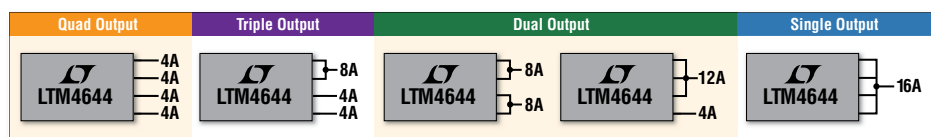




# Quad 4A $\mu$ Module Regulator



9mm x 15mm x 5.01mm  
(Actual Size)



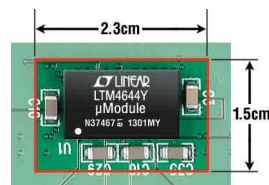
## Current Share from 1 to 4 Outputs, up to 16A from 4V<sub>IN</sub> – 14V<sub>IN</sub>

Simplify your power. The LTM<sup>®</sup>4644 is a  $\mu$ Module<sup>®</sup> switchmode step-down regulator with 4 outputs, configurable as a single, dual, triple or quad. With this flexibility, a simple and compact 9mm x 15mm BGA  $\mu$ Module regulator can power the variety of voltage and load requirements of FPGAs, ASICs and microprocessors.

### Features

- 4V<sub>IN</sub> ≤ 14V or 2.375V<sub>IN</sub> ≤ 14V with External Bias Voltage
- 0.6V ≤ V<sub>OUT</sub> ≤ 5.5V Each Output
- Guaranteed ±1.5% DC Output Voltage Accuracy from -40°C to 125°C
- Independent Input Supply Pins for Each Channel
- Output Overvoltage, Over Temperature and Short-Circuit Protection
- Internal Temperature Sensing Diode

### Only 8 Capacitors and 4 Resistors



Double-Sided PCB

### Info

- ▼ Obtain Data Sheet
- ▼ Request Demo Board
- ▼ Download LTspice<sup>®</sup> Demo Circuits
- ▼ Download CAD Symbols and Footprints
- ▼ Supported by LTpowerCAD<sup>™</sup> II

[www.linear.com/product/LTM4644](http://www.linear.com/product/LTM4644)  
+49-89-962455-0

LT, LT, LTC, LTM, Linear Technology, the Linear logo, LTspice and  $\mu$ Module are registered trademarks and LTpowerCAD is a trademark of Linear Technology Corporation. All other trademarks are the property of their respective owners.



Europe Sales offices: France 33-1-41079555 Italy 39-02-38093656 Germany 49-89-9624550 Sweden 46-8-623-1600 UK 44-1628-477066 Finland 358-9-88733699 Distributors: Belgium ACAL 32-0-2-7205983 Finland Tech Data 358-9-88733382 France Arrow Electronique 33-1-49-784978, Tekelec Airtronic 33-1-56302425 Germany Insight 49-89-611080,

Setron 49-531-80980 Ireland MEMEC 353-61-411842 Israel Avnet Components 972-9-778-0351 Italy Silverstar 39-02-66125-1 Netherlands ACAL 31-0-402502602 Spain Arrow 34-91-304-3040 Turkey Arrow Elektronik 90-216-4645090 UK Arrow Electronics 44-1234-791719, Insight Memec 44-1296-330061



Empowering Global Innovation

[WWW.POWERSYSTEMSDESIGN.COM](http://WWW.POWERSYSTEMSDESIGN.COM)

Visit us online for exclusive content; Industry News, Products, Reviews, and full PSD archives and back issues

### 2 VIEWpoint

*Should we put bigger batteries in airplane black boxes?*  
By Alix Paultre, Editorial Director, Power Systems Design

### 4 POWERline

*IR's LEDrivr control IC simplifies design, reduces part count*

### 6 POWERplayer

*Smart Grid Band-Aids*  
By Edward Herbert, PSMA

### 8 MARKETwatch

*A bright outlook for LED lighting*  
By Ryan Sanderson, IHS

### 9 DESIGNtips

*Interpreting loop gain measurements*  
By Dr. Ray Ridley, Ridley Engineering

### 20 Power Supplies

*Advanced design topics for offline flyback power supplies - Part 1*  
By Jason Guo, Fairchild Semiconductor

### 24 Embedded Power

*Using micro converters for board-level DC/DC*  
By Yojiro Shiina, Torex Semiconductor

### 29 Industrial Applications

*Two-switch forward converter: operation, FOM, and guidelines for device selection*  
By Sanjay Havanur and Philip Zuk Vishay Intertechnology

### 33 Power Semiconductors

*Moving forward with reverse-blocking IGBTs*  
By Nitesh Satheesh and Akihiro Fukuchi Fuji Electric

### COVER STORY

### 13 Digital power providers must play to their strengths

By Mark Downing Intersil

### TECHNICAL FEATURES

### 17 Wide-Bandgap Semiconductors

*Driving high-power GaN transistors*  
By John Roberts, GaN systems

### 36 Improving Thermal Management of LEDs

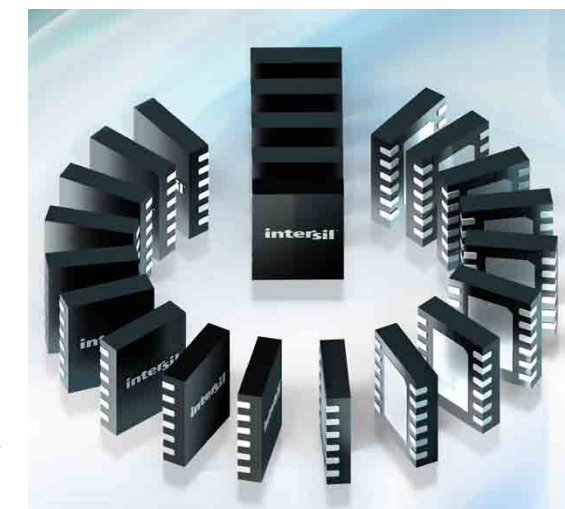
By Mark Youmans, Cree

### 40 Connecting Modern Lighting to a Brighter Future

By Jim Bachle and Amanda Bell, WAGO

### 43 Decoding the Digital Addressable Lighting Interface (DALI) protocol

By David Maliniak, Teledyne LeCroy



### COVER STORY

Digital power providers must play to their strengths (pg 13)



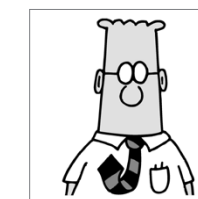
Highlighted Products News, Industry News and more web-only content, to:

[www.powersystemsdesign.com](http://www.powersystemsdesign.com)

### 48 GREENpage

*Blocking the sun*  
By Alix Paultre, Editorial Director, Power Systems Design

### 48 Dilbert





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

**Editorial Director**  
Alix Paultre, Editorial Director,  
Power Systems Design  
alixp@powersystemsdesign.com

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

Ryan Sanderson, IMS Research  
ryan.sanderson@imsresearch.com

Dr. Ray Ridley, Ridley Engineering  
RRidley@ridleyengineering.com

**Publishing Director**  
Jim Graham  
jim.graham@powersystemsdesign.com

**Publisher**  
Julia Stocks  
julia.stocks@powersystemsdesign.com

**Production Manager**  
Chris Corneal  
chris.corneal@powersystemsdesign.com

**Circulation Management**  
Christie Penque  
christie.penque@powersystemsdesign.com

**Magazine Design**  
Louis C. Geiger  
louis@agencyofrecord.com

Registration of copyright: January 2004  
ISSN number: 1613-6365

Power Systems Corporation and Power Systems Design Magazine assume and hereby disclaim any liability to any person for any loss or damage by errors or omissions in the material contained herein regardless of whether such errors result from negligence, accident or any other cause whatsoever.

Free Magazine Subscriptions, go to:  
www.powersystemsdesign.com

Volume 11, Issue 04



## Should we put bigger batteries in airplane black boxes?

One question a lot of people are asking in the wake of the Malaysia Airline Flight 370 tragedy (yet to be resolved as I write this), and the resulting mystery as to its fate, is why don't flight data recorders (called "black boxes"), have bigger batteries? In many cases a crashed aircraft can be relatively easily found, especially if the crash was on land or near shore. However, as this case demonstrates, an aircraft loss in the deep sea can take months, and the battery in current black boxes only last weeks. What should we do?

Sadly, any change would have to wind its way through the regulatory and commercial process of adoption, and also require significant engineering effort to upgrade the related systems and redesign the packaging to accommodate and protect a larger battery, but we will not address these issues here. Let's just concern ourselves with the issue of how to improve our oversight on airplane crashes so we can prevent (or at least significantly reduce) their recurrence. The biggest issue involved is the recovery of data from the aircraft after the fact.

Data recovery is a problem other vehicular black-box systems do not share, as they occur on known and explored land and can be easily recovered. Sea vessels, having had to deal with disaster management far before any autonomous systems, have long ago developed their own multiple-redundancy processes and technologies for both dealing with and recovering from catastrophic situations. Only in aircraft do we have the potential need to search through woods, mountains, and seas for the data package that would tell us the fate of the passengers and crew.

But would putting in a larger battery be the best solution? This has come up in the debates going on in the industry and legislature, as it has become apparent to all that even in busy world very large things can fall through the cracks without proper oversight. A larger battery in the black box would enable the search for Flight 370 to go one for longer, increasing the chances that the aircraft wreckage would be found. Larger batteries in all black boxes would give us that much more time to find that vital information in the future.

However, that just increases the chances of finding the recorder, it does not guarantee that the box will be found. It is an appealing and intuitive solution to a very real problem, but it is a solution based on last-century technology. We need a solution that will not only prevent what is going on with Flight 370 from ever happening again, the solution should also bring with it modern real-world added value due to its advanced nature.

The best (but recognizably costly, but how much is safety worth?) solution would be to put aircraft into the Cloud. If every aircraft streamed its location, status, and other significant parameters while airborne, this situation would not exist, and we would know everything important about what happened to Flight 370. (Remote control to eliminate any hijacking or pilot-incapacitation issue would be an option worth looking into as well.)

Best Regards,

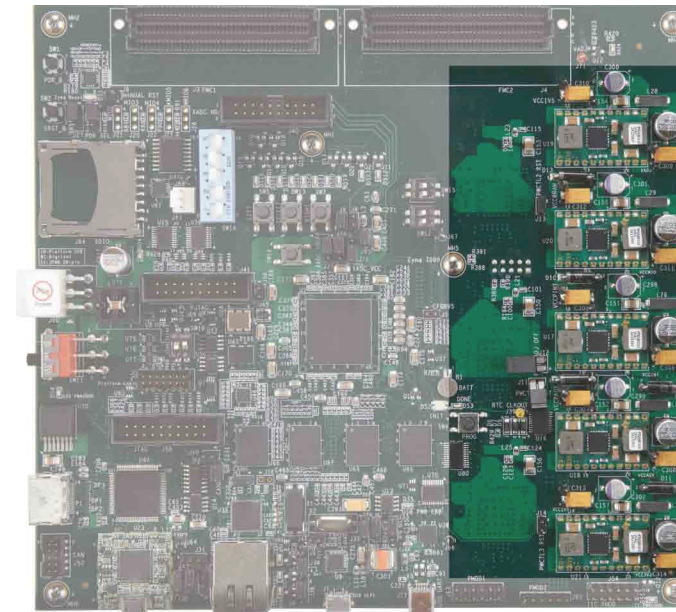
**Alix Paultre**

Editorial Director, Power Systems Design  
alixp@powersystemsdesign.com

# Exar's Universal PMIC Family

## Programmable Power Solution for Any FPGA or SOC

Exar's FPGA Power Solution is 90% Smaller with More Functionality



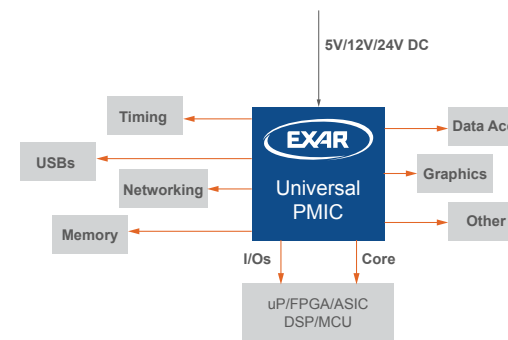
Traditional Power Solution



Exar's FPGA Power Solution



- Customize Your Own PMIC
- Easy to Use Design Software
- Reduced Time to Market
- 2 to 4 Channels at up to 30A
- Minimal Size & Component Count
- On Board Non-Volatile Memory
- Power and Status Telemetry
- Dynamic Voltage Scaling
- Remote Re-configurability



	XRP7713/14	XRP7720/24	XRP9710/11
Channel(s)	3 + 2 / 4 + 2	4 + 2	2 + 1 / 2 + 2 + 1
V <sub>IN</sub> Range	4.75-25V	4.75-25V	4.75-22V
Vo Resolution	50mV	2.5mV	2.5mV
Frequency	Up to 1.5MHz	Up to 1.2MHz	Up to 750kHz
Non-volatile memory	OTP	Flash	Flash
High Efficiency Light Load		✓	✓
Integrated Power Stage			✓
Package (mm)	5x5 / 6x6	7x7	12x12x2.75



A New Direction in Mixed-Signal

www.exar.com



# IR's LEDrivr control IC simplifies design, reduces part count

International Rectifier, a leader in power management technology, introduced the IRS2983 control IC for single stage Flyback and Buck-Boost topologies used in LED drivers and power supplies. The IRS2983 employs primary side regulation that reduces component count and simplifies design by eliminating the opto-isolator and other components necessary for isolated feedback for fixed loads.

The device also features a rapid startup circuit that drastically reduces the turn on time of the system, and also offers high power factor and low THD over a wide input range for many LED lighting applications. Comprehensive protection features including hiccup mode over-voltage protection, cycle-by-cycle over-current protection and open and short circuit protection are also included. The device also supports TRIAC dimming.

“Traditional incandescent, halogen, and CFL light sources are rapidly being replaced by LED bulbs, tubes and fixtures. The Flyback converter is the preferred power supply topology for a large segment of the LED driver market. Flyback LED drivers are simple, cost effective and efficient. IR's IRS2983 helps simplify the design



process and reduce part count and can also be configured to work with TRIAC dimmers,” said Peter Green, LED Group Manager in IR's Energy Saving Products Business Unit.

Available in an SO-8 package, the IRS2983 utilizes IR's advanced high-voltage IC process to deliver superior protection from electrical over-stress also offering micro-power startup, low quiescent current, latch immunity and ESD protection and noise immunity. Other key features of the IRS2983 include critical-conduction mode

operation, with discontinuous and burst modes at light load as well as flexibility allowing easy connection opto-isolated feedback circuitry for more complex designs.

**Availability and Pricing**  
Pricing for the IRS2983 begins at US \$0.45 each in quantities of 10,000-units. Production quantities are available immediately. The devices are lead free and RoHS compliant. Prices are subject to change.

[www.irf.com](http://www.irf.com)

Part Number	I <sub>o+</sub> /I <sub>o-</sub> (typ)	t <sub>ON</sub> & t <sub>OFF</sub> (typ)	V <sub>CCUV+</sub> (typ)	V <sub>CCUV-</sub> (typ)	I <sub>QC</sub> CVV(typ)	I <sub>CC</sub> (typ):	Package
IRS2983	200 mA / 400 mA	60 ns / 30 ns	12.5 V	10.5 V	150 μA	2.5 mA	SO-8

Specifications

## Flexible, Convenient Online Ordering Options



For more information contact:

**OrderManager**  
**@pwrx.com**

[www.pwrx.com](http://www.pwrx.com)

**EXPERTISE** ■ **INNOVATION** ■ **RELIABILITY**





## Smart Grid Band-Aids

By: Edward Herbert, PSMA Energy Efficiency Committee

They have a problem in Europe. On bright, sunny, windy days, they have too much “alternative energy,” and the clocks are running too fast. Something needs to be done, and urgently. The problem is more serious than clocks running fast. The “European 50.2 Hz Problem” means is that if the frequency ever reaches 50.2 Hz, under regulations introduced in 2005, most PV inverters will switch off-line. All at once.

The SunSpec control model (embodied in IEC 61850-90-7) doesn’t fix the problem, it covers it up, a Band-Aid. The frequency can now drift to 50.5 Hz. Italy went further. In addition to the frequency-controlled shutdown, CEI 0-21 adds a command interface so that the power grid providers can turn the inverters off remotely. California’s updated CPUC Rule 21 is the most sophisticated yet, with bells and whistles optimized for remote control. Many feel that it fails to address the fundamental problems and may have far-reaching unintended consequences.

Who are we to judge? We do not

have all the answers, but we can report a general feeling of unease. The latest revision to CPUC Rule 21 was fast-tracked, some say, broadsiding them. Who will write the software? Will they get it right? What happens when the computer crashes, or is hacked? Security is also a big worry. Even if protected from unsavory characters, a knowledgeable insider can easily circumvent security measures. 80% of attacks are inside jobs, by disgruntled employees, consultants or contractors.

Clearly, there is a need for frequency stabilization in inverters and active loads. Anecdotes abound about companies that have proposed methods for grid stabilization but have been ignored by regulators in favor of Band-Aids solutions.

It seems fundamentally wrong and unfair that we are encouraged to install alternative energy, but can be turned off remotely so that we cannot sell our power and recover our investment. Energy storage may be the key, but it will take large-scale seasonal energy storage like the Drake Landing Solar Community in Okotoks, Alberta. Large borehole thermal

energy storage is quite popular in Europe, and resistance heaters in them could absorb virtually unlimited surplus energy for later use, carbon free.

Abengoa’s Solana plant in the desert near Gila Bend, Arizona is now operational. Solana’s thermal storage system can produce clean energy for six hours at maximum power (280 MW). Similar energy storage systems installed at mothballed coal-fired plants might give them a new life as “super batteries” to store excess carbon free energy for later use.

Some jurisdictions throw in the towel without a fight, by limiting alternative energy penetration to as little as 4 percent. Do they have a strong coal lobby, or are they just running scared? We think that it is Probably the latter. They recognize that the know Band-Aid solutions only put off the day of reckoning and are expensive. They may be waiting for the perfect solution, which is perpetually elusive. In some cases, “Perfect” is can be the enemy of “good enough.” Oh, for a happy medium.

The opinions expressed are the author’s, not those of PSMA.

# “Superinductors”



## That’s what engineers are calling our new ultra-low DCR power inductors

Superconductors pass current with virtually no resistance.

Our new XAL/XFL inductors do much the same. Their DCR is incredibly low: often half that of similar size parts.

And their current handling is equally impressive. Coilcraft’s proprietary core material has a soft saturation characteristic that



Competitors’ 4.7uH inductors have much higher DCR per mm<sup>3</sup> than Coilcraft’s XAL5030.

prevents drastic inductance drops during current spikes.

Unlike competitive parts, these inductors don’t suffer from thermal aging. And we give you far more footprint options to maximize PCB density.

To see what else makes our new XAL/XFL inductors so super, visit [coilcraft.com/xal](http://coilcraft.com/xal).



WWW.COILCRAFT.COM





## A bright outlook for LED lighting

By: Ryan Sanderson, IHS

In 2013 LED lamps and luminaires accounted for just 2% of the global lighting installed base. Collectively incandescent and fluorescent lamps and luminaires still accounted for 80% of total shipments, with CFL and HID technologies accounting for the remainder. With legislation which inhibits the use of incandescent lamps in some countries already and a continued drive to decrease power consumption from lighting on a global scale, this is set to change. In 2018 20% of the installed base is forecast to be accounted for by LED technology. This rapid increase is not only predicted to drive opportunities for LED lamp and luminaire manufacturers but also power supply manufacturers who provide the electronics required to drive the LED lighting solutions.

The market for power supplies (driver circuits) for LED lamps is already very competitive and average selling prices of both LED lamps and their associated power supplies have declined rapidly in the last five years. Annual shipments of LED lamps, however, are forecast to more than double from 2013 to 2014 to over 1 billion

and continue to grow rapidly to more than 2.5 billion in 2017. The market for power supplies (driver circuits) for LED lamps is forecast to more than double in 2014 to \$1.8 billion and grow to \$3.4 billion in 2017. This market is therefore very attractive to power supply manufacturers with a “low-cost, high volume” business model.

