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Special Report: Driving Consumer Electronics (pg 35)

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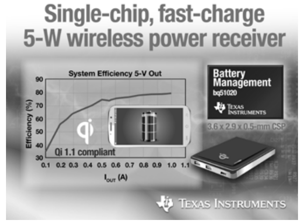
COVER STORY
Managing power & noise in advanced consumer products (pg 12)



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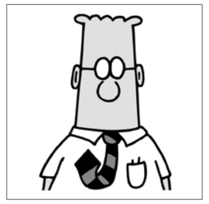

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AGS Media Group
146 Charles Street
Annapolis, MD 21401 USA
Tel: +410.295.0177
Fax: +510.217.3608
www.powersystemsdesign.com

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@ridleyengineerng.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

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My interesting adventure in Germany with Google Glass

Let me start by saying that Google Glass is a very powerful tool even as a beta device, and this essay is intended more to enlighten than complain. However, being an early adopter of disruptive technology is a very interesting (and awkward) experience, especially when traveling in a foreign country. In my case, I got my Google Glass to blog conventions more easily, and took it with me to the 2014 PCIM conference in Nuremberg, Germany.

A promising start

I spent the day prior to the conference re-exporing Nuremberg and using Glass as my only camera. Hands-free photography and online posting is a breeze with Glass, although I did attract attention saying "OK Glass, share with Facebook public" and such as I walked about. The perceived immediacy impressed everyone I showed Glass to, and I showed it to everyone who expressed interest. Everyone was very impressed with the voice commands, but the touch interface isn't as easy and intuitive as Google could make it.

I said "perceived immediacy" because once you tell Glass to share or send something, it processes it and moves on, giving you the impression the image or video was sent. In reality, it gets buffered and Glass sends it when the bandwidth is suitable. Sometimes this can take a really long time if you are traveling in a bandwidth-poor area. Glass tethers to your phone, or any acceptable Wi-Fi connection in the area. My (T-Mobile) phone reception was passable, and there were no wireless networks I could join.

Glass also provoked conversations about privacy and intrusion. Several people came up to me and asked me questions about Glass as I walked about, and almost all the comments had to do with privacy. I pointed out that it would be difficult to sneak into a place with a visible apparatus on my face anywhere people cared, and also pointed to the ubiquitous cameras on the walls and street poles while suggesting they be more concerned about those than mine. I do think Glass should have a small red LED to show people when you are recording (and reassure them when you aren't).

The weakest link

The nuisance of yesterday's sluggish uploads became my nightmare of connectivity at the trade show. Cell-phone reception was barely adequate for voice, and the show sold two-tier Wi-Fi access, with only the top paid tier barely satisfactory for small images. There was always a line in the press room for the three CAT5 lines, and the terrible state of wireless was a constant theme, with the chorus being it ironic (not to mention counterintuitive and short-sighted) that an engineering conference would invite press and then make it difficult for them to broadcast their coverage because their communications infrastructure was not up to the task. I managed to post a couple of videos (one made the Glass newsletter) by using an exhibitor's Wi-Fi connection.

In all, the biggest problems I had with Glass had to do with infrastructure, not the device itself. This only underscores the importance of net neutrality and having open high-speed broadband everywhere, as it is a critical support infrastructure without which the most sophisticated devices are simply lumps of plastic and metal.

Best Regards,

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

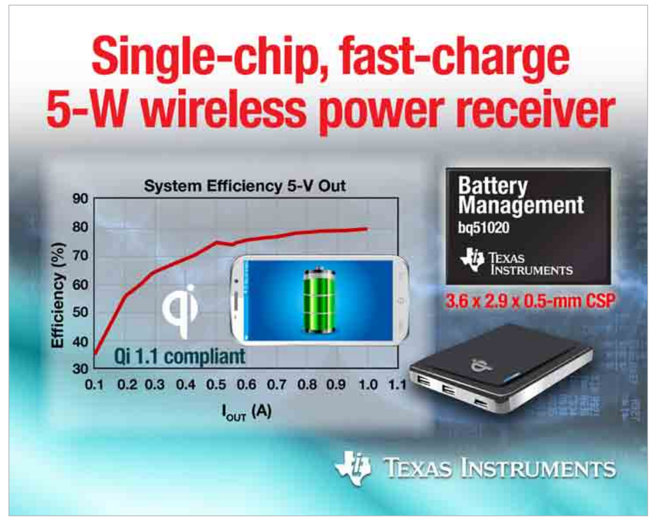
TI's fast-charge Qi wireless power receivers cut loss by 50%

Texas Instruments introduced the industry's most power-efficient 5-watt wireless power receivers that support the Wireless Power Consortium (WPC) Qi 1.1 standard. TI's new bq51020 and bq51021 allow consumers to charge their Qi-compliant mobile phones, tablets, power banks and other electronics faster, cooler and more efficiently compared to other available wireless power solutions.

Available to ship in volume today, the bq51020 and bq51021 single-chip receivers feature a programmable output voltage up to 8 V and low on-resistance MOSFETs to reduce power loss by as much as 50 percent, compared to existing solutions in the market. The bq51021 features an I2C interface, which allows system designers to implement foreign object detection and a unique "pad-detect" feature that makes aligning the receiver with the charger easier for a better user experience.

Features and benefits of bq51020 and bq51021:

-Highest efficiency for faster, cooler wireless charging: Achieves up to 96 percent power efficiency, and an adjustable output voltage helps reduce power loss by as much as 50 percent; and reduces temperature rise by 35-percent compared to other solutions.



-Single-chip 5-watt receivers: Provide rectification, regulation, and digital control and communications to support the Qi 1.1 specification.

-Ultra-small, thin solutions: 3.6-mm by 2.9-mm by 0.5-mm single-chip wireless power receiver achieves a solution size of 75 mm2 without the need for an inductor.

The new receivers join the bq51221, which TI introduced in February as the industry's first dual-mode 5-W wireless power receiver to support Qi and the Power Matters Alliance (PMA) specifications. TI also recently released the bq51003 2.5-W receiver for small portable and wearable applications. With these additions to the portfolio, designers can now order the bq51020EVM-520, bq51221EVM-520 and bq51003EVM-765 evaluation modules to get started on wireless power designs.

Availability and pricing

The bq51020, bq51021, bq51221 and bq51003 wireless power receivers are available now in volume production through TI and its worldwide network of authorized distributors. All three receivers come in a 42-ball, 3.6-mm by 2.9-mm by 0.5-mm chip scale package at a suggested resale price of US$2.50 for the bq51020, US$2.70 for the bq51021 and US$3.00 each for the bq51221 in 1,000-unit quantities. The low-power bq51003 receiver comes in a 28-ball, 1.9-mm by 3.0-mm chip scale package at US$1.30 each in 1,000-unit quantities.

www.ti.com

Is Your Medical Device RoHS Compliant?

By: Peter Blyth, XP Power

By 22 July 2014 all medical devices must be compliant to the RoHS II legislative Directive (2011/65/EU). The key question is, are you ready? It may feel like the deadline crept up rather fast for some, but we've known since July 2011 when RoHS II was published. There has been plenty of time, but if you've only just started (or worse, done nothing) , it may not be as bad as you first thought.

The original RoHS I Directive (2002/95/EU) was published in February 2003 and came into force during June 2006. The original directive deliberately excluded medical devices, as it was recognized that banning the six substances might have an undesirable impact on reliability and durability. Problems in life-saving or -supporting medical devices would not have been tolerable. It was always understood that medical devices would be included with the scope once the consequences of changing to alternatives for the banned substances were better understood and the risks appreciated.

Medical device manufacturers can now make the switch to RoHS compliance more prepared than non-medical device manufacturers were 8 years ago. There is still an element of risk in change, but this risk may actually be quite small when one considers that many components in medical devices are already RoHS compliant. Products for the mass electronics market already RoHS compliant can make the process to become completely RoHS compliant less complicated than first thought.

For example, if one finds that the components on the BOM are RoHS compliant then the only thing that needs to be taken care of is the manufacturing technique. In the case of lead-free soldering, which requires approximately 40°C higher soldering temperatures, the concern in 2006 was that the higher temperatures would cause thermal stress on the components. If the components being used now are RoHS compliant, they already have the correct thermal properties.

One of the most crucial components in a medical device is the power supply, which is in fact a collection of components in itself. As well as efficiently converting AC power to DC power the power supply is also the main safety isolation barrier. XP Power specializes in high-quality power conversion products for critical applications, such as medical devices, lasers, 3D printers, etc. A consequence of this approach was XP needed to fully embrace RoHS I directive in 2006 as virtually all the component suppliers were moving to RoHS components. If XP hadn't switched then we would have been faced with higher component prices and in some cases obsolesce. Because of our proactive approach we were able to help our customers with the transition to RoHS I and we were in a position to deliver RoHS compliant power supplies in June 2006. The same can be said today, that XP has an extensive range of RoHS II complaint power supplies suitable for all sorts of medical devices.

www.xppower.com

Will we see mass adoption of wireless charging soon?

By: Ryan Sanderson, IHS

The market for wireless charging hasn't quite taken off as quickly as many in the industry had hoped. Last year, shipments of wireless power receivers grew to 20 million units. These included receivers in accessory/add-on products, and those built into to a device so it's enabled to charge wirelessly straight out of the box. In fact the majority of these were accounted for by built-in solutions in smartphones and tablets, demonstrating that the technology can be miniaturised and successfully implemented for such applications. Despite this growth in demand, IHS revealed that only 5 million wireless transmitters (chargers) shipped in the same period. So why hasn't there already been mass adoption of this technology?

The development steeplechase
A number of barriers and challenges still exist. Consumer awareness of wireless charging is still extremely low. A recent survey carried out by IHS revealed that out of one thousand consumers, two thirds still did not know or understand what wireless charging is. This is understandable from the lack of advertising we see for wireless charging, even from larger OEMs who are early adopters. But why are major OEMs and solution providers not screaming about their wireless charging products from the rooftops?

IHS believes that a large element of this is still due to competing standards. Manufacturers who have already developed existing products based around a single wireless charging specification are concerned that the one they used could be obsolete in a few years. Those that haven't yet adopted wireless charging in their products are sitting back to see which specification will be become most widely adopted.

A choice of technologies
In addition to multiple specifications, there are also multiple technologies. PMA and WPC (Qi) first generation specifications are based on closely coupled inductive charging technology, whilst the A4WP (Rezence) specification is based on a loosely coupled technology, termed in the industry as magnetic resonance. The WPC has also announced it's working on a magnetic resonance specification.

The consumer survey from IHS revealed that well over half of consumers who indicated an interest in wireless charging had never heard of one of the above alliances, though almost all agreed that interoperability across all wireless charging products is crucial.

IHS forecasts that adoption of wireless charging will accelerate towards the end of 2014, as solutions become commercially available which offer a greater level of interoperability. Broadcom recently announced the release of a multi-mode IC which it claims supports the specifications from all three alliances and automatically detects and switches between them. MediaTek announced it was sampling a similar product earlier this year.

IHS forecasts the number of devices shipped annually that are enabled to charge wirelessly to increase to over 50 million in 2014 and accelerate to 900 million in 2018. This is projected to drive a combined market for wireless power receivers and transmitters worth $8.5 billion in 2018.

www.ihs.com

Input Impedance Measurements

By: Dr. Ray Ridley, President, Ridley Engineering

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

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

The first three parameters, loop gain, output impedance, and audiosusceptibility were discussed in the first two articles of this series. It is highly recommended that all three of these measurements are made on every switching power supply that you design and build. The loop measurement is essential to guarantee stability over the lifetime of the power supply, and the output impedance gives comprehensive information about the performance in the presence of load variations. The audiosusceptibility is measured is very useful for showing the rejection of noise from input source to output.

An input impedance measurement gives information about the characteristics of the power supply input terminals. It is usually a requirement of the documentation package in the aerospace industry. As with the audiosusceptibility measurement, a signal must be injected on top of the high-power input rail. Once you have set up your test equipment to do audiosusceptibility measurements, input impedance measurements are straightforward to do.

Input Impedance Measurements
The input impedance measurement can predict how well the power supply will integrate into a system. If the input impedance is too low, it can load down the source and provide adverse system interactions. In order to measure input impedance, a voltage source must be injected in series with the input of the power supply as shown in Figure 1.
Figure 2 shows how this is implemented practically using a frequency response analyzer and a few discrete devices. The output of the analyzer is connected to wide-bandwidth isolator which is then AC coupled to a FET hooked up as a voltage follower. The size and rating of the FET may vary according to the power level and voltage level of the converter that is being driven. This injection technique is much simpler and more cost effective than inserting a high-power amplifier in series with the input source, and will allow sufficient signal to be injected for most applications.

The only difference between this setup and the setup for audiosusceptibility is that the signals sent to the analyzer are different. For input impedance measurements, Channel B of the analyzer measures the input voltage perturbation, and Channel A measures the input current perturbation. The current is measured with some kind of transducer – either a small sense resistor, current transformer, or active probe.
Dr. Middlebrook, in his famous paper on input filter interactions, specified that the input impedance of a converter should be analyzed and measured at the switching cell input. This is the point at which

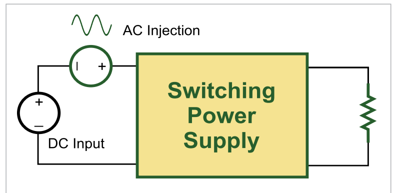


Figure 1: Input impedance is measured by adding a voltage signal at the input terminals of a power supply and measuring input voltage and input current perturbations.

