UBM Tech

EDN®

MAR 2013
www.edn.com
Issue 3

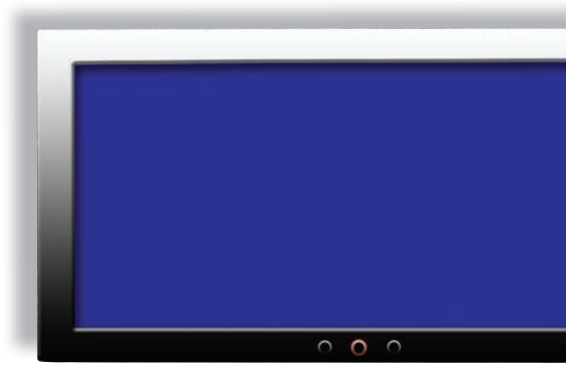
POWER
Si vs. GaN vs. SiC

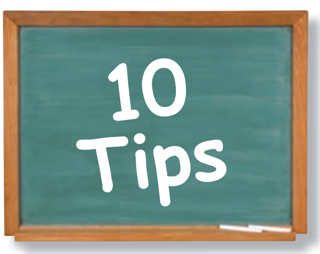
Page 38

EDN contents

March 2013

POWER
Si vs. GaN vs. SiC:
Which process and supplier are best for my design?



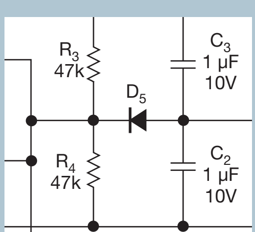


10 software tips for hardware engineers

LED-driving techniques reduce power in LCD TVs

COVER IMAGE: GIULIA FINI IMAGE(S): SHUTTERSTOCK, THINKSTOCK

DESIGNIDEAS



▶ Find out how to submit your own Design Idea: www.edn.com/4394666.

contents March 2013

pulse

DEPARTMENTS & COLUMNS

63

66

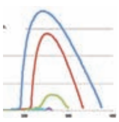
EDN® (ISSN# 0012-7515) is published monthly by UBM Tech, 600 Community Drive, Manhasset, NY 11030-3825. Periodicals postage paid at Manhasset, NY, and at additional mailing offices. SUBSCRIPTIONS—Free to qualified subscribers as defined on the subscription card. Rates for nonqualified subscriptions, including all issues: US, $150 one year; $250 two years; $300 three years. Except for special issues where price changes are indicated, single copies are available for $10 US and $15 foreign. For telephone inquiries regarding subscriptions, call 847-559-7597. Email: edn@omeda.com. CHANGE OF ADDRESS—Notices should be sent promptly to EDN, PO Box 3609, Northbrook, IL 60065-3257. Please provide old mailing label as well as new address. Allow two months for change. NOTICE—Every precaution is taken to ensure accuracy of content; however, the publishers cannot accept responsibility for the correctness of the information supplied or advertised or for any opinion expressed herein. POSTMASTER—Send address changes to EDN, PO Box 3609, Northbrook, IL 60065-3257. CANADA POST: Publications Mail Agreement 40612608. Return undeliverable Canadian addresses to APC, PO Box 503, RPO West BVR CRE, Rich Hill, ON L4B 4R6.

Volume 58, Number 3 (Printed in USA).

EDN online

JOIN THE CONVERSATION

Comments, thoughts, and opinions shared by *EDN*'s community

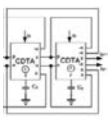


In response to "Runaway lithium-ion batteries," an entry in the Dave's Powertrips blog at www.edn.com/4407381, emc_eng commented:

"Lithium-ion battery fires are old news. So, also, is the fact that they are in wide use without problems ...

Remember the wing and rudder separation problems experienced on the 787 development? The military side of Boeing tried to advise the 787 commercial folks on the proper way to join composite airplane sections. They have been accomplishing that for years, but their advice was brushed aside.

[More than three] major innovations ... at once in a major new commercial airframe project are not recommended risk management. If you are going to innovate on such a scale, you can expect the unexpected, unless you suffer from hubris."



In response to "The current differencing transconductance amplifier," an article by Jun Xu and Chunhua Wang at www.edn.com/4405810, atemp commented:

"Until somebody starts sampling and shipping actual chips that are practical, repeatable, and stable, with lots of competition and drop-in equivalents, CDTAs will join current conveyors and 'perfect' OTAs in being purely SPICE or lab curiosities—impractical and irrelevant."

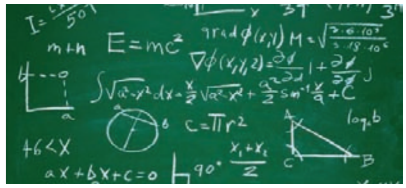
In response to the 5 Engineers question "What's the most idiotic question you've ever been asked during a job interview?" at www.edn.com/4407394, georgegrimes commented:

"I was asked, 'What do you want inscribed on the headstone of your grave?'"

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

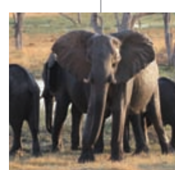


WHY ENGINEERS ARE AWESOME

When there's an opportunity to celebrate engineers and all they do, *EDN* is not going to let it go by without adding our cheers. Here are 10 reasons engineers and being an engineer are awesome.

www.edn.com/4407077

AN ENGINEER ON SAFARI—WHAT AFRICAN ANIMALS TEACH ABOUT PROBLEM SOLVING



Tamara Schmitz has turned her visit to Botswana into an entertaining and educational exercise in problem-solving techniques she has garnered from the natural instincts of some amazing animals living and coexisting in the wild.

www.edn.com/4407329

ENGINEERING COMMUNITY

Opportunities to get involved and show your smarts

designwest

center of the engineering universe

DESIGN West

Increase your knowledge level and skill set while networking with your peers at this year's DESIGN West, April 22 to 25, in San Jose, CA. With scheduled keynote presentations from NASA Mars Science Laboratory Mission Engineer Luke Dubord and MIT Media Lab Biomechatronics group Director Hugh Herr; 250 exhibitors; and more than 150 technical lectures, panels, tutorials, certification programs, and hands-on training sessions, DESIGN West is a can't-miss event. For more information and to register, visit **www.ubmdesign.com**.

BY PATRICK MANNION, BRAND DIRECTOR

Pick your favorite contributor; winner gets $5000!

On April 23, as part of the annual ACE Awards celebration at DESIGN West in San Jose, CA, we will be presenting a plaque and a $5000 check to the person we as a community consider to be most deserving of the Jim Williams Memorial Contributor of the Year Award.

The award came into being in the aftermath of that double tragedy during the summer of 2011, when we lost Jim Williams and then Bob Pease (see "Remembering Jim Williams and Bob Pease," www.edn.com/4375963). Those losses resonated throughout the industry and highlighted not just the absolute and intrinsic value of Jim's and Bob's respective contributions, but also the gulf left behind upon their passing. The question became, Who could be the next Jim or Bob?

While both men had been strong contributors to the community at large, Jim had been particularly prolific with his contributions to *EDN*. He published his first article in *EDN* in 1975; his final two *EDN* articles appeared in print shortly after his death. (A selection of Jim's articles is available at www.edn.com/4374116.) We at *EDN* knew we had to find some way to memorialize the man, his contributions, and the spirit with which he gave of himself to inspire and help so many to be the best engineers they could be.

At the time of his passing, Jim was working at Linear Technology, so we talked with John Hamburger, Doug Dickinson, and Bob Dobkin, and together we concluded that there could be no better way to celebrate Jim's legacy than to spotlight others who have found their own way to help, inspire, mentor, teach, or otherwise give back to the engineering community.

Those conversations led to the creation of the first Jim Williams Memorial Contributor of the Year Award, distributed at last year's ACE Awards. The award was granted posthumously to Jim himself during a touching presentation by Jim's friend and longtime *EDN* and UBM Tech editor Bill Schweber. Jim's wife, Siu, and son, Michael, as well as Bob Dobkin and several other colleagues and friends, attended the ceremony.

It may be that in the course of selecting this year's winner—a process that actually began in June of last year (see "Who can carry on Jim Williams' and Bob Pease's work?" www.edn.com/4375194)—we end up uncovering another Jim or Bob, and if so, that's great. But everyone finds his or her own way to contribute to the industry, inspire others, and give back to advance the state of the art in electronic engineering and design. So, while we already have some names in the hat for consideration, it's important that we continue to search far and wide for those we believe to be likely candidates.

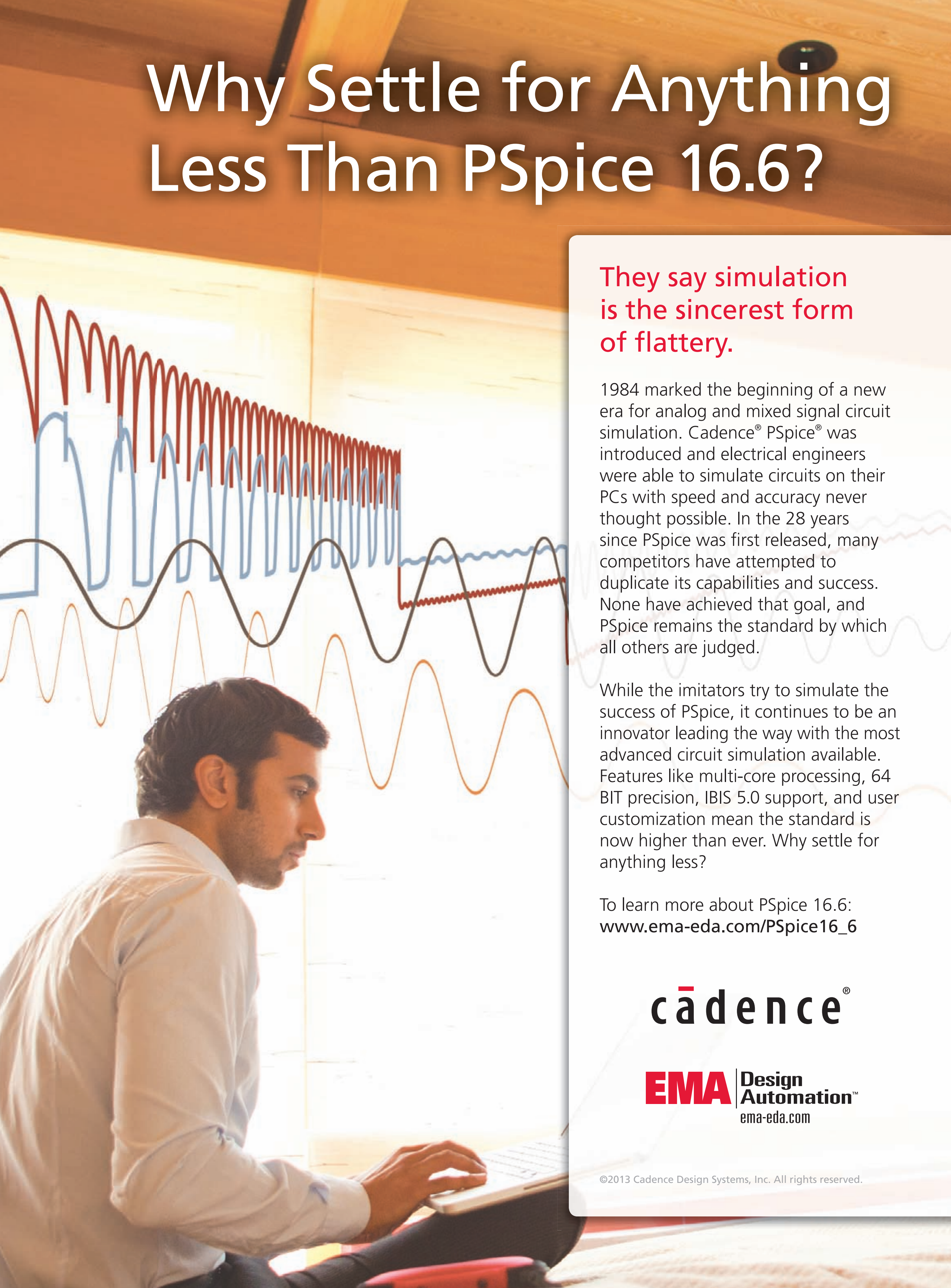
I'm very grateful to our mother ship at UBM Tech for freeing up the $5000 as a token of our appreciation for the winner's efforts. I hope that this extra perk also inspires you to nominate your own choices for this year's award, so he or she may receive some well-deserved recognition, as well as funds either to celebrate with or, just as likely, to apply to a new home or even a small garage-shop engineering project.

Who will receive the 2013 Jim Williams Memorial Contributor of the Year Award?

Please send along your nominations. We'll compile them, put the top candidates to you for a vote, and announce the winner during the ACE Awards on Tuesday, April 23, at the Sainte Claire Hotel in San Jose. The festivities are scheduled to start at 6:30 p.m.; tickets are available at www.ubm-ace.com. Note: I'm also grateful to Linear Technology for its support in sponsoring the event itself.

I hope to see you either at the awards ceremony or while shuffling between meetings at the conference. It's very possible I'll be wearing a beanie hat (there's a story there: http://bit.ly/12zDfG4), so be sure to stop and connect. EDN

Contact me at patrick.mannion@ubm.com.


Why Settle for Anything Less Than PSpice 16.6?
They say simulation is the sincerest form of flattery.
1984 marked the beginning of a new era for analog and mixed signal circuit simulation. Cadence® PSpice® was introduced and electrical engineers were able to simulate circuits on their PCs with speed and accuracy never thought possible. In the 28 years since PSpice was first released, many competitors have attempted to duplicate its capabilities and success. None have achieved that goal, and PSpice remains the standard by which all others are judged.
While the imitators try to simulate the success of PSpice, it continues to be an innovator leading the way with the most advanced circuit simulation available. Features like multi-core processing, 64 BIT precision, IBIS 5.0 support, and user customization mean the standard is now higher than ever. Why settle for anything less?
To learn more about PSpice 16.6:
www.ema-eda.com/PSpice16_6
cadence®
EMA Design Automation™
ema-eda.com
©2013 Cadence Design Systems, Inc. All rights reserved.

pulse

INNOVATIONS & INNOVATORS

Self-contained RF recording system weighs less than 10 lbs

For less than $60,000, it is now possible to record and play back RF signals to evaluate radio signals all over the world. The impressive thing is that no longer do you need a technician and a van stocked with rack-mounted equipment to collect data. Now, if there is a problem with interference or dropped calls, the carrier can send out a QRC Technologies wideband transcorder (WBT) and evaluate the signals in the lab.

A notable feature of the WBT is that it uses an open-file format to record the data, so you can collect signals off the air and run the data through MATLAB—a good option for universities. "Other tools have their own file format that works only on their equipment," notes Tom Callahan, QRC's chief technology officer. "We have always been good at making things simple. This product is intentionally designed to be friendly to whoever might want to use it."

The WBT can record 2×25-MHz blocks of spectrum between 50 MHz and 4.4 GHz. It is physically stackable with other WBTs, to enable simultaneous recording/playback of larger chunks of spectrum. The top unit can remotely control the other WBTs.

Other features include 84-dB instantaneous dynamic range; power consumption of 60W typical, 25W idle; and the ability to upgrade online. The first year of upgrades is included. In addition, no external receiver or transmitter is needed, playback can be done at any frequency, and the interface allows for one-button record/playback.

The WBT measures 18.7×12.4×3.1 in. and contains an embedded GPS disciplined oscillator, Gigabit Ethernet and eSATAp ports, a removable CFAST flash card, and two bays that use 2.5-in. solid-state disk drives for continuous recording. An optional lightweight power pack enables more than two hours of use.

Pricing for the WBT begins at $59,995. It is available for order immediately for July shipping. **—by Janine Love**

▷**QRC Technologies,** www.qrctech.com

The wideband-transcorder RF recording and playback system from QRC Technologies aids interference and quality-of-service identification and resolution.

TALKBACK

"It always fascinated me how analogous physical principles rule the various engineering disciplines. A well-designed physics course at the high school or undergraduate level could incorporate these analogies and cement the knowledge and interest of budding engineers."

—Commenter BillyD, in response to the article "Three things they should have taught in Engineering 101, Part 2: How to visualize electrical components," at www.edn.com/4407227. Join the conversation and add your own comment.

Dash-cam video: benefit or distraction?

In the wake of the recent meteor strike in Russia, the prevalence of dash-cam video and stills has been brought to the front of discussions. The vast availability of vehicles with these devices—most with resolution ranging from VGA to 1080p—makes for a great source of scientific content for analyzing such an event.

The cameras, most with MicroSD storage for the DVR, record 30 to 60 minutes of video and then re-record the loop. The goal is to help document accidents and determine fault.

The diversity of dash cams also has a range of "ease of use" levels. The typical dash cam uses a suction mount to connect it to the front window. Just as with navigation systems, phones, radar detectors, toll tags, parking stickers, and so on, it is another device or obstacle that consumes the precious visibility area of the front window. This device, however, requires buttons to control, and in some models has a distracting screen that is in the driver's line of sight.

While the benefits of OEM cameras that can record activities with a control view into the car AV system (as is done with the rear-view cameras) are obvious, the aftermarket ones need some controls. For example, the problem that results from the sale of the image of the meteor is drivers chasing after events for video content, rather than observing traffic and the road. If the focus of the driver is on the scene or to properly capture the events as they are happening, there is a strong chance that this will affect the number of accidents that are occurring on the roadways.

Just as when YouTube was first launched, there is a flood of "in car" video and photos of people trying to get recognized doing stupid things or capture events that are re-sellable as unique. The difference in this case is that to re-point the lens you need to re-point the vehicle.

The most common use in the United States is actually in-cabin-facing cameras for cabs, public transit, limos, and airport transportation. These cameras are manually controlled and used to protect passenger safety.

The typical dashboard camera uses a suction mount to connect it to the front window (a). Some models, however, have a distracting screen that is in the driver's line of sight (b).

The outfacing cameras are a new application. A few of the designs are unobtrusive, being integrated with the rear-view mirror or existing alongside driver-assist and lane-change warning cameras. The United States has not determined whether dash cams are good or bad. To date, there are no rules or regulations about them, other than you cannot put one on the front window directly in front of the driver.

> "With the addition of interactive video screens, the time spent looking at the road is dropping.

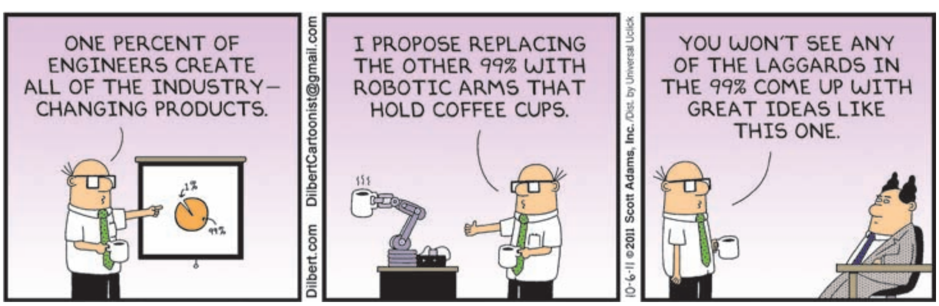
The question that comes to mind is whether the level of AV and integration with mobile devices is overwhelming the driver. While attempts are being made to keep the driver's hands on the wheel with hands-free accessories, the limits of visual awareness and ability to process the information are coming into play. With the addition of interactive and engaging video screens, live-playback content on dash cams, rear-view cameras, and infotainment, the time spent looking at the road and other cars or people is dropping.

Automotive designers need to have a system-level integration of all of these AV feeds into a single area. That integration will allow for the control of the feeds to a single display that can manage the appropriate time to display the information based on the driver's activities. Just as infotainment systems support AUX inputs for audio from headphone jacks, the need to bring multichannel and multisource AV via, for example, MHL, wireless, and HDMI to this central console will allow these functions to be safely used in vehicles.

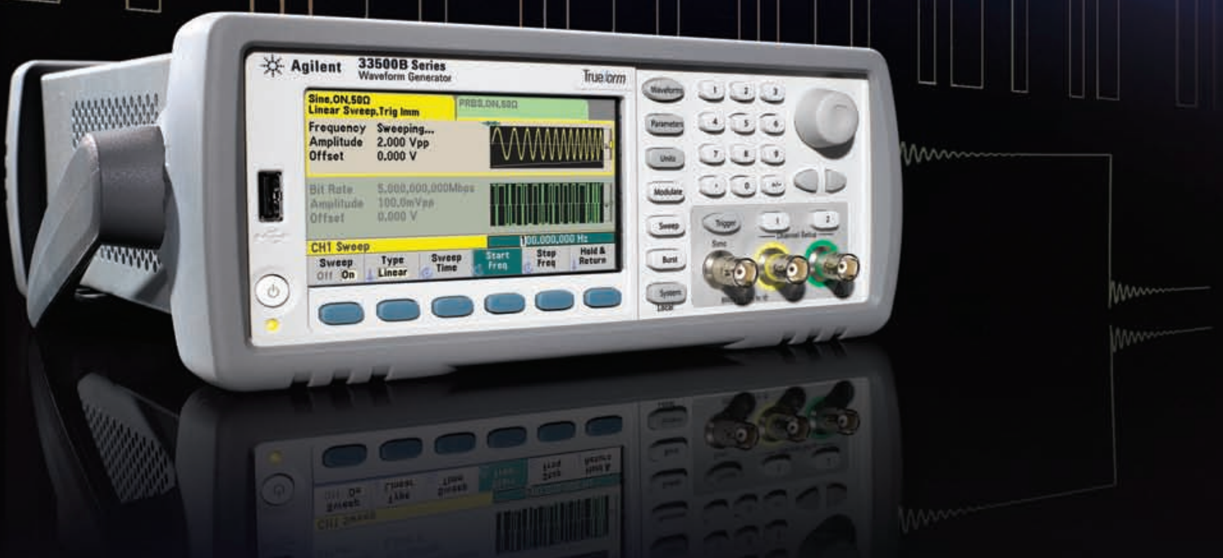
—by Pallab Chatterjee

▷**Automotive Innovation blog**, www.edn.com/4408061

DILBERT By Scott Adams



Generate the exact waveforms you want. Introducing Agilent True*form* technology.



Agilent 33500B Series waveform generators with exclusive Trueform signal generation technology offer more capability, fidelity and choice than traditional DDS generators. Get the precision and flexibility you need to characterize new components and designs with superior confidence. And accelerate development from start to finish.

Scan or visit http://qrs.ly/lu2yhdn to view a 35500B Series product overview

33500B Series Waveform Generators
Sine waves with 5x lower harmonic distortion
Pulses up to 30 MHz with 10x less jitter
Point-by-point arbitrary waveforms with sequencing
16-bit resolution with 1 mV_{pp} to 10 V_{pp} amplitude
8 upgradable models in 20 & 30 MHz

Agilent and our Distributor Network
Right Instrument.
Right Expertise.
Delivered Right Now.

Newark element14

800-463-9275
www.newark.com/agilent

Learn more about the advantages of Trueform waveform generation
www.newark.com/Agilent_Function_Generator

Anticipate ___Accelerate ___Achieve

Agilent Technologies

Time-of-flight proximity sensor allows new smartphone-user interactions

Combining three optical elements in a single compact package, the VL6180 is the first member of STMicroelectronics' FlightSense family and uses a new optical-sensing technology that enables innovative new user interactions with smartphones.

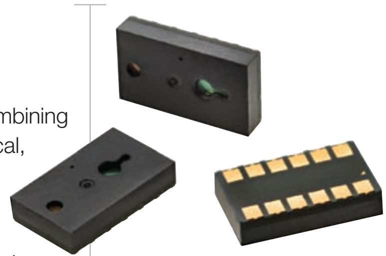
The VL6180 uses a proximity measuring technology to offer what the company calls unprecedented accuracy and reliability in calculating the distance between the smartphone and the user. Instead of estimating distance by measuring the amount of light reflected back from the object, which is significantly influenced by color and surface, the sensor precisely measures the time the light takes to travel to the nearest object and reflect back to the sensor. This "time of flight" approach ignores the amount of light reflected back and considers only the time for the light to make the return journey.

The key to ST's patented new solution is an infrared emitter that sends out light pulses, an ultrafast light detector that picks up the reflected pulses, and electronic circuitry that accurately measures the time difference between the emission of a pulse and the detection of its reflection. Combining unique electronic, optical, and packaging expertise from across the company, the VL6180 embeds both a robust ranging time-of-flight sensor and a wide dynamic ambient-light sensor die, along with an infrared emitter.

Thanks to its all-in-one, ready-to-use architecture, the device is easy to integrate and saves phone makers long and costly optical and mechanical design optimizations. The ability to measure a reliable absolute distance from the phone to a hand or other object opens up new user-interaction scenarios that phone manufacturers and app developers can rapidly exploit.

—by Julien Happich

▷**STMicroelectronics**, www.st.com



The VL6180 proximity sensor from STMicroelectronics uses a "time of flight" approach to accurately and reliably calculate the distance between a smartphone and its user.

Motor-control solution simplifies field-oriented-control designs

Texas Instruments has announced its InstaSPIN-FOC (field-oriented control), a sensorless software-based solution built on the company's FAST (flux, angle, speed, and torque) algorithm. Embedded in ROM on 32-bit C2000 Piccolo microcontrollers, the new package is intended to slash the time required to spin up motors using FOC techniques, enabling engineers to identify, tune, and fully control any type of three-phase, synchronous, or asynchronous motor within five minutes.

