month. He wishes you the best of success with your next product design and thanks you for your interest in high-speed digital design. If you appreciate his writing, please let him know by making a small donation to his favorite charitable foundation: www.methowmusicfestival.org.

BY BONNIE BAKER

Don't be fooled by your amplifier's bandwidth

As we design our SAR-converter analog circuits, we may be tempted to match the voltage-feedback amplifier's data-sheet bandwidth to the bandwidth of our analog signal source. We keep the amplifier bandwidths as low as possible, because faster amplifiers on the board potentially can produce layout headaches. These layout headaches come from putting higher-speed amplifiers in the circuit that are producing fast rise and fall times. The faster signals have the potential to produce EMI signals that other devices or traces on the board can receive, resulting in unexpected noise.

Given this scenario, it makes sense to keep the bandwidth of the circuit's amplifiers as low as possible. With a maximum signal frequency input from dc to 20 kHz, one would think that the required amplifiers would have very low unity-gain bandwidths or a gain-bandwidth product (GBWP).

On the contrary, you need higher-speed amplifiers in the circuit for two basic reasons. The primary reason is to accommodate the lost bandwidth in amplifier circuits that have a closed-loop noise gain greater than one. The other reason is to make sure the bits in your system at the end of the signal path can reliably convert the signal throughout the entire system's frequency range.

Figure 1 shows an example of how the amplifier's closed-loop gain affects the system's overall bandwidth. The GBWP of this amplifier is 20 MHz. The amplifier's closed-loop gain is 10V/V, or 20 dB. In our circuit, we already require an amplifier that has a bandwidth that is 10 times higher than our input signal. You can see this by comparing the intersect of the closed-loop gain ($f_{3\,dB}$) with the amplifier GBWP frequency (f_{GBWP}).

The amplifier characteristics shown in **Figure 1** appear to be a perfect fit, but we are looking for the correct amplifier for a 16-bit system.

One sticky point with this circuit is that the amplifier's closed-loop gain is not equal to 20 dB all the way up to 2 MHz. In fact, the closed-loop gain at 2 MHz is 17 dB. This is down 3 dB, which is approximately 70.7% lower than the closed-loop gain, or a 29.3% increase is needed to get up to that curve.

Of course, the circuit's closed-loop gain does not instantaneously change from 20 dB to 17 dB at 2 MHz. Instead, it gradually gets closer to the closed-loop gain curve starting about a decade before 2 MHz. A 20-MHz bandwidth for an amplifier should be good enough, but let's do the math.

This intersection has a simple, first-order attenuation. The correct formula to determine the attenuation back from the 3-dB point toward 0 Hz is $f_1=f_{3\,dB}\times\sqrt{(A_{CL\_DC}/A_{CL1})^2-1}$, where A_{CL1} is the target closed-loop gain, A_{CL_DC} is the closed-loop gain at dc, f_1 is the target frequency, and $f_{3\,dB}$ is the corner 3-dB frequency of this amplifier system. If you make A_{CL1} equal to 9.9988752, which produces a ~0.0112% error at the full-scale frequency, the bandwidth of the closed-loop system is approximately 100 times lower than $f_{3\,dB}$.

With our amplifier circuit, we are not so lucky. We have a 20-kHz signal that we need to increase by 10 times. At the end of the signal chain, we have a 16-bit converter. We find that a 20-kHz amplifier does not work for our circuit. With a signal gain of 10V/V, or 20 dB, the amplifier bandwidth needs to be at least 10 times higher than the signal. We also find that the amplifier bandwidth needs to be at least 100 times higher to maintain ADC integrity. This situation places our amplifier unity-gain bandwidth at 20 MHz. So much for lower-speed amplifiers. **EDN**

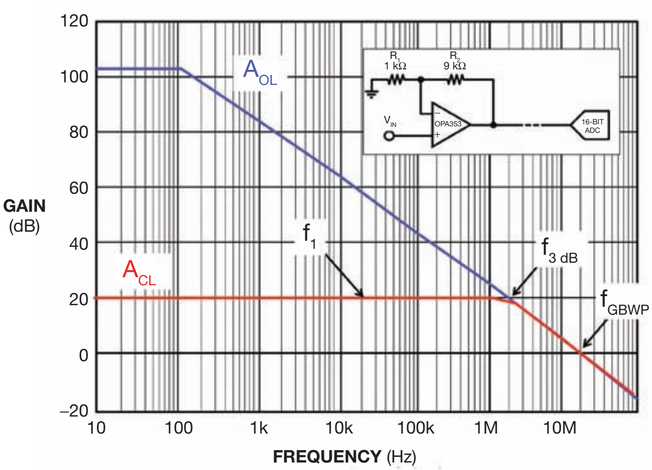


Figure 1 The system bandwidth becomes lower due to the closed-loop (A_{CL}) intercept point with the amplifier's open-loop gain (A_{OL}) and the need to accommodate bit accuracy across the entire frequency range at f_1.

REFERENCE

1 "OPA353 data sheet," Texas Instruments, www.ti.com/opa353-ca.

Bonnie C Baker is a senior applications engineer at Texas Instruments.

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The engineer's mind

With this being the final print issue of *EDN*, I thought I'd cleave a piece off our recent Mind of the Engineer study to provide a view of your perception of the engineering mind, so this one's all about you: what you think of you, and what you think others think of you. There are some surprises, some affirmations, and of course, some fun twists.

The charts below at first look imposing, but here's how to read them: They show the mean aggregate of pairs of opposing terms, which anchor either end of a scale (from −5 to +5). For each pair of anchored terms, respondents adjust this scale to more accurately express their sentiments about engineers. In the case of **Figure 1**, your peers were asked to review a series of words or phrases that might describe how they view themselves as an engineer. In the case of **Figure 2**, they were also asked how others (non-engineers) generally view you, as engineers.

Some quick observations: We generally see ourselves as being risk takers, extroverted, humble, and smart and having a wide range of interests (**Figure 2**). As we mature in our careers, however, we tend to take more risks, get less humble (More confident, or worse, arrogant?), feel more content (Less ambitious? Settling?), and have a wider range of interests (Done the engineering thing, now what? Retirement?).

For many, **Figure 2** will be rather amusing. We think we're risk takers, humble, and ambitious and have a wide range of interests, while we think others view us as risk-averse, borderline arrogant, and not so ambitious and with a very narrow range of interests. Could it be that we're a bit misunderstood? Maybe even feared? For example, we think others view us as smarter than even we think we are! Is that even possible?

Like all studies, you could spend (Waste?) a lot of time analyzing the conditions and parameters of the research: the caveats, biases, sample numbers and source database, culture, conditions, and on and on. Don't do that. Just look at the findings, have some fun with it, take away things that correlate with your experience, and then send this to someone who's not an engineer. See what they think of us!

Add your comments, your observations, and your friends' feedback to this post at www.edn.com/4415695.

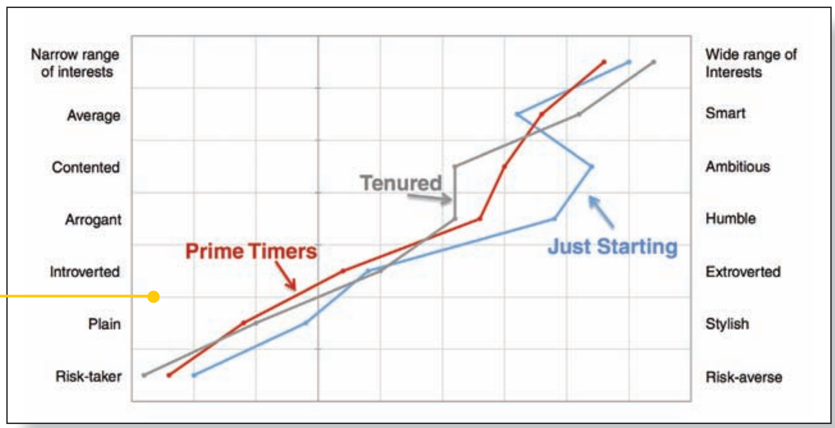

Figure 1 As we grow, we remain somewhat introverted but become a lot less humble (More arrogant?), take greater risks, and have a wider range of Interests.

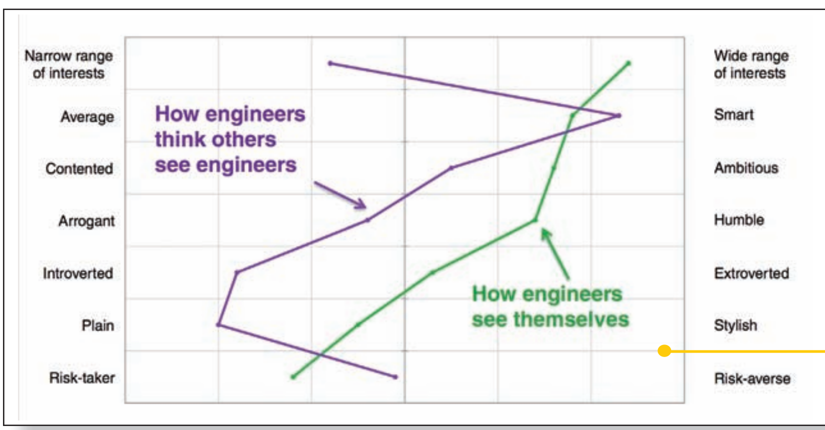

Figure 2 Oddly, we think people view us as smarter than even we think we are. How could that possibly be?


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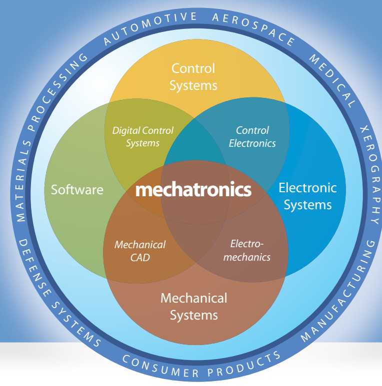

Managing complexity and reducing risk

High-risk technologies exist everywhere. How should engineers respond?

By Kevin C Craig, PhD

This column, over the years, has had the theme that human-centered, model-based design is the most direct path to insight and innovation. The innovation diagram (**Figure 1**) shows the added importance of viability and sustainability, and also introduces the need to manage complexity.

We are now surrounded by high-risk technological systems in all aspects of our lives. Is the potential for catastrophic failure inherent in the system itself, or in the way the system was designed? Charles Perrow, in his most relevant book, *Normal Accidents* (Princeton University Press, 1999), addresses this question and develops an explanation based on system characteristics.

Systems are fundamentally made up of components or parts. A functionally related collection of components forms a unit. An array of units forms a subsystem. Subsystems come together to form the system. An accident is a failure in a subsystem, or the system as a whole, that damages more than one unit, and in so doing disrupts the ongoing or future output of the system.

What kinds of systems are prone to system accidents? To answer this question, you need to consider two concepts: interactiveness and coupling.

The notion of baffling system interactions is increasingly familiar to all of us. Interactiveness is not a problem if the interactions are expected and obvious. However, components sometimes have a common-mode function in that if one fails, other modes fail. The situation then gets more complex. Ironically, complexity is often added to a system to reduce common-mode failures.

Proximity and indirect information sources are two other indicators of interactiveness.

Simple, comprehensible interactions are predominant in all systems. But as the complexity of a system increases, the probability that baffling, unintended interactions exist increases dramatically. This classification is fuzzy, and systems must be characterized in terms of the degree of either quality. Complex systems are not undesirable. They typically are more efficient with less slack, less underutilized space, less tolerance of low-quality performance, and more multifunction components. But they also could have the potential for catastrophic failure.

The second concept to consider is coupling. Tightly coupled systems have more time-dependent processes, the sequences are invariant, and there is little slack. The overall design of the system allows only one way to reach the goal. Coupling is particularly germane to recovery from inevitable component failures. In tightly coupled systems, the buffers, redundancies, and substitutions must be designed in; they must be thought of in advance. In loosely coupled systems, there is a better chance that expedient, spur-of-the-moment buffers, redundancies, and substitutions can be found.

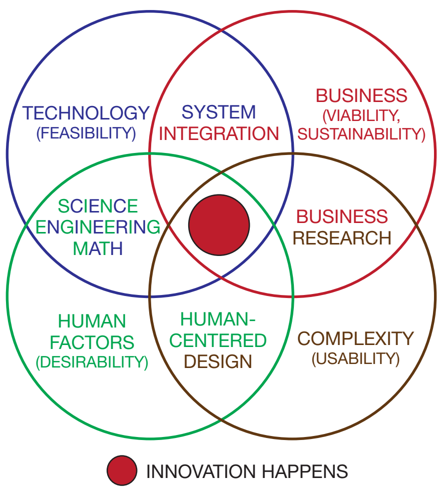

Figure 1 The innovation diagram shows the added importance of viability and sustainability, and also introduces the need to manage complexity.

The world of systems can be organized according to two largely independent variables: loose versus tight coupling and predictable versus baffling interactions. Loosely coupled, predictable systems include assembly-line production and most manufacturing, while tightly coupled, predictable systems include rail transport and dams. Loosely coupled, complex-interaction systems include R&D firms and universities, while tightly coupled, complex-interaction systems include nuclear plants, aircraft, and space missions.

There are no answers here. Engineers must manage complexity and prevent catastrophic failures. Interactiveness and coupling are two concepts that should aid engineers in accomplishing that goal. EDN


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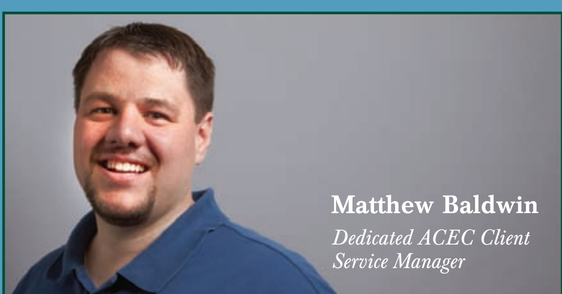
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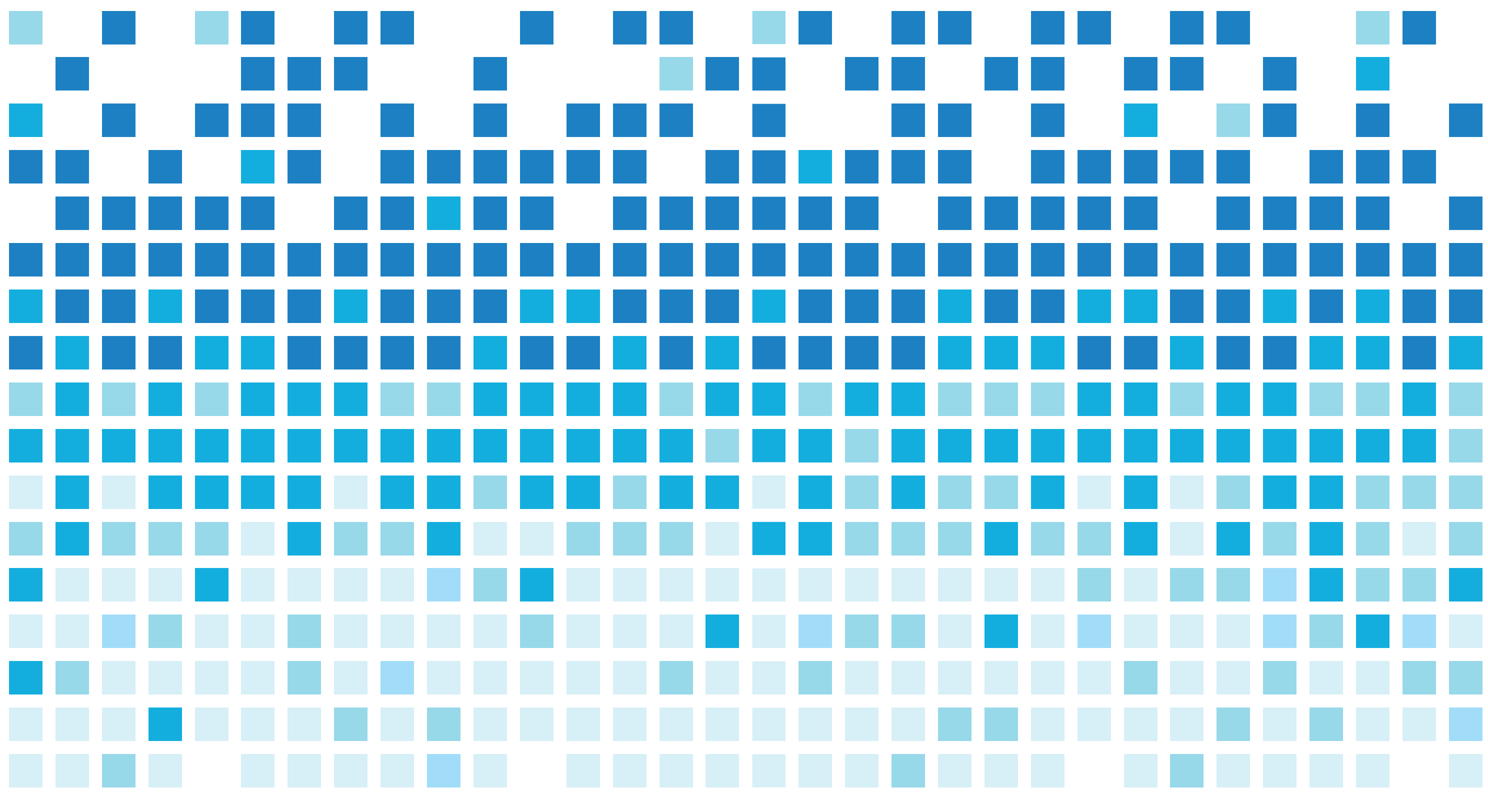

COUNTING SQUARES: A METHOD TO QUICKLY ESTIMATE PWB TRACE RESISTANCE

COMPLEX GEOMETRIES CAN BE BROKEN UP INTO DIFFERENT SIZE SQUARES OF COPPER TO APPROXIMATE THE ENTIRE REGION OF INTEREST.