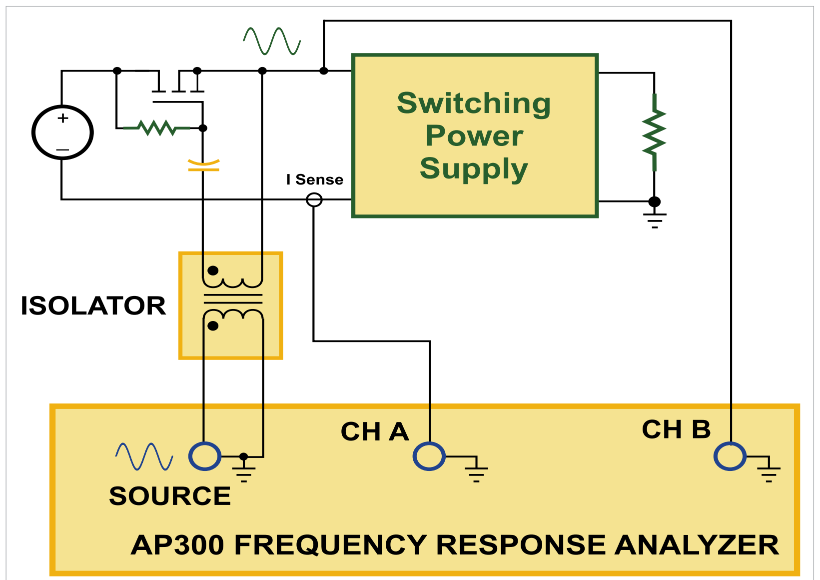


Figure 2: Practical test setup for injecting voltage signal and measuring input impedance.

the interaction analysis can be properly applied to predict whether the input filter will affect the control loop. However, in most practical situations, the input impedance measurement includes some or all of the input filter components in parallel with the input impedance of the power supply. This can lead to false low measurements that are not relevant to Middlebrook's original discussions. More information on this topic can be found in [3].

Before closing the control loop on a converter, it is useful to measure the open loop input impedance of the power supply. The results of this measurement are shown in Figure 4. There are four asymptotes to gain curve of this figure. The first, A, is proportional to the load resistance of the converter. Notice that the phase of the impedance at this point is zero degrees, denoting a positive value of resistance.

Just before 100 Hz, the asymptote B is due to the output capacitance of the power supply, and the input impedance starts to drop. This continues until to the resonant frequency of the LC filter of the power supply, and then the impedance climbs along asymptote C, according the value of the flyback inductance.

Eventually the impedance of the input filter capacitor becomes lower than the impedance of the inductor, so the final impedance follows the asymptote D. Notice that the final value of the phase of the input impedance is -90 degrees, corresponding to a capacitive value.

The open-loop input impedance is quite a complex curve, even with just a single capacitor as the input filter. With more complicated input filters included in the measurement, the complexity of the measured or predicted impedance will increase.

Figure 5 shows the input impedance of the same converter with the control loop closed.

The green curve of Fig. 5 shows the closed-loop input impedance of the converter. At low frequencies, along asymptote A, the dc value is determined by the power output of the converter and the input voltage. You can see from the green phase curve that the impedance now has a starting phase of -180 degrees, denoting a negative resistance. This is the classic characteristic of all constant-power switching power supplies, and it is at the heart of the stability problem that can arise when coupling switching power supplies with input filters.

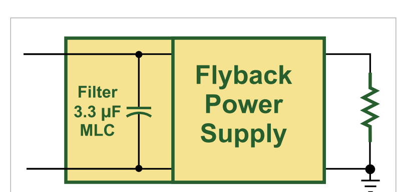


Figure 3: Flyback converter with input filter capacitor. In most cases, practical measurements require some input filter components to be included in the impedance measurement.

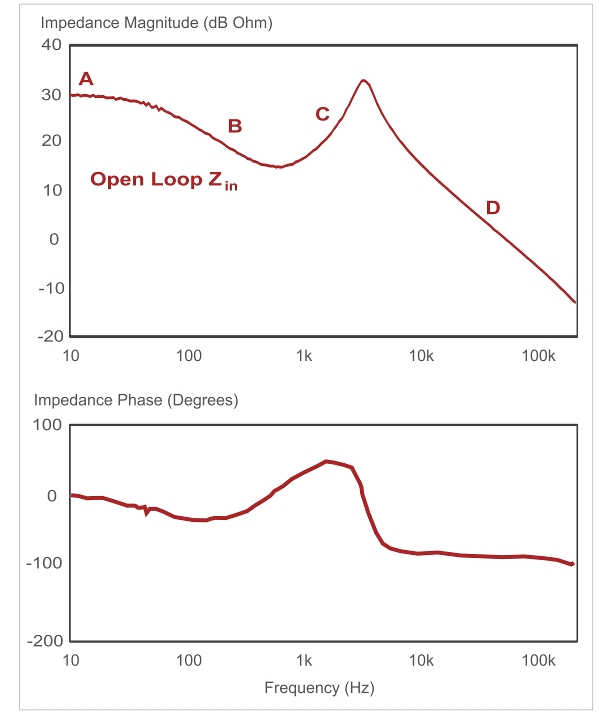


Figure 4: Open-loop input impedance measurement of a flyback converter.

This closed-loop input impedance stays relatively constant until the impedance of the input filter capacitor becomes lower than the starting negative resistance. The impedance then follows the asymptote B, with a 90 degree phase delay, as observed for the open-loop characteristic.

Notice that there is not the same simple relationship between the open-loop and closed-loop input impedance and loop gain that exists for the audiosusceptibility and output impedance. For these two quantities, the open-loop characteristic was attenuated by 1+T(s). Input impedance is different. When there is significant loop gain, the input impedance is transformed into a fixed-value negative resistance. Without any input filter components, the input impedance rises with frequency after the crossover frequency. However, as can be seen in this example, the input impedance is heavily influenced by the present of the input filter capacitor.

Summary

This article discusses the significance of power supply input impedance, and shows how it can be practically measured. Most aerospace designs require a power supply input impedance measurement in order to properly assess the impact of integration of power supplies into larger systems. In most cases, input impedance measurements include the impedance of the input filter, and this complicates the proper application of Middlebrook's impedance interaction criteria. [3].

www.ridleyengineering.com

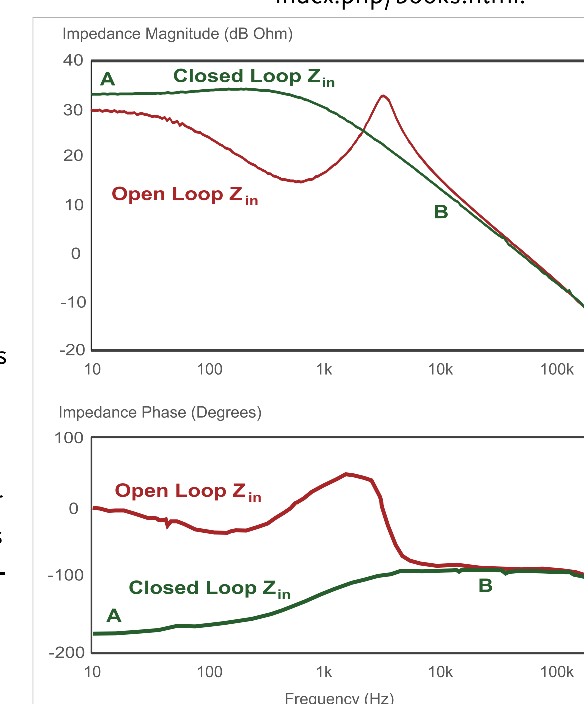


Figure 5: Closed-loop and open-loop input impedance measurements of a flyback converter.

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Managing power & noise in advanced consumer products

Noise is becoming an serious issue when driving a consumer product

By: Clive Jones, Exar

Driving consumer devices cleanly and efficiently is more important now than ever before, because of the growing amount of functionality being put into products today. From our telecommunications infrastructure to power recliners, people are getting used to an increased level of functionality and interoperability in the things around them while expecting even more functionality and connectivity in the future.

The twin issues of power management and signal integrity in consumer devices from sophisticated subsystems, the increase in wireless "smart" households, and intelligent web-based white goods, demand better power solutions. For example, a typical processor-based board needs multiple rails to supply core voltages for all of the chips and components at voltages from 1.8V down to 0.6V, with load requirements up to 3A. Add to that requirement the rails for memory, with voltages from 1.8V for DDR2 to 1.35 for DDR4 (see **Figure 1**). Many of these systems use PWM switching buck

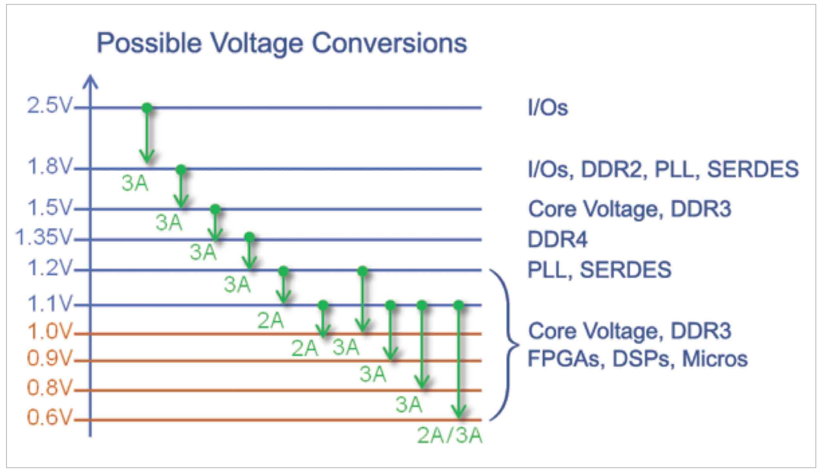

Figure 1: A power solution must address all expected voltage rail conversions and currents

converters, but when low noise and space saving are required, a low dropout regulator (LDO) can be a better solution.

Overcoming some of the previous limitations of using LDOs in these point-of-load applications poses a number of design challenges. Since these devices may need to take an input voltage as low as 1.045V, the control circuit must be able to operate below 1V. These operations of course include all critical functionality such as overcurrent and short-circuit protection, as well as a stable control loop. To handle challenging current ratings as high as 2A and 3A means that the design still needs to be accurate even at these very low input voltages, so soft-start and current-limiting performance continues to work. Don't forget that with very little voltage overhead, the transient response of the LDO must work extremely well to keep the transient ripple under control and within specifications. Properly done, a 1.2V rail can be down-converted to 1.1V at up to 91.6% efficiency.

Ultra-low-dropout LDO

For example, Exar's latest ultra-low-dropout LDOs can address all of these concerns and performance requirements.

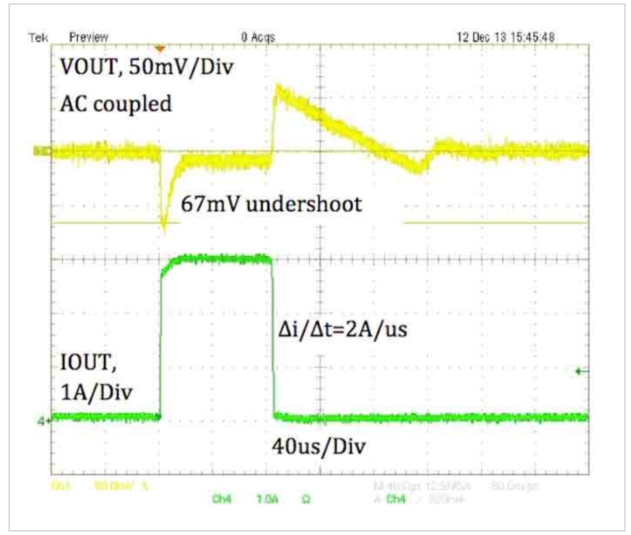

Figure 2a: Transient response at 20mA-3A, 1.5VIN, 1VOUT

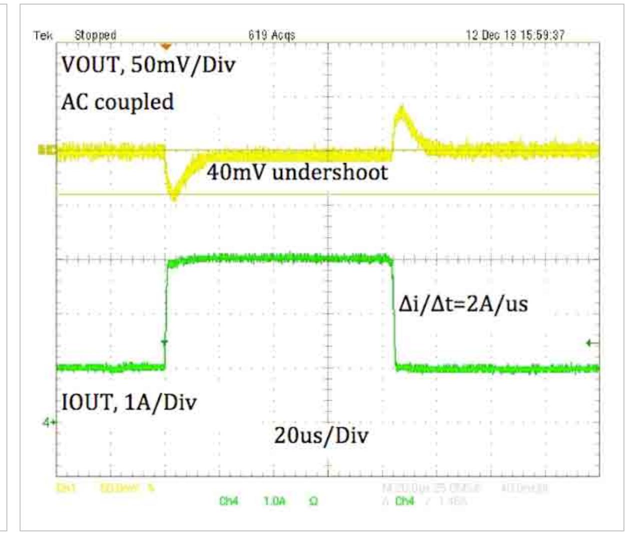

Figure 2b: Transient response at 1A-3A, 1.5VIN, 1VOUT

Exar's XRP6274/75 family challenges the industry with an ultra-low dropout voltage of only 75mV at 2A and 140mV with 3A loads over their entire operating temperature range. Well-suited for high-current and extremely tight input/output voltage conversions, the XRP6274/75 family can address applications previously unthought-of, such as applications requiring between 1.35V to 1.2V at up to 3 amps.

Since many devices often operate at 2.5V, a set of XRP6274/75 devices can create a complete low-voltage power solution very efficiently, economically, and reliably implemented without the EMI problems or larger PCB space requirements associated with switchmode supplies. These LDOs require no bias voltage and offer excellent transient response, as illustrated in **Figure 2**. Other solutions cannot match this performance without using extra subsystems and components on already-dense and crowded boards.

In addition to having a very low noise performance of 200μVrms from 10Hz to 100kHz, the XRP6274 and XRP6275 challenge the industry in being able to operate from a single supply rail of 1.045V to 2.625V without the need for a noise generating charge pump or an extra voltage supply. This next-generation performance enables the creation of extremely efficient power conversion solutions that can surpass the current crop of switch-mode regulators at the same input/output voltages.

Space-saving design

With its low drop out, single-input rail operating down to 1.045V, the XRP6275 Ultra LDO can deliver up to 3A of output current at high percentage efficiencies (as high as the mid-90's), making it very well suited as a solution for high current and extremely tight input/output voltage conversions. Since the solution does not require a separate bias voltage or charge pump for the analog control circuits, combined with its small 3mm x 3mm x 0.8mm package, the XRP6275/74 can be placed in some of the tightest spaces existing on almost any PCB.

