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SPECIAL REPORT: POWERING CONSUMER ELECTRONICS (PG29)

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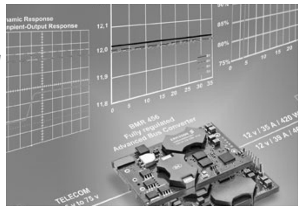
COVER STORY

Battery-Charger Trends in Portable Power Products (pg 15)



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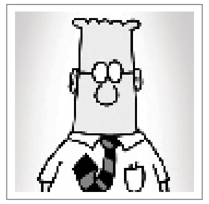

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AGS Media Group
146 Charles Street
Annapolis, MD 21401 USATel: +410.295.0177
Fax: +510.217.3608
www.powersystemsdesign.com

Editor-in-Chief
Joshua Israelsohn, Editor-in-Chief, Power Systems Design
joshua@powersystemsdesign.com

Gail Purvis, European Editor, Power Systems Design
Gail.Purvis@powersystemsdesign.com

Contributing Editors
Liu Hong, Editor-in-Chief, Power Systems Design China
powersdc@126.com

Ash Sharma, IMS Research
Ash.sharma@imsresearch.com

Dr. Ray Ridley, Ridley *Engineering*
RRidley@ridleyengineerng.com

David Morrison, How2Power
david@how2power.com

Publishing Director
Jim Graham
jim.graham@powersystemsdesign.com

Publisher
Julia Stocks
Julia.stocks@powersystemsdesign.com

Circulation Management
Kathryn Philips
kathryn.phillips@powersystemsdesign.com

Magazine Design
Louis C. Geiger
louis@agencyofrecord.com

Production Manager
Chris Corneal
chris.corneal@powersystemsdesign.com

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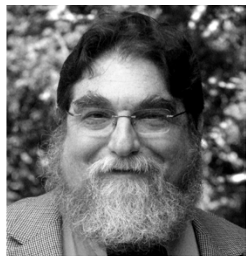


POWERING PSD AND CONSUMER ELECTRONICS

Though I may horn in from time to time, this space will soon not be mine to fill: Power Systems Design recently welcomed aboard Gail Purvis as European Editor and key point of contact for Europe-based companies. Kicked upstairs, I'll serve as Editor in Chief and contact for companies in North America.

I've been reading, enjoying, and learning from Gail's reporting on technologies, the companies that develop them, and the markets in which they compete for more than a decade. I'm indeed pleased that she's now helping to power PSD.

Gail is an award-winning technical journalist with extensive experience. Her practice has included editing stints at Photovoltaics, Smart Materials, European Semiconductor, and III-V Review. She was also founding editor for the public journal of Scotland's Environmental Protection Agency, SEPA View. Her broad subject experience will help us deepen PSD's editorial in sector-specific power topics.

The theme for this issue's Special Report is Powering Consumer Electronics. Despite guarded consumer spending in Europe and North America during the last several years, the consumer-electronics sector continues as a key point of focus for many technology companies and the OEMs they supply.

In keeping with general trends in the consumer-electronics sector, battery powered and multiply-powered energy-management subsystems are key in many products. Our cover story from Linear Technology discusses charger trends for modern consumer-electronic products, many of which operate on single-cell lithium as their primary energy reserve and must charge from any of several sources. Battery-charge management and protection are also central topics in articles this month from Cadex, TE Connectivity, and Texas Instruments.

Of course managing battery power isn't the only challenge consumer electronics bring to the party. Vicor reports on an interesting new approach to PFC (power-factor correction) and AVX offers a method for minimizing capacitor leakage.

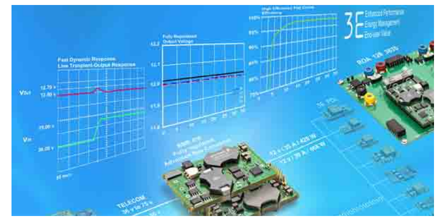
Lastly, I take a bit of a departure from all of the above with a small review of a very large trade show: The PCIM Europe International Exhibition and Conference organized by Mesago. And our newly-minted European Editor, Gail Purvis, brings news from the oft-overlooked world of fuel cells in this month's Green Page.

Best Regards,

Joshua Israelsohn

Editor in Chief
Power Systems Design
joshua@powersystemsdesign.com

NEW DIGITAL QUARTER-BRICK ABC LOWERS POWER CONSUMPTION



Ericsson's first model in its second-generation digital-ABC (Advanced Bus Converter) product line is based on the company's FRIDA II digitally controlled power platform.

The BMR456 3E ABC delivers fast response time, tightly regulates intermediate-bus voltages, and provides high efficiency at any operating point to reduce power consumption for system architects working on telecom and datacom applications.

This latest generation of Ericsson DC-DC converters is based on the 32-bit ARM microcontroller. The FRIDA II firmware developed by Ericsson assures high performance from low-load to high-load operation, and the ability to handle line transients, such as those occurring in ATCA (Advanced Telecommunications Computing Architecture) applications when switching feeds.

Designed for telecom and datacom applications, the quarter-brick BRM456 comes in two input-voltage ranges: 36 V to 75 V, delivering output power of 420 W; and 40 V to 60 V, delivering output power up to 468 W. Systems can adjust the converter's output voltage from 4.0 V to 13.2 V by means of PMBus commands. This capability makes the BMR456 suitable for dynamic bus voltage operation, which facilitates energy savings when communication traffic is low.

The converter's typical efficiency is 96.5%, exhibiting a flat curve from 14% to 100% load. Designed for flexible, high-power applications when connected in parallel, the DLS (droop load sharing) version of the BMR456 telecom (36-75V) and datacom (40-60V) versions deliver 756 W and 842 W, respectively.

The BMR456 handles input-voltage transients with slew rates of up to 0.5 V/µs, keeping its output voltage within ±10% to ensure loads do not exceed their over-voltage protection thresholds. Highly efficient management of pre-bias start-up operation and a fully controlled shutdown process avoids avalanche conditions in the secondary-side synchronous rectification MOSFET, and contributes to improved reliability.

A USER_STORE memory block for system designers and customized configuration files combined with PMBus control offers high flexibility to meet the load's energy demand, avoiding unnecessary power loss.

A new power-train and embedded transformer layout, combined with FRIDA II firmware provides end users with fully regulated output voltage across the overall operation range from 36V to 75V without grey zones below 40 V.

The BRM456 is fully backward compatible with Ericsson's previous generation of ABCs. The I/O connector guarantees full alignment and co-planarity in both through-hole and surface-mount soldering processes.

For more information, see http://bit.ly/LoPKCJ.

www.ericsson.com

GAN DEVICES OFFER NEW WAYS TO REDUCE EMI

By: Carl Blake

One of the lessons I previously learned about introducing new technology into the power-conversion market is that engineers have an intuitive understanding about what is possible.

If a new product changes the paradigm on which that intuition rests, they will not believe test results that contradict that intuitive knowledge. If there was any doubt that new 600 V GaN devices disrupt the existing paradigm, the questions engineers asked Transphorm at PCIM confirmed the suspicion. A common challenge was, "If you switch faster, the EMI must be worse." This assertion need not hold and, if they consider packaging parasitics, engineers can resolve this issue.

Three factors determine the level of EMI a power supply emits:

1. The magnitude of the power source, often linked to the di/dt in an inductor or dv/dt in a capacitor
2. The parasitic impedance that acts like an antenna to amplify the source.
3. The shielding the power supply's case provides or line filters power supply designers use to reduce noise to specified limits.

The engineer's intuition usually assumes that the parasitic impedance and the shielding will be the same, therefore the power supply's EMI will increase with the switching rate. Knowing that the only way to reduce switching losses is to reduce the cross conduction, which demands higher switching rates, Transphorm and other GaN suppliers have focused on reducing the parasitic impedance.

One method is to shrink the package as much as possible, reducing the lead and pad parasitics. Another method Transphorm has pursued makes small changes to existing packages that accomplish the same result, allowing customers to use existing assembly tools and heat sinks. The resulting package provides additional isolation between the transistor's input (gate-source) and the output (drain-source) by changing the pin layout of standard TO-220 packages from G-D-S to G-S-D. To resolve the capacitive-coupled noise, Transphorm provides both drain-tab and source-tab versions of the TO-220 so the layout can always connect the largest package capacitance to a dc voltage.

Multiple customers' EMI-test results have confirmed the predicted results but, if history is any indicator, most senior engineers will have to build the circuit and obtain results themselves in their own labs. For those that have, the paradigm has already changed.

Carl Blake
Vice President, Marketing
Transphorm

www.transphorm.com

SET-TOP BOX POWER DRAWS REGULATORS' ATTENTION

By: Stephen Froehlich

Over recent years, IMS Research and its sister organization, IHS Screen Digest, have been supplying set-top-box data to energy and environmental regulators in North America and Europe.

As light bulbs, refrigerators, televisions, washers, and driers have become more efficient, the STB (set-top box) has emerged as one of the largest remaining opportunities to reduce home energy use. The STB is not a major contributor to peak energy use, but because many STBs include no off state, they are big consumers of vampire power, with some of the worst consuming 50 W, day and night.

How did we get here?

There are two reasons that STBs have fallen behind the power efficiency curve: First, pay –TV operators create the specification but do not pay the power bill. Second, closed broadcast networks transmit security and guide information at regular intervals, so STB boot times can run several minutes. Note: IP-based STBs are immune to this, though many still have long boot times. The major power consumers in an STB in standby are the tuner and demodulator, the hard drive, and the processor.

What is the way out?

When regulators expressed their interest in STB power consumption about five years ago, some in the industry took steps to improve both peak and standby power consumption. Several of the largest operators, namely DirecTV in the US and BSkyB in the UK, publicly committed to provide energy-efficient STBs. The US EPA and STB makers created an ENERGY STAR rating for STBs. European STB makers and The European Commission Directorate-General for Energy and Transport formed a similar Voluntary Industry Agreement. The improvements, while significant, still leave STBs as one of the biggest opportunities for further energy savings in homes. In North America, where multiple STBs per household are common, the most economical path seems to be to consolidate the RF front ends in the house from each STB and the cable modem into a single one. This allows the server, which houses the master RF front-end, to update security keys and guide information while the clients can be built with much lighter security but limited to a short (typically 7 ms) ping time, limiting their distance from the server. While a few European operators are also pursuing server + client strategies, there are fewer homes with multiple STBs in most European countries. Thus, incremental improvements in current architectures must suffice until cable systems transition to IP video.

Stephen Froehlich
Consumer Electronics Analyst
IMS Research

www.imsresearch.com

OUTPUT IMPEDANCE MEASUREMENTS AND LOOP GAINS

By: Dr. Ray Ridley

In this series of articles, Dr. Ridley discusses the four important frequency-response measurements to be made during full characterization of a switching power supply. The important relationships between loop gain and output impedance measurements are highlighted in this first article. If you want to ensure a rugged and reliable design, both of these parameters must be directly measured.

Power Supply Transfer Function Measurements

There are four fundamental transfer functions that characterize the small-signal performance of a switching power supply. They are as follows:

1. **Loop gain and phase** – determines the stability of your design, and available margin to accommodate variations in components.
2. **Output impedance** – determines the output regulation, dynamic load response, and susceptibility to complex loading.
3. **Audiosusceptibility** – determines the transmission of noise from input to output.
4. **Input impedance** – determines the sensitivity of the power system to input filter or input power system components.

These parameters are listed in the order in which they are commonly measured and used in the industry.

A direct **loop gain** measurement is essential to guarantee stability of a power supply design over the lifetime of its usage in the field. Most reliable power supply designs include loop gain measurements as part of the design verification process.

If loop gain is the only parameter that is measured, there can be a tendency to focus too much on the stability at the expense of better closed-loop performance. More experienced designers include an **output impedance** measurement as part of their design verification and documentation, even if it is not directly required by the end customer. The output impedance measurement contains a wealth of information about how the converter will respond to dynamic load changes at different frequencies. It also provides information about the susceptibility of the power supply to complex loads. This allows a designer to predict with confidence how a converter will work when presented with different load scenarios.

An **audiosusceptibility** measurement gives information on the transmission of noise from the input of the power supply through to the output. It is usually a requirement of the documentation package in the aerospace industry. This measurement is more difficult to make since a perturbation must be injected on top of the high-power input rail. Most commercial designs omit this measurement.

A measurement of **input impedance** is also usually required by the aerospace industry. It is very useful for anyone designing large and complex power systems. As with audiosusceptibility, this is a more difficult measurement to make, but once injection is set up for the audiosusceptibility measurement, it is easy to measure the input impedance. (Note: most systems designers that perform an input impedance measurement do not apply the results properly, and this is an advanced topic discussed in a later article in this series.)

Output Impedance Measurements

While loop gain measurements are essential for showing the stability of a power supply, it is the output impedance that directly shows how well a converter will regulate and how it

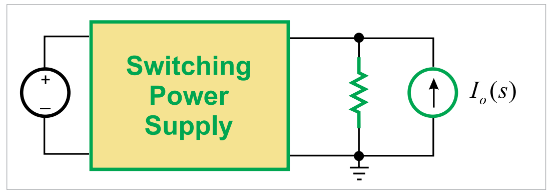


Fig. 1: Output impedance is measured by driving a current into the output terminals of a power supply

will respond to changing loads. In order to measure output impedance, current must be injected into the output of the power supply as shown in Figure 1.

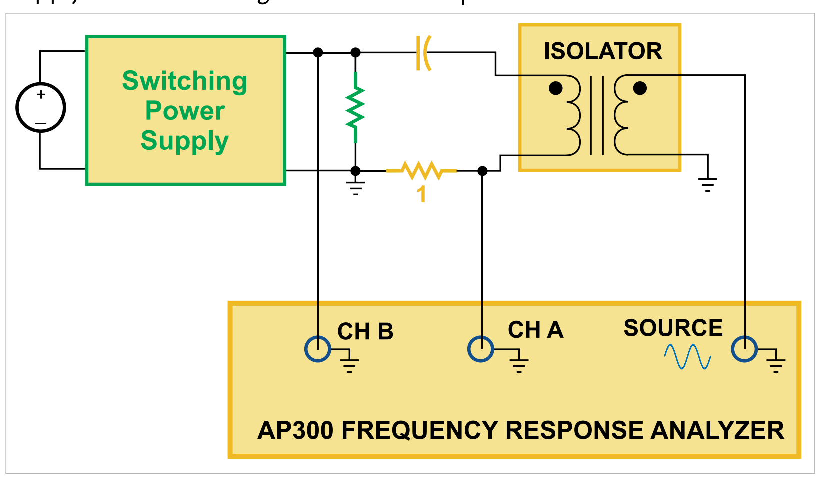


Fig. 2: Practical test setup for injecting current and measuring impedance.

Figure 2 shows how this is implemented practically using a frequency response analyzer. Good results are obtained with this measurement setup up to about 100 W power, and alternative injection approaches can be used for higher power levels [1].

You should always plot both the open-loop and closed-loop output impedance to show how well your control design is implemented. These two measurements are shown in Figure 3 for a flyback converter.

The green curve of Fig. 3 shows the open-loop output impedance of the converter. At low frequencies, the dc level is set by the parasitic resistances of the power circuit, including the magnetics winding resistances and FET resistance. Above 1 kHz,

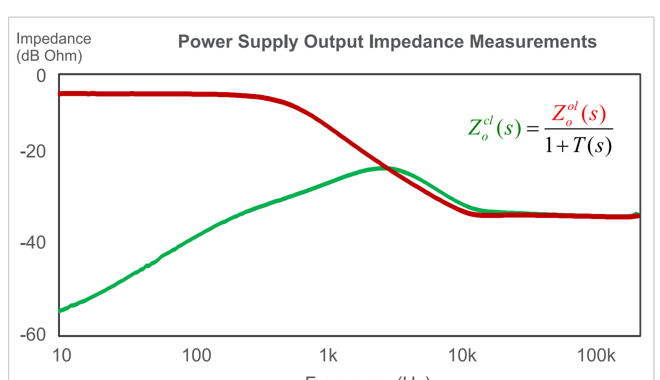


Fig. 3: Open-loop and closed-loop output impedance of a flyback converter.

beyond the resonant frequency, the measured impedance tracks the impedance of the output capacitor, flattening out with its ESR value at about 15 kHz. Great care must be taken with connection of the test cables to ensure that parasitic resistance and inductance is minimized during this measurement.