The majority of this growth is predicted to be driven by demand in the residential sector as consumers replace incandescent and fluorescent lamps with LED lamps. The main benefits of transitioning to LED lamps are that they can produce the same lumen output at a much lower input power. This means that the power required to light a room/house is lower and the consumer’s utility bills are therefore lower. Under optimal operating conditions, LED lamps also last at least five times longer before replacement is required.

Designs of LED luminaires compared with LED lamps are more complex, typically require a greater number of LEDs/LED lamps, have a higher power rating and are therefore more expensive. Annual shipments of LED

luminaires are much lower than for LED lamps with just 40 million shipped in 2013. This is predicted to grow by 60% in 2014 and to more than quadruple in 2017.

Power supplies for LED luminaires are also more complex than those for LED lamps and are therefore also more expensive. Although the number of units shipped each year is much lower than those for LED lamps, the revenue opportunity remains attractive. The market is forecast to more than triple from 2013 to 2017 to be worth \$3.5 billion.

As with LED lamps, the main market growth driver is cost savings from lower energy usage. The longer life expectancy of LED luminaires compared with luminaires which use alternative lighting technologies is also extremely important in applications where there is typically a cost of labour to replace the luminaire. For this reason, strongest growth is forecast to be driven by commercial/retail and bay/industrial sectors due to the costs associated for lighting buildings,

[www.ihs.com](http://www.ihs.com)



## Interpreting loop gain measurements

By: Dr. Ray Ridley, President, Ridley Engineering

There have been many dramatic changes in power supply development over the last 20 years, but loop gain measurements remain the key to rugged and aggressive system performance. Understanding how to read a loop gain is important.

### Loop gain measurements in modern systems

Quite a few years ago, I emerged from college to enter the world of commercial power supply design. I had studied microprocessors, optimal control theory, multi-state feedback, and I was ready to tackle some real hardware and put everything I thought I knew into practice. It was a time when current-mode control was just coming into use, and I could see that current-mode was a classic example of multi-state feedback. All we needed to do was determine the proper gains from each state, and we could do placement of the closed-loop poles wherever we wanted them - just like in college!

But there was a problem. Nobody at work knew what I was talking about. And, unlike in the problem sets in college courses, nobody could tell me where they wanted

the closed-loop poles to be. They all talked in strange terms like output impedance, loop gains, and audiosusceptibility, and it wasn’t clear what to do next.

Then I attended Middlebrook’s famous course on analog circuit design. It was a long time ago, but there are three things I can remember clearly from that course: First, he measured loop gains for all his power supply and other analog examples and injected into the loop using a current probe driven backwards from an oscillator. A very neat trick, all you had to do was put a loop of wire in the feedback path and clip on the current probe.

The second thing I remember was the zero-ripple Cuk converter. There was an overhead projector transparency (pre-Powerpoint days!) where he rotated a picture of coupled cores and as the gap changed on the core, the ripple current flattened out to zero on the input and output. It was a great visual that really drove the point home. Finally, he showed that the classic solution to the quadratic equation using the usual  $b \pm \sqrt{b^2 - 4ac}$  radical was numerically inaccurate, and he gave a much

better solution.

I haven’t used his quadratic solution since then, nor have I designed with a coupled-inductor Cuk converter. But once I left his course I started measuring and understanding loop gains and found that they have never gone out of style for switching power supplies. Archaic though they seemed to me at the time, they are simply the best way to optimize the feedback of your power supply. Even if you are using a digital controller, an analog loop gain is simply the best way to verify that the feedback system is designed and working properly.

If you understand how to interpret loops properly, they are all you need for stability analysis. Textbooks talk about Nyquist plots, and characteristic equations, but in the real world we need to use the incredibly powerful tool for engineers that Mr. Bode gave to us. It is an amazing thing – with a couple of pen strokes on paper showing the loop gain and phase, we can determine the stability of systems of almost any order. What a potent engineering tool, no math needed, no calculus, only lab measurements! This was the great



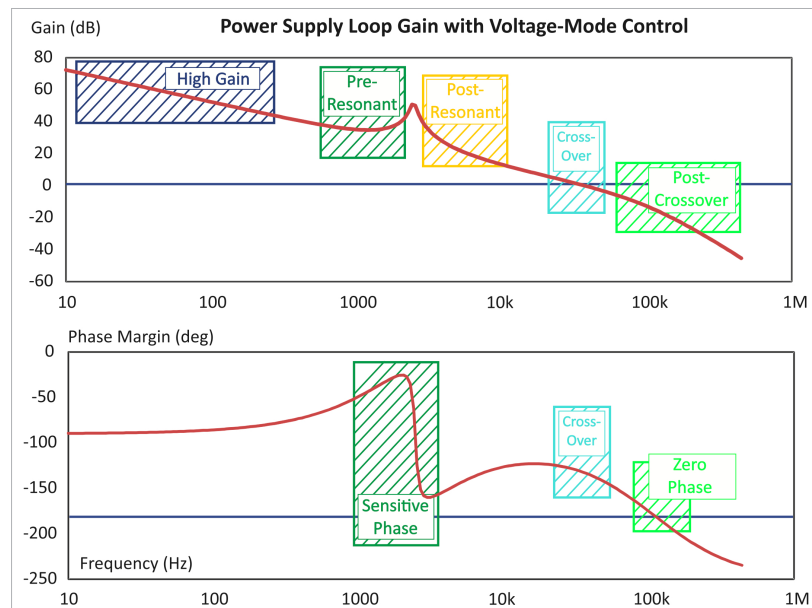


Figure 1: Voltage-Mode Loop Gain and Phase, Showing Key Measurement Regions contribution of Bode.

The aerospace design world is probably the most rigorous in making complete sets of bode plots for input impedance, output impedance, audiosusceptibility, and loop gain. Outside of the aerospace world, it is less common to make this full set of measurements. Most experienced designers will make a loop gain measurement since they find that it is a very sensitive measure of just about everything in the power stage and the feedback path. If some component is the wrong value, or something is built wrong, the loop gain is very likely to show that there is a problem.

**Critical regions of a voltage-mode loop gain measurement**

When talking about loop gains, most articles refer to just the crossover frequency and the

phase margin at that frequency. In reality, there is far more to a loop gain, and if you want to derive maximum benefit from making these measurements, it is important to understand where to look.

Figure 1 shows a typical loop gain for a voltage-mode power supply, with the plot starting at 10 Hz. This is always recommended, regardless of your power system switching frequency. It is very common to have substantial noise in the first decade of measurement (audio people are painfully aware of this, regarding hum) and you must be able to verify that you have high gain in the low frequency regions to reject line and other low-frequency noise. This area is shown shaded in blue in Figure 1. The AP300 frequency response analyzer [2,3] is capable of measuring gains in excess of 90

dB in the presence of high noise, and this is crucial for resolving high performance systems properly.

The green highlighted region in the loop gain of Figure 1 shows the region just before the resonant frequency of voltage-mode control. Because of the two compensation zeros in the feedback loop, and the high-Q double pole, there is a dip in the gain in this region. It is important that this gain is kept well above 20 dB to provide good transient performance.

Right after the resonance, the phase of the loop will drop very quickly and it will be very sensitive to changes in damping and loading. It is best to cross the loop over well beyond the filter resonance if you want to have a well-behaved system. At the crossover frequency, shown in light blue region, we measure the phase margin of the system, and this gives an indication of the relative stability. It is recommended to have at least 50 degrees of phase margin under all conceivable operating conditions at the crossover frequency.

(Some people insist on not doing a loop gain measurement almost as a matter of principle. If you are relying on step-load transients to determine the phase margin, you are really only getting indirect information about the loop gain in the region of the crossover. This is not sufficient to optimize your system or to ensure it will

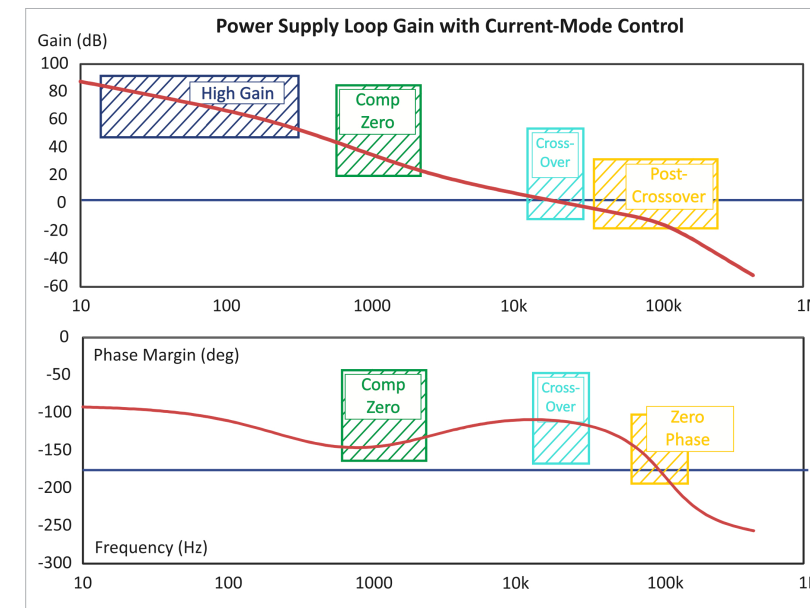


Figure 2: Current-Mode Loop Gain and Phase, Showing Key Measurement Regions

always be stable. [1]. The same is true of output impedance measurements – they are not an adequate replacement for making a real loop-gain measurement.)

It is important to measure the loop gains well beyond the crossover frequency, as indicated in the light green region of Figure 1. You want to be sure that the gain in this region is monotonically decreasing. Even though the loop is below zero dB, it can still have an effect on the closed-loop output impedance of the system as will be shown below for a current-mode loop.

**Critical Regions of a Current-Mode Loop Gain Measurement**

Figure 2 shows a typical loop gain for a current-mode system. Again we start at 10 Hz to cover the low frequency noise region. Gains are much higher

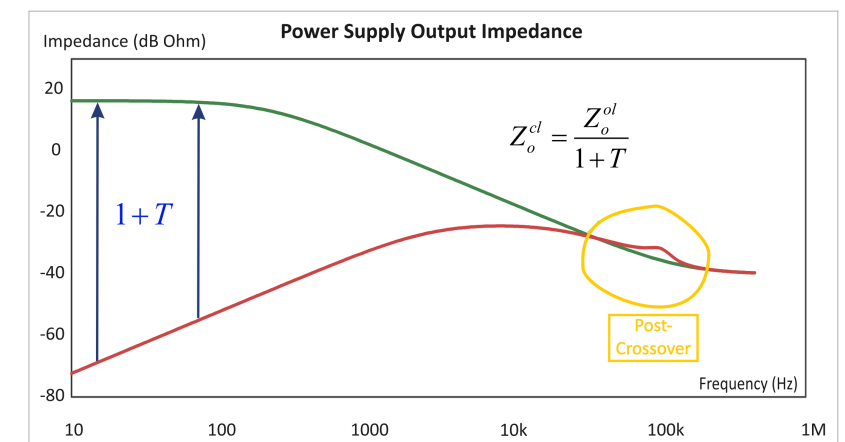


Figure 3: Open- and Closed-Loop Output Impedance

at low frequencies with current-mode control, and this provides outstanding closed-loop noise rejection.

The green region of the curve shows where the compensation zero of current-mode comes into play. Unlike voltage-mode control, there is no resonant frequency, and no need to match power stage poles with compensation zeros. We just put

the compensation zero before the crossover frequency to make sure that we pull up the phase at crossover.

Notice the dip in the phase in this region. It is possible to avoid this dip by moving the compensation zero to a lower frequency, but this will result in lower gains at low frequency and less-than optimal performance.

As with voltage-mode control, we want to have a phase margin in excess of 50 degrees. The plot is continued well past crossover to make sure there is sufficient

gain margin (what the gain is when the phase margin hits zero.) If you do not have a good gain margin, the closed-loop characteristics can show peaking, as shown in Figure 3.

Most designers are not aware that the loop gain still has an effect on performance even after it crosses over 0 dB. But as can be seen in the area circled in yellow, there is a peaking in

the output impedance after the crossover frequency. This output impedance peaking has nothing to do with the phase margin of the power supply control loop, which is more than adequate in this case.

**Summary**

Loop gain measurements are potent tools for optimizing your system and making sure everything is working properly. It is important to look beyond just the crossover frequency and the phase margin of the loop gain, this is just a part of the story. This article has explained the importance of the low-frequency measurements and

the importance of continuing the loop gain measurements well after the crossover frequency.

Readers are encouraged to view the videos listed below to learn more about making these measurements [5].

[www.ridleyengineering.com](http://www.ridleyengineering.com)

**References**

1. Step-Load Testing [Articles 29-30], <http://www.ridleyengineering.com/design-center.html>
2. AP300 Application Notes and Videos, <http://www.ridleyengineering.com>

[ridleyengineering.com/analyzer.html](http://ridleyengineering.com/analyzer.html)

3. Testing High Performance Loops Video, <https://www.youtube.com/watch?v=CbjtGZtaUaQ>
4. Join our LinkedIn group titled "Power Supply Design Center". Noncommercial site with over 3900 helpful members with lots of experience.
5. See our videos on loop testing and power supply design at <http://www.youtube.com/channel/UC4fShOOg9sg-SlaLAeVq19Q>

# Digital power providers must play to their strengths

It is important to properly address diverse mobile, industrial, and infrastructure markets

By: Mark Downing, Intersil

Investing in product areas where a company has distinct competitive technological advantages only makes sense in markets where there are also large, sustainable opportunities. Power management has evolved from simple regulation and power control to increasingly sophisticated power management devices providing monitoring, feedback and fault logging. 'Digital power' represents the latest generation of designs with products that feature advanced control loops, improved efficiency under all load conditions, and the ease-of-use benefits from having a point and click GUI and integrated power FETs, either on chip or in power modules.

Naturally the various markets for power management have differing requirements. However a common theme is the increasing supply current demands posed as processor platforms become more and more complex. The most challenging power management issues in systems today are

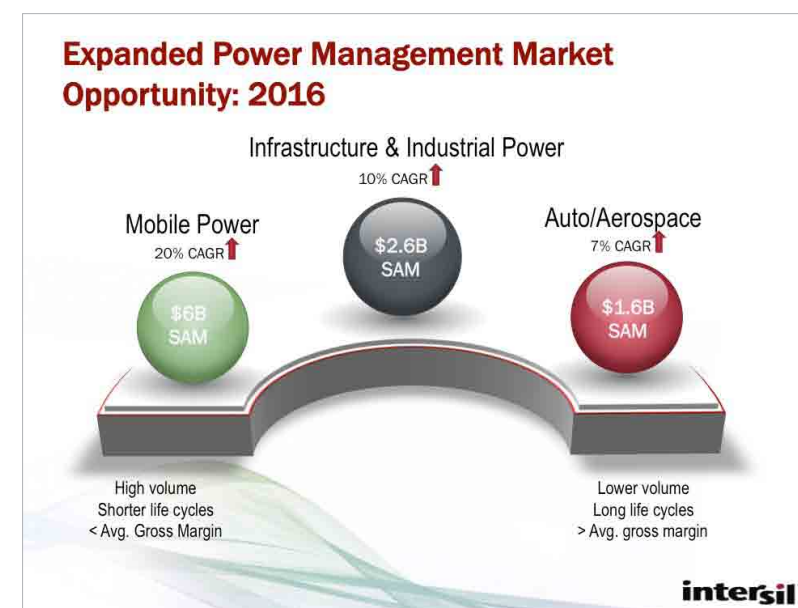


Figure 1: Demand is fuelling growth in Intersil's target market sectors with a total projected value expected to exceed \$10 Billion by 2016

efficiency, reliability and intelligence.

These issues are certainly applicable in the high-growth, high-volume, mobile power market where Intersil's strong heritage in delivering compelling products for laptop PCs and gaming consoles is enabling it to address the specific need for longer battery life and higher integration, demanded by the increased functionality and smaller, thinner form factors

of smartphones and tablets (see Figure 1). For example, Intersil prides itself on its long experience in the mobile space where knowing how to source the 8-10A core currents needed by some handsets today, with 3-phase converters that allow the use of low profile inductors, differentiates it from its competitors.

Infrastructure and industrial power is a relatively stable market characterized by longer

## PCIM EUROPE

International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management  
Nuremberg, 20 – 22 May 2014

# This is your powerful connection!

The marketplace for developers and innovators.  
Future starts here!

Messe Frankfurt Group

More information at +49 711 61946-0  
[pcim@mesago.com](mailto:pcim@mesago.com) or [pcim-europe.com](http://pcim-europe.com)





Figure 2: Intersil's ISL911xx switching regulator family can extend battery life

equipment life cycles but still with significant growth potential, especially in the power hungry network and data infrastructure due to the explosion in cloud-computing applications. Server designs now require many more power rails making Intersil's best-in-class range of efficient, high-density integrated power solutions particularly attractive in simplifying system design and lowering equipment and maintenance costs.

Industrial applications have seen a similar proliferation of voltage rails as complex system designs embed processors, memory, FPGAs and ASICs. Power designers are consequently seeking advanced, robust power management solutions that are more densely integrated while being simple to design with. This is exactly what Intersil offers with its family of analog and digital

controllers, power modules and switching regulators, which provide processor and memory power solutions as well as point-of-load (POL) and other power management building blocks. These solutions are as relevant in traditional sectors, such as test and measurement, factory automation and medical applications, as they are to more recent smart home and smart grid applications in allowing customers to take advantage of the latest advances in power management.

The automotive and aerospace markets are often seen as more conservative but continue to evolve, particularly in automotive where new technologies for electric vehicles, infotainment and car-to-car communications are becoming more prevalent, bringing with them new demands in battery and power

management. Intersil has gained a leadership position in this sector through its expertise in supplying high reliability and radiation hard components, essential for space applications but also relevant to other harsh environments.

Solutions for mobile devices

Tablets and smartphones present increasingly complex demands for their power sub-systems. DC-DC converters, either buck, boost or buck-boost, along with PMICs

address the basic handheld power requirements for all the processor, memory, wireless and other analog circuits. But displays and their backlights often have more specialist requirements, as do sensors such as ambient light, proximity and motion detection or orientation sensors.

Intersil's latest ISL911xx switching regulator family can extend battery life in smartphones, tablets and other single-cell lithium-ion (Li) battery-based systems. A proprietary, fully synchronous 4-switch architecture enables seamless transitions between operating modes, without significant output disturbance (see **Figure 2**). The design also maintains system operation when the voltage drops, functioning at high current down to the lowest battery voltages and delivering up

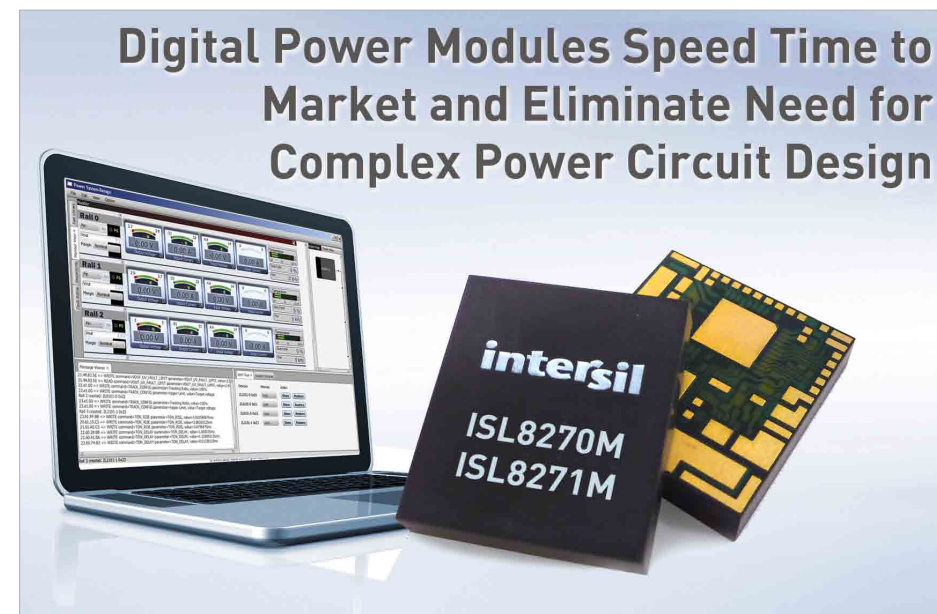


Figure 3: Intersil's ISL8270M and ISL8271M digital power modules provide either a 25 or 33 Amp supply current

to 96% efficiency. Perhaps most significant is that the device is the first high current buck-boost configuration to be offered in an industry-leading, small-footprint CSP package.