Suitable for a wide range of applications, the XRP6274/75 ultra low drop out LDOs provide single-rail operation at voltages from 1.045V to 2.625V in very small footprints, with an extensive array of protection features to ensure high performance operation along with the extreme high reliability required by the latest crop of applications.

Figure 3 shows a typical power solution application block diagram. Usually LDOs aren't known for high power-conversion efficiencies, but an LDO-based

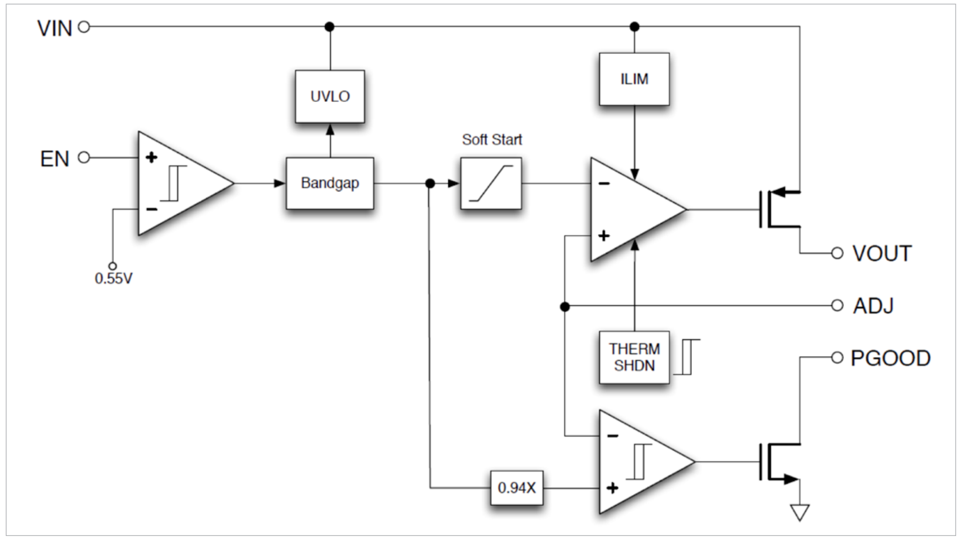

Figure 3: The device block diagram showing the major building blocks and safety features

solution with as little as 5 external passive components can deliver conversion efficiencies as high as 88.9% for applications from 1.35V to 1.2V at up to 2A or 3A with a board footprint measuring only 0.6" x 0.6". Achieving this level of performance along with the ability to fit into a very small footprint gives the design engineer to place these LDOs in the immediate vicinity of the loads nearly anywhere on the PCB easily, without sacrificing power conversion performance or taking up excessive board space.

Many applications require high levels of performance, such as driving graphics processors, PC cards, low-voltage digital ICs, and advanced microprocessors and microcontrollers. 1. The output voltage on the XRP6274/75 ultra low drop out LDOs can be set as low as 0.6V with ±0.5% accuracy, making them very well suited for devices such as FPGAs, DSPs, ASICs, and other SOCs.

Keeping it safe

Protection features are also important for performance and safety, so the XRP6275 integrates output current limit protection to protect the main power supply, the regulator itself, and the load being driven from excess current. In short circuit conditions, the device will take additional steps to limit input current and power by disabling and re-enabling the pass device until the short condition is removed and normal operation can resume. Depending on the impedance of the short, this short circuit protection function may initiate operation between 10% and 50% of the targeted output voltage.

The XRP6274 also includes thermal shutdown circuitry to restrict the device's operating temperature within a safe range. When activated (typically at 160°C), the XRP6274 is forced into a low-power reset state with a typical hysteresis of 30 degrees. Combined with the short circuit current protection, it reduces and limits the heating effects of over-temperature and/or over-current conditions on the LDO and surrounding circuits.

In addition, the XRP6274 features a soft-start function, which controls the output voltage ramp, and allows the regulator to gradually reach its initial steady-state operating point. This reduces current spikes and surges at start up due to output capacitor inrush current. Internal sequencing completes in 50µs, and then the reference voltage is linearly ramped over a period of approximately 2ms.

In addition to the standard protection features, these ultra-low-dropout LDOs also have reverse bias protection. Most LDOs have a parasitic body diode that provides a path from VOUT to VIN if the input is shorted to ground. The XRP6274 has a blocking diode to ensure that no high discharge currents can occur between the output and the input when the input is shorted to ground.

www.exar.com

Intelligent LED luminaires save energy and costs

Successful pilot project: parking garage lighting with LEDs

By: Jhanick Iringer, Osram Opto Semiconductors

There are several parking garages in the downtown area of almost every German city, many of which are heavily frequented – in winter more than in the summer. Naturally, lighting these buildings, which are generally several floors high, consumes a great deal of energy, incurring high costs in the process. Gerald Stuible, proprietor of a parking garage in Nuremberg, was therefore keen to leverage this particular cost parameter and introduce energy-efficient lighting. As part of a pilot project, he arranged for the existing fluorescent lamps in the parking garage at Jakobsmarkt in Nuremberg to be exchanged for intelligent LED luminaires of the IPL series from SchahlLED Lighting (see **Figure 1**). Modules with Duris E 3 light-emitting diodes (LEDs) from Osram Opto Semiconductors are installed in each luminaire. Additionally, an integrated presence detector only switches the illumination from the default basic illumination to maximum output where this is actually required.

Modern LED luminaires from

Figure 1: Energy-efficient lighting with Duris E 3-LEDs from Osram Opto Semiconductors.

SchahlLED Lighting's IPL series have been illuminating the five-level Nuremberg parking garage at Jakobsmarkt since November 2012, replacing the fluorescent lamps previously used (see **Figure 2**). The LED luminaires were specially designed for applications in low-ceilinged spaces such as parking garages or warehouses. The lower part of the housing is made from light gray polycarbonate. The highly flexible, shatterproof cover is opalescent so that some of the light is reflected back to the ceiling while a high degree of light diffusion completely eliminates glare for the users of the parking garage. The luminaires are mounted on the ceiling by means of threaded bars or suspension

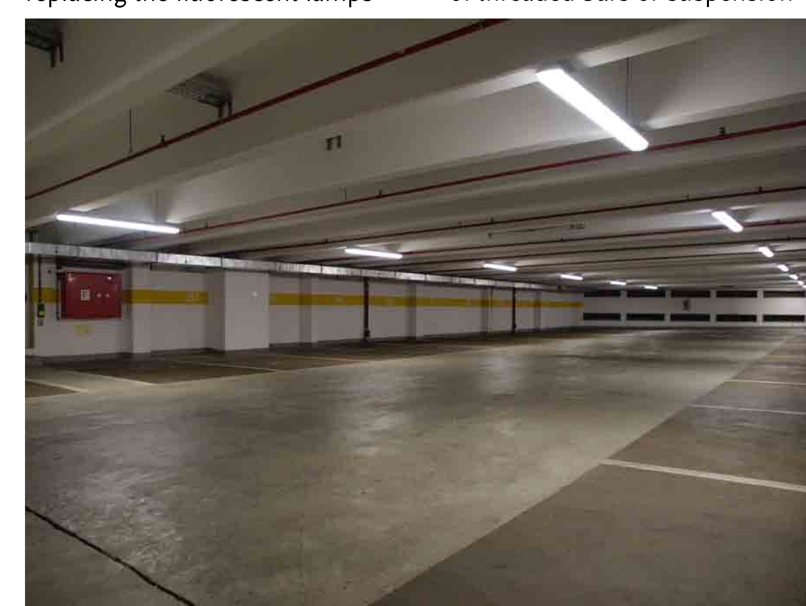

Figure 2: The intelligent luminaires from SchahlLED Lighting with installed Osram LEDs save around 70 percent on energy.

devices. Measuring 1572 x 110 x 145 mm, the luminaires are in the safety class IP-65 (dust-tight and protected against water jets), as recommended for light systems in outdoor applications.

Impressive illumination
Each luminaire has five modules, each fitted 120 Duris E 3 LEDs from Osram Opto Semiconductors. The DURIS® E 3 combines high efficacy and a wide beam angle into a compact format (3.0 mm x 1.4 mm). This is key to homogeneous illumination applications where the DURIS® E 3 never fails to impress with its performance on system level. The modules can be replaced without tools and provide high-quality, energy-efficient light. Due to the impressive 50,000-hour service life of the Osram LEDs (when operated at their full load of 50 W), the luminaires probably will not need to be replaced for decades if operated at a typical load of just 35 W or 15 W in dimmed mode. That also minimizes the maintenance costs of the lighting system, making this a very sustainable investment compared with fluorescent lamps or LED tubes. The Duris E 3s can be arranged very close together, thanks to their small dimensions of 3 x 1.4 mm. A wide beam angle of 120 degrees ensures that the light cones overlap when arranged in close formation so that the light is distributed very evenly. The Duris E 3s are thus ideal for applications requiring homogenous illumination combined with high efficiency

Luminaire	Conventional (fluorescent)	SchahlLED IPL
Power consumption per light point (system)	75	34
Power consumption in passive mode		12
Replacement interval (h)	20,000	70,000
Price of electricity (€ per KWh)	0.18	0.18
Hours of active operation/year (h) Activation period	8,760	1,747 20%
Energy costs/year (€)	**31,843**	**6,963**
CO_2 emissions/year(kg)	106,142	23,210
Total operating costs/year (€)* **incl. replacement of defective tubes**	**32,804**	**6,963** -78.8 %
Savings over a 20-year period (€)		**526,160**
Interest on capital used		9.6 %
Packback period in years		**3.2**

Table 1: Economic feasibility study - Parking garage with 270 installed IPL luminaires (conversion of property, excepting emergency lighting and other luminaires in continual operation)

and low acquisition costs. They are mainly intended for lighting applications in open-plan offices, production plants, warehouses, or, as in this case, parking garages which have hitherto been fitted with T5 and T8 luminaires. With a brightness of 4,500 lumens and a color temperature of 4,000 Kelvin, the low-power LEDs produce excellent ceiling illumination and homogenous light.

Thanks to the new luminaires, the parking garage at Jakobsmarkt now fulfills the applicable standards requiring that an average of 75 Lux reaches the roadway and specifying a minimum illumination of 20 Lux in every other part of the parking garage. The superb lighting of the parking spaces now offers users even more safety.

Intelligent control reduces the activation period
With the new lighting solution, two parking spaces can now be illuminated by just one LED luminaire with an output of 35 W or 15 W in the basic illumination mode, rather than a fluorescent lamp with a system power draw of 75 W, as required in the past. Using a presence detector, an intelligent control system in the luminaires activates the lighting in the building, only selecting maximum output in the locations where this is currently required. Only if a vehicle is driving through the garage or a pedestrian is moving do the luminaires installed in the vicinity increase their brightness to the maximum output of 35 W. If not activated by the presence detector, they operate at a very much lower basic illumination output of 15 W, saving energy and costs.

"With the new lighting system, we have already been able to cut the activation period per parking deck to a third of the former value. And we are expecting further reductions. By the time the project had been under way for just a few months, we had already saved a great deal of energy and hence also costs – despite it being the busy winter months," said Stuible, summarizing the initial project phase. The parking garage operator and the two companies involved – SchahlLED Lighting and Osram Opto Semiconductors – expect further drops in the activation period in the summer months. The acquisition costs for the new LED lighting system will thus have paid off within as little as about three years.

Converting to LEDs: A clear reduction in costs
Luminaires in parking garages are exposed to a great deal of stress, particularly due to their continual contact with exhaust fumes. Operators must therefore plan to replace luminaires after about 30 years. In cases where new luminaires need to be installed after a lifecycle like this, it is advisable to conduct a profitability calculation on the option of installing LED luminaires (see **Table 1**).

After converting to the new intelligent lighting system, the average consumption of the lighting system in the parking garage project has fallen from 75 W to just 22 W. Calculated per parking space, this comes to around 11 W in the parking garage at Jakobsmarkt. As a result, with the connected IPL luminaires, the operator, Gerald Stuible, has been able to slash his power consumption by 70% in just 8 months since the project began. In the long term, the project partners expect that the LED luminaires will spend less than 20 percent of the time in the activated mode, on average. Depending on how the price of electricity develops, this could result in energy cost savings of between €20,000 and 25,000 per year.

"After extensive comparative tests, replacing the fluorescent lamps in the parking garage with intelligent LED system luminaires was an easy decision to make, as we consider the LED technology to be a pathbreaking system. We were looking for a future-oriented, energy-saving solution that would cut operating costs, not least because our company also operates other parking facilities. We are gaining experience with the installed system. What convinced me to opt for lighting solution from Osram Opto Semiconductors and SchahlLED Lighting was above all the good experiences made in the trial operation," said Gerals Stuible. With the luminaires that are now installed we can implement a light solution for the future,"

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Advanced design for off-line flyback power supplies - Part II

Basic design choices - primary- or secondary-side regulation?

By: Jason Guo, Fairchild Semiconductor

Conventional secondary-side regulation is the subject of this paper, but primary-side regulation (PSR) is a lower-cost option offered in PSW for output power up to 30W. In this scheme there is no output-voltage sensing or control circuitry on the secondary side of the transformer; instead, the auxiliary-winding voltage is sensed when the output diode is conducting and that is regulated. Therefore the output voltage is regulated indirectly, relying on the fact that the transformer winding voltages are proportional to the turns ratio. Relatively loose regulation of the output voltage results for line and load variations, but Fairchild uses special control techniques to tighten the regulation band to +7/€5%, compared to secondary-side regulation, which can achieve ±2%. Still the transient response is slower for PSR.

Fairchild's PSR controllers also have a constant-current mode where for falling load impedance, the output voltage is regulated until current limit is reached, then the output voltage begins to drop. This is useful for battery charging, and these controllers are frequently found in ac adapters for portable equipment. Secondary-side regulation (SSR) can provide faster transient response and tighter output-voltage regulation, therefore it's the most common control scheme used, especially with multiple, cross-regulated outputs. The additional cost compared to PSR comes from a TL(V)431 shunt voltage regulator used as a secondary-side voltage reference, an opto-isolator, and several passive components around those, visible in the schematic diagram of Figure 4 from part 1 of this series. Using FPS controller+MOSFETs, PSW can provide SSR flyback designs up to 100W with up to 3 outputs.