The red curve of Fig. 3 shows the effect of closing the loop on the output impedance. At low frequencies, where the loop gain is high, the output impedance is greatly reduced. The two curves converge together at the crossover frequency of the loop. As is well known, the theoretical closed-loop output impedance is related to the open-loop output impedance by the equation:

$$Z_o^{cl}(s) = \frac{Z_o^{ol}(s)}{1+T(s)}$$

From this equation we can see that the higher the loop gain T(s), the more the output impedance is reduced by the feedback loop. When you are designing a power supply, there are two ways to reduce the output impedance and hence improve transient load response. The first is by increasing the amount of capacitance on the output of the power supply to lower the open-loop impedance. This, of course, requires more expense in terms of parts and space. Or, you can increase the gain of the loop. Changing loop components is usually a zero-cost option, but you must be careful not to increase the loop gain too high or instability can result.

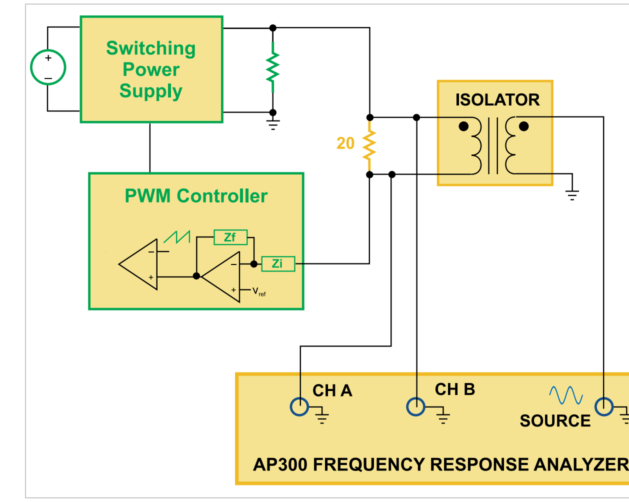


Fig. 4: Measurement technique for loop gain.

Loop Gain Measurements

You should always measure the loop gain of your converter to ensure you are maximizing the performance in terms of output impedance whilst retaining rugged stability. Fig. 4 shows the test setup for injecting into the feedback loop for accurate results. This setup requires the insertion of a test resistor into the feedback loop, but this is not a difficult process. Further details of using this test setup are covered in detail in [1,2]. Fig. 5 shows the measured loop results for the flyback converter.

The gain at 10 Hz is approximately 50 dB, and this corresponds to the difference in magnitude of the open- and closed-loop output impedances shown in Fig. 3.

The crossover frequency is at around 3 kHz, and the phase margin at crossover is 60 degrees. The open and closed-loop output impedances are approximately equal at this

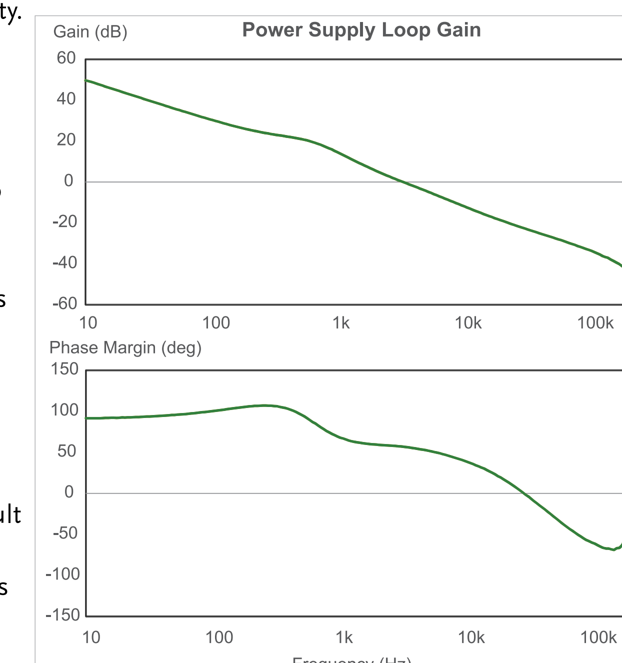


Fig. 5: Direct loop gain measurement of flyback converter.

point. It is interesting to see that beyond this frequency, the closed-loop output impedance is actually higher than the open-loop measurement. This is because the vector sum of 1+T(s) is less than one as the phase margin of the measured loop drops below 60 degrees.

Synthesized Loop Gain Measurements

Three measurements have been made so far for this converter – open-loop output impedance, closed-loop output impedance, and loop gain. In theory, only two of these measurements should be necessary since the three quantities are related to each other by Eq. 1. In practice, however, we always measure all three quantities since direct measurement of each gives the most dependable results. This will be illustrated below.

If we rearrange Eq. 1, we can express the loop gain of the converter in terms of the impedance measurements as follows:

$$T(s) = \frac{Z_o^{ol}(s)}{Z_o^{cl}(s)} - 1$$

From this, we can try to plot the loop gain from just the impedance measurements. Note that it is crucial that both the magnitude and phase of the impedances are measured in order to perform this calculation, even though we commonly only present the magnitude as part of a power supply characterization.

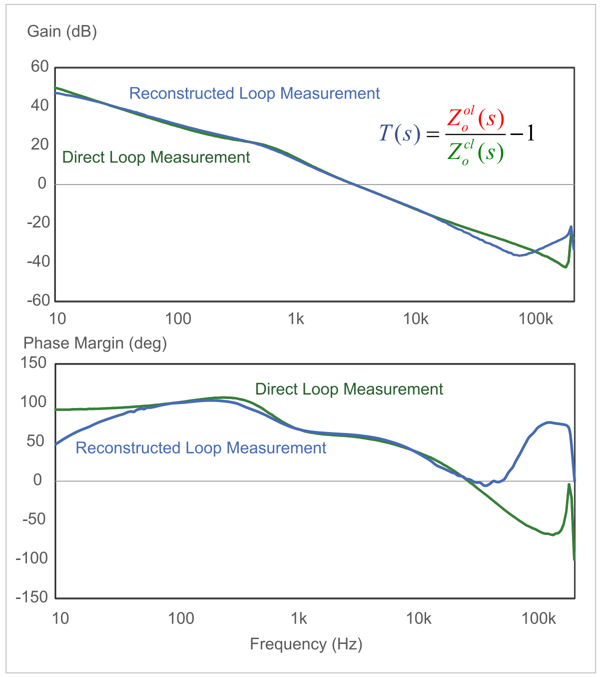


Fig. 6: Direct loop gain measurement compared with synthesized loop from impedance measurements.

Fig. 6 shows the result of this equation plotted against the directly-measured loop. The green curve of Fig. 6 shows the real loop gain, and the blue curve shows the calculated loop gain, synthesized from the impedance measurements.

For this power supply example, the measured and calculated loop gains agree fairly well in the region of the crossover frequency. At high and low frequencies, there is very significant deviation of the directly-measured true loop gain, and the gain synthesized from the output impedance measurements. At low frequencies, parasitic resistance of connections an impact the lowest-measurable impedance, and give false readings.

At high frequencies, Eq. 2 becomes numerically inaccurate, and small errors in the impedance measurements result in large errors in the calculated loop gain and phase. This is illustrated further in Fig. 7 where a small change is made in the measurement setup by just moving test cables. Additional EMI picked up from the layout change of the instrumentation results in a very large change in the calculated loop gain and phase.

Clearly, this kind of sensitivity is not acceptable when trying to properly characterize power supplies for their long-term stability. This is the reason that we always make the complete set of measurements. The direct loop gain gives the most rugged measurement that is not nearly as sensitive to noise issues and cable layout.

In this example, the calculated loop gain and phase at the crossover frequency was quite good. However, this is not always the case – in many real-world power supplies, the introduction of the feedback loop does more than

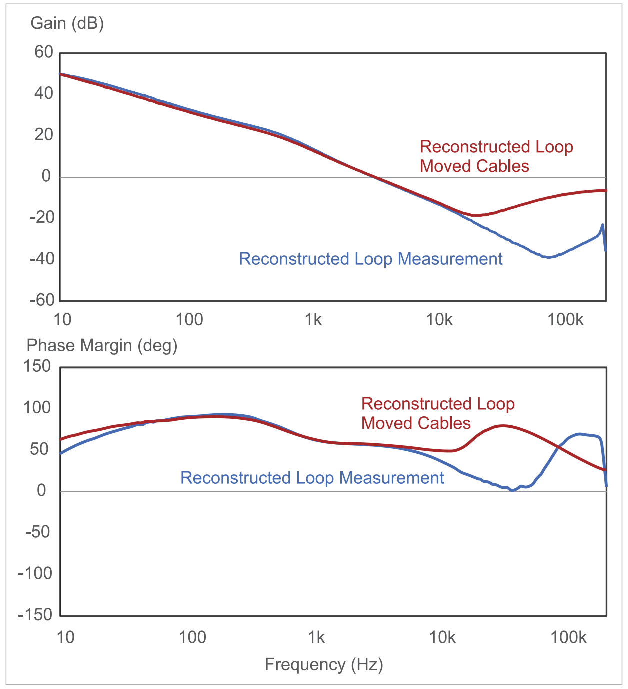


Fig. 7: Different synthesized loops result with small changes in test setup. Loop gains should always be directly measured for the most reliable results

just attenuate the open-loop output impedance. It also modifies the operation of the PWM modulator, changing the slopes of the waveforms, and the gain of the system. This is especially true of current-mode control where the PWM ramp slopes are usually much smaller. In other cases, the real-world feedback waveforms introduce feedforward gains from the load current that have a significant effect on the output impedance. In all of these situations Eq. 2 becomes invalid.

Summary

This article clearly shows the relationship between loop gain and output impedance measurements. For a thorough power supply design and documentation, you should measure the output impedance and loop gain separately. Only direct loop gain measurements will give you dependable results for the high-noise environment and nonlinearities of a switching power supply. In some cases where the loop is truly not accessible, the only choice is to estimate. However, if the loop is accessible, measurements should always be made for reliable designs.

In the next article of this series, we will look at the audiosusceptibility measurement and its correlation to loop gain.

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1. Ridley Engineering Frequency Response Analyzer from AP Instruments, www.ridleyengineering.com/index.php/analyzer.html
2. Ridley Engineering Design Center, www.ridleyengineering.com/index.php/design-center.html

Dr. Ray Ridley
President, Ridley Engineering
www.ridleyengineering.com

BATTERY-CHARGER TRENDS IN PORTABLE POWER PRODUCTS

Applications demand high power and wide-ranging inputs

By: Trevor Barcelo

Designers continue to demand more power in their products to support increasing functionality and look to charge the battery from any available power source.

The first trend requires increased battery capacities. Unfortunately, users are often impatient and charge systems must recharge these increased capacities in a reasonable time, which leads to increased charge currents. The second trend requires tremendous flexibility from the battery charging system.

More Power

Consider modern handheld devices—both consumer and industrial devices may include a cellular-phone modem, a WiFi module, a Bluetooth module, a large back-lit display, and more. The power architecture of many handheld devices mirrors that of a cell phone. Typically, a 3.7 V Li-ion battery serves as the primary power source due to its high gravimetric (Wh/kg) and volumetric (Wh/m3) energy density. In the past, many high-powered devices used a 7.4 V lithium-ion battery to reduce current requirements, but the availability of inexpensive 5 V power management ICs has pushed more and more handhelds to the lower voltage architecture.

The tablet computer illustrates this point well: A typical tablet computer provides significant functionality with a very large screen (for a portable device). When a 3.7 V battery powers such a device, engineers must measure battery capacity in Ampere-hours, not milliamp-hours. In order to charge such a battery in just a few hours, Amperes of charge current are necessary as well.

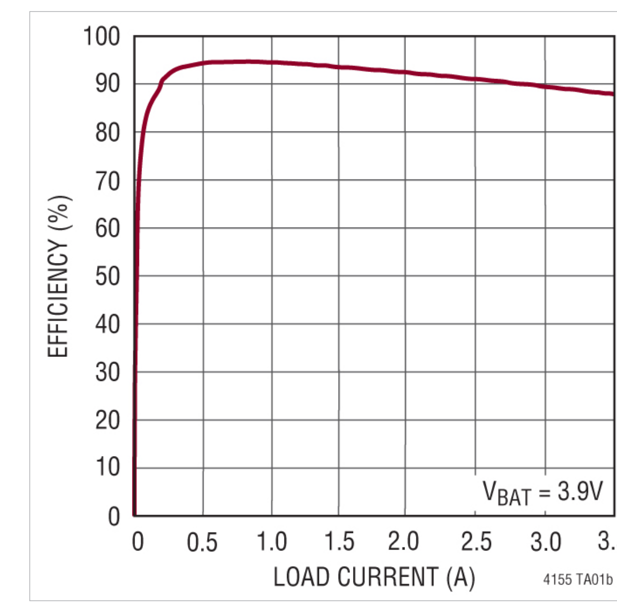

Figure 1: LTC4155 Typical Efficiency

However, this high charge current does not prevent consumers from also wanting to charge their high-powered devices from a USB port if a high current wall adapter is not available. To satisfy these requirements, a battery charger must be able to charge at a high current (>2 A) when a wall adapter is available, but still efficiently make use of the 2.5 to 4.5 W available from USB.

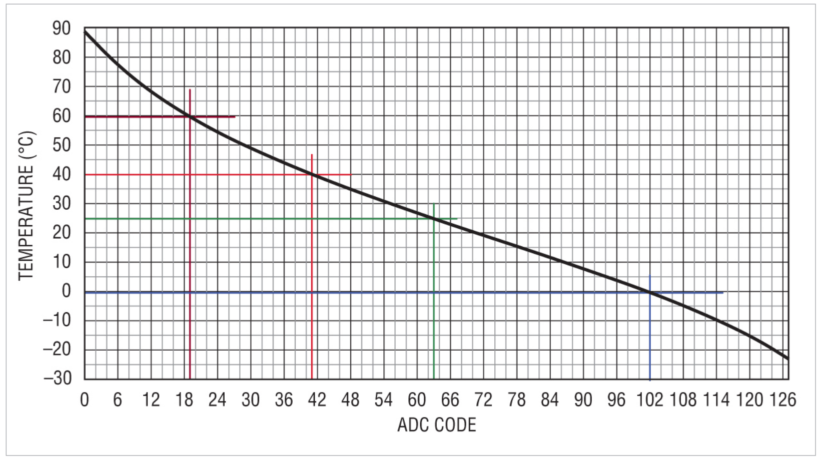

Figure 2: 7-Bit Thermistor ADC Showing Preset LTC4155 Temperature Trip Points

Furthermore, the product needs to protect sensitive downstream low-voltage components from potentially damaging overvoltage events and seamlessly direct high currents to the load from a USB input, a wall adapter, or the battery while minimizing power loss. Simultaneously, the charge-control IC must safely manage the battery-charging algorithm and monitor critical system parameters.

Charging single-cell portables
An example of a lithium-ion battery-charge control IC with these traits is the LTC4155. This high-power, I2C controlled charger efficiently transfers up to 3 A from a variety of 5 V sources, resulting in over 3.5 A available for battery charging and system use. Even at these high current levels, the LTC4155's 88 to 94% efficiency eases thermal-budgeting constraints (Figure 1). The LTC4155's switching topology seamlessly manages power distribution from two input sources such as a wall adapter and USB port to the application's rechargeable lithium-ion battery while preferentially providing power to the system load when input power is limited.

The LTC4155's switching regulator acts like a transformer, allowing the load current on VOUT to exceed the current drawn by the input supply, and making greatly improved use of the available power for battery charging compared to typical linear-mode chargers. Unlike ordinary switching battery chargers, the LTC4155 features instant-on operation to ensure system power is available at plug-in even with a dead or deeply discharged battery.

While charging a battery at a high rate, it is important to monitor battery safety. The LTC4155 will automatically stop charging when the battery temperature falls below 0°C or rises above 40°C as measured by an external NTC (negative temperature coefficient) thermistor. In addition to this autonomous feature, the LTC4155 provides a 7-bit expanded scale ADC to monitor the battery temperature with approximately 1°C resolution (Figure 2). Combined with four available float-voltage settings and fifteen battery charge-current settings, designers can use this ADC to create custom charge algorithms based on battery temperature.