In addition to around a 25% improvement in battery life, the ISL911xx regulators ensure the stable supply voltage that is so essential for the reliable operation of sensitive RF circuitry. These buck-boost devices support new battery chemistries, down to 2.5V, are capable of low temperature operation, and support both high burst current requirements while also achieving high efficiencies under light load conditions. This world-leading performance has already secured design wins for the ISL911xx family in top tier smartphones.

#### Solutions for infrastructure and industrial equipment

The industrial and infrastructure market is currently Intersil's largest source of revenue. Within this market, power customers are increasingly looking for improved power density and ease of use. Digital power addresses this need and while the price premium of digital controllers was previously seen as an inhibitor to their adoption, the advances realized in the latest 4th generation controllers are such that digital power can significantly reduce the bill of material (BOM) cost and total cost of ownership through shorter development timescales, faster time to market and efficiency improvements.

Fully digital power solutions make coping with the complexity of multiple rails easier, allow different firmware configurations

to be held on chip and generally provides the flexibility and benefits that programmability intrinsically offers. Digital power enables advanced system monitoring of every aspect of the power supply, including input/output voltages and currents, as well as temperature. This data can be used for dynamic control and for enhancing overall system reliability through automated fault logging.

As an example, Intersil's ISL8270M and ISL8271M digital power modules provide either a 25 or 33 Amp supply current, ideal for servers and infrastructure equipment (see **Figure 3**). These modules incorporate Intersil's 4th generation ZL8800 controller that utilizes a patented control loop technique to deliver a highly integrated digital DC/DC power control solution with a real-time configuration capability and true system intelligence. Finally, the configuration and monitoring of digital devices benefits enormously from an intuitive graphical user interface (GUI).

Intersil's PowerNavigator provides exactly that and allows designers to use Intersil's digital power products without writing a single line of code. This free, downloadable tool offers an easy-

## Intersil's Next-Generation PowerNavigator™ GUI for Digital Power Simplifies System Design



Figure 4: Intersil's PowerNavigator allows designers to use digital power products without writing code

to-use, drag-and-drop interface that significantly accelerates design time, while also ensuring the flexibility that designers need to quickly set up and control

any power supply architecture (see **Figure 4**). PowerNavigator even provides a “hardware-free” mode that lets users create their required power architecture

and select components prior to hardware development, without design risk.

The PowerNavigator GUI provides access to all commands and setup configurations, including the ability to load predefined configurations for common applications. Once the initial hardware has been developed, the GUI can apply saved settings and monitor all the rails, displaying whatever telemetric data may be required. Designers can make final system adjustments through the GUI with simple and intuitive controls and even sequencing of the rails is possible through the visual drag-and-drop interface.

[www.intersil.com](http://www.intersil.com)

**PSD**  
Empowering Global Innovation

Anywhere!

NEW! PSDmobile.com adapts to all devices without the need for APPs! Visit us today at [www.PSDmobile.com](http://www.PSDmobile.com)



[www.PSDmobile.com](http://www.PSDmobile.com)

Tablets Desktops Phones

## Driving high-power GaN transistors

Large-area high-power GaN transistors with on-chip drivers can be easily driven

By: John Roberts, GaN Systems

High voltage normally-off GaN transistors are being introduced into the marketplace, and most of these devices will have low threshold voltages of below 2.5 Volts. This presents a severe challenge to conventional drivers, particularly when these very large GaN devices are used to provide 100 - 400A of switching current, as is typical in automotive motor drive circuits.

Conventional drivers can be used if they are carefully mounted in very close proximity to the GaN power switch. Thermal issues then become the dominant concern because of the driver's self-heating when combined with the heat generated by the GaN power switch.

The input capacitance of GaN power switches increases significantly and non-linearly at low drain voltages. The gate of the GaN transistor must therefore be cleanly clamped to a well-positioned source sense connection. The switching transition losses increase substantially if the gate - source

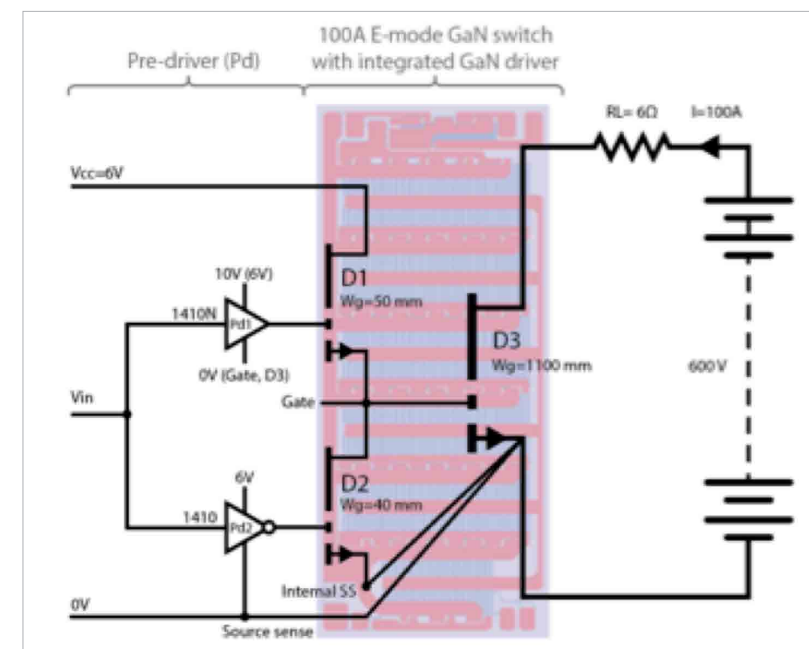


Figure 1: The source sense loop is internal and very effective because of the very low loop inductance that is achieved.

voltage is not cleanly brought well below the GaN device's threshold voltage or rapidly raised to the maximum allowed gate voltage.

### Using an on-chip driver

A better result can be achieved if an on-chip driver is provided. The circuit shown in **Figure 1** uses two on-chip, normally-off GaN transistors D1 and D2 to drive the large transistor D3 (Gate width,  $W_g$ , of 1100 mm) on and off. In this circuit, the source sense loop is

internal and very effective because of the very low loop inductance that is achieved.

As a result of providing D1 and D2 on-chip, the external pre-driver devices can be far smaller than the drivers typically used for very high current power switches. The pre-drivers shown are the Microchip TC 1410 and TC 1410N devices. These are small devices rated to provide only 0.5A of output current, but they are however, ideal



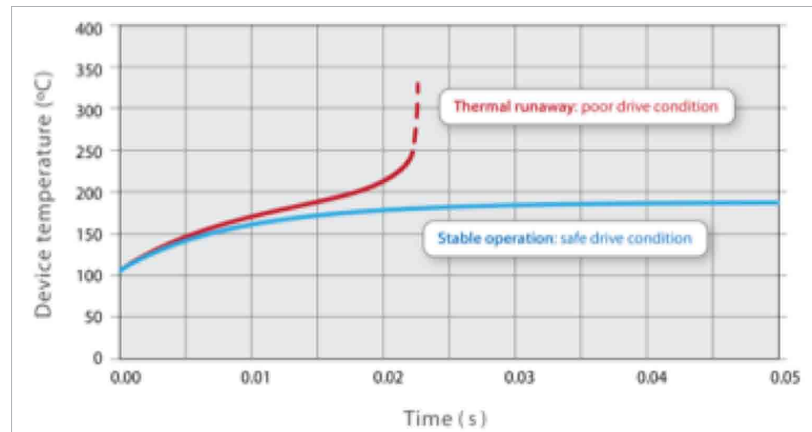


Figure 2: Safe drive condition provides stable operation

for use in this circuit because the required peak current is well within their 0.5A capability. If the D3 device was driven directly, a 10A peak current drive capability would be required and these large driver devices, with corresponding high current capability, also suffer from higher internal delays. Additionally, as noted previously, it is difficult to mount the large driver close enough to the large GaN transistor to eliminate loop inductance.

Any weakness in the drive circuitry can lead to excessive power dissipation during the on-off transitions as shown in the temperature-time chart of Figure 2. This chart shows that stable, thermal operation – or catastrophic thermal runaway, depends on the drive circuit design. Unsafe drive conditions occur when the internal D1 and D2 driver devices are not cleanly driven to clamp the gate of D3 rapidly, to either the 6V supply or the source sense connection.

Drive issues therefore can limit GaN transistor performance.

**Island Technology**

The Island Technology designs with numerous, totally independent cells shown in Figure 3, are compact, scalable and they more evenly spread heat over the whole die. The large area, GaN power switch with the on-chip drivers, can then be accurately simulated in conjunction with the models for the 1400 series pre-drivers provided by Microchip. This is an important practical

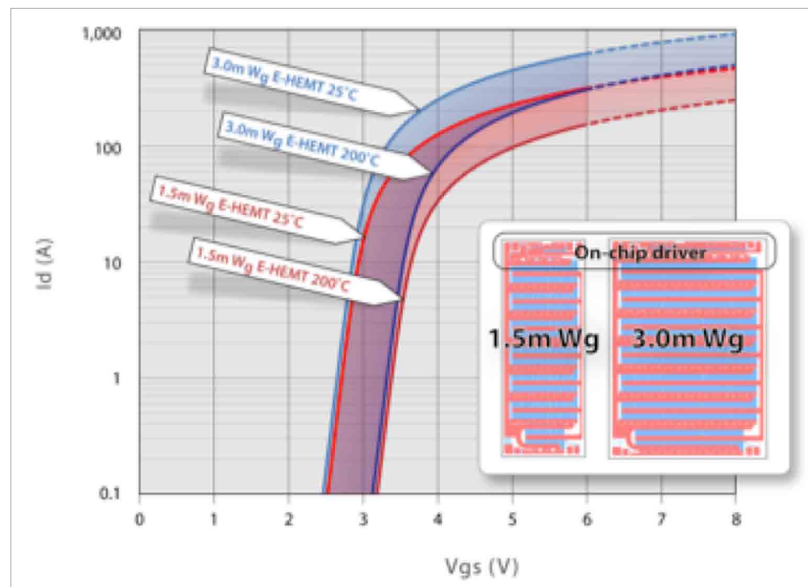


Figure 3: Island Technology designs with numerous, totally independent cells

It is also vitally important to use sophisticated, thermally augmented SPICE models. However, these models cannot cope with the localized heating effects common in simple, conventional ladder layouts that produce hot spots in the center of large die. Standard, hot chuck testing will not reveal these characteristic limitations of the traditional ladder layout and they are definitely not revealed when using conventional SPICE models [1].

requirement because GaN-on-Si devices are very challenging to thin below 250 μm. The Island Technology devices are far more easily modelled.

When the thermal models are correctly applied and the highly non-linear device capacitances are correctly represented, very complete and accurate simulations of the circuit shown in Figure 1 can be produced. The effect of providing a poor drive signal at

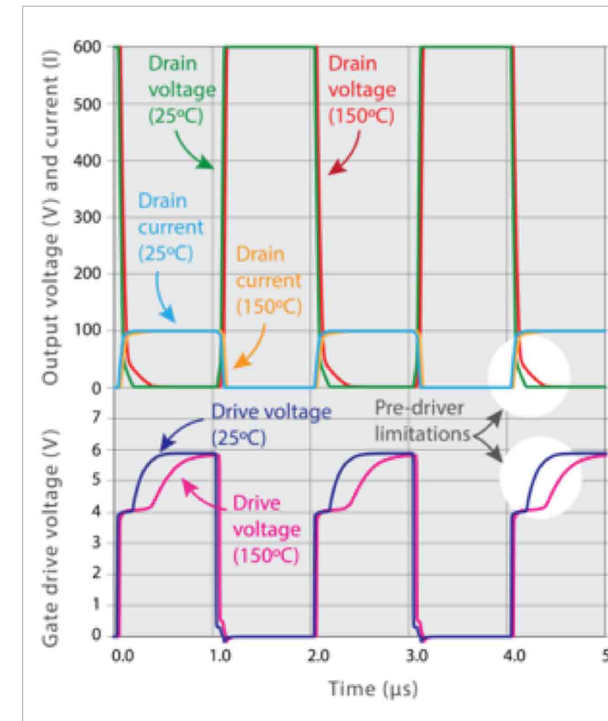


Figure 4a

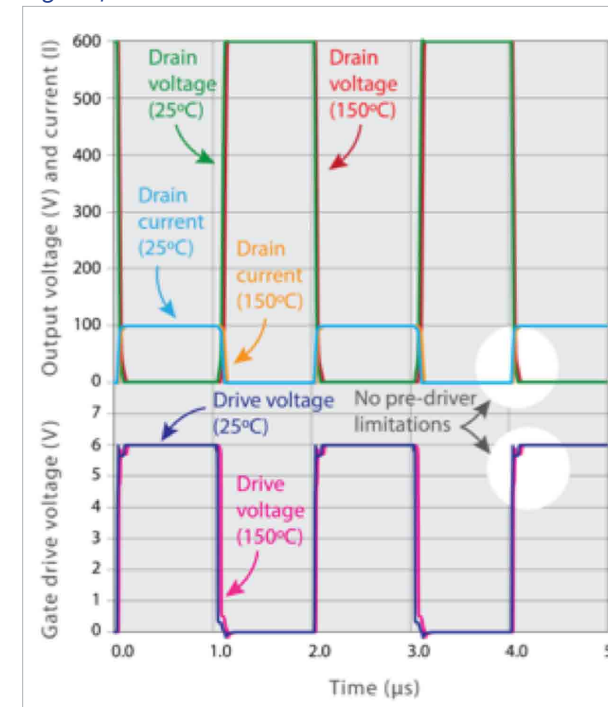


Figure 4b

Figure 4: Poor drive conditions result in excessive power loss (a). Good drive circuitry removes the major power loss (b). The highlighted sections display the difference.

the gate of D3 is shown in Figure 4a. The slow fall time of the 600V transistor is caused by the poor pre-driver transition also shown. However, when the drive signal is optimized, as shown in Figure 4b, the safe drive condition can be achieved, rather than the thermal runaway condition as shown in Figure 2.

Clean drive signals to the on-chip drive transistors result in the smallest overlap of the output voltage and output current as shown in the highlighted sections of Figure 4 (a) and (b). Minimum losses occur when the smallest overlap is achieved.

**Conclusion**  
The value of

having on-chip drivers for very large, high power 650V GaN transistors with Wg of 1100mm, 1500mm and 3000mm has been described. These devices are suitable for drive train use in all classes of electric automobile types. For vehicles that require 1200V operation, three level inverter circuitry will be used because the 650V GaN devices will be the most prolific, low cost, high voltage devices available, replacing IGBTs and SJ MOSFETs. However, they initially need to be proven in the less demanding and disposable IT applications.

Manufacturing very large, high reliability, 650V devices with high yield is a challenge. However, the Island Technology allows for the required redundancy because the devices are made from numerous totally independent cells. For example, the 3000mm 400A device has 136 cells. The yield and reliability issues have been addressed by using this island layout technique. The drive problem has been solved by using the on-chip GaN driver.

[www.gansystems.com](http://www.gansystems.com)

**References**

1. J. Roberts, T. MacElwee, and L. Yushyna, "The Thermal Integrity of Integrated GaN Power Modules", IMAPS Conference & Exhibition on High Temperature Electronics Network (HiTEN 2013), July 8-10, 2013, Oxford, UK, pp.61-68.

# Advanced design topics for off-line flyback power supplies – Part 1

Using an on-line design tool can help your efforts

By: Jason Guo, Fairchild Semiconductor

The flyback is the simplest and most commonly used isolated power-converter topology, able to step voltage up or down while providing galvanic isolation from the ac mains in off-line applications. It is the most cost-effective topology for powering many kinds of electronic equipment, having acceptable efficiency and small enough size as long as the output power is less than about 200W. We will cover some of the finer points of designing flyback converters, and an on-line expert system called Power Supply WebDesigner (PSW).

A standard flyback converter takes ac or dc input and one secondary-side-regulated output, plus up to two additional cross-regulated outputs. The design includes a wire-wound transformer, an RCD clamp (sometimes called a snubber) on the primary side, and one or two stages of filtering on each output. An important part of the design is the selection the right controller+MOSFET, because the design must be tailored to the built-in limits of this component. These controllers have external control-loop compensation, which

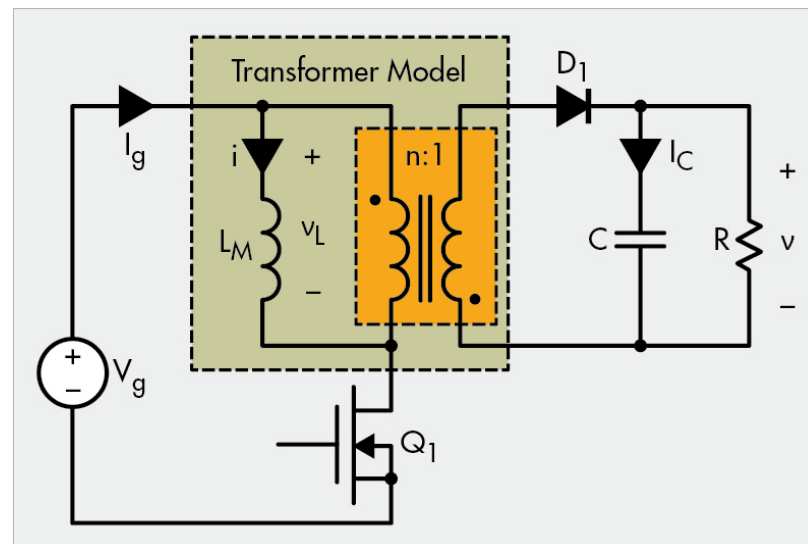


Figure 1: Power train of a flyback converter where the transformer is represented by a model consisting of an ideal transformer plus magnetizing inductance. is also addressed here.

While the standard flyback converter is most common, there are other more complex variations not covered here that are designed to meet specific needs. For example, a two-switch version reduces the voltage rating of the main switch but adds a second power switch and a high-side drive. An active-clamp version increases efficiency and further limits voltage stress on the main switch but adds an auxiliary switch. A final example is quasi-resonant operation, which reduces turn-on losses but in-

creases control complexity and limits operation to boundary- or discontinuous-conduction mode.

Our main purpose is to explain how to make the design choices necessary for a flyback converter, whether using PSW or any other design method. PSW will make all these choices automatically, but it offers great flexibility in allowing the user to change any of them and see the effects in a matter of seconds. For this reason it's also an excellent tool for learning about flyback design, and most of the guidance offered in this paper is

included in “information notes” available at appropriate places throughout the design procedure. As a result, there should be no need to refer to other documentation to complete a flyback design, but if more detail is desired, a complete design procedure and many of the embedded design equations are provided in an application note. Other application notes address more specific aspects of flyback design, including the use of synchronous rectification at the output.

## Flyback Converter

The standard flyback converter as shown in Figure 1 is widely used in low-power (<200W) and/or high-voltage applications due to its low part count and ability to deliver multiple outputs with few additional parts, although cross-regulation is inferior to isolated buck-derived converters. The converter is often operated in discontinuous conduction mode (DCM), especially at less than 50W, where the magnetizing current returns to zero at the end of each switching cycle and may remain there for some time, until the start of the next switching cycle. The control design is very simple for DCM, described by the same equations as a non-isolated buck-boost topology but with a turns ratio inserted.

The “transformer” of a flyback converter is actually used as a coupled inductor, where the primary winding conducts current during a different portion of the switching cycle than the secondary

winding(s). As a result, all the energy transferred from the input to the output must be alternately stored and discharged from the magnetizing inductance, which requires a small magnetizing inductance relative to most isolated topologies. While the instantaneous winding voltages are related by the turns ratio, the instantaneous and rms winding currents are not. Basic waveforms of the converter operating in continuous- and discontinuous conduction mode are shown in Figure 2.