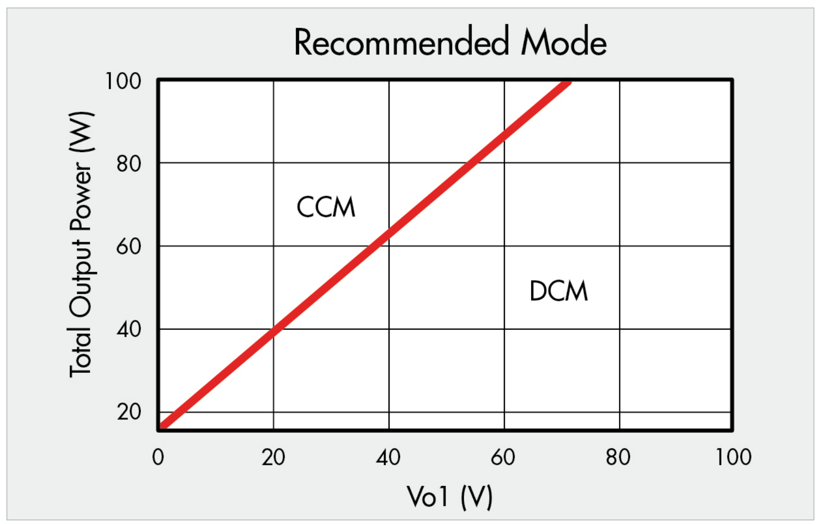

Figure 5: The thumb rule used to recommend a CCM or DCM design based on total output power and the regulated output voltage.

Continuous- or Discontinuous Conduction

A fundamental choice to be made at the beginning of a flyback design is whether the converter should operate in CCM or DCM at full load, illustrated in Figure 2 from part 1 of this series. A third option not considered here is boundary- or critical-conduction mode (BCM or CrM), where the main switch turns on as soon as the magnetizing current returns to zero, which causes switching frequency to vary with line and load.

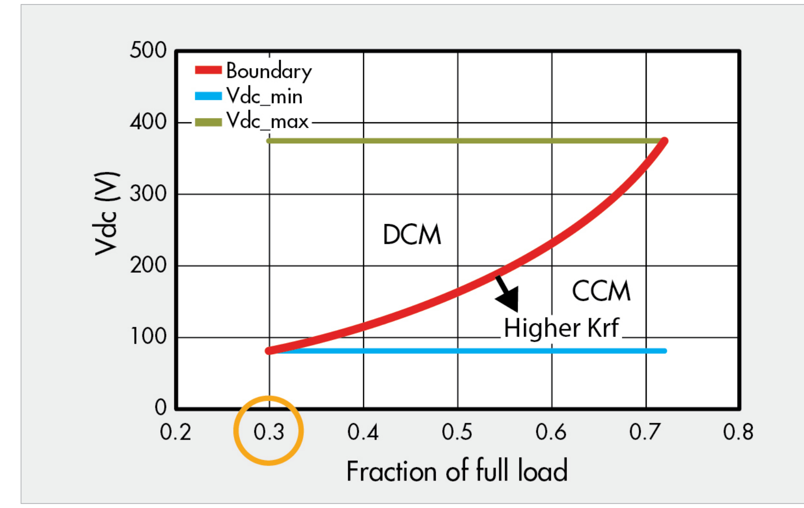

Figure 6: DCM-CCM operating boundary in the plane of input voltage Vdc vs. load.

An initial choice between CCM and DCM is made from experience using a thumb rule illustrated in **Figure 5**, but it is always better to weigh the following advantages of each mode in light of the design requirements (or complete a design each way & compare). DCM is recommended for lower power or higher output voltage, as it has a lower-cost output diode due to zero-current turn-off (no reverse recovery), a smaller transformer due to lower magnetizing inductance, and lower FET switching loss (but higher conduction loss due to higher peak and rms current).

In contrast, a CCM design offers better efficiency due to lower rms currents therefore lower FET conduction loss, and a slightly smaller output capacitor due to less ripple current although the diode current is still discontinuous.

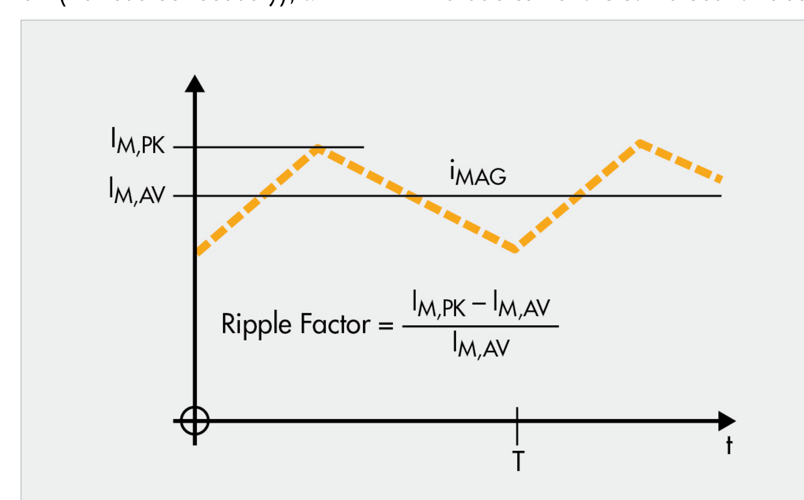

Figure 7: Definition of ripple factor Krf according to the waveform of magnetizing current iMAG.

Although CCM designs are by nature dual-mode, the DCM mode is always more stable than CCM so only CCM must be considered for control design.

A proper DCM design will never enter CCM for any "normal" combination of input voltage and load (within design limits), while a CCM design will always enter DCM at light load and possibly at full load for high input voltage. This can be seen in **Figure 6**, a plot of the critical-conduction boundary in the plane of input voltage vs. load for a particular design. There the transformer magnetizing current is discontinuous (DCM) above & to the left of the curve while continuous (CCM) below & to the right.

For a CCM design, the "ripple factor" Krf defined in **Figure 7** is the design "knob" that determines the position of the critical-conduction boundary in **Figure 6**, in fact at low-line, Krf is the fraction of full load at which the mode transition occurs. Raising the ripple factor moves this curve lower and to the right, resulting in a lower magnetizing inductance and smaller transformer, but the rms currents and conduction losses are higher as a result. This also enlarges the DCM operating region where transient response is slower.

The ripple factor Krf is defined in **Figure 7** as half the peak-to-peak MOSFET current during conduction divided by the

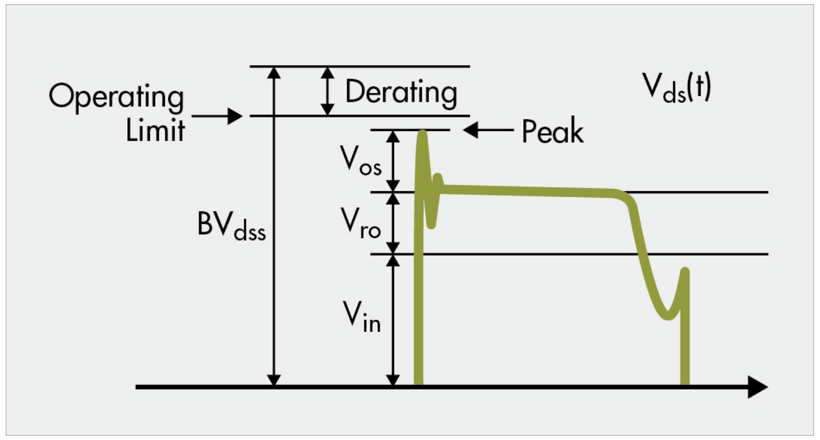

Figure 8: Waveform of the drain-to-source voltage Vds of the main switch to show its components: input voltage Vin, reflected output voltage Vro and overshoot voltage Vos.

average MOSFET current during conduction. It depends on input voltage and load, but it is always between 0 (no ripple, or infinite magnetizing inductance) and 1 (DCM). While Krf=1 for any DCM design, good practice is to design for near-critical conduction at low line, full load to minimize rms currents and losses.

An initial recommended value of ripple factor for a CCM design comes from the following thumb rule: at nominal input voltage and full load, use 0.25–0.5 for universal ac input voltage (85-265 Vac) or 0.4–0.8 for European ac input voltage (195-265 Vac).

Interrelationship of Design Variables

While most flyback design equations are left to other references [5], a few of the key ones are included here to illustrate how the design variables are interrelated, meaning a change in one has effects on others that must be considered to find a optimum balance, often through iteration.

First some definitions illustrated on the MOSFET drain-to-source waveform in **Figure 8**:

BV*dss* is the maximum rated drain-to-source voltage of the MOSFET
fs is the switching frequency
n =Np/Ns1 is the transformer turns ratio

Vf1 is the forward drop when the output-1 diode is conducting
Vin = Vdc is the input voltage to the flyback converter, which varies slowly (relative to the switching frequency) over an ac line cycle
Vo1 is the voltage of the regulated output
Vos is the overshoot voltage caused by ringing after MOSFET turn-off between the junction capacitance and transformer leakage inductance
Vro is the "reflected output voltage," n × *Vo1* (referred to the primary winding)

Next some design input:

Overshoot factor:

$$Kos = \frac{Vos}{Vro}$$

is an empirically determined quantity typically in the range 1.2–1.5, that is used to estimate Vos from a calculated value of Vro. It is somewhat proportional to transformer leakage inductance and in the design process, it affects turns ratio and/or MOSFET voltage stress.

$$DF_{FET} = \frac{BVdss - Derating}{BVdss}$$

creates a safety margin for the MOSFET voltage, typically specified in the range 60-95%. 100% which represents no margin is not recommended because Kos and other design variables are only approximate. For low-input-voltage designs, the maximum allowed value should be lowered to keep the turns ratio reasonable.

Finally some design equations:

Drain-to-source voltage operating limit:

$$Vds,lim = DF_{FET} \times BVdss$$

Maximum reflected output voltage:

$$Vro,max = \frac{Vds,lim - Vdc,max}{1 + Kos}$$

Maximum duty cycle (derived from a volt-second balance):

$$Dmax = \frac{Vro,max}{Vro,max + Vdc,min}$$

If the calculated Dmax > 47%, it is reset to 47% to ensure it would not exceed 50% where subharmonic oscillation could occur with Fairchild controllers ("ramp compensation" is unnecessary). In this case, Vro,max is recalculated as follows.

$$Vro,max = \frac{47\%}{1 - 47\%} Vdc,min$$

Finally the following key design quantities are calculated.

Max peak MOSFET current:

$$Ipk = \frac{Pin}{Vdc,min\ Dmax}(1 + Krf)$$

Maximum transformer turns ratio:

$$n\_max = \frac{Vro,max}{Vo1 + Vf1}$$

Magnetizing inductance:

$$Lm = \frac{(Vdc,min\ Dmax)^2}{2\ Pin\ fs\ Krf}$$

The recommended design puts the maximum allowed voltage stress on the MOSFET to minimize the stress on the output rectifier diode. To shift some stress from the MOSFET back to the rectifier diode, simply lower the MOSFET derating factor DFFET, which also (a) lowers the primary-to-secondary turns ratio n, (b) lowers the magnetizing inductance Lm, and (c) lowers the max duty cycle Dmax. A particular FPS (controller+MOSFET) is selected based in part on features but mainly on current-limit derating factor:

$$DF_{Ilim} = Ipk/Imax$$

where Imax is the controller maximum operating current. It is essential to choose a controller for which DFIlim< 100%, but < 90% is recommended.

If Ipk is just a little too high to use a desire controller—meaning DFIlim calculated for that controller is too high—(7) shows that Ipk can be lowered by either raising DFFET to raise Dmax per (3) through (5), or raising the value of the dc-link capacitor Cdc to reduce input-voltage droop, thereby raising Vdc,min.

Most of the subject controllers enters burst mode when output power drops sufficiently low, to increase light-load efficiency. The power level of burst-mode inception as a percentage of full load is determined largely by internal controller settings, but it may be lowered by raising DFIlim either by choosing a different controller with a lower current limit Imax, or lowering DFFET to raise Ipk according to (3)-(5) and (7).

In Part III we'll discuss output filters and control design.

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Intelligent diagnostics maximizes factory-floor up-times

Using a power management IC with integrated diagnostic functions can benefit industrial control applications

By: Hubert Baierl, Infineon Technologies

More than often it is common that when technical equipment fails, finding the root cause of the failure consumes significantly more time than actually fixing the problem. In highly sophisticated factory automation environments where capital-intensive equipment is in operation or where time-coupled chemical processes are at work, line-downs can have substantial implications on the commercial viability of the enterprise. Therefore, the days of machinery providing no diagnostic feedback are becoming obsolete. Solutions that can provide intelligent diagnostic feedback as the system is beginning to fail ("preventive maintenance") or when a hard failure has occurred ("repair") are key to reducing expensive unscheduled downtimes (see **Figure 1**).

For example, the ISO2H823V is an 8-channel high-side driver IC with integrated 2.5kVrms galvanic isolation, which exceeds the IEC 61131-2 requirements for reinforced isolation.

Figure 1: Solutions that can provide intelligent diagnostic feedback when a failure has occurred are key to reducing expensive unscheduled downtimes.

Concurrently, the ISO2H823V sets a new standard for system-level diagnostics. Each of the 8 channels is equipped with five-fold diagnostic monitoring capabilities: Open Load Active, Open Load Inactive, Short-to-Vbb, Over Current and Over Temperature. Additionally five types of diagnostic feedback on the IC-level are provided. This is all integrated into a small 12 x 12 mm VQFN package (see **Figure 2**).

In the industrial control system, thanks to the integrated galvanic isolation, the ISO2H823V is positioned between the 3.3V micro-controller domain ("control side") and the 24V factory floor domain ("process side").