A simple 2-wire I2C port provides access to the NTC ADC results, enabling adjustment of the charge current and voltage settings. The I2C port also provides USB compliance by controlling 16 input current-limit settings including USB 2.0 and 3.0 compatible settings. The communication bus allows the LTC4155 to indicate additional status information such as input-supply status, charger status, and fault status. USB On-The-Go support provides a 5-V supply back to the USB port without any additional components.

The LTC4155's dual input priority multiplexer autonomously selects the most appropriate input—wall adapter or USB—based on a user-defined priority. The default priority goes to the adapter input. An OVP (overvoltage protection) circuit simultaneously protects both inputs from damage caused by accidental application of high voltage or reverse voltage. The LTC4155's multiplexing capability guarantees that ample power is always available to VOUT even if input power is insufficient or absent.

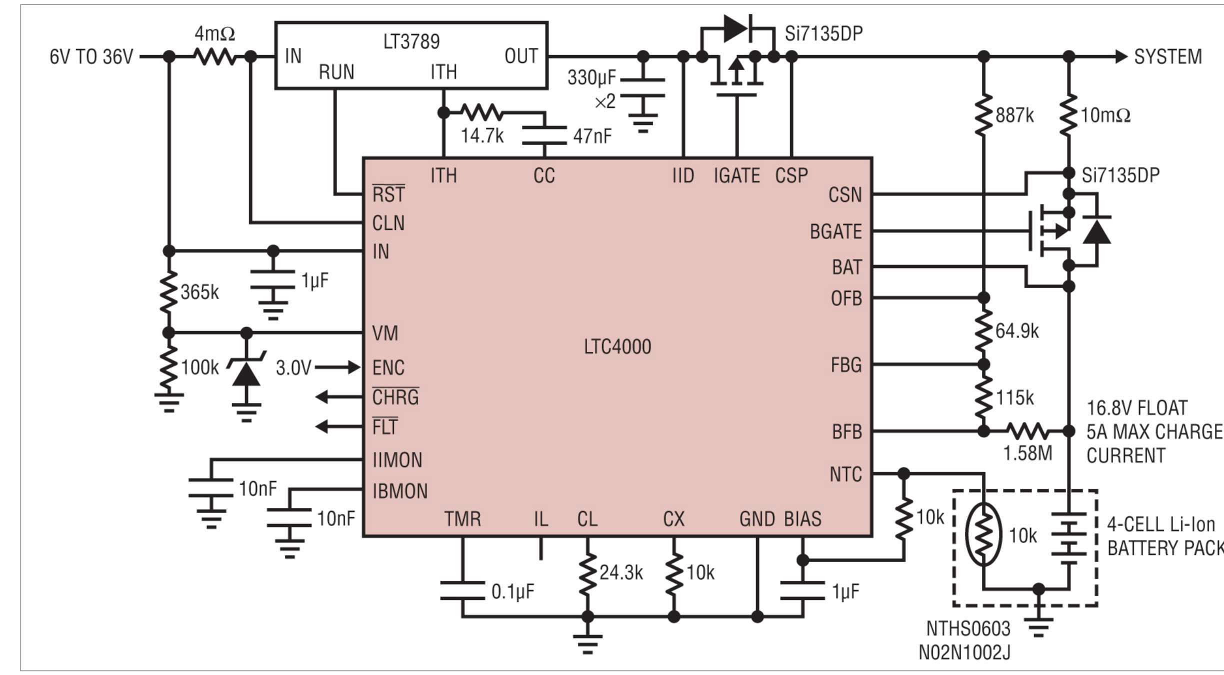

Figure 3: LTC4000 & LTC3789: 6V to 36VIN 4-Cell Li-Ion 5A Battery Charger

Managing two inputs is sufficient for many portable applications such as tablet computers or bar-code scanners. However, designers of portable devices continue to seek ways to charge the battery from any available power source.

Multiple Input Sources
There are several reasons for users to charge batteries from multiple input sources. Some applications may need to be untethered from the grid and look to solar panels to provide power. Other applications demand the convenience of being able to charge from a wall adapter or an automotive battery or a high-voltage industrial or telecom supply. Whatever the reason, the requirement places a significant burden on the battery charging system.

Most battery chargers make use of a step-down architecture to charge a battery from a voltage supply higher than the maximum battery voltage. Prior charger products have typically been limited to input voltages of about 30 V. These limitations prevent a designer from considering a telecom supply as a viable input supply or a solar panel with a 42 V open-circuit voltage.

In some cases the voltage range of the desired input supplies varies both above and below the battery voltage. Designing a charger for these challenges typically involves a compilation of high-precision current-sense amplifiers, ADCs, a microprocessor to control charging, a high performance DC-DC converter, and a so-called ideal diode or multi plexing circuitry.

Flexible charging
Another example of charge controllers that accommodate multiple energy sources is the LTC4000, which converts any externally compensated DC-DC power supply into a full- featured battery charger. Typical DC-DC converter topologies that the LTC4000 can driveinclude, but are not limited to, buck, boost, buck-boost, Sepic, and flyback. The device offers precision input and charge-current regulation and operates across a wide input-and output-voltage range of 3 V to 60 V, allowing compatibility

with a variety of different input-voltage sources, battery-stack sizes, and chemistries. Typical applications are widespread due to the device's general-purpose configuration and include high-power battery-charger systems, high-performance portable instruments, battery-backup systems, industrial battery-equipped devices, and notebook or subnotebook computers.

The LTC4000's high-voltage capability and its ability to operate with many different DC-DC topologies, allow it to form battery-charging circuits with virtually any input supply (Figure 3). To ensure that power from these inputs flows to the appropriate load, the LTC4000 features an intelligent topology that preferentially provides power to the system load when input power is limited. The LTC4000 controls external PFETs to provide low-loss reverse-current protection, low-loss battery charging and discharging, and instant-on operation to ensure system power is available at plug-in even with a dead or deeply discharged battery. External sense resistors provide input current and battery-charge current information, allowing the LTC4000 to work with converters that span the power range from mW to kW.

The LTC4000's full-featured battery-charge controller charges a variety of battery chemistries including lithium-ion/polymer/phosphate, sealed lead acid, and nickel. The battery charger also includes precision current sensing that allows lower sense voltages for high-current applications.

Trevor Barcelo
Product Line Manager
Battery Management Products
Linear Technology Corporation

www.linear.com

PCIM EUROPE 2012 IN REVIEW

A strong show makes a strong showing despite economic challenges

By: Joshua Israelsohn

Before even making one's way to the first stand, the overall impression this year's PCIM Europe International Exhibition and Conference exuded was that of optimism—even confidence. Large, well-staffed stands and crowded corridors were a welcome sight, contrasting to the headlines of the day and their rather dreary outlook for economies in much of Europe and the United States.

The impression wasn't merely subjective. Conference and exhibition organizers Mesago (http://bit.ly/KJpkpt) report exhibition attendance of 6874, up 3.3%—the third straight year of growth (Figure 1). The count of exhibiting companies was up as well, numbering 451—a strong year-on-year increase of 23% (Figure 2). Total exhibition space has stayed roughly proportional to exhibitor count, totaling about 16,500 m2. The space per exhibitor—36.6 m2—was essentially stable—up 1% from 2011—suggesting that the jump in exhibitor population was broad-based and not limited to companies making small commitments to the exhibition.

It's impossible to review a show of this size in a single article or even an issue of Power Systems Design. However, a few presentations I saw stood out. Here are a few of those:

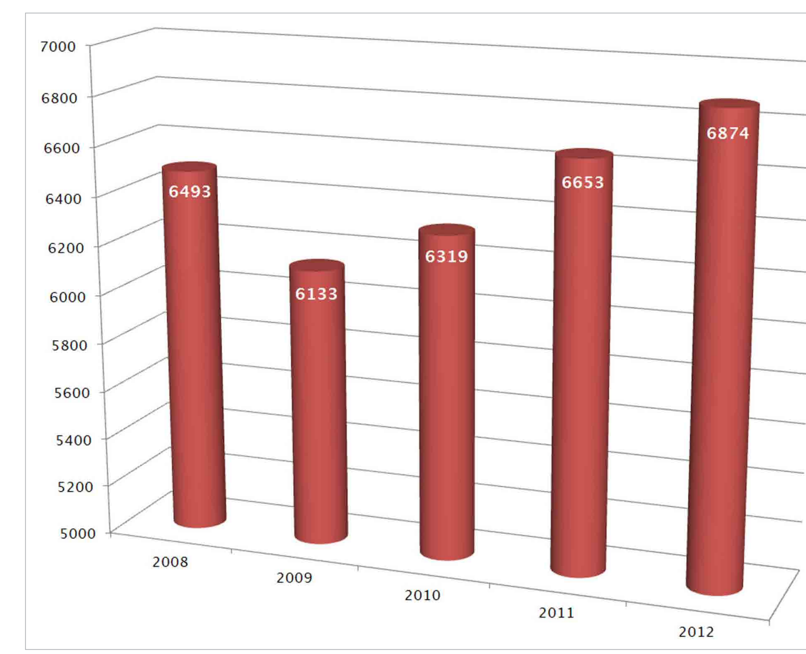

Figure 1: PCIM attendance continues to grow despite economic uncertainty in Europe and North America.

Voted least likely

Most companies are founded on fairly predictable relationships. Principals typically come with likely backgrounds and

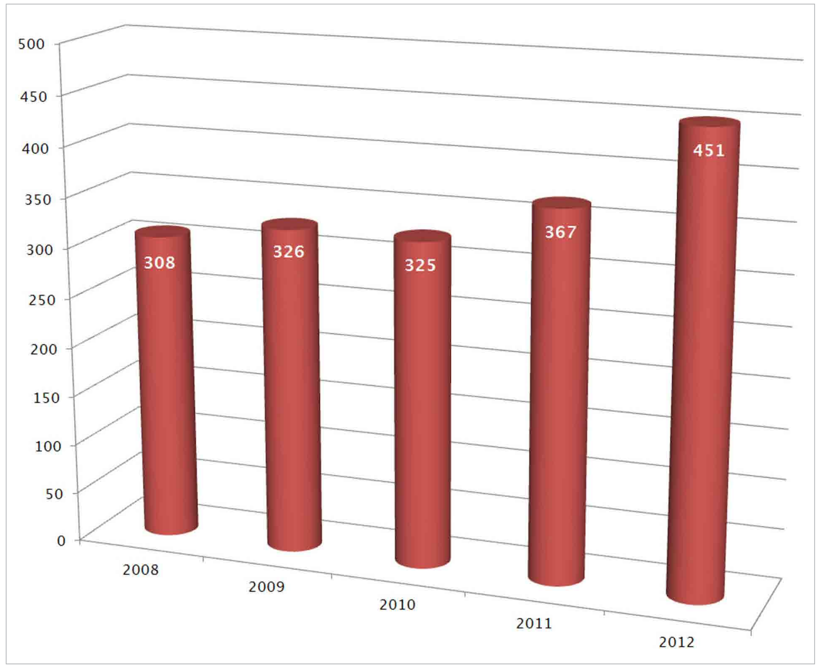

Figure 2: The number of companies exhibiting at PCIM were up smartly in 2012.

experiences for the technologies, products, and applications they plan to pursue and, though certainly not built of homogeneous populations, it's rare to find surprises of any serious magnitude among the founding team.

Amantys is not most companies. Established by former ARM executives just two years ago, Amantys supplies IGBT-switch drives and monitors for what the company refers to as medium- and high-voltage applications. These start at 1.2 kV and work their way up to 3.6 kV with 4.5 and 6.3 kV products in development. Current-handling capability ranges from 1.2 kA to 3.6 kA.

Although, based on their origins, one could easily vote Amantys least likely company in the power business, based on their IGBT-driver technology it's clear that they are competing aggressively with both features and performance. The drives are essentially switch-agnostic: The company has demonstrated compatibility with IGBTs from ABB, Dynex, Fuji, Hitachi, Infineon, and Mitsubishi with a single driver product. Customers can program a driver to operate with IGBTs from various sources, eliminating the need to stock separate drivers for each vendor's switches or risk single sourcing a key component.

Since their debut, Anantys has modified their gate drives to fit in an IGBT-module form factor—a step that required roughly a 30% reduction in PCB size. Meanwhile, they increased the drivers' creepage clearance to 35mm to pass isolation tests to 14 kV. The drivers provide zero dead time during startup and recovery unlike many competing drivers, which according to the company, can take as much as a full second.

The driver also monitors and reports operating conditions on a pulse-by-pulse basis without additional user-provided sensors. Among the parameters it monitors are VCE(SAT), VCE(OFF), t(CE), VGE, and temperature. The driver is compatible with existing IGBT modules for easy system upgrades and low design-in complexity for new products.

During product development, designers can remotely change the gate-drive strength based on driver-provided data, streamlining design verification testing and commissioning. In running systems, the same remotely accessible data can help optimize maintenance schedules and help gauge system health.

At the core of high-current inductors

Rarely do electronic-design engineers involve themselves in materials selection. A key exception is in the area of inductor and transformer design, in which core-material and shape selections are every bit parts of the design as determining the wire gauge, turns count, and wind geometry. So I was keenly interested to hear that core makers Magnetics (http://bit.ly/KtFtL4) have introduced a new low-permeability material for high-current DC applications.

Previously, Magnetic's lowest permeability powder-core material provided a nominal $\mu/\mu_0 = 26$. According to Vice President of Marketing Bradley Yourish, their new material provides a permeability of 14 for better inductor DC-bias performance in inverters for applications including battery chargers, UPSs, welders, and traction drives.

Historically, Magnetics formed toroids as large as 78 mm OD—a limitation set by the press that shapes the raw material into the unfired core. With the addition of a new press, the company has increased their maximum toroid size to 165 mm OD, allowing inductor winding houses to make larger devices for high-current applications without stacking cores. The company continues to formulate powder and ferrite core materials, providing a mix of tradeoffs among permeability, saturation flux, core loss, and cost.

Get your motor running

International Rectifier introduced its IRSM836 series of power modules that integrate a three-phase gate drive and six power MOSFETs, configured to drive fractional-horsepower motors as large as 195 W. Six models ranging from a 2 A, 250 V device to a 4 A, 500 V module share a common QFN package measuring only 12 x 12 x 0.9 mm.

The drive fits into a space only 40% the size of the next smallest competitor according to the company's Vice President of Strategic Market Development, Alberto Guerra. The small QFN package also provides a smaller thermal impedance than conventional dual-inline packaged modules.

"From the thermal point of view, this is more efficient because [the IRSM836 modules] transfer the power directly through the lead frame to the PCB copper," Guerra said. The modules, thereby, operate without the need of an external heatsink in many applications, "while in a traditional dual-inline design, this type of module requires an external heatsink," he continued.

The company showed results of a comparison between an IRSM836-series module and a conventional leaded module in a fan-controller application. The controller used a 1 oz copper PCB and operated at 100 mA with a switching rate of 15 kHz and a 320 VDC bus. "The net effect is a 35 °C difference in junction temperature. We can project a longer life because the parts operate at a lower temperature," Guerra concluded.

Target applications include fans for air conditioning, refrigeration, and ventilation; pumps for white goods and heating-system circulators; and variable-speed compressors. Pricing for the IRSM836 series ranges from $1.59 to $2.99 (10,000). International Rectifier's parametric selection tool is available at http://bit.ly/KeNMxL

Much buzzing around wide-bandgap devices.

At top level, it was good to see that OEM and power-subsystem designers have become comfortable with depletion-mode wide-bandgap devices in cascode with enhancement-mode silicon MOSFETs. Device makers have demonstrated to most everybody's satisfaction that coercing a natively depletion-mode switch technology into assuming the characteristics of an enhancement-mode device is not worth the cost to performance. The benefits the cascode brings are worth the increase in device complexity, and take the worry out of startup and drive-fault conditions.

Several companies demonstrated wide-bandgap devices including Transphorm with its 600 V GaN switches, which claim 99% efficiency in boost DC-DC circuits and 98.5% efficiency in three-phase motor drives. Both demonstrations provided visiting engineers the opportunity for (well-insulated) hands-on circuit measurement.