For a multiple-output flyback converter, Figure 3 illustrates two important points. One is the output-diode conduction times for different outputs can be different, and it depends on the relative loading. In fact, the lower set of waveforms shows output 2 in DCM while output 1 operates

in CCM, evidenced by the abrupt step of current down to zero at the end of the conduction time. The second point is that cross-regulation becomes poor at very light load, evidenced by output 2 rising from 15.2V at 0.5A load to 19.6V at 0.1A--and 31.5V at no load! (Not shown.) To protect the loads on cross-regulated outputs, often a minimum load is specified or zener-diode voltage clamps are installed across those outputs.

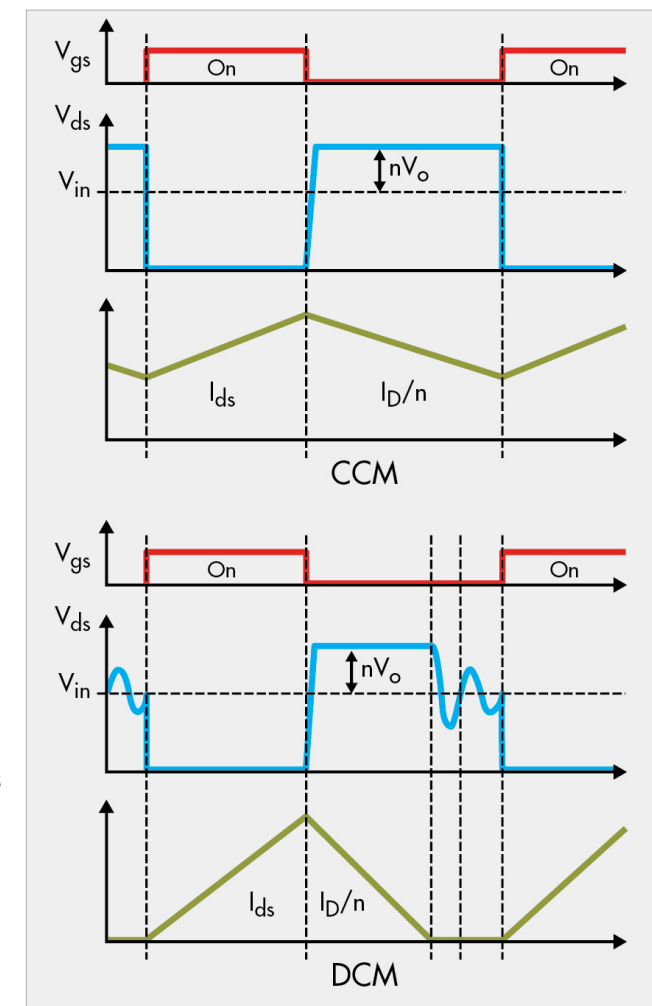


Figure 2: Basic waveforms of a flyback converter operating in continuous conduction mode (CCM) and discontinuous conduction mode (DCM), where the lower waveform in each set is the transformer magnetizing current.

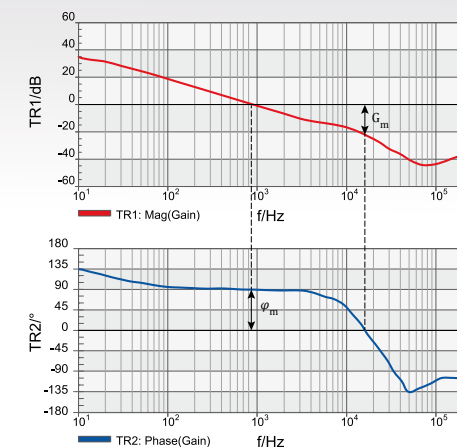


## How stable is your power supply?



Easily determine stability using the **Vector Network Analyzer Bode 100** in combination with the Wideband-Injection Transformer B-WIT 100.

Measure **loop gain, plant transfer function, phase margin** and **gain margin** from **1 Hz to 40 MHz**.



Visit us at PCIM Europe in Nuremberg Hall 6, Booth 228

For more information and free application notes go to: [www.omicron-lab.com/psd](http://www.omicron-lab.com/psd)

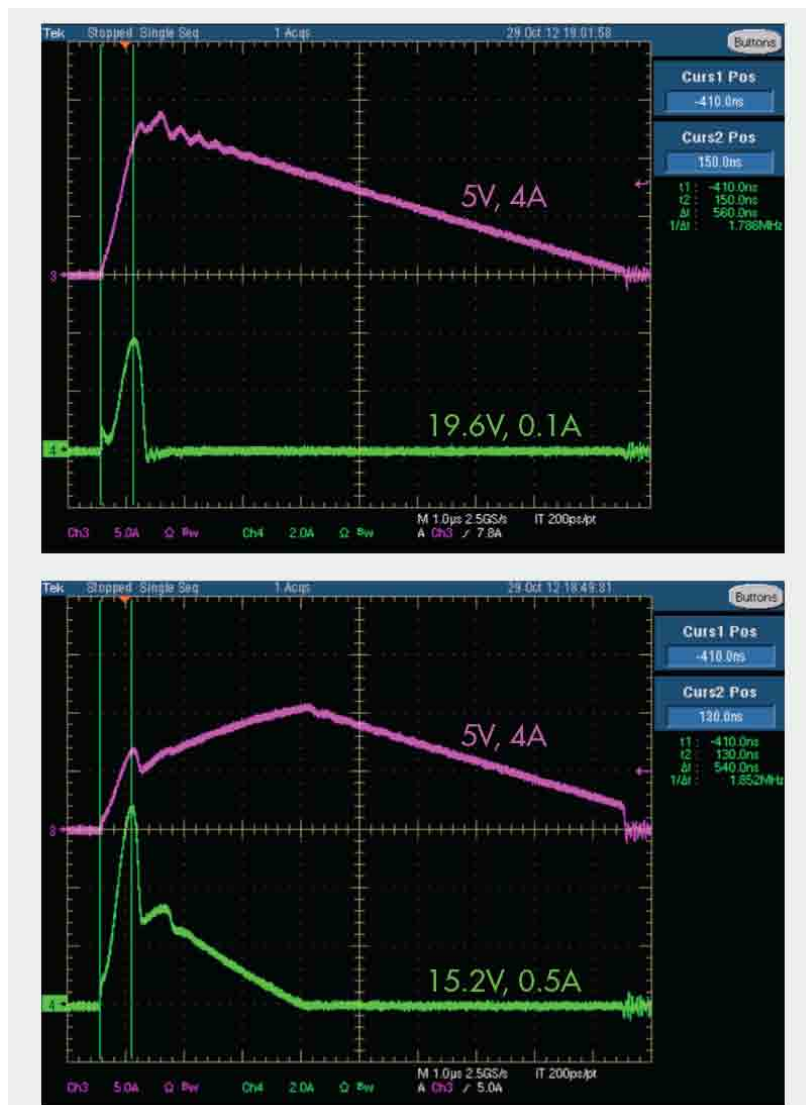


Figure 3: Waveforms of output-diode current for output 1 (magenta) and output 2 (green) for two different loads on output 2.

### Power Supply WebDesigner

On Fairchild Semiconductor's website is a sophisticated, web-based design and simulation tool called Power Supply WebDesigner (PSW), with example output shown in **Figure 4** and other figures of this paper. It's "auto design" feature classifies it as an expert system, able to make the numerous design choices explained in the next section without user intervention,

based on the experience of expert designers captured in its algorithms. If a user would like to make adjustments to the design, he/she can review the detailed design procedure and override the "recommended" value of any design variable, guided by text information notes and dynamic limits that ensure input is reasonable. After manual adjustments are made, the tool recalculates later recommend-

ed values to optimize the design given the new input. A user may then continue stepping through and reviewing each design step, or at any time he/she may have the tool complete the rest of the design automatically.

PSW generates a complete, prototype-ready schematic with all the necessary components, and it provides results from four types of circuit analysis: calculated component losses, steady-state waveforms, transient waveforms, and loop-gain Bode plots to indicate stability. (Only component losses and Bode plots are included in this paper, to illustrate the effects of some manual design changes.) If any results are unacceptable, further adjustments can be made in the design procedure (with the benefit of error and limit checking), or component values can be changed directly on the schematic diagram. Finally, a bill of materials is generated with the option to choose parts and assemble an order from catalog distributors of electronic components.

Although not covered in this paper, the SIMPLIS™ piecewise linear circuit simulator is used to provide simulation and stability results on-line, using circuit models that have been simplified sufficiently to provide results in less than one minute. As a result, it cannot predict higher order-effects such as voltage ringing; therefore simulated waveforms won't look like lab measurements. The simulation also cannot pre-

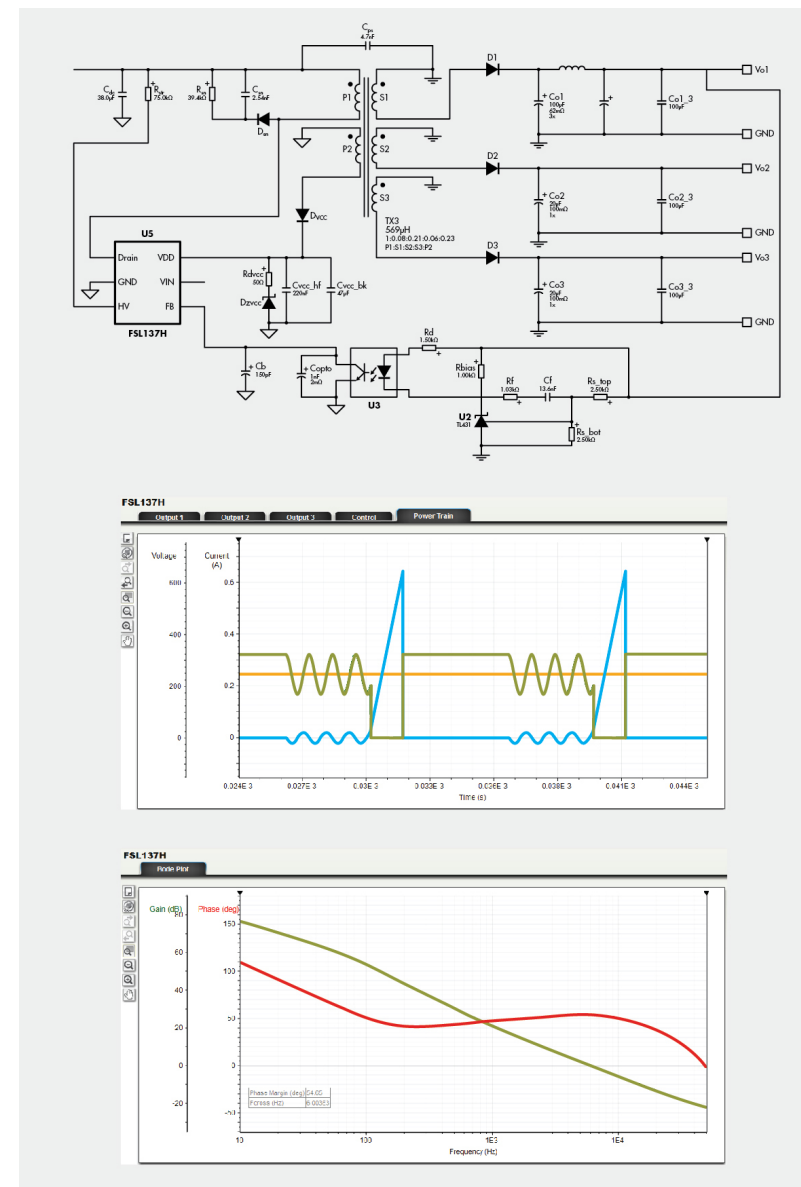


Figure 4: Examples of some output from Power Supply WebDesigner™ (PSW): design schematic, waveforms, and Bode plot.

sophisticated models (which take longer to run) as well as lab measurements made on selected test circuits. In Part II, we will continue our discussion, starting with Basic Design Choices

sophisticated models (which take longer to run) as well as lab measurements made on selected test circuits.

In Part II, we will continue our discussion, starting with Basic Design Choices

[www.fairchildsemi.com](http://www.fairchildsemi.com)

# Using micro converters for board-level DC/DC

Modules address inappropriate component selection and board layout issues

By: Yojiro Shiina, Torex Semiconductor

Miniaturization and a low profile are demanded of the semiconductors and electronic components used in portable devices such as smartphones and tablets. Accompanying the lower voltages and larger currents used in semiconductors in devices, DC/DC converters, which have a higher conversion efficiency than linear regulators, are seeing increasing use.

DC/DC converters normally include a power control IC, coil, capacitor, and resistor. For this reason, more mounting space is needed than a linear regulator, which contributes to increased board cost. In addition, inappropriate selection of components and board layout may lead to circuit malfunctioning and noise problems. As a solution to these issues, micro DC/DC converters are gaining increasing attention.

Micro DC/DC converters have a small number of components, and thus the board layout is simple and little noise occurs, which helps reduce development time.

### Structures and Features of micro DC/DC Converters

TOREX micro DC/DC converter products are centered on a switching regulator with a single output that integrates the control IC and coil. The

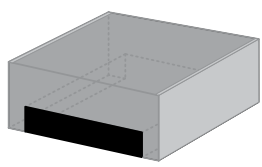
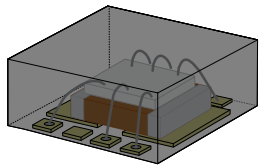
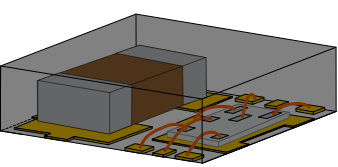
Structure number	TYPE - 1	TYPE - 2	TYPE - 3
Drawing			
Description	The IC is covered by the coil	The IC is stacked on the coil	The IC and coil are placed side-by-side
Features*	a) Radiated noise a) Near magnetics field c) Cost a) Mounting area b) Large current b) Heat dissipation	b) Radiated noise c) Near magnetics field a) Cost b) Mounting area c) Large current c) Heat dissipation	b) Radiated noise b) Near magnetics field b) Cost c) Mounting area a) Large current a) Heat dissipation
Products	XCL101 (step-up) XCL201/XCL202 (step-down) XCL205/XCL206/XCL207 (step-down)	XCL208/XCL209 (step-down)	XCL211/XCL212 (step-down) XCL213/XCL214 (step-down)

Table 1: Structure and features of micro DC/DC converters - a Best, b Better, c Good

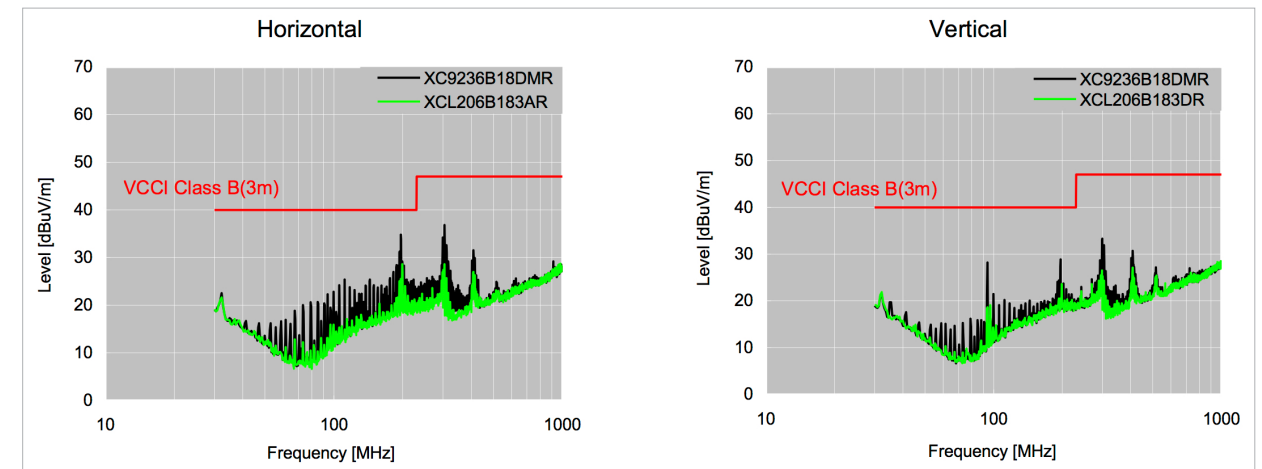


Figure 1: Radiated Noise, XC9236B18DMR-G vs. XCL206B183AR-G

package structure is determined by consideration of the product specifications, IC, coil, heat generation (heat dissipation), and other characteristics. Each package structure has advantages and disadvantages (see Table 1). In the Type -1 structure, the coil lies flat on the IC package. This shortens the path of the switching current and minimizes noise. In the Type -2 Structure, the resin mold mounts the IC chip on top of the coil. This is relatively inexpensive because a coil with a generic shape can be used. In the Type -3 structure, the coil and IC chip are placed side-by-side in the resin mold. The IC and coil have good heat dissipation, so large currents can be used.

### Designed for Noise Reduction

In order to obtain full performance from electronic components, “whether or not the design achieves noise reduction” is an important concern from the stage of circuit design. However, even though the power circuit

is a source of noise, component selection comes last. No matter how high the performance of the ICs and LSIs that are used, it will not be possible to obtain good performance from these components if the power circuit design is bad. In order to reduce noise in TOREX micro DC/DC converters, a variety of measures are taken, including:

- Using a coil with minimal flux leakage
- Adjustment of coil characteristics for the micro DC/DC
- Optimization of DC/DC operation
- Deciding pin assignments and structure based on consideration of the current path

Using measurements of radiated noise and near magnetics field strength, the following section describes the extent to which noise characteristics actually differ in “a power circuit composed of discreet

components (XC9236)”and in “a micro DC/DC converter (XCL206)”.

### EMI (Electromagnetic Interference)

Figure 1 shows a comparison of radiated noise in two products, the “XC9236B18DMR-G” and the “XCL206B183AR-G”. The XC9236 (black waveform) generates noise over a wide range from 50MHz to 300MHz. By contrast, the XCL206 (yellowish green waveform) has a very low noise level. Even at the same operating frequency, the difference is clear. For this reason, the XCL206 (micro DC/DC converter) does not require full implementation of the noise measures that always tend to be put off until later. And on the XCL202 (Freq = 1.2MHz), which has the same structure as the XCL206, the operating frequency is reduced for even lower noise. Testing conditions: VIN = 3.7V (DC power supply), VOUT = 1.8V, IOU = 200mA (resistor: 9Ω), XC9236B18DMR-G (Freq



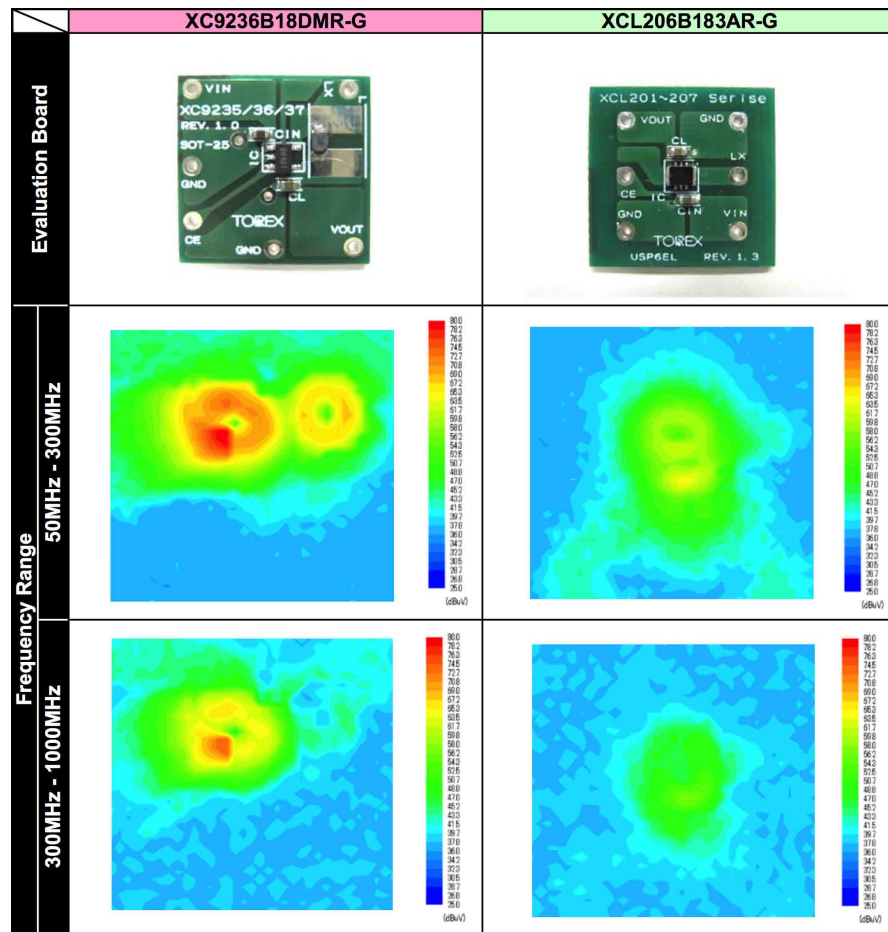


Figure 2: Near Magnetics Field Strength, XC9236B18DMR-G vs. XCL206B183AR-G (Freq = 3MHz): Cin = 4.7µF, CL = 10µF, XCL206B183AR-G (Freq = 3MHz): Cin = 4.7µF, CL = 10µF.