Until now, engineers have had to rely on encoder/resolver sensors or complex software algorithms as observers to generate the precise data about rotor position required to produce maximum torque with FOC methods. Sensor-based solutions have suffered from cost and reliability concerns, while software observers require extensive characterization of motor properties and are typically challenged by operating modes outside of their primary range of operation. Even with precise rotor-positioning data, however, engineers have still faced difficulties in designing motor-control algorithms able to ensure maximum torque through a full range of operating conditions.

TI's InstaSPIN-FOC is designed to shorten development time of FOC-based applications by delivering a drop-in sensorless solution that effectively automates FOC-based motor-control system development. Working out of the Piccolo MCU's on-chip ROM, InstaSPIN-FOC uses TI's proprietary FAST algorithm, which automatically characterizes a motor during an initial 90-second identification phase, enabling engineers to start development of any specialized features on a stable, working platform. The algorithm remains stable through start-up, zero speed, and stall recovery. Along with the basic information about angle and speed, TI's algorithmic solution is unique in providing a torque signal that can eliminate the need for separate mechanical torque sensors, further reducing the cost and complexity of motor applications.

TI offers InstaSpin-FOC as a ROM-based library in its 90-MHz, 32-bit Piccolo F2806xF MCUs, which, along with on-chip ROM, include 256 kbytes of flash memory; 96 kbytes of RAM; multiple timers; peripherals; a 16-channel, 12-bit, 3-MSPS ADC; and serial interfaces.

InstaSPIN-FOC is available now on the Piccolo F2806xF MCUs starting at $6.70 (10k). TI plans to make InstaSPIN-FOC available on several other Piccolo microcontrollers in the near future. Three InstaSpin-FOC design kits are also available, including a low-voltage, low-current motor-control kit for $299; a low-voltage, high-current motor-control kit for $299; and a high-voltage motor-control kit for $699. Engineers who already own a TI motor-control development kit can order a modular InstaSPIN-FOC-enabled Piccolo controlCARD for $99.—by Stephen Evanczuk

▶**Texas Instruments**, www.ti.com

Will 2013 bring tighter power-supply efficiency requirements?

Things have remained quiet during the past few years with respect to new external-power-supply (EPS) efficiency requirements. Despite some minor tweaks in no-load power-consumption levels by mobile-phone consortia and government groups, things haven't changed much since early 2011, when the European Commission (EC) adopted the 2008 Energy Star EPS Version 2 program specifications. (The US Environmental Protection Agency [EPA] "retired" its EPS-specific efficiency program at the end of 2010, citing relatively high Energy Star market penetration and existing US federal minimum-efficiency standards for EPSs.)

The situation, however, may be about to change. If recent agency draft specifications are finalized this year, the result could shake up the current EPS-efficiency-regulation landscape. Here are a few examples:

- As of late February, the US Department of Energy (DOE) had still not publicly commented on the final status of 2012's proposed expanded EPS efficiency requirements, intended to revise EISA2007's EPS regulation currently in effect. The proposed standard not only tightens both active-mode efficiency levels and no-load power consumption of currently covered product but also includes more types of power supplies, setting a new bar for EPS efficiency programs. The DOE had hoped to release both its EPS and battery-charger-system standards in 2012, but so far neither has appeared in the pages of the US Federal Register.
- Meanwhile, in Europe, the EC in September 2012 published a draft of its Code of Conduct on Energy Efficiency of External Power Supplies, Version 5. The new, voluntary code-of-conduct specs propose tightening active-mode efficiency and no-load power consumption. An additional efficiency requirement at 10% load has been added to ensure that the EPS is efficient in applications where a product spends time in lower-power idle or standby mode. The proposal is currently under discussion, but the tier 1 effective date is still planned for January 2014.

The US Department of Energy's 2012 proposed standard for external power supplies (EPSs) raises the bar for EPS efficiency programs.

- In November 2012, the EPA published the latest draft proposal for version 6 of its Energy Star computer program. Draft 3 includes an incentive for products that come with a more efficient power supply than required by the basic program spec. In that case, the typical energy-consumption equation is modified, making it easier for the computer to achieve Energy Star compliance. The incentive affects internal power supplies as well as EPSs. As with the code of conduct, this allowance also encourages power-supply efficiency at 10% load, corresponding to a computer's approximate idle-mode condition.

Add to the above activity the fact that the EC is required to review its current Ecodesign Directive EPS efficiency standard this year for possible revision, and you'll see why 2013 could be an interesting one for power-supply designers.

—by Richard Fassler

▷**Eye on Efficiency blog**, www.edn.com/4407921

Smaller Raspberry Pi costs under $25

A smaller version of the Raspberry Pi computer built in the United Kingdom is driving the cost to less than $25. Element14 has announced the launch of the new credit-card-sized Raspberry Pi Model A board in Europe. It uses the same 700-MHz ARM1176 Broadcom BCM2835 processor but includes as standard only 256 MBytes of RAM. There is no Ethernet connection and only one USB port, but it does use considerably less energy for battery-powered applications.

The Raspberry Pi Model A board uses the same 700-MHz ARM1176 Broadcom BCM2835 processor as the Model B board but includes as standard only 256 MBytes of RAM.

The larger Model B sold more than 500,000 units, and demand for the Model A board is anticipated to be from those making industrial-control modules, roboticists, people doing automation, and, significantly, those wanting to use the Pi as a cheap media center.

In recent weeks, Element14 has launched two exclusive accessories to support the development of new applications and uses: the Gertboard, a flexible experimenter board that connects the Raspberry Pi out to the physical world, and PiFace, which allows the user to sense and control the real world. Both are available for purchase to supplement activity on the Raspberry Pi and can be used with both the Model A and Model B boards.

"The Model A board is the next item in the Raspberry Pi range to be manufactured exclusively in Wales by Sony in partnership with Element14," says Claire Doyle, global head of Raspberry Pi at Element14. "Being a part of the Raspberry Pi revolution is something we are very proud of, as computer science and programming skills are key to ensure future generations of design engineers."

The Model A board costs just under $25 (£15.95), plus tax and shipping, and is available today through Farnell Element14 in Europe and CPC in the United Kingdom and Ireland. Additional countries will be added in the coming weeks.

—by Nick Flaherty

▷**Raspberry Pi**, www.raspberrypi.org

VOICES

Peter Spitzer: Motivated by testing, challenges, and constant learning

In late January, *EDN*'s sister site *Test & Measurement World* named Peter Spitzer its 2013 Test Engineer of the Year. A member of the TRICENTIS team since 2008, Spitzer is currently the team lead at TRICENTIS Test, responsible for quality assurance of the TOSCA Testsuite, including creation/planning and implementation of test concepts and reporting the test results. *Test & Measurement World* Editor-in-Chief Janine Love spoke to Spitzer about his fascination with test, as well as his plans for the $10,000 grant that comes with the award. Following is a portion of that discussion. Read more online at www.edn.com/4406136.

How/why did you get started in engineering?

A I was influenced by my uncle. He worked as a test manager for many years and gave me my first desktop PC. It was great fun for me (and still is) to solve problems with hardware and software. I guess this first professional contact blazed the trail for my career. At the age of 15 or 16, I discarded my dreams of becoming a policeman and decided that I wanted to work in the IT business. The testing part of my job just happened.

Tell me a bit about your professional history.

A I studied at the Technical University of Vienna for four years and am still studying medical information systems at the university.

I first worked for a large pharmaceutical company, Boehringer Ingelheim, on internal support and software testing and then joined TRICENTIS in 2008. My first assignment at TRICENTIS was to test the company's own TOSCA Testsuite prior to release rollout. I was later promoted to senior consultant, and two years ago I became the test manager.

What do you find interesting/intriguing/fascinating about test?

A One of the endlessly interesting and fascinating things about software testing, test automation, and test management is the variability in terms of what needs to be tested. Testing as a profession is never straightforward. You always have new situations where you have to adapt your skills, methods, strategies, and even tools.

I wasn't born to do repetitive work. This is why I enjoy solving the redundant testing with test automation and finding ways to increase efficiency and improve effectiveness. I love the challenge, the competition, and solving tricky puzzles.

Another point that fascinates me is the never-ending learning that comes with software quality assurance.

I never go to work without learning something new. There are new hurdles that I have to overcome, and this motivates me every day.

When I started as a test engineer in 2008, the most intriguing facet of testing was the endless variety of options and methodologies to develop and execute tests and all the different flavors of test tools and methods in the market. What impressed me about TOSCA is that the tools are not just ways to automate but can also enable testers to take a risk-based approach and test the right things in the right priority order.

Any test tools you wish you had?

A I wish that we had test data management (TDM) in the early days when I started testing. In the past, we had to create our own test data for particular test cases. We could try to use production data but then needed to mask the data or spend weeks creating fictitious test data for a particular test. Today with TDM, this step is no longer necessary because the test team is able to build a test case and automatically generate the perfect test data for that particular scenario. This saves us months of work.

In the future, I can see a time where the next generation of testing is much more integrated with the agile sprints and where the test automation begins much earlier in a project. Often we are brought in a bit later in the game. Shifting the testing to the left of the development release cycle would let us catch defects and errors much sooner in the process. If we could catch these when they are in the requirements phase, that would be even better.

Any advice for new engineers?

A I'm not yet an "old hand" in this business. What I can tell you is that, for me, working as a test engineer is one of the most fulfilling and rewarding experiences I've had so far. As a tester you should be a communicative person, offer good analytical and social skills, and have good perception along with a passion for solving tricky puzzles. All I would recommend is be persistent, insist on excellence in testing, and use every source of knowledge you can get to become a better tester.

You will receive a $10,000 grant to give to the educational institution of your choice (courtesy of award sponsor National Instruments). What will you do with it?

A I would like to set up a scholarship fund for a student who is interested in a career in software testing but is economically disadvantaged. We will be contacting a university shortly to see if this is feasible.

What's next for you?

A There is always a "next." You'll never reach a point where you can say, "I've seen everything; I know everything." There's constant learning and further training until the end of your career.

BY HOWARD JOHNSON, PhD

Measuring shadows

Try measuring the height of a building using its shadow. The building's shadow is, at best, a distorted, fuzzy, and somewhat inaccurate impression of the real article, sometimes missing completely. It may be long or short according to the angle of the sun and the tilt of the street upon which the shadow falls. The entire procedure is plagued by a host of imprecise effects.

Would a surveyor's transit level (**Figure 1**) give a more accurate measurement? Possibly, but it's still not perfect. The accuracy of a transit depends on the level set of the instrument, the alignment of its spotting scope with the frame, careful adjustment by the operator, and a reference distance established between the instrument and the base of the building. All said and done, the operator isn't really measuring the height of the building; he is reading a number from a protractor bolted to the side of the unit that shows the approximate position of the scope, which points generally in the direction of the top of the building. Measurements always work that way; they never reveal the thing you wish to know, only the shadow of that thing.

Figure 1 The surveyor's transit level measures both horizontal and vertical angles.

IMAGE: THINKSTOCK

Consider the measurement of voltage. Take a conductive sphere the size of a basketball, suspend it on a silk thread, and charge the sphere with respect to the earth to a potential of more than 10,000V. Stick your arm into the space between the earth and the sphere, touching neither. You can feel the potential on your skin; it makes the hairs on your arm stand straight out. You needn't touch the sphere to know it is highly charged.

Now hold your best scope probe in the same space. It will not respond. A scope probe does not respond to voltage potential. It responds to the flow of current in its first stage of amplification. No current, no response. Even a high-quality FET amplifier requires current to charge its gate capacitance. Because the air surrounding the sphere cannot supply much current, the probe fails to respond unless you touch the sphere, which instantly destroys the probe.

In electrical-engineering language, a good scope probe gives a meaningful response only when the input impedance of the probe vastly exceeds the impedance of the device under test (DUT). When that impedance condition is not met, as in the sphere example, the probe gives no warning; it simply reports the shadow it sees, which gives a wrong answer.

You needn't touch the sphere to know it is highly charged.

In a perfect world, you would know the input impedance of your probe and the impedance of the DUT—both as functions of frequency—and you would apply a frequency-dependent correction factor to your results. In the real world, that situation rarely occurs.

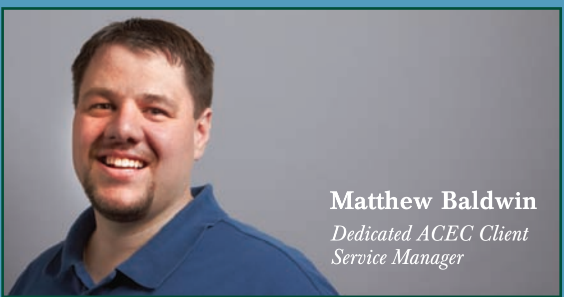
Here is a practical way to test the impedance condition. Obtain a second probe of the same type. With the first probe connected to the DUT, apply the second probe to the same spot on the DUT. If the second probe changes the measured waveform in any noticeable way, you may assume that the first probe probably induced at least as much of a change. Keep trying different probe styles until you find the one that changes the signal the least. Thereafter, mark that probe with a yellow tag that says, "Do not use; needs calibration." That way, the good probe will still be in your lab the next time you need it. **EDN**

Howard Johnson, PhD, of Signal Consulting, frequently conducts technical workshops for digital engineers at Oxford University and other sites worldwide. Visit his Web site at www.sigcon.com, or e-mail him at howie03@sigcon.com.

ACEC
LIFE/HEALTH TRUST

Meet Your Dream Team

Four great reasons to join ACEC and our health plan



Your dedicated account team is U.S.-based, with 20+ years of combined engineering industry/health care coverage experience.

When you become an ACEC member and choose the ACEC Life/Health Trust insured by UnitedHealthcare, you're aligned with experts who provide solutions that may lead to healthier employees and lower health care coverage costs.

As an ACEC member, you may benefit from:

- **Savings —** ACEC members may receive up to 12%* savings on their annual premium.
- **A broad network —** 98% of the U.S. population has local access to a UnitedHealthcare provider.**
- **Your choice of broker —** There's no need to switch agents.
- **Streamlined administration —** Moving from your current health plan is surprisingly simple.

Learn how your engineering firm can benefit from membership in ACEC and the ACEC Life/Health Trust insured by UnitedHealthcare.

Call 1-877-271-6825 or visit uhctogether.com/3337 for more information and to download a copy of our complimentary white paper.

The American Council of Engineering Companies (ACEC), the ACEC Life/Health Insurance Trust and UnitedHealthcare Insurance Company are three separate legal operating entities and, as such, the organizations are governed and function independently. UnitedHealthcare's services are provided with the authorization of the ACEC Life/Health Trust. Questions related to health benefits offered through the Life/Health Trust should be directed to 1-800-573-0415. HMO products don't apply. ACEC membership qualification is determined by the association.

*Potential 12% savings on annual premiums for businesses with 2-99 employees, as compared to UnitedHealthcare products sold outside the ACEC Life/Health Trust.

**Network statistic based on GeoAccess information and UnitedHealthcare standard network access mileage criteria, 2010.

Insured and serviced by:

UnitedHealthcare®

UHCEW628726-000

BY PALLAB CHATTERJEE

Another radio, another set of apps

In the effort to simplify and improve wireless communications for non-streaming data, yet another standard is making inroads to the market. The near-field-communication (NFC) connection methodology, first standardized in 2004 by a consortium of wireless and RFID partners, was created to address burst-mode and small packet data with a minimum handshake. The communication protocol originated in the RFID industry and uses the same 13.56-MHz band as the mainstream tag industry while supporting both active-powered and passive communication products.

NFC products are unique in the variety of product spaces they address and in the extent of their development support. The three main markets for NFC are proximity/tap and go, secured access, and e-commerce/e-payment applications.

Passive cards for electronic-wallet applications and smartcards, including ID tags, dominate the e-commerce market. The volume market for NFC e-commerce cards is expected to exceed 1 billion units by 2015. The cards extend to the access-control marketplace using the security engine and encryption that are part of the core specification of NFC. These e-commerce applications, also targeted toward retail, point-of-sale (POS), and banking functions, will account for at least an additional 40 million units in 2015.

These major applications are seen in the commercial marketplace under the banners of Google Wallet; Isis Wallet; the Smart Card Alliance; and Europay, Mastercard, and Visa (EMVCo). **Figure 1**, taken from an Intel Corp presentation at last year's Intel Developer Forum, shows examples of this application segment.

The active side is centered on mobile devices and laptops. Current operating systems such as Windows and Android include native support for the NFC stack and security engine as part of their development environments. For the implementation side, Intel supports an NFC software driver; a manageability engine, in firmware; an identity-protection technology/Public Key Infrastructure tool kit; and a Common Connectivity Framework—currently in version 3.0—which is a middleware solution. The support tools work with NFC-certified radios and control ICs for the phone, tablet, and ultrabook segments.

Among the differences between the NFC protocol and such others as USB, Wi-Fi, Intel Wireless Display (WiDi), and Bluetooth is NFC's optimization for burst-mode data. The system is set up for automated pairing and sharing, thus enabling the wireless high-speed transfer of small object data, using a secure, error-correcting block-transfer scheme. This allows POS transaction and billing data, such as account numbers and confirmation codes, to be quickly transferred with high reliability. The block-based data can be extended to photos and audio playlist data but is not targeted toward gigabyte-level video content.

Figure 1 This graphic, presented at the 2012 Intel Developer Forum, shows examples of NFC e-commerce applications (courtesy Intel Corp).

Because the security engine is an integral part of the protocol, the NFC proxy to and from the host can operate in two modes: filter, for secure usage, and pass-through, for non-financial/ID applications. The interface and SoCs support the creation of ad-hoc and short-duration peer-to-peer networks between two devices with compliant radios but spread over platform, OS, and application spaces. The peer-to-peer networks include authentication through extended WANs. In this application, a smart device (card, ID tag, phone, or the like) can be "tapped" to a laptop for authentication. If the laptop is on a wired or wireless LAN to a WAN, it can be used as a conduit for the smart device to authenticate at a cloud-based endpoint and establish a direct peer-to-peer connection between the smart device and the cloud server.

Unlike active-only wireless formats, NFC is becoming a dominant technology for machine-to-machine (M2M) communications. Adding intelligence and secure communication to Internet of Things (IoT) devices, most of which only need to transfer data on demand, is the fastest growing application for NFC radios. The addition of NFC to mobile phones as a native portion of the Android OS is driving the growth of NFC on those devices as the default host device and portal to the cloud-based processing of IoT data.

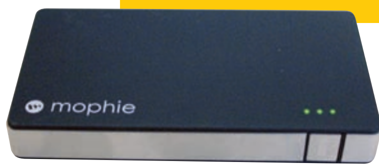
With the incorporation of low-power modes and on-demand data transfer for NFC, the protocol has joined cellular and Wi-Fi RF design as a staple of mobile- and laptop-system design. EDN

Pallab Chatterjee has been an independent design consultant since 1985.

WANT MORE?

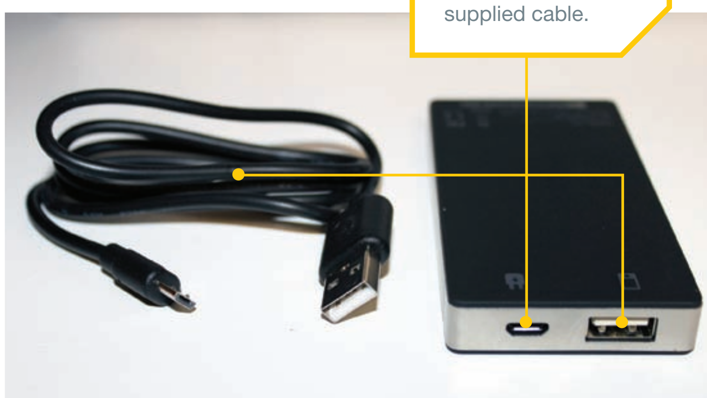
- Read more on the juice pack, and provide feedback, at www.edn.com/4408109.
- Go to www.edn.com/learning/teardowns for more Teardowns.
- For data sheets on the devices discussed in this Teardown and thousands of other parts, go to www.datasheets.com.

Cell-phone charger: nice idea done right



Back in November 2012, *EDN* Brand Director Patrick Mannion published a teardown of a cell-phone battery charger (www.edn.com/4401998). The design was not well done and received bad reviews. Redemption! I recently acquired a Mophie juice pack powerstation mini smartphone and USB-device battery charger that not only negates the previous teardown fiasco but also demonstrates the ability to provide more than twice the battery life to your smartphone while still keeping a low-profile shape that slips right into your pocket.

Mophie, a California-based designer and manufacturer of mobile intelligent devices and accessories, developed the juice pack, the first ever "Works with iPhone" portable battery case certified by Apple. I contacted the company via e-mail for its help clarifying this design as well as the component types. It has not yet responded, so I give you my educated guesses. *EDN* readers are encouraged to weigh in with their own thoughts and expertise.

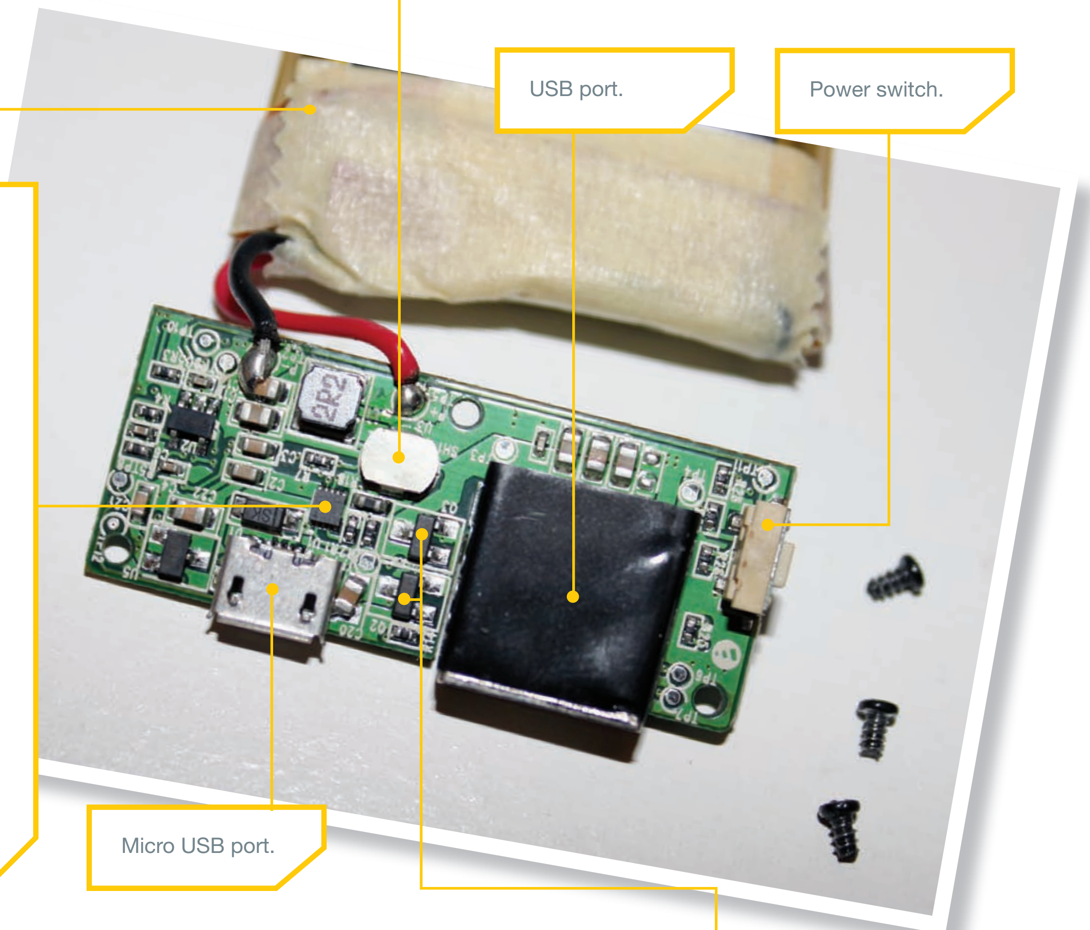


The micro USB and standard USB ports on the side of the case were quite secure. I tested them many, many times, inserting and extracting the connectors from the supplied cable.

I think a Microchip MCU is located under the shield shown. The microcontroller usually controls the housekeeping; provides charge control for the USB battery-charger IC, IC_1; controls the four LEDs for the charge-status indicator; has I^2C bus capability if needed for IC_1; and controls the power MOSFETs. The Microchip part is unusual for a few reasons. It appears to have a Microchip symbol and only a date code, with no sign of a part number. There are eight pins on two sides opposing one another. On the other two sides are what look like eight pins—six of the eight are cut off and two are connected to the PCB, on each opposing side. Sometimes manufacturers provide early samples of a new die not yet fully qualified in a nonstandard package, but I am not sure.

2500-mAh lithium-ion battery.

Power-indicator LEDs with rubber elastomer.



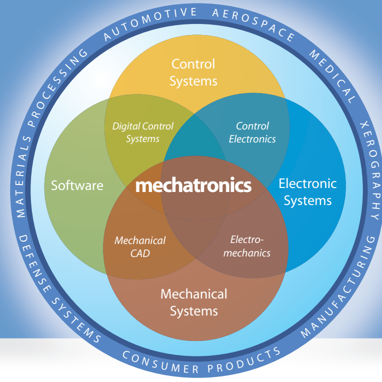
There are three USB specifications—USB 1.0, 2.0, and 3.0—but here we focus on USB 2.0, as it's by far the most common. In any USB network, there is one host and one device. In this case, the Mophie juice pack is the host, and your smartphone/tablet/camera is the device. Power always flows from the host to the device, but data can flow in both directions. In this case, the USB port is a dedicated charging port.