International Rectifier featured its comparatively low-voltage GaN switches in the role of output-bridge devices in a class-D audio-amplifier demonstration with a Jun-Honda-designed amplifier/controller setting the pace. This is an intriguing application because class-D audio amplifiers are notoriously unforgiving of devices less than well matched to the controller and gate drive circuitry. The demo receives two extra cleverness points for mounting the output devices in glass vacuum-tube envelopes about the size and shape of the venerable KT66 beam tetrode valve. Alas, it loses 10 effectiveness points by hooking

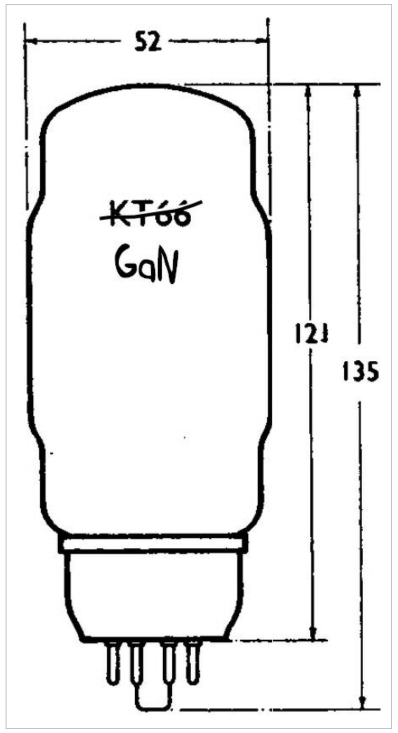

Figure 3: IR tried serving GaN under Glass—a clever idea but, in audio, hearing is believing. IR's QFN-packaged motor-drive modules, by contrast, were indeed noteworthy.

the same devices to palm-sized speakers that offer no hope of replicating the fidelity that the electronics claimed to deliver (Figure 3). Guys: You've got a $B company—get yourselves a pair of Westlakes (http://bit.ly/KHRH7F) or at least a pair of Paradigms (http://bit.ly/KYtKmm). I'm looking forward to hearing what the GaN devices can do at your next event.

A number of companies have new SiC devices including Rohm, Semisouth, Infineon, Fairchild, and Cree. Cree is unusual in that it runs both SiC and GaN in addition to several other III/V processes for its LED business.

On the power SiC side of the business, Cree (http://bit.ly/LAnCSv) has been aggressively building its HV portfolio. Director of Marketing Paul Kierstead presented 50-A, 1.2 and 1.7 kV MOSFETS and Schottky diodes. "Fabricating reliable gate oxides on silicon carbide is not an easy thing to do," Kierstead said, which is why HV SiC devices are typically depletion-mode JFETs. With several years of successful SiC MOSFET manufacture behind them, Cree appears to have engineered a reliable approach to device design in that process.

The 1.7 kV switches are targeting wind, solar, and motor-drive applications. "Where we are today [with HV SiC MOSFET switches] is somewhere between ⅓ and ¼ the area of silicon IGBTs for comparable voltage- and current-handling capability," Kierstead observed.

Joshua Israelsohn
Editor in Chief
Power Systems Design

www.powersystemsdesign.com

DESIGNING WITH LOW-LEAKAGE TANTALUM AND NIOBIUM OXIDE CAPACITORS

Battery-powered equipment benefits from advanced dielectrics

By: Radovan Faltus

DCL (direct current leakage) is an effect common to all capacitors. DCL values and behavior under varying electrical and environmental conditions relate to the capacitor's dielectric. The leakage current in tantalum and niobium oxide capacitors consists of the dielectric absorption current and the fault current that results from impurities and irregularities within the dielectric.

Since operating currents in most systems are significantly higher than a capacitor's leakage current, a circuit's functionality remains unaffected by DCL.

However, in a battery-operated application the leakage of the capacitor will directly influence standby time, as it directly discharges energy from the battery. This occurs frequently in applications like mobile phones, MP3/MP4 players, DVD players, and in automotive applications where battery-operated wireless sensor transmitters, for example, use capacitors.

Battery-powered, handheld equipment commonly use capacitors with 3.7V lithium-ion rechargeable batteries for several functions.

- Back up data and settings during battery replacement.
- Smooth the voltage and current peaks during battery insertion, and when the charger connects or disconnects.
- Support the battery with stored energy when the application's current demand suddenly increases.

In automotive applications, tire pressure management systems wirelessly transmit pressure and temperature data from in-wheel sensors to a central control unit, which provides information and warning alerts to the driver. This system uses a bulk (parallel) capacitor in conjunction with the sensor to deliver an energy pulse when the measurement or transmission sequence is initiated, especially at low ambient temperatures.

Often specified for tire pressure warning systems because of their exceptional operating life of more than ten years, lithium batteries function well at low temperatures. However, under such conditions, they may exhibit an increased internal resistance that can result in a larger voltage drop.

Capacitor requirements

The suitable nominal capacitance value for battery circuits is typically in the range of 22 to 220 µF. A small-footprint, low-profile device is a common requirement to match the small size of the end device. Excellent performance at extremely low temperatures is an obvious necessity to ensure portable devices' reliability. Tantalum and niobium oxide capacitors make excellent choices for such applications.

Designers must minimize standby power consumption to extend battery life. You must consider both active parts and passive functions and, since the leakage current of the bulk capacitor directly drains a battery, reducing DCL is important. Selecting the correct tantalum or niobium oxide capacitor is imperative to minimize leakage current. Different formulas exist for the various capacitor families to determine the basic DCL, which capacitor manufacturers specify at full rated voltage and room temperature:

$$DCL = kCV_R \quad \text{,(Eq 1)}$$

where C is the nominal capacitance, VR is the capacitor's rated voltage, and k is a dielectric-dependent constant. For example, values of k corresponding to three of AVX's capacitor series are:

- TAJ series (tantalum): 0.01
- TRJ series (tantalum): 0.0075
- NOJ series (niobium oxide): 0.02

Ambient temperature and voltage derating are important factors when calculating DCL. Leakage current is proportional to temperature, which manufacturers typically specify at 20 °C. See the manufacturer's datasheet for derating curves to calculate the temperature-related leakage factor. Similarly, leakage current is proportional to operating voltage. The extent to which leakage current at V < VR is less than the leakage at VR differs by capacitor construction (Figure 1).

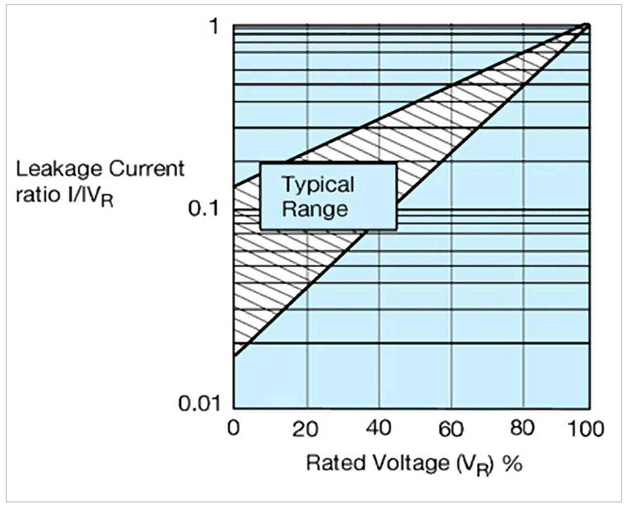

Figure 1: The effect of voltage derating on DCL

This relationship is an approximately linear measure by reverse decimal logarithmic function with offset (Figure 2)

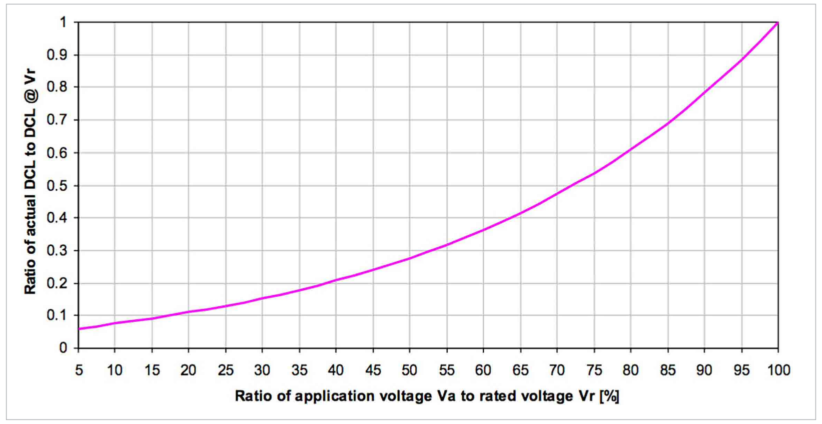

Figure 2: Median curve of typical range of DCL versus voltage derating

Optimal voltage derating for minimal DCL

To achieve the optimal leakage current ratings for the application (DCLA) at room ambient temperature, we need to consider two factors: the basic DCL defined at rated voltage (Vr as in Eq 1); and the DCL ratio versus voltage derating, as shown in Figure 2:

$$DCL = kCV_R R_I \quad \text{,(Eq 2)}$$

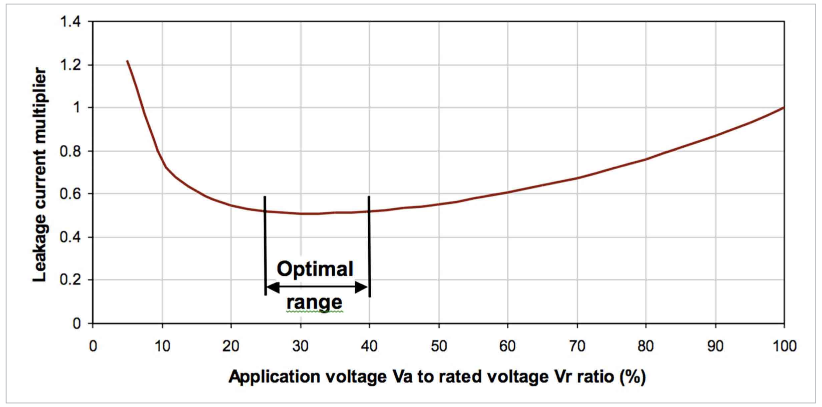

Figure 3: Leakage current multiplier vs voltage derating for fixed application voltage, VA

where RI is the ratio of DCLA:DCL at VR k are the dielectric-dependent constants given with Eq 1.

Figure 3 shows The maximum DCL multiplier versus VA/VR for a fixed application voltage VA. The maximum DCL value varies with capacitor type, nominal capacitance, and rated voltage. The shape of the graph will be the same, so you can identify the range of Va/Vr (derating) values with minimum DCL as the 'optimal' range. Therefore, you'll obtain the minimum DCL when a capacitor is operates at 25 to 40% of its rated voltage, which translates to a rated capacitor voltage 2.5 to 4 times higher than the application's operating voltage.

Comparison in typical battery circuits

The typical energy source of a handheld device is a lithium-ion rechargeable battery with a nominal voltage VA = 3.7V. To support device functionality, designers can choose from several different capacitor series.

Where the VA is 3.7V, the optimal rated voltage, VR, is 10V, (which means optimal operating conditions are at 37% of rated voltage. This ratio of VR:VA is independent of capacitance.

Radovan Faltus
Technical Marketing,
AVX Tantalum

www.avx.com

SMART ACTIVATION CIRCUIT PROTECTION IN LI-ION BATTERY APPLICATIONS

As high-power applications switch to Li-ion batteries, a protection method for ratings over 30 VDC emerges

By: Ty Bowman

Li-ion technology with smaller, lighter-weight, and higher-power batteries is now replacing nickel-cadmium or lead-acid batteries in high-discharge-rate battery applications

Meanwhile, more high-power applications are switching to Li-ion batteries, which create a need for more robust circuit protection to ensure safety in battery-powered products. Currently, few protection systems address high-discharge-rate Li-ion battery applications, such as power tools, E-bikes, LEVs (light electric vehicles) and standby-power applications. Traditional circuit-protection techniques also tend to be large, complex, and expensive.

MHP (metal hybrid polymeric) technology addresses the Li-ion battery-pack market trends by offering a cost-effective, space-saving circuit protection device. Connecting a bimetal protector in parallel with a PPTC (polymeric positive temperature coefficient) device, the MHP device provides resettable overcurrent protection using the PPTC device's low resistance to help prevent arcing in the bimetal protector at higher currents.

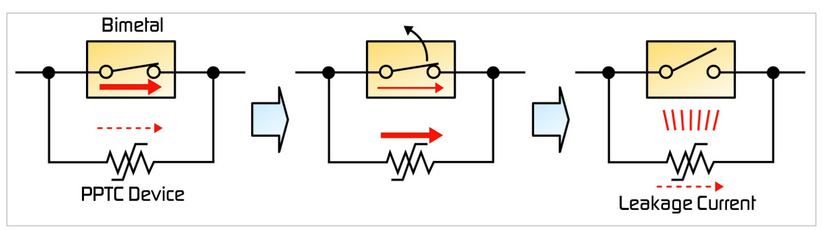

Figure 1: The activation steps of the MHP device

Core design concept

During normal operation of an MHP, current passes through the bimetal contact due to its low contact resistance. When an abnormal event occurs, such as a power-tool rotor lock, the tool's motor draws more current, causing the bimetal contact to open. At this point, the current shunts to the lower resistance PPTC device, which prevents arcing between the contacts while also heating the bimetal, keeping it open and in a latched position (Figure 1).

The activation steps of the MHP device include:

1. During normal operation, because contact resistance is very low, most of the current goes through the bimetal.
2. When the contact begins to open, resistance increases quickly. If the contact resistance is higher than the PPTC device's resistance, most of the current goes to the PPTC device and no — or less — current remains on the contact, preventing arcing between the contacts. When current shunts to the PPTC device, its resistance rapidly increases to a level much higher than the contact resistance and the PPTC device heats up.
3. After the contact opens, the PPTC device heats up the bimetal and keeps it open until the over-current event ends, or power is turned off.

An PPTC device's resistance is much lower than that of a ceramic PTC, so even when the contact opens a small amount, resistance increases only slightly, and the current shunts to the PPTC device to help prevent contact arcing.

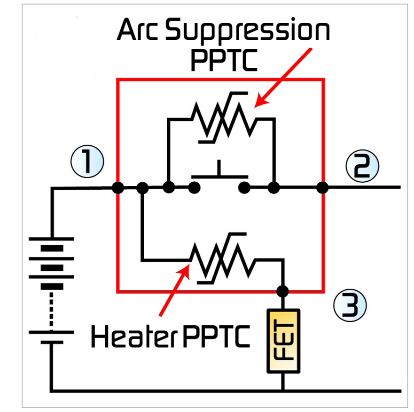

Figure 2: The IC monitoring activation steps

Typically, resistance ratio at room temperature between ceramic and polymer PTC devices is in the range of 100:1, so higher resistance ceramic PTC devices combined in parallel with a bimetal are less effective at suppressing arcs at higher currents than MHP devices.

Smart activation

Smart-activation devices are the latest generation technology and incorporate a third terminal as a signal line for over-charge protection. This allows the device to take advantage of battery-monitoring ICs advanced features. When the IC detects an abnormality, it sends a signal via a low power switch line to activate the smart-activation device and open the main line (Figure 2). The activation steps are:

1. The IC monitors the battery system for temperature, current, and voltage abnormalities.
2. The switch is ON at an abnormal event (1 → 3).
3. The PPTC heater activates and heats bimetal.
4. The contact opens and cuts contact to the main line (1 → 2).

Figure 3 shows an example of the overcharge-protection concept and activation steps for a 50 A, 400 VDC device with a hold current of 50 A on the main line. Here the IC monitors individual cell voltage, the FET turns on during an abnormal voltage event, the heater PPTC activates and heats the bimetal, the contact opens and cuts the current to the main line.