**Near magnetics field strength**  
 Figure 2 shows a comparison of the near magnetics field strength of the “XC9236B18DMR-G” and the “XCL206B183AR-G”. The near magnetics field strength does not always correlate directly to the strength of unwanted radiated noise, however, it provides an effective means of identifying noise sources due to high-frequency current flowing in the board. Testing conditions: VIN = 3.7V (DC power supply),

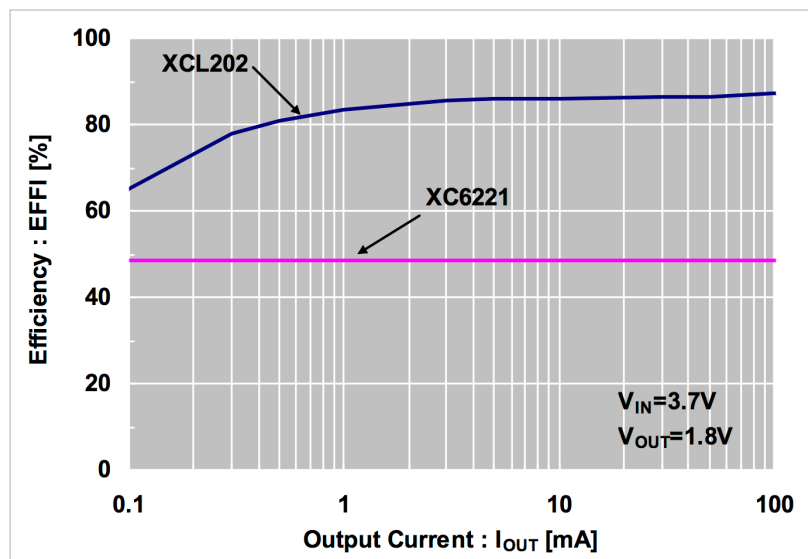


Figure 3: Power Conversion Efficiency, XC6221A182MR-G vs. XCL202B181BR-G

VOUT = 1.8V, IOU = 200mA (resistor: 9Ω), XC9236B18DMR-G (Freq = 3MHz): Cin = 4.7µF, CL = 10µF, XCL206B183AR-G (Freq=3MHz): Cin = 4.7µF, CL = 10µF.

At a frequency range of 50M to 300MHz, orange and red appear in a ring-like shape around the XC9236 IC. It can be seen that the strongest noise occurs in the vicinity of the IC’s GND pin. Yellow ring-shaped noise can also be seen at the coil. The coil is a simple shield type (ferrite powder mixed in the resin), and thus it is likely that the noise is due to flux leakage. By contrast, the XCL206 (micro DC/DC converter) has no red or orange, and little noise is generated.

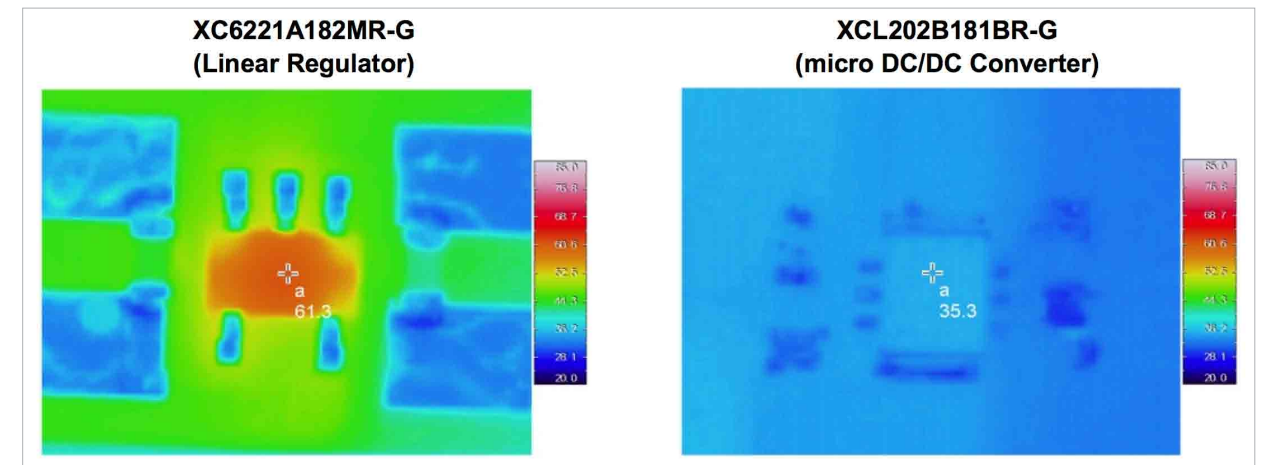


Figure 4: Heat Characteristics, XC6221A182MR-G vs. XCL202B181BR-G  
**Using micro DC/DC converters effectively**

A micro DC/DC converter can be operated without detailed knowledge. A basic knowledge is sufficient to reduce noise and heat generation in circuit components, increase component reliability, and improve product acclaim. A micro DC/DC converter requires only half the mounting space of a regular DC/DC converter consisting of discrete components, and thus also helps save board cost. The same board space as a linear regulator is sufficient.

**Efficiency and component temperature**

There is a large difference in power conversion efficiency between linear regulators and micro DC/DC converters (see Figure 3). This difference in efficiency creates a big difference in device battery drive time. The efficiency difference is loss due to conversion to IC heat (see Figure 4). Testing conditions: VIN = 3.7V, VOUT = 1.8V, IOU = 100mA (resistor: 18Ω), Ta = 23.4°C

**Board Layout Points**

The GND wiring appears simple in the circuit diagram, however, in some cases the actual layout on the printed circuit board is

very difficult. It is not a matter of simply making connections, because if the connection positions and board layout are bad, the performance of the entire system will be degraded. For example, a step-down DC/DC converter alternately switches switch 1 (SW1) and switch 2 (SW2) ON/OFF, controlling the currents in order to stabilize the output voltage. The currents that flow when this is done are Current (1) and Current (2) (refer to Figure 5).

Current only flows in the red wiring shown in Figure 6 when either Current (1) only or Current

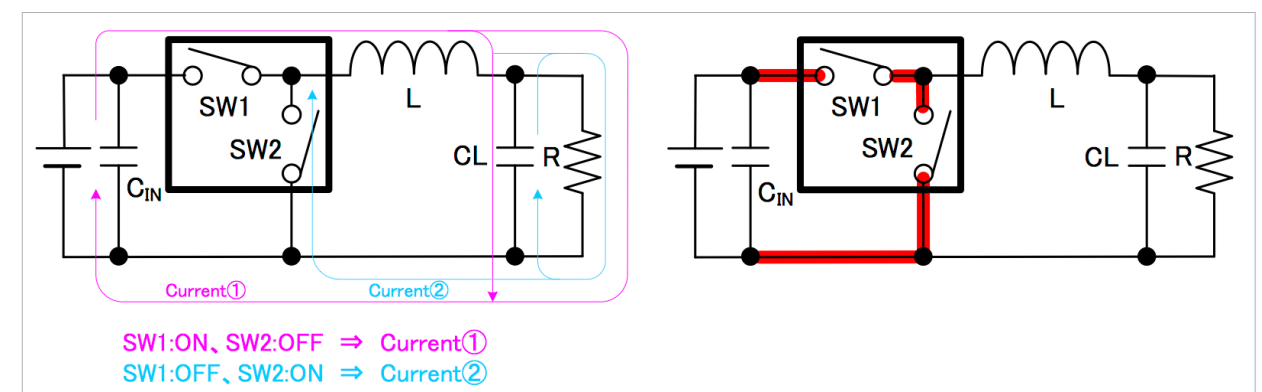


Figure 5 (L): Current Path of Step-Down DC/DC Converter and Figure 6 (R): Step-Down DC/DC Converter Noise

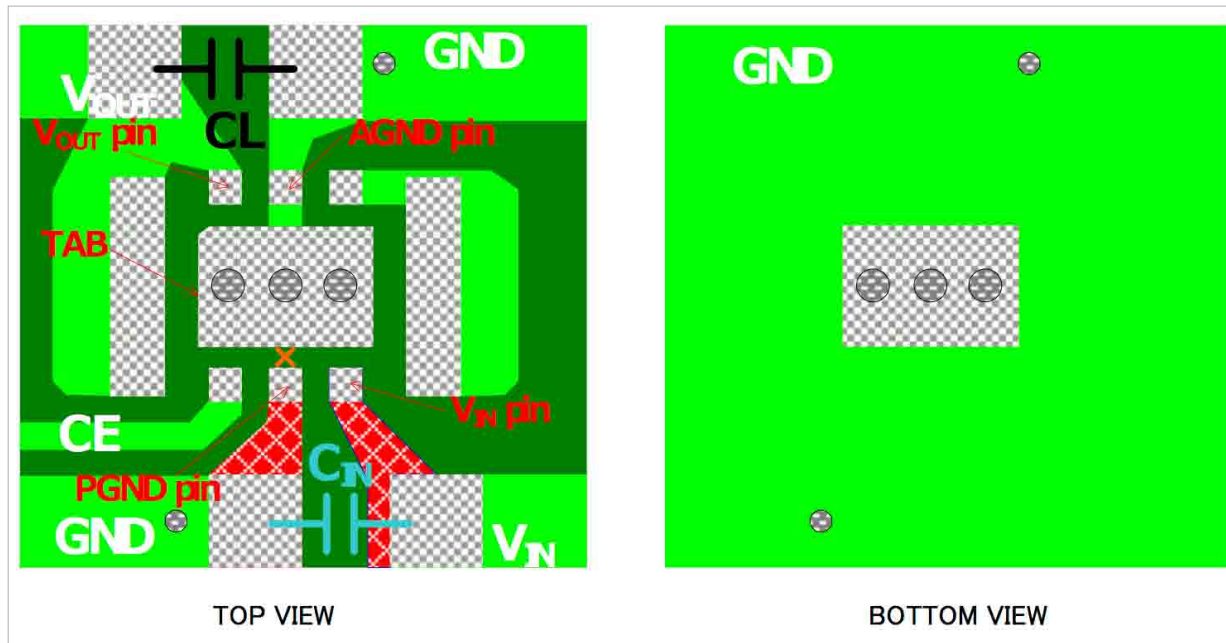


Figure 7: XCL206 Printed Circuit Board Layout

(2) only operates. When switch 1 (SW1) and switch 2 (SW2) are switched, the switching current is instantaneously interrupted, causing the L (inductance) component of the wiring to generate an electromotive force.

The detailed steps that must be taken are explained below using circuit diagrams. To reduce noise, the red wiring in **Figure 6** must be kept short. Apart from the wiring inside the IC, the input capacitance (CIN) should be placed near the VIN – GND pins of the DC/DC converter and connected with short wiring. Caution is required because GND in particular will disperse noise throughout the entire system.

The next explanation refers to the actual test board of the XCL206 (micro DC/DC

converter). There is a power GND (PGND) and an analog GND (AGND). In this case, the input capacitance (CIN) can be connected by a short connection to the power GND (PGND) to make the area of the GND pattern (red) where the electromotive force generated is extremely small (see **Figure 7**).

In terms of pin assignments on the XCL206 test board, the layout of the GND pattern appears to be simply a matter of connecting the power GND (PGND), TAB, and analog GND (AGND) in a line on the front pattern. However, from the perspective of noise, caution is required because the current path changes and the effectiveness of CIN drops, resulting in a negative effect. Manufacturers inside and outside Japan have recently

been aggressively pursuing the development of wearable devices. Starting several years ago, many TOREX micro DC/DC converters have been adopted for use in GPS watches (sports watches), HMDs (Head Mounted Displays), pulse oximeters, and other devices. Wearable devices are worn for long periods of time, and as such their design reflects concern for preventing “burn injury due to component heat generation”, “battery drive time”, and “the effects of high frequency noise on the body.” This is a likely reason for the increased use of micro DC/DC converters with their compact size, high efficiency, and low noise among the manufacturers.

[www.torex.co.jp/english](http://www.torex.co.jp/english)

# Two-switch forward converter: operation, FOM, and guidelines for device selection

This technology also competes with Zero Voltage Switching (ZVS) LLC topologies

By: Sanjay Havanur and Philip Zuk, Vishay Intertechnology

The two-switch forward converter is quite popular with ATX power supplies/silver boxes in 150 W to 750 W output power levels, and also competes with Zero Voltage Switching (ZVS) LLC topologies. It is a hard-switched topology and does not operate in ZVS mode. But for that very reason it offers the benefit of having no body diode conduction. The input voltage seen by the MOSFETs used in this power range is the output voltage of a Power Factor Correction (PFC) converter, as required for any supply with output power  $\geq 65$  W. This voltage is typically 380 V to 400 V. During turn-off the MOSFETs may see an additional

spike coming from leakage inductance energy, though it is clamped by the fast recovery diodes.

The basic operation is as follows: **Figure 1a** shows transistors  $Q_1$  and  $Q_2$ , which turn on together transferring energy through the transformer primary into the secondary. On the secondary, the forward rectifying diode conducts, transferring the energy into the output filter and load.

When transistors  $Q_1$  and  $Q_2$  are turned off, the transformer magnetizing current flows through the now forward biased diodes  $D_1$  and  $D_2$  and back into the source as shown in **Figure**

**1b**. The diodes conduct until all magnetizing energy in the primary, along with energy stored in the leakage inductances, is returned to input supply. Since diodes  $D_1$  and  $D_2$  clamp the input voltage, no snubber circuit is required. Any overshoot beyond the input voltage needs to be managed with proper circuit layout to minimize stray inductances. On the secondary, the freewheeling diode conducts as shown, transferring the output inductor energy to the load.

During the non-power delivery cycle of the primary, proper transformer reset time is achieved when the ON time is less than its OFF time (duty cycle is less than

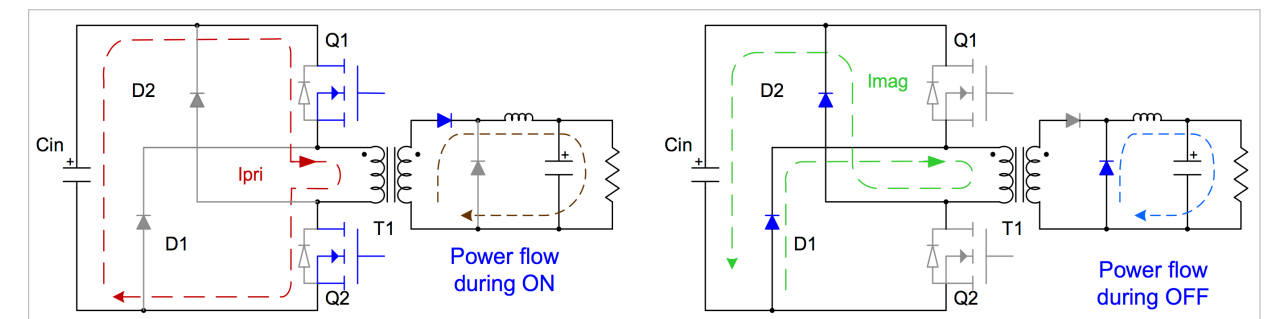


Figure 1a (L): Power transfer stage of operation and Figure 1b (R): Power flow from output cap to power load



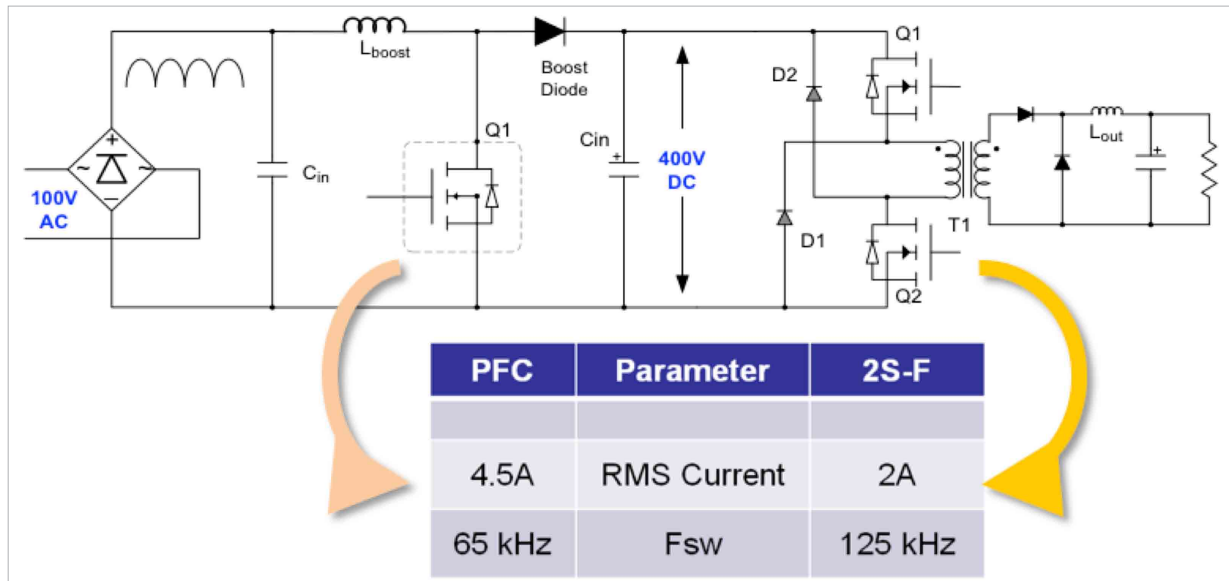


Figure 2: PFC converter versus a two-switch forward converter

50 percent). In other words, the primary winding itself acts as the reset winding. Having the OFF time longer than the ON time will always reset the transformer.

**Dual Switch Versus PFC Converter, FOM, and Power Loss**

Figure 2 compares power losses of the two-switch forward converter to the single-switch PFC front-end converter in a 400 W power stage. The MOSFETs in the two-switch forward converter carry half the current, and switch at twice the frequency (125 kHz versus 65 kHz, typical). With this doubling of the frequency, the switching losses become a more dominant factor in the overall Figure of Merit (FOM) and power loss measurement.

To illustrate further, consider a TO-220 / TO-220F device with a maximum power loss of 8 W. Assume that this is an optimum choice for a PFC

application. By optimum it is implied that conduction losses are approximately 40 % to 50 % of the total losses at rated power. Would it also serve as an optimum solution for the two-switch converter that follows? The answer is a definite no. In the two-switch topology the  $C_{oss} / Q_{oss}$  and  $Q_{sw}$  would contribute approximately 87% of the total losses and the remaining would be conduction losses. Such unbalance between conduction and switching losses is highly undesirable for efficiency and cost. The reason why conduction losses are less than what would be seen in a single-switch PFC converter, is that each MOSFET used will have half the current of a single-switch PFC circuit, while switching at twice the frequency.