VINCENT SPATARO • BAE SYSTEMS

We often have a need to quickly estimate the resistance of a printed wire board trace or plane without resorting to a lengthy calculation. Although printed circuit board layout and signal-integrity computer programs exist that can accurately compute trace resistance, we sometimes want to be able to make a fast rough estimate as part of the design process.

A method that allows us to accomplish this task with very little effort is called "counting squares." Using the method, you can make accurate (within 10% or so) estimates of any trace geometry in just seconds. Once you understand the method, you simply divide the printed wire board area that you want to estimate into squares and then count all of the squares to estimate your total trace or plane resistance.

THE BASIC CONCEPT

The key concept in counting squares is that any size square of printed wire board trace (of a given thickness) has the same resistance as any other size square. The resistance of the square depends only upon the resistivity of the conducting material and the thickness.

This concept can be used on any type of conducting material. **Table 1** shows a number of common conductors, along with their bulk resistivity.

For printed circuit boards, the most important material is copper, which is used to fabricate most circuit boards. (Note that aluminum is used to metallize integrated circuit die, and these principles apply there, too.)

Let's start by looking at the square of copper represented by **Figure 1**. The copper has a length (L), and because it is a square, a width (L). It has a thickness (t), and the current flows through the cross-sectional area of copper (A). The resistance of this copper square is expressed simply as R= ρL/A, where L is the resistivity of the copper (an intrinsic property of the material—0.67 µΩ in. at 25°C).

But notice that the cross-section A is just the length times the thickness. The result is that the L in the denominator cancels the L in the numerator, leaving R=ρ/t. Hence, the resistance of the copper is independent of the square's size. It just depends upon the resistivity of the material and the thickness.

AT A GLANCE

- Any size square of PWB trace (of a given thickness) has the same resistance as any other size square.
- Accurate (~10%) estimates of any trace geometry can be made in just seconds.
- The concept works on any type of conducting material.
- The resistance of any size square becomes a known quantity once the copper weight is determined.
- The resistivity of a corner square counts as fewer squares due to higher current density.
- Each via has a finite resistance that must be considered in the overall calculation.

If we know the resistance of any size square of copper and if we can break up the entire trace that we want to estimate into a number of squares, then we can simply add up (count) the number of squares to find the total resistance of the trace!

IMPLEMENTATION

To implement this technique, we need only a table showing the resistance of a square of printed wire board trace as a function of the thickness of our copper. Copper thickness is commonly specified by copper weight. For instance, 1 oz. of copper weighs 1 oz. per square foot.

Table 2 shows four of the most commonly used copper weights and the resistivity of each at 25°C and 100°C. Note that the copper resistance increases with increasing temperature, owing to the positive temperature coefficient of the material.

We now know, for example, that a square of 0.5-oz. copper has a resistance of about 1 mΩ. This is regardless of the size of the square. If we can break up the printed wire board trace that we want to measure into imaginary squares, then adding up all of the squares in series will give us the resistance of the trace.

A SIMPLE EXAMPLE

Let's take a somewhat trivial example. **Figure 2** shows a rectangular trace of copper, which is assumed to weigh 0.5 oz. at 25°C. The trace is 1 inch wide and 12 inches long. We can divide this trace into a series of squares, each 1 inch long on a side. There would be 12 squares altogether. Since each square of 0.5-oz. copper is 1 mΩ according to **Table 2**, and there are 12 squares in series, the total resistance of the trace is 12 mΩ.

WHAT ABOUT CORNERS?

Before we look at a less trivial example to realize the power of this technique, let's look at a few refinements.

The first thing to realize is that, in

TABLE 1 BULK RESISTIVITY OF COMMON METALS USED FOR ELECTRICAL INTERCONNECTS

Metal	Bulk resistivity (uΩ-in.)
Aluminum	1.11
Copper	0.665
Gold	0.866
Molybdenum	2.24
Silver	0.642
Tungsten	2.13

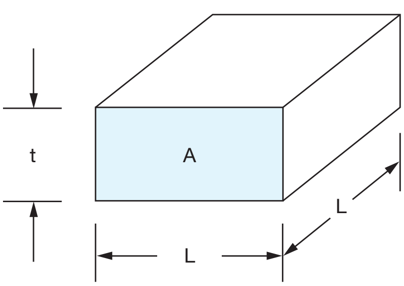

Figure 1 A square of copper can be represented with a length (L) and, because it is a square, a width (L) and a thickness (t).

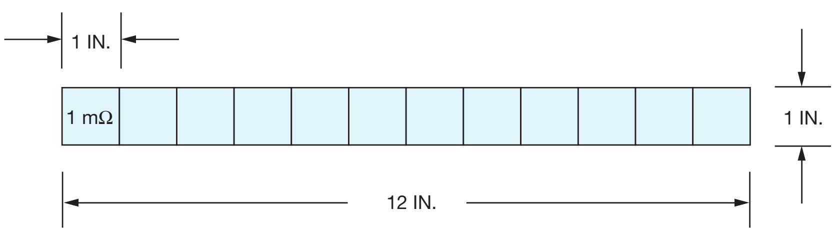

Figure 2 This example 1×12-in. rectangular trace of copper, assumed to weigh 0.5 oz. at 25°C, comprises 12 squares in series, resulting in a total resistance of 12 mΩ.

TABLE 2 COPPER RESISTANCE VERSUS WEIGHT

Weight (oz.)	Thickness (mm/mils)	mΩ/square at 25°C	mΩ/square at 100°C
0.5	0.02/0.7	1	1.3
1	0.04/1.4	0.5	0.65
2	0.07/2.8	0.25	0.36
4	0.13/5.3	0.13	0.18

the previous case, we assumed that current in our square flowed in a straight line along the length of the square, from one end to the other, as illustrated in **Figure 3a**. However, if current is taking a right-angle turn—for example, in a corner square, as shown in **Figure 3b**—the situation is a bit different.

Here we see that the current has a shorter path to take in the lower left section of the square than it does in the upper right. As a result, the current tends to crowd in the lower-resistance, lower-left-hand section. The resultant current density is higher in this section than what we see in the upper-right-hand section. The spacing of the arrows illustrates this disparity in current den-

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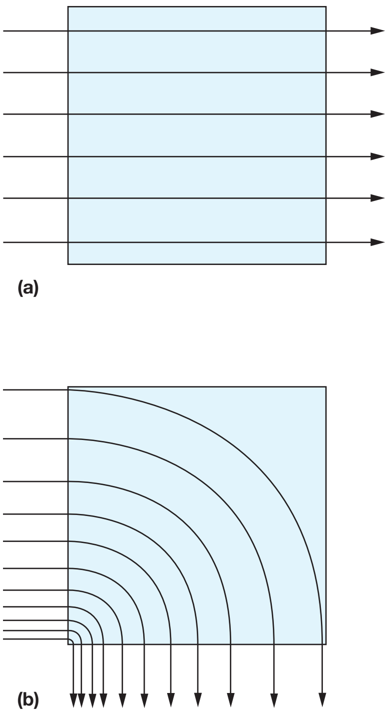

Figure 3 The previous example assumed that current in the square flowed in a straight line along the length of the square, from one end to the other (a). If current takes a right-angle turn in a corner square, as shown, we see that the current has a shorter path to take in the lower left section of the square than it does in the upper right (b).

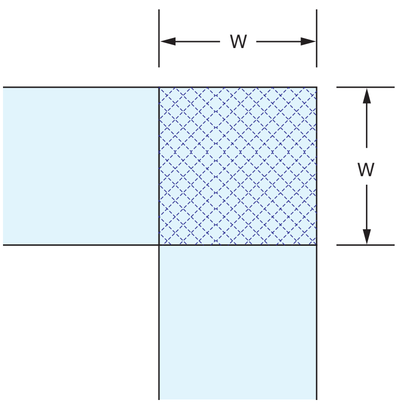

Figure 4 The higher current density resulting when current flows around a corner means the resistivity of a corner square counts as only 0.56 squares.

sity. As a result, the resistivity of a corner square counts as only 0.56 squares (**Figure 4**)[1].

Similarly, we can make corrections for connectors that are soldered onto a printed circuit board. Here we make the assumption that the resistance of the connector is negligible compared with the resistance of the copper board.

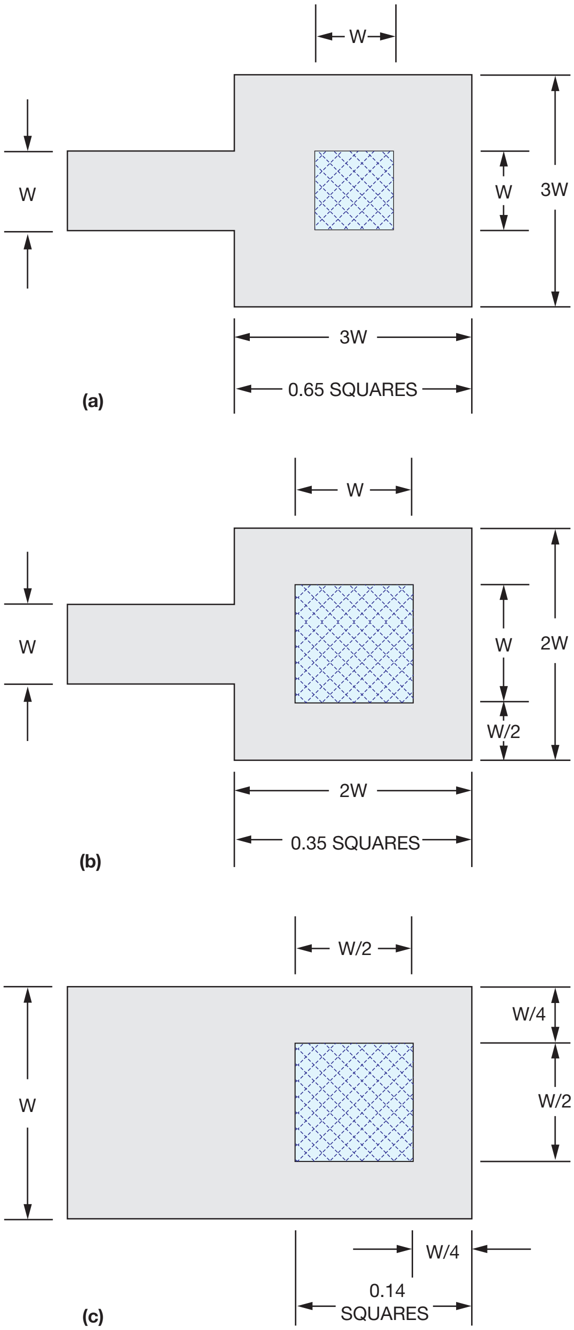

Figure 5 For the case of a connector soldered onto a board, we make the assumption that the resistance of the connector is negligible compared with the resistance of the copper board, resulting in a lower estimate of that square's resistance. Shown are three connector-pin configurations and their equivalent square counts: equivalent to 0.65 squares (a), 0.35 squares (b), and 0.14 squares (c).

We can see that if a connector occupies a significant portion of the copper square that is being evaluated, the resistance of that square should be commensurately lower. Three connector-pin configurations and their equivalent square counts[1] are given in **Figure 5**. The shaded regions represent the connector pin in the field of copper.

A MORE COMPLEX EXAMPLE

Let's now look a less trivial example to see how we can use this technique. **Figure 6a** shows a more complex shape that would require some work to calculate its resistance. Our assumption for this example is that we are using 1-oz. copper at 25°C, and current is flowing along the entire length of the trace, from point A to point B. Connectors are placed at each end, A and B.

Using the same technique discussed previously, we can break the complex shape into a series of squares, as shown in **Figure 6b**. The squares can be any size that is convenient, and different size squares can be used to fill the entire area of interest. As long as we have a square and the weight of the copper trace is known, we know the resistance.

We count six full squares, two squares containing connectors, and three corner squares. Because 1-oz. copper has a resistance of 0.5 mΩ per square, and the current flows linearly through six full squares, the total resistance for these squares is 6×0.5 mΩ=3 mΩ.

Then we add the two squares that have connectors attached, which count as 0.14 squares each (**Figure 5c**). Therefore, the two connectors count as 0.28 squares (2×0.14). For our 1-oz. copper, this adds 0.14 mΩ (0.28×0.5 mΩ=0.14 mΩ).

Lastly, add the three corner squares. These squares count as 0.56 squares each, contributing a total of 3×0.56×0.5 mΩ=0.84 mΩ. So the total resistance from A to B is 3.98 mΩ (3 mΩ+0.14 mΩ+0.84 mΩ).

To summarize, we have the following:

- Six full squares at 1=6 equivalent squares; two connector squares at 0.14=0.28 equivalent squares; and three corner squares at 0.56=1.68 equivalent squares
- Total equivalent squares=7.96 equivalent squares
- Resistance (A to B)=7.96 squares at 0.5 mΩ per square=3.98 mΩ

The technique can be easily extended to more complex geometries. Once the resistance of a particular trace is known, it is simple to calculate other quantities of interest, such as voltage drop or power dissipation.