A USB socket has four pins, and a USB cable has four wires. The inside pins carry data (D+ and D–); the outside pins provide a 5V power supply. In terms of actual current (milliamps, or mA), there are three kinds of USB ports dictated by the current specs: a standard downstream port, a charging downstream port, and a dedicated charging port. The first two can be found on your computer (and should be labeled as such); the third kind applies to "dumb" wall chargers. In the USB 1.0 and 2.0 specs, a standard downstream port is capable of delivering up to 500 mA (0.5A); in USB 3.0, it moves up to 900 mA (0.9A). The charging downstream and dedicated charging ports provide up to 1500 mA (1.5A).

UBM Tech
DesignNews EDN

MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS, AND SOFTWARE IN DESIGN



Angular velocity is often misstated

Kinematic analysis requires defined reference frames and precise notation.

By Kevin C Craig, PhD

Ask any engineer what the velocity of a point on a rigid body is, and he will correctly say that it is the time rate of change of a linear position vector. Ask any engineer what angular velocity is, and he most likely will incorrectly say that it is the time rate of change of an angular position vector. In both cases, there is usually no mention of the reference frames involved. The misunderstanding of angular velocity—and the ambiguity that imprecise notation creates—can lead to errors that cause lost time and money, and even tragic results.

A reference frame is a perspective from which observations are made regarding the motion of a system. A moving body, such as an automobile or airplane, frequently provides a useful reference frame for our observations of motion. Even when we are not moving, it is often easier to describe the motion of a point by reference to a moving object. This is the case for many common machines, such as robots. An engineer needs to be able to correlate observations of position, velocity, and acceleration of points on moving bodies, as well as the angular velocities and angular accelerations of those moving bodies, from both fixed and moving reference frames.

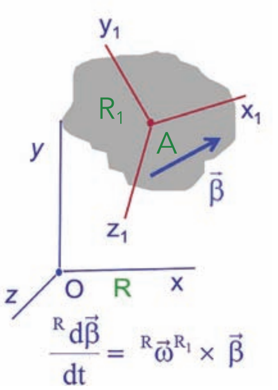


Figure 1 R is the ground reference frame, with coordinate axes x, y, and z fixed in R.

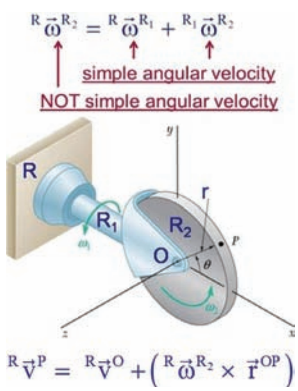


Figure 2 In a two-degree-of-freedom mechanism, you can determine the angular velocity of R_2 in R, which is not a simple angular velocity.

In **Figure 1**, R is the ground reference frame, with coordinate axes x,y, and z fixed in R. The R_1 reference frame is a rigid body moving in reference frame R, with coordinate axes x_1, y_1, and z_1 fixed in R_1. $\vec{\beta}$ is any vector fixed in R_1. The defining equation for angular velocity, ω, is shown. Angular velocity is the time rate of change of orientation of the body; it is not in general equal to the derivative of any single vector. However, when a rigid body, R_1, moves in a reference frame in such a way that there exists throughout some time interval a unit vector whose orientation in both R_1 and R is independent of the time, then R_1 is said to have simple angular velocity in R throughout this time interval, and the magnitude of this angular-velocity vector is the time derivative of an angle.

Figure 3 In this serial robot, a series of links is connected by motor-actuated joints that extend from a base to an end effector.

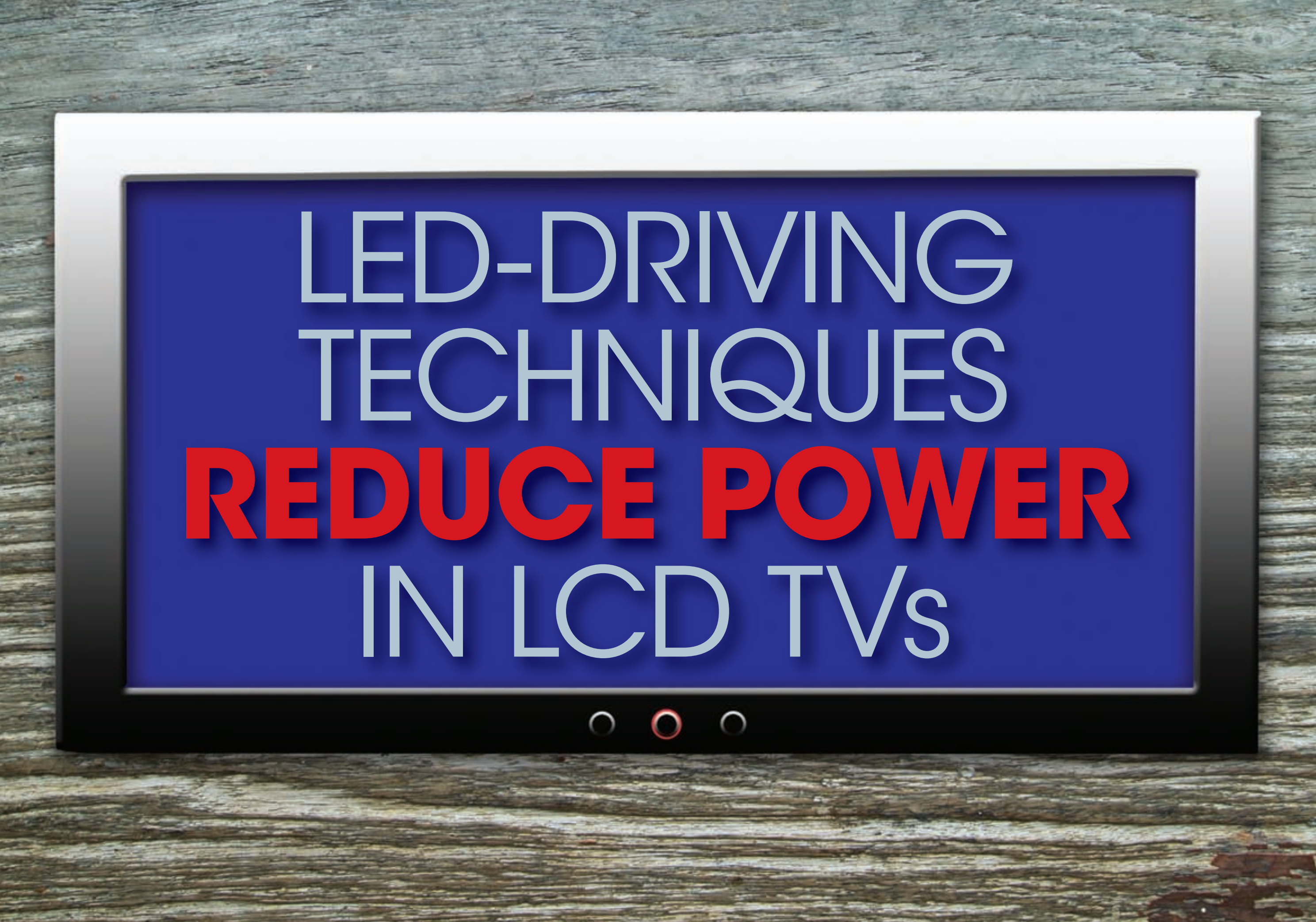
Figure 2 shows a two-degree-of-freedom mechanism. R_1 has simple angular velocity in R (ω_1), and R_2 has simple angular velocity in R_1 (ω_2). The addition theorem for angular velocity, ${}^{R}\vec{\omega}^{R_N} = {}^{R}\vec{\omega}^{R_1} + {}^{R_1}\vec{\omega}^{R_2} + \ldots + {}^{R_{N-1}}\vec{\omega}^{R_N}$, allows you to easily determine the angular velocity of R_2 in R, which is not a simple angular velocity.

This theorem is powerful, as it allows you to develop an expression for a complicated angular velocity by using intermediate reference frames—real or fictitious—that have simple-angular-velocity relationships between each of them. Note that there is no similar addition theorem for angular accelerations.

Figure 3 shows a serial robot; that is, a series of links connected by motor-actuated joints that extend from a base to an end effector. Each link has a simple-angular-velocity relationship with the preceding link. These relationships make it easy to determine the angular velocity of a link with respect to any other link. EDN


THiNK
T-1 LED SPACER MOUNTS


62-217D Series (5630)
- Package : 0.5W PLCC-2
- Efficacy : >93lm/W (3000K CCT)
- CRI : >80
- Thermal Resistance : 22°C/W
XI3535 Series (3535)
- Package : 1.0W EMC
- Efficacy : >105lm/W (3000K CCT)
- CRI : >80
- Thermal Resistance : 20°C/W
Structures and materials depend on demand of client.



LED-DRIVING TECHNIQUES REDUCE POWER IN LCD TVs

IMAGE: SHUTTERSTOCK

NEW DESIGN TECHNIQUES IN LED-DRIVER CIRCUITS PROMISE TO DELIVER SIGNIFICANT ENERGY SAVINGS.

PETER RUST, WERNER SCHÖGLER, MANFRED PAURITSCH, AND HERBERT TRUPPE • AMS AG

According to the SEAD (Super-efficient Equipment and Appliance Deployment) initiative, televisions are responsible for approximately 3% to 8% of global residential electricity consumption. An analysis conducted by Lawrence Berkeley National Laboratory suggests that advances such as more efficient LED driving can yield major reductions in television electricity consumption in the coming years.

There seems little doubt that liquid-crystal-display (LCD) technology with LED backlighting is the only viable way to reach the efficiency targets that authorities are proposing. Plasma has the disadvantage that each pixel is an active light emitter, so power consumption is directly proportional to the number of pixels. As a result, high-definition plasma televisions consume approximately two to three times the power of an LCD TV for the same resolution and brightness.

AT A GLANCE

- Standards regulating TV power consumption continue to strengthen, meaning designers must develop new ways to meet efficiency targets.
- LED backlighting accounts for 30% to 70% of overall system power in LCD TVs, making this area a good candidate for improving energy efficiency.
- Manufacturers are investigating sophisticated methods for reducing power consumption, including feedback regulation and smart dimming.

Highly touted organic light-emitting-diode (OLED) technology, as recently reported, may not come anytime soon, if ever. The investment required for this "bleeding edge" large-panel technology is prohibitive. In contrast, large display panels with state-of-the-art thin-film-transistor LCD technology and "smart" direct LED backlighting with local dimming are far less expensive than OLEDs but compare well for both power consumption and picture quality.

Today's LCD TVs—even those with LED backlighting—are still some distance from achieving the efficiency targets they will face in the coming years. New design techniques in LED-driver circuits, however, promise to deliver significant energy savings that will go a long way toward helping TV manufacturers meet tough requirements for power consumption.

CHANGING REQUIREMENTS

Standards for TV power consumption were raised in 2008, and each year the specification reduces the amount of power a TV can draw. The current maximum for any size screen is 85W, making the design challenge even tougher for large-screen TVs.

Energy Star is an international standard for energy-efficient consumer products. Compliance is voluntary—and highly influential—but it's not the only form of regulation. The state of California's Energy Commission, for example, introduced its own standard, which went into effect in 2011. This regulation is a bit tougher than Energy Star and also has real teeth: It prohibits the sale of TVs in California that do not meet the state's efficiency specifications.

In Europe, regulations have for many years allowed direct comparison of the energy consumption of white goods (EU Energy Label), and customers use it as a basis for purchasing decisions. These regulations are now mandatory for TVs, cars, and household appliances.

LED BACKLIGHTING

LED backlighting power ranges from 30% to 70% of overall system power in LCD TVs, so improvements in the efficiency of the backlighting power circuit can make a considerable contribution to system efficiency. As is often the case in power system design, a number of small improvements in efficiency can deliver a large combined saving.

There are two ways to implement LED backlighting (**Figure 1**). In indirect, or edge-lit, backlighting, the LEDs are arranged at the edges of the screen. A light guide distributes the light uniformly across the display. This arrangement can be deployed with good optical uniformity in screen sizes up to 60 in. and enables backlighting units with a thickness of just 5 to 10 mm.

In direct-backlit systems, the LEDs are located directly behind the LCD, enabling low power, good thermal design, and excellent scalability with practically no limit to the screen size. These panels tend to be thicker than edge-lit versions, but with the latest technologies for light distribution, displays as thin as 8 mm can now be found. An important advantage of direct backlighting is that it enables sophisticated local dimming, which lowers power consumption and increases the dynamic contrast ratio, allowing the latest TV designs to compare favorably with OLED technology.

SYSTEM ARCHITECTURE

The choice of architecture for a backlit LED-driver system is the decision with the greatest potential to produce power savings and significantly enhanced picture quality. The designer looks for the best balance between local control of strings of LEDs and the lowest possible BOM.

In a single-string, single-dc/dc-converter backlit system, a switched-mode power supply (SMPS) is used to provide the voltage for backlit LEDs arranged in strings. A current sink is included to regulate the current through the LED string. To minimize power dissipation, the voltage at the I_{LED} sink needs to be a fraction above the voltage necessary to guarantee that the LEDs receive their specified current (**Figure 2**).

A common design approach is to use a feedback path from the I_{LED} sink to the SMPS to regulate the SMPS's output voltage. This feedback path is required to allow for variations in forward voltage (V_F) from one LED to another. The typical forward voltage of a white LED is approximately 3.2V—and may vary as much as ±200 mV per LED—so, for example, in a string of 10 LEDs, the total for V_{LED} may range from 30 to 34V.

The voltage that is required at the dc/dc converter can be expressed as $V_{DC\text{-}DC}=V_{LED}+V_{SINK}$; $V_{LED}=n\times V_{F(LED)}$. V_{SINK}

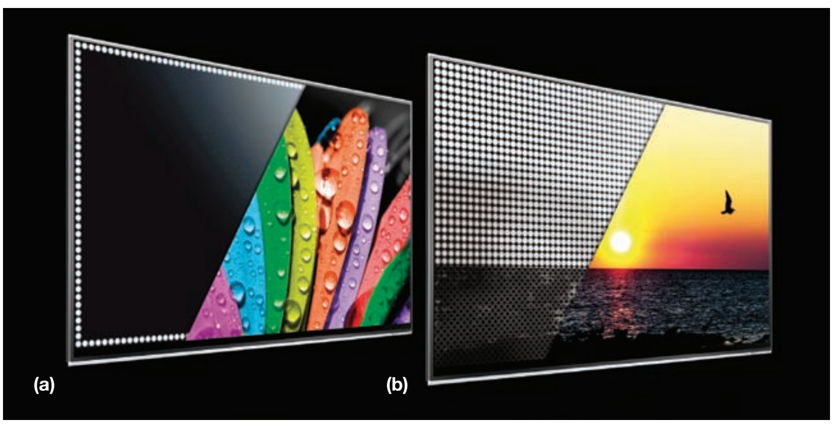


Figure 1 LCD TVs can adopt one of two arrangements for LED backlighting: indirect (edge light) (a) or direct (b).

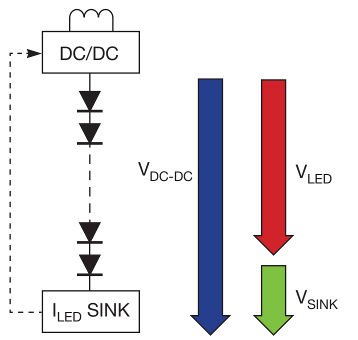


Figure 2 To minimize power dissipation in a single-string, single-dc/dc-converter backlight system architecture, the voltage at the I_{LED} sink needs to be a fraction above the voltage necessary to guarantee that the LEDs receive their specified current.

is assumed to be 0.5V, so the I_{LED} sink must regulate $V_{DC\text{-}DC}$ in the range of 30.5 to 34.5V, depending on the actual LED forward voltages.

A single string of LEDs is rarely adequate because, as the number of LEDs in the string increases, the required output voltage also increases. Above a certain V_{OUT}/V_{IN} ratio, the SMPS's efficiency falls dramatically. LED-backlight designers can therefore use several strings in order to avoid an excessively high output voltage required of the SMPS.

The simplest approach is to duplicate the single-string, single-dc/dc-converter topology at each string (**Figure 3**). The advantage is efficiency, because each string's voltage is regulated separately. The disadvantage is the high cost, since each string requires its own dc/dc converter, MOSFET, coil, diode, and output capacitor. In order to save on BOM cost, the designer could reduce the number of LED channels, using long strings with many LEDs in each string. This approach, however, compromises the system's ability to implement local dimming, which is another important power-saving technique. Therefore, none of the trade-offs of this topology is particularly attractive.

A more radical approach to reducing BOM cost can be found in the multistring, single-dc/dc-converter topology (**Figure 4**). The drawback of this approach is that the SMPS voltage must be regulated higher than the LED string with the highest forward voltage, which means that it operates at a higher voltage than is necessary for those strings with a lower forward voltage. As a result, the I_{LED} sink must dissipate the excess power from the strings with lower forward voltage, generating heat that must be conducted away from the circuit board and resulting in reduced power efficiency.

The architecture that provides the best balance between efficiency and BOM cost is one that combines elements of the multistring and multi-dc/dc-converter architectures described previously. This mixed architecture (**Figure 5**) has multiple dc/dc converters supplying groups of LED strings.

The multistring, mixed-architecture solution offers the best overall power efficiency because it combines the advantage of local dimming in direct-backlit systems with good dc/dc output voltage regulation. It also offers a substantial BOM saving over the efficient multistring, multi-dc/dc-converter architecture.

REGULATING CURRENT

The LED-manufacturing process causes wide variations in brightness and color temperature from one LED to the next. As a guide to users, white-LED manufacturers allocate each manufactured unit to groups, or "bins," of LEDs with comparable performance in terms of color, brightness, and forward voltage. But the manufacturer's specification for each brightness and color-temperature bin is valid only under specific nominal operating conditions. This means that the LED current must be set to the nominal current stated in the data sheet in order to generate the specified brightness and color.

Consequently, dimming and bright-

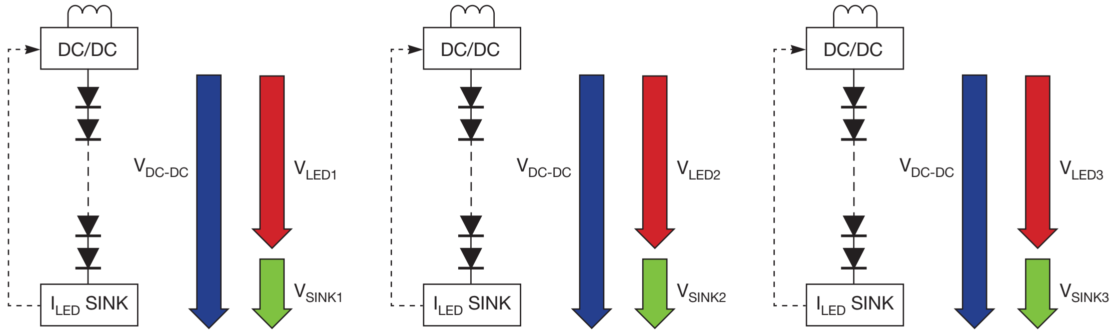


Figure 3 A separate dc/dc converter with each LED string is an expensive option.

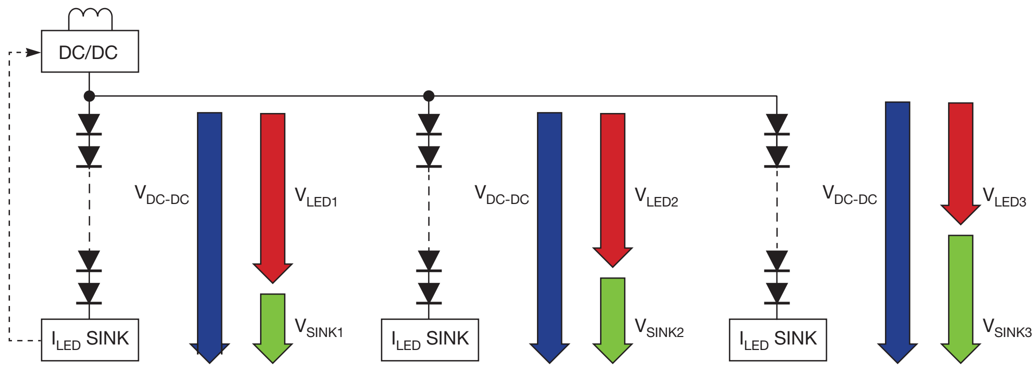


Figure 4 With one dc/dc converter serving multiple LED strings, SMPS voltage is not optimized.

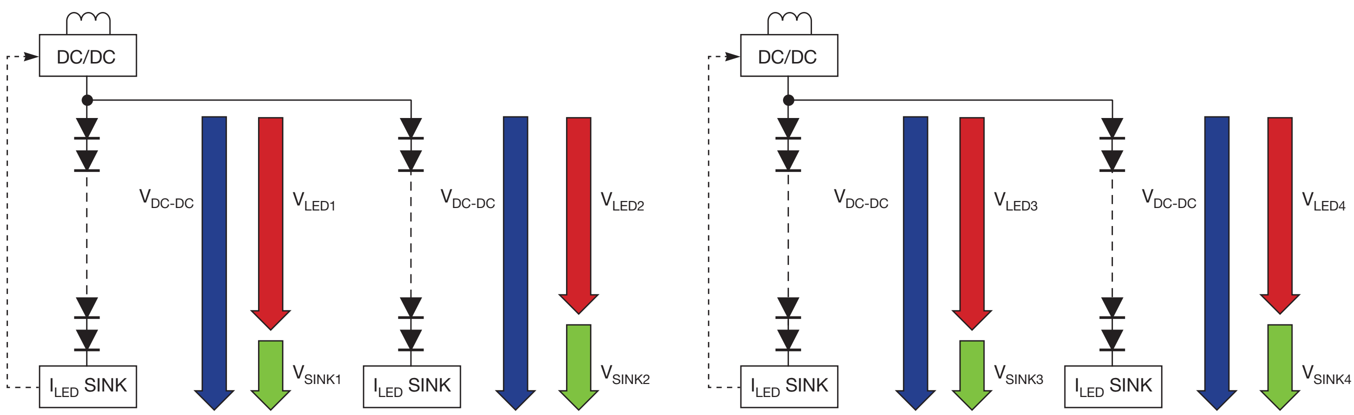


Figure 5 A mixed architecture optimizes the balance between BOM cost and power efficiency.

ness control can be implemented only by switching the current sent to any single LED to either on (nominal current) or off (zero current) through a digital PWM control signal. In analog dimming, the LED would be operating outside its specified nominal current, leading to unacceptable changes in color temperature and poor LED-to-LED brightness matching (**Figure 6**).

CURRENT-SINK PROPERTIES

Since LEDs require a perfectly regulated constant-current power supply, it follows that the primary role of the LED driver is to set the current to the nominal value when on and to 0A when off. Therefore, the feedback loop controlling the accuracy of regulation requires an extremely precise current sink (**Figure 7**).

While there are a variety of current-sink designs, the precision requirements of TV backlighting (current regulation better than ±0.5%) require an accurate op amp to set the I_{LED} current independent of the I_{LED} voltage. In backlighting driver applications, however, the task is more challenging because the accuracy of current regulation must be maintained even when the voltage at the current sink falls to very low levels.

This requirement is difficult to meet, but four generations of accurate current-sink LED drivers from AMS have been designed specifically for such applications. The AS369x, AS381x, AS382x, and AS385x devices also incorporate an offset-compensated op amp. Current-sink drivers require a minimum voltage at the drain ($V_{DS(SAT)}$) to ensure the full accuracy and proper operation of the sink transistor inside the saturation region. For the saturated region, the gate-source voltage primarily controls the output current.

If the current sink is to operate at high efficiency, it is important that the voltage drop between V_{SET} and V_{DS} is low. LED drivers with op amps that include built-in offset cancellation can maintain V_{SET} at levels as low as 125 to 250 mV. Allowing an additional margin for V_{DS} above $V_{DS(SAT)}$ of 150 mV, a total voltage drop at the cur-

LIKE THIS?
For more articles like this one, go to www.edn.com/design/LED.

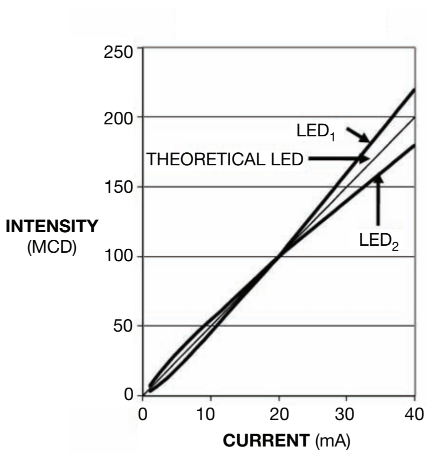


Figure 6 The brightness of LEDs from the same bin is guaranteed to match only at nominal current (in this case, 20 mA).

rent sink of approximately 400 mV is necessary. For a string of eight LEDs (where V_F=8×3.2=25.6V), this results in a power loss of approximately 1.5% in I_{SINK}. Without the offset cancellation included in the AMS backlight LED drivers, the value of V_{SET} would be higher, leading to higher power losses at the current sink.