In any switching circuit there are two kinds of switching losses. The first is due to the  $V_{ds} \times I_{ds}$  crossover that happens during

turn-on and turn-off. These losses are weighted to what we call “ $Q_{sw}$ ,” which is the combination of the  $Q_{gd}$  and the  $Q_{gs}$  and represents the effective switching charge of the MOSFET. The crossover-related switching losses are a function of both load and switching frequency.

The second switching loss is associated with the charging and discharging of the MOSFET output capacitance  $C_{oss}$ . In ATX power supplies, the popular two-switch forward converter follows the PFC converter having an input voltage ~ 400 V. As a result, the output switching loss can be a significant portion of the total losses. The  $C_{oss} / Q_{oss}$  of the device is a very important loss, especially at light loads where switching losses trump conduction losses. This loss is essentially independent of load and  $Q_{oss}$ , along with  $Q_{sw}$ , needs to be taken into account

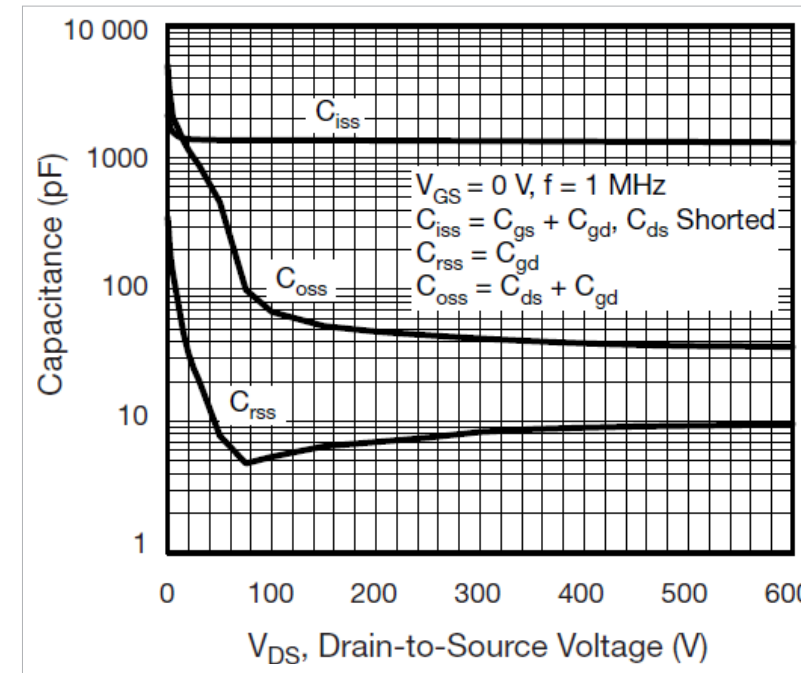


Figure 3a: Super Junction technology capacitive plot

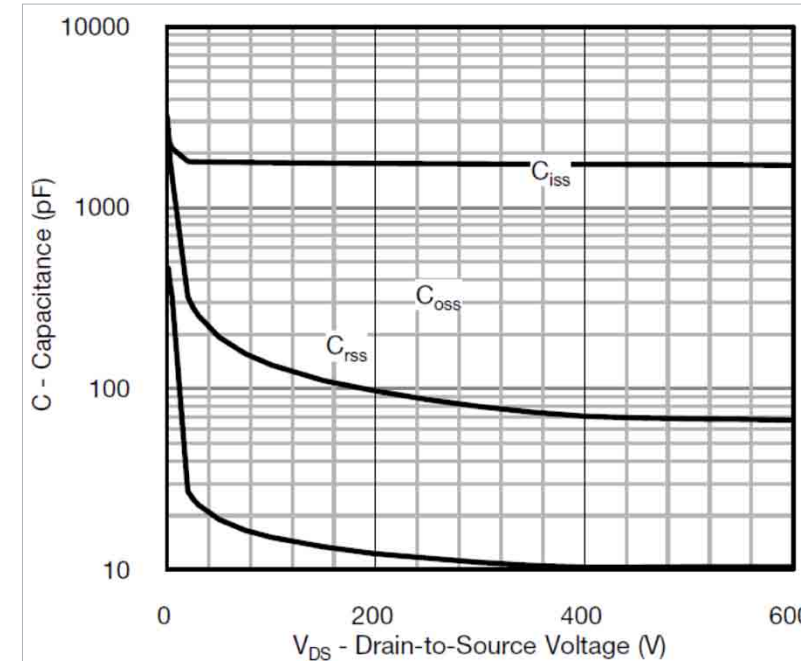


Figure 3b: Planar technology capacitive plot

when selecting the appropriate MOSFET. An application-specific FOM based on loss contributions will look like:

Conduction losses ( $R_{ds(on)}$ ) +

Switching losses ( $Q_{switch}$ ) + Output losses ( $Q_{oss}$ )

The  $C_{oss}$  of a high-voltage MOSFET varies considerably with the applied  $V_{DS}$ . This variation



Two-Switch Forward Converter Operating Conditions	
Input Voltage	400 V
Input Power	450 W
PFC Switching Frequency	125 kHz
Duty Cycle	3/8
MOSFET Drive Voltage	12 V
On / Off Gate Current Range	0.5 A (100 W) to 1.0 A (750 W)

Table 1: Two-switch forward converter design conditions

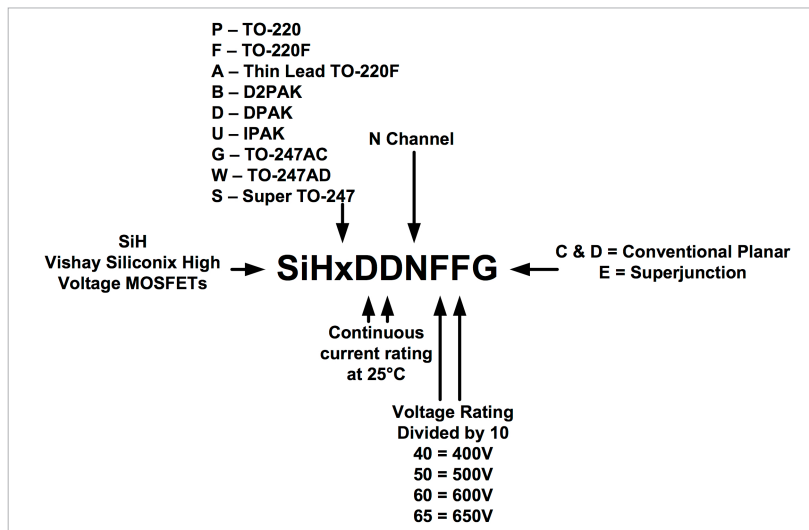


Figure 4: Part numbers definition

Recommended Power Levels Based on Package Type	
Packages	Recommended Maximum Ratings
DPAK (TO-252) / IPAK	Up to 150 W
D2PAK (TO-263) / TO-220	Up to 200 W
TO-220	Up to 350 W
TO-220F / Thin Lead TO-220F	Up to 350 W
TO-247AC	Up to 1000 W
Super TO-247	Up to 1500 W

Table 2: Maximum power levels based on package type

is much wider for high-voltage superjunction power MOSFETs (Figure 3a) than for planar types (Figure 3b). To account for the non-linearity of the output capacitor,  $P_{oss} = \frac{1}{2} C_{o(er)} \times V^2 \times F_{sw}$  may be used as an approximate

loss equation. The energy-related capacitance  $C_{o(er)}$  is the effective capacitance that has the same stored energy and same losses as the integrated  $C_{oss}$  of the MOSFET (o V to VDS) and is provided in the datasheets. It

may be pointed out that output capacitor related losses, which constitute a significant part of the total loss equation in any high voltage topology, are not taken into account in the industry standard FOM  $R_{DS(on)} (typ) \times Q_g (typ)$ . However, they are integral to the application specific FOM used in this analysis for device selection.

With this in mind, we have developed a list of components that we feel will achieve the highest efficiency for a two-switch forward converter based on typical operating conditions to ensure the most efficient design possible. Each MOSFET has a target loss of less than 0.5 % of the total converter loss. So, for a 400 W ATX power supply, the losses would be no more than 2 W per device.

Table 1 illustrates the operating conditions assumed for such a power supply. The list of recommended devices includes an “x” in the “Package” location. For the same set of electrical characteristics, a number of package options may be available per device. The packages used will depend on the power level as well as what MOSFET real estate is allowed. Figure 4 defines the packages, current rating, voltage, and device technology of the different part numbers. With many package options available, Table 2 lists the recommended maximum power rating for the different package offerings.

[www.vishay.com](http://www.vishay.com)

# Moving forward with reverse-blocking IGBTs

RB-IGBTs can find application in systems requiring the use of a bidirectional switch

By: Nitesh Satheesh and Akihiro Fukuchi, Fuji Electric

Energy is an issue that affects every person on the planet. With the advancement of the Human Race, Energy Dependence has increased and this has strained the Earth’s natural resources. To make better use of the available resources, numerous efforts have been made to improve existing technology and change the way new products are made and used.

Fuji Electric has developed a century-long reputation for being on the forefront of Energy innovation. The manufacturer’s operating philosophy is centered on the creation of responsible and sustainable societies through innovation in Energy Technology, and they continue to lead the market with revolutionary, advanced solutions, which serve the global effort toward a brighter and healthier tomorrow.

The company recently introduced RB-IGBT’s (Reverse Blocking Insulated Gate Bipolar Transistor, developed for use in Matrix Converters, but the company

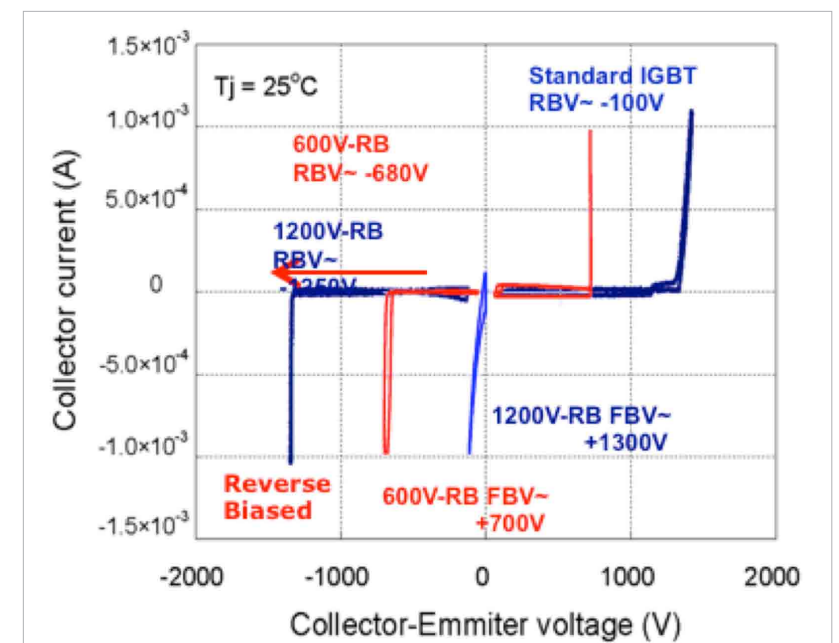


Figure 1: Advantage of using RB-IGBT’s reverse-blocking capability.

has been expanding its target application areas which now include Current Source Inverter for Motor Drives (EV/ HEV) and 3 level inverters for PV, Wind and UPS. Their use in the Advanced T-type NPC (Neutral Point Clamping) 3 level modules give energy efficiency a new meaning.

### Device Structure

A conventional IGBT has forward and reverse blocking capability. So theoretically, we can use the IGBT to block

reverse voltages equivalent to the IGBT forward voltage rating. However, practically, this is not true. Under reverse bias, there is a leakage current, the dependence of this current on reverse voltage is exponential. The primary difference in structure between the Fuji RB-IGBT & a conventional IGBT is that the former has deep junction isolation structure that limits carrier generation thereby providing the needed (higher) reverse blocking capability.



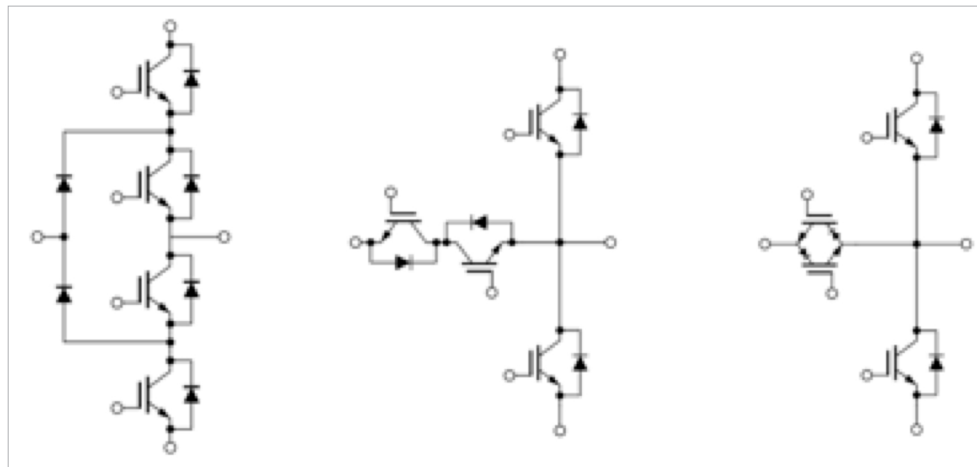


Figure 2: Li-ion Battery System

**Performance**

The forward characteristics of the RB-IGBT are very similar to that of a standard IGBT. Therefore switching speed and trade-off curve of  $V_{on}$  are similar. **Figure 1** shows the reverse characteristics of a conventional IGBT as compared to a RB-IGBT.

**The Reverse Blocking IGBT**

has found a use in many applications, including but not limited to Inverters, Converters, battery charging systems, matrix converters, pfc circuits, etc. RB-IGBT's in Inverters Multilevel Inverters have been in discussion from the early 1980's, with an end goal to reduce inverter harmonics and thereby reduce use of magnetic components. An added advantage is reduced losses, with the introduction of NPC, TNPC & ATNPC (Advanced T-type Neutral Point Clamp) topologies.

A direct application of the Fuji RB-IGBT is the Advanced T-type Neutral Point Clamped

module. The T-type modules in existence/ those offered by our competitors use the conventional AC-Switch shown in 5(a). More components means more losses and more chances of failure. A loss comparison is presented in the next section that details the performance of the 2-level inverter, 3 level NPC inverter, Advanced NPC 3 level inverter and the Advanced T-type 3 level inverter.

There is a significant performance improvement with an efficiency increase of 2% from 95.1% to 97.1%. There is also an added benefit of a 33% volume reduction, weight reduction of 36%, due to the reduction in filter components & magnetics.

**RB-IGBT's in matrix converters**

The largest consumers of power in the US today are Industrial Motors. A reduction of losses in this segment will greatly benefit our Energy Efficiency initiative. A Matrix Converter is essentially an AC-AC Converter that does away with the rectification

and filtration steps required when having the conventional AC-DC-AC conversion.

Conventionally, between the Source of power and consumer, we have a number of steps to condition the power to ensure smooth operability.

In the example of driving an Industrial Motor, the Matrix converter assumes the role of a Rectifier/ Inverter block and does away with the Boost block (Required to suppress inrush current to DC Caps).

Internal Fuji Electric studies have shown that the using RB-IGBT's in the design of a Matrix converter reduces losses 30% compared to system implemented in the traditional form with reactor and PWM rectifier.

**Battery chargers**

An internal Fuji study was conducted to verify benefit of using the RB-IGBT in place of the conventional IGBT in reverse series in battery charger systems. For the internal tests, a battery voltage of 450V and charge current of 24A was simulated with the result that, using Fuji RB-IGBT has 35% reduced losses compared to conventional system (see **Figure 2**).

[www.fujielectric.com](http://www.fujielectric.com)

# Special Report: Lighting and Illumination



INSIDE:

- Improving Thermal Management of LEDs... 36
- Connecting Modern Lighting to a Brighter Future... 40
- Decoding the Digital Addressable Lighting Interface (DALI) protocol... 43

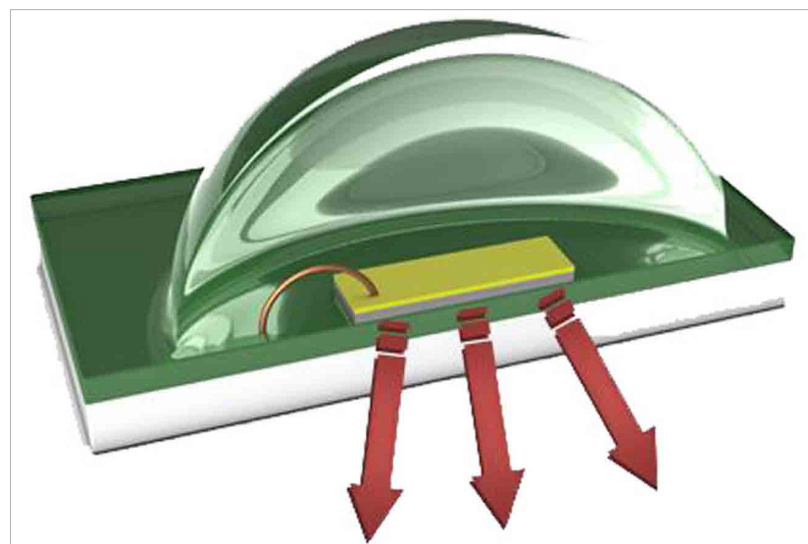
# Improving Thermal Management of LEDs

Proper thermal design is necessary to ensure quality and reliability of SSL products

By: Mark Youmans, Cree

**M**any LED failures are temperature related since an LED's performance and projected lifetime correlate tightly to thermal management and the resulting junction temperature of the LED semiconductor chip. Elevated junction temperatures cause a reduction in light output and accelerated LED lifetime degradation. Proper thermal management of an LED luminaire is vital for performance (see **Figure 1**). Measuring and validating thermal design assumptions is necessary to ensure quality and reliability of SSL products.

Some performance characteristics experience a recoverable change, such as light output, color and voltage, while others, such as lifetime, can experience a non-recoverable degradation due to high operating temperatures. However, exceeding the maximum operating temperature specification, which is typically a 150 °C junction temperature, can cause damage to LEDs, so care



*Figure 1: Proper thermal management of an LED luminaire is vital for performance*

must be taken to operate LEDs below this limit.

## Light output issues

Important performance characteristics and implications of improper thermal management include light output, as elevated junction temperatures cause recoverable light output reduction. As the junction temperature increases, the light output of the LED decreases, but recovers when the LED cools. Also, with increasing junction temperatures, the color of all LEDs shifts.

## Voltage

Forward voltage decreases as the junction temperature of an LED increases. It is important to understand the full operating conditions for an LED system so the driver can accommodate the potential range of drive voltages over the operating temperature of the system.

## Reliability

The reliability of any LED is a direct function of junction temperature—the higher the junction temperature, the shorter the lifetime of the LED. Data

from an IES LM-80-08 report can be used to predict the lumen maintenance of an LED under various temperatures and drive current operating environments. A TM-21 calculator from the Environmental Protection Agency (EPA) can be used with the LM-80 data to predict lumen degradation and expected lifetime under specific operating conditions.

## Heat Generation

LEDs generate visible light when current passes across the junction of the semiconductor chip. However, LEDs are not 100 percent efficient; much of the power running through an LED is output as heat, which thus needs to be dissipated. For example, Cree royal blue XLamp LEDs are over 50% efficient and white XLamp LEDs are over 40% efficient. That means, under ideal operating conditions, approximately 50% to 60% of the input power is output as heat, while the rest of the input power is converted to light. The harder an LED is driven, the less efficient it is, so to be conservative, assume LEDs convert 25% of the input power to light and output 75% of the input power as heat when designing thermal management systems.

## Heat Transfer

There are three basic modes of heat transfer: conduction, convection and radiation. Each plays a role in LED performance

and final system design, and must be understood for proper thermal management.

**Conduction:** Conduction is the transfer of heat through a solid material by direct contact. This is the first mode of heat transfer to get thermal power from the LED junction to the heat sink. Metals are typically the best conductors of heat.