TABLE 3 RESISTANCE OF COMMON VIA SIZES

Via-hole diameter (mils)	mΩ 25°C	mΩ 100°C
12	4.3	5.6
14	3.6	4.7
18	2.8	3.6
20	2.5	3.2
24	2.1	2.7
30	1.6	2.1
38	1.3	1.7

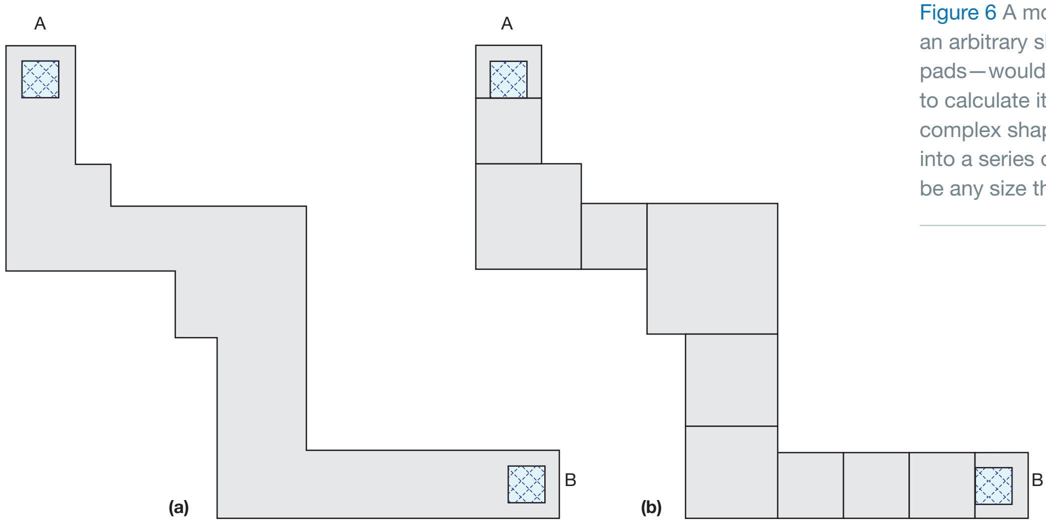

Figure 6 A more complex shape—an arbitrary shape with connector pads—would require some work to calculate its resistance (a). The complex shape can be partitioned into a series of squares, which can be any size that is convenient (b).

WHAT ABOUT VIAS?

Often, printed wire traces or planes are not confined to a single layer but continue on a different layer in the stackup. Vias are used to connect traces together on different layers. Each via has a finite resistance that must be considered in the overall calculation of the trace resistance.

Generally, vias constitute series-resistance elements when they connect two traces (or planes) together. Multiple vias are frequently employed in parallel to reduce their effective resistance.

The calculation of via resistance is based upon the simplified via geometry shown in **Figure 7**. Current flows along the length of the via (L), as indicated by the arrow, and through a cross-sectional area (A). The thickness (t) is based upon the plated thickness of copper inside the walls of the via.

After some simple algebra, the resistance of the via is expressed as $R=\rho L/(\pi(Dt-t^2))$, where ρ is the resistivity of plated copper (2.36 μΩ-in. at 25°C). Note that the resistivity of plated copper is much higher than that of pure copper. We can assume that t, the thickness of the plating in the via hole, will generally be 1 mil, regardless of the copper weight of the board. For a 10-layer board, built using 3.5-mil cores and 2-oz. copper, L is about 63 mils.

Based on these assumptions, **Table 3** shows commonly used via sizes, along with their resistances. We can easily ratio the numbers up or down for our particular board thickness. Alternately, a number of free, easy-to-use via calculator programs are available online[2, 3].

A simple method of estimating the dc resistance of a printed wire board trace or plane was presented. Fairly complex geometries can be broken up into various size squares of copper to approximate the entire region of interest. Once the copper weight is determined, the resistance of any size square becomes a known quantity. The estimation process is then reduced to simply counting the squares of copper. **EDN**

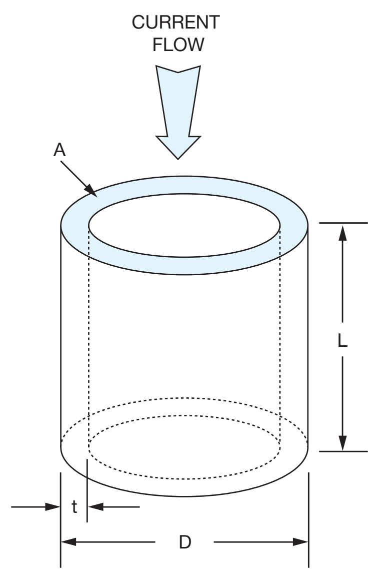

Figure 7 The calculation of via resistance is based on the simplified via geometry shown. Current flows along the length of the via (L), as indicated by the arrow, through a cross-sectional area (A). The thickness (t) is based on the plated thickness of copper inside the walls of the via.

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AUTHOR'S BIOGRAPHY

Vince Spataro is a senior member of the technical staff at BAE Systems, Wayne, NJ. He has more than 30 years of experience in the analysis, simulation, and design of commercial/military/aerospace power supplies, as well as experience with a wide range of analog and mixed-signal circuitry. Spataro received a bachelor's degree in physics from Fairleigh Dickinson University (Teaneck, NJ) and a master's degree in engineering physics from Stevens Institute of Technology (Hoboken, NJ). He holds two patents in the power-conversion technology field.

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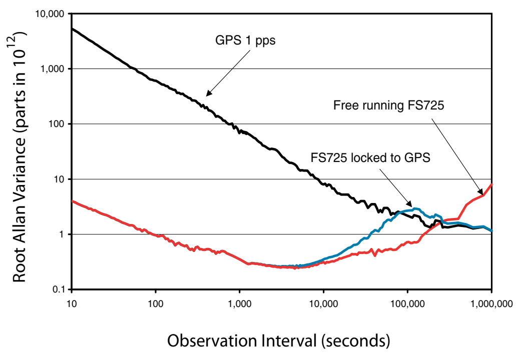

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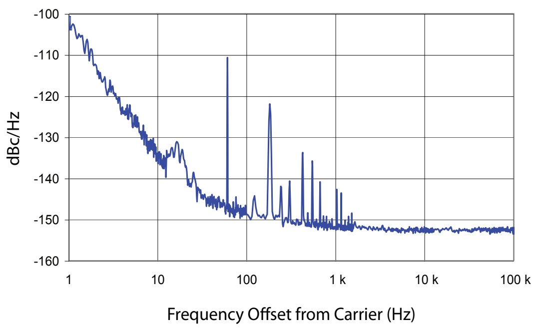

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POWER TO THE PEOPLE

BY SUZANNE DEFFREE • EXECUTIVE EDITOR

There's a growing design trend, some even say there's a revolution brewing, that's beginning to have an impact on the world of design and how engineers go about innovating. Open source—buoyed by the likes of Raspberry Pi, Arduino, 3-D printing, embedded Linux, and strong community knowledge sharing and feedback—is coming to the world of hardware faster than many may think, and with it could come an increasingly democratized approach to the design cycle.

In the world of open source, hardware is years behind software, which is predominantly led by Linux. And there's a key reason for the discrepancy: Hardware is physical, making it more costly and difficult to reproduce. Beyond that, licensing can still be nebulous in some cases, and concerns about IP theft and who profits also hold some back.

But the benefits—including the ability to prototype quickly off of existing, shared work, input from user communities, and low cost or no cost to entry—outweigh the concerns for many design engineers, makers, hackers, or hobbyists, as well as young companies such as SparkFun and Gadget Factory and even more established industry players. These benefits, for many, enhance professional engineering. And open-source hardware is finding its way into designs for everything from fun facial-recognition cameras that add mustaches to photos, to smart watches, to the technology used in the Red Bull Stratos space jump.

The democratization of engineering

WHEN IT COMES TO OPEN SOURCE, SOFTWARE IS YEARS AHEAD OF HARDWARE. BUT WITH ENCOURAGEMENT FROM ESTABLISHED ELECTRONICS-INDUSTRY PLAYERS AND MOVES FROM MAKERS AND HACKERS, ENGINEERS COULD SEE OPEN-SOURCE HARDWARE AND AN INCREASINGLY DEMOCRATIZED, COMMUNITY-BASED APPROACH WORKED INTO AND ENHANCING THEIR DESIGN CYCLES.

IMAGE: SHUTTERSTOCK

The definition of what is open source and what is not can be somewhat foggy, varying from company to company or engineer to engineer. According to the Open-Source Hardware Association (OSHWA):

Open-source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it. Ideally, open-source hardware uses readily available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open-source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.

What can't be defined, however, are the spirit and passion that open-source hardware ignites in some engineers and developers. Such an excitement is evident at events such as Burning Man and Maker Faire, where creativity, often expressed through open-source hardware, is put on display.

Atmel Corp, for one, has for years been cheering on Arduino, a leading open-source electronics prototyping platform and community. The company continues with its traditional lines but has also begun incorporating Arduino into some products, and showed off its Arduino development boards based on Atmel AVR UC3, megaAVR, and SAM3X8 ARM processor-based MCUs at last month's Maker Faire Bay Area.

AT A GLANCE

- Open source can enhance professional engineering and design by expanding the creative pool, offering routes to quick prototyping, and encouraging learning and knowledge sharing.
- User feedback from open-source communities becomes invaluable as part of an increasingly democratized approach to design.
- It's not just start-ups and independent hackers and makers involved in open source. Established electronics-industry players include Atmel and Texas Instruments.
- "Free" and "open source" are different things, with the definitions of open-source hardware and open-source software largely dependent on licensing.
- Open source can be profitable, with some open-source hardware companies showing tremendous growth and profit.

Bob Martin, Atmel's applications manager, hacks a hexbug and puts in an Atmel microcontroller so the bug has intelligence during Maker Faire Bay Area 2013 in May.

Open-source design wins for Atmel include the Agent Smart Watch, prototyped on an Atmel SAM7X-powered Netduino open-source electronics board. Built by Secret Labs and House of Horology and introduced on Kickstarter, Agent had received more than $850,000 in funding as of press time for this article, a whopping eight and a half times its original $100,000 goal. The smart watch is expected to ship this fall with a finished dual-processor design, using an Atmel SAM4S microcontroller and a tinyAVR.

Eric Weddington, open-source community manager at Atmel, notes that there's been a major increase in the number of companies that are using Ardunio and open-source hardware for prototyping and then further on in product development. "Democratization of engineering: We're already seeing that happen," says Weddington. "Arduino has made it so easy to get involved in a complex subject, embedded engineering, which in the past has been the purview of engineers who have a wide range of skills, both hardware and software, in dealing with conflicting restraints and requirements, especially in deeply embedded systems. It has been a kind of very exclusive party of people who can work in embedded systems. But with open-source hardware and Arduino, and open-source software, it has become so easy to use that all of these people who have never had a chance to do [embedded engineering] before can be brought in. That, to me, is the story. It opens up a lot of creativity. People come up with all sorts of uses for the Arduino."

Atmel is not the only big-name player in electronics engineering to broaden its scope and include open source in its strategy. Texas Instruments Inc supports open source through its LaunchPad kits and BeagleBoard and BeagleBone products. BeagleBoard.org—a community where professional developers and hobbyists alike collaborate, showcase projects, ask questions, and offer feedback—launched in 2008 and now averages 50,000 hits per week as one of the most active open-source communities in the industry.

TI's latest addition to the Beagle family is the $45, 1-GHz BeagleBone Black open-source Linux computer, released at DESIGN West in April and based on the company's 1-GHz Sitara AM335x ARM Cortex-A8 processor. More than 30 plug-in boards, which the BeagleBoard.org community calls "capes," are compatible with BeagleBone Black, and more capes are expected. Integration of BeagleBone Black with these capes—such as 3-D printers, a DMX lighting controller,


INNOVATORS THINK STATUS-QUO IS LATIN FOR "I QUIT."
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The Agent Smart Watch, prototyped using an Atmel SAM7X-powered Netduino, offers two-way communication to smartphones, wireless charging, and long battery life.

a Geiger counter, a telerobotic submarine, and LCD touch screens—so far has received positive reviews.

Black has even gotten a thumbs-up from Limor "Ladyada" Fried, recently named *Entrepreneur* magazine's Entrepreneur of the Year in the established-engineer category for her work as a longtime supporter of open-source design and founder of Adafruit Industries, which is selling the Black platform.

Jason Kridner, co-founder of BeagleBoard.org and TI software architecture manager for embedded processors, points out that there's a difference between free hardware and open-source hardware. "You can have things that are freely available, but there can still be things in the licensing terms that restrict where you can go and what you can do with it. Whether or not it's open source is really just in the license terms, not in how much you pay for it or don't pay for it," he explains. "Sometimes there are things where you need to contribute back, and that's an important part of growing the community. But for the most part, we [at TI] try to make sure you can do what you want, and for certain that you can do what you want with the hardware."

Contributing back often comes in the form of feedback in such open-source communities. "The most valuable element that the community lends is the improvement cycle, the feedback cycle," says Chris Taylor, an engineer at 10-year-old SparkFun Electronics, an open-hardware company that's growing quickly with more than 130 employees and 450 original products.

"In our case at SparkFun, when we post a design's code online and someone takes that code, uses it, and finds an improvement or an error, we can make the improvement immediately, thanks to the community," Taylor adds. "If the hardware has an improvement to be made, that is put as a comment on the product page as a forum. Because it's open source, anyone can make an improvement, and when SparkFun sees it, they put the improvement into the revision cycle. So the next version of that product is going to be better because of that community. That feedback, coupled with agility to turn out a new product, is the benefit to having the open-source community."

Gert van Loo, who developed the prototype of the extremely popular Raspberry Pi board and created the Gertboard, an IO expansion board for the Raspberry Pi with a lot of flexibility, points out that the Pi would be nowhere without community feedback. The Pi was created to spur creativity and computer science and engineering learning—a goal it has achieved tremendously—but van Loo notes that the low-priced board never would have achieved this without nourishment from the open-source community.

The $45 BeagleBone Black is a credit-card-sized, Linux computer open-hardware and -software development platform.

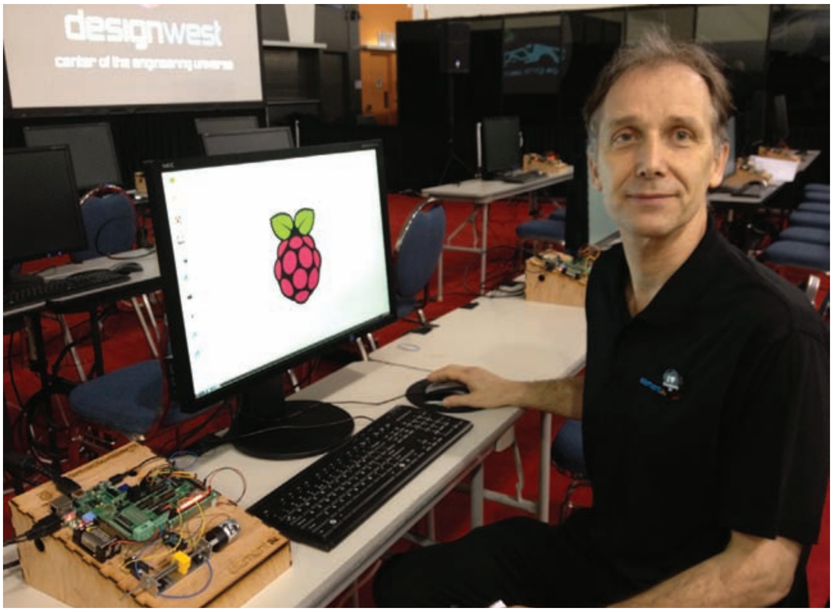
"The plan has always been from the beginning to throw a lot of boards into the community, and then quite a lot of the development for the education, support, software, and drivers, all that stuff that you needed, would come back from open source again. That was always the idea," he says. "At the beginning, it was very clear that the final target was education, but the first batch that went out into the world we knew would definitely not be going into education. That would have been a disaster. This line of development, envisioned by [Eben Upton, founder of the Raspberry Pi Foundation], was the initial target we followed."

SKILLS, BUT CAN THEY PAY THE BILLS?