POWER OPTIMIZATION

As described earlier, a feedback path from the LED driver to the SMPS sets the drain voltage to the minimum required value. The output current sink can be implemented either with a simple, defined current output driver and an external capacitor (**Figure 8a**) or with a digital control circuit that sets attack/release times and controls the current output with a digital-to-analog converter (I_{DAC}) (**Figure 8b**).

Both of these solutions offer good efficiency, work with every type of SMPS with voltage feedback, and can be implemented by attaching feedback lines from more than one driver to the same SMPS, as is required in mixed-architecture systems. The second, digital implementation, however, provides some special advantages. In addition to not requiring an output capacitor, the digital circuit gives the designer the freedom to define the feedback system's attack and decay times. Combining a fast attack time with decay latency and relatively slow decay can improve the display's performance.

This benefit is particularly noticeable in scenes that require brightness to change rapidly. In this case, a fast attack time eliminates perceptible brightness

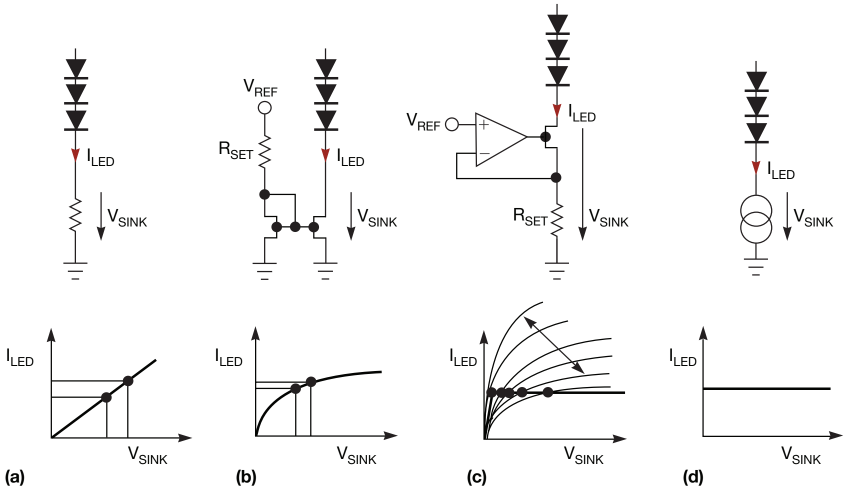


Figure 7 Of the current-sink designs—primitive (a), simple (b), precision (c), and ideal (d)—a precision current sink requires an accurate op amp with offset compensation.

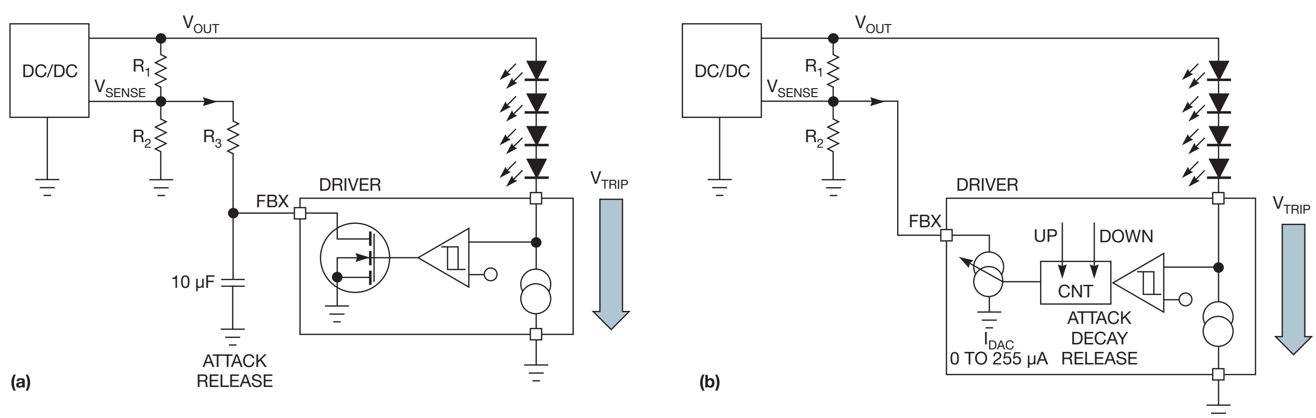


Figure 8 Two different methods can be used for applying a feedback loop to the SMPS: The output current sink can be implemented either with a simple, defined current output driver and an external capacitor (a) or with a digital control circuit that sets attack/release times and controls the current output with a DAC (I_{DAC}) (b).

TABLE 1 ENERGY-SAVING POTENTIAL USING SMART LED DRIVERS AND SMART AMBIENT-LIGHT SENSORS (ALSs) IN LED TVs

TV LED-backlight architecture	Power-reduction method	Energy-saving percentage LED backlight	Energy-saving percentage LED backlight and ALS
Global dimming	Global dimming with phase shift	5%	25%
Edge local dimming	Edge smart dimming	10% to 20%	40% to 50%
Direct local dimming	Local dimming	20% to 30%	50% to 60%

artifacts as the screen changes from dark to full brightness. The analog solution dims the LEDs' output gradually during a short dark frame, resulting in a visible delay in achieving full brightness for the next bright frame.

This delay is a noticeable distraction for TV viewers because films and other video content create large dynamics from one frame to another. Such artifacts can be eliminated with digital regulation circuits by inserting latencies of several hundred milliseconds into the decay instruction. Thus, when bright frames are interrupted by a short sequence of dark frames, the second bright frame starts at full brightness because the driver has automatically delayed the voltage ramp-down.

Another useful feature integrated in LED-driver ICs is a fast SPI. In direct-backlit TVs, the LEDs are arranged in a large number of relatively short strings so that small areas of the panel can be dimmed to save energy. Typically, such arrangements contain 256 channels in a matrix of 16×16 fields, each individually configured through PWM. But generating 256 PWM signals with variable PWM width and delay is a hugely intensive processing task, even for the fastest microcontroller.

These backlighting systems therefore use local PWM generators integrated into the LED-driver ICs. This approach enables brightness to be configured with simple SPI data transfers. In an architecture with multiple driver ICs (for example, 256 channels with 16 channels per IC and 16 ICs), the LED channels can be configured by daisy-chaining SPI signals and transferring the data that are used in a V_{SYNC} frame to the frame before. In this arrangement, data transfer over an SPI can reach speeds of 20 Mbps, or 50 kb/frame at a 400-Hz frame rate—fast enough to change dimming of each field in sync with the actual frame. Ideal local dimming then can be achieved with minimum overhead on the microcontroller.

SMART DIMMING

This local dimming technique is possible only with direct-backlit systems. But a certain amount of smart dimming also can be achieved with edge lighting. In particular, PWM dimming can be used to vary brightness without changing the color temperature of the white LEDs. Instead of having the edge-

JOIN THE CONVERSATION

To comment on this article, go to **www.edn.com/4406820**.

lit LEDs permanently set to a specific brightness value, the brightness can be dynamically altered via changes to the pulse width.

Another technique for saving power is dynamic luminance scaling. With this technique, the LCD's white/brightness level is increased in certain scenes to allow the backlight LEDs' power output to be reduced.

Yet another method to reduce power consumption is the use of ambient-light sensors. If the room where the TV is being watched is fairly dark, the backlight brightness can be reduced (**Table 1**).

TV manufacturers are exploring even more sophisticated methods. For instance, cameras are beginning to be designed into displays to enable consumers to use video-telephone services such as Skype on their TVs. These cameras also can be used to detect if someone is actually watching TV; if the TV is on without anyone being in the room, the backlight is reduced to a minimum brightness level.

Even customized energy-consumption patterns can be implemented. While you might prefer watching TV in the energy-friendly eco-mode with reduced backlighting, another member of the household might prefer full brightness.

Considerable power savings can be realized by implementing today's advanced techniques for efficient LED driving. This is important, because ever-tougher regulations continue to reduce the maximum power that a new TV can consume. **EDN**

ACKNOWLEDGMENT

This article originally appeared on EDN *sister site,* SmartEnergy Designline, *at www.eetimes/4405016.*

AUTHORS' BIOGRAPHIES

Peter Rust, Werner Schögler, and Manfred Pauritsch are senior design engineers at AMS.

Herbert Truppe is a product-line manager at AMS.

POWER

Si vs. GaN vs. SiC

WHICH PROCESS AND SUPPLIER ARE BEST FOR MY DESIGN?

IMAGE: GIULIA FINI

ONE OF THE MOST DIFFICULT TASKS CIRCUIT DESIGNERS FACE IS SELECTING THE OPTIMUM COMPONENTS TO MEET THE DEMANDS OF BOTH THE SYSTEM AND THE ENVIRONMENT.

BY STEVE TARANOVICH • SENIOR TECHNICAL EDITOR

As silicon (Si), gallium-nitride (GaN), and silicon-carbide (SiC) processes are maturing, so, too, are their suppliers' expertise and creativity. It is worthwhile to examine the pros and cons of each process, as well as what is unique about the suppliers of the power elements fabricated on these processes. All of these components factor into the decision on the right solution for a particular design. That solution will be a culmination of process maturity and robustness, as well as supplier expertise, support, and capability—and even some intangibles.

GaN and SiC are wide-bandgap (WBG) materials, which means the energy required for an electron to jump from the top of the valence band to the bottom of the conduction band within the semiconductor is typically larger than one or two electron volts (eV). SiC and GaN semiconductors are also commonly referred to as compound semiconductors, because they comprise multiple elements from the periodic table. Si is a mature incumbent in this arena.

As the race toward leadership in the power element continues to evolve, industry experts have said that by mid-2013 about half a dozen GaN, Si, and SiC suppliers will reveal process enhancements, new architectures, and the latest new capabilities that will bring new choices and tools to the industry. We discuss some of these companies and technologies here.

EFFICIENT POWER CONVERSION

Efficient Power Conversion (EPC) started its GaN efforts five years ago and targeted markets with voltages of 200V and under. The company grows its GaN as an epitaxial layer on silicon.

The two-dimensional electron gas (2DEG) transport mechanism in GaN allows higher mobility of carriers in GaN than in SiC or Si. The 2DEG is on the surface and so lends itself to a lateral device structure; as a result, all of the terminals are located on top of the device.

A problem in existing devices is that the 2DEG in a normally on structure requires a negative voltage on the gate electrode to turn the device off (depletion mode). EPC understood that the power-conversion market would more naturally want to be normally off, so three years ago it developed enhancement-mode GaN (eGaN) devices that are manufactured in the same facility as silicon ICs (**Figure 1**).

SiC is also used to manufacture power transistors, but because SiC does not have an electron-gas structure, only vertical conduction devices are practical. With a vertical conduction device in GaN or SiC, 1- to 2-kV breakdown voltage levels are easier to reach than with Si. SiC requires an expensive fab, too, because existing Si fab processes are not compatible.

For the future, EPC has plans to go to 900V, which would require a vertical device structure. In that case, SiC has a better thermal conductivity than GaN. GaN, however, has the performance advantage at low voltage and high power and a cost advantage at all voltages. The company predicts the battle between SiC and GaN will begin at the 900V levels and move upward.

AT A GLANCE

- Enhancement-mode gallium nitride (eGaN) is the normally off, natural mode for MOSFETs.
- The primary advantage of silicon-carbide (SiC) MOSFETs is their very low, high-frequency switching losses.
- Silicon (Si) MOSFETs can easily integrate drivers in a single monolithic solution.

In the inverter market for photovoltaic (PV) panels, small to medium-sized inverters with one inverter per panel would ideally fit with EPC's strategy of 900V or less. Higher-voltage devices would fit the central inverter market, which needs to connect a high number of panels together into a big, higher-voltage inverter. This architecture would cause cost and efficiency problems. If one PV panel fails, it would need to be removed from the system to avoid bringing down the entire unit, and efficiency would be lost. If the inverter is trying to convert a lower voltage to the grid-level voltages, however, efficiency would be lost in the inverter itself.

Differences in board space can be seen in a bus converter design for Si and eGaN (**Figure 2**). GaN transistors are extremely fast. As a result, the system is far more sensitive to the layout than it is with slower Si devices. In particular, stray inductance plays a larger role in the overall system efficiency. Hundreds of picohenries will significantly affect performance.

Stacked devices are better than bond-wire connections. GaN needs no package—it is inert to its environment—and so EPC uses a packageless design. This approach greatly reduces any resistive, inductive, and thermal problems. EPC plans to eventually integrate the driver into the FET.

Episil, EPC's Taiwan-based CMOS foundry, uses 6-in. wafers. EPC plans to scale to 8-in. wafers in the years to come.

The entire process is compatible with silicon except for one machine, which grows the layers of GaN on Si. The metal organic chemical vapor deposition (MOCVD) epitaxial reactor was designed for blue LEDs and is therefore not optimized for eGaN FETs. This is the only step that is more expensive than a straight Si process, so, as the cost of growing epitaxial GaN decreases with improved MOCVD-equipment technology, cost differences compared with Si will become negligible and ultimately disappear.

GaN SYSTEMS

In speed, temperature, and power handling, GaN is set to displace Si power devices as they reach their performance limits. GaN is the technology that will allow the implementation of essential future "cleantech" innovations, where power, weight, and volumetric efficiency are key requirements.

GaN devices offer five key characteristics: high dielectric strength, high operating temperature, high current density, high switching speed, and low on-resistance (**Figure 3**). These characteristics flow from its electrical properties, which, when compared with Si, offer 10 times higher electrical breakdown, higher operating temperature, and exceptional carrier mobility.

Taking advantage of these properties, GaN Systems has successfully developed transistors with a key switching figure of merit two orders of magnitude better than that attainable with silicon. This together with GaN's inherent

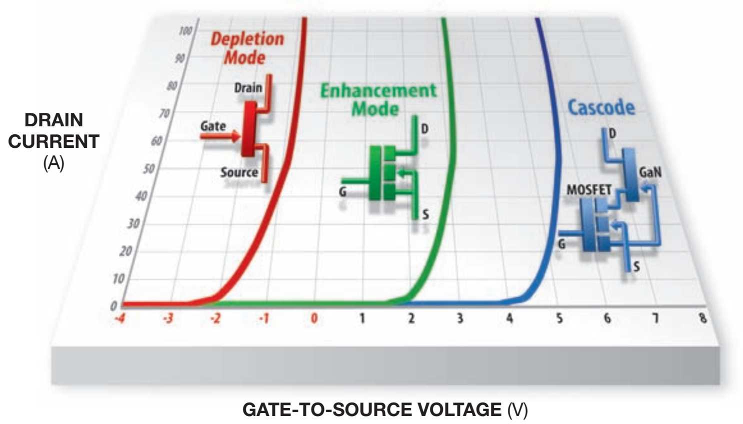


Figure 1 There are marked differences between eGaN and depletion-mode GaN MOSFETs. Unlike depletion-mode GaN's need for negative voltage turnoff, eGAN requires only positive gate voltages to transition from fully off to fully on.

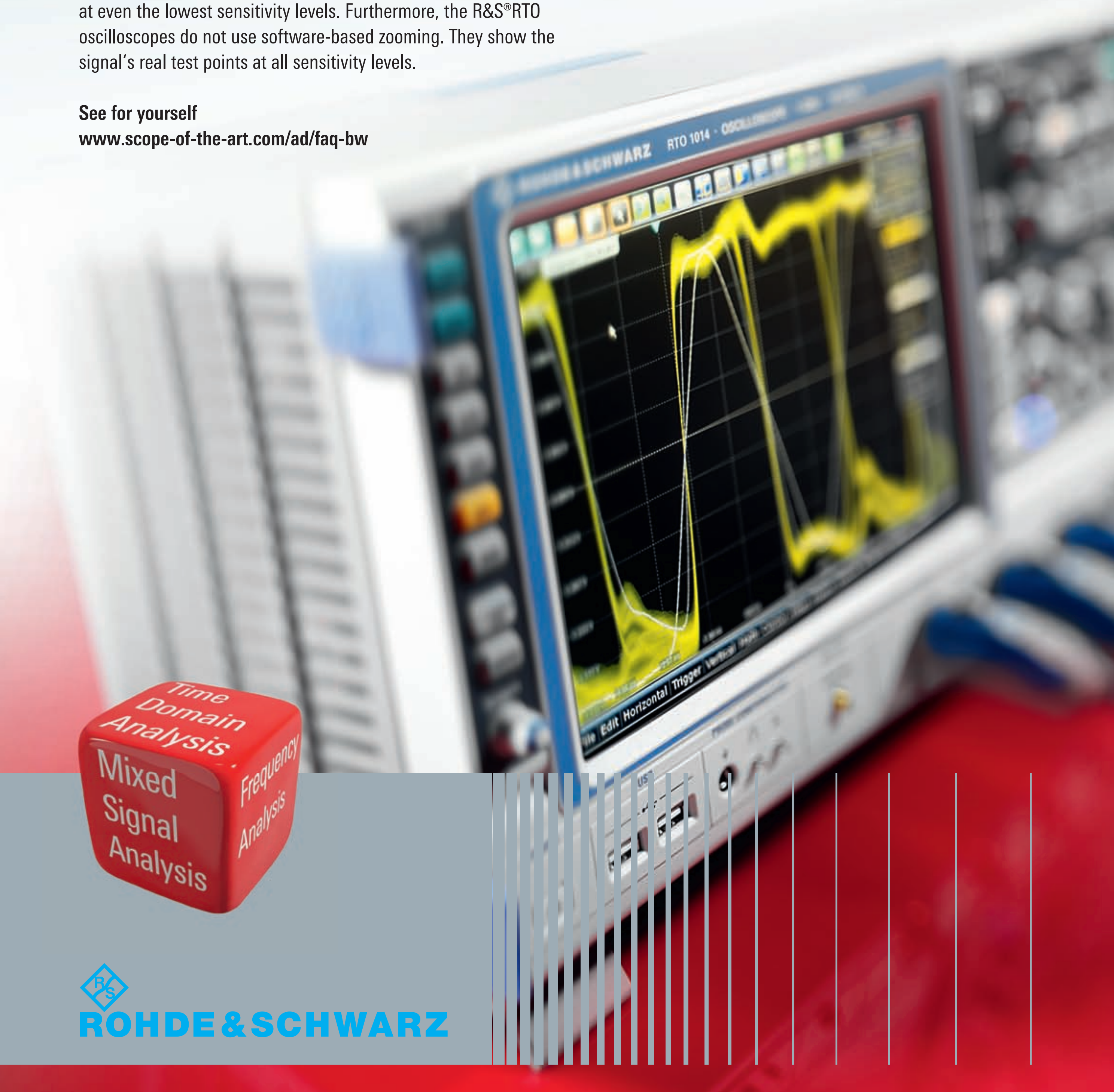
Your question:

Why full bandwidth up to 1 mV/div?

Our answer: For high signal fidelity and measurement accuracy on fast, low-amplitude signals.
The R&S®RTO oscilloscopes offer high vertical input sensitivity of up to 1 mV/div. They always operate at high measurement accuracy because the full bandwidth of the oscilloscope can be used at even the lowest sensitivity levels. Furthermore, the R&S®RTO oscilloscopes do not use software-based zooming. They show the signal's real test points at all sensitivity levels.

See for yourself
www.scope-of-the-art.com/ad/faq-bw

Trade In Program available until June 2013:
Save up to 40 % on a new scope now!
www.scope-of-the-art.com/ad/trade-in



ROHDE&SCHWARZ

negligible charge storage permits the design of power switching circuits with formerly unheard of efficiencies, small size, and very low heat losses. Using a unique, proprietary, custom "island" transistor topology, the company has overcome the limitation of device operating current associated with traditional "finger" designs. This design approach is applicable to processes that grow a GaN epitaxial layer on base wafers of either SiC or Si. As a result, very low costs can be achieved for fast switches operating at 600V or below built on large-diameter silicon wafers, while operating voltages in excess of 1200V can be achieved using higher-cost SiC base wafers.

At operating voltages below 1200V, the vastly superior mutual conductance afforded by the electron gas that forms the channel of the GaN HEMT is responsible for the devices' two orders of magnitude improved key figure of merit (the product of on-resistance and total gate charge).

SiC gate drives typically require a tightly controlled 20V swing. The island-design GaN devices can be driven with a 5V swing and present significantly lower gate capacitance. GaN-on-Si wafers cost perhaps one-tenth of SiC wafers while having up to four times the area. The

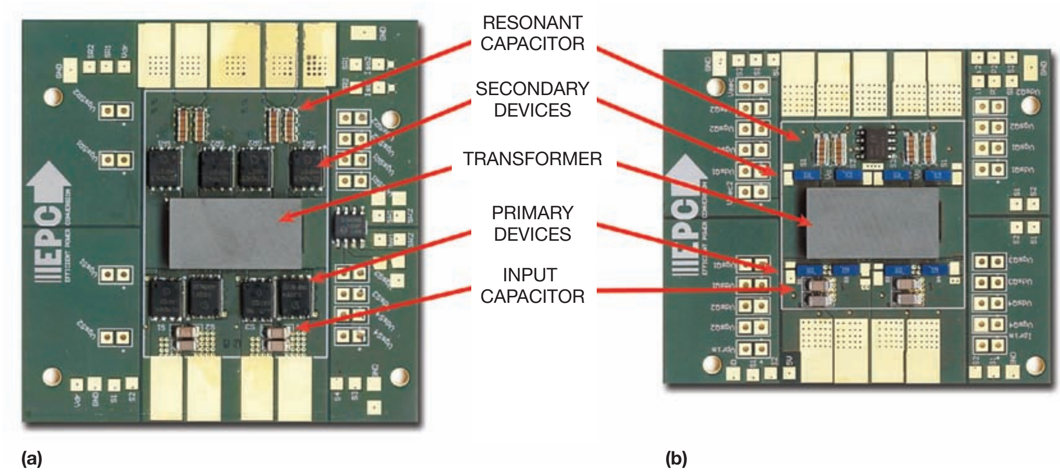


Figure 2 The experimental bus converter prototypes shown here with V_{IN}=48V and V_{OUT}=12V use an (a) Si MOSFET and (b) eGAN FET in the design.

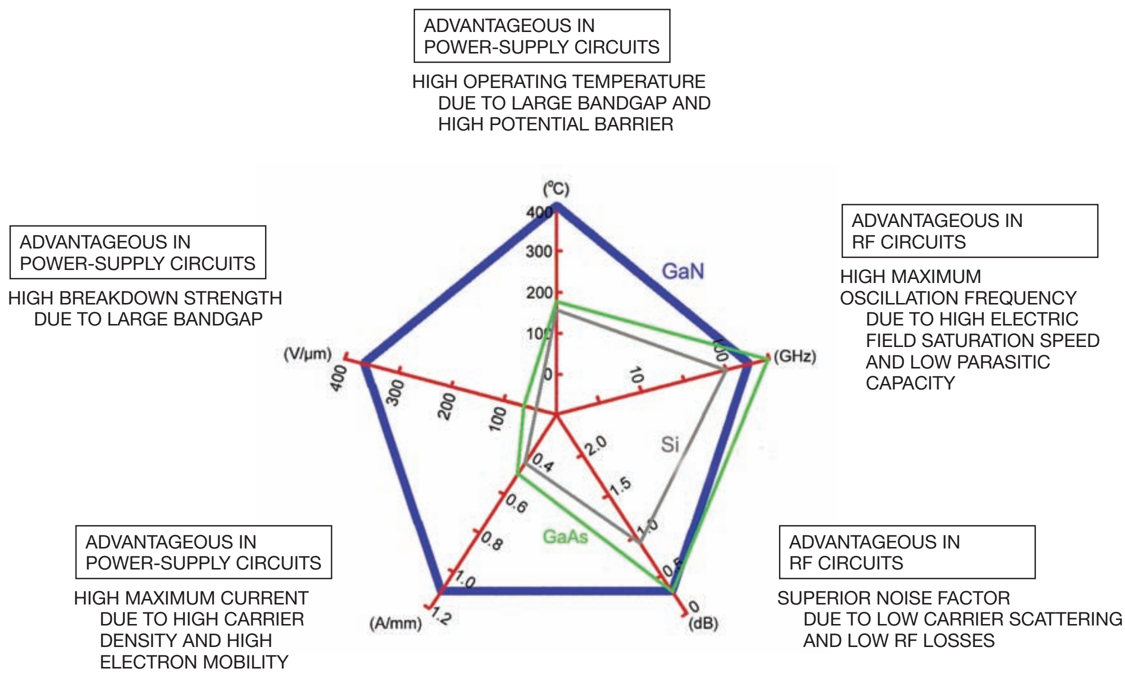


Figure 3 GaN has five key characteristics, which make it advantageous in power-supply and RF circuits (courtesy GaN Systems).

JOIN THE CONVERSATION

To comment on this article, go to www.edn.com/4409627.

GaN Systems island devices also occupy less than half the area of equivalent-performance MOSFET SiC die.

GaN Systems' flip-chip approach to assembly—using copper posts—eliminates the inductance of traditional bond wires. This becomes important with the achievable switching speeds of some 40V per nanosecond. The scalable design topology and the elimination of large switch currents flowing in the on-chip metallization offer the prospect of transistors capable of switching hundreds of amps.