**Convection:** Convection is the transfer of heat through the movement of fluids and gases. In LED systems, this is typically the transfer of heat from the heat sink to the ambient air. There are two sub-categories of convection: natural and forced. Natural convection occurs with no artificial source of field movement and is due to the buoyancy forces induced by thermal gradients between the fluid and solid. Forced convection occurs when an external instrument such as a fan, pump or other device is used to artificially move the fluid or gas. In LED cooling systems, convection is the main mode of heat transfer to remove the generated heat from the LED system and heat sink.

**Radiation:** The transfer of thermal energy through an electromagnetic field is the third component of heat transfer, radiation. The magnitude of radiation heat transfer is based on the emissivity of the material, which is the ratio of how closely

the surface approximates a blackbody and the temperature gradient of the system surfaces relative to the ambient air. In an LED system, radiation typically has a very small effect on the net system heat transfer since the surface areas are typically fairly small and surface temperatures are relatively low, to keep the LED junction temperatures below the maximum rated temperature of 150°C.

## Thermal Stack

For purposes of thermal analysis, an LED system typically consists of a multi-component assembly, called a thermal stack, in which all components contribute in varying degrees to the total system thermal performance. In a typical system, the LED is soldered to a PCB, either metal core or FR4, which is then usually attached to a heat sink. It is critical to maximize heat transfer between the heat sink and PCB, so a good thermal interface material (TIM) is needed to fill any air voids. The best method to enhance the thermal path and minimize the system thermal resistance is to minimize the number of materials in the thermal stack and use the most thermally conductive materials available.

The heat sink is the most influential part of the thermal stack, and is needed to first conduct heat away from the LEDs and then to convect and radiate heat to the ambient air.



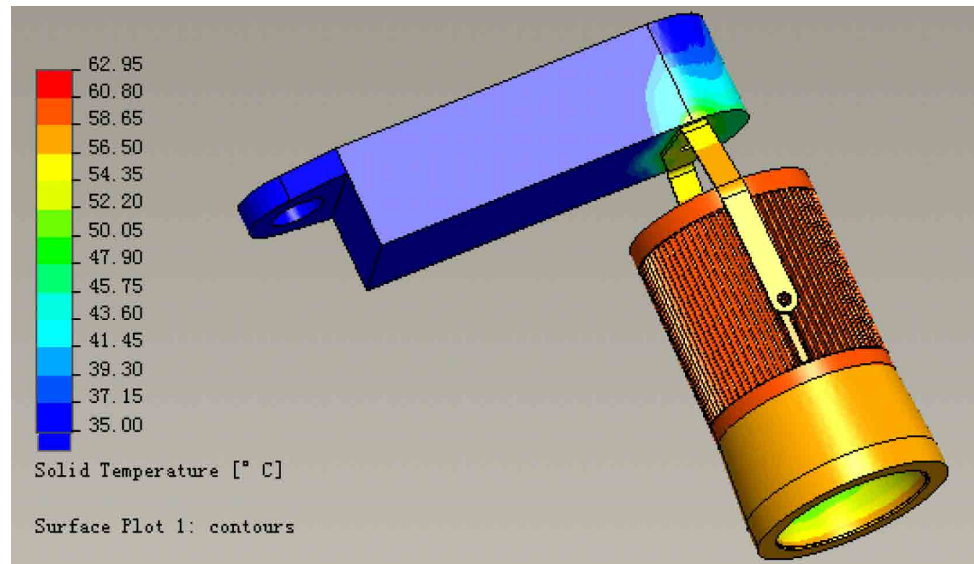


Figure 2a

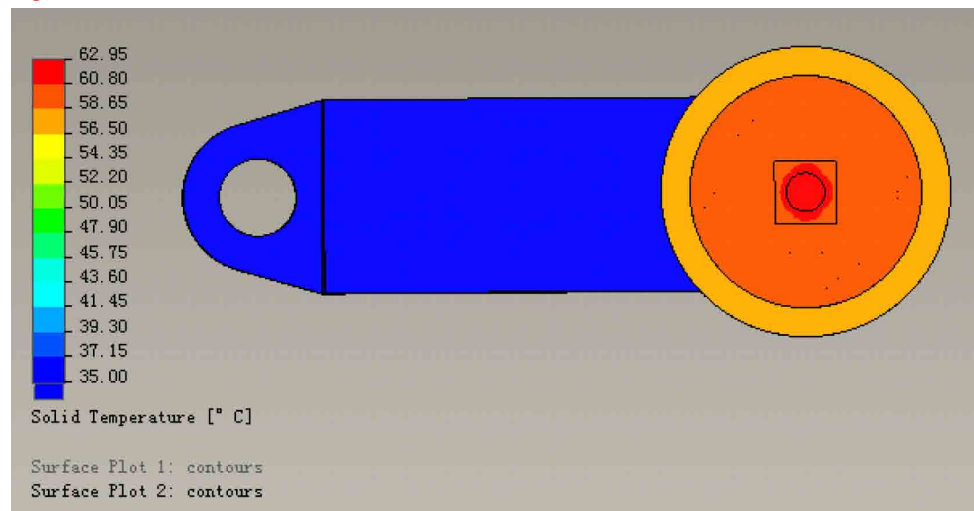


Figure 2b

Figure 2: Thermal simulations can show problematic areas and hot spots within a design

Thus, the first task of the heat sink necessitates that the heat sink be fabricated from a high thermal conductivity material to conduct heat away. The second task requires that the heat sink have a large surface area to convect heat to ambient and also have high emissivity so it can radiate heat away.

When the thermal load of an LED

system is too high to be properly dissipated by passive means, active cooling may be the only solution. There are many types of actively cooled systems, from fans to liquid cooling to heat pipes to other exotic methods. The effectiveness, reliability, noise, cost, added power (and thus lower system efficiency) and maintenance of these devices need to be weighed

against the benefits of an actively cooled system. Very few active cooling devices can equal the long LED lifetimes of many thousands to hundreds of thousands of hours, so care must be taken to not compromise system lifetime with inept active cooling solutions. An LED system is only as good as its weakest link, and active cooling can be this link without careful selection.

### Thermal Measurement

Accurate temperature measurements are required to appropriately design a thermal system and to evaluate and assess an existing

design. Whether for a final design or a prototype, the measurement process is the same and requires due diligence to make sure realistic and accurate measurements are made. LED reliability is a major advantage compared to traditional light sources, so proper and realistic measurement procedures should be used so this benefit is not jeopardized.

When performing thermal measurements, it is critical to set up the test subject as close as possible to the real-life, worst-case scenario to which the system may be subjected. Ensure that the measurement setup accounts for similar airflow, material properties, orientation, ambient conditions and any additional heat sources such as power supplies or contributory heat loads. This ensures that the temperatures measured correspond to real-world, worst-case scenarios and could identify potential problems that best-case scenarios may miss.

Another factor to note is the time required for the system to thermally stabilize. Depending on the size of the heat load and the mass and effectiveness of the heat sink, some systems take only a few minutes to stabilize while others take hours. It is best to monitor the thermal stability and wait one hour at the very least for each thermal measurement. It is also recommended to monitor the ambient temperature and look exclusively at the difference between the measurement point and ambient temperature, as any change in ambient will be reflected in the measured data.

### Thermal Simulations

For early design validation, before investing in expensive prototyping and multiple design revisions, it is highly recommended to perform

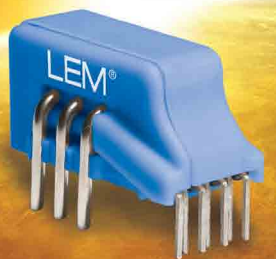
thermal simulations. Cree® Services offers thermal simulation through its Thermal, Electrical, Mechanical, Photometric and Optical (TEMPO) service options. Thermal simulations can show problematic areas and hot spots within a design and can allow for iterative design adjustments to address problems and optimize the system (see **Figures 2a and 2b**). Computational fluid dynamics (CFD) analysis further enhances thermal simulations by solving for conduction, convection, whether natural or forced, and radiation to fully evaluate the total system design and the effect of the fluid flow around the system.

Simulations are good for quick and inexpensive design adjustments and give a good visual representation of spreading, potential bottlenecks, and thus possible areas of improvement. After simulating a system and optimizing a design, building a final prototype to accurately measure its performance is always recommended. However, thermal simulations can be used to minimize the iterative steps of seemingly infinite prototyping by proactively reducing the number of options and focusing the design work instead of investing in prototypes, testing and repeating.

[www.cree.com](http://www.cree.com)

Dawn of a new intelligence for current measurement

PCM Europe 2014 Hall 9-204



## HO

Conventional current transducers are over. The age of intelligent, interactive transducers begins with the dawn of the programmable HO. Set its operational characteristics using a simple microcontroller interface to meet your applications' needs. Its outstanding performance gives you better control and improves the efficiency of your system whilst minimising inventory with one configurable device.

The future starts now!

- Three programmable ranges: 8 A<sub>RMS</sub>, 15 A<sub>RMS</sub>, 25 A<sub>RMS</sub>
- Single +5V or +3.3V power supply
- Through-hole and SMT packages
- Up to 8 mm creepage and clearance distances + CTI 600 for high insulation
- Half the offset and gain drifts of previous generation
- Overcurrent detection with programmable thresholds
- Programmable slow (6 μs) or fast (2 μs) mode
- Up to 4 programmable internal reference voltages
- Access to voltage reference
- -40 to +105°C operation

[www.lem.com](http://www.lem.com)

At the heart of power electronics



# Connecting Modern Lighting to a Brighter Future

Solid-state technology has dramatically altered the industry

By: Jim Bachle and Amanda Bell, WAGO

The controversy over when, where and who developed the incandescent lamp continues with dates and places varying from the early 1800's in Hungary to the late 1800's in Menlo Park, California. What cannot be disputed is that this product brought about a revolution to the lighting industry, leading to the constant creation of new lighting technologies for generations to come.

The introduction of fluorescent lighting in the 1940's brought a new evolution in the lighting industry and has since been a dominant technology in the marketplace. With an installed base exceeding 30 billion units in commercial and institutional properties, the end product continues to increase efficiency, life expectancy, and lumen output while maintaining an affordable price point.

Despite discovery in the early 1900's, the Light Emitting Diode has only recently been instituted in this latest revolution in lighting. Touting very high operating efficiency coupled with

extended life, this technology has generated an entirely new set of challenges associated with control, certification, and manufacturing while allowing designers new freedom in creating lighting schemes to fit their applications.

While designers enjoy their new autonomy from the lack of constraints from conventional lamps, and tubes no longer trying to innovate designs while handcuffed by 'the same old box', the engineering community is thrilled with the new challenges and opportunities to be creative in their own right.

## Solid-state lighting issues

Managing the headaches associated with previously unseen issues such as with thermal dynamics, color shift, and certification are offset by the rewards gleaned by the fresh capabilities and possibilities of full-range dimming, 'instant-on' regardless of ambient temperatures, as well as infinite control possibilities.

Although the price tag associated with the end-product continues to fall, OEMs face ever-

present demands for increased performance at lower operating costs while designing for extended life and warranty periods.

Solid-state technology has dramatically altered practices and components implemented in the manufacturing process. The industry is faced with dealing with an entirely new range of components and conductor ranges and regulations; quickly going by the wayside are the days of tombstone sockets, ballasts and 18 AWG solid conductors. Industry pressures and Energy Star requirements are forcing manufacturers to make this magical new technology maintenance friendly.

Maintaining the integrity of the technology is gaining new prominence in this revolution as manufacturers continue their evaluation of every component within the system specific to solid, long-term performance.

Connectors specifically have shifted to surface mount technology as the light source has also shifted from a lamp or tube to a circuit board. Challenges

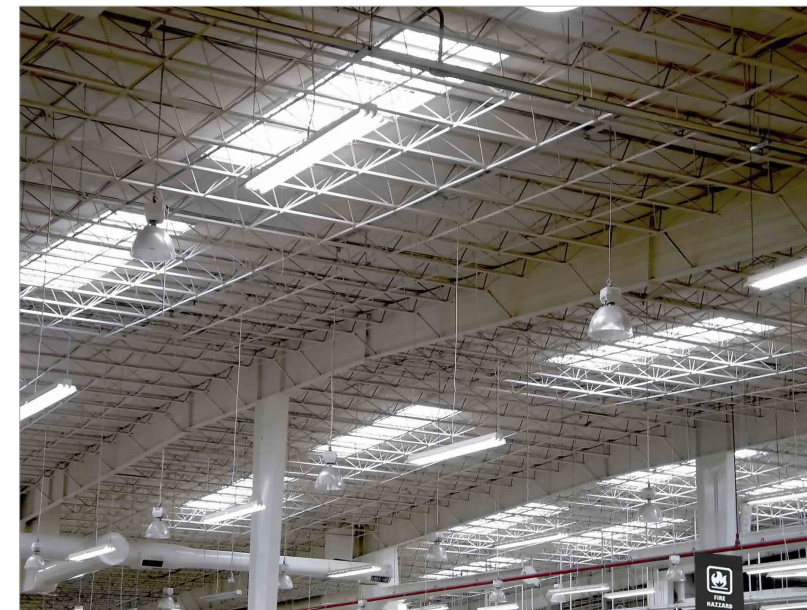


Figure 1: Consideration must be given to the environment the lighting is deployed associated with height and color (to prevent shadowing) must be weighed against current and voltage requirements that can reach Class I thresholds. Consideration must be given to environmental issues such as shock and vibration, temperature changes and salt-spray/corrosion (See Figure 1).

Building on a long history of solid performance under the most challenging of conditions, WAGO Corporation continues to produce innovative products that provide solutions via our industry-proven, maintenance-free CAGE CLAMP® connection technology. WAGO's ISO 9001 manufacturing processes ensure the ultimate in quality while providing components with a competitive value and cost ratio.

## Compact Surface-Mount Connection Technology



Figure 2: The compact size and light color reduce shadowing in an LED application

WAGO offers a comprehensive range of surface-mount PCB terminal blocks with pushbuttons for the lighting industry, including the 2060, 2061 and 2059 Series. Each series is available in tape-and-reel packaging for ease of implementation into the automated assembly process, offers easy handling via side-entry wiring and top-of-unit actuation, and features 1-, 2- or 3-pole variants. The compact size and

light color of each surface-mount PCB terminal block helps conserve space and reduce shadowing in LED applications (see Figure 2).

Ideal for interconnecting PCB-based LED modules in luminaires and signs, WAGO's 2060 Series SMD PCB Terminal Block with Pushbuttons features a low profile, contoured edges and a light color. A larger variant than the field-proven 2060 Series is the new 2061 Series SMD PCB Terminal Block with Pushbuttons, ideal for PCB-based LED lighting and industrial electronics. The perfect connection for incoming power to an LED driver, or for higher power

LED modules, the 2061 Series is a cost-effective, manufacturing-friendly alternative to hand-soldering leads.

As the smallest product in WAGO's range, the 2059 Series SMD PCB Terminal Block is

the ideal solution for extremely small LED applications, offering a fast, cost-effective alternative to soldering leads (see Figure 3). Due to its ease of use and compact size, the 2059 Series is especially suited for solid state lighting applications that often utilize metal-core PCBs, including compact or miniaturized LED modules and LED 'bulbs'.

## Street Light Application





Figure 3: The 2059 Series SMD PCB Terminal Block suits extremely small LED applications

Unlike interior fixture applications, several lighting manufacturers are implementing LED drivers capable of delivering an output voltage of 400V DC, changing the electrical environment from Class II (Low Voltage) to Class I. Insulation properties of connector bodies must meet the certification requirements for 600V as well as spacing criteria for differing potentials.

A WAGO customer had built prototypes without a connector and was experiencing concerns over the expense and reliability associated with direct solder of the conductor to the metal-core circuit board. The challenges associated with the application called for an end-product that could withstand vibration associated with heavy traffic flow, temperatures that could range from -30°F to 100°F+, and possible locations in coastal areas where salt-spray would be of concern.

WAGO offered two options: either two 'single-pole' 2060 series connectors, or a custom unit

developed specifically for this application – a single unit with spacing that met the requirements of the certification agencies.

The single unit (series 2060-802) was selected for the following reasons:

- Wide range of conductor size and type (24-18 AWG, solid/stranded/stranded prepared)
- Excellent resistance to vibration, corrosion and temperature cycling
- Single component placement reduced cost of mounting while increasing throughput of automated equipment
- Voltage and current requirements were exceeded (rated at 600V/9A)
- Ease of maintenance and replacement of arrays
- Standard two year warranty of WAGO products

#### Interior Downlighting Application

The proven design of the recessed downlight has been a favorite of designers for decades due to its' clean lines and excellent performance. Updating this platform from the previous generations of incandescent or compact fluorescent to LED greatly expands the capabilities of the unit.

Throughput in both automated and manual assembly areas of the manufacturing process are key factors in obtaining a palatable

market price for the end-product. Shadowing and minimizing obstructions for LEDs and their optics are considered critical factors for acceptable product design. With base platform designs of 4" or 6" apertures, space is at a premium.

Two single-pole 2060 series (2060-401) were selected for a WAGO customer for the following reasons:

- Small footprint allowing placement to minimize shadowing
- Wide range of conductor size and type (24-18 AWG, solid/stranded/stranded prepared)
- Direct insertion of conductors reduced cost of assembly while increasing throughput of the manual assembly process
- High voltage and current thresholds exceeded the requirements of the application providing assurance of long-term performance
- Ease of maintenance and replacement of arrays
- Standard two year warranty of WAGO products

The rapidly changing technologies within modern lighting schemes have significantly reduced the chasm between economies of operation and aesthetics. With the increasing demands and expectations for extended service-life, connection technology has gained new prominence as an integral component of the finished product.

[www.wago.us](http://www.wago.us)

# Decoding the Digital Addressable Lighting Interface (DALI) protocol

Lighting is one of the factors that greatly impacts human comfort

By: David Maliniak, Teledyne LeCroy

In this age of "green" building systems, it is incumbent upon commercial building owners and operators to reduce their day-to-day operating costs while at the same time ensuring the comfort of occupants. Lighting is one of the factors that greatly impacts human comfort. Too much or too little light can result in eyestrain and/or hamper productivity.

Intelligent lighting control systems allow building owners to create inviting and functional office environments that improve light quality, enhance efficiency and productivity, and optimize energy use. Think of it as a system that allows a building to make intelligent decisions about the optimum delivery of light. Lighting controls can switch lights off when no one is around, automatically adjust lighting levels based on the amount of natural daylight in the space and turn off or dim lights, based on the daily cycle of the office.

#### Digital Addressable Lighting Interface

One approach to an intelligent lighting control system is

implemented through the Digital Addressable Lighting Interface (DALI). DALI is a protocol described in the technical standard IEC 62386 for digital control of building lighting systems. The interface is a simple two-wire affair with a maximum system size of 64 addresses. DALI stands separate from building-automation bus architectures but can be tied into those structures to pass along data regarding the status and condition of the lighting system.

Many standard interfaces, including DALI, are based on the fundamental building blocks of the Manchester or NRZ line-encoding schemes. As with any serial-data protocol, debugging depends on the ability of instruments such as digital oscilloscopes to properly decode the protocol. In this article, we'll look at how this is accomplished by Teledyne LeCroy's instruments through the use of a configurable Manchester decoder.

#### DALI Physical and Data Link Layers

Before examining the decoding of the specific signal as an example in this article, here are some basics on the DALI technical

specification. More information on DALI is available at: [dali-ag.org](http://dali-ag.org). Additionally, the DALI-interface has been described in the fluorescent lamp ballast standard IEC 60929 under Annex E.

At the physical layer, DALI uses an effective data transfer rate of 1.2 kb/s, enabling interference-free system operation. The physical low-level has been defined with the interface voltage at 0 V (-4.5 V to 4.5 V) on the receiver's side. The high-level condition is represented by the interface voltage of 16 V (9.5 V to 22.5 V) on the receiving side. A maximum voltage drop of 2 V between sender and receiver is admissible on the leads of the interface.

There are two types of data frames in the DALI interface: forward frames and backward frames. Forward frames consist of 19 bits with timing and must have a duration in time of  $38 T_e$ , with  $T_e$ , the duration in time of 1 bit at 1.2 kb/s being  $416.67 \mu s$ .