Figure 2: The ISO2H823V is a power management integrated circuit setting a new standard for system-level diagnostics in a tiny 12 x 12 mm VQFN package.

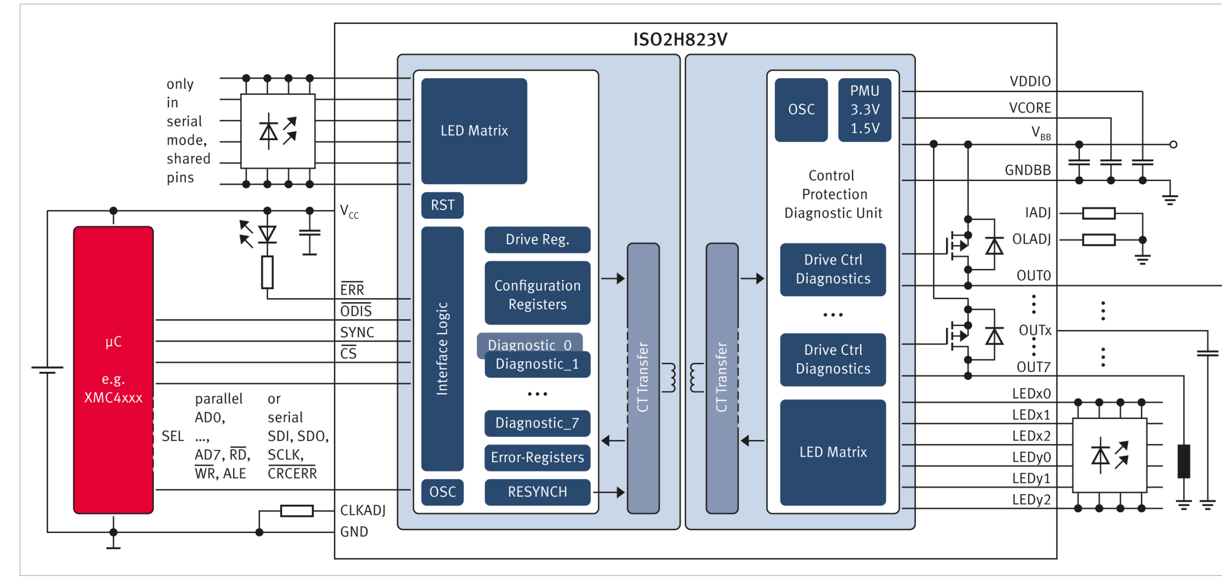

Figure 3: Many integrated diagnostic capabilities are available in the single IC. This eliminates the need to develop complex and space consuming circuit layouts based on multiple discrete components.

Powerful and Versatile Integrated Diagnostics

The most frequent failure mechanisms on the application level include overload of the driver outputs or actually having no load ("open load") connected to the driver outputs. Another severe deficiency is lack of or insufficient supply of the 24V Vbb on the on the factory side of the system. The ISO2H823V can detect either of these problems and many more. This capability is highly valuable for OEMs to prompt preventive maintenance and in case of malfunctions to drastically reduce the time required for repair.

The great benefit for the system designer rests in the fact that many powerful diagnostic capabilities are available in the single IC (see **Figure 3**). This eliminates the need to develop complex and potentially cumbersome circuit layouts based on multiple discrete components, to be able to perform diagnostic monitoring. In consequence, system design efforts, risks and time are reduced substantially, PCB area can be kept small, and the reliability of the solution is not compromised.

Overload diagnostics

Wear-out of machinery may lead to an output overload. In its extreme form there is actually a short circuit to GND caused either by erroneous wiring, short-circuit during operation, or a natural disaster that leaves the equipment flooded under water. A device such as the ISO2H823V can detect such cases. When the switch of a channel is "on", that channel's output current is monitored. If the output current exceeds the threshold to activate the current limitation, typically set at 1A, then

Over Current Limitation ("OCL") is flagged to the micro-controller.

Unlike other products, the ISO2H823V provides not only overload feedback, but it also informs the system controller which channel is subjected to the overload. This information can be instrumental to identify the root cause, which is critical to getting the system back on line within the shortest time possible.

Managing an open load

Mechanical strain, e.g. vibration or excessive bend stress of a

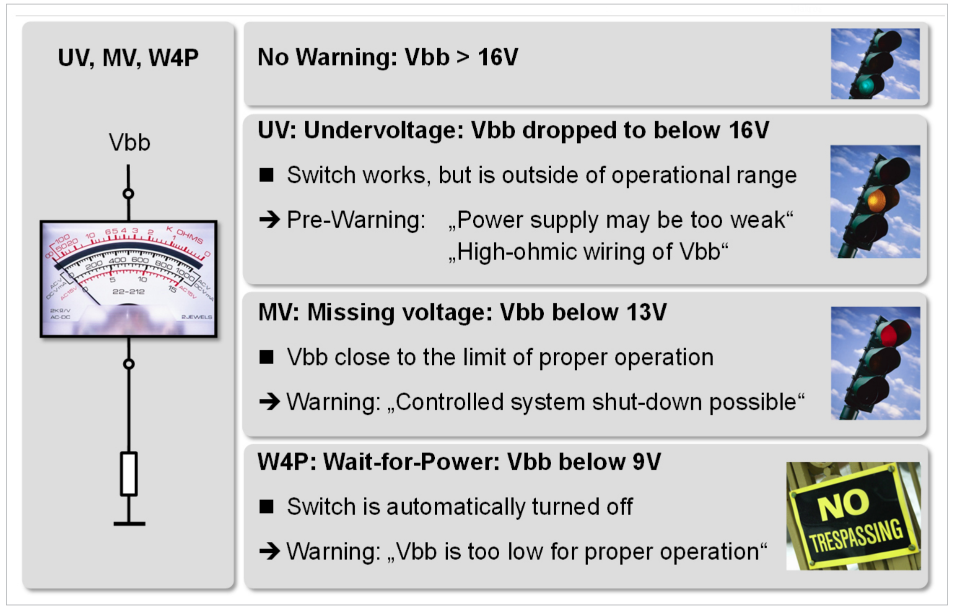

Figure 4: Vbb-monitoring checks the voltage level on the driver's output side.

cable, as well as corrosion can lead to the wiring between the IC switching output and the load to become high-ohmic or even disconnected ("wire-break"). The ISO2H823V can detect such circumstances. The IC performs output current monitoring, but not only for the purpose of limiting the maximum output current. The same capability is used to detect "no load" situations. An Open Load Active ("OLA") feedback is provided if an output is turned on and the output current of an individual channel is less than 0.5mA to 3mA. The system hardware design has the freedom to set the triggering threshold level within this range.

Designed for the industrial control market, the device provides integrated "open load" detection that is specific to any of the individual channels. Like with the overload detection, this greatly helps OEMs to reduce the time to identify the root cause of such a failure.

Open load when driver is still off [OLI]
Even before the switch is turned on, an open load ("wire-break") can be detected. This is possible because in addition to monitoring the output current, the voltage at the output of the IC is also being monitored. In case of the output being in "off" state a small trickle current of 25μA is flown through the load. For loads with an ohmic resistance of less than 12 kOhm, if the output is disconnected from the load, the output will float at a voltage higher than 2V, which in turn triggers the OLI diagnostic feedback.

Short to Vbb while the output is off [SCV]
The switch output could erroneously be connected to Vbb. Root causes may include wiring error, short-circuit during operation or a natural disaster which leaves the equipment flooded. This condition can also be detected by the ISO2H823V.

Over-Temperature at an output [OTA]
Excessive heavy-duty operation of outputs may be an indication for gradual degradation of the machinery on the factory floor. For this reason each of the output channels is equipped with an individual temperature sensor. When the output driver temperature reaches 150°C the respective output channel is automatically turned off to avoid material damage to the IC.

Vbb Monitoring [UV, MV, W4P]
Of all of the IC-level diagnostics, Vbb-monitoring (see **figure 4**) is probably the most important one. Vbb-monitoring checks the voltage level on the driver's output side. The possible reasons for this voltage failing and falling below the normal operation level could be that the power supply is not adequately designed for the loads, or the power supply is simply beginning to fail. It is also conceivable that the electrical connection between the power supply and the switching IC is gradually increasing its ohmic resistance, i.e. corrosion may be at work.

In a large number of applications the nominal supply voltage (Vbb) on the factory side is 24V +/-20%. However, if that voltage drops to a level as low as 9V, the outputs are turned off while it is still possible to do so. This is not done without a pre-warning, as a matter of fact, there are two intermittent stages:

- If the supply voltage drops below 16V then an Under-Voltage warning [UV] is issued. At that voltage the performance level of outputs of the IC is not yet compromised. The UV feedback provides a pre-warning.
- If the supply voltage drops further, i.e. to a level of 13V and below, then a Missing Voltage warning [MV] is sent. At this supply voltage level, the IC outputs are still working. However one may be well advised to perform a controlled system shut-down while it is still possible.
- Only if the supply voltage drops to 9V or less, all outputs are automatically turned off and a Wait-for-Power [W4P] feedback is triggered. In this case the supply voltage has dropped to a level too low for proper operation.

Over-Temperature on IC-level [OTP]
In addition to the temperature monitoring of each of the eight output channels, the IC has a ninth temperature sensor. This additional sensor provides on IC-level over temperature protection. The threshold is set to 125°C in order to remain below the glazing temperature of standard FR4 PCB materials. When this threshold is exceeded all outputs are automatically shut off ("OTP").

Incandescent Lamp [LAMP]
While the ISO2H823V delivers compelling benefits over previous generation solutions, it must also be able to retrofit with factory automation systems which are not yet at the end of their operational life. The detection of the presence of an incandescent lamp (used for signaling purposes on the factory floor) is a requirement for many such legacy systems. The LAMP feedback permits the system controller to distinguish between turning on of a cold incandescent bulb and a short-circuit.

Integrity of the communication across the Integrated Galvanic Isolation [TE]
To attain uncompromised robustness against electro-magnetic interference the communication across the integrated galvanic isolation is save-guarded by multiple proprietary measures. In the unlikely event there were to be disturbance of that communication its occurrence would be flagged to the μC by way of setting the transmit error ("TE") flag. If this error were to occur repetitively then it would indicate a substantial problem present on PCB-level.

Being sure all outputs are in fact off [ALLOFF]
To verify system status, but also for safety reasons, it can be of importance to be sure that all outputs are in fact off. The IC provides such explicit "ALLOFF" feedback if indeed all outputs are off.

Preventive Diagnostics and Full Control
With this impressive list of ten different types of diagnostic feedbacks, the ISO2H823V clearly sets a new standard in diagnostics for industrial control applications. The channel-specific diagnostic as well as the types of channel-specific diagnostic feedbacks can be enabled and disabled on a channel per channel basis. This grants the user the maximum of flexibility and allows the selective use these features to meet application specific requirements.

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Replacing vintage subsea cable to scenic Michigan Island

New line can handle all growth expected on this "Gem of the Huron"

By: Peter Ebersold, Kerite Company

When Cloverland Electric Cooperative wanted to replace the aging subsea cable that serves Drummond Island in Michigan's Upper Peninsula, they turned to experienced utility consultant GRP Engineering, Inc. to plan and design the tricky project. As the successful bidder to Cloverland Electric, Kerite Corporation provided the new cable, which was shipped out using a special truck designed for extra-heavy loads.

Running cable from the Michigan mainland out to Drummond Island under the tight timeline dictated by permit conditions went very smoothly, despite a few "bumps in the road." The successful project ensures that island visitors, residents, and businesses have the electrical power they need for the foreseeable future.

Growing load from resort communities drives need to replace cables

Two subsea electrical cables serve Drummond Island, located at the end of Michigan's eastern Upper Peninsula. Referred to as the "Gem of the Huron," and "Michigan's Ultimate Playground," the 87,000-acre island is the second largest fresh water island in the nation. It has 150 miles of rugged scenic shoreline, 133 square miles of forested landscape, and 34 inland lakes.

Figure 1: Kerite used a subcontractor to dig trenches and install the cable

The island has large and growing number of resort communities, as well as some full time residents. It is also home to the Drummond Island Quarry, a major producer of crushed and broken dolomite, which is used in manufacturing steel, glass, paper, and as a soil neutralizer for agricultural applications.

The two subsea cables, one serving mainly residential dwellings and one serving the quarry, were installed in 1975 and 1989 respectively, and had reached the end of their useful life. When the quarry was operating at full capacity, there was insufficient capacity between the cables in the event of a failure, causing the quarry to partially shut down.

While the load at the quarry is not anticipated to grow, Cloverland determined that the resort load is likely to increase as older smaller cabins are turned into larger ones, and modern amenities like air conditioning are added. Cloverland decided to install a new cable that could handle the entire island.

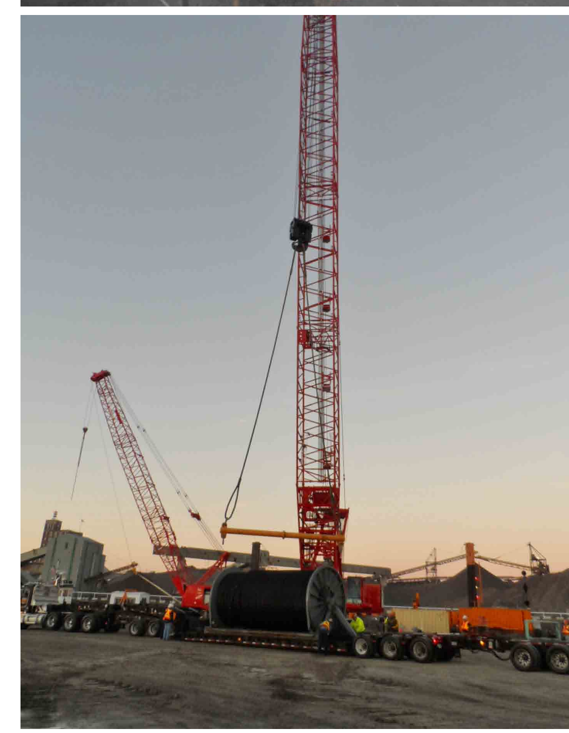

Figure 2: The reel was loaded onto a barge for the final part of the journey

The plan was to maintain two circuits. The first would be replaced in 2014, while the sister cable is budgeted for completion in 2017.