The design also allows packaging approaches for high-power applications that facilitate cooling from both faces of the chip. The GaN switches can be mounted directly onto a custom CMOS driver chip that offers a strong degree of noise immunity and galvanic isolation and can be simply assembled into power subsystem modules.

Figure 4 All-SiC modules can eventually lead to higher integration in one process. The Cree module shown here measures 87.5×50 mm.

CREE

Cree is in a unique position in the industry in that it uses a GaN process for its RF devices and an SiC process for its power devices. Due to its in-depth knowledge and use of both processes, the company has made a conscious decision to use SiC for high voltages.

Cree's target market for SiC power devices is 1200V and 1700V solutions, with 600V coming later. At higher voltages, SiC unipolar devices have an advantage over bipolar Si. The challenge at 600V is that Si has better performance, while Si CoolMOS and insulated-gate bipolar transistors (IGBTs) are lower cost.

The primary advantage of SiC MOSFETs is their very low switching losses, which increase efficiency and enable higher-frequency operation. In addition, the SiC MOSFET's positive temperature coefficient allows easy paralleling to obtain higher operating currents.

SiC has been successfully tested at 10-kV levels. Cree targets future MOSFETs at around the 3.3- and 6.5-kV levels and at 10 kV. IGBTs have that market now, but SiC's low switching losses would provide significant performance advantages. Even at frequencies below 4 kHz, SiC MOSFETs substantially reduce losses compared with IGBTs at these voltages.

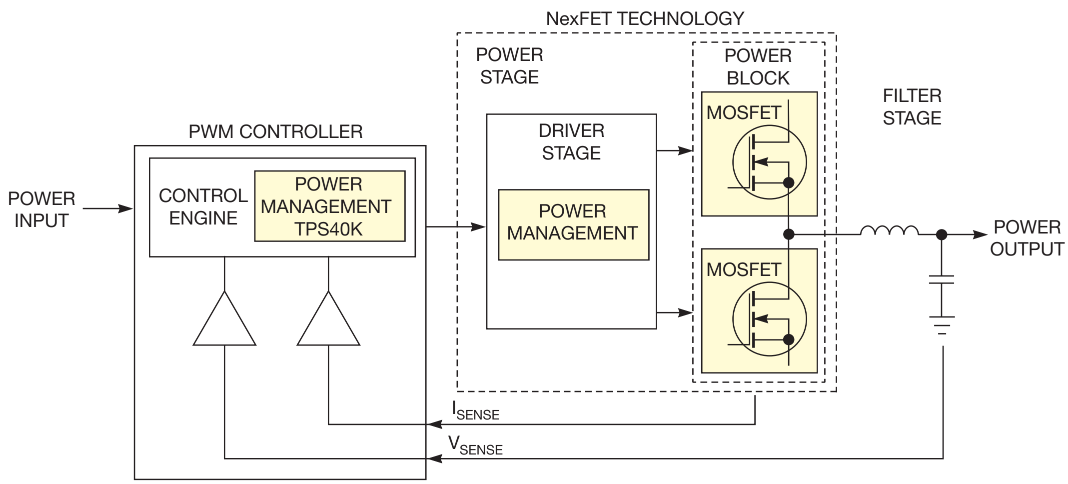


Figure 5 Texas Instruments' NexFET technology smoothly fits in power-management point-of-load applications.

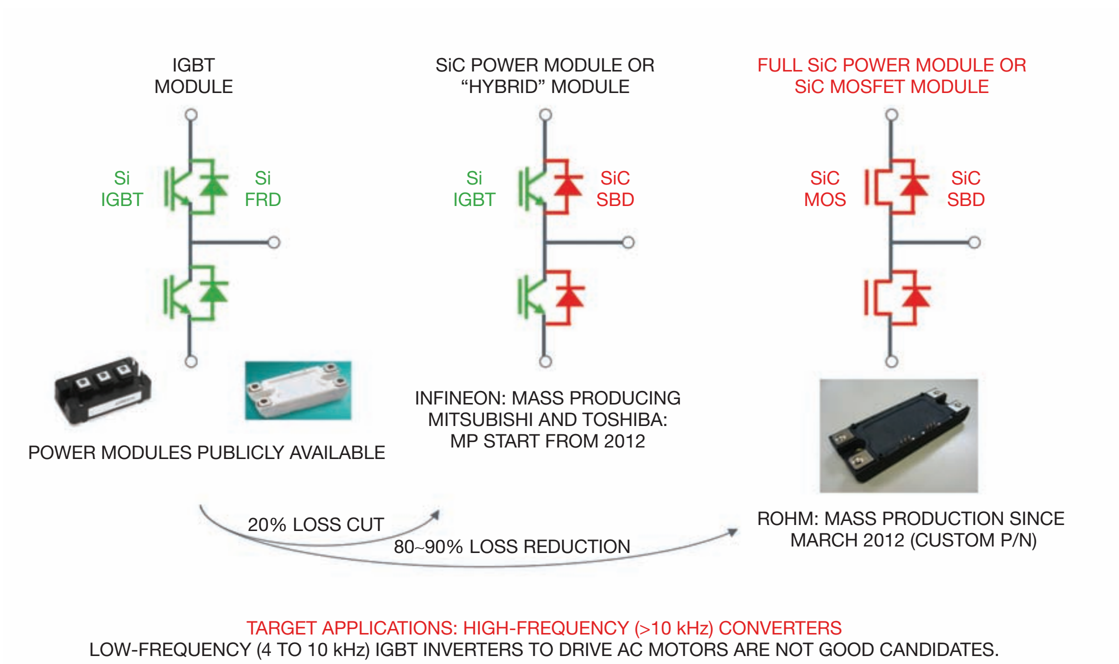


Figure 6 An all-SiC module greatly reduces power losses by eliminating any Si lossy components (courtesy Rohm Semiconductor).

Cree's goal is to go to 6-in. wafers from the current 4-in. and a die shrink for high current and 600V to 10 kV over the next few years to lower cost. The company will be able to do this on its existing 4-in. line and convert *in situ* with no process change. It already has a 6-in. separate LED line. Cree will fill its 4-in. line to capacity and then move to 6 in.—a good business decision. The wafers have already been sampled along with 6-in. EPI. All of the company's tools are 6-in.-capable now, and all processes are in-house for SiC.

CREE IS IN A UNIQUE POSITION IN THE INDUSTRY IN THAT IT USES A GaN PROCESS FOR ITS RF DEVICES AND AN SiC PROCESS FOR ITS POWER DEVICES.

Avago, Texas Instruments, and Ixys have driver ICs for their products. Cree feels that good layout and keeping the driver close to the power element will suffice for a good signal without ringing, even though it uses these types of separate Si drivers instead of integrated drivers like an Si MOSFET process can.

As for comparison with IGBTs, SiC MOSFETs' figure of merit at 1200V is less than 20% of switching losses of an IGBT and less than 10% at 1700V. SiC switching losses are much lower than those of IGBTs; the conduction losses are lower, too. Cree's 100A half-bridge module can replace a 200A IGBT and switch at two to three times the frequency with better efficiency (**Figure 4**).

The company's case as to why SiC can replace Si: SiC is two times better than Si in terms of current and five times better in terms of frequency, with lower thermal losses.

As far as GaN is concerned, Cree has a 6-in. RF line now and is the number 1 supplier in switching. Knowing both SiC and GaN, it chose SiC for power, which is more efficient than Si or GaN. At the same current capability, the company's SiC devices will be smaller than a GaN device.

TEXAS INSTRUMENTS

Early in 2009, TI acquired Ciclon Semiconductor Device Corp, a maker of NexFET MOSFET technology. TI's NexFET power switches are under 30V and synergistic with the company's silicon MOSFET drivers and switching controllers (**Figure 5**). Having both types of devices on the same process allows for easier integration into a monolithic die containing driver and power elements. This setup eliminates any connection or bonding-wire parasitics that can cause ringing at higher-speed switching between a discrete driver and a power device whether they are on the same or a different process.

Snubbers can be used to reduce ringing, but efficiency would be lost as a result. GaN switching devices certainly have attractive properties, especially above 10 MHz, except for the potential driver/power-device interconnect issues.

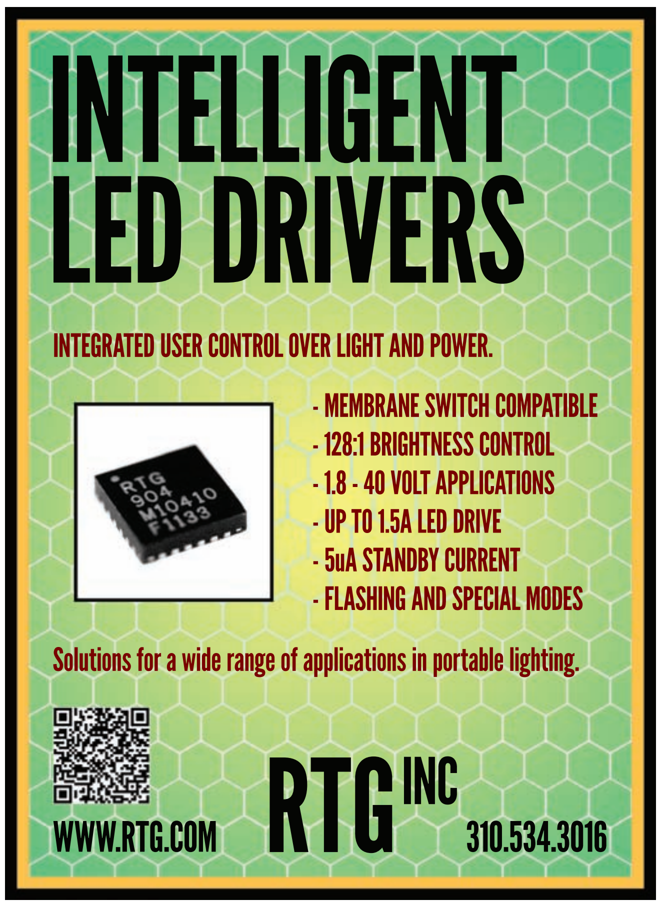
Packaging technology is an important part of TI's NexFET solutions, giving them optimal performance. To optimize the performance of a typical voltage regulator, especially for CPUs, you need to minimize the parasitic inductances and resistances in the power circuit formed by the two MOSFETs in the buck power stage. TI accomplished both of these requirements through a unique packaging approach. To achieve a small footprint and the lowest parasitic possible, a stacking topology is used in the NexFET PowerStack package design. PowerStack reduces power consumption by approximately 20% (at 20A) and can reduce device temperatures by more than 30%.

In the GaN arena, TI offers GaN FET driver solutions such as the LM5114, a 7.6A single, low-side driver with independent source and sink outputs, and the LM5113, a 100V integrated half-bridge driver that solves the challenges of driving GaN power FETs. Compared with discrete implementations, these drivers provide significant PCB-area savings to achieve solid power density and efficiency while simplifying the task of reliably driving GaN FETs.

ROHM SEMICONDUCTOR

Rohm Semiconductor's MOSFET manufacturing involves the SiC bulk wafer, epitaxial growth, the power device, and, finally, the integrated power module. With its Japan-based corporate location, Rohm enjoys a solid relationship with the automotive industry. The company also offers a mature SiC Schottky barrier diode (SBD) line. The SiC SBD has 3% to 5% lower forward-voltage drop than Si SBDs.

The SiC MOSFET combines all three key desirable features of the ideal power-element switch (**Table 1**).



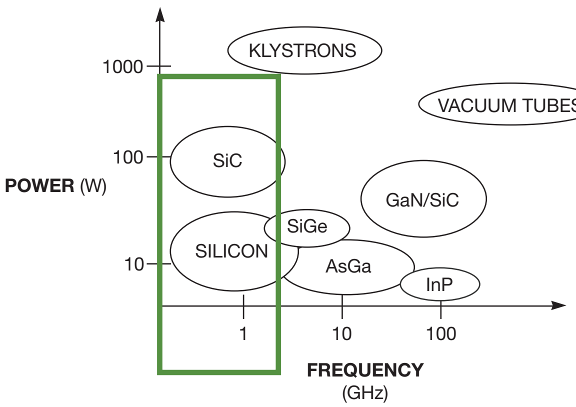


Figure 7 In this chart showing semiconductor materials and frequency regions, the green box outlines Microsemi's application space.

Rohm's MOSFET line, although relatively new, was expected to have a 1700V device in 1Q13 based on second-generation technology. By the end of 2013, the company plans to have packaging higher than its existing temperature devices, which are at 175°C. This allows operation at somewhat lower temperatures than 175°C without a heat sink.

Rohm feels it has the small-package advantage among its competitors, as well as modules that are optimized for performance (**Figure 6**).

MICROSEMI

Microsemi uses the technology customers feel will optimize their designs—Si, SiC, or GaN—from processes performed in-house as well as at outside foundries. It is just getting started with GaN from 40 to 200V for space and high reliability.

GaN is a defect-laden material as compared with SiC and Si, but the company grows GaN on SiC, which minimizes defects. It can reach 1200V on SiC vs. Si and with better efficiency.

Microsemi targets high-temperature applications with its solutions that have the advantages of not needing a heat sink, such as their use in "down-hole" applications and in engines where temperature cycling would likely cause major mechanical failures with most processes (**Figure 7**).

INTERNATIONAL RECTIFIER

IR's goal is to target the 20 to 1200V market with better switch on-resistance vs. the V rating of the device to get lower resistance in a smaller package. The figure of merit, based on switch on-resistance, is dramatically improved in the power device, depending on the process and breakdown voltage (see chart in the online version of this article at www.edn.com/4409627). Keeping an eye on a good performance/cost ratio compared with Si is key.

The company believes that GaN on Si is better than SiC to compete with pure-Si devices. It has in-house process-

TABLE 1 SWITCHING-DEVICE FEATURES

	SiC MOSFET	Si IGBT	Si Super-junction MOSFET
Breakdown voltage	Up to 1200V currently; higher in the future	High	Up to approximately 900V
On-resistance	Low (only 35% increase from 25°C to 150°C)	Low (but high at lower current due to threshold voltage)	Low (only 250% increase from 25°C to 150°C)
Switching speed	High	Limited switching frequency due to tail current at turn-off <10 kHz	High

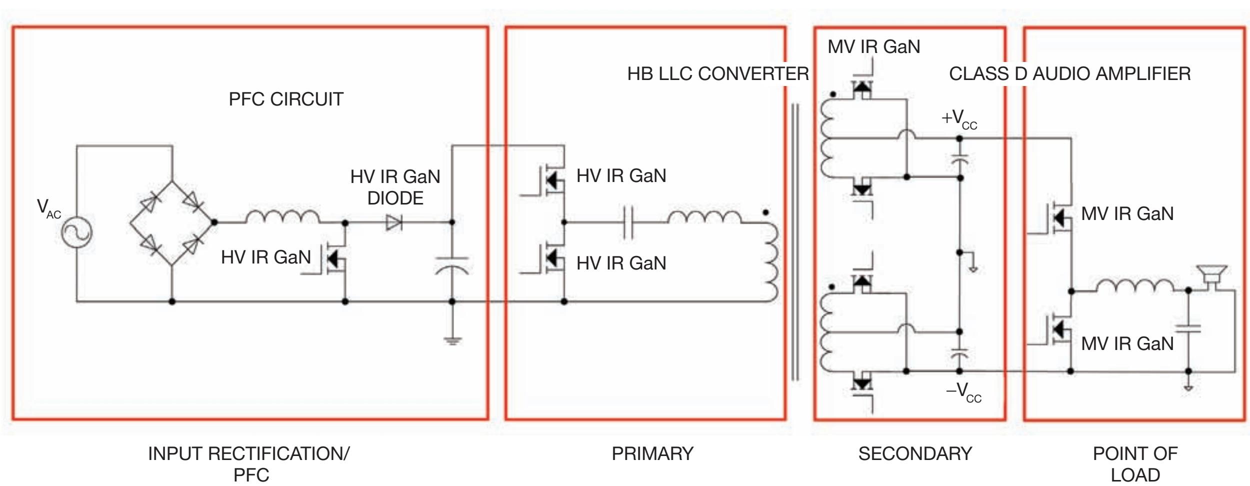


Figure 8 GaN has a good value proposition in the power-management chain because it can be used throughout the design, adding performance improvements (courtesy IR).

DATA SHEETS

For a collection of data sheets on the latest MOSFETs, FETs, and MOSFET drivers, go to www.datasheets.com.

es for Si and GaN and also grows its own GaN as well as hetero epitaxial GaN on Si, for which it has IP and patents.

While MOSFET drain-to-source on-resistance is a focus, keeping in mind lower cost, higher efficiency, and better density—or a combination of these characteristics—is also important. GaN devices' value proposition in the power-management chain is evident, as shown in **Figure 8**.

Class D audio with GaN at higher frequencies gives better noise and harmonic distortion, and the same is true for a power switch.

IR believes that SiC is great at 1500V and above, compared with Si, especially in applications such as electric trains and PV inverters.

A market exists for GaN in automobiles and computer power supplies. IR says early adopters are low-end consumer designs such as class D audio and power supplies, and the design-in time is 18 to 24 months. This is a good near-term market. The five- to seven-year auto- and medical-market cycle is another promising area as the company's product matures.

There are far more selection criteria than what appears in a data sheet or in a simple comparison of Si, GaN, and SiC processes. Consider every aspect of both the supplier and the process, as well as other intangibles, such as experience with and longevity of the process, unique configurations, and synergy with other parts of the system design. Delve deeply into all that is available in this power-element industry that most designers would not consider, and your design will be unique, robust, and the best fit possible for the system's overall needs. **EDN**

You can reach Senior Technical Editor Steve Taranovich at 1-632-413-1834 and steve.taranovich@ubm.com.

BY JACOB BENINGO • BENINGO ENGINEERING

10 software tips for hardware engineers

HERE IS SOME ADVICE THAT I WISH I'D RECEIVED BACK IN THE DAY WHEN I WAS TRANSITIONING FROM HARDWARE TO SOFTWARE.

Embedded system design often requires an understanding of not only the hardware but also how the software affects and interacts with it. Designing hardware requires a certain engineering paradigm that can be the polar opposite of designing software. When transitioning from hardware design to include software design, here are 10 tips that hardware engineers should keep in mind.

TIP #1: FLOWCHART FIRST, IMPLEMENT SECOND

When an engineer first enters the realm of developing software, there is an intense temptation to jump right in and start writing code. This mind-set is the equivalent of trying to lay out a PCB before the schematics have been completed. It is critical when sitting down to develop software that the urge to start writing code be ignored and instead an architectural diagram of the software be developed using flowcharts. This approach will give the developer an idea of the different parts and components needed for the application, much like how a schematic tells an engineer what hardware components are required. Doing this step first ensures that the program overall will stand a better chance of being well organized and well thought out, which will save time and headaches in the long run by decreasing debugging time.

TIP #2: USE STATE MACHINES TO CONTROL PROGRAM FLOW

One of the great software inventions of the 20th century was the state machine. An application often can be broken up into multiple state machines, each of which controls a specific component of the application. Each of these state machines has its own internal states and state transitions that dictate how the software reacts to various stimuli. Designing software using state machines will ease the development of software that is modular, maintainable, and easy to understand. A wide variety of resources exist that demonstrate state-machine theory and algorithms.

TIP #3: AVOID THE USE OF GLOBAL VARIABLES

In the old days of functional programming, function came before form, with the programmer's only goal being to make the program operate as expected as quickly as possible without regard for program structure or reusability. This programming paradigm held no apprehension about using variables that were global in scope and that any function within the program could modify. The result was an increased chance of variable corruption or misuse of variables. In the new recommended object-oriented paradigm, variables should be defined in the smallest possible scope and encapsulated to prevent other functions from misusing or corrupting the variables. It is therefore recommended that you limit the number of variables that use a global scope. These variables can be identified in the C language by the use of the external keyword.

TIP #4: TAKE ADVANTAGE OF MODULARITY

If you ask any engineer what part of a project is most likely to be delivered late and over budget, the answer will be the software. Software is often complex and can be difficult to develop and maintain, especially if the entire application resides in a single file or multiple files that are loosely correlated. To ease maintainability, reusability, and complexity, it is highly recommended that the programmer take advantage of the modularity of modern programming languages and break common functionality into modules. Breaking the code up in this manner will allow the programmer to start building libraries of functions and features that can then be reused from one application to the next, thus improving code quality through continuous testing in addition to decreasing time and development costs.

TIP #5: KEEP INTERRUPT SERVICE ROUTINES SIMPLE

An interrupt service routine is used to interrupt the processor from the branch of code that is currently being executed in order to handle a peripheral whose interrupt has just been triggered. Whenever an interrupt is executed, there is a certain amount of overhead required to save the current program state, run the interrupt, and then return the processor to the original program state. Modern processors are much faster than they were years ago, but this overhead still needs to be taken into account. In general, a programmer wants to minimize the time spent in interrupts and so avoid interfering with the primary code branch. This means that interrupts should be short and simple. Functions should not be called from an interrupt. In addition, if an interrupt starts to get too complex or take too much time, the interrupt should be used to do the minimum required at the time, such as loading data into a buffer and setting a flag to then allow the main branch to process the incoming data. Doing this ensures that the majority of the processors' cycles are being spent running the application and not just processing interrupts.

TIP #6: USE PROCESSOR EXAMPLE CODE TO EXPERIMENT WITH PERIPHERALS

When designing hardware, it is always helpful to build prototype test circuits to make sure that an engineer's understanding of the circuit is correct before laying out a board. The same can be done when writing software. Silicon manufacturers usually have example code that can be used to test out parts of the microprocessor so that the engineer can get a feel for how the part works. This approach allows insights to be made into how the software architecture should be organized and any potential issues that could be encountered. Identifying potential roadblocks early in the design process is preferable to finding them in the last hours before shipping a product. This is a great way to test out code snippets beforehand, but be warned that manufacturer code is usually not modular and easily used in the actual application without considerable modification. Over time, this limitation has been changing and may one day result in production-ready code right from the chip provider.

TIP #7: LIMIT FUNCTION COMPLEXITY

There is an old expression in engineering called KISS—Keep it simple, silly. When dealing with any complex task, the simplest approach is to break it up into smaller and simpler

WHEN DEALING WITH ANY COMPLEX TASK, THE SIMPLEST APPROACH IS TO BREAK IT UP INTO MORE MANAGEABLE TASKS.

tasks that are more manageable. As tasks or functions become more complex, it becomes harder for humans to keep track of all the details without allowing errors to slip in. When a function is written, the complexity may seem appropriate at the time, but how an engineer will view the code when it needs to be maintained six months down the road should be considered. There are a number of techniques for measuring function complexity, such as cyclomatic complexity. Tools exist that can automatically calculate the cyclomatic complexity of a function. A general rule of thumb suggests that functions with a cyclomatic complexity below 10 are desirable.

TIP #8: USE A SOURCE-CODE REPOSITORY AND COMMIT FREQUENTLY

Making mistakes is part of being human, and when humans write code, they don't miraculously change. That's why it is critical that developers use a source-code repository. A source-code repository allows a developer to "check in" a good version of code with a description of what changes were made to the code base. This step allows the developer to not only revert or go back to an old version of code but also compare previous versions for changes. In the event a developer makes a number of changes that then break the system, going back to a good version of code is just a click away! Remember that if code is not committed frequently, the repository will not work as intended. Waiting two weeks to commit code and then going back will cause the loss of a lot of work and time if an irreversible change is made!

TIP #9: DOCUMENT THE CODE THOROUGHLY

When in the heat of software-development battles, it is very easy to focus just on getting the code written and debugged and ignore the need to document it. Documentation often becomes an end-of-project task, as it is the last thing on a developer's mind when the pressure is on. It is important, however, to document the code when it is fresh in your mind so that a future developer or your future self can read the comments and understand how the code works.

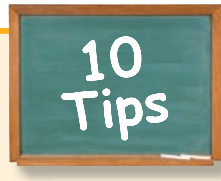
IF A DEVELOPER MAKES CHANGES THAT BREAK THE SYSTEM, GOING BACK TO A GOOD VERSION OF CODE IS JUST A CLICK AWAY!

TIP #10: USE AN AGILE DEVELOPMENT PROCESS

When doing engineering of any kind, it is always recommended that some sort of process be defined and followed. The result should be consistent quality and costs, as well as on-time delivery. Software developers have been successfully using the Agile development process to develop quality software. The process allows for requirements to be developed with priorities. The highest-priority tasks are performed first within a scheduled period of time known as an iteration. The beauty of the approach is that it permits the software-development process to be fluid, allowing requirements and tasks to adapt and change with each iteration based on the results and needs of the client.

TIP #10A: STAY ON TOP OF DEVELOPING TECHNOLOGIES

A great place to learn about the latest tools and techniques being used to develop embedded software is one of the Embedded Systems Conferences, held twice a year, in San Jose, CA (www.ubmdesign.com/sanjose) and Boston (east.ubmdesign.com). These conferences draw engineers from around the world, providing the opportunity to interact, attend seminars, and try hands-on exercises that will improve their understanding of software development. In addition, the Community area of EDN.com offers a variety of blogs (www.edn.com/blogs) on hardware and software topics to keep engineers always engaged and learning so that they are ready to apply cutting-edge technologies in their next development project.EDN



Readers weigh in

▶ **"I don't agree with the advice on interrupt routines. When using a low-power microcontroller such as TI's MSP430, the main line code is often nothing more than putting the processor to sleep. All of the action takes place in the interrupt routine when the processor is awakened."**—DickB

▶ **"From my experience, perhaps this should have been titled '10 software tips for software engineers.'**

Once interviewed a software engineer for a new position and asked the question 'How do you go about writing software for a new project?'