While all of this giving back is wonderful knowledge sharing, the big question to some engineers then becomes one of income and payment for IP. How will the individuals who participate in these communities benefit if they do so for free? Who's getting paid?

"The Linux foundation has good stats in this," says Brad Dixon, director of open source and tools solutions at Mentor Graphics Corp, which plays in open source with its Embedded Alley runtime Linux and Android offerings and CodeSourcery GNU-based toolchains for embedded development. "It's a myth that people think the Linux kernel is created by hobbyists at home. The overwhelming majority of people who contribute to Linux do so because it's their job and they get paid to do it. People contribute because they get paid.

"Often you see people contribute because it benefits them. There's an issue they've struggled with, and they know that if they can make the improvement they won't have to fight it again. Or, in many cases, they want to get into a field and this is their way to audition, to be part of a global talent pool. We have a number of engi-



Gert van Loo sets up a Gertboard at a workshop during April's DESIGN West 2013 event. Everyone who attended this session received a free Gertboard provided by Newark element14.

neers [at Mentor] that we've met along the way in the open-source world that we've [invited] to come work for us."

When it comes to open source as a base for a start-up business, things can get tricky, say the founders of Gadget Factory, the four-year-old company behind the Papilio FPGA platform, that is quickly making a name for itself.

"Without open source, none of the products we've made so far would even exist. That's why all of our boards are open source. We want people to be able to build on top of what we've done," says founder Jack Gassett.

But Gassett believes there needs to be another revision of the open-source-hardware (OSHW) license to allow for better commercial licensing. "At the end of the day, we live in a capitalistic society. Open source is sometimes at odds with that," he explains. "We are running a business, and our intention is to build the business and make money. We continue to gather resources so that we can continue to invent and bring new products to the market, but neither one of us are setting out to be millionaires."

Adds his partner, Kalesh Weaver, a former hacker, "Open source isn't saying don't make money; it's saying the information is free. Every successful open-source community has a successful side commercial community, usually made of the developers who first started working on it and know it best. Don't those people deserve to be paid to keep working on it?

"Look at the Internet and freedom of information. It's changing cultures across the world. And that's what the hackers have said all along: We can't stop it; just find your niche and do it well, and someone will compensate you for it."

As a group, the OSHWA is reviewing licensing as part of exploratory meet-ups it calls "document jams," where active OSHW developers gather to discuss and look for ways to make more standardized open-source design documentation. This includes unclear licensing and fear of infringement on IP rights that the group believes may discourage people from producing documentation. Says the OSHWA, "Documenting involves reuse of content from other sources. If people do not understand IP licenses or have little understanding of their own IP rights to use content, they may be afraid to contribute documentation. A clear how-to on open hardware documentation IP issues, as well as a legal support framework, can mitigate this."

That's not to say that closed-source hardware doesn't have its own set of licensing and IP issues, nor to suggest that open-source hardware design immediately comes with licensing and IP problems.

"You always have to understand the license under which you acquire intellectual property. Whether it's an open license or closed license, you have to understand what you are getting," TI's Kridner says. "An open nature doesn't necessarily generate a problem; you just always need to be aware of the terms under which you acquire intellectual property."

NEAR-TERM LIMITS, BUT WITH LIMITLESS POTENTIAL

Clearly in the near future, engineering won't jump to entirely open-source hardware design, just as all software design has not become Linux based. But there's tremendous potential ahead for enhanced design as more individual engineers and companies embrace it.

"There's no such thing anymore as hobbyist hardware," van Loo says. "Processors and PCB electronics are no longer simple to develop. That's a reason why open-source hardware is gaining place. A high-end processor is not trivial to design anymore. On the other hand, for a big company it's peanuts compared to what they spend on marketing and everything else.

"[Open-source hardware] makes it easy to select a processor, try it out, and a lot of amateurs can use it, but it only goes so far," he adds, cautioning against the use of current open-source hardware in areas that have to be absolutely safe and excessively tested, such as automotive and military.

LIKE THIS?

For more open-source articles, products, and projects, visit *EDN*'s DIY Design Center at **www.edn.com/design/diy**.

OPEN-SOURCE HARDWARE: ARE YOU ON BOARD?

We recently asked EDN.com's community of engineers if they were on board with open source. Here's what some of you said:

▶ **"I view open-source hardware as like any other tool ... it has a time and a place where it is the right thing to use. Would I use open-source hardware for an actual production product? No, simply because of the requirements needed for the industries I am involved in."**—sam512bb

▶ **"After one of the staff engineers converted our teaching lab over to Arduino, I've been hooked. The ability to prototype so quickly and cheaply overcomes so many of the drawbacks of open-source hardware for test, measurement, and prototyping."**—Casey H

▶ **"I am actually about to start a computer project with my university club. I guess we'll put it as open-source hardware/software. In that way, even after we leave [university], the project will continue to live, hopefully ... "**—Ajmal14

▶ **"If I publish my design as open source, it prevents anyone else from patenting it and preventing me from using it without paying them a licensing fee."**—Douglas.Butler

Share your own thoughts at www.edn.com/4412385.

Still, open-source hardware and its simple systems are part of a broader change. "Open-source hardware is just one component of the democratization of manufacturing overall," says TI's Kridner. "There's an outburst of maker spaces and hacker spaces. There's been the development of tools around laser cutters and 3-D printers, and all these things that you need to do professional-grade manufacturing seem to be accessible to the average person. That's really democratizing manufacturing."

Indeed, when companies such as Cooking Hacks can offer an Arduino-based 3-D printer kit for around $850 that allows for inexpensive and quick production of mechanical parts for prototyping (see page 14), there's a potential shift in design methodology.

"We're getting closer and closer to being able to e-mail someone a design and print out a cell phone," says SparkFun's Taylor. "People are taking closed-source designs and replicating them, scanning them into 3-D files, and printing them out on 3-D printers."

But that's not coming tomorrow, or the day after, for that matter. And, although open source will allow for more amateurs to engineer, the role of the professional engineer only enhances.

"Democratization of engineering, overall, really enlarges the pool of creative ideas that can get to market, but we also have to differentiate between the types of ideas that can get to market without the formal engineering, the more professional engineering," says Atmel's Weddington. "Blinking a light is always mentioned in embedded systems as the 'hello world' application. It's easy to do something like that. But you really need the professional engineering background if you are going to develop something like a medical device or avionics on a plane. I don't see the democratization of hardware taking away from the traditional professional engineering group at all; I just see it as adding to it."EDN

You can reach Executive Editor Suzanne Deffree at 1-631-266-3433 and suzanne.deffree@ubm.com.

BY JACOB BENINGO • BENINGO ENGINEERING

10 tips for maximizing battery life

SELECTING A LOW-POWER MICROCONTROLLER IS AN OBVIOUS FIRST STEP, BUT YOU CAN FOLLOW A NUMBER OF SOFTWARE AND HARDWARE TIPS TO ENSURE THAT EVERY MILLIAMPERE-HOUR OF BATTERY CHARGE IS UTILIZED.

Portable, battery-powered devices are sweeping through society like wildfire. Mobile computing and sensor devices are springing up everywhere, providing engineers with not only a plethora of data but also applications. Requirements often dictate constraints on size and weight that limit how much capacity the battery can carry. The number of features on devices in addition to the time between charges make it very challenging to near impossible to meet the requirements.

Selecting a low-power microcontroller is an obvious first step, but there are a number of software and hardware tips that can be followed to ensure that every last milliampere-hour of charge is put to good use.

TIP #1: CREATE A BATTERY BUDGET

Early in the design cycle it is highly recommended that you put together a battery budget. Current requirements for each device on the board can be tallied to obtain a rough idea of how much battery current is going to be needed and whether the selected battery is up to the job. Device data sheets have gotten fairly good at providing minimum, typical, and maximum current data.

Taking a very conservative approach, a battery budget could be based solely on the maximum current values for the devices. An Excel worksheet is easy to duplicate, however, and creating a budget for both typical and maximum current data will produce a good ballpark range.

If more battery is needed than is available, please don't just move forward on the project! Make the necessary changes up front to spare weeks or months of heartache down the road!

Battery Budget Worksheet (Typical)

Device - Example Device

BENINGO ENGINEERING

Battery Capacity (mAh)	1200	Calculated Values
Desired Battery Life (hours)	24	

Component	On (mA)	Idle (mA)	Standby (mA)	On Duty Cycle (% per hour)	Idle Duty Cycle (% per hour)	Standby Duty Cycle (% per hour)	mAh	Comments
Microcontroller	24	5.6	0.1	20	80	0	9.28	Wake-up every 10ms to handle maintenance tasks
EEPROM(Write)	7	0.001	0.001	5	0	95	0.35	Assume writing 100 data points per hour
Radio Receive	28	1	1	40	0	60	11.80	On once every minute for 100 ms.
Radio Transmit	33	1	1	40	0	60	13.80	Transmit data once per hour
Sensor	27	0	0	50	0	50	13.50	Always on. Current from datasheet ~100mW
Accelerometer	0.2	0.2	0.01	0	0	100	0.01	Always on
Add Next Device	0	0	0	0	0	100	0.00	Enter Comment

Results	
Average mA/h	48.74
Estimated Battery Life (hours)	24.62
Desired Life Remaining (hours)	0.62

Figure 1 Early in the design cycle, it is highly recommended that you put together a battery budget.

Figure 1 shows an example battery-budget template that can be downloaded from http://bit.ly/17XMtfe.

TIP #2: SET UNUSED MCU I/O TO LOWEST POWER STATE

It is easy to overlook what should be done with an input/output pin that is not being used. This oversight, however, can be the difference between having a marketable product and an expensive paperweight.

Each microcontroller has different recommendations on what to do with unused pins, and close ex amination of the data sheet will reveal what should be done. For example, an unnamed silicon-vendor data sheet recommends that any unused I/O be set as an output and driven low. The purpose of this approach is to minimize leakage and quiescent currents in an effort to minimize power usage. These currents are tiny, but each unused pin adds to this loss, and over the period of a day can be a substantial amount of battery life.

TIP #3: TURN OFF UNUSED MCU PERIPHERALS

Just like in any home, if you aren't in a room, then the light should be turned off to conserve energy. It is the same thing with a microcontroller. If there is an unused peripheral such as an analog-to-digital converter or a pulse-width modulator, turn it off to save power!

Peripherals can be quite a power hog! For fun, pick out a favorite microcontroller and scroll through the data sheet's power section to see how much current is being drawn by each peripheral. Some providers don't include this information, and it is up to the engineer to set up some hardware on the bench and then, using test software, turn peripherals on and off, one at a time, to get an understanding of the current draw. ADCs and USB peripherals tend to be near the top of the biggest users list.

TIP #4: TURN OFF UNUSED MCU CLOCKS

Now that all of the unused peripherals have been turned off, there is not much point in running a clock signal to them. Running clock signals to different peripherals within a microcontroller requires the use of energy! There are internal clock gates that need to be powered up in order to propagate the clock. These gates use voltage and a small amount of current. To help minimize the power profile of the MCU, turn off any unused clocks. It may be only a small amount, but once again, the laws of addition can be staggering!

TIP #5: USE POWER-SAVINGS MODES

Every modern microcontroller has some type of power-savings mode. The idea is that the processor and peripherals can be put into a near-shutdown or stopped state that minimizes power usage but still allows them to return to normal operation very quickly.

Most microcontrollers will have at least three power modes, but more sophisticated processors can have in excess of seven! The common modes are run, idle, and standby. Examining a data sheet from one particular vendor revealed that run mode consisted of a current draw of 24 mA, idle mode of 5.6 mA, and standby mode of 0.1 mA. What a difference! Proper use of the power-savings mode can account for a very big increase in battery life.

TIP #6: THROTTLE THE SYSTEM CLOCK

The clock frequency at which the MCU runs is one area that has the potential to squeeze a lot of extra operating time out of the battery. There is a direct linear relationship between the frequency of the CPU clock and the amount of current that is drawn to operate the microprocessor.

Take a look at **Figure 2**; the higher the frequency, the higher the current draw. Throttling the microcontroller clock up and down is a great way to save power. When a math-intensive or fast operation needs to be performed, speed up the clock. When the task is done and the system is operating at a lower frequency, clock it down. Throttling the system clock has the potential to add hours of operating time to the battery life.

Be aware that this endeavor can be complicated. Any peripheral that is dependent on the clock may also need to have its clock dividers updated in order to maintain the same rate of operation.

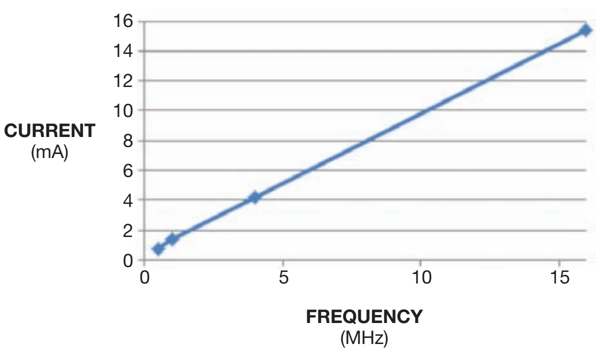


Figure 2 There is a direct linear relationship between the frequency of the CPU clock and the amount of current that is drawn to operate the microprocessor.

Readers weigh in

▸ "I have used PIC micros for years. I have a keyboard that runs on a CR2032 lithium, has IR interface, and is used daily for several hours. Battery life about 18 months. The key was to switch off the watchdog and brownout detector and sleep mode between key strokes, then wake up on key press. This dropped the quiescent current from 20 µA to significantly less than 1 µA on a PIC16LF628A. Clearly in some applications a watchdog is desirable/essential."—Bellaire

▸ "Nice tips. Concerning #9: There is no 'diode drop' when the FET is ON, because the FET's 'parasitic diode' is parallel to the FET's channel. However, someone should be concerned about the way that the FET is connected. Its parasitic diode must be reverse biased so that no current passes through (i.e., no supply voltage exists) on the device side when the FET is OFF."—G.K.

▸ "Be careful if you specified a lithium-thionyl chloride battery. These batteries suffer from passivation and die if you don't draw current from them. Take into account that the internal leakage current in the battery can be the biggest drain in devices that, like cats, spend most of their lives asleep."—Battar

▸ "Sometimes it is useful to start with some kind of battery estimator (Freescale, Silicon Labs), but you are depending on correct data from the company. For the wireless protocols it is sometimes not easy to set duty cycles for worksheets. I use supercaps (0.5-1F) instead of batteries to compare various SW modifications in sensors."—gt

▸ "A good checklist that focuses mainly on the MCU. Thanks.