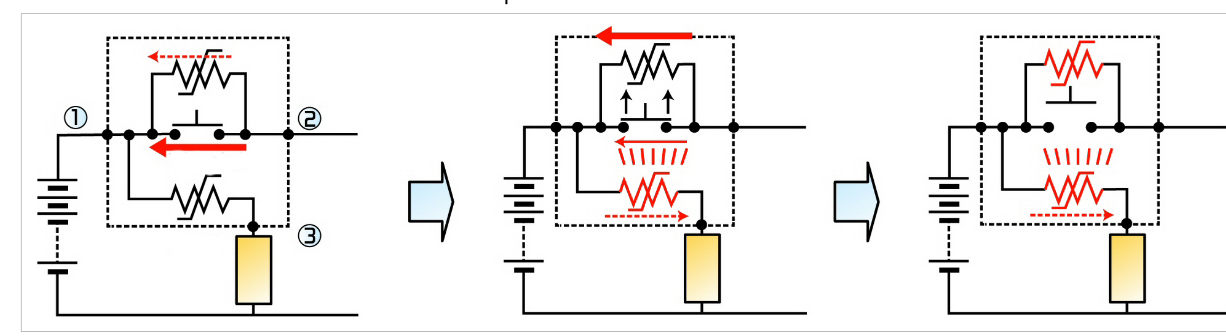

Figure 3: Under normal operation, contact resistance < PPTC resistance (a). Under abnormal operation, contact resistance ≥ PPTC resistance (b). Under continued fault conditions, heater PPTC keeps bimetal latched open (c).

The smart-activation device's benefits include:

- Over-charge protection in battery packs
- External activation allowing the device to use the battery-monitoring IC to detect voltage, current, and temperature faults and trigger the device
- Resettable device; no need to overrate for inrush current
- Smaller size, thinner form factor compared to fuses or other breaker devices
- Arc-suppression PPTC design suppresses arc at contacts
- Low power switch line opens main line; uses a lower cost FET

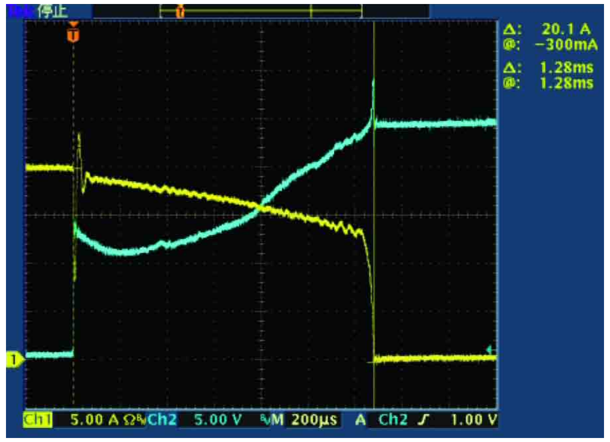

Figure 4a

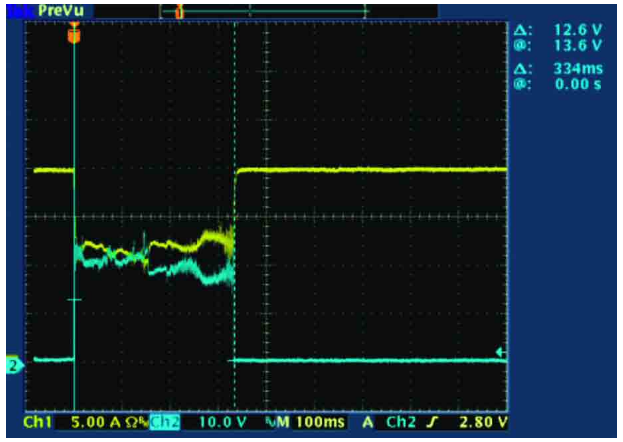

Figure 4b

Response curves for a simple bimetal protector at a rated voltage of 24 V and 20 A. The time scale is 200 µs/div; vertical scales are 5 V (blue) and 5 A (yellow) per division, respectively.

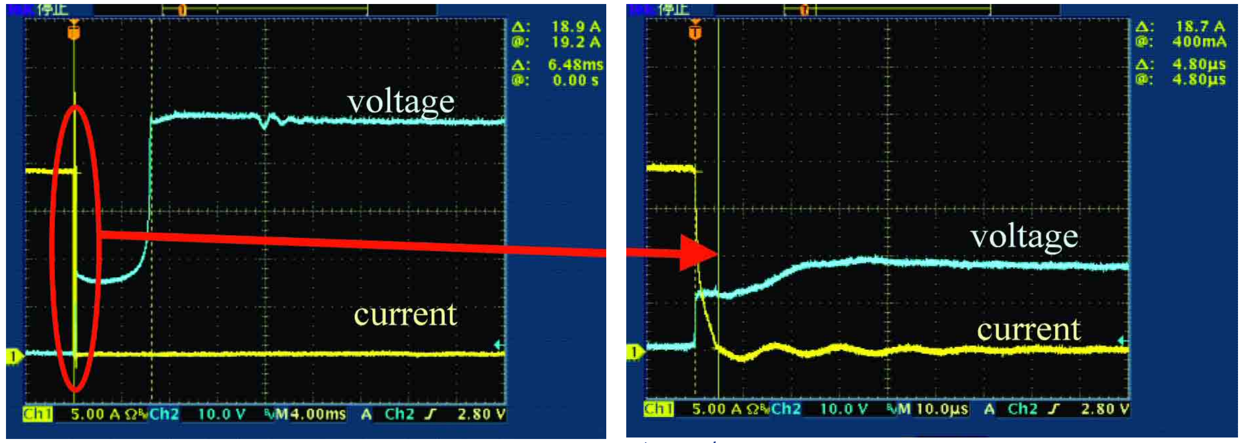

Figure 5a

Figure 5b

Response curves for a bimetal protector combined with a PPTC device at twice the rated voltage—48 V—and 20 A . The time scales are 4 ms/div in A (left) and 10 µs/div in B (right). Vertical scales are 10 V (blue) and 5 A (yellow) per division, respectively.

Arcless contacts

Figures 4a and 4b show current and voltage using only a bimetal protector. Figure 4a shows typical results of the open bimetal protector at a rated voltage of 24 VDC and 20 A. It opens in 1.28 ms. Figure 4b depicts double the rated voltage of the bimetal protector. A standard bimetal protector arcs under fault conditions and the time from when contact starts to open to welding of the short circuit is 334 ms.

Figures 5a and 5b show the result of combining a PPTC device and bimetal in parallel in which current is clearly cut off. Figure 5a shows the time lapse between when the bimetal protector starts operating, until the PPTC device fully activates is 6.48 ms. Figure 5b shows the time from the protector operating until current cut off is 4.80 µs, when the applied voltage is twice the rated voltage. This succession of images demonstrates the smooth transfer from bimetal protector to the PPTC device with no welding of protector contacts, and shows how the PPTC device protects the contacts from arcing.

Ty Bowman
Global Battery Market Manager
TE Connectivity

www.te.com

SPECIAL REPORT: POWERING CONSUMER ELECTRONICS

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Power Systems Design: Empowering Global Innovation

INSIDE:

INPUT-LINE-CURRENT SYNTHESIS IN PFC CONTROL

Digital-control method improves PFC performance

By: Maurizio Salato

Traditionally, PFC (power-factor-correction) controls present a purely resistive behavior with respect to the power line.

By means of multiplier or equivalent blocks, front-end converters draw a current the shape of which closely follows the input line voltage. This approach presents one issue: the converters operate over a condition range that is far from optimal, particularly in close proximity of the power line's zero crossing. An alternative approach implements a digital control that forces a particular line-current shape, which avoids the issue while meeting all applicable EMI and EMC standards. Moreover, an improved algorithm reduces line-voltage harmonic propagation to the line.

Background

Circuit designers have addressed PFC control in a variety of ways over the last twenty years. The majority focus has always been on the quality of converter's control technique and the result in terms of PF and input-current THD (total harmonic distortion). While the most common converter topology has been the non-isolated boost, the need for isolated low-output-voltage products led to the development of single-stage isolated topologies. Design constraints add up quickly, however, and force less-than-optimal component sizes and ratings. To minimize those constraints, more recent research focuses on radical approaches that actively modulate some reactive elements. These methods achieve better performance at the expense of available headroom on power factor and line-current THD with respect to IEC standards.

In both the industrial and consumer environments, electricity is processed from raw AC, as distributed to homes and industrial plants, to a variety of DC levels. As electronic converters overcome the number of linear loads, such as incandescent lighting or heating, the need for PFC arises to avoid unnecessary losses on the power-distribution system and to meet the stringent regulations utility providers enforce. There are several traditional PFC approaches within consumer and industrial markets. These include distributed active PFCs within individual equipment such as PCs, washing machines, and TV sets in contrast to centralized, plant-level devices such as active power-quality compensators.

The approach the consumer market takes is rapidly expanding into industrial segments, where it's become more effective to deploy equipment with embedded PFC. In fact, industrial plants today include a diverse set of equipment: uncompensated non-linear electronic loads and PFC-managed ones. The control system that PFCs such as Vicor's PFM use avoid propagating spurious harmonics legacy electronic loads generate and provide significant benefits to the utility line in terms of overall power quality.

Avoid operation near power minima

Every switch-mode power supply presents an efficiency curve that quickly approaches zero when minimal power is processed. In PFC applications, the goal is to present a purely resistive behavior with respect to the input line, aiming for sinusoidal input power to the converter. The nature of this task implies a variety of tradeoffs:

- CCM (continuous-conduction mode), constant frequency operation enables optimal powertrain design, but operates the converter efficiency curve close to zero at line crossings.
- DCM (discontinuous-conduction mode), variable frequency operation enables better efficiency, but the powertrain and magnetics designs are suboptimal.
- Hybrid approaches such as burst-mode or hysteretic converters present EMC and EMI challenges.

A new technique uses an effective current-modulation angle or dead-band with respect to the line voltage, symmetric around the zero crossing, and based on avoiding the portion of the line cycle not significantly contributing to overall power transfer. Figure 1 shows the relative reduction in power effectively drained from a pure sinusoidal line (resistive load) as a function of a symmetric conduction angle imposed on the input current (orange trace). The blue trace shows that, for example, 15 degrees of electrical angle around the zero crossing are worth just 3% of total available power, but this avoids the lower 25% of the entire line voltage operating range. The impact on the converter is not in avoiding processing the mere 3% of power with lower efficiency, but rather in optimizing powertrain, magnetics, and modulation timing within a narrower voltage range.

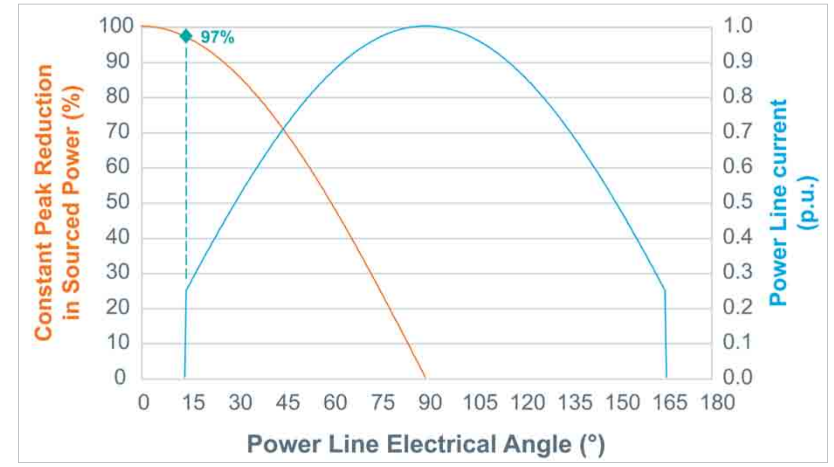

Figure 1: Converter input power vs. line current with a symmetric conduction angle, constant current peak and resistive load.

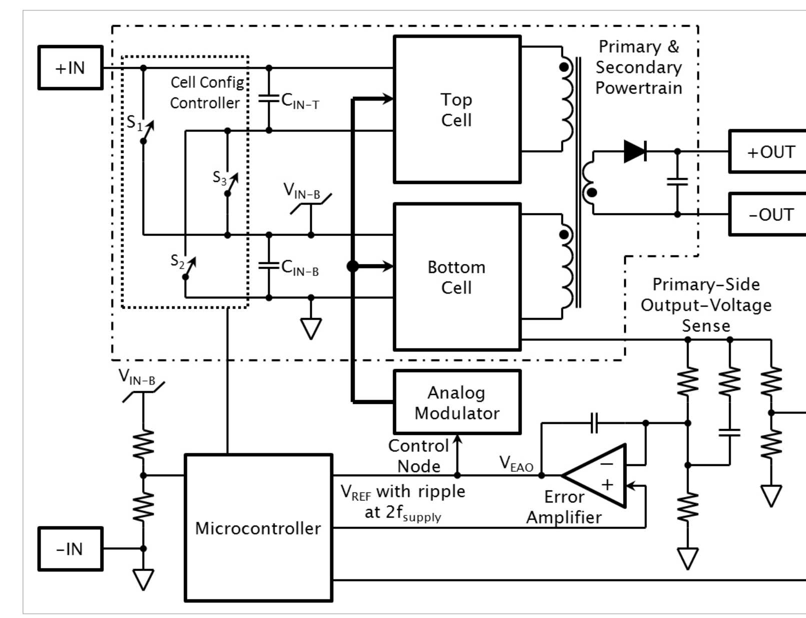

Figure 2: AC-DC converter block diagram

Implementation

In the PFC block diagram, two primary-stage cells magnetically couple with a single-ended secondary stage, while their inputs are configurable in either series or parallel with respect to the rectified power line (Figure 2). This approach provides several benefits, the most notable being the invariance of efficiency with respect to the input voltage.

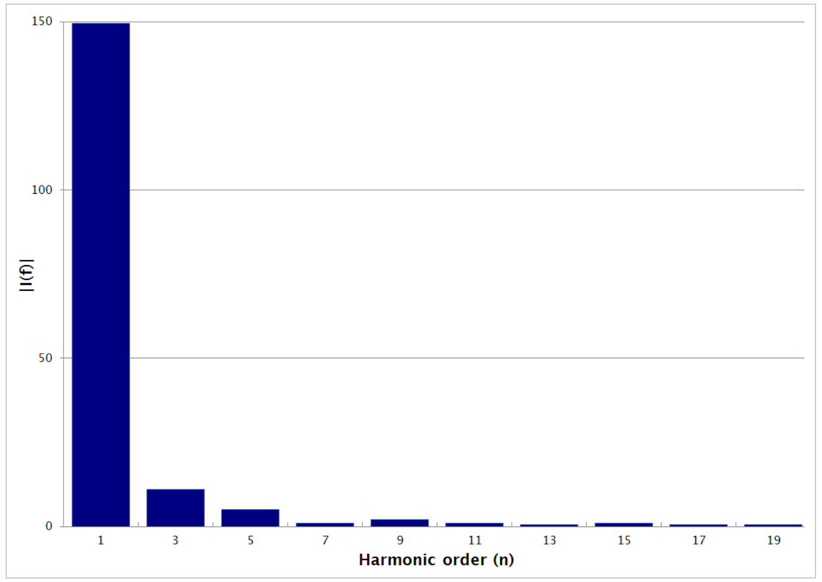

Figure 3: The harmonic content of a 120 VRMS sinusoid, clipped to 80% of its amplitude

Controls, which appear at the bottom of Figure 2, consist of a classic analog voltage-regulation loop. This loop manages the control node of an analog modulator to control the converter's output voltage. The microcontroller implements the algorithm: the analog loop reference is actively modulated based on input and output voltage, to achieve power factor correction and shape the input current appropriately.

It is important to note that the microcontroller only needs input line frequency and phase information to enable the powertrain outside the dead-band around the line's zero crossing. Although the controller samples the input voltage at a relatively high rate, line frequency acquisition requires few line cycles. This is a minor task for the digital control, resources of which apply to achieve power factor correction and shape the line current.

The conduction angle forced on the line current is responsible for 14% of THD. However, the circuit meets all applicable EMC standards.

Propagation of line-voltage harmonics

Classic PFC relies on direct or indirect measurement of the line voltage, which the controller uses to shape the input current. In cases where the line voltage presents greater harmonic content (typically in heavy industrial environments), the following issue can arise:

The current drawn by the input line closely follows the shape of the input line voltage. Harmonics on the voltage waveform is also present in the current waveform, which causes further line drops with the same harmonic content, therefore compounding and worsening the overall power-distribution quality.