Cloverland called on GRP Engineering, a MI-based power utility consulting firm, to handle the first cable replacement project. The firm, which has more than a decade of experience with municipal and rural electricity cooperatives in Michigan, handled initial planning, cost estimates, permitting and design, as well as installation oversight and startup.

GRP Engineering developed the bid specifications, and the project was bid out "from termination top to termination top." Kerite was the successful bidder for the subsea cable, offering the lowest price as well as the most experience. With more than a hundred years' of know-how in providing subsea cable, Kerite is also the only US manufacturer of EPR subsea cable. Kerite's ethylene-propylene-rubber (EPR) insulation formula enables its subsea cables to operate in direct contact with water, without the need for an impervious lead sheet or asphalt coating. The cable can be covered with individually jacketed steel armor wires for mechanical protection and ease of installation pulling.

During the bidding process, Kerite responded to Cloverland's questions about thermal issues, providing a report with engineering test data to confirm the cable's ampacity, showing that the cable is good for 340 amps. Kerite used a subcontractor to dig trenches and install the cable (see **Figure 1**).

Coordinating closely with Cloverland on permitting and budgeting, GRP Engineering was responsible for oversight of manufacturing and installation done by Kerite and its subcontractors to ensure everything was done in accordance with the permit. For example, the island's location in a sensitive environmental area meant a joint permit was required, incorporating separate guidelines from both the Michigan Department of

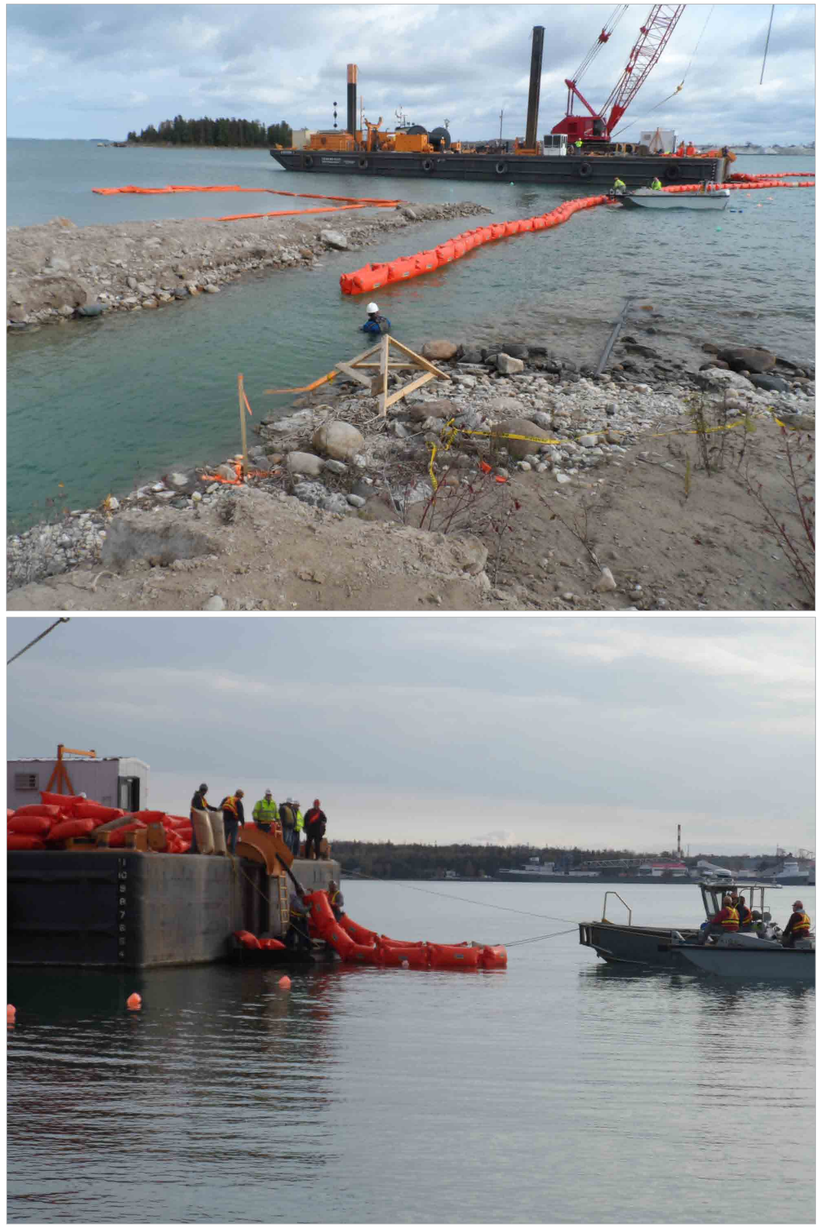

Figure 3: Engineering made the decision to pull the cable from the Drummond side to the DeTour side

Environmental Quality and the U.S. Army Corps of Engineers. Fish spawning was an important issue at the time of the year during which the project was scheduled, and the permit schedule accommodated that concern.

The project required 7465 foot of 28 kilovolt (KV) cable; Kerite provided the full length in one continuous piece of cable – with no splices. The line is currently being operated at 7.2/12.5 KV, and Cloverland will potentially be switching to a 14.4/ 24.9 KV operating voltage. There are three single phase conductors, each 350 KCM (1000 circular mils), and a full uninsulated neutral at 350 KCM. Also included is a 24-count fiber optics cable that Cloverland is using for communications with its substation and motor-operated switches on the island. Spare fibers are being leased out to the island's high speed Internet service.

The design called for installing the cable 20 feet below the low water datum at a depth of six feet. Once the cable is beyond 20 feet, the cable is transitioned out and then lays on the bottomland of the DeTour Passage. Typical cables are installed 15 feet below the low water datum at a depth of four feet, but with this location on the St. Mary's River, the deeper installation protects the cable from boats, ice, or other objects that might puncture the cable.

After tricky shipping, installation goes smoothly

The reel holding the continuous piece of cable weighed 171,000 pounds. Kerite used its onsite rail siding and special lifting equipment at its Seymour, CT manufacturing plant to place the reel onto a freight truck specially equipped to handle the extra weight. The truck had a larger than standard number of axles and a trailer that sits very low to the ground so it can clear most bridges. The vehicle was subject to special permitting and there was a few days delay when New York State did not have troopers available to escort the truck in accordance with that state's requirements.

Because the truck was not permitted to go over the Mackinaw Bridge, when it arrived at Rogers City, MI, the reel was loaded onto a barge for the final part of the journey. **Figure 2a & 2b** shows photos of the cable reel being loaded onto the barge in Rogers City and later ready for use.

The cable arrived safe and sound, and the installation then went forward. The original plan was to pull the cable from the mainland side at DeTour village, to the Drummond side. However, due to a rather strong southwest wind, GRP Engineering made the decision to pull from the Drummond side to the DeTour side. **Figure 3a & 3b** shows the cable installation. The left shows cable payout from DeTour, and the right shows cable floating to DeTour.

To protect the aforementioned fish spawning, the project was originally scheduled for completion by October 1st. Due to shipping issues encountered, GRP Engineering worked with the MIDEQ to get a brief extension. Weather is a main concern for a project like this, but all went smoothly and the entire project was completed in eight days. The cable is now energized and carrying the quarry load on the cable.

Michael McGeehan, President of GRP Engineering, says he was extremely satisfied with the project, which was the company's first subsea cable assignment. "Kerite did a great job. They were concerned about getting it done properly and on time, and keeping to the schedule to ensure compliance with the permit conditions required by fish spawning concerns." He added, "We were very happy when it was completed and installed. Everyone involved made sure the cable would be a success."

www.kerite.com

LED lighting performance depends on proper component choice

LEDs and how they need to be correctly biased to achieve the optimum light output performance

By: Phil Ebbert, Riedon

Not all resistors are the same, and growth in new markets like high-power LED lighting (see **Figure 1**) is serving to highlight the importance of understanding all aspects of an application in order to correctly and safely specify the right type of resistor.

Figure 1: The growth in new markets like high-power LED lighting underscore the importance of the power systems behind them.

Let's first return to basics to understand the operating principles of LEDs and how they need to be correctly biased to achieve the optimum light output performance specified by the manufacturers. We'll look at the electrical, optical and thermal characteristics of LEDs to appreciate why driving several LEDs in series can be more efficient than overdriving single LEDs, and why keeping temperatures in check is not just key to maximizing output but also to maintaining the desired color tone and ensuring reliability and long life.

Having understood the biasing calculations for some typical lighting scenarios, it quickly becomes apparent that in many applications the necessary ballast resistor is likely to dissipate several Watts of power. This not only dictates the need for a suitable high-power resistor type but may call for a design suitable for mounting on a heat sink, to help carry heat away from the LED rather than contribute to an already challenging design requirement.

All these considerations and more will be explored in the context of potential design solutions from specialist resistor manufacturer and supplier, Riedon, whose product line includes its UT series of wirewound power resistor for up to 13W dissipation, its PF series of power film resistor with ratings up to 20W and other series that allow for additional heatsinking and surface mount options.

Understanding LED operation and biasing requirements

A light emitting diode (LED) is a type of semiconductor diode that emits light when a current flows from anode to cathode across the P-N junction of the device. Hence, in normal operation, an LED requires a direct current (DC) supply to provide the necessary positive bias (forward voltage) across this junction.

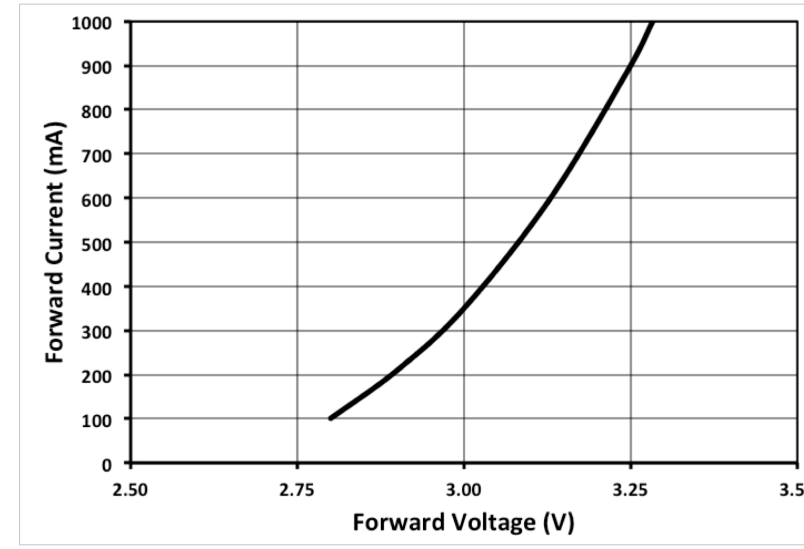

Figure 2: Typical LED current versus voltage characteristic

High brightness LEDs intended for lighting applications typically deliver optimum performance with a forward voltage of around 3V. However, as can be seen in **Figure 2**, the relationship of voltage to current is non-linear so while the LED will start to turn on at a lower voltage it will rapidly draw a much higher current as the voltage increases above its nominal rating.
Apart from considerations of heat dissipation and reliability (more on this below), this is inefficient since the relationship of luminous flux (a measure of light output) with LED current is also non-linear. So a doubling of current certainly does not result in twice the light output and a far better solution to achieve the desired light output is to use multiple LEDs.

Given these characteristics, the conventional solution for driving LEDs is to control the current through the device and the simplest method, as shown in **Figure 3**, employs a series resistor to limit current such that, using Ohm's Law:

IF = (VDC – VF)/R

where IF = forward current
VDC = supply voltage
VF = forward voltage
R = ballast resistor

It is possible to use a rectified and smoothed mains input to power the LED bias circuit but the resulting supply voltage (VDC) will be much higher than the forward voltage (VF) across a single LED, meaning that considerable power would be wasted in the ballast resistor compared to the power consumed by the LED. Connecting a number of LEDs in series, which is typical of many LED lamp designs, only partially addresses the issue, as the cumulative forward voltage will still be less that the voltage dropped across the resistor.

Instead most LED lighting systems employ power supply units (PSUs) with dedicated LED driver circuits providing an output to suit the required LED configuration. These PSUs typically accept AC mains input with a DC output that may drive a single LED but more likely a string of LEDs operating at voltages up to 60V. Even the "60W replacement" type of LED bulb uses a built-in LED driver circuit to convert AC mains to a suitable DC voltage to power its LEDs. Using dedicated power supplies also allows the connection of LEDs or LED strings in parallel for distributed lighting systems but normally the current in each parallel path still needs to be limited by a separate series resistor.

Ballast resistor selection considerations

We can most readily understand this by performing some simple calculations based on the bias circuit and LED characteristics shown above. For example, using a 24V DC supply and six LEDs connected in series (each with a nominal forward voltage of 3V) leaves us with 6V to be dropped across the ballast resistor.