More can be done, especially regarding power-saving circuit design. Quite often you can significantly lower the power consumption of 'low-power' devices through good circuit design, although you may need to do some fundamental design using discrete components and Spice simulations. We are just completing an industrial wireless multisensor unit that runs for 10 years solely on primary cells. It is a challenging and interesting project where even the wireless protocols are power-optimized."—Dale Shpak

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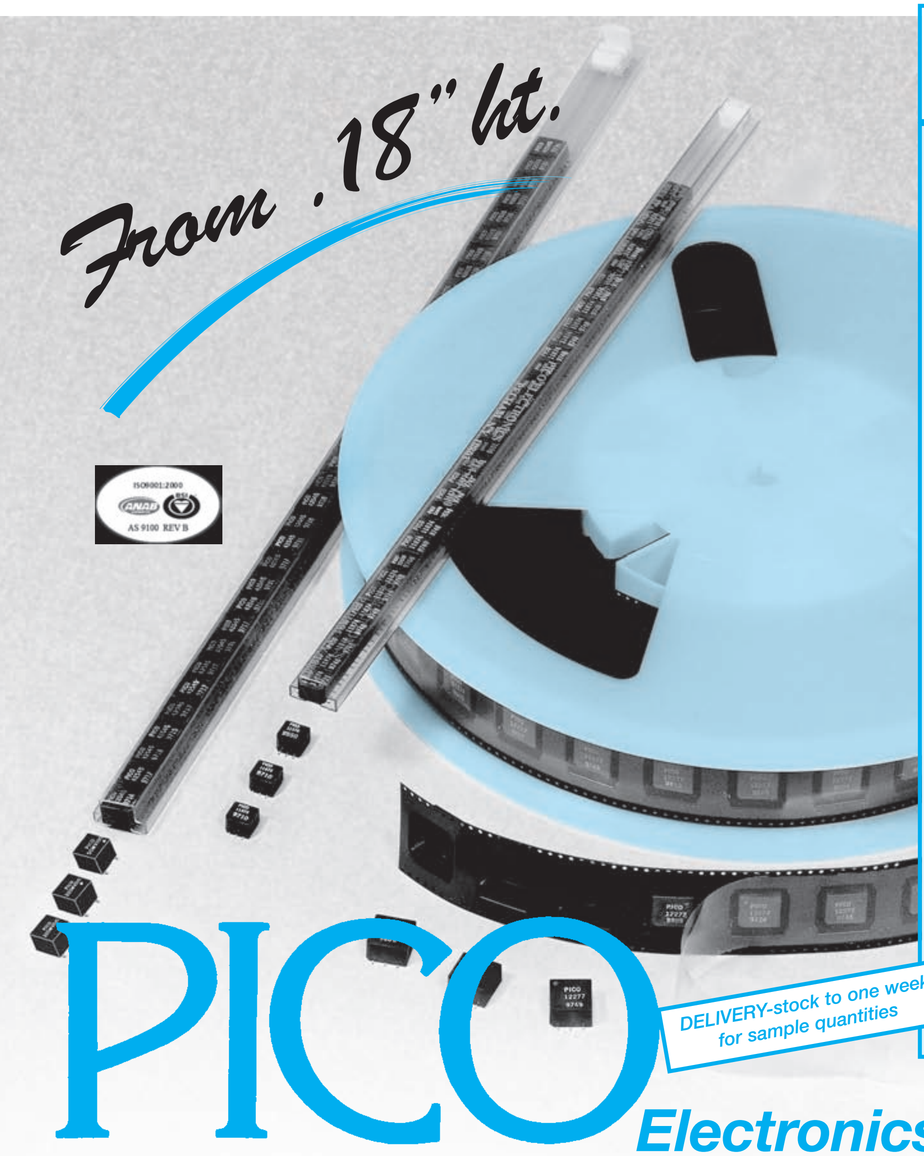

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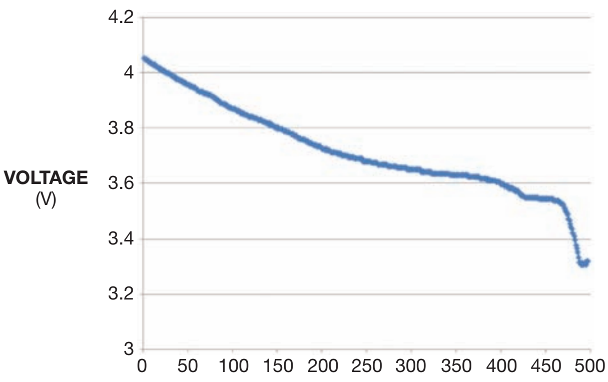
TIP #7: USE EFFICIENT ALGORITHMS

The idea of using efficient algorithms is to get at the fact that the more time that is spent in a low-power mode and a throttled-back frequency, the longer the battery is going to last. Using algorithms that are fast and efficient will result in the system's spending more time in power-savings modes.

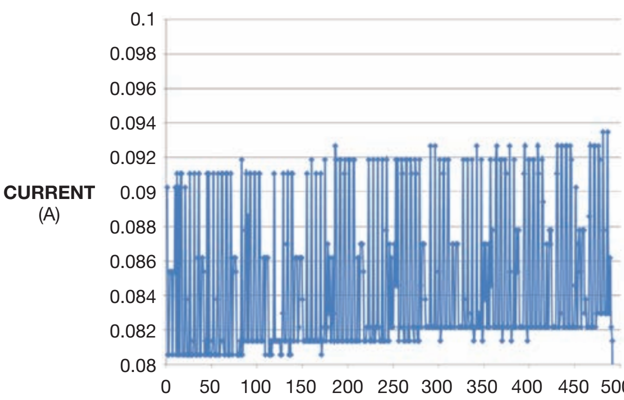
Power-savings modes use only a fraction of the current that batteries use when in full-tilt mode. Try to design the software and the system to do what needs to be done and then get into a low-power mode. The result will be not only longer battery life but also, possibly, a smaller, lighter, cheaper battery!

TIP #8: WATCH FOR DEVICES WITH HIGH LEAKAGE CURRENT

When circuits are being designed, make sure that the leakage and quiescent currents are well understood. If necessary, prototype out the circuit and verify what the current draw of the circuit is. Things to watch for are devices with high standby currents and low-valued pull-ups or pull-downs. Make sure that this information gets put into the battery budget!



(a)



(b)

Figure 3 One of the best ways to understand the battery performance of the system is to include two simple circuits to monitor battery voltage and current. Shown are an example battery voltage (a) and current (b) over the course of a single discharge cycle.

LIKE THIS?

For more from Jacob Beningo, see his Embedded Basics blog at **www.edn.com/4375394**.

TIP #9: SELECT EXTERNAL DEVICES THAT CAN BE TURNED OFF

During the hardware design when components are being selected, it can be extremely useful to select sensors and external components that have low-power modes themselves or that can be switched off. External parts such as EEPROMs, flash, and sensors usually support low-power modes. When they don't, there are a couple of methods that can be used to disable them. One option is to design in a switch such as a FET to turn power on and off for the device. One issue with this approach, however, is that the engineer can't forget that there is a diode drop of at least 0.3V and up to 0.7V, which can affect the operation of the device. The second option for disabling external parts is to use a regulator that includes an enable/disable pin.

TIP #10: ADD A VOLTAGE- AND CURRENT-MONITOR CIRCUIT TO THE DEVICE

Engineers rely on data in order to make design decisions. In many cases, battery-life optimizations are the last thing done on a project. All other features are implemented first and then, before the product rolls off the production line, the team scrambles to improve battery life.

One of the best ways to understand the battery performance of the system is to include two simple circuits to monitor battery voltage and current. This information can then be logged and used to determine discharge/charge cycles, determine steady-state currents, and really understand how the system is operating from a power-usage standpoint. **Figure 3** shows an example battery voltage and current over the course of a single discharge cycle. Armed with this tool, the savings of each tip can be determined as it is implemented!

Using these tips, it is possible to tame even the most unwieldy of power-hogging devices. It is important to keep in mind, though, that while these tips will decrease system power and improve operating efficiency, they need to be utilized during the design cycle and shouldn't be thought of as a last-ditch effort to get a product out the door. With a little luck, that new sensor design will have enough battery life to last a long time. Happy power savings! EDN

AUTHOR'S BIOGRAPHY

Jacob Beningo is a Certified Software Development Professional (CSDP) who specializes in the development and design of quality, robust embedded systems. He has written technical papers on embedded design methods and taught courses on programmable devices, boot-loaders, and software methods. Beningo holds bachelor's degrees in engineering and physics from Central Michigan University (Mount Pleasant, MI) and a master's degree in space-systems engineering from the University of Michigan (Ann Arbor, MI).

DESIGN NOTES

High Input IP3 Mixer Enables Robust VHF Receivers

Design Note 515

Andy Mo

Introduction

An increasing number of applications occupy the 30MHz to 300MHz very high frequency (FHF) band. Television and radio broadcasting, navigation controls and amateur radios are a few examples. Modern RF component development is aimed at much higher frequency bands used for voice and data communications systems. Significant advance in circuit techniques and manufacturing processes are required to meet the demanding performance requirements of the next generation of radios. Applying these techniques to lower frequency designs can significantly improve performance.

The LTC®5567 is a wideband mixer designed and optimized for performance in the 300MHz to 4GHz frequency band. To create very compact circuit implementations, the LTC5567 contains integrated RF and LO transformers. The Input IP3 linearity performance benchmark is an excellent 30dBm for the LTC5567 in its specified frequency range. Going lower in frequency requires the built-in transformers to maintain this linearity as well as conversion gain. With such a high level of linearity to start from, it is worthwhile to modify the mixer circuit design and characterize the performance over lower VHF frequencies. The proof of performance is in the testing.

Impedance Match Design

Figure 1 shows an impedance match design with the LTC5567. Table 1 shows the design values extending input port match below 300MHz, down to 150MHz,

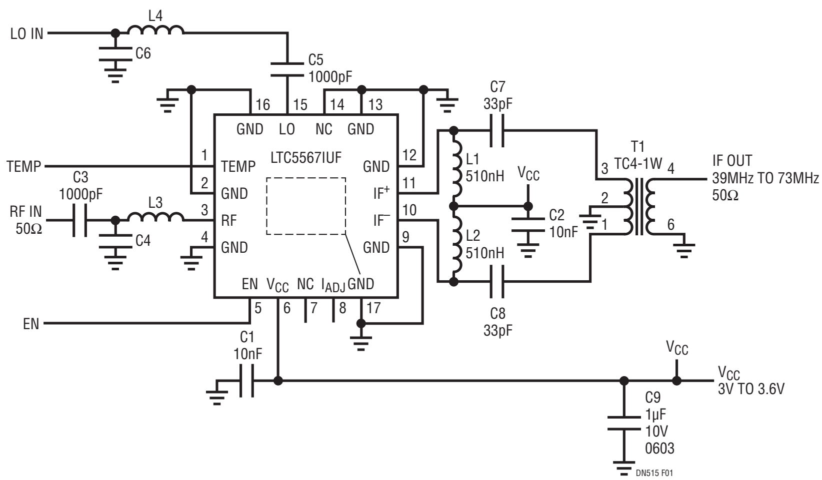


Figure 1. VHF Mixer Design

Table 1. VHF Impedance Match Design Values

MATCH	RF INPUT	L3	C4	LO INPUT	L4	C6
A	150MHz	8.2nH	56pF	200MHz	3.9nH	47pF
B	200MHz	6.8nH	39pF	250MHz	2.7nH	33pF
C	250MHz	3.9nH	27pF	300MHz	1.5nH	27pF

while still achieving outstanding performance. Test results are also provided.

Figure 2 shows the LTC5567 mixer gain and input IP3 versus input frequency. The mixer linearity performance improves as input frequency approaches 150MHz. Input, LO and output port return loss measurements are shown in Figures 3, 4 and 5, respectively. The overall performance is maintained in the VHF range compared to higher input frequencies. As a result, the high IP3 and conversion gain yields maximum dynamic range when used in radio designs. Higher dynamic range minimizes adjacent channel interference, improving selectivity. Operating the LTC5567 below 150MHz input is possible with reduced conversion gain, but not recommended, due to the internal transformer becoming lossy.

Conclusion

The LTC5567 offers very high linearity performance at VHF and UHF input frequencies. High IP3 figures and P1dB in (Table 2) make it an excellent choice for high performance radio design over a wide range of frequencies.

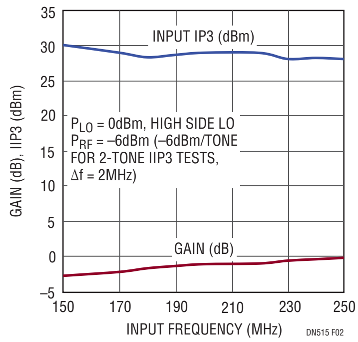


Figure 2. Mixer IIP3 and Gain Performance Results

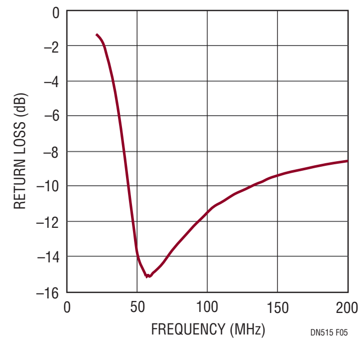


Figure 5. IF Output Return Loss

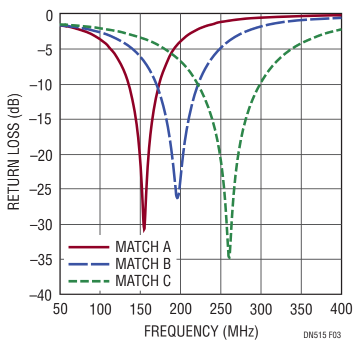


Figure 3. RF Input Return Loss

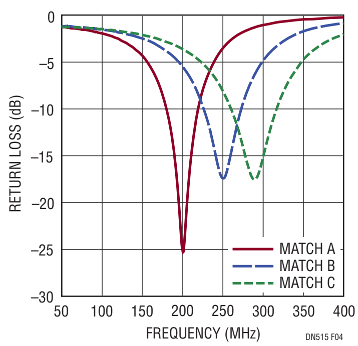


Figure 4. LO Input Return Loss

Table 2. P1dB Compression Point and LO Leakage Over Input Frequency. Output Frequency = 50MHz, HSLO

RF INPUT FREQUENCY (MHz)	P1dB (dBm)	LO TO IF LEAKAGE (dBm)
150	12.29	–35
160	12.9	–42
170	12.9	–42
180	12.75	–42
190	12.70	–41.2
200	11.61	–43
210	12.48	–43
220	12.7	–44
230	11.7	–44
240	11.08	–44
250	12.89	–44

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Derive an efficient dual-rail power supply from USB

RO Ocaya, University of the Free State, Phuthaditjhaba, South Africa

When designing low-power USB circuits that require power-supply voltages other than 5V, you must decide whether to use a separate battery or a physically small mains-based power source. The problem is particularly troublesome if the circuits to be powered require dual rails greater than 5V, such as instrumentation amplifiers based on operational amplifiers, or must be run on portable computers, such as laptops.

The USB 2 standard specifies the power requirements of a connected device as either low power if it consumes at most 100 mA, or high power if it consumes up to 500 mA. The origin of the circuit described here is the design of a thermoluminescence (TL) instrument for which the microcontroller, the USB-interface controller, and 10 operational amplifiers are all powered from a standard USB port as a low-power device. The operation of the device requires high-efficiency performance with little noise pickup and keeping radio-frequency emission from the system as low as possible. The circuit was simulated before being built and verified and then used in the TL system. The design is attractive because its use of common components improves repeatability while keeping costs extremely low.

The operation is based on the flyback concept (**Figure 1**), where a small transformer is driven at 115 to 300 kHz generated by a pulse-width-modulated 555 astable circuit. The high frequency of operation allows the overall size of the circuit to be kept small while delivering relatively high power output with good regulation, and allows easier output filtering for low ripple.

In the actual circuit, you implement the switch using a MOSFET. In **Figure 1**, the diode is shown forward biased for positive V_{OUT}. Reversing the diode direction and the polarity of one transformer winding gives a negative V_{OUT}. The circuit operates in three distinct phases. In phase one, the switch is closed and energy is stored in a magnetic field due to current flowing in the transformer primary. The diode is reverse biased, and no current flows in the secondary.

In phase two, the switch opens, the diode becomes forward biased, and the energy is transferred from the magnetic field into capacitor C. In phase three, with the energy dump completed, any residual charge stored on the switch drain-source capacitance is completely discharged. The cycle is then repeated.