PFCs often use active compensators in these cases, in order to meet utility regulations, but add operational costs. An alternative approach uses a digital algorithm, with the objective of obtaining a line current shape that meets all applicable IEC standards, achieves high power factor, but does not propagate line voltage harmonics. The technique's targets are:

- To maintain the ratio between input voltage and input current constant, therefore achieving PFC
- To maintain constant the ratio of the input voltage's moving average to the input current's moving average to reduce, and in some cases even cancel, harmonic content in the current waveform.

Equation 1 summarizes how this is achieved: v_{IN} and v_{CN} are the instantaneous values of the converter input voltage and the control node voltage, respectively (as shown in Figure 2), while $\overline{V}_{CN}$ and $\overline{V}_{IN}$ are their moving average values.

$$\frac{v_{IN}}{v_{CN}} = \frac{\overline{V}_{IN}}{\overline{V}_{CN}} = const. \quad \text{(eq 1)}$$

The introduction of the average term effectively causes a phase delay and affects the power factor by about 1%. The term also significantly reduces line-voltage-distortion propagation to the converter's input current, because higher-order harmonics whose periods falls within the averaging window are reduced over several sampling periods within the modulation algorithm.

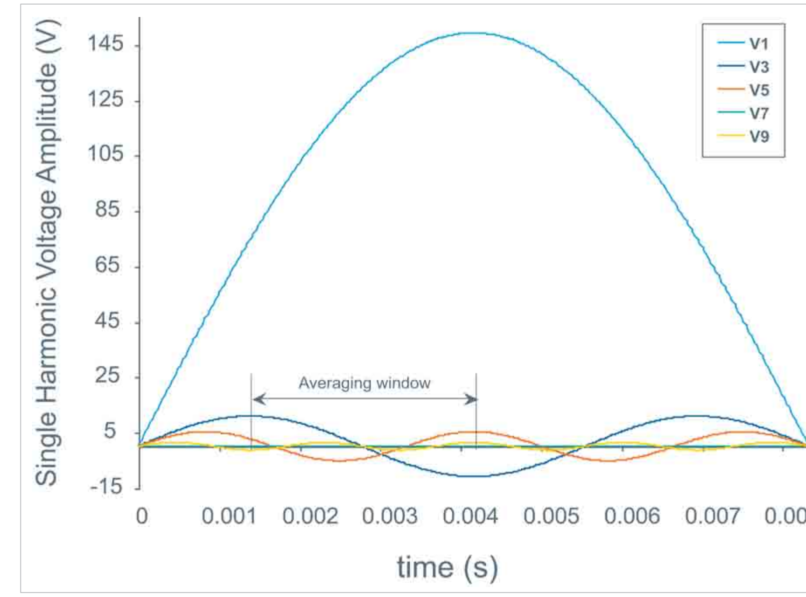

Figure 4: Time domain plot of the harmonics in figure 3, with a digital averaging window

Figure 3 shows the harmonic content of a 120 VRMS sinusoid clipped to 80% of its amplitude. Figure 4 shows those harmonics individually in the time domain, with an averaging window for the digital control, which helps to visualize how, by managing sampling rate and window width, higher harmonics are practically canceled.

Maurizio Salato
Director of Systems Engineering
Vicor

www.vicorpower.com

IMPROVING BATTERY-FUEL-GAUGE ACCURACY

New gauging technologies promise higher SoC accuracy, state-of-health assessment, and end-of-life prediction.

By: Isidor Buchmann

For simplicity, you can imagine the battery as an energy storage device analogous to a fuel tank. However, measuring stored energy from an electrochemical device is far more complex than that comparison suggests.

While an ordinary fuel gauge measures liquid flow from a tank of known size, a battery fuel gauge has unconfirmed definitions and only reveals the OCV (open circuit voltage)—a reflection of the battery's SoC (state of charge). A battery's nameplate ampere-hour rating remains only true for the short time when the battery is new. In essence, a battery is a shrinking vessel that takes on less energy with each charge, and the marked Ah rating is no more than a reference of what the battery should hold.

A battery cannot guarantee a quantified amount of energy because prevailing conditions restrict delivery. These are mostly unknown to the user and include battery capacity, load currents, and operating temperature. Considering these limitations, one can appreciate why battery fuel gauges may be inaccurate.

The most simplistic method to measure a battery's SoC is to read its voltage, but this can be inaccurate. Batteries within a given chemistry have dissimilar architectures and deliver unique voltage profiles. Temperature also plays a role: Heat raises the voltage and a cold ambient lowers it. Furthermore, when the battery is agitated with a charge or discharge, the OCV no longer represents the true SoC reading and the battery requires a few hours of rest to regain equilibrium. Battery manufacturers recommend 24 hours.

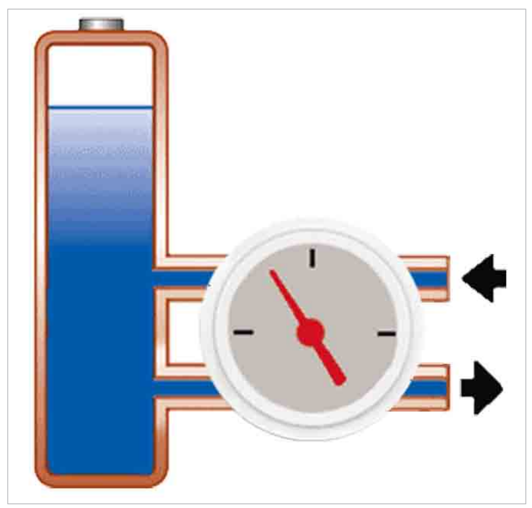

Figure 1: The principle of fuel gauging based on coulomb counting: The stored energy represents state of charge. A circuit measures the in- and out-flowing current

The largest challenge, however, is the flat discharge voltage curve on nickel- and lithium-based batteries. Additionally, load current through the battery's source impedance reflects as a voltage drop during discharge.

Many fuel gauges measure SoC by coulomb counting. The theory goes back 250 years when Charles-Augustin de Coulomb first established the Coulomb Rule. It works on the principle of measuring in- and out-flowing currents (Figure 1).

Theoretically, Coulomb counting should be flawless but, in practice, its accuracy is limited. For example, if a battery charges for one hour at one ampere, the same amount of energy should be available on discharge, but this is not the case. Inefficiencies in charge acceptance, especially towards the end of charge, and losses during discharge and storage reduce the total energy delivered and skew the readings. The available energy is always less than what the charging circuit had fed into the battery. For example, the energy cycle (charging and then discharging) of the Li-ion batteries in the Tesla Roadster automobile is about 86% efficient.

A common error in fuel-gauge design is assuming that the battery will stay the same. Such an oversight renders the readings inaccurate after about two years.

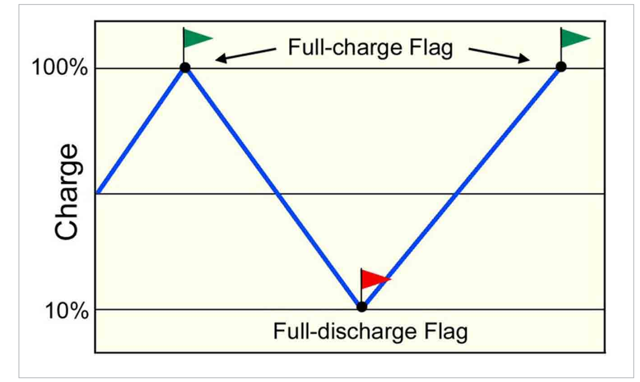

Figure 2: Full-discharge and full-charge flags set calibration

If, for example, the capacity decreases to 50% due to old age, the fuel gauge will still show 100% SoC on full charge but the runtime will be half. For the user of a mobile phone or a laptop, this fuel-gauge error may only cause a mild inconvenience. The problem becomes more acute, however, with an electric drivetrain that depends on precise predictions to reach the destination.

A fuel gauge based on coulomb counting needs periodic calibration, also known as capacity re-learning. Calibration corrects the tracking error that develops between the chemical and digital battery on charge and discharge cycles. The gauging system could omit the correction if the battery received a periodic full discharge at a constant current followed by a full charge. The battery would reset with each full cycle and the tracking error would remain at less than 1% per cycle. In real life, however, a battery may discharge for a few minutes with a load signature that is difficult to capture, then partially recharge and store with varying levels of self-discharge depending on temperature and age.

Manual calibration is possible by running the battery down to a Low Battery limit. This discharge can take place in the equipment or with a battery analyzer. A full discharge sets the discharge flag and the subsequent recharge fixes the charge flag (Figure 2). Establishing these two markers allows SoC calculation by tracking the charge between the flags. For best results, calibrate a frequently used device every three months or after 40 partial cycles. If the device applies a periodic deep discharge on its own accord, no additional calibration is necessary.

Calibration occurs by applying a full charge, discharge, and charge. This cycle can run in the equipment or with a battery analyzer as part of battery maintenance. If the application does not calibrate the battery regularly, most smart battery chargers obey the dictates of the chemical battery rather than the electronic circuit. There are no safety concerns if a battery is out of calibration. The battery will charge fully and function normally but the digital readout may be inaccurate and become a nuisance.

To overcome the need for calibration, modern fuel gauges use learning by estimating how much energy the battery was able to deliver on the previous discharge. Learning, or trending, may also include charge times because a faded battery charges quicker than a good one. The ASOD (Adaptive System on Diffusion) from Cadex Electronics, for example, features a unique learn function that adjusts to battery aging and achieves a

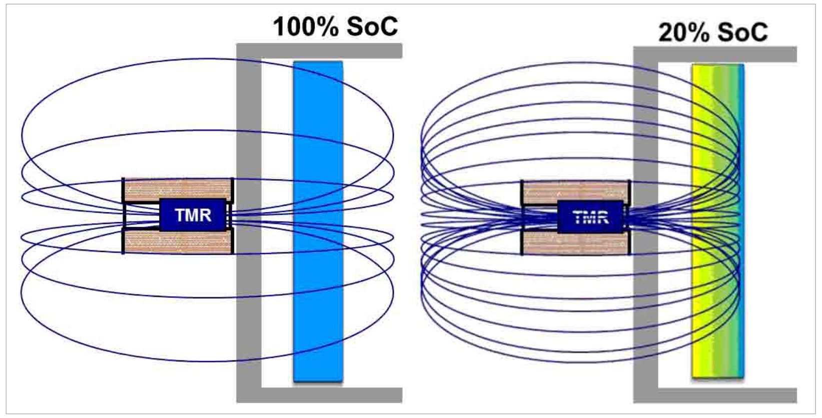

Figure 3: SoC by magnetic field response: The permeability of the plates increases by a factor of three from full charge to empty. Note: TMR (Tunneling Magneto Resistance) is also known as MTJ (Magnetic Tunneling Junction).

capacity estimation of ±2% across 1,000 battery cycles, the typical life span of a battery. SoC estimation is within ±5%, independent of age and load current. ASOD does not require outside parameters. When replacing the battery, the self-learning matrix will gradually adapt to the new battery and achieve the high accuracy of the previous battery. The replacement battery must be of same type.

Researchers are exploring new methods to measure battery SoC. Such an innovative technology is quantum magnetism, which does not rely on voltage or current but looks at the battery's magnetic characteristics. For example, the negative plate on a discharging lead-acid battery changes from lead to lead sulfate, which has a different magnetic susceptibility than lead. A sensor based on a quantum-mechanical process reads the magnetic field through a process called tunneling. A battery with low charge has a three-fold increase in magnetic susceptibility compared to a full charge (Figure 3). Cadex's calls its implementation of this technology Q-Mag.

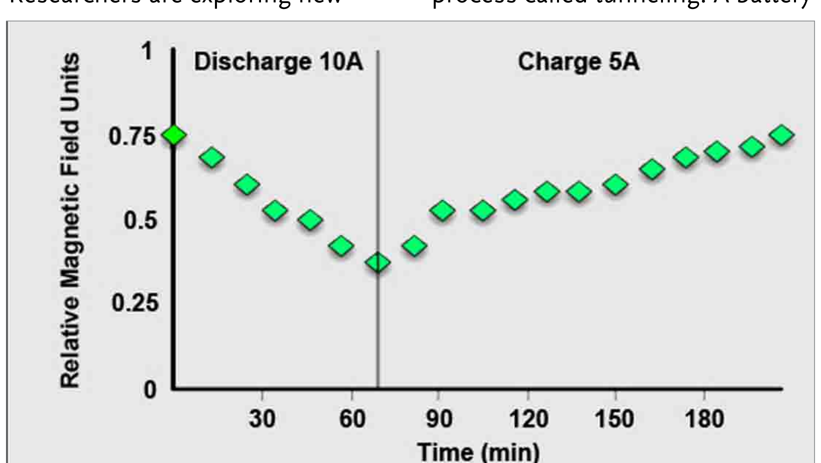

Figure 4: Magnetic field measurements of a lithium iron phosphate during charge and discharge. Relative magnetic field units provide accurate state-of-charge of lithium- and lead-based batteries.

Knowing the precise SoC enhances battery charging but more importantly, the technology enables diagnostics that include capacity estimation and end-of-life prediction. However, the immediate benefit gravitates towards a better fuel gauge, and this is of special interest for Li-ion with flat discharge curves.

Q-Mag-based measurements show a steady drop of the relative magnetic field units while discharging a lithium-iron-phosphate battery and a rise during the charge cycle (figure 4). The measurement data does not suffer from the rubber-band effect that is common with voltage-based measurements in which discharge lowers the voltage and charge raises it. Q-Mag reads SoC while the battery is charged or discharged. The SoC accuracy with Li-ion is ±5%, lead acid is ±7%; calibration occurs by applying a full charge. The excitation current to generate the magnetic field is less than 1mA, and the system is immune to most interference. Q-Mag works with cells encased in foil, aluminum, stainless steel, but not ferrous metals.

Isidor Buchmann
CEO & founder
Cadex Electronics Inc.
www.cadex.com
www.BatteryUniversity.com

SAFETY AND RELIABILITY IN HOME ALTERNATIVE-ENERGY SYSTEMS

Isolation and protection circuits keep homeowners and their equipment safe

By: Chun Keong Tee

Solar- and wind-power-based home AESs (alternative energy systems) are becoming more popular among consumers.

To achieve the product lifetime that consumers demand and ensure user safety, system designs need built-in protections against short circuits and other failures. The power inverter and its control system are the place to focus.

A home AES has several major components that must work together for optimum efficiency and lowest cost (Figure 1). The defining component is the power source. Solar panels are often equipped with an MPP (maximum power point) controller to increase efficiency. Home systems also use wind generators, both alone and to supplement solar panels as primary power sources.

Battery banks commonly serve in combination with solar panels and especially wind generators, to buffer the variable output of those sources and store surplus energy

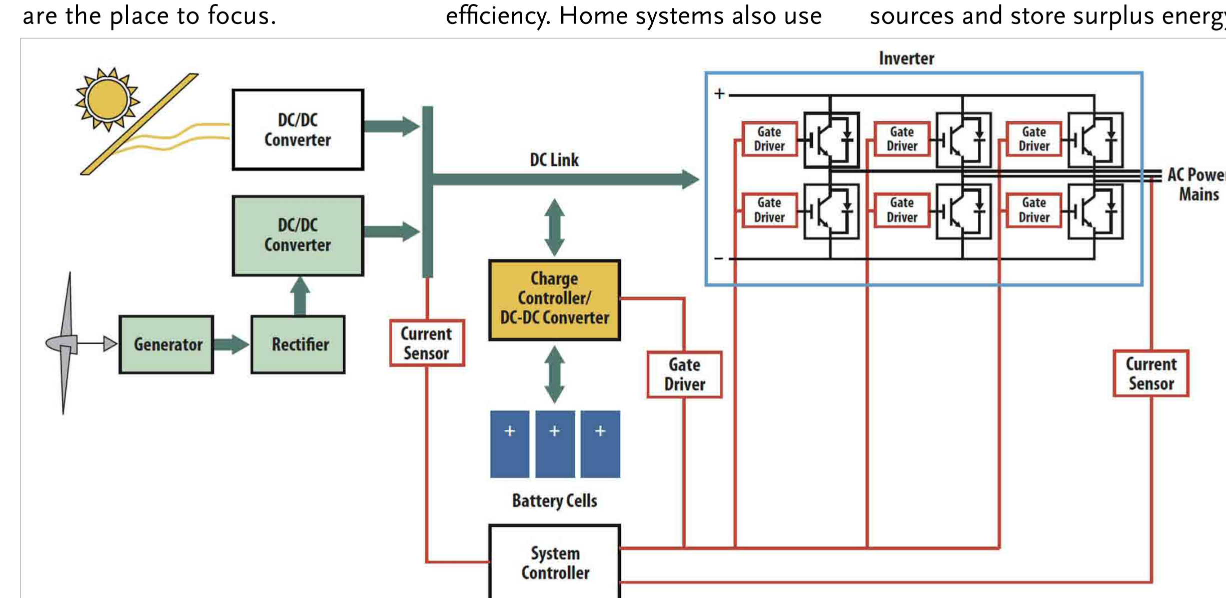

Figure 1: A typical AES design includes power sources sharing a common high-voltage DC Link, an inverter for generating AC, and a system controller ensuring coordinated operation.