So, with a corresponding LED forward current of 350mA, the required resistor value is given by:

R = (VDC – 6 x VF) / IF = (24 – 6

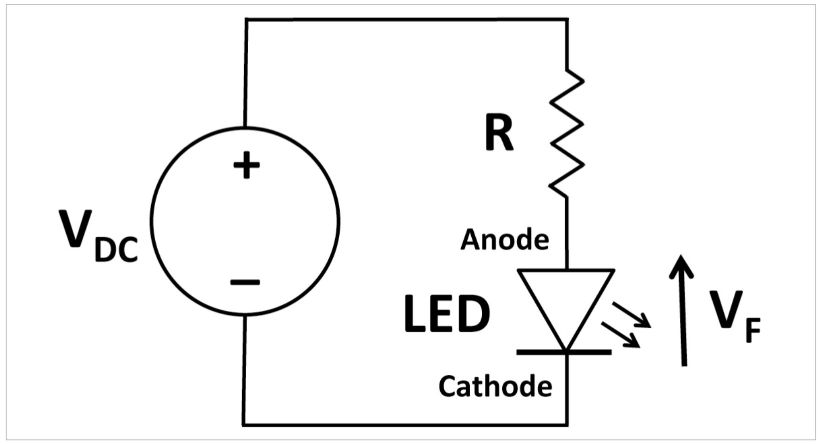

Figure 3: Simple LED biasing circuit

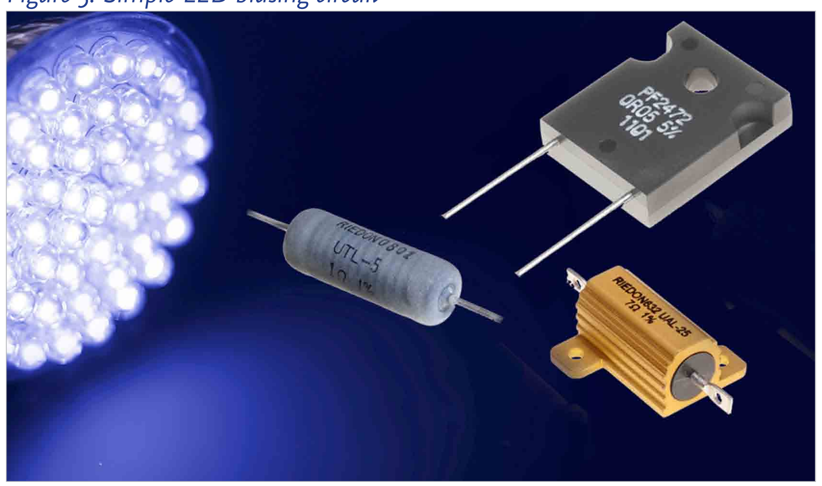

Figure 4. Riedon resistors for LED lighting

x 3) / 0.35 = 17.1Ω (ohms)

And, the power that the resistor has to dissipate is given by:

P = V x I = 6 x 0.35 = 2.1W (watts)

This provides the baseline specification for the resistor but before moving on to see what type of resistor might be suitable it is perhaps useful to question some of our assumptions. Such as, why a 24V supply when clearly a 20V supply would reduce the power dissipation in the resistor to just 0.7W? One reason lies with design and component tolerances.

A typical PSU may have an output voltage tolerance of ±5% and, while the current / voltage characteristic of the LEDs is still a factor; most of the output variation will affect the voltage across the resistor. Hence in our example with a 24V PSU an increase of +5% (+1.2V) will result in a current increase to around 400mA, which is still close to nominal for the LEDs. However with a 20V PSU a +5% increase (+1V) takes the forward current to around 450mA, which is disproportionally higher than the target 350mA.

Similar effects on the forward current will result if the resistor value itself deviates significantly from the design target value or if the LEDs vary from their nominal characteristics. Although there are no absolute rules for the design of LED bias circuits, all these factors need to be taken into account. The penalty, as noted earlier, is that the increased power dissipation from operating at higher currents leads to higher LED junction temperatures. This results in reduced relative light output, which partly negates any increase from operating at a higher current, but more importantly impacts on the device's reliability and expected lifetime.

The relative chromaticity, i.e. color tone, of an LED is also affected by variations in current and temperature and is another reason for keeping both under control. This raises the issue of LED dimming since, although it is possible to achieve analog dimming of LEDs over a limited brightness range by varying the drive current, sometimes even beyond its nominal rating, this comes with the same problem of color variations. Instead the preferred method is pulse-width modulation (PWM) of the bias current.

This approach typically drives the LEDs with a rectangular waveform, effectively switching the LEDs on and off at a rate (100kHz or more) which is too high to be noticed. In this way the LEDs see the ideal nominal forward current during the 'on' part of the cycle and there is negligible power dissipation during the 'off' phase. The potential requirement for PWM dimming does however impose another constraint on the choice of ballast resistor; namely that it needs to be a non-reactive load i.e. with minimal inductance or capacitance.

Potential types of resistor for LED ballasts

For LED lighting applications, devices with a nominal rated forward current of 350mA are quite typical but LEDs designed for operation at 700mA, 1A and even 1.5A are becoming increasingly common. So where the application example discussed above requires a resistor with a rating just over 2W, higher power LEDs may well require resistors rated at 10W or more.

Axial-leaded wirewound resistors offer reasonable power handling with low resistance tolerances, excellent low TCR (temperature coefficient of resistance) performance and they can operate over a wide temperature range. For example, Riedon's UT series wirewound power resistor offers power ratings up to 13W and a temperature range of -55°C to +250°C (or even +350°C for some types). For even higher power dissipation, or where it is important to remove heat more effectively from the ballast resistor, Riedon has its UAL series of aluminum-housed wirewound power resistor with ratings to 50W and above.

Wirewound resistors are available with non-inductive windings but thin film resistor technology provides an alternative that may suit some applications. Riedon's PF series offers low-inductance power film resistors in various package housings to support different power ratings e.g. 20W TO-126 and 50W TO-220. For surface mount designs the PFS series of power SMD film resistor from Riedon can handle up to 35W (see **Figure 4**).

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Special Report: Driving Consumer Electronics

PSD EUROPE
Empowering Global Innovation

Inside:

Zero-crossover-distortion amplifiers improve linearity of DAC Systems

Used in many applications, digital-to-analog converters are often accompanied by an amplifier

By: Vicky Wong, Analog Devices

Digital-to-analog converters are widely used in many different applications and an amplifier often accompanies them to signal-condition the output. The amplifier functions to increase output current drive, to convert differential to single ended output, to isolate the downstream signal path, or to provide a complementary bipolar output voltage. **Figure 1** shows a typical section of a single supply signal chain, consisting of a voltage reference, a digital-to-analog converter, and a buffer. To maintain a high dynamic output range and high signal-to-noise ratio, digital-to-analog converters (DACs) are often designed to operate full swing, where the reference voltage (VREF) is set equal to the supply voltage (VDD). This allows maximum usage of the digital codes. With a single supply, the DAC and the output buffer power supply are often connected to the same supply line. In this configuration, a rail-to-rail input and output amplifier is required to buffer the converter.

A classic non rail-to-rail input amplifier uses a p-type (or n-type) differential pair at its input stage. The p-type input amplifiers allow input common-mode voltage to reach and include the lower supply rail. This is especially useful in ground sensing application. On the other hand, the n-type input amplifiers allow input voltage to range from a few Volts above the lower supply rail to the upper supply rail. Such amplifiers suit applications that need to include the upper supply rail, for example, high side current sensing monitors. To enable the input common-mode voltage to extend to both supply rails, rail-to-rail input amplifiers incorporate both n-type and p-type input stages.

The majority of rail-to-rail input amplifiers are designed using two input differential pairs in parallel, an n-type and a complementary p-type. The input common-mode voltage determines which differential pair turns on and is active. The p-type differential pair turns on when the input voltage approaches and reaches the lower supply rail. The n-type pair is active for input voltages up to and including the upper supply rail. This topology allows the amplifier to maintain a wide dynamic input voltage range and maximize signal swing to both supply rails. However, these amplifiers exhibit a trade-off – a unique characteristic generally known as 'crossover distortion'.

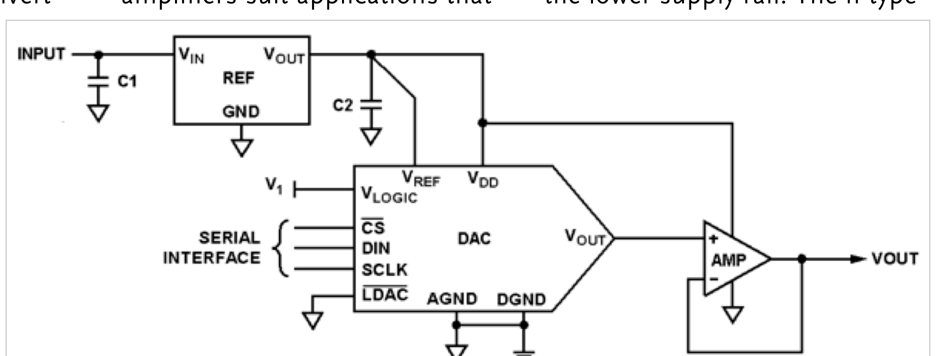

Figure 1: Typical section of a single supply signal chain

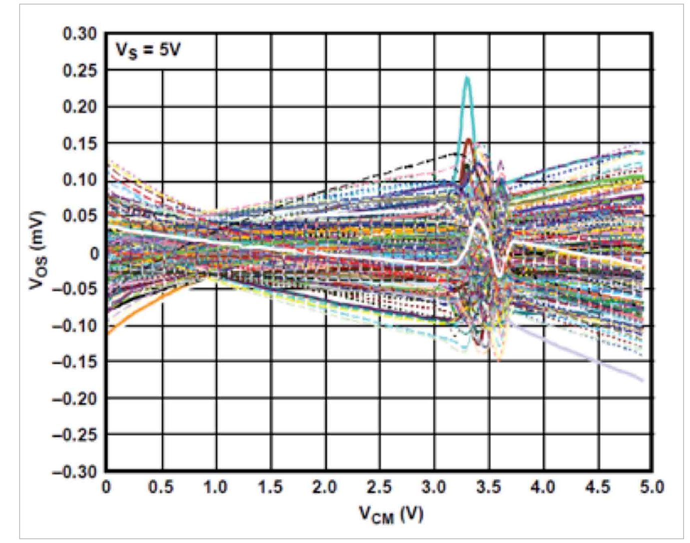

Figure 2: Input offset voltage vs. input common-mode voltage of a typical rail-to-rail input amplifier

Input differential pairs commonly exhibit different offset voltages. The hand-off from one pair to the other due to input common-mode voltage change creates a step-like characteristic that is visible in the graph of offset voltage vs. input common-mode voltage. This crossover distortion is inherent to all rail-to-rail input amplifiers designed with the dual differential pair topology. Refer to **Figure 2** for an example. For this amplifier running on +5V and ground, the crossover region occurs at 3.4 Volts of input common-mode voltage. Such an amplifier is used in applications where the input voltage range goes rail to rail, but can pose a problem when the input common-mode voltage is at the transition region. As an example, this unique characteristic causes nonlinearity when the amplifier is used as a buffer for a DAC output.

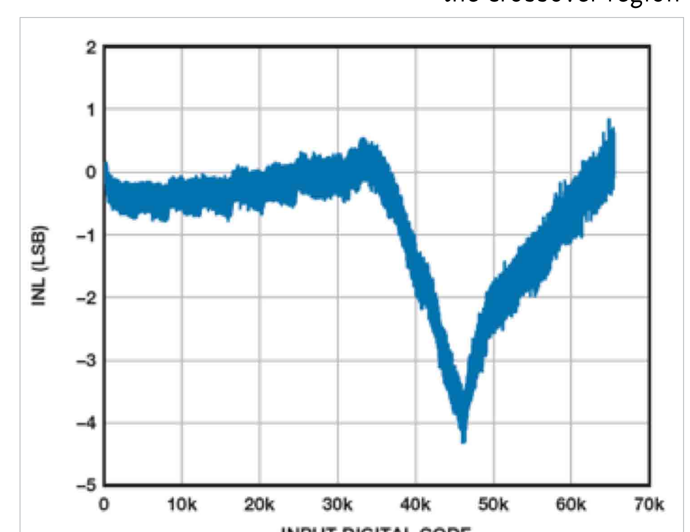

Figure 3: Integral nonlinearity (INL) of a 16 bit DAC and a typical rail-to-rail input buffer companion

Figure 3 shows the integral nonlinearity (INL) error of a circuit using a 16 bit digital-to-analog converter and a typical rail-to-rail input and output buffer. INL error is the deviation (in LSBs) of the actual converter transfer function from an idealized transfer function. Note that the input of the digital-to-analog converter is swept from code 200 to code 216-200. Approximately 15mV (200 codes) from either end of the range is excluded because a rail-to-rail output amplifier is not truly rail to rail out and require some output headroom (usually specified in the data sheet). The crossover distortion is detected at an input digital code of about 45000. This corresponds to an input common-mode voltage of 3.4V. Clearly, the amplifier crossover distortion degrades INL, affecting system accuracy. In this particular example, the crossover nonlinearity is as high as 4 to 5 LSBs for a 16-bit system. Many systems perform calibration to remove initial offset voltage, but such nonlinearity cannot be removed by calibration.

Crossover nonlinearity can be resolved by using a zero-crossover-distortion amplifier. This type of amplifier integrates a charge pump input enhancement circuit

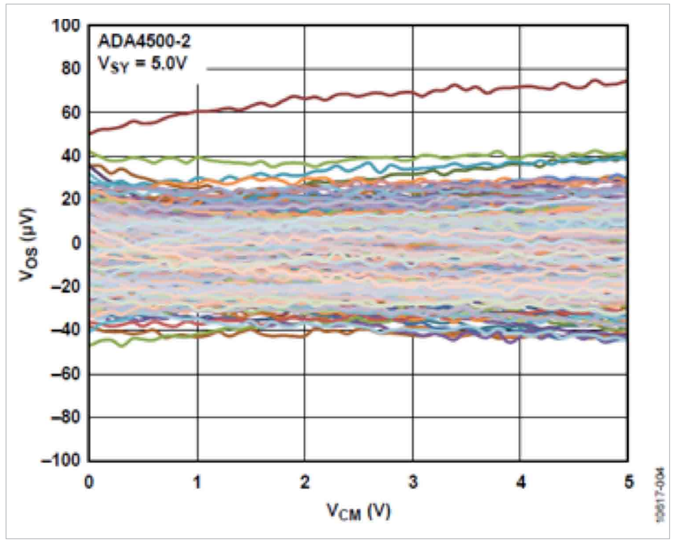

Figure 4: Offset voltage vs. input common-mode voltage of a zero-crossover-distortion amplifier

on chip to achieve rail-to-rail input swing. The charge pump increases the internal supply by a few Volts to provide the headroom needed for the input stage; the amplifier then achieves rail-to-rail input swing without the need for a complementary input differential pair. Consequently, it does not exhibit crossover distortion. An example of a zero-crossover-distortion amplifier is Analog Devices' ADA4500-2. **Figure 4** shows the offset voltage vs. input common-mode voltage of the device. Notice that offset voltage is quite constant over the input common-mode voltage range.