To better explain the operation of the circuit, it is easier to presuppose that just prior to time t=0, the filter capacitor is already charged to the nominal output voltage and that the current through the primary windings of the transformer is zero. At t=0, the switch closes and a current starts to flow through the primary winding. This will induce a voltage across the secondary winding with a polarity as indicated. Since the diode is reverse biased, no secondary current can flow and the secondary winding is effectively open-circuit. The primary side of the transformer behaves like a simple inductor. As a result, the primary current increases linearly according to the following **equation**:

$$I=\frac{V_{CC}}{L_1}t.$$

During the time the switch is closed, the voltage induced across the secondary windings is nV_{CC}. The diode must therefore withstand a minimum reverse voltage of $(nV_{CC}+V_{OUT})$. At a given instant later, the switch is opened. In the practical circuit, this corresponds to the MOSFET's being turned off. Suppose that the current in the primary winding at that instant is I_{PK}. The magnetic energy stored in the inductor is then equal to

$$E=\frac{1}{2}I_{PK}^2L_1.$$

Due to the flux linkage between the primary winding and the secondary winding, with the primary circuit

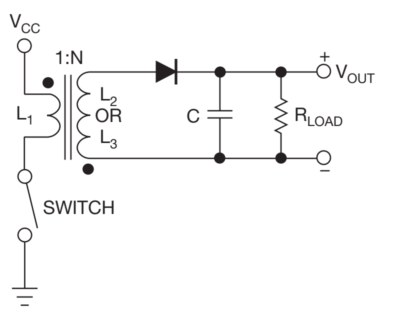

Figure 1 This basic flyback converter pumps magnetically stored charge into filter capacitor C when the switch opens.

DIs Inside

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open, the inductor's stored but collapsing magnetic field induces a voltage at the secondary side high enough (>V_{OUT}) to forward bias the diode. The initial value of the current will be $I^2=I_{PK}/n$. During the time that the diode is forward biased, the voltage across the secondary winding will equal (V_{OUT}+0.7). This can also be seen as a transformation of the primary-side voltage down to V_{OUT}/n. The switch, therefore, has to withstand a voltage of effectively

$$V_{REVERSE}=\left(V_{CC}+\frac{V_{CC}}{n}\right)$$

when it is open. This last **equation** highlights the main advantage that the flyback converter has over the boost converter of comparable input and output voltages, namely the reduced voltage the switch must handle when it is opened. In effect, the voltage during the "off" phase is transformed down to a value determined by the transformer winding turns ratio. This allows a MOSFET with a much lower breakdown voltage to be used. Additionally, in the boost-converter topology, the diode must handle both the high "on" current and a high reverse voltage in the "off" phase. In the flyback converter, the diode at the secondary side has to withstand only a high voltage while the current is low (I_{PK}/n). This permits the use of a diode with smaller capacitances that results in higher switching speed with the consequence of reduced energy losses and an increased efficiency.

Although it is beyond our current scope, you can calculate the output voltage by equating the amount of energy input in L_1 to the energy transferred to the load, R_{LOAD}. In steady state, the output is related to the duty cycle, D, of the switch and the frequency at which the switch is operated; that is, the open-circuit output voltage is given by

$$V_{OUT}=V_{CC}\left(\sqrt{\frac{R_{LOAD}T}{2L_1}}\right)D.$$

In the practical circuit of **Figure 2**, all of the elements of the basic flyback circuit of **Figure 1** can be identified. However, there are a number of refinements that lead to better operation and stability. For example, two output diodes are configured so that dual-rail output is possible. Also, the positive rail feedback is sampled by the voltage divider comprising R_4 and R_5, with a level that is smoothed by capacitor C_2. In normal 555 astable operation, the output waveform generation is possible since the timing capacitor (C_1) charges from V_{CC} through the sum of R_1 and R_2 and discharges through R_2. With the resistor values used (that is, $R_2 >> R_1$), the duty cycle is close to 50%. The charging/discharging voltage levels are internally set to $V_{CC}/3$ and $2V_{CC}/3$ (that is, 1.67V and 3.33V, respectively, if operated at 5V). Without feedback, the values in **Figure 2** give an open-loop output voltage of about 20V.

The feedback operates as follows: The transistor, Q_1, does not conduct until the voltage at its base (V_{BE}) is around 0.55V. This enables the output voltage to be calculated from

$$V_{OUT}=\left(1+\frac{R_4}{R_5}\right)V_{BE}.$$

As the output voltage continues to increase under the action of flyback, Q_1 is driven even harder, causing its collector voltage to fall. Since the collector is connected to the control input of the 555 timer that is nominally the upper limit above ($2V_{CC}/3$), this causes the capacitor to charge and discharge at the same rate but through a narrower voltage range. This has the effect of reducing both the "on" and "off" times of the output pulses that drive the MOSFET switch. The net variation in both the frequency and the duty cycle (D) causes V_{OUT} to fall and eventually lower the feedback voltage, with the effect of reducing the "on" time of Q_1.

One aspect of the circuit that needs careful setting up is the flyback transformer. Several home-made transformers were tried and worked reasonably well. The solution settled on was to reuse the core of an RFI suppression inductor commonly found at the mains input end of switched-mode power supplies in television sets. The windings of the transformer primary are multi-filar to reduce their series resistance. For example, using four strands of 0.3-mm insu-

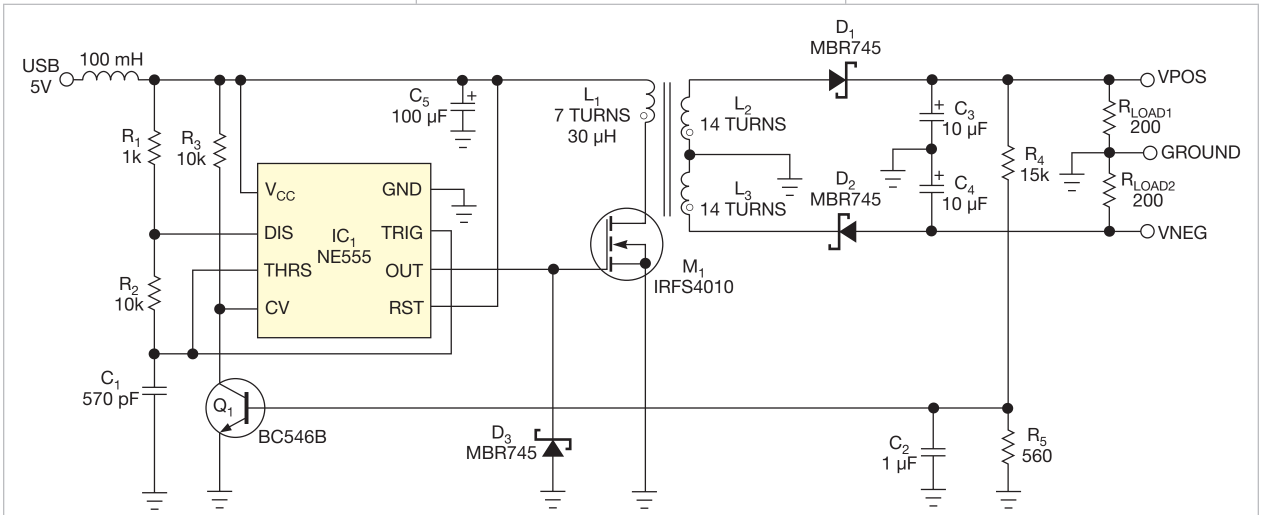

Figure 2 In this complete circuit, you can use many alternatives for M_1, Q_1, and the Schottky diodes.

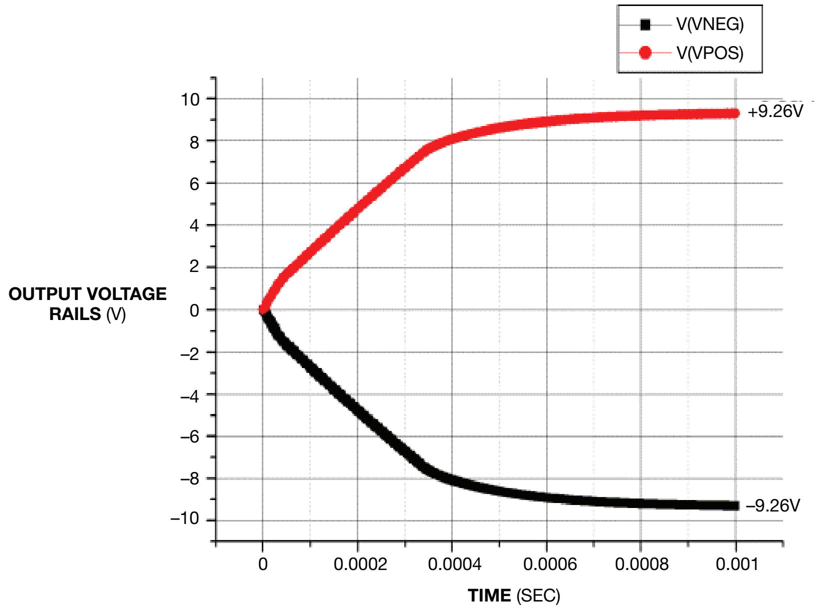

Figure 3 At turn-on, the output stabilizes within 0.8 msec, with two loads of 200Ω each.

lated copper wire closely wound seven turns gave an inductance of 30 μH for the primary with a measured series resistance of 0.03Ω. A lower coil resistance reduces joule heating in the inductor as it is switched, leading to higher efficiency. A suitable commercially available ferrite core and bobbin set is available from RS-Electronics (RS stock number 647-9446, manufactured by Epcos).

A further refinement is the use of high-current, high-speed, and low-forward-voltage Schottky diodes for D_1 and D_2. An additional diode is used in reverse bias at the gate of the MOSFET to reduce RFI. Including a 100-mH choke on the 5V USB line also reduces switching noises further.

For the purposes of our design, the USB port was modelled as a 5V source with a series resistance of 10Ω for a worst-case current of 500 mA. A decoupling capacitor, C_5, of 100 μF is used to prevent switching noises from being developed across the power rails. The measured output efficiency was around 72%, with a load of 50Ω, with the output voltage dropping to ±7.6V. The output has also been connected successfully to linear regulators such as the 78L05 for other voltages. A further design refinement is possible to make the output switchable under software control. We have not done it here, but some means of turning the 555 off or on using a separate active transistor would implement standby or active operation.

Figure 3 shows the turn-on transient response of the converter. **Figure 4**, available with the online version of this Design Idea at www.edn.com/4415896, shows that the circuit responds gracefully to a step load change 10 msec after turn-on. EDN

H-bridge paves new ways for LED lighting

Subodh Johri and Prateek Johri, Central Electronics Engineering Research Institute (CSIR-CEERI), Pilani, Rajasthan, India

The H-bridge is a classic circuit used for driving dc motors in a user-defined manner, such as in forward/reverse direction or PWM-assisted controlled RPM with the help of four discrete/integrated switches or electromechanical relays. It is widely employed in robotics and power electronics. This Design Idea is a novel implementation of this technique for driving white-LED arrays directly from the ac mains in full-wave current-limited mode to realize an excellent flicker-free, energy-efficient solid-state lamp. The circuit controls and maintains the LED excitation current in both negative and positive half cycles of the excitation voltage to a constant level by way of electronic switches operating alternately during the positive and negative excursion of the excitation voltage. This approach facilitates current-controlled rectification of ac voltage into a dc voltage for energizing series-connected LEDs with clean dc current with negligible ripple and substantially enhances the power factor.

As shown in **Figure 1**, transistors Q_1, Q_3, and Q_5 and diode D_4 as well as transistors Q_2, Q_4, and Q_6 and diode D_3 are configured as series-connected voltage-controlled current switches to form two arms of the H-bridge; diodes D_1 and D_2 form the other two arms of the bridge. The LED string is connected between the midpoints of the bridge designated as V_{LED}+ and V_{LED} GND, respectively. The ac is applied to the circuit through a current-limiting PTC resistor, R_5; series-connected capacitors, C_4 and C_5 (configured as a nonpolar capacitor, C_{EFF}); and inductor, L_1. Likewise, the neutral side of the mains is connected to the circuit ground through an inductor, L_2.

During the positive half cycle, the ac power bus becomes positive with respect to the ground, and transistor Q_1 gets appropriate base bias through resistor R_1. Current flows through diode D_4, transistor Q_1, and resistor R_3, as illustrated by arrow A_1, and then through the LED string comprising 12 medium-power LEDs (LED_1 to LED_{12}) to the ground through diode D_2, as shown by arrow A_2. In a similar fashion, dur-

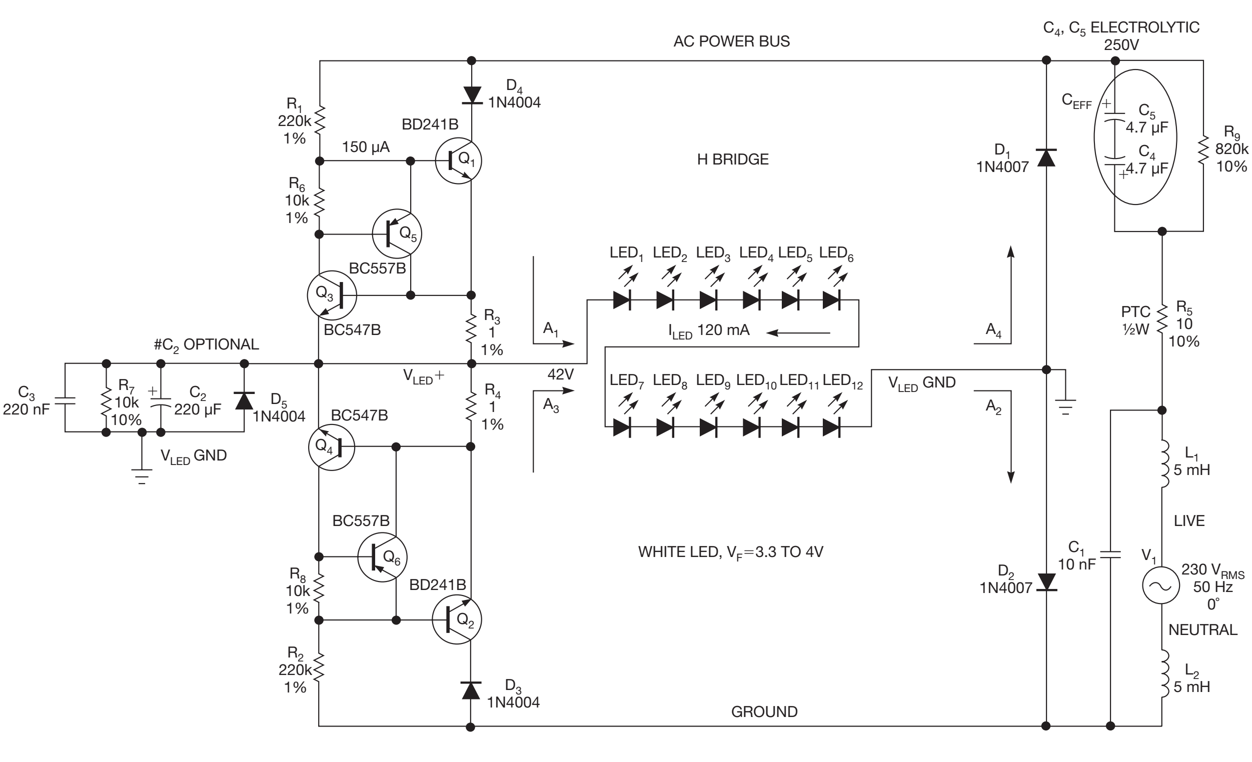

Figure1 Current-limiting transistors and diodes route alternate ac half cycles to the series LED string.

ing the negative half cycle when the ac power bus becomes negative with respect to ground and transistor Q_2 gets base bias through resistor R_2, the current flows through diode D_3, transistor Q_2, and resistor R_4, as illustrated by arrow A_3, and then through the LED string to the ac power bus through diode D_1,

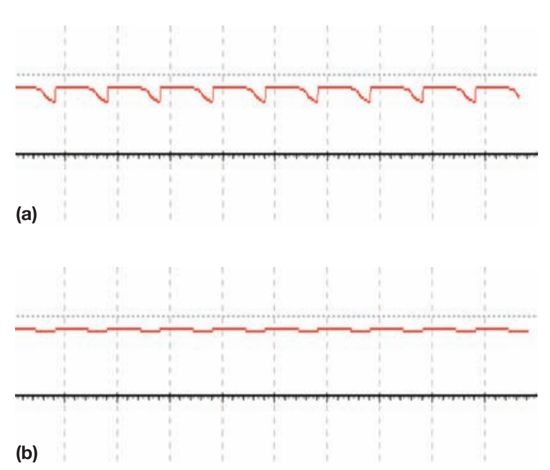

Figure 2 $V_{LED}+$ without capacitor C_2 has ripple (a); $V_{LED}+$ with capacitor C_2 has reduced ripple (b).

as shown by arrow A_4. In this way, during a complete cycle the current flows through the string in the same direction and gets added up like you would get in a full-wave bridge rectifier. However, the magnitude of current I_{LED} remains constant as regulated by the respective switches serving as voltage-controlled current sources.