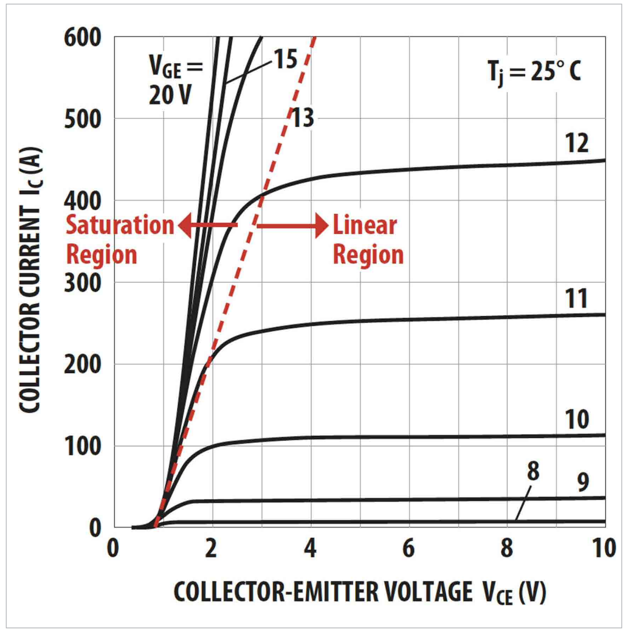

Figure 2: The IGBT switching transistors in inverters must operate in their saturation region when delivering high power in to avoid generating self-destructive heat.

for later use. Battery stacks include a battery-charge controller as a core system element. The controller continually monitors both user power demand, and power generation to direct current flow into or out of the battery as appropriate.

Each power source incorporates a DC-DC converter and feeds a common high-voltage DC bus, the DC Link. This DC Link is what feeds power to the inverter that produces the system's AC output. The DC Link typically runs in the 600 V to 1200 V range to maximise the inverter's DC to AC power-conversion efficiency. Inverters for home power systems range in capacity from 1 kW to 30 kW and operate by rapidly switching the DC Link voltage to the AC power mains. High-voltage IGBTs (insulated-gate bipolar transistors) typically serve as the switches, operating in pairs to provide positive and negative output voltages.

Inside the inverter, switching typically occurs at a frequency of 50 kHz, and is on sufficiently long to charge the load capacitance on each main line to the instantaneous voltage that will properly mimic the AC supply. Providing the complex timing this mimicry requires under all load conditions is the job of the system controller. The controller also acts as the power monitor that drives the battery-charge controller, controls whatever user interface the system offers, and provides both fault detection and the system's safe response.

Safety and Protection Requirements

The controller's central role in both system operation and user interface brings a requirement to isolate the controller from the high voltages in the power pathways. Isolation is necessary to prevent the high DC-Link voltage from arcing into control lines, which could damage the controller electronics and possibly injure users. All sensor lines into and signal lines out of the controller need such isolation, especially those driving the inverter's IGBT power switches.

The inverter's central role in the power circuits requires that it offer high reliability to achieve the 15 to 20 year productive lifetime that consumers will demand of AESs to justify their cost. For customer satisfaction, the inverter should also be relatively immune to accidental damage since, at a cost of $2000 to $4000, failures would create an expense of nearly 10% of the initial system investment.

The inverter design must include circuitry to mitigate several known failure mechanisms in the IGBT switches. These include switching transients that can occur during normal operation, low gate voltages that can occur when system batteries have depleted, and short-circuits on the mains that can occur at any time due to faults or user error. Ideally, the IGBT drive electronics would provide both this fault protection and the controller isolation the system needs.

Isolation Choices

Designers have several technology choices for providing isolation in a home energy system. A magnetic isolation device, for instance, couples signals across a thin insulating barrier through magnetic induction. This approach may not be fail-safe, however. During a high-voltage electric fault, the thin insulation barrier breakdown may cause a short circuit that can potentially be user hazardous when touching controls and causing damage to low voltage logic components. Magnetic isolation is susceptible to EMI, confounding controller operation.

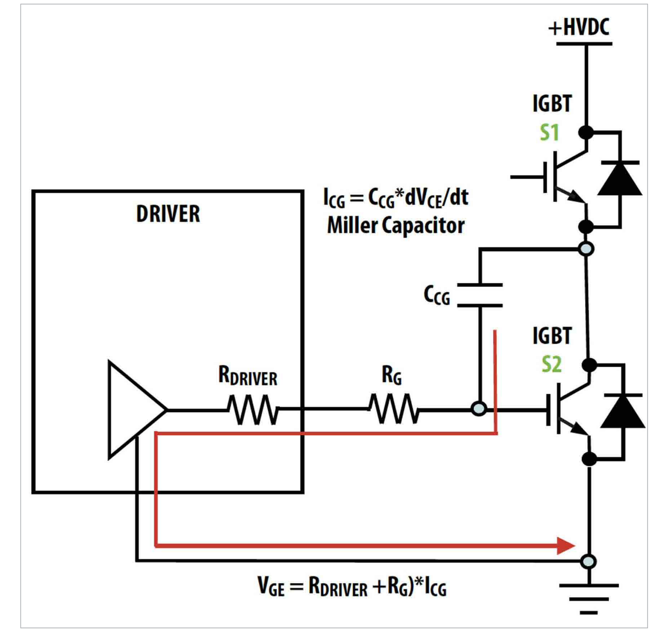

Figure 3: Two transistors alternate connections to the output to generate AC from DC. But parasitic Miller capacitance in the driver can keep switch S2 turned on too long, creating a damaging short circuit.

Capacitive coupling is another means of isolation. The insulation barrier is also a thin dielectric within the capacitor. Like magnetic coupling, capacitor-based isolation is susceptible to EMI, readily passing high-frequency noise to the controller.

A third alternative, optical isolation, offers several advantages having no need of the high- and low-voltage lines to be in close proximity. The distance through insulation that a short circuit would have to travel virtually guarantees that no such short can occur.

An optocoupler LED-photodiode combination is immune to EMI due to the optical coupling path Optocouplers can withstand much higher electromagnetic fields than other currently available isolators.

Choose optocouplers, such as those that Avago provides, that component-level safety standards recognise including UL1577, CSA and IEC 60747-5-5. IEC 60747-5-5 is the official release of the International Safety Standard for optocoupler for reinforced insulation since 2007.

Although this standard pertains to optical isolators only, other isolation technologies such as magnetic or capacitive have also obtained the certifications to the optocoupler safety standard. However, their recognition is limited to obsolete IEC 60747-5-2 standard and for basic insulation only against electrical shock. Such devices cannot be considered failsafe. Reinforced insulation provides protection from electric shock and is also a failsafe device design.

Inverter Fault Protection

For high inverter reliability in the home-energy system, IGBT transistor drivers must incorporate circuits to prevent or mitigate common failure modes that can damage the IGBT. Normally, the IGBT is operating in the transistor's saturation region, which allows it to conduct high currents with a low VCE voltage drop across the transistor (Figure 2). To enter this state, the IGBT needs at least 12 V on its control gate.

A home energy system can fail to meet that gate drive requirement in several ways An excessive load or a direct short on the inverter's AC mains would result in abnormal current through the IGBTs causing the voltage drop across the transistor to rise and quickly lead to device failure.

Another way for the IGBT to leave its saturation region is for the gate-control voltage to drop below its minimum level. This drop can occur if there is a decline in the logic supply voltage due to deep battery discharge, if power generation has been insufficient to meet demand over a sustained period. As with the excessive current draw condition, the low gate voltage results in a rise in transistor voltage, VCE, and heating leading to device failure.

Failures also arise from the inevitable parasitic inductance and capacitance in switching circuits. Inductance causes voltage spikes if the IGBT shuts its output down too quickly, which can be large enough to damage the device. Energy stored in a the parasitic Miller capacitance at the IGBT's control gate can cause one switch of the pair to stay closed too long, resulting in a short circuit across the DC Link (Figure 3).

Fortunately, protective circuits can prevent or mitigate these failure modes, and signal the system controller when a fault has occurred. An under-voltage lockout circuit, for instance, can ground the gate voltage, keeping the IGBT turned off in the event the supply voltage is too low to provide proper gate drive. Such a circuit should include hysteresis, however, to avoid oscillation when the supply voltage is at the lockout threshold.

Another useful protective circuit is a desaturation detector. This circuit monitors the VCE voltage across the IGBT. If it rises above about 7 V the IGBT is in danger of damage from excessive heating. The detector circuit shuts down the IGBT gate driver during desaturation, eliminating the danger.

Careful circuit design and board layout can reduce parasitic inductance in the inverter, reducing the magnitude of transient voltages when the IGBT switches off, but they cannot guarantee eliminating the danger. Designing the IGBT driver for a soft turn-off, however, ensures that the transient voltages never become dangerous.

Board design cannot eliminate the Miller capacitance; it is inherent in the IGBT's structure. A clamping circuit, however, can eliminate its effect. An active Miller clamp can monitor the gate voltage when turning off the IGBT, stepping in to short the parasitic capacitance when the gate voltage drops below a threshold, guaranteeing shutdown timing.

The protection against fault conditions that these circuits provide as well as the protection against short-circuits that isolation provides, are both essential for enhanced safety and reliability in home energy systems. Optocouplers provide the isolation necessary to ensure user safety, preventing component damage despite high voltages present in the DC Link. Protective circuits in the IGBT gate drivers help extend inverter lifetime, preventing the most common failure modes. Together, these functions can help AESs achieve the reliability and safety consumers demand of an operating energy system.

Chun Keong Tee
Technical Marketing Engineer
Avago Technologies

www.avagotech.com

CONSUMER-FRIENDLY POWER DESIGN

Efficiency, heat dissipation, battery management, and ease of use all affect the customer experience of electronic products

By: Masoud Beheshti

The intricacies of power design are not conversation pieces for electronic-product consumers. Nor should they be.

Consumers care about visible signs of power design in the product, including the size of the power adaptor, how hot the product gets while in use or at rest, runtime, and battery lifetime.

The journey from source to load is not free

Power's journey from a source to various points of load in the system is a necessity. It is also an opportunity for creativity and innovation. This is a concept that consumers are fairly familiar with in other domains. When we fill up our gas tank and pay cash, we know how the gas mileage of the vehicle determines the next time we need to reach into our pocket again. Of course, our driving habits play a role, but all things being equal, ultimately the vehicle design determines what we can expect.

When it comes to electrical and electronic products, the direct correlation between cash and

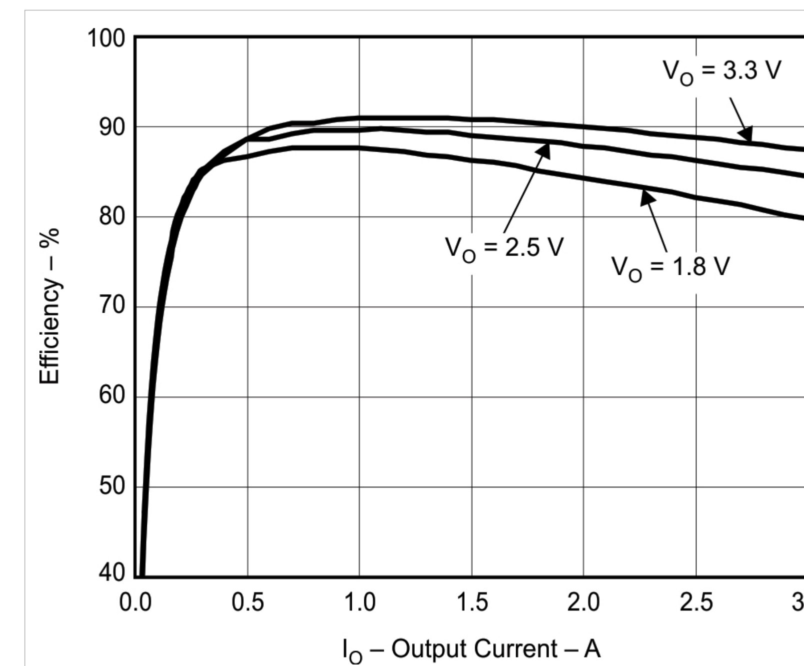

Figure 1: Step-down converter efficiency used to power the main processor in a set top box

mileage may not be as obvious. However, consumers have come to appreciate the relationship between power use and waste to their electric bill each month. Factors such as leaving the lights on unnecessarily or setting thermostats extremely low at the height of summer, contribute to power waste. However, ultimately, it is the product's power design that determines its efficiency and how much power is wasted.

Several key elements drive efficiency performance in these products. These include but are not limited to:

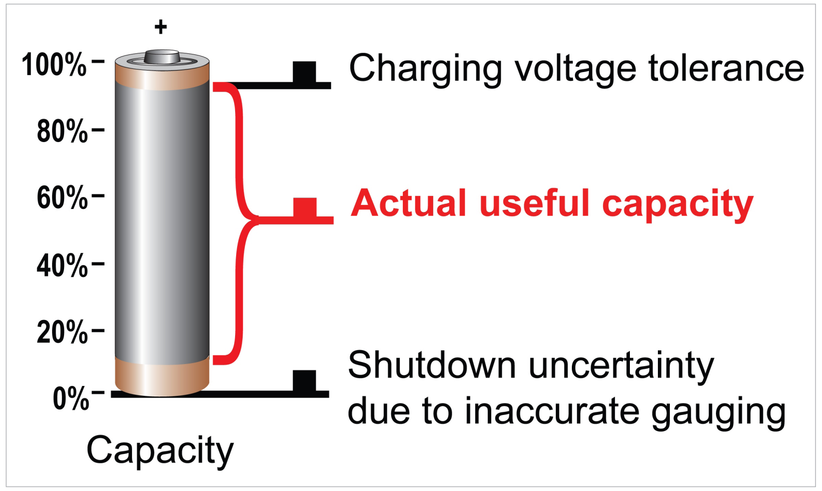

Figure 2: Inaccurate capacity measurement reduces system runtime by as much as 10-20%

- System power conversion topology, including both AC-DC and DC-DC power stages
- Switching and conduction losses in both active and passive components
- System thermal and mechanical designs
- Cost and performance tradeoffs

In a fairly complex system, such as a set-top box with DVR capability, there are many load points requiring a common or dedicated power rail. The efficiency of each power stage adds and drives the overall system performance and amount of heat generated and experienced by the consumer.

Efficiency, though critical at full load, is important across the product's entire operating range (Figure 1). This includes light-load conditions when the device is idling. Light-load efficiency reduces long-term power consumption and what has become known as the vampire power drain.

Can I make one more call?
As consumers, we have come to not only love, but depend on portable devices such as smartphones, tablets, and ultrabooks. Similar to a car, when the gas tank is full we are happy and worry free. As the needle moves closer to empty, the anxiety level starts to rise: Can I make it to the next gas station? Or in our case here, can I make that one urgent call, or can I finish watching the last 10 minutes of the movie before the flight lands?

System efficiency is a major factor but so too is the battery management—an all-encompassing term that covers many aspects of how we use and treat advanced rechargeable batteries:

- safety during charge and discharge
- authentication
- cell balancing
- charging methods that minimize charge time without compromising battery health
- monitoring and compensating for battery aging
- accurately measuring remaining capacity

When it comes to battery capacity monitoring, no one method fits all applications. High-end portable devices, such as notebook computers, may require a more sophisticated approach, both in terms of the number of parameters monitored and calculated, and in terms of interface to the battery pack electronics and system processor.