Backward frames are sent only after the reception of a query command or a write memory command. A backward frame

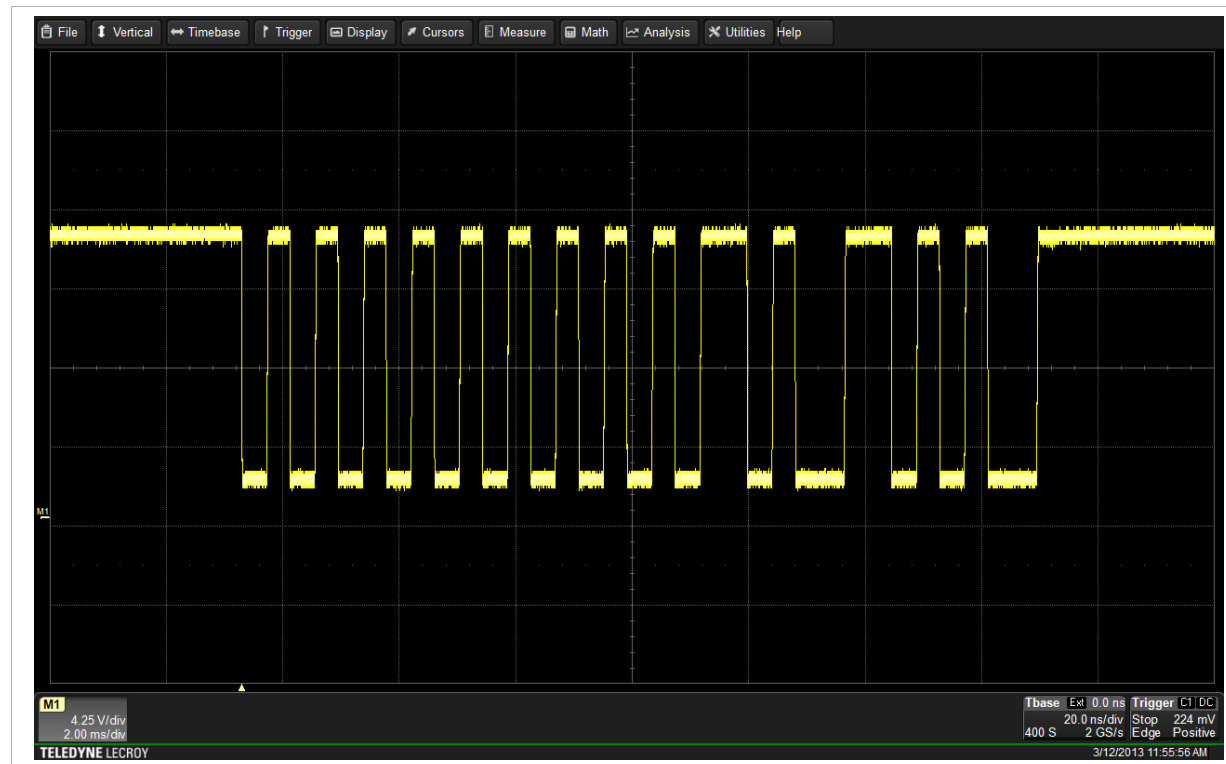


Figure 1: A DALI signal with two start bits, a 6-bit address, and one data bit consists of 11 bits and must have a duration of 22 Te.

### Embarking on a Decode

For this article, the signal at hand is a 1.2-kb/s DALI forward-frame signal consisting of two start bits (skipped), a 6-bit address, and one data bit as shown in **Figure 1**.

Through the Analysis drop-down menu at the top of the oscilloscope's screen, one accesses the Serial Decode dialog and from there, the Protocol menu. Selecting Manchester will activate the configurable Manchester protocol decoder.

The next step is to designate the source of the on-screen trace. For this article, the trace is stored in Memory 1 or M1. Although this

example uses a memory trace, the decoder works on all channels and math, memory, and zoom traces. After assigning the on-screen trace to Decode 1 in the Serial Decode dialog box, pressing the Setup button opens the Decode Setup tab, where the oscilloscope is prepared for the Manchester decode.

### Decode Setup: The Basic Tab

The Basic tab provides all of the fundamental controls required to allow proper bit-level decoding (names of settable parameters are shown in bold). The configurable Manchester decoder supports a wide range of bit rates. We know that the DALI physical specification dictates a fixed data rate of 1.2 kb/s, so the Bit Rate parameter in the Physical Layer portion of the Basic

tab is set to that value.

The Timeout Definition for the gap between bursts comprises two parameters, Units and # Bits. The former can be set to either Bits or Seconds. If Bits is chosen, the range is from 1 to 100. If Seconds is used, the range is from 1 to 99.99  $\mu$ s. The DALI specification dictates that for transmission of consecutive forward frames, the elapsed time between the end of the last stop bit and the beginning of the first start bit in the next forward frame must be at least 22 Te.

The Idle State, which complements the Timeout Definition parameter, may be set to either IdleHigh, IdleLow, or Don't Care. Setting the Idle State parameter helps to

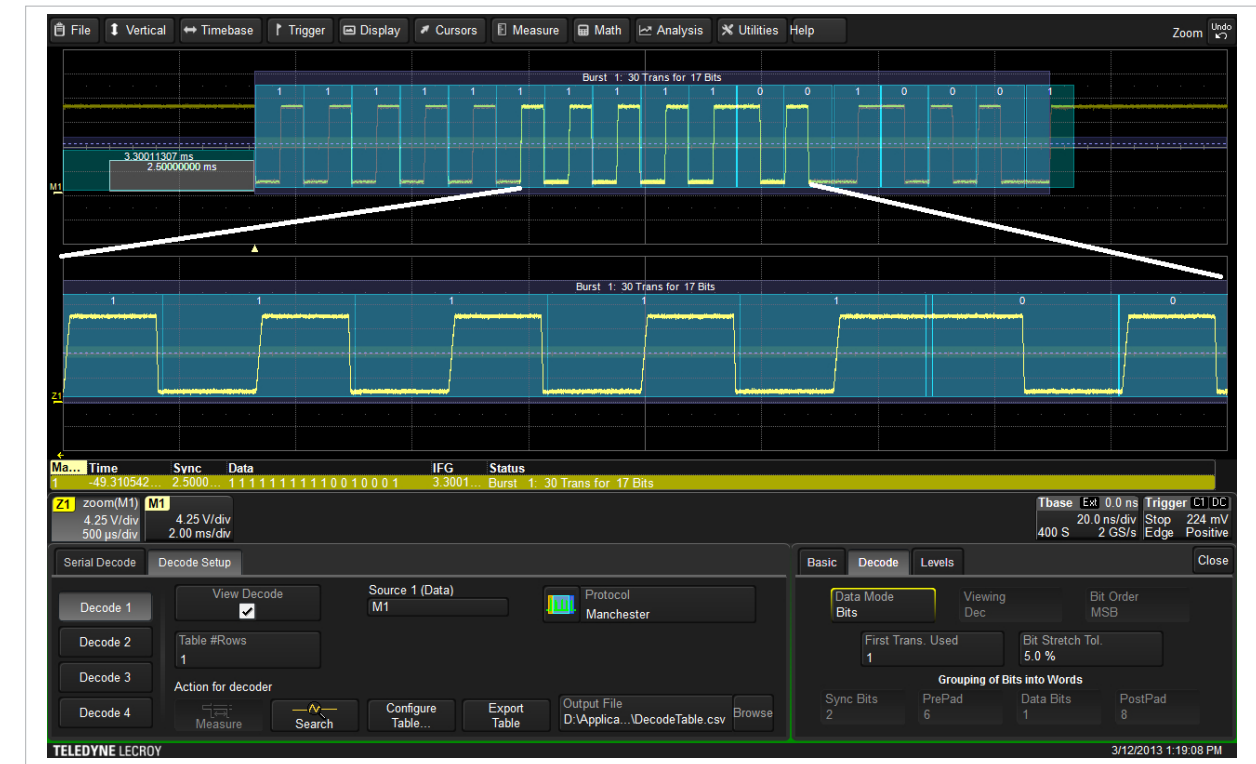


Figure 2: Verifying correct bit-level decode with a zoomed view

define the separation gap between data bursts. In the case of DALI, the idle state is set to IdleHigh.

The Polarity may be set to either Falling = 0 or Falling = 1. This determines whether an edge falling through the threshold level is decoded as a logical 0 or a logical 1, respectively. The DALI specification dictates that an edge rising through the threshold is decoded as a logical 1. Thus, for this example, Polarity is set at Falling = 0.

Next, we will look at the Decode tab. However, open a zoomed-in view of a portion of the decoded signal to ensure that the bit-level decode is correct (see **Figure 2**).

### Decode Setup: The Decode Tab

On the Decode tab, which is where

decoding at the word level is set up, set the Data Mode to Bits. Note that in the zoomed view Z1, which corresponds to the highlighted portion in the center of M1, each binary 1 is represented by a negative half-bit period pulse followed by a positive half-bit period pulse. Similarly, a binary 0 is represented by a positive half-bit period pulse followed by a negative half-bit period pulse. This type of signaling is also called split-phase encoding. In this case, Polarity is set to physical Falling = 0.

The First Transition Used (FTU) parameter accounts for items that may precede the actual data payload. These might include such elements as a preamble or a synchronization sequence. The default setting for FTU is zero; it

can range in increments of one to a maximum of 400.

The Bit Stretch Tolerance parameter comes into play when transitions often occur at mid-bit. Due to hardware or signal-propagation issues, these mid-bits may not be perfectly equidistant. This parameter is adjusted to better decode jittery signals. After setting the Bit Rate on the Basic tab, the Bit Stretch Tolerance may require adjustment from its default setting of 20% to achieve stable decoding.

At the bottom of the Decode tab is a number of parameters for Grouping of Bits into Words. **Figure 3** shows the DALI signal grouped into words. It is important here to ensure that the Data Mode



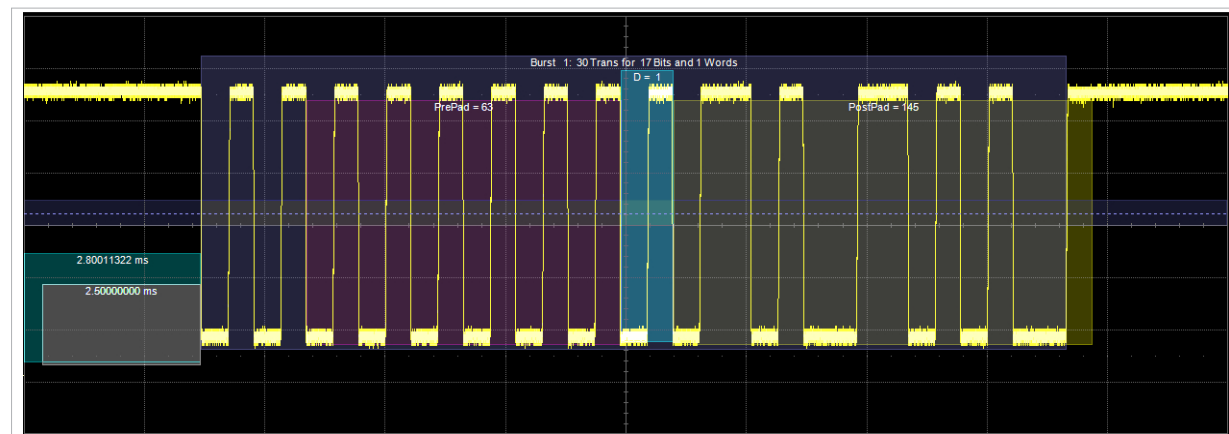


Figure 3: A Manchester signal shown decoded in Word Mode is set to Words.

Within the Manchester decode software are tools and capabilities to group bits into Sync Bits, PrePad, Data Bits, and PostPad. Again, the DALI forward frame signal consists of one start bit, one address byte, one data byte, and two stop bits (idle line).

PrePad bits in a DALI frame would include the start bits and address. In **Figure 3**, they are the portions of the bit stream seen with a purple overlay. With the start bits skipped in this example, the PrePad bits are the six address bits in this example. As noted above, the Y and S bits shown in **Figure 1** are omitted.

The Manchester decoder can parse from 1 to 32 Data bits. The DALI specification calls for one data byte. The trace used for this document uses a single Data bit for the Selector bit. The selector bit is set at a logical one, indicating that the data payload will contain a command. The Data Bits appear with a blue overlay.

Typically, PostPad bits numbering from zero to 32 serve to group information following the data bits. PostPad bits can represent a CRC, a checksum, or other protocol constructs. In the example shown in this document, the PostPad bits are used for the actual data payload of the frame. Within the data is the value 145, which in the DALI protocol represents a command to Query Control Gear. Because they are idle-line bits, the Stop bits are omitted. PostPad bits appear with a yellow overlay.

#### Decode Setup: The Level Tab

The last of the three tabs in the Decode Setup dialog box is the Level tab. Levels can be set using either percentage or absolute voltage values as determined by the Level Type setting. The Level setting itself determines the threshold that transitions must cross to be counted as transitions. The default value is 50% or 1.5 V for percentage and absolute level types, respectively.

Hysteresis settings account for noisy signals with spikes that may

create false transitions if they cross the Level threshold. It appears as a blue-shaded band centered vertically on the Level setting. The default Hysteresis value is 15% but can vary from zero to 50%.

#### Conclusion

For designers and/or integrators of DALI-based intelligent lighting systems in commercial buildings, the protocol provides a means to reducing operating costs and delivering a work environment that is aesthetically pleasing as well as comfortable. An oscilloscope equipped with a configurable Manchester protocol decoder can be an invaluable tool in debugging the DALI protocol, as well as other protocols encoded with the Manchester scheme. Armed with a bit of foreknowledge of the signal under test, users may exploit the decoder's nearly unlimited flexibility with respect to signal parameters to cleanly decode and display signals and extract data relative to their physical characteristics.

[www.teledynelecroy.com](http://www.teledynelecroy.com)

# PCIM SOUTH AMERICA



International Conference and Exhibition  
for Power Electronics, Intelligent Motion,  
Renewable Energy and Energy Management  
São Paulo, 14 – 15 October 2014

## Power On!

Your Gateway to ...  
the South American Power Electronics Market.



# Blocking the sun

By: Alix Paultre, Editorial Director, PSD

There is a very real problem in the USA right now in the development and deployment of alternate energy into the grid, as the country fights amongst itself over how energy will be generated, distributed, and managed in the future. This is especially the case with solar, as it continues to mature in both energy conversion efficiency as well cost effectiveness to become a more and more attractive source of energy. Even now, when all costs are factored in, solar is now more cost-effective than some fossil fuels in many cases.

The problem is that the debate about how the USA will generate and distribute energy is being driven by ideology, not science or economics. Entrenched business and political interests are blocking solar in many ways, from condemning research expenditures to outright legislation designed to restrict the development of solar energy as a viable supplement to the nation's growing power needs. Even much of the mainstream media is buying into the lie that solar power is not viable.

This is not only a foolish attitude, but it is ignorant of both history and market forces. In every single case

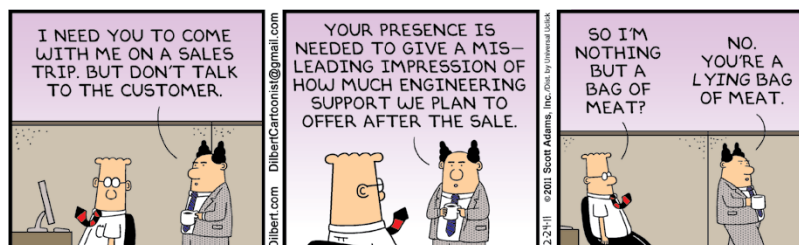
where a solid-state technology was developed to address an application area, it eventually came to dominate that space. Solar is no different, and conversion efficiencies are such that it is obvious to all but the most in denial that solar is not only a viable, but a cost-effective technology. In the marketplace, American neo- and pseudo-Luddites completely forget that this is now a flat earth, and if we do not develop and deploy these technologies others will, and they will wind up dominating those future markets.

Solar power is also logical from a usage sense, as peak power consumption occurs during the day. Solar does not have to replace fossil fuel power generation at all times and in all things, but it is illogical not to use solar as a supplement to existing energy sources. Once you add mechanisms for grid stability, load balancing, managerial oversight, and time-shifting power, you also get a pretty robust smart grid in the process.

A future smart grid that properly integrated all viable alternate energy technologies would not only result in a significant reduction of dependence on fossil fuel and the resulting ecological impact (which is rarely calculated, and never accurately), but it would also create many well-paying infrastructure jobs from electronic engineers to electricians, and everything in between. Technical jobs, jobs that help move America forward. Skilled jobs. Clean(er) jobs.

This won't happen, at least not in any decent fashion, unless we as a country stop basing our arguments on ideology and vested interest instead of what is best for the country, its citizens, and its future. Only by properly deploying a truly smart grid that integrates all manageable types of energy with the proper controls and safeguards, including security, will the USA reach the full potential of what such an infrastructure can provide.

[www.powersystemsdesign.com](http://www.powersystemsdesign.com)



# It's all you need.

## The AP300 Frequency Response Analyzer

Designed for switching power supplies, it is simply the best product on the market for all of your frequency response measurement needs.



 **Ridley Engineering**  
[www.ridleyengineering.com](http://www.ridleyengineering.com)

Ridley Engineering, Inc.  
3547 53rd Ave W, Ste 347  
Bradenton, FL 34210 US  
+1 941 538 6325

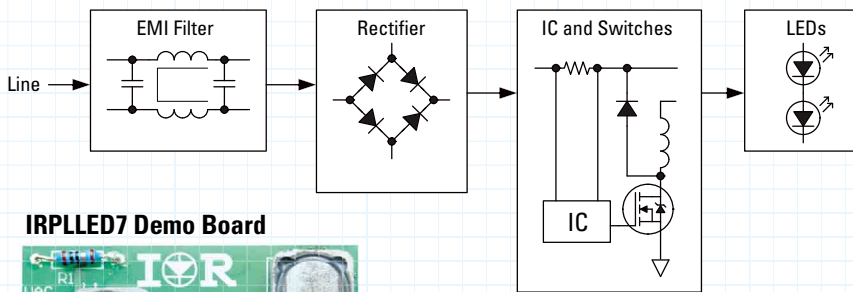
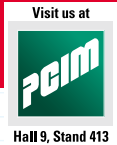
Ridley Engineering Europe  
Chemin de la Poterne  
Monpazier 24540 FR  
+33 (0)5 53 27 87 20



# LEDrivIR™



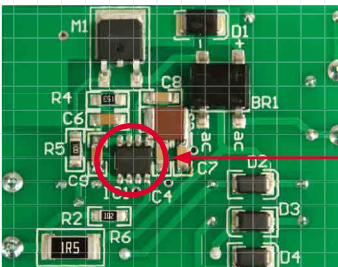
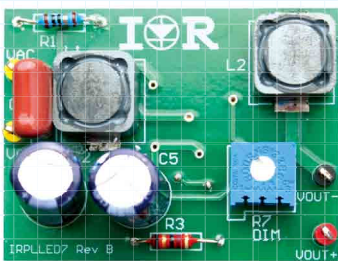
## High-Voltage Buck Control ICs for Constant LED Current Regulation



### IRS2980 Features

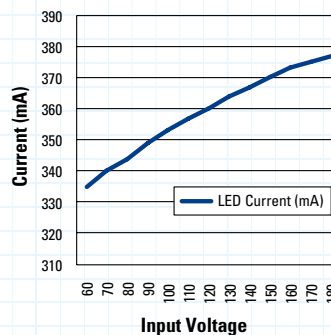
- Internal high voltage regulator
- Hysteretic current control
- High side current sensing
- PWM dimming with analog or PWM control input
- Free running frequency with maximum limiting (150kHz)

### IRPLED7 Demo Board



LEDrivIR™  
IRS2980

### IRPLED7 Demo Board LED Current vs Input Voltage



### IRS2980 Benefits

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

### Demo Board Specifications

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

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

For more information call +49 (0) 6102 884 311  
or visit us at [www.irf.com](http://www.irf.com)

International  
**IR** Rectifier  
THE POWER MANAGEMENT LEADER