As the base emitter junctions of transistors Q_3 and Q_4 are connected across current-sensing resistors R_3 and R_4, respectively, they turn on when the voltage drop across R_3 and R_4 increases beyond Q_3 and Q_4's base emitter voltages. At this point, Q_1's and Q_2's bases are pulled down, disrupting the flow of current through them during respective half cycles of the ac mains. In this way, the current flowing through the transistors is kept constant and never allowed to go beyond a threshold, set by appropriately choosing the R_3 and R_4 values. Q_5 and Q_6 limit the base current of Q_1 and Q_2 to a safe value (around 150 µA) to ensure that they are never overdriven. The substantial parts of the base currents of Q_1 and Q_2 are shunted to R_3 and R_4 by means of Q_5 and Q_6 when their respective base emitter voltages exceed the potential drop across R_6 and R_8 connected in series with R_1 and R_2, respectively.

The magnitude of ac current flowing into the bus is limited by the reactance of $C_{EFF}(1/2\pi fC_{EFF})$ at the mains frequency and can be altered by appropriately choosing C_4 and C_5, configured as a nonpolar capacitor. The circuit can also be driven by a resistive supply by replacing C_{EFF} with a suitable high-power resistor of 50 to 200Ω. This may facilitate an excellent power factor, but at the expense of very high power losses in the current-limiting resistor. R_3 and R_4 can be chosen appropriately as per the required constant-current magnitude. D_5 protects the LED string from high reverse voltage, and R_5 limits the inrush of current at turn-on. Inductors L_1 and L_2 and capacitor C_1 help in minimizing the EMI/RFI besides improving the power factor. A metal oxide varistor can also be inserted in parallel with the ac mains to protect the circuit from transients.

In the circuit, 12 0.5W LEDs operate at 120-mA dc (135-mA RMS) with respect to current-sensing resistors R_3 and R_4, chosen as 1Ω. You can, however, increase the number of LEDs to 18 as long as the voltage being applied across the string is more than the sum of the forward voltage of the individual LEDs. (White LEDs' forward voltage varies from 3.3 to 4V.) The voltage appearing across the string is self-limiting (in this case, it is around 42V) and does not require any additional regulation, since series-connected LEDs behave like high-power zener diodes when operated in forward-biased mode. The circuit draws 11.5W power at 230V-ac RMS and exhibits a power factor of 0.93 without any perceptible flicker in the LEDs. You may optionally connect a 220-μF capacitor, C_2, between V_{LED}+ and V_{LED} GND to further suppress ripple, as shown in **Figure 2**. Alternatively, the given string can be replaced by six parallel-connected strings of LEDs, each having 12 to 18 20-mA rated high-brightness LEDs. You must mount transistors Q_1 and Q_2 on heat sinks to avoid thermal runaway. EDN

Leakage-energy recuperating winding self-supplies a dc/dc converter

Todor Arsenov, Ontario, Canada

One of the effective passive means you can use to suppress the ringing and clamp the overvoltages caused by the leakage energy in a flyback transformer is to implement a recuperating winding bifilar with the primary winding. This is the same technique commonly used to demagnetize the transformer in a forward converter topology. Indeed, this winding is tightly magnetically coupled with the primary winding, but after steering the leakage energy back to the power input, technically it is still a secondary winding. Therefore, it also can be used for other purposes, for example to self-supply a PWM controller or an embedded converter.

Figure 1 shows a flyback converter with an additional recuperating and self-supplying winding, N_R, wound bifilar with the primary winding, N_P, implemented on a modified demonstration board of the Viper17L from STMicroelectronics[1]. N_S is the secondary winding, and the residual leakage inductance is represented by L_{LK}. R_{S1} is a current sense resistor, and R_1 is a current-limiting resistor. Transformer ratios are the same as in the original transformer.

The output voltage is slightly lowered (11.5V) from the original 12V to accommodate a power-supply rail down to 145V DC. **Figure 2a** shows the power switch voltage and primary current waveforms of the origi-

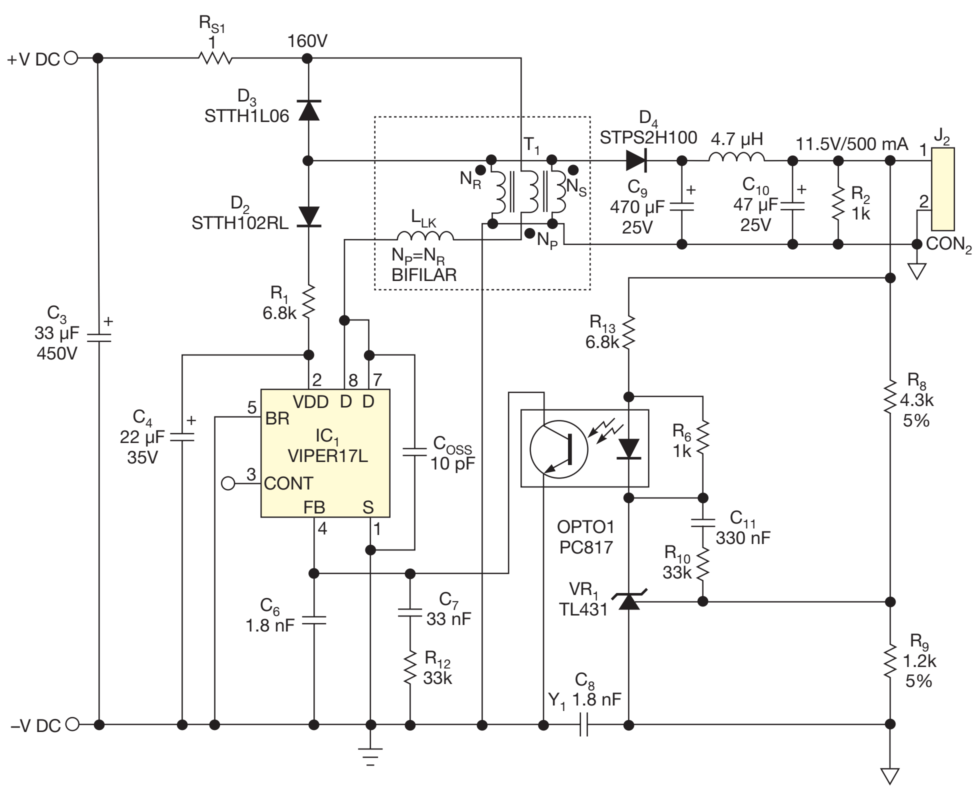

Figure 1 A bifilar demagnetizing winding added to a flyback transformer shunts the power switch output capacitance, C_{OSS}; steers the leakage energy back to the supply rail; and clamps the switch voltage during the turn-off transition. Then, switched to the supply pin of a converter, this winding works as a self-supply winding.

nal Viper17L configuration with the snubber disconnected. You can see that the ringing due to the leakage inductance is around 540V peak at 160V DC power-supply line at full load (500 mA). **Figures 2b** and **2c** show the same waveforms when the recuperating bifilar winding is implemented as a snubber and a self-supply winding. When the supply rail voltage is first applied, the high voltage current generator implemented in the Viper 17 starts charging capacitor C_4 until the V_{DD} start-up threshold of the converter is reached and the PWM control is activated[2]. The converter is then powered by the energy stored in capacitor C_4. During the on phase, all diodes, D_2, D_3, and D_4, are reversed biased. When the power switch turns off, the magnetizing current flows in the recuperating winding, forcing D_3 to conduct and thus limiting V_{DS} to 2×V DC. When the leakage energy is fully returned to the power input, D_3 is reversed biased and the recuperating winding starts recharging capacitor C_4 through diode D_2. Charging current cannot flow from the power rail as D_3 is biased off, and thus the recuperating winding is supplying the converter.

The Viper 17 is efficiently designed for low standby power consumption by entering burst-mode operation at no load, switching the internal circuitry to low power consumption when idling, and so on. To preserve the burst mode of operation, a preload resistor, R_2, of 1 kΩ is included, thus lowering the average switching frequency at no load, as seen in **Figure 2d**. In this way, the bifilar recuperating winding successfully sustains the operation of the converter at any load conditions and, at the same time, effectively clamps the overvoltages on the power switch caused by the leakage inductance of the flyback transformer. EDN

REFERENCES

1 "EVALVIPER17L-7W demonstration board," STMicroelectronics, June 2008, http://bit.ly/145jGHF.
2 "VIPER17 data sheet," STMicroelectronics, June 2010, http://bit.ly/Z8xOqM.

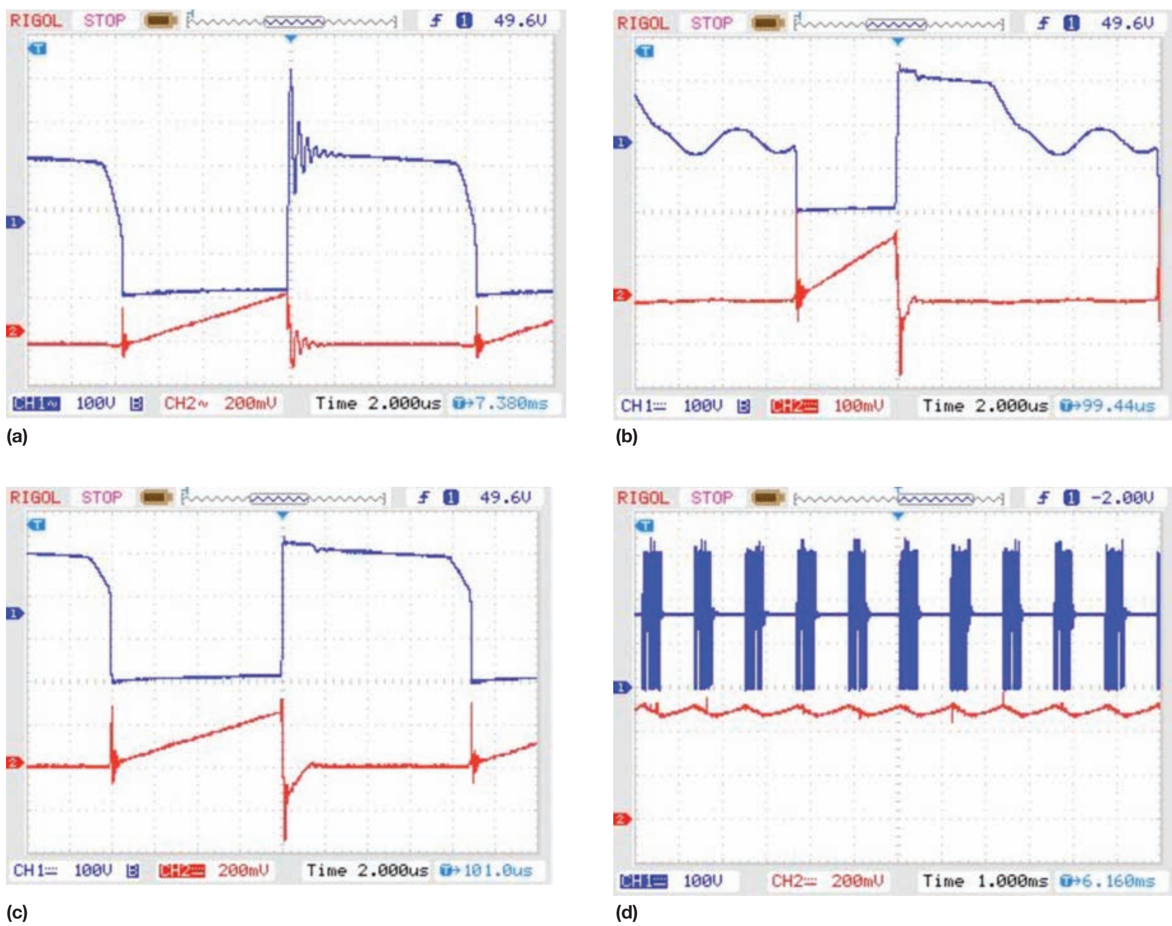

Figure 2 With the snubber disconnected, ringing occurs at the power switch voltage (Channel 1, blue) and primary current (Channel 2, red) waveforms when the converter is without the recuperating winding at full load (a). Shown are waveforms with the recuperating winding at light load, 100 mA (b), and full load, 500 mA (c). When in burst mode, the switching frequency is lowered to about 1 kHz (Channel 1), and the regulation is maintained by keeping the feedback voltage, pin 4 (Channel 2), within the burst-mode threshold levels (d).

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What business are you in?

It goes without saying that the rate of change in business today is staggering, and it shows no signs of slowing. But as we grapple with that pace in our day-to-day business lives, it's usually difficult to see the forest for the trees. We tackle our tasks faster and take on more responsibility, all with near-term goals in mind.

Sometimes, though, we might be lucky enough to catch our collective breath and wonder just what we're doing—not just ourselves but our businesses.

Let's take a trip back in time to the 1970s. Back then, if you worked in electronics, odds are your company made something like mainframes or spacecraft or jet airplanes or communications systems. The people you worked with made everything that went into the end product.

But over the next four decades, the industry disaggregated slowly but surely. If you worked in the semiconductors division of that vertically integrated company, you might have ended up working for a semiconductor company after management sold off that unit.

THE MORE THINGS CHANGE ...

The **photo** shown at the top of the next column, from a recent post in Tim Kastelle's Innovation for Growth blog (http://bit.ly/10dWbba), tells the story. Each of the technologies in the top part of the picture had enormous revenues ... until each one didn't. Suddenly.

> The one constant will be the semiconductor components hot potato: They're crucial to innovation, but no one wants to hold them for longer than is absolutely necessary.

Flash forward to now and today's supply chain. If you're in distribution, your company is radically different than it was 15 years ago. If you're in contract manufacturing, you're not just making things anymore. You're designing them. So are you a contract manufacturer or a design house?

If you were a company that sold software into systems, odds are you are in the services business today, maybe hosting something for your customers via the cloud.

Kastelle's point—that your market is never stable—is spot on, but could you have predicted in 1993 that the Newton, of all products, would effectively end up sweeping up the functionality of all those other devices? Never in a million years.

The drivers turned out to be Moore's Law, software, and wireless connectivity.

WHAT THE FUTURE HOLDS

For the supply chain, the battle during the next 20 years (maybe just 10, given the quickening pace of innovation) will be driven by data and the Internet of Things. Established companies that get that will grow; new companies that get that will disrupt today's smaller players.

The one constant will be the semiconductor components hot potato: They're crucial to innovation, but no one wants to hold them for longer than is absolutely necessary. Now, some financial innovation may emerge in the next decade that makes holding inventory less onerous. Only time will tell.