The answer was 'Start coding the software'!

What I was expecting was 'Read the specifications,' followed by 'Break down the software into individual modules and flowchart them,' or something similar.

He didn't get the job."—The Real Dr Bob

▶ **"All very good. Would like to add 10b: Get rest of organization (management) educated on 'Agile' (and general compromises related to the other development processes).**

Biggest 'truth' to be understood: setting realistic goals for the completion of the project while still at the beginning of the project (a recurring theme).

Another perspective on same subject: assigning appropriate manpower and processes at the beginning, not adding later, when things are late.

One 'man year' effort equals 720 people working a problem 'til lunch time? (Hard to kill this one.)"—Thinking_J

JOIN THE CONVERSATION
To share your own comments on this article, go to www.edn.com/4405862.

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

65V, 500mA Step-Down Converter Fits Easily into Automotive and Industrial Applications

Design Note 512

Charlie Zhao

Introduction

The trend in automobiles and industrial systems is to replace mechanical functions with electronics, thus multiplying the number of microcontrollers, signal processors, sensors and other electronic devices throughout. The issue is that 24V truck electrical systems and industrial equipment use relatively high voltages for motors and solenoids while the microcontrollers and other electronics require much lower voltages. As a result, there is a clear need for compact, high efficiency step-down converters that can produce very low voltages from the high input voltages.

65V Input, 500mA DC/DC Converter with an Adjustable Output Down to 800mV

The LTC®3630 is a versatile Burst Mode® synchronous step-down DC/DC converter that includes three pin-selectable preset output voltages. Alternatively, the output can be set via feedback resistors down to 800mV. An adjustable output or input current limit from 50mA to 500mA can be set via a single resistor. The hysteretic nature of this topology provides inherent short-circuit protection. Higher output currents are possible by paralleling multiple LTC3630s together and connecting the FBO of the master device to the VFB pin of a slave device. An adjustable soft-start is included. A precision RUN pin threshold voltage can be used for an undervoltage lockout function.

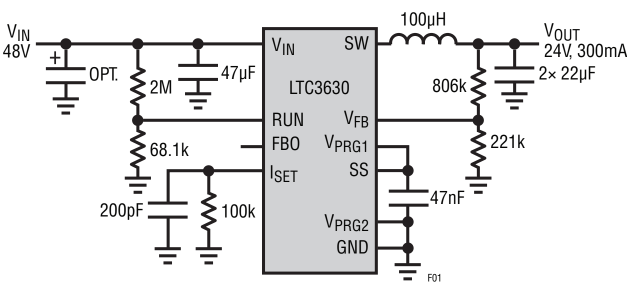


Figure 1. High Efficiency 24V Regulator with Undervoltage Lockout and 300mA Current Limit

24V Regulator with 300mA Output Current Limit and Input Undervoltage Lockout

Figure 1 shows a 48V to 24V application that showcases several of the LTC3630's features, including the undervoltage lockout and output current limit. Operational efficiencies are shown in Figure 2.

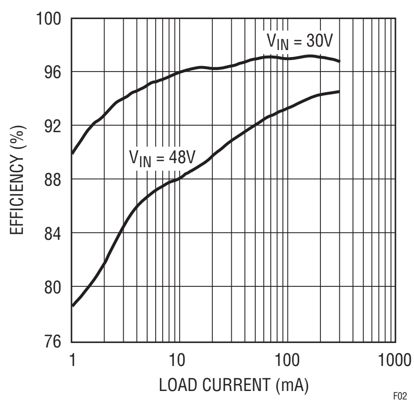


Figure 2. Efficiency of Circuit in Figure 1

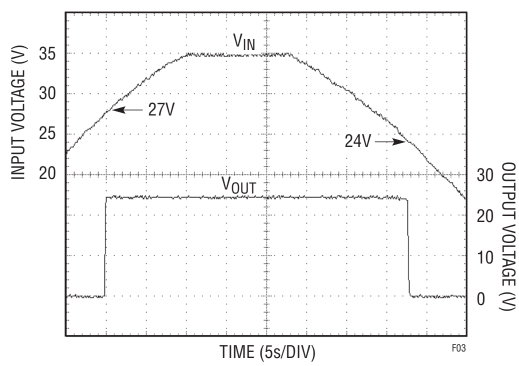


Figure 3. Input Voltage Sweep vs Output Voltage Showing Undervoltage Lockout Threshold Levels

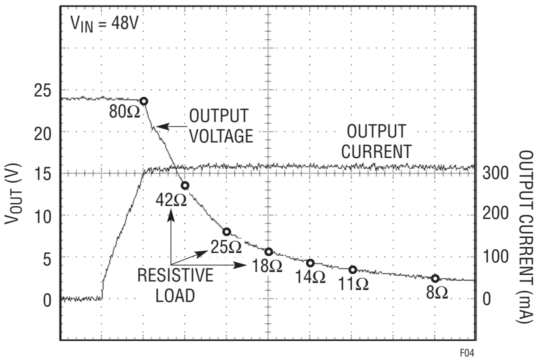


Figure 4. Resistive Load Sweep vs Output Current vs Output Voltage with Output Current Limit Set to 300mA

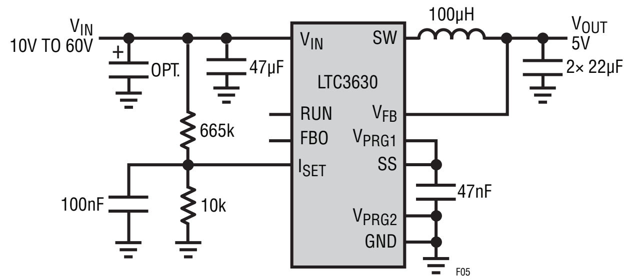


Figure 5. 5V Regulator with 55mA Input Current Limit

The RUN pin is programmed for V_{IN} undervoltage lockout threshold levels of 27V rising and 24V falling. Figure 3 shows V_{OUT} vs V_{IN}. This feature assures that V_{OUT} is in regulation only when sufficient input voltage is available.

The 24V output voltage can be programmed using the 800mV 1% reference or one of the preset voltages. This circuit uses the 5V preset option along with feedback resistors to program the output voltage. This increases circuit noise immunity and allows lower value feedback resistors to be used.

Although the LTC3630 can supply up to 500mA of output current, the circuit in Figure 1 is programmed for a maximum of 300mA. An internally generated 5µA bias out of the I_{SET} pin produces a voltage across an I_{SET} resistor, which determines the maximum output current. Figure 4 shows the output voltage as a resistive load is varied from approximately 100Ω down to 8Ω while maintaining the output current near the programmed value of 300mA. In addition, the hysteretic topology used in this DC/DC converter provides inherent short-circuit protection.

Input Current Limit

Another useful feature of the LTC3630 is shown in Figure 5. In this 5V circuit, the current limit is set by a resistive divider from V_{IN} to I_{SET}, which produces a voltage on the I_{SET} pin that tracks V_{IN}. This allows V_{IN} to control output current which determines input current.

An increased voltage on I_{SET} increases the converter's current limit. Figure 6 shows the steady-state input current vs input voltage and the available output current before the output voltage begins to drop out of regulation. For the values shown in Figure 5, the input current is limited to approximately 55mA over a 10V to 60V input voltage range.

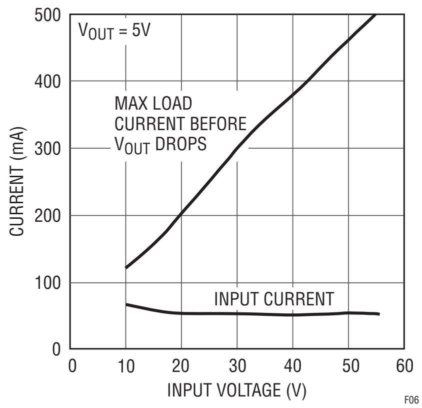


Figure 6. Input Voltage vs Load Current and Input Current with Input Current Limit Circuit Shown in Figure 5

Conclusion

The LTC3630 offers a mixture of features useful in high efficiency, high voltage applications. Its wide output voltage range, adjustable current capabilities and inherent short-circuit tolerant operation makes this DC/DC converter an easy fit in demanding applications.

Data Sheet Download

www.linear.com/3630

For applications help,
call (408) 432-1900, Ext. 3258

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

dn512 LT/AP 0313 196K • PRINTED IN THE USA

DESIGN NOTES

Supercapacitor-Based Power Backup System Protects Volatile Data in Handhelds when Power Is Lost

Design Note 498

Jim Drew

Introduction

Handheld electronic devices play a key role in our everyday lives. Because dependability is paramount, handhelds are carefully engineered with lightweight power sources for reliable use under normal conditions. But no amount of careful engineering can prevent the mistreatment they will undergo at the hands of humans. For example, what happens when a factory worker drops a bar code scanner, causing the battery to pop out? Such events are electronically unpredictable, and important data stored in volatile memory would be lost without some form of safety net—namely a short-term power holdup system that stores sufficient energy to supply standby power until the battery can be replaced or the data can be stored in permanent memory.

Supercapacitors are compact, robust, reliable and can support the power requirements of a backup system for short-term power-loss events. Like batteries, they require careful charging and power regulation at the output. The LTC®3226 is a 2-cell series supercapacitor charger with a PowerPath™ controller that simplifies the design of backup systems. Specifically, it includes a charge pump supercapacitor charger with programmable output voltage and automatic cell voltage balancing, a low dropout regulator and a power-fail comparator for switching between normal and backup modes. Low input noise, low quiescent current and a compact footprint make the LTC3226 ideal for compact, handheld, battery-powered applications. The device comes in a 3mm × 3mm 16-lead QFN package.

Backup Power Application

Figure 1 shows a power holdup system that incorporates a supercapacitor stack with the capacity to provide standby power of 165mW for about 45 seconds in the absence of battery power. An LDO converts the output of the supercapacitor stack to a constant voltage supply during backup mode.

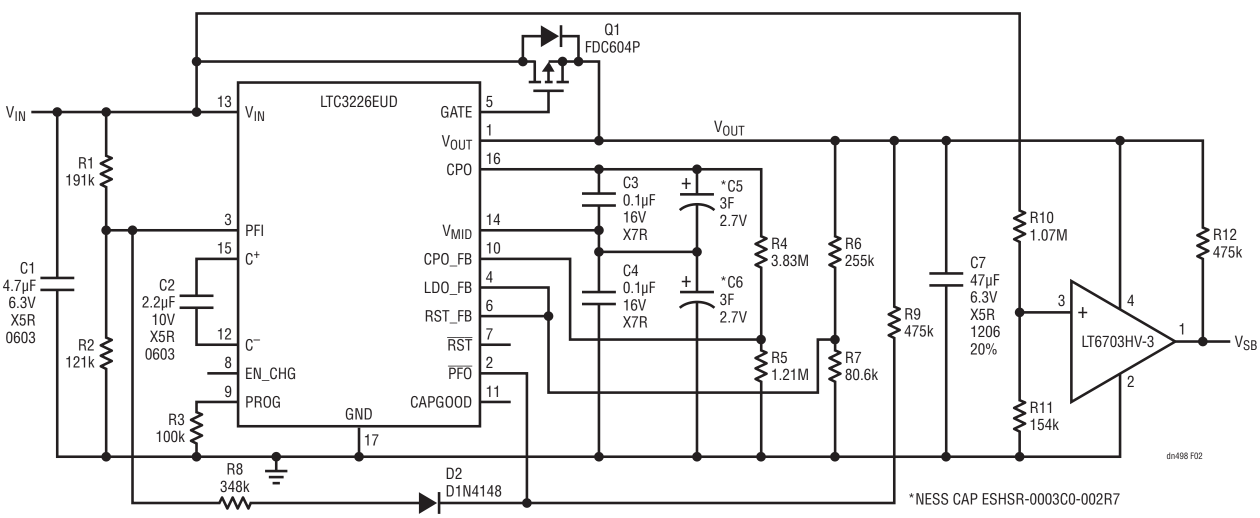


Figure 1. A Typical Power Backup System Using Supercapacitors

Designing a power backup system is easy with the LTC3226. For example, take a device that has an operating current of 150mA and a standby current (I_{SB}) of 50mA when powered from a single-cell Li-Ion battery. To ensure that a charged battery is present, the power-fail comparator (PFI) high trigger point is set to 3.6V. The device enters standby mode when the battery voltage reaches 3.15V and enters backup mode at 3.10V ($V_{BAT(MIN)}$), initializing holdup power for a time period (t_{HU}) of about 45 seconds.

The standby mode trigger level is controlled by an external comparator circuit while the backup mode trigger level is controlled by the PFI comparator. While in backup mode, the device must be inhibited from entering full operational mode to prevent overly fast discharge of the supercapacitors.

The design begins by setting the PFI trigger level. R2 is set at 121k and R1 is calculated to set the PFI trigger level at the PFI pin (V_{PFI}) to 1.2V.

$$R1 = \frac{V_{BAT(MIN)} - V_{PFI}}{V_{PFI}} \bullet R2 = 191.6k\Omega$$

Set R1 to 191k.

The hysteresis on the V_{IN} pin needs to be extended to meet the 3.6V trigger level. This can be accomplished by adding a series combination of a resistor and diode from the PFI pin to the PFO pin. $V_{IN(HYS)}$ is 0.5V, $V_{PFI(HYS)}$ is 20mV and V_f is 0.4V.

$$R8 = \frac{V_{PFI} + V_{PFI(HYS)} - V_f}{V_{IN(HYS)} - \frac{V_{PFI(HYS)}}{R2} \bullet (R1+R2)} \bullet R1 = 349.3k\Omega$$

Set R8 to 348k.

Set the LDO backup mode output voltage to 3.3V by setting R7 to 80.6k and calculating R6. $V_{LDO(FB)}$ is 0.8V.

$$R6 = \frac{V_{OUT} - V_{LDO(FB)}}{V_{LDO(FB)}} \bullet R7 = 251.9k\Omega$$

Set R6 to 255k.

The fully charged voltage on the series-connected supercapacitors is set to 5V. This is accomplished with a voltage divider network between the CPO pin and the CPO_FB pin. R5 is set to 1.21M and R4 is calculated. $V_{CPO(FB)}$ is 1.21V.

$$R4 = \frac{V_{CPO} - V_{CPO(FB)}}{V_{CPO(FB)}} \bullet R5 = 3.78M\Omega$$

Let R4 equal 3.83M.

As the voltage on the supercapacitor stack starts to approach V_{OUT} in backup mode, the ESR of the two supercapacitors and the output resistance of the LDO must be accounted for in the calculation of the minimum voltage on the supercapacitors at the end of t_{HU}. Assume that the ESR of each supercapacitor is 100mΩ and the LDO output resistance is 200mΩ, which results in an additional 20mV to $V_{OUT(MIN)}$ due to the 50mA standby current. $V_{OUT(MIN)}$ is set to 3.1V, resulting in a discharge voltage (ΔV_{SCAP}) of 1.88V on the supercapacitor stack. The size of each supercapacitor can now be determined.

$$C_{SCAP} = 2 \bullet \frac{I_{SB} \bullet t_{HU}}{\Delta V_{SCAP}} = 2.39F$$

Each supercapacitor is chosen to be a 3F/2.7V capacitor from Nesscap (ESHSR-0003C0-002R7).

Figure 2 shows the actual backup time of the system with a 50mA load. The backup time is 55.4 seconds due to the larger 3F capacitors used in the actual circuit.

Conclusion

High performance handheld devices require power backup systems that can power the device long enough to safely store volatile data when the battery is suddenly removed. Supercapacitors are compact and reliable energy sources in these systems, but they require specialized control systems for charging and output voltage regulation. The LTC3226 makes it easy to build a complete backup solution by integrating a 2-cell supercapacitor charger, PowerPath controller, an LDO regulator and a power-fail comparator, all in a 3mm × 3mm 16-lead QFN package.

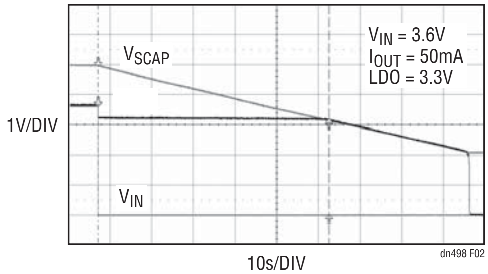


Figure 2. Backup Time Supporting 50mA Load

Data Sheet Download

www.linear.com

For applications help,
call (978) 656-3768

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

dn498f LT/TP 0112 196K • PRINTED IN THE USA

Circuit maximizes pulse-width-modulated DAC throughput

Ajoy Raman, Bangalore, India

Simple DACs realized by low-pass filtering microcontroller-generated pulse-width-modulated (PWM) signals have a response that is typically a tenth of the PWM frequency. This Design Idea is a novel implementation of a previously published method[1] employing a reference ramp whose output is sampled and held by the PWM signal. This approach results in a throughput rate equal to the PWM frequency.

You can use the circuit in **Figure 1** to implement a ±10V 10-bit DAC with a throughput of 20 kHz. A DSPIC30F4011 microcontroller (not shown) is operated at a clock frequency of 96 MHz to generate the capture signals OC_1 and OC_4. Clock/4 is fed to an internal 16-bit timer whose period is set for a count of 1200 corresponding to a PWM frequency of 20 kHz. Signal OC_4 is mostly high and goes low at a fixed count of 1170 as a reference for ramp generation. IC_{1A}, along with Q_1, forms a precision constant-current source that linearly charges capacitor C_2 when Q_2 is off. This signal inverted by IC_{3A} switches Q_2 on for a period of 30 counts to discharge C_2 for the start of the next ramp. IC_{1B} buffers, amplifies, and offsets the ramp; potentiometers R_2 and R_5 adjust the offset and gain.

The OC_1 falling edge controls the PWM DAC sample timing relative to

DIs Inside

▶To see and comment on all of *EDN*'s Design Ideas, visit www.edn.com/designideas.

the ramp voltage. The data word to be converted determines the OC_1 duty cycle by comparing it internally in the

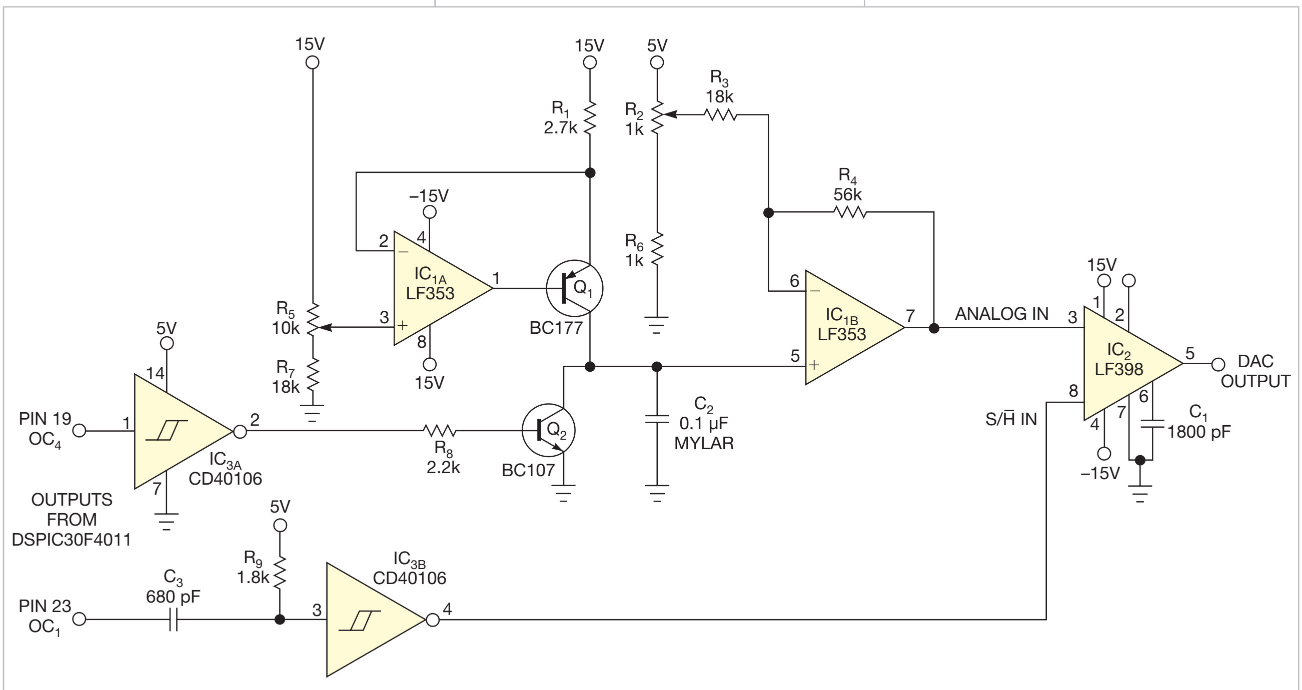


Figure 1 The off-page microcontroller generates signals for ramp control (OC_4) and sample timing (OC_1).

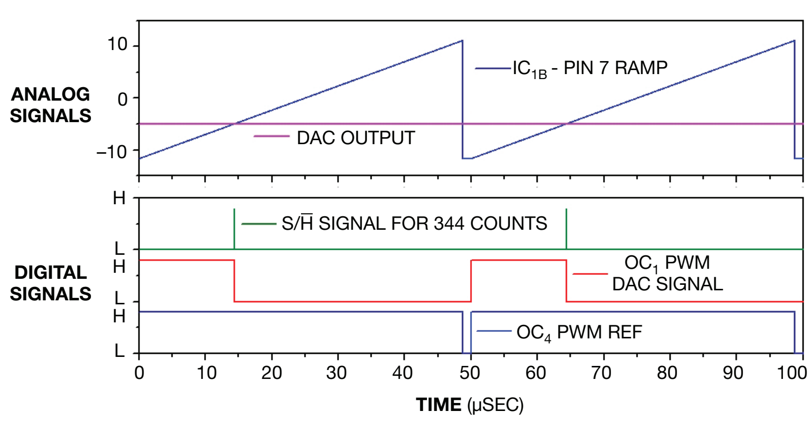


Figure 2 The differentiated OC_1 falling edge generates the S/$\overline{H}$ sample pulse at the ramp –5V point.

microcontroller with the internal 16-bit timer. C_3 and R_9 differentiate the resulting PWM signal; IC_{3B} then inverts it, forming a 1-μsec sample signal for the sample-and-hold IC_2. Pin 5 of IC_2 forms the DAC output and is adjusted to –10, 0, and +10V for OC_1 PWM counts of 88, 600, and 1112, respectively, corresponding to a 10-bit count of 1024.

The count offset of 88 helps to avoid the initial nonlinear region of the ramp so that the PWM DAC shows good linearity with a LSB of 20 mV and an accuracy of ±40 mV. Additional PWM DACs could also be implemented using capture PWM outputs OC_2 and OC_3.

Figure 2 shows the waveforms to be expected for a DAC output corresponding to 256 on a 10-bit scale of 1024. OC_4 forms the PWM reference based on which a 20-kHz bipolar ramp signal is output at Pin 7 of IC_{1B}. This ramp is sampled and held at a count of 256+88=344, corresponding to a DAC output of –5V. EDN

REFERENCES

1. Kester, Walt (editor), *The Data Conversion Handbook*, section 3-1, pg 3-28, Newnes, 2005, http://bit.ly/KjU8fU.
2. Raman, Ajoy, "Universal Analog Hardware Testbench," http://bit.ly/QCYXmb.

A circuit for mains synchronization has two separate outputs for each half-period

Dušan Ponikvar, University of Ljubljana, Ljubljana, Slovenia

Often a measurement of weak signals has to be performed in the presence of strong interference from the ac power mains. If the interfering signal cannot be filtered out, then you can still obtain a clean result by making two consecutive measurements separated in time by an odd number of half-periods of the mains and calculating the average of the two measurements. The interfering signals have opposite polarities in consecutive measurements, and averaging cancels them out. If you average several consecutive pairs of measurements, the results will improve still further. Instead of counting the half-periods of the mains, you may find that a circuit having two outputs for synchronization with odd or even half-periods of the mains can come in handy.