A battery-capacity monitor, or gas-gauge IC, reports a multitude of critical information to the system processor, which uses this information as the basis for managing the system power. The parameters the IC reports include cell voltage, average and instantaneous current, temperature, remaining battery capacity, remaining time to empty with system alarms, relative and absolute battery state-of-charge, and battery- and manufacturer-specific information. This data communicates to the system processor over a digital interface bus such I2C or SMBus.

Accurate gas gauging plays a major role in extending the system runtime. Without it, systems tend to shut down prematurely because the host cannot assess the battery's capacity (Figure 2).

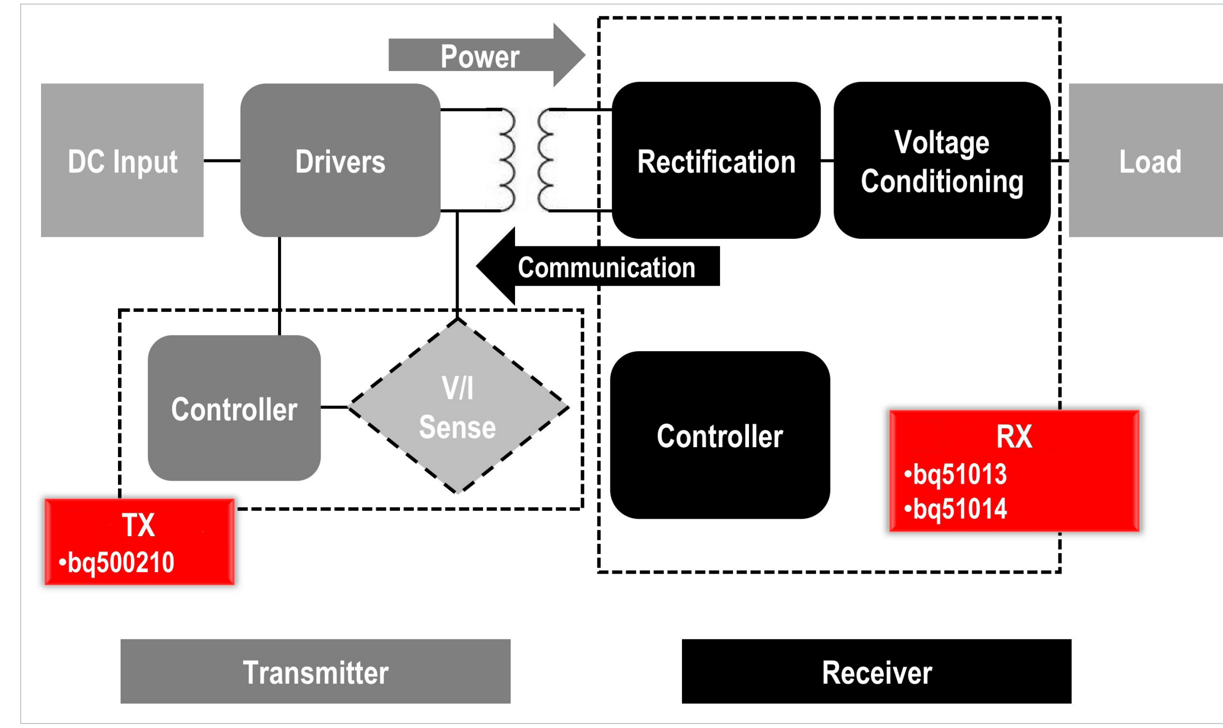

Figure 3: System block diagram for a wireless charger transmitter and receiver

It's all about ease-of-use
Ease-of-use is a critical differentiating factor in the consumer space. New technologies now enable OEMs to extend this trait to the power area. One great example is energy harvesting. This technology allows the product to seamlessly take power from alternative energy sources such as solar, vibration, heat, and RF. Advancements in both the harvesters and power converters are increasing the use and reach of this method well beyond the traditional solar cells calculator and watches use.

Another exciting area is wireless power. Also known as inductive or contactless charging, it enables the consumers to charge their portable products without the hassles of cables and connectors and by simply placing the device on a charging surface.

To make this technology more consumer-friendly, a considerable amount of work and collaboration has been applied to standardization. Standardization makes various devices interoperable, so various makes and models of portable devices, from phones to digital cameras to Bluetooth headsets, charge using a common charging pad.

Many industry participants, including Texas Instruments, have been active in the WPC (Wireless Power Consortium). The WPC first published a Qi-standard specification in 2009 and many OEMS are now offering Qi-compatible products. Qi technology includes an inductively coupled power circuit that dynamically seeks resonance, allowing the primary supply circuit to adapt its operation to match the needs of the devices it supplies (Figure 3). It does so by communicating with each device individually in real time. This allows the technology to determine power needs and factors such as the battery or device age and charging lifecycles. Qi technology supplies the optimal amount of power to keep a device at peak efficiency.

Masoud Beheshti
Director of Product and Marketing Strategy
Texas Instruments
Power Supply Solutions

www.ti.com

WIRELESS POWER EMERGES AS NEW FIELD FOR POWER SUPPLY AND ELECTROMAGNETICS DESIGN

By: David G. Morrison

Hoping to make battery charging more convenient, many mobile-device manufacturers are now turning to wireless power technology. Mobile-device manufacturers seek to eliminate the consumer's need for multiple power adapters, while improving access to charging stations in public places like cafes and airports.

The activities of the Wireless Power Consortium (WPC) with its 5-W Qi standard and 100+ company membership attest to the high level of interest in wireless charging solutions for handheld consumer products. But the efforts to develop wireless power transmission go well beyond those applications, encompassing a range of equipment types, power levels, charging and non-charging uses, and technologies for transmitting power over different distances.

Though the concept of wireless power transmission goes all the way back to Tesla, much of the technology and its applications are new. Moreover, the large number of companies currently developing wireless power products suggests that this is an area that may generate new career opportunities for power electronics (PE) engineers in the years ahead. (Some examples of recent job postings and resources for learning more about the companies in this field appear in the online version of this article.)

For PE engineers looking to work in this area, it may be encouraging to learn that the power supply topologies, design techniques, and components being deployed in wireless power applications are, for the most part, similar to those PE engineers have been working with in other application areas. However, there are some design challenges unique to the wireless power products, most notably the design of the transmitting and receiving coils. This aspect of the technology creates a fundamental requirement for electromagnetics modeling and simulation.

Depending on what stage of technology development a company is working on, and how the design team is organized, the requirements for electromagnetics simulation may impact the type of skills demanded of PE engineers working in this emerging field of wireless power. In this column, two developers of proprietary technologies—Wireless Power & Communication AS and WiTricity Corp.— share their insights on the design challenges encountered in their applications and the types of engineering skills that they and their customers rely on to create wireless power solutions.

Wireless Capability is Crucial in Some Industrial Applications

Wireless Power & Communication AS of Kristiansand, Norway uses its proprietary wireless power technology to address power supply requirements in industrial applications for which wired solutions are problematic. For example, their wireless power designs are used in hazardous environments such as oil rigs where the spark produced during mating/unmating of a power connector could ignite explosive gases.

Wireless Power & Communication's designs are also used on remotely operated vehicles (ROVs) for subsea applications where wireless power enables tool changes on the ROV while at depths of several thousand meters. Without wireless power transfer, the ROV would need to return to the surface vehicle to disconnect/connect a power plug, which would add hours of transit time (and cost) to the operation. In these and other applications, there is a need to avoid exposed metal and there is difficulty in positioning traditional multi-pin connectors.

This company's technology inductively couples power to the device of interest, either to charge a battery or to power that device directly. The distance over which power is transmitted is typically limited to the thickness of the product's encapsulation, which is usually in the range of 5 to 10 mm. But the transmit capability can be extended to cover greater distances such as 10 cm. While the inductive coupling across a span of several millimeters sounds similar to the methods associated with the Qi standard for wireless charging, the power levels are vastly different. Wireless Power & Communication's designs typically target applications in the range of 500 to 2000 watts.

According to Audun Andersen, Sales & Development Engineer at Wireless Power & Communications, the most challenging aspect of the design may be limiting noise generation and emissions to comply with EMI standards such as those demanded for CE certification. "If you do a search on the web, you will find many demos of wireless power, but you won't find many products that are for sale. And one of the challenges people are facing is complying with the regulatory limits on EMI," says Andersen.

He adds that many wireless power designs "generate too much noise, either radiated or conducted back onto the power lines. And the higher the power you want to transfer, the bigger the challenge to keep the noise down. So if you look at the products that actually are for sale, you'll see that most of them are maybe 5 watts."

According to Andersen, limiting noise is largely a matter of design technique rather than material selection. "It's mostly related to design technique and how you control the field. So it's the power between your coils, and how you control that."

For PE engineers working on these types of wireless power applications, there are a number of skills that come into play.

"To be successful in doing these kind of designs you need to have a complex understanding of the design because you have a voltage regulation system that needs to control the variation in position and in the load and you also have to have a noise level that allows your regulation signals to go from the secondary side to the primary side. So, to make such a regulation system, you have to have knowledge of both software and hardware, especially analog design. And to design the coils, you need to have some knowledge about inductors and different materials that you can use," says Andersen.

He adds that "In terms of the magnetics, the big challenge is that you're now using coils and ferrite materials in a different way than traditional power supplies. So we have to start thinking a bit differently."

Simulation is an important element of the magnetics design. "We do simulations for designing the coils," says Andersen who notes "You don't find many tools that are optimized for these kinds of problems or coils. But there are ways to use traditional magnetic simulation tools to get decent results."

Looking at the overall skillset required of the PE engineer, he characterizes it as including a wide variety of skills "especially if you want to make a cost efficient product with high efficiency on the transmission." Nevertheless, despite the unique aspects of wireless power, the experience gained by PE engineers in other applications is very much transferrable to this field. "Typically, an experienced power supply designer will be capable of understanding a lot of the concepts being used here," says Andersen.

"A lot of these designs are actually, more-or-less power supply designs in the traditional way. You have to adapt to the input power that's available to you. In some cases, you might have a low dc voltage, in other cases you have a high ac voltage. And typically on the secondary side, the receive voltage is higher than what you're actually delivering out to the application. So you need to downconvert to the appropriate voltage. Maybe in some cases you want to change the received dc to an ac voltage as well. So there are a lot of power supply design issues," says Andersen.

Moreover, PE engineers are not working alone. "Usually this is not a one man show and you typically combine people with software-hardware experiences," says Andersen. "So in addition to the power supply typical software, there are engineers with embedded programming skills and analog hardware design." The latter are called on to implement communications and filters.

While inductive power transfer is the basis for many wireless power designs, an alternative approach known as highly resonant power transfer developed by WiTricity promises more robust performance over longer distances. To read about WiTricity's insights into wireless power design challenges, see "Highly Resonant Technology Expands Usability of Wireless Power" in the online version of this article.

David G. Morrison
Editor

How2Power.com

FUEL CELLS EDGING IN AND AROUND RENEWABLES

By: Gail Purvis, Editor-in-Chief, Power Systems Design

Three fuel cell news items current suggest a sound growth of the fuel cell for the power-systems market.

Germany's SFC Energy founder Manfred Stefener is among nominees for the European Inventor Award this month. In the UK, Logan Energy goes for second round funding. Japan's MHI (Mitsubishi Heavy Industries) begins research into developing technologies for a triple combined cycle power-generation system, integrating SOFC (solid oxide fuel cells), GTCC (gas turbine and steam combined cycle) for the FCCC (fuel cell combined cycle) system.

German engineer, Manfred Stefener, whose 1977 PhD showed hydrogen as an expensive fuel, lacking infrastructure, turned him instead to methanol as four times denser than hydrogen. SFC Energy miniaturised the fuel-cell structure, making it more commercially viable for off-grid power generation and distribution and has now received an order from the German Bundeswehr for the portable JENNY fuel cells in a new energy network comprising an SFC Power Manager, a hybrid battery, with a solar panel as alternative power source.

The network allows the use of radios, navigational equipment, night-vision equipment, laser range finders, portable computers and PDAs, both used when stationary and on the march. The €5M network should deliver this year.

Logan Energy directors in Scotland have led a management buyout in order to secure second-round funding. US Atlanta parent Logan Energy Corp is redistributing its minority holdings to the directors.

Logan has supplied Proton Exchange Membrane, Phosphoric Acid and Carbonate power plants ranging from 5 kW to 2.8 MW capacities. The company has installed more than 140 fuel-cell plants exceeding 8 MW of capacity at more than 90 locations in the US and UK. The new structure will enable the company to secure the second-round funding for a marketplace currently doubling every year.

MHI is launching its two-year study this year as part of a project for SOFC that it tendered and has had accepted by NEDO (New Energy and Industrial Technology Development Organization) Japan. In the triple combined-cycle power generation system, the SOFC power generation system is placed before the GTCC system. Generating power in three stages—fuel cell, gas turbine, and steam turbine—the FCCC system claims to efficiency exceeding 70% LHV (Lower Heating Value) for several-hundred-MW class generation and over 60% LHV efficiency for several-tens-of-MW class generation.

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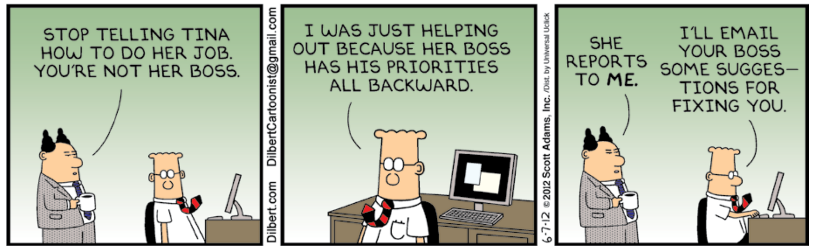
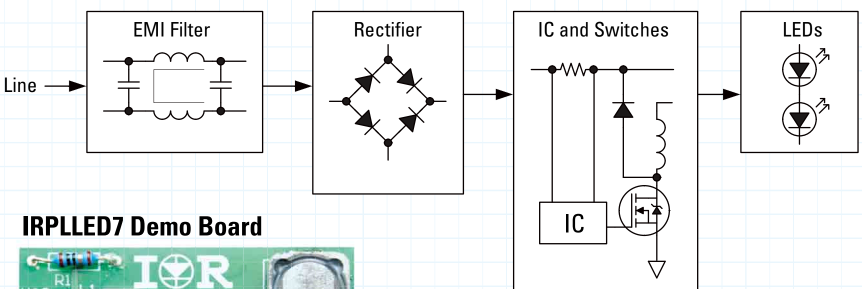
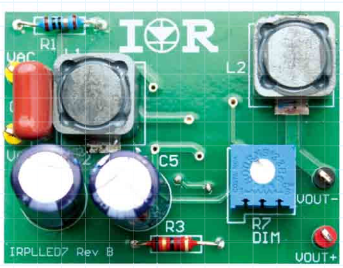
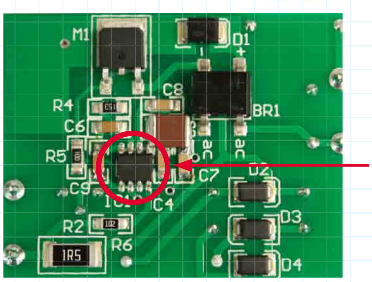


High-Voltage Buck Control ICs for Constant LED Current Regulation



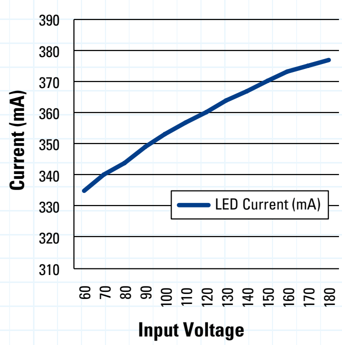
IRPLLED7 Demo Board





LEDrivIR™
IRS2980

IRPLLED7 Demo Board LED Current vs Input Voltage



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

IRS2980 Features

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

IRS2980 Benefits

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

Demo Board Specifications

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

For more information call +49 (0) 6102 884 311
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