The bottom line is things will change faster than we imagine, and it may behoove you to put the words "What is your business?" up on a wall near your desk as a daily reminder.

—by Brian Fuller, *EBN*

This story was originally posted by EBN: *http://bit.ly/194qbr6*.

OUTLOOK

SEMICONDUCTOR SUPPLIERS HAVE LARGEST INVENTORY IN PC CHAIN

Semiconductor suppliers averaged the largest amount of inventory in the PC supply chain over the last six years, while PC distributors had the least, an equation determined not just by the business model ruling each node but also by PCs having lost clout among consumers to more popular smartphones and tablets, according to market-research firm IHS.

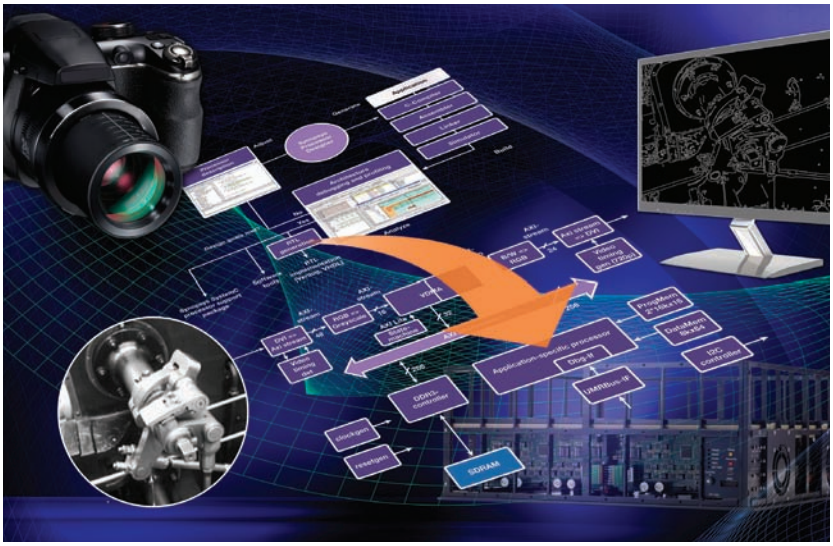
From 2007 to 2013, semiconductor suppliers held the greatest amount of stockpiles at 78 days on average as quantified by the days-of-inventory (DOI) metric; PC distributors carried the least with 31 days. The DOI measure in this case applied to the goods and subcomponents manufactured by the category in question.

After semiconductor distributors, the next-highest DOI was 45 days, claimed by pure-play foundry suppliers for wafers, chips, and chemicals. Also in the range of 40 or so DOI were semiconductor suppliers as well as EMS providers, while ODMs at 34 DOI placed just above PC distributors during the fourth quarter last year.

All told, the DOI for chip distributors was up by more than a third compared with the second-highest node in the chain. **—by Amy Norcross**

productroundup

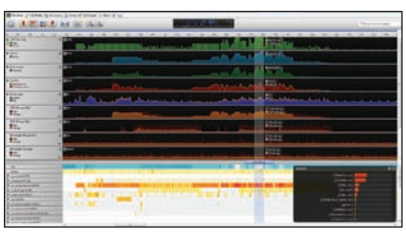
TOOLS



Synopsys development system reduces development time from months to weeks

The Embedded Vision Development System accelerates the design of embedded vision processors using its Processor Designer tool set and HAPS FPGA-based prototyping system. It allows designers to explore and tune processor architectures for the optimal combination of power and speed, and implement the design on a HAPS FPGA-based prototype. The system includes pre-verified design examples to help designers implement an ASIP optimized to meet their SoC objectives. It provides a ready-to-use, modifiable base processor including a full C/C++ compiler, which supports all functions provided by the OpenCV library. The execution of the compiled code with the automatically generated instruction-set simulator (ISS) is easy to profile, identifying performance-intensive parts of the application, which can be accelerated by changes in the processor architecture. Processor Designer generates optimized RTL of the ASIP, which can be downloaded into a HAPS FPGA-based prototyping system. The Embedded Vision Development System is available now.
Synopsys, www.synopsys.com

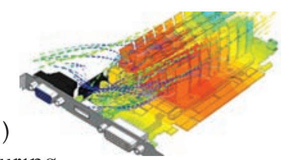
ARM launches free development tools for embedded Linux



The Development Studio 5 Community Edition (DS-5 CE) provides a free-to-use software development environment for embedded Linux applications including Android. It runs on Linux, Windows, and Mac OS hosts, with an integrated solution including an Eclipse IDE, GNU cross-compiler, DS-5 Debugger, Streamline performance analyzer, online help, and software examples. The graphical DS-5 Debugger only needs an Ethernet connection to the target to enable power debug features and integrates Linux-specific functionality, such as a target file system explorer and an automated flow for downloading applications to the target, launching them, and connecting the debugger. The Streamline performance analyzer makes it easy to locate code hotspots, system bottlenecks, inefficient threading, ineffective use of the cache memories, and GPUs, and many other software issues. The free DS-5 CE is available now; the professional edition costs $3300 for one year, node-clocked.
ARM, www.arm.com

Mentor Graphics tool bridges EDA, MDA to simplify thermal design cycle

The FloTHERM XT software package is designed to simplify detailed thermal design and shorten the thermal design cycle for ICs, boards, systems, and enclosures of arbitrary shape. The tool combines FloTHERM thermal analysis software with Concurrent CFD (computational fluid dynamics) from FloEFD. During analysis, the tool integrates data from EDA and MDA (mechanical design automation) to speed analysis and enhance accuracy of results. The FloTHERM XT software uses improved data integration capabilities and solver algorithms to speed analysis. Native MCAD data can be filtered, and a data import tool, FloEDA Bridge, can import IDF (intermediate data format) through rule-based filters that filter out non-contributors. An enhanced solver extends the use of hexahedral meshes to deal with arbitrary shapes and, with automated handling of boundary conditions, offers a solution that is guaranteed to converge, according to the company.

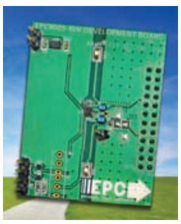


productroundup

FloTHERM XT is available now; prices start at $27,000.
Mentor Graphics, www.mentor.com

Development board from EPC simplifies eGaN FET design

Outfitted with two 40V EPC2014 eGaN FETs in a half-bridge configuration using TI's LM5113 gate driver, the EPC9005 development board eases the task of transitioning from silicon to eGaN technology. It provides a maximum output current of 7A, includes all critical components on a 2×1.5-in. board, and can be connected to any existing converter. Various probe points on the board allow simple waveform measurement and efficiency calculation. The onboard LM5113 gate driver is housed in a 2×2 BGA package, enabling a compact power stage. The EPC9005 costs $99.18 and is available for immediate delivery from Digi-Key.



Efficient Power Conversion, epc-co.com

Altera FPGA development kit includes optimized SoC debug tools

The Cyclone V SoC development kit enables hardware and software developers to accelerate their embedded systems design development. Developed with ARM, it features the DS-5 Altera Edition Toolkit software, the Cyclone V SX SoC with an 800-MHz dual-core ARM Cortex-A9 processor, 110K logic elements (LEs) of logic density, 3.125 Gbps transceivers, PCI Express root-port and endpoint support, and DDR3 memory for both the FPGA and hard processor system via hardened memory controllers. The SoC Embedded Design Suite (EDS) features the DS-5 Altera Edition Toolkit that removes the debugging barrier between the integrated dual-core processor subsystem and FPGA fabric to offer full-chip visibility and control through the standard DS-5 user interface. The kit includes a broad set of memories, peripherals, and interfaces and a high-speed mezzanine connector (HSMC). Two onboard Ethernet PHYs support all of the top industrial networking protocols. The Cyclone V SoC development kit is available for $1595.

Altera, www.altera.com

Grayhill's Instinct 2.0 offers 3-D image control

The Instinct Gesture Recognition Library is a software tool that converts multitouch sensor data into gestures. The latest version provides capability for 3-D image control and is suited for use with control panels on a variety of equipment. Instinct Touch Technology combines the library with a human interface device (HID) to track movements from the device's touch pad. The data is converted into gestures, which are fed to the application or operating system. The software collects and interprets gesture events and dynamic gestures for machine control and image manipulation. The Instinct 2.0 can interpret gestures and optimize data for the control of 3-D images by recognizing multitouch gestures, including movements along the X-, Y-, and Z-axes and rotations around each. Users will be able to turn and rotate an image to view it from any angle. Instinct can execute more commands than single-point touch technologies, so the control panel needs fewer control components, reducing its size and complexity. The software parameters within the library are customizable and developed utilizing the Instinct Software Development Kit. The tool kit includes a mounted MTRE or MTCW, a standard USB cable, and demo software and is priced at $200.

Grayhill, www.grayhill.com

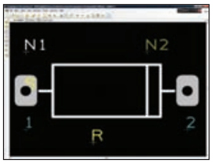
dSpace simulation tool eases automotive-suspension design

Automotive simulation models (ASMs) now include a module for designing and simulating wheel suspensions on a virtual test bench. The ASM Kinematics and Compliance (ASM KnC) tool allows engineers to run virtual tests for numerous vehicle variants and driving maneuvers to optimize vehicle suspensions. Wheel suspensions are defined via a graphical user interface and exported as lookup tables for vehicle simulation models. ASM KnC provides predefined configurations for common suspension types, including McPherson, double wishbone, and 3-, 4-, and multiple-link suspensions.

dSpace, www.dspace.com

RS Components' DesignSpark PCB Version 5.0 minimizes errors

DesignSpark PCB Version 5.0 software for schematic capture and PCB layout integrates online design rule checking and buses within the free design tool. Design rule checking determines whether the physical layout of an integrated circuit satisfies a series of recommended parameters. It enables the engineer to detect errors in real time during the design stage. The increasing adoption of digital design has resulted in the use of on-chip buses to transfer data,



enabling the engineer to combine multiple data signals into a bus in multiples of eight. Instead of drawing and/or labeling the individual wires in a schematic, a single 'bus wire' can be used to represent related wires, simplifying the schematic. This also enables simulation and debugging to be carried out with minimum errors. Buses have been added directly into DesignSpark PCB Version 5.0, allowing the engineer to refine the schematic during the design phase.
RS Components,
www.rs-components.com

Wireless platform from Marvell enables smart lighting systems

Based on the 88EM8511 AC/DC controller and wireless microcontroller embedded inside a smart LED bulb, the Smart Bulb Residential Wireless Platform offers an end-to-end solution for developing smart lighting systems that adhere to Energy Star requirements. The system-on-chip approach achieves a 50% reduction in the number of ICs compared with a typical wireless-connected bulb. The first products based on this open platform are smart bulbs from Leedarson connected to home gateways from Zonoff.

The platform includes a ZigBee remote control or a dedicated Wi-Fi-to-ZigBee lighting bridge. It supports a range of ZigBee protocols, is accessible by mobile devices via Wi-Fi, and can be connected to multiservice home gateways or directly to wireless routers when Wi-Fi is embedded in the smart bulb itself.
Marvell, www.marvell.com

Orca releases DVB-T2 front-end reference design

The DVB-T2/T/C and analog TV front-end reference design for televisions that employ ORC5310 hybrid TV tuner and Panasonic's MN88472 demodulator was tested to meet the latest DVB-T2 specifications, including NorDig and D-Book. The ORC5310 is a single-chip, CMOS-based hybrid TV tuner with an analog demodulator that can receive analog and digital signals from either terrestrial or cable networks worldwide. The MN88472 DVB-T2/T/C demodulator IC is a second-generation, low-power device. The reference design achieves high sensitivity, good interference rejection, and stable reception in multipath environments, according to the company. The reference design includes schematics, Gerber layout files, BOM list, and GUI evaluation software with integrated tuner and demodulator drivers.
Orca Systems,
www.orcasystems.com

EDN ADVERTISER INDEX

Company	Page
Advanced Interconnections	45
Agilent Technologies	15, C-3
AMS AG	17
Avnet	61
Coilcraft	3
CST of America Inc	27
Dassault Systems	29
Digi-Key Corp	C-1, C-2, 55
Emulation Technology	43
Front Panel Express LLC	44
Future Electronics Inc	21
International Rectifier	8
Keystone Electronics	23
Kontron America	25
Linear Technology	50A–50B, C-4

Company	Page
Maxim Integrated	53
Melexis Inc	33
Memory Protection Devices	59
Mill-Max Manufacturing	11
Mouser Electronics	6
Nallatech	19
National Instruments	4
Pico Electronics Inc	7, 49
Rohde & Schwarz & Co	13, 35, 46
RTG Inc	44
Stanford Research Systems	37
TDK-Lambda Americas Inc	16
United Healthcare	30
Wind River	41

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VILLY MADSEN • IT COMPLIANCE ANALYST

Blame the programmer!

The spring of 1974 saw me working in the technical assistance center (TAC) of a major Canadian telecommunications company. We provided second-level support for two different generations of computer-controlled telephone switching systems. The older system was implemented using discrete diode transistor logic (DTL); the newer system used SSI DTL.

These systems comprised fully duplicated Harvard processors that usually ran in parallel. A control console monitored the state of critical registers in the processors, and any difference in the contents of these register pairs would generate a hardware interrupt—bells ringing and volumes of paper spewing from the maintenance TTY—initiating diagnostic routines to isolate the problem.

Early one morning, we received a call from the foreman at a switching office an hour or so north of us, wondering about the parity failures that were being reported on his switch. We ran memory diagnostics on the processor logging the errors a number of times, never logging any errors; re-synced the processors; and waited for the next "audit." The parity failure flag had been set during the previous 15 minutes, and again logged numerous errors.

The R/W memory on these systems was implemented using ferrite sheets—just like core but a lot denser. Each module contained 4K (16-bit) words and weighed about 80 lbs. Each SP1 switch would have four to 16 modules. When an error occurred in one of these modules, usually evidenced by the processors' dropping "sync," a printed report would identify the memory location in error.

We had a problem: The processors never dropped sync, and the memory exerciser did not report any problems. A few days of discussions with the manufacturer led nowhere. We couldn't even isolate the problem to a specific module.

Come the weekend, I headed up north and met with the switch foreman. Since this was an in-service telephone switch, we could not do anything that would disrupt processing. I had an idea.

A review of the processor schematics showed us that all of the parity error circuits were routed back to an SR flip-flop in the processor. The state of this flip-flop was read and reset once every 15 minutes by one of the audit routines. The maintenance counsel also had the capability to display register information for the "offline" processor. With a little trepidation, we mounted a couple of the CPU cards on extenders and ran a wire from the parity error flip-flop to the reset pin of the CPU stop flip-flop (a wired OR; this was DTL after all). We ran our memory exerciser and, with the CPU stopped, read the address of the failing memory location on the maintenance console, quickly isolating the problem to a single memory module.

It would have been nice to describe how we quickly swapped modules and went home for supper, but the truth is that we spent most of the day tweaking the various analog amplifiers in the memory module. When this failed to resolve the problem, we were told to swap the failing 80-lb module with one that wasn't failing to "prove" that we had isolated the problem.

It was late Sunday evening before we finally finished that task—the failing address moving as we expected. A replacement module arrived in time to be installed the following weekend.

In a quiet moment back at the TAC, I pulled out the source code. It looked good; it checked every word of the module under test, running various patterns through the memory. What had I missed?

The eureka moment came when I realized that the memory exerciser never checked the state of the parity error flip-flop. It was the memory parity bit line that had the problem, and since the data bus to the CPU did not include the parity bit, there was no way that the exerciser could determine the parity bit was in error!

Problem was solved, a snide note was sent to the manufacturer suggesting that it correct the shortcoming in the memory exerciser, and another feather was added to my cap—an important consideration when you are 23 years old and out to conquer the world! EDN

DANIEL VASCONCELLOS