The circuit shown in **Figure 1** provides two separate and optically isolated outputs, ISO_1 and ISO_2, for synchronization with the desired half-period of the mains. **Figure 2** shows the results of simulation (using the free version of

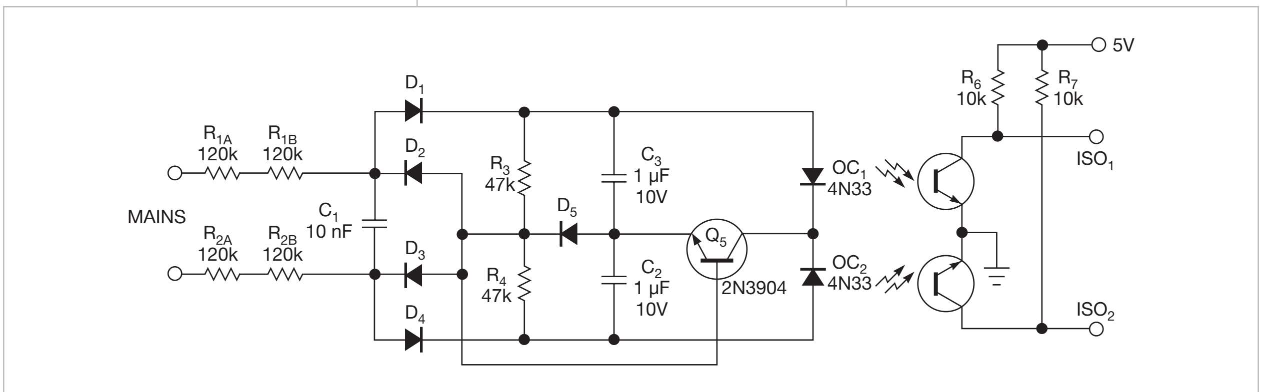
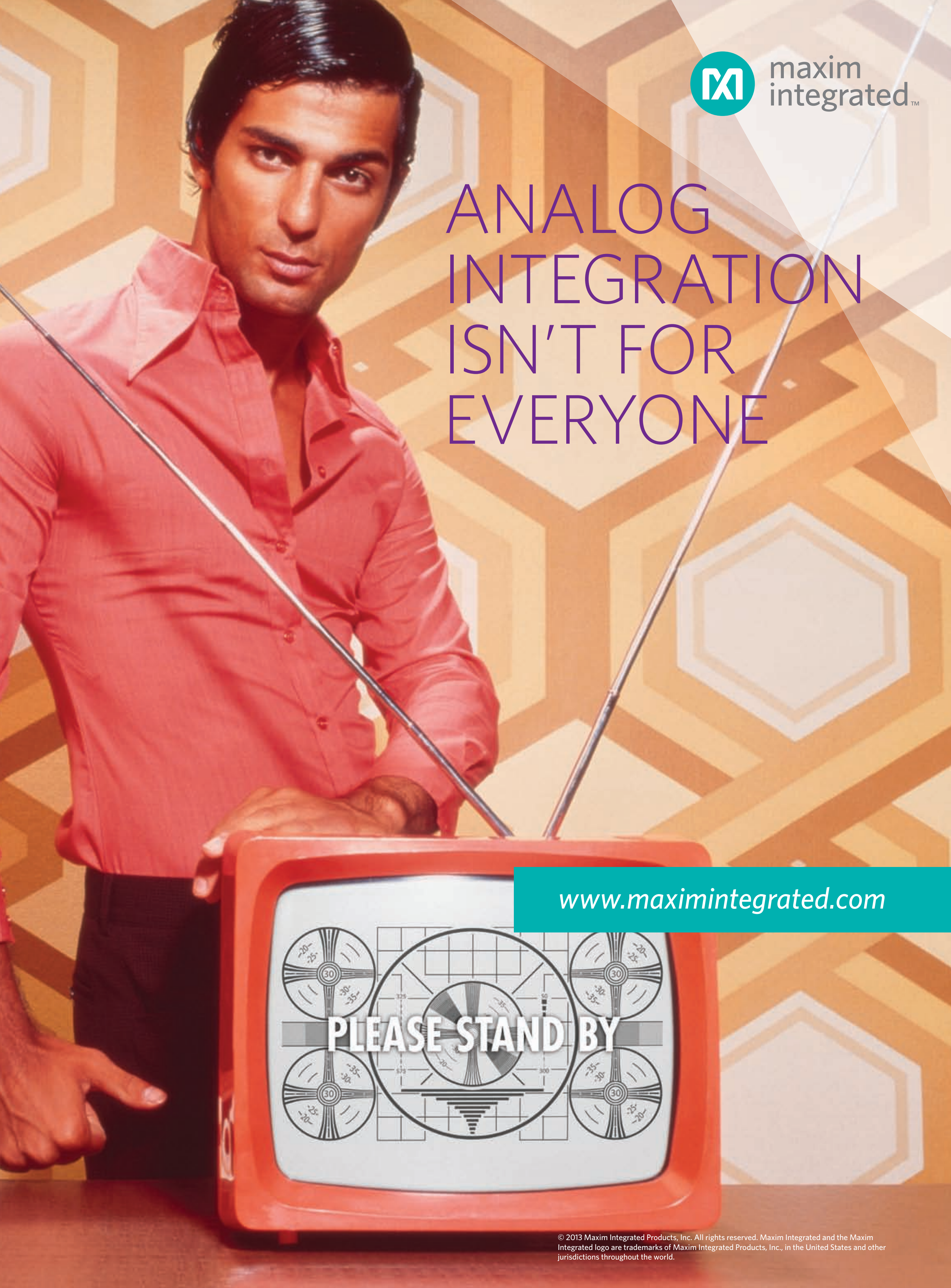


Figure 1 Mains zero crossings are marked by the optically isolated outputs.


maxim integrated
ANALOG INTEGRATION ISN'T FOR EVERYONE
www.maximintegrated.com
PLEASE STAND BY
© 2013 Maxim Integrated Products, Inc. All rights reserved. Maxim Integrated and the Maxim Integrated logo are trademarks of Maxim Integrated Products, Inc., in the United States and other jurisdictions throughout the world.

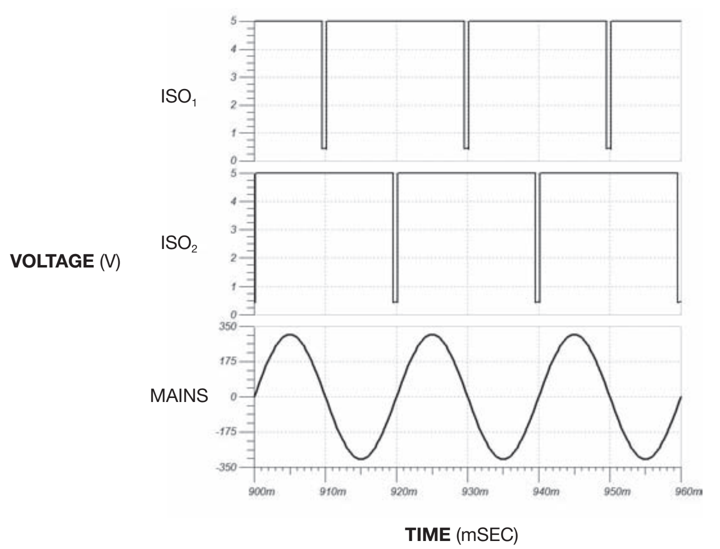


Figure 2 Simulation results demonstrate the circuit action.

TINA-TI). The circuit accepts mains input from 80V ac to 240V ac, and consumes less than a milliamp of current.

The duration of the pulses at outputs ISO_1 and ISO_2 is less than a millisecond, and capacitor C_1 can be adjusted to achieve the exact alignment of the falling edges of outputs ISO_1 and ISO_2 with the zero crossing of the mains. All diodes, D_1 to D_5, are small-signal type 1N4148 or similar.

The circuit works as follows: During the positive half-period of the mains, C_3 is charged through R_{1A}, R_{1B}, D_1 and D_5, D_3, R_{2B}, and R_{2A}. The effective time constant, τ, for charging is about 43 msec, and C_3 barely picks up some charge in the half-period. Once the mains drops below the voltage stored on C_3 (this happens just before the end of the half-period),

THE CIRCUIT ACCEPTS MAINS INPUT FROM 80V AC TO 240V AC.

the charging stops and current begins to flow from C_3 through R_3 into the base of Q_5, turning it on. This discharges C_3 through the LED in optocoupler OC_1, and produces a pulse at the output ISO_1 of the circuit. During the negative half-period, the action repeats, only this time D_4 and D_2 are used to charge C_2, and R_4 is used to activate Q_5 when the negative half-period is nearly finished.

The duration of the output pulse can be shortened to about 600 µsec by increasing the time constant—therefore by increasing the value of resistors R_1 and R_2 or capacitors C_2 and C_3—but this also reduces the range of acceptable input voltages.

The detailed simulation reveals that the maximum voltage on C_2 and C_3 is less than 5V, with 250V ac connected to the input; a voltage rating of 10V for the capacitors is sufficient. Additionally, the maximum voltage on C_1 is less than 10V ac, and the reverse voltage on the diodes is less than 6V. The peak current through the optocoupler LEDs is below 8 mA. The only components that are exposed to the mains are input resistors R_{1A}, R_{1B}, R_{2B}, and R_{2B}. They have equal values, so each one needs to withstand 25% of the mains voltage.

The measurements obtained from the constructed circuit show good correlation with the simulation results. **Figure 3** shows output signals; **Figure 4** shows the timing detail of the zero crossing and corresponding output pulse for three different values of C_1. **EDN**

REFERENCES

1 "DIY: Isolated high-quality mains voltage zero-crossing detector," www.dextrel.net/diyzerocrosser.htm.

2 Matteini, Luca, "Mains-driven zero-crossing detector uses only a few high-voltage parts," *EDN*, Dec 1, 2011, www.edn.com/4368740.

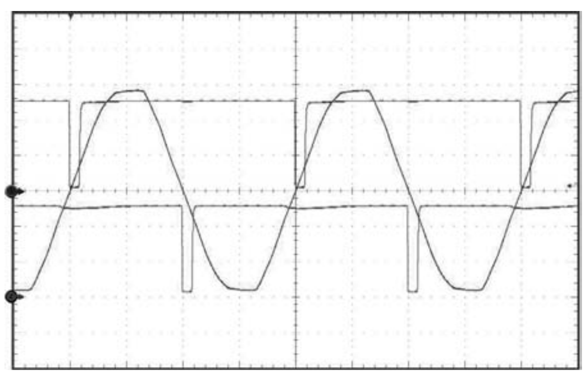


Figure 3 Measured output signals ISO_1 and ISO_2 and the mains voltage verify the circuit operation.

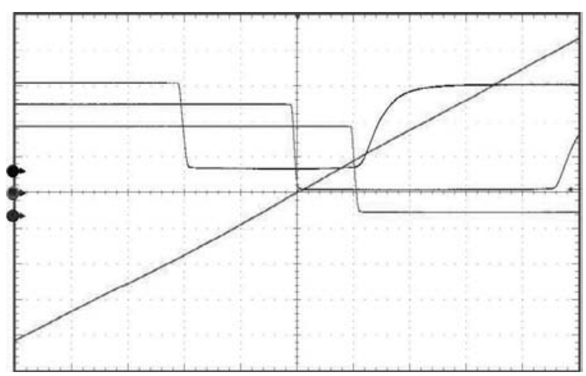


Figure 4 C_1 determines the position of the pulse leading edge in this detail from the center portion of Figure 3. The horizontal scale is 200 µsec/div. Pulses are vertically shifted for better visibility: C_1=0 (upper), 12 nF (middle), and 22 nF (lower).

Low-component-count zero-crossing detector is low power

C Castro-Miguens and M Pérez Suárez, University of Vigo, Spain,
and JB Castro-Miguens, Cesinel, Madrid, Spain

There are many circuits published showing zero-crossing detectors for use with 50- and 60-Hz power lines. Though the circuit variations are plentiful, many have shortcomings. This Design Idea shows a circuit that uses only a few commonly available parts and provides good performance with low power consumption.

In the circuit shown in **Figure 1**, a waveform is produced at V_O with rising edges that are synchronized with the zero crossings of the line voltage, V_{AC}. The circuit can be easily modified so that it produces a falling-edge waveform that is synchronized with V_{AC}.

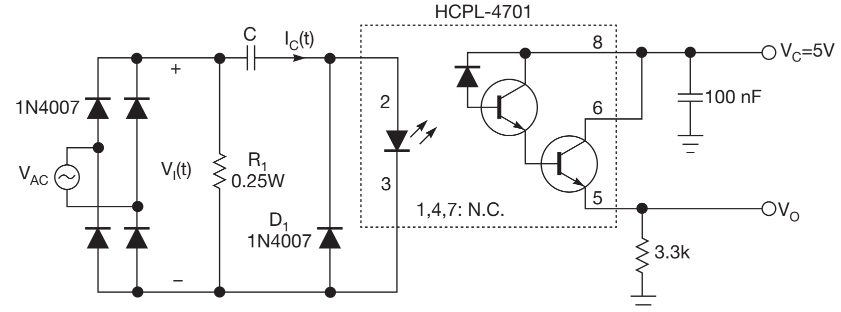


Figure 1 The zero-crossing detector uses few components and consumes very little power. The V_O signal has a rising edge that is coincident with each zero crossing of the line voltage, V_{AC}.

The circuit operates as follows. At the zero crossings of V_{AC}, the current through the capacitor and the LED of the HCPL-4701 optocoupler satisfies **Equation 1** below. **Equation 2** shows the standard conversion between radians per second and hertz; it also shows the derivation and explanation for $v_i(t)$. **Equations 3** and **4** show the simplification used in **Equation 1**. Because the voltage across the LED is close to constant, differentiation of that value with respect to time results in a zero value.

$$i_c(t)=i_{LED}(t)=C\frac{d}{dt}[v_i(t)-v_{LED}]\approx C\frac{d}{dt}\times v_i(t)$$
$$=C\times\omega\times V_{AC-PK}\times\cos(\omega t)\rightarrow i_c(0)\approx C\times\omega\times V_{AC-PK}, \quad (1)$$

where $\omega=2\times\pi\times f_{AC}$ and

$$v_i(t)=|V_{AC}(t)|=|V_{AC-PK}\times\sin(\omega t)|. \quad (2)$$

$$C\frac{d}{dt}[v_i(t)-v_{LED}]$$
$$=C\frac{d}{dt}\times v_i(t)-C\frac{d}{dt}\times v_{LED}\approx C\frac{d}{dt}\times v_i(t), \quad (3)$$

$$\text{because } C\frac{d}{dt}\times v_{LED}\approx 0\ (v_{LED}\approx\text{constant}). \quad (4)$$

The peak value of the current through the LED is a function of the capacitor, C, so you must choose a value for C under the constraint that at the initial time (t=0) and for a given minimum supply-voltage value, the intensity exceeds the triggering threshold value for the optocoupler. In the case of the HCPL-4701, it is $I_{F(ON)}$=40 µA.

Diode D_1 not only allows for the capacitor to discharge but also prevents the application of a reverse voltage on the LED. The maximum reverse input voltage of the HCPL-4701 is 2.5V.

Resistor R_1 is included in order to discharge the energy stored in the capacitor in the latter portion of each cycle of $v_i(t)$ when $i_c(t)<0$ (**Figure 1**). Its maximum value is limited by the capacitor, by the peak value of the supply voltage ($V_{AC\text{-}PEAK}$), and by the maximum acceptable time delay of the current rising edges through the LED with respect to the corresponding ac-voltage zero crossing (**Figure 2**). Its minimum value is limited by the maximum allowable power dissipation in R_1 ($[V_{AC\text{-}RMS}]^2/R_1$). A practical compromise has to be reached.

Table 1 shows the time delay (t_{DELAY}) of the current rising edges through the LED and the power dissipation for three different values of R_1. Notice that the time delay of the rising edges of V_O with respect to the zero crossings of V_{AC} must

TABLE 1 I_{LED} TIME DELAY FOR DIFFERENT VALUES OF R_1

R_1	t_{DELAY} (µSEC)	$V^2_{AC\text{-}RMS}/R_1$ (mW)
470 kΩ	60	112.5
820 kΩ	100	64.5
4.7 MΩ	450	11.2

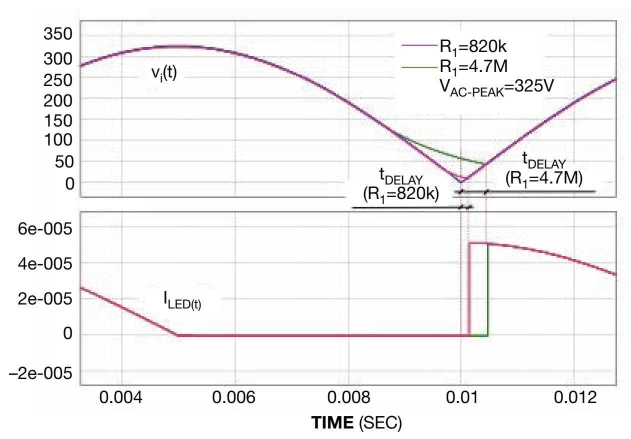


Figure 2 The relationship between $v_i(t)$ and $I_{LED}(t)$ is a function of the value of R_1. The time delay between the zero crossing and the LED current is shown.

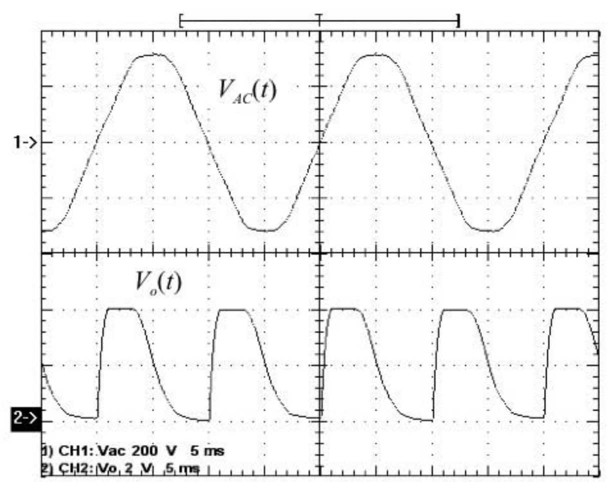


Figure 3 Empirical results are shown for V_{AC}=230V_{RMS}, C=0.5 nF, and R_1=560 kΩ.

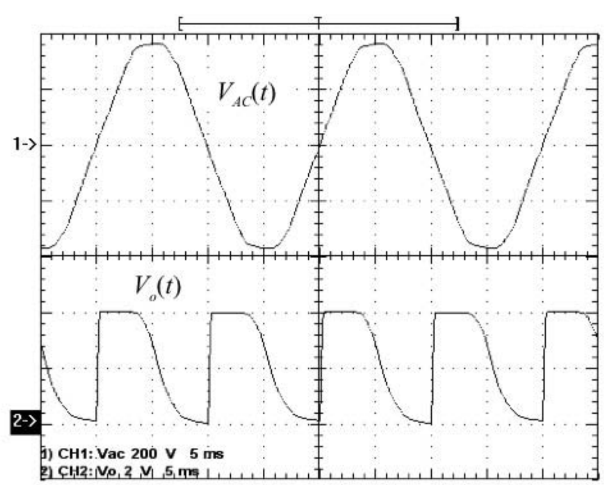


Figure 4 Empirical results are shown for V_{AC}=115V_{RMS}, C=1 nF, and R_1=220 kΩ.

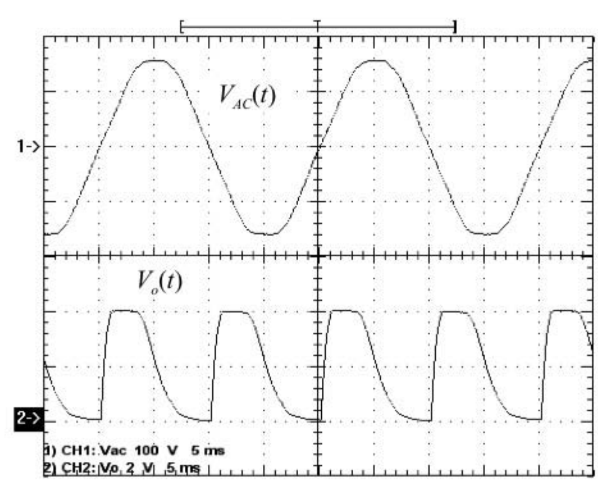


Figure 5 Empirical results are shown for V_{AC}=267V_{RMS}, C=1 nF, and R_1=220 kΩ.

include an additional delay for the optocoupler's propagation time delay. The HCPL-4701 has a typical propagation time delay of 70 µsec.

Based on the previous information, the following practical values for C and R_1 are obtained:

- For V_{AC}=230V_{RMS}±20% (**Figure 3**): C=0.5 nF/400V (MKT-HQ 370 polyester metallized, MKT series), R_1=560 kΩ/0.25W, t_{DELAY}=114 µsec (the time delay in the rising edges of V_O with respect to the zero crossings of V_{AC}), and P≈100 mW (average power from the ac line).
- For V_{AC}=115V_{RMS}±20% (**Figure 4**): C=1 nF/200V, R_1=220 kΩ/0.25W, t_{DELAY}=130 µsec (time delay in the rising edges of V_O with respect to the zero crossings of V_{AC}), and P≈65 mW (average power from the ac line).
- For operation from 80 to 280V_{RMS}: C=1 nF/400V and R_1=330 kΩ/0.25W.

Empirical results are shown for V_{AC}=267V_{RMS}, C_1=1 nF, and R_1=220 kΩ (**Figure 5**). Additional empirical results can be viewed in the online version of this Design Idea, which is available at www.edn.com/4408530.

Note that as with any device connected directly to the mains, exercise extreme caution while bench testing the circuit. Follow proper guidelines when laying out a printed circuit board. EDN

DC-DC converter starts up and operates from a single photocell

Marián Štofka, Slovak University of Technology, Bratislava, Slovakia

The bq25504 from Texas Instruments is a good candidate to become a milestone on the road to micro-power management and energy harvesting. A prominent feature of this IC is its ability to start up at a supply voltage as low as 330 mV typically, and 450 mV guaranteed. With an SMD inductor and a few capacitors and resistors, it forms a dc-dc converter with a high power efficiency that is unprecedented, especially in the ultralow-power region.

A possible explanation for this breakthrough in achieving an extremely low value of start-up voltage could be the use of an internal oscillator based on submicron-wide-channel FET transistors. It is known that the narrower the FET's channel is, the lower its threshold value of gate-source voltage will be—down to a few hundred millivolts. You could assume that FETs in the internal oscillator of the bq25504 have a threshold voltage on the order of 200 mV.

The circuit in **Figure 1** differs from those shown in the bq25504 data sheet (www.ti.com/product/bq25504) in that it exploits a feature of the bq25504: The reference voltage at V_{BAT_OV} (overvoltage) is internally multiplied by a factor of 3/2, as compared with the reference voltage at V_{BAT_UV} (undervoltage). If limiting the battery voltage within an interval of V_{BAT_UV} and $(3/2)\times V_{BAT\_UV}$ suits your application, you can connect the V_{BAT_UV} and V_{BAT_OV} inputs as shown in the **figure** and use a single resistor divider network for both, instead of two separate divider networks.

Thus, not only do you save two resistors, but you also can lower the value of the sum of resistances as $R_{UV1}+R_{UV2}=5M$ without sacrificing the overall power efficiency of the circuit. As a by-product, you get a higher insensitivity to EMI at the V_{BAT_UV} and V_{BAT_OV} inputs.

The bq25504 has an ability to draw the maximum possible power from an input source. A photovoltaic cell, due to its nonlinear nature, outputs maximum power at about 80% of its open-circuit voltage. Resistors R_{OC1} and R_{OC2} determine this operating point of the solar cell, PD. This novel IC even tracks the chosen source operation point slowly to get as much power as possible under varying input source capability.

Experiments were performed with a single solar cell of diameter D=7.5 cm positioned horizontally on a desk located 1 meter from a window. Although it was sunny outside, practically no direct sunlight passed through the window. Under these circumstances, the short-circuit current, I_{SH}, of the solar cell was 16.27 mA. Note that the I_{SH} of the same cell reaches a value of 300 mA when the plane of the cell is oriented perpendicularly to full-sun radiation. With no load on the converter, the output voltages V_{BAT} and V_{STOR} varied from 4.396V to 4.404V. This ±0.1% variation can be attributed to the fact that the boost converter operates in discontinuous mode to compensate for self-discharge of the capacitors C_{BAT} and C_{STOR} and then idles for a relatively long time. The solar-cell terminal voltage was 0.441V with the converter unloaded.

When a 10-kΩ load resistor was connected to the V_{BAT} output, this "wavering" of V_{BAT} and V_{STOR} disappeared, and both become a constant 4.4V. The dc component of V_{IN_DC} dropped to 0.4073V. By increasingly shadowing the solar cell with a metallic plate and thus depleting the energy available, I was able to reach an operating point where the output voltage was still 4.4V, while the mean value of voltage at the photocell terminals had dropped to 0.336V. It can be assumed that at this point the converter had entered a continuous-operation mode. (Note that even though the bq25504 data sheet shows V_{STOR} as the loaded output, in this application V_{BAT} is used as the output because even a low output voltage is often better than none under energy-deficient conditions.)EDN

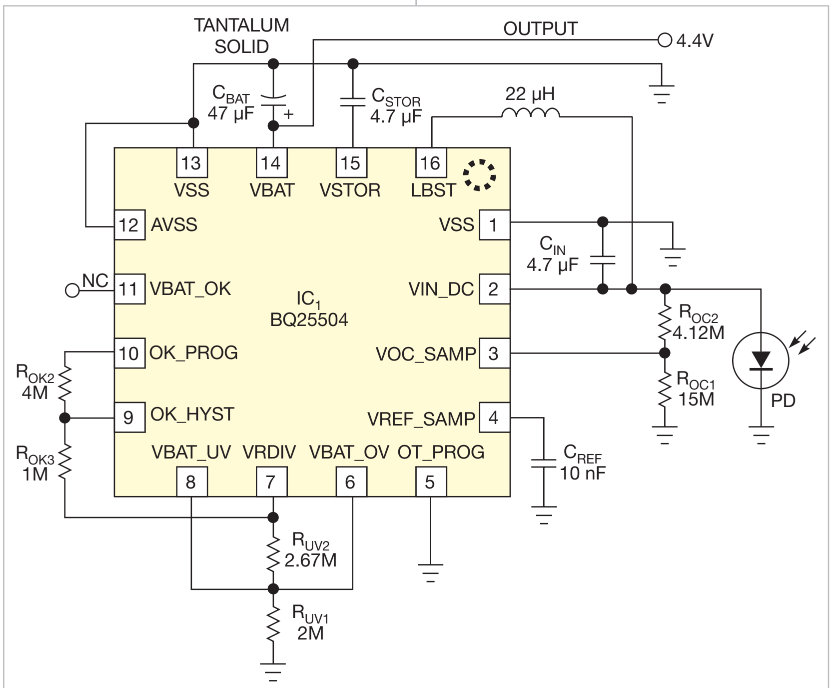


Figure 1 By exploiting the inherent weights of V_{BAT_UV} and V_{BAT_OV} inputs as 2/3:1, you can save at least two precision resistors in many applications. (IC_1 is shown from the bottom view since, if breadboarding, the package style requires connections from the bottom.)

designideas CLASSICS

Originally published in the December 19, 1991, issue of *EDN*

Filter quashes 60-Hz interference

Adolfo A Garcia, Analog Devices, Santa Clara, CA

The circuit in **Figure 1** filters 60-Hz interference from low-frequency, low-level signals. The filter exhibits 40-dB rejection (Q=0.75) and draws 95 µA max from a single-sided 5V supply.

Resistors R_1, R_2, and R_3 and capacitors C_1, C_2, and C_3 form a classic twin-T section, and IC_1 and IC_2 provide local and global feedback. The frequency selectivity (Q) and the rejection performance of this active filter are very sensitive to the relative matching of the capacitors and resistors in the twin-T section. **Table 1** shows rejection and Q as a function of the value of R_Q.

IF ADDITIONAL REJECTION IS NEEDED, CASCADE FILTER SECTIONS.

R_4, R_5, C_4, and IC_3 form a very-low-impedance reference source to bias IC_1 and the twin-T section to half the supply voltage.

To configure the filter to operate at 60 Hz, choose a Q that will provide enough rejection without excessive loss of desired low-frequency signals that may be close to the filter's notch frequency. The value of R_Q is expressed as

$$R_Q=(4Q-2)R_7.$$

The gain of the output amplifier is simply that of a conventional noninverting amplifier:

$$A=1+(R_Q/R_7)=4Q-1,$$

and the overall gain of the band-reject filter below and above the notch frequency is expressed as

$$V_{OUT}/V_{IN}=2A/(1+A).$$

If you need additional rejection, cascade filter sections. Keep in mind that you might have to modify the circuit to account for out-of-band gain multiplication. **EDN**

TABLE 1 R_Q REJECTION AT 60 Hz, AND THE FILTER'S VOLTAGE GAIN AS A FUNCTION OF THE FILTER Q

Filter Q	R_Q (kΩ)	Rejection (dB)	V_{OUT}/V_{IN}
0.75	1	40	1.33
1	2	35	1.5
1.25	3	30	1.6
2.5	8	25	1.8
5	18	20	1.9
10	38	15	1.95

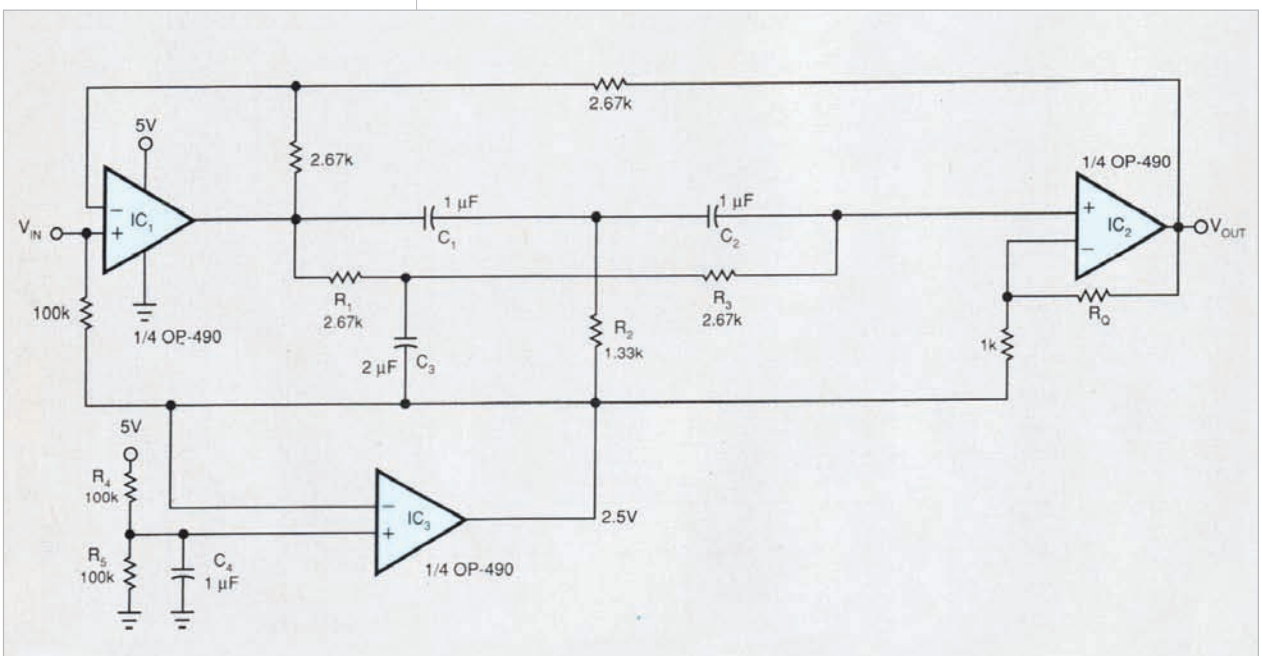


Figure 1 This notch filter suppresses 60-Hz interference in low-frequency signals.

Automotive electronics' supply-chain impact

Back-up cameras seem almost quaint today, even though the technology is just moving into the mainstream automotive market. That's because there's a sense that technology is catching fire really quickly in automotive design, and not just at the high end. But what does this mean along the supply chain? We know automotive electronics is a red-hot market right now, but the standards and the technology requirements are changing quickly.

> "Open standards are helping to quicken the pace of automotive innovation.

On the Drive for Innovation, an Avnet Express/UBM Tech joint project (www.driveforinnovation.com), we wanted to check the pulse of this segment, so we punched in the latitude and longitude for Broadcom and headed to Irvine, CA. We convened a panel of automotive experts to get their perspectives on what's going on in the industry, and determined two big takeaways on open standards:

- They are helping to quicken the pace of automotive innovation.
- At the same time, they are giving OEMs and car manufacturers an opportunity to move their R&D dollars into new and exciting areas.

A video showing the complete 34-minute session, along with guidance to the segments where the panelists made a particular point, can be found at http://bit.ly/XUsh7r. What follows here are some highlights.

First off was our discussion of Ethernet, which is rapidly becoming the de facto networking backbone in automotive designs. This situation has implications not only for reducing cabling weight in an automotive design but also for allowing design engineers to leverage the standard to plug in Ethernet-ready services inside the car, according to Ali Abaye, senior director of marketing and networking infrastructure at Broadcom. The question arises, then, Is this the type of solution, given the relative low cost of an established technology such as Ethernet, that might get proliferated quickly from high- to low-end vehicles?

We then asked Richard Barrett, product marketing director for wireless connectivity in the automotive sector at Broadcom, what trends he was seeing. The biggie? Wireless LAN leveraging the smartphone as the control device.

Barrett also described how the expected completion of the 802.11ac wireless standard will affect automotive design. The big application he expected was personalization of the car. Driverless cars are getting a boost from Ethernet, but more so from wireless communications. You have microseconds' improvement in the ability of a car to respond.

In fact, if you take into consideration the fact that the automotive design cycle is five to seven years, engineers at this very moment are designing driverless-car systems that will be introduced in model years at the end of the decade, according to Yongbum Kim, senior technical director for automotive at Broadcom.

Tim Lau, senior product-line manager for automotive Ethernet at Broadcom, discussed existing designs that are happening now, especially the shift from passive safety to active safety. In fact, at a higher level, said Lau, the automotive industry is about to enter a period of explosive innovation.

Perhaps the biggest impact we will see in the coming years, Abaye said, is how the adoption of technologies such as Wi-Fi and Ethernet will free car makers to focus their R&D in other, more pressing areas. All of this automotive electronics innovation may have a downside for drivers, added Kim, who acknowledged that he loves to drive but has two fears: Safety issues may mandate his driving habits to be "something less." In addition, he may end up paying a higher supply-chain margin at the end for all of these technologies EMs are encouraged to adopt in a low-cost fashion.

—by Brian Fuller, editor-in-chief, *EBN*

This story was originally posted by EBN: *http://bit.ly/XUsh7r.*

OUTLOOK

FEWER IC SUPPLIERS TO HOLD MORE OF 2013 MARKET

A greater percentage of semiconductor-industry capital spending is coming from a shrinking number of companies. As a result, IC-industry capacity is also becoming more concentrated, and this trend is especially prevalent in 300-mm wafer technology.

According to the IC Insights report, "Global wafer capacity 2013—detailed analysis and forecast of the IC industry's wafer fab capacity," Samsung was the leader in 2012, with about 61% more 300-mm capacity than second-place SK Hynix. Intel was the only other company that held a double-digit share of 300-mm capacity at the end of 2012. If Micron is successful in acquiring Elpida in 1H13, the companies' combined 300-mm wafer capacity will make the merged company the second-largest holder of 300-mm capacity in the world.

Samsung is expected to maintain its installed-capacity lead through 2017. IC Insights anticipates the largest increase in 300-mm capacity, in terms of growth rate, to come from the pure-play foundries—TSMC, GlobalFoundries, UMC, and SMIC. These four companies are expected to more than double their collective monthly 300-mm wafer starts by 2017. **—by Amy Norcross**

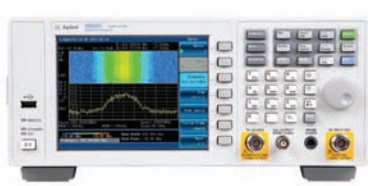
productroundup

TEST & MEASUREMENT

Tektronix portable spectrum analyzers find elusive signals

With built-in mapping and signal classification, the H500 and SA2500 handheld spectrum analyzers scan, classify, and locate signals missed by conventional swept analysis. DPX waveform image-processing technology provides a live RF view of the spectrum to allow regulators to efficiently manage and monitor spectrum in the field and find signals and interferers. The field-portable analyzers offer frequency coverage from 10 kHz to 6.2 GHz, a real-time bandwidth of 20 MHz, and DANL (displayed average noise level) of –163 dBm. Fully ruggedized to withstand shock and moisture, the H500 and SA2500 weigh just over 12 lbs and employ a hot-swap power system. Battery life is rated for 5 hours of continuous spectrum scanning. The SA2500 costs $24,600; the H500 sells for $43,400.
Tektronix, www.tek.com

Spectrum analyzer from Agilent suits budget environments



The N9322C basic spectrum analyzer covers a frequency range of 9 kHz to 7 GHz with 1-Hz resolution. It also has a typical DANL (displayed average noise level) of –152 dBm for viewing low-level signals, and its ±0.1-ppm annual aging rate reduces frequency drift. The channel scanner measures up to 20 channels simultaneously, while the 7-GHz tracking generator with built-in VSWR bridge supports general-purpose transmission and reflection measurements. Supplied with the N9322C is Agilent's PowerSuite, which enables one-button measurement of channel power, occupied bandwidth, adjacent-channel power, and spectrum emission mask. Prices for the N9322C start at $11,413. The tracking-generator option starts at $2484.
Agilent Technologies, www.agilent.com

TECA liquid-cooled benchtop system cools down to –70°C

With a footprint of just 11.2×15.1 in., the LHP-1200CAS liquid-cooled cold-plate system is a compact bench unit that provides direct contact cooling down to –70°C when outfitted with an optional cascade assembly. It can be used to cool components, materials, chemicals, and samples. The thermoelectric cold-plate system operates with any of TECA's three cascade accessories to achieve low-temperature cooling or without the cascade attachment to retain a larger cooling surface. Other features include a programmable temperature controller; RS-232 communications interface; and software for programming, charting, and data acquisition. Pricing for the LHP-1200CAS starts at $5348.

TECA, www.thermoelectric.com

R&S step attenuators span dc to 67 GHz

The RSC family of switchable, mechanical step attenuators covers frequencies from dc to 67 GHz and includes a precision model with 0.1-dB step size for enhanced accuracy and stability. The family includes a base unit with or without an internal step attenuator and a choice of two external step attenuators. Internal step attenuators come in three versions. The standard version has an attenuation range of 0 to 139 dB with a 1-dB step size up to 6 GHz. The other two units offer an attenuation range of 0 to 139.9 dB with a 0.1-dB step size from dc to 6 GHz and 0 to 115 dB with a 5-dB step size from dc to 18 GHz. External step attenuators provide an attenuation range of 0 to 75 dB with a 5-dB step size from dc to 40

productroundup

GHz and 0 to 75 dB with a 5-dB step size from dc to 67 GHz. Depending on the configuration, the price range of the product is $5000 to about $10,000.
Rohde & Schwarz,
www.rohde-schwarz.com

Digital power meters from Yokogawa boast 0.1% accuracy

The WT300 series of digital power meters deliver basic measurement accuracy of 0.1% of reading + 0.2% of range, low-current measurements down to 50 μA, and high-current measurements up to 40A RMS. The instruments measure all ac and dc parameters and have a dc measurement range of 0.5 Hz to 100 kHz. A wide range of communication interfaces

allows power meters to be integrated into laboratory test benches or automated test setups on production lines. USB and GPIB or RS-232 interfaces are standard, while Ethernet is optional. The basic price for the WT310 is $2210; pricing for the WT330 starts at $3875.
Yokogawa, www.tmi.yokogawa.com

TDK-Lambda extends programmable supply line

The Z+ series of programmable dc power supplies now includes models that provide 200W of output power with an output voltage range of 0 to 100V dc and output currents of up to 20A. The standard models are only 3.27×2.76 in., and six units can be installed in an optional 19-in. rack housing. Options for front-panel output jacks and multiple-unit housings are available for bench applications. All models operate in constant-current or constant-voltage mode from an input of 85 to 265V ac. They also feature USB, RS-232, and RS-485 interfaces, with optional LAN, GPIB, and isolated analog programming. The base price for the power supplies is $1185.

TDK-Lambda Americas,
us.tdk-lambda.com/lp

ProPlus 1/f noise system integrates dynamic signal analyzer

The NoiseProPlus 9812D wafer-level 1/f noise-measurement system delivers accurate measurement up to 10 MHz, while its built-in DSA eliminates the need for external signal-processing equipment. The system measures low-frequency noise characteristics of on-wafer and packaged semiconductor devices, including MOSFETs, BJTs, JFETs, diodes, and diffusion resistors. The 9812D handles up to 100V from the source-measure unit for high-voltage and/or low-current (<0.1 μA) biases. It also employs multiple voltage and current low-noise amplifiers to ensure high measurement accuracy. The 9812D is shipping now; pricing is available upon request.
ProPlus Design Solutions,
www.proplussolutions.com

Anritsu battery-operated unit detects PIM in remote locations

The PIM Master MW82119A is truly portable and battery-operated, making testing for PIM (passive intermodulation) in remote radio head and indoor distributed antenna systems possible. The device tests at 40W, and power can be adjusted down to 0.3W. Six new models cover the upper and lower 700-MHz bands, 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, and 1900/2100 MHz. The PIM Master includes standardized testing setups and an ac and automotive adapter to recharge the battery. The unit has several operating modes, including PIM vs. time measurement, swept PIM measurement, and distance to PIM measurement. It also has report management capabilities, allowing you to overlay PIM plots, store results, and create a unified test report that includes PIM, VSWR, distance to fault, and distance to PIM. Delivery for the PIM Master is 4 to 6 weeks. Prices start at $1000.

Anritsu, www.anritsu.com

B&K Precision revamps DDS function generators

DDS sweep generators Model 4007B and Model 4013B generate sine and square waveforms from 0.1 Hz to 7 MHz and 0.1 Hz to 12 MHz, respectively. They output triangle/ramp waveforms from 0.1 Hz to 1 MHz and provide variable output voltages from 0 to 10V pk-pk into 50Ω or 20V pk-pk into an open circuit. Both models also provide linear and logarithmic sweep functions, variable dc offset from –4.5 to +4.5V (into 50Ω), and adjustable 20% to 80% duty cycle up to 1 MHz for square and triangle waveform output. A sync output is accessible on the front panel for out-

putting TTL-level pulses synchronized to the main output. The Model 4007B costs $375; the Model 4013B costs $425.
B&K Precision,
www.bkprecision.com

EXFO's handheld platform adds wideband copper and DSL testing

The FTB-610 wideband copper test module and the FTB-635 wideband copper and DSL test module reduce the complexity of testing and troubleshooting triple-play and broadband ADSL2+ and VDSL2 services. The modules are housed inside the FTB-1 handheld platform and extend the FTB line of modular, field-test products to DSL, FTTN, and hybrid network circuits and services. The FTB-610 offers deep copper analysis, leveraging the SmartR test suite, which automatically runs all of the decisive copper tests and translates the results in plain language and graphical results to speed interpretation of twisted-pair faults. The FTB-635 adds ADSL2+ and VDSL2 test capabilities, providing full vectoring and bonding support. Both products are now available for shipping. Prices range from $4000 to $15,000, depending on hardware and software options, including an FTB-1 platform.
EXFO, www.exfo.com

Agilent expands mixed-signal oscilloscope range

The Infiniium 90000 X-Series has added six new MSO models with bandwidths ranging from 13 to 33 GHz,

as well as 13-GHz DSO and DSA models. The tightly integrated channels of the new MSO models can function at 20G samples/sec in an 8-channel configuration, or at 10G samples/sec in a 16-channel configuration. The DSO and DSA models can be upgraded to MSO functionality to obtain the additional trigger flexibility of these scopes for debugging and validation. Infiniium 90000 X-Series MSOs have up to 400 million points of data capture behind each digital channel. To accommodate sample-rate differences between the high-speed analog channels and the digital MSO channels, this memory depth can be automatically sized with the analog trace length, including the full 2-Gpts memory available on Agilent oscilloscopes. Shipments of MSOs, including upgrades, will begin midyear. Prices for the MSOs start at $146,860; the logic-analysis MSO upgrade costs $25,049.
Agilent Technologies,
www.agilent.com

Tektronix unveils entry-level oscilloscopes

Each of the five models in the TBS1000 series of digital storage oscilloscopes provides two analog channels, a record length of 2500 points across all time bases, 16 automated waveform measurements, an external trigger input, and a 5.7-in. color TFT

LCD. The series offers bandwidths with sample rates of 500M samples/sec for the 25-MHz and 40-MHz scopes and 1G sample/sec for the 60-MHz, 100-MHz, and 150-MHz scopes. DC vertical accuracy is ±3% on all models, and vertical sensitivity ranges from 2 mV to 5 V/div with calibrated fine adjustment. A waveform data-logging function can be used to save up to 8 hours of triggered waveforms to a USB flash drive. Prices range from $520 for a two-channel, 25-MHz oscilloscope to $1520 for a two-channel, 150-MHz instrument.
Tektronix, www.tek.com

EDN ADVERTISER INDEX

EDN provides this index as an additional service. The publisher assumes no liability for errors or omissions.

Resolving a simulation complication

In the 1990s, I worked for a military contractor that built flight simulators for fighter jets. After successfully building an analog simulated radio and intercom communication system, I took on the task of building a digital audio version, since the entire industry was moving in that direction and we were starting to connect flight trainers via Ethernet LAN, WAN, and worldwide data networks. Having digital audio was a new and important requirement.

I designed a circuit board that connected headsets in trainer cockpits and instructor stations to audio codecs that converted analog audio to digital audio, and vice versa. The board also transmitted data to, and received data from, another circuit board that had a VME slave interface so it could plug into a VME chassis. The VME board had two DSPs interconnected by quad-port SRAMs, and it was designed to add a mezzanine board that could add two more DSPs.

We first built, tested, and installed a wire-wrap version that we sold as part of a research project, after which we obtained funding to have actual PCBs produced. The headset interface was a six-layer board, while the VME board had eight layers.

We populated and tested the PCBs without using the VME slave interface to control them, and they seemed to work correctly. When we tried the boards live in the VME chassis, however, they would run until accessed via the VME slave interface, at which time the VME board would crash.

I didn't find any obvious errors in the design or circuit-board connectivity, so I asked one of the hardware technicians to help me troubleshoot the problem. After looking at various parts of the circuitry, we noticed that the clock signal that came from the 33-MHz oscillator (one of those four-pin metal-can parts) to the DSPs rose, then dipped some, then rose again. The dip seemed to be a bit worse during VMEbus access.

The technician suggested buffering the output of the oscillator part with a 74F04 (a FAST logic part), because although the oscillators were rated to drive 10 TTL loads, he had found that they didn't always work well on multiple-layer circuit boards. The distance from the oscillator to the DSP that was failing was only about 1.25 in., while the distance to the DSP that continued running was about 0.75 in., so there didn't seem to be much difference. But the technician's suggestion seemed reasonable, and the board had been made in such a way that it was fairly easy to add a small board with a 74F04 and connect it to the two DSPs. Once we made this modification, we retested the boards, and they worked correctly.

ALTHOUGH THE OSCILLATORS WERE RATED TO DRIVE 10 TTL LOADS, THE TECHNICIAN HAD FOUND THAT THEY DIDN'T ALWAYS WORK WELL ON MULTIPLE-LAYER CIRCUIT BOARDS AND SUGGESTED BUFFERING THE OUTPUT OF THE OSCILLATOR PART WITH A FAST LOGIC PART.

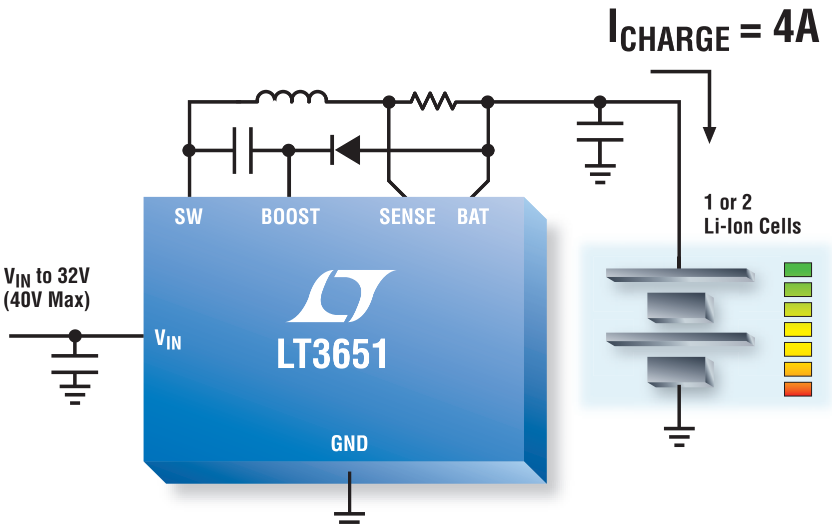
I suspect that the capacitance of the multiple layers of the board along with the weak drive capability of the oscillator caused this problem, since there were no problems with the wire-wrap version. The capacitance appeared to be causing the clock signal to rise and then fall prematurely, making the DSP think a new instruction fetch cycle was being initiated before the previous fetch cycle had been completed and the instruction executed.

A few months later, the company sold 11 systems for use in various flight trainers. EDN

Ken Ciszewski is a system designer and project manager in St. Louis. He has more than 30 years of experience designing electronic systems at all levels.

DANIEL VASCONCELLOS

Charge BIG Batteries Fast



Demo Circuit

Actual Size
23mm x 23mm

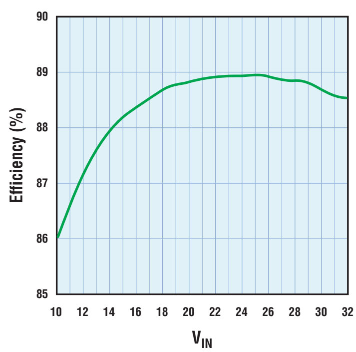
High Voltage, High Current, High Efficiency Charger

The LT®3651 enables fast charging of Li-Ion/Polymer batteries by delivering up to 4A of continuous charge current with minimal power loss. This is due to its high efficiency switchmode topology, including on-chip synchronous MOSFETs. Its autonomous operation means no microcontroller is necessary and the device integrates an onboard C/10 or timer charge termination. The LT3651's programmable input current limit with PowerPath™ control regulates charge current to maintain a constant supply current, preventing the input supply from collapsing.

Features

- Charge Current up to 4A
- Wide Input Voltage Range: 4.8V to 32V (40V Max)
- Programmable Switching Frequency: 200kHz to 1MHz
- C/10 or Timer Onboard Charge Termination
- High Efficiency Operation Minimizes Power Loss
- Programmable Input Current Limit
- Compact 5mm x 6mm QFN Package

Efficiency vs V_{IN}



Info & Free Samples

www.linear.com/3651

1-800-4-LINEAR

www.linear.com/batsolutions

LINEAR TECHNOLOGY