Using a zero-crossover-distortion amplifier eliminates crossover nonlinearity in a digital-to-analog converter system. **Figure 5** shows the INL of a circuit using the same 16 bit digital-to-analog converter and the ADA4500-2. The zero-crossover-distortion feature improves INL to less than +/-1LSB.

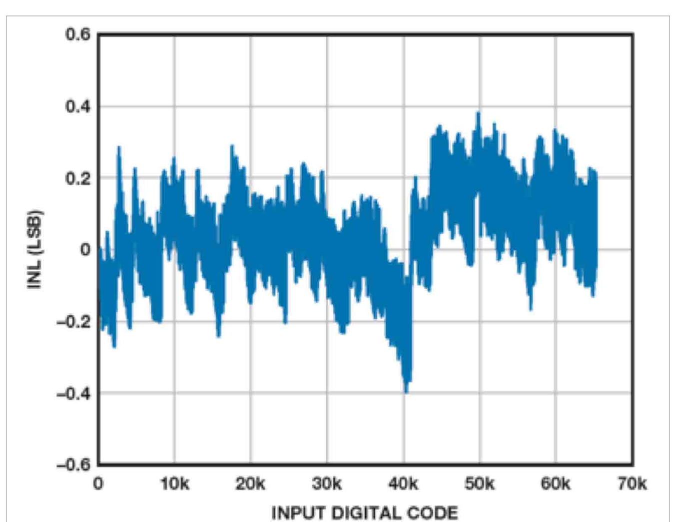

Figure 5: Integral nonlinearity (INL) of a 16-bit DAC and the ADA4500-2

As an alternative to using a zero-crossover-distortion amplifier to avoid crossover nonlinearity, one could also supply the converter with a reference voltage (VREF) that is lower than its supply (VDD). For example, use a 2.5V reference voltage with a 5V supply. This would ensure that the cross-over region of a typical rail-to-rail input amplifier is out of the input digital code range. As a tradeoff, this halves the output range. An external amplifier might also be needed to amplify the output if the signal level is too low. Another option, if the system has multiple supplies, is to provide the amplifier with a higher power supply, allowing the use of a non-rail-to-rail input amplifier. The increase in power supply would provide enou`gh headroom for the input stage. This however would be less power efficient.

All in all, it is important to carefully consider the appropriate amplifier as a DAC output buffer. You can use a lower DAC reference voltage at the expense of a reduced output range, or increase the buffer supplies at the expense of higher power consumption. Better yet, you can use a rail-to-rail input and output amplifier to maximize input and output range, but consider using a zero-crossover-distortion amplifier to avoid errors that come from crossover nonlinearity.

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Powering mobile devices with ICs just got easier

Much of the burden of a device's reliability, run-time, and robustness falls on the power system

By: Tony Armstrong, Linear Technology

As with many other applications, low power precision components have enabled rapid growth of mobile devices. However, unlike many other applications, portable products targeted at industrial, medical and military applications typically have much higher standards for reliability, run time and robustness. Much of this burden falls on the power system and its components. A common feature of such products is that they must operate properly and switch seamlessly between a variety of power sources. As a result, great lengths must be taken to protect against and tolerate faults, maximize operating time when powered from batteries and ensure that operation is reliable whenever a valid power source is present.

Clearly, the power management integrated circuits (PMICs) required to address these needs must allow an application to receive power from multiple power sources; which could include: a wall adapter, a USB port, a car lighter adapter or even a Li-Ion battery. This can easily be done if the PMIC has integrated PowerPath control. This technique ensures that system power remains uninterrupted and tolerates hot plugging between external power and battery power. In some instances, a battery charger may also be included on the PMIC. If so, this battery-charging circuitry needs to ensure that the battery remains charged using excess power not needed by the application. Furthermore, on-chip protection circuitry is sometimes necessary to guard against external overvoltage faults exceeding 30V. Finally, low no-load quiescent current is essential to provide optimal power efficiency over a wide range of load and operating conditions. Features such as these are all critical to the success and utility of any products.

Industry Trends

While product form factors are decreasing, demand for their functionality and features are continuously increasing. Furthermore, the industry trend for sophisticated digital ICs such as microprocessors (µP) and microcontrollers (µC) or field programmable gate arrays (FPGAs) that power mobile products continue to lower their operating voltages while simultaneously increasing their amperage.

Microprocessors are among the most popular of these to design in, and there is a growing list of power efficient types from such suppliers as Freescale, Intel, NVIDIA, Samsung and others. They are designed to provide low power consumption and high performance processing for a wide range of portable, wireless and mobile device applications across multiple market segments.

The original intent of these processors was to enable OEMs to develop smaller and more cost-effective portable handheld devices with long battery life, while simultaneously offering enhanced computing performance to run feature-rich multimedia applications. Nevertheless, demand for this same combination of high power efficiency and processing performance has spread to non-portable applications.

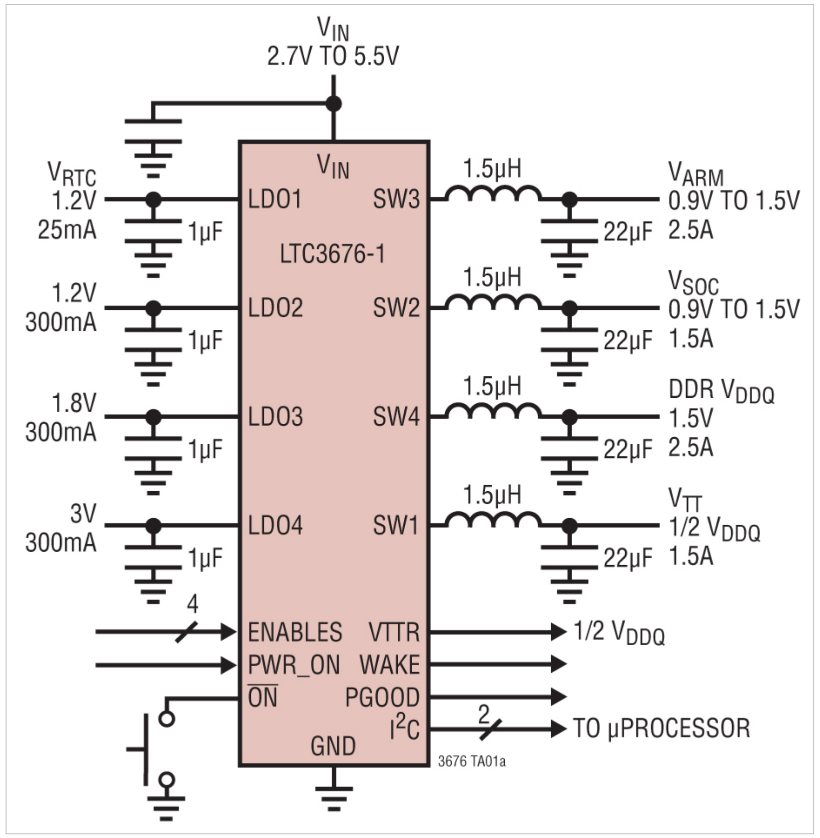

Figure 1: LTC3676-1 Simplified Typical Application Diagram

A couple of examples include automotive infotainment systems and other embedded applications, both of which demand similar levels of power efficiency and processing horsepower. In all cases, a highly specialized, high performance power management IC is necessary to properly control and monitor the microprocessor's power so that all of the performance benefits of these processors can be attained.

Many of today's industrial and medical mobile devices require controlled and choreographed sequencing as power supplies are powered up and applied to various circuits. Allowing for system flexibility and a simple approach to sequencing not only makes the system design easier, but it also enhances system reliability and allows for a single PMIC to handle a broader range of the system than just a specific processor's requirements.

Historically, many PMICs have not possessed the necessary power to handle these modern systems and microprocessors. Any solution to satisfy the Industrial or medical power management IC design constraints as already outlined must combine a high level of integration, including high-current switching regulators and LDOs, wide temperature range of operation, power sequencing and dynamic I²C control of key parameters with hard-to-do functional blocks.

Furthermore, a device with high switching frequency reduces the size of external components while ceramic capacitors reduce output ripple. This low ripple combines with accurate, fast response regulators to satisfy demanding voltage tolerances of 45nm type processors. Such power ICs must also be capable of meeting rigorous environmental constraints, such as radiated emission suppression, even if the input voltage is directly from the battery itself.

Design Challenges

Designers of today's smart phones and tablets are faced with unprecedented challenges. Among these are the demands for high performance power management systems to accommodate growing system complexity and higher power budgets. These systems strive for an optimum balance among competing objectives including long battery runtime, compatibility with multiple power sources, high power density, small size and effective thermal management.

One common goal that all smart phones and tablets share is to reduce the amount of power they consume from their current levels. Power consumption in any system can be addressed in two ways, firstly by maximizing conversion efficiency across the entire range of load current, and secondly, by reducing the quiescent current drawn from the DC/DC converters in all modes of operation. Therefore, in order to have an active role in the reduction of system power consumption, power conversion and management ICs must be more efficient, with lower levels of power consumption under all operating conditions.

To address these specific requirements, Linear Technology incorporates its Burst Mode technology into many of its power management and conversion ICs. This technique minimizes the current needed by the IC itself during standby mode. In many cases, this standby quiescent current is less than 20µA.

Until recently, designers of Li-Ion battery-powered products have used two basic approaches to address the challenges of limited battery capacity within their small form factor. One choice is to architect the system using individual components, each optimized for a single function. This approach yields maximum flexibility in design, layout and thermal management while achieving the appropriate level of performance for each function. But this choice has the major disadvantage of being relatively costly and requiring substantial board space to address the growing list of functional requirements.

The other alternative is that designers may choose from a variety of highly integrated PMICs. These devices typically support a superset of the functionality needed for most applications, including unwieldy combinations of switching DC/DC controllers, monolithic switchers and numerous LDOs integrated with unrelated mixed signal functions like touch screen controllers, audio CODECs and more. As a result, they can be cumbersome to use and most require a substantial investment in firmware just to turn them on.

These products tend to favor integration over performance, and often complicate thermal management by concentrating heat in a single "hot spot" within the product. Ironically, these highly integrated solutions also require relatively more board space due to their large, high pin-count packages. Finally, they force board layout heroics in order to accommodate all the related external components (MOSFETs, inductors, diodes and assorted passive components) and associated trace routing needed to get from the PMIC to the various loads across the system.

However, a new approach is now available which is sandwiched between these two approaches of utilizing multiple power ICs or a highly complex PMICs, and that is a modestly integrated, yet powerful PMIC. Such and IC is the LTC3676/-1 recently released from Linear Technology.

The LTC3676/-1 are complete power management solutions for Freescale i.MX6 processors, ARM based processors and other advanced portable microprocessor systems. The LTC3676/-1 contain four synchronous step-down DC/DC converters at up to 2.5A each for core, memory, I/O and system on-chip (SoC) rails plus three 300mA linear regulators for low noise analog supplies. The LTC3676-1 configures a 1.5A buck regulator for source/sink and tracking operation to support DDR memory termination and also adds a VTTR reference output for DDR. These two pin features replace the LDO4 enable pin and feedback pins of the LTC3676. LDO4 is still programmable by I²C.

Supporting the multiple regulators is a highly configurable power sequencing capability, dynamic output voltage scaling, a pushbutton interface controller, plus regulator control via an I2C interface with extensive status and fault reporting via an interrupt output. The LTC3676 supports i.MX6, PXA and OMAP processors with eight independent rails at appropriate power levels with dynamic control and sequencing. Other features include interface signals such as the VSTB pin that toggles between programmed run and standby output voltages on up to four rails simultaneously. The device is available in a low profile 40-pin 6mm x 6mm x 0.75mm exposed pad QFN package.

The LTC3676 power management

solution for application processors can solve the industrial and military system design challenges outlined above. The LTC3676IUJ is available in a high temperature (I-Grade) option with a junction temperature rating from -40°C to +125°C, easily satisfying the high temperature operating requirement. The IC includes a thermal warning flag and interrupt specifically for junction temperature monitoring and also includes a hard thermal shutdown for reliable protection of the hardware, should power dissipation be mismanaged, or in the event of a severe fault condition.

The LTC3676 PWM switching frequency is specifically trimmed to 2.25MHz with a guaranteed range of 1.7MHz to 2.7MHz. Its internal regulators can also be set to a forced continuous PWM operating mode to prevent operation in pulse skip or burst-mode even at light loads. This not only keeps the frequency fixed but also further reduces voltage ripple on the DC-DC output capacitors.

Conclusion

Designing a modern mobile device for the industrial, medical or military market segments is a challenging task due to the seemingly diametrical opposed requirements of high processing capability in an ever-shrinking form factor. However, thanks to suppliers like Linear Technology, systems designers now have the option to take a "middle ground" approach to resolving their power needs with a modestly integrated PMIC. This is a more practical approach when compared to using either individual ICs to build their system piece by piece or using highly integrated PMICs with all of their cumbersome functionality and firmware needs.

Either way, the choice is theirs to make.

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Ensuring accuracy in standby power evaluation

High levels of accuracy can be achieved

By: Hafeez Najumudeen and Erik Kroon, Yokogawa Europe

For more than a decade, energy consumption in low-power and standby modes has been recognized as an important issue. Standby power measurement is a challenge because most power meters on the market today do not have the accuracy to measure low power values accurately - especially at high crest factors and low power factors.

High-precision power meters and analyzers are now available with standby power consumption measurement software that complies with all the stringent conditions, testing methods and resolution of the test instruments specified in the IEC 62301 Ed.2.0 and EN50564:2011 standards.

Let's examine the results of tests on one of these instruments to show the levels of accuracy available: in some cases at least 15 times better than the uncertainty requirements of the international standby standards. In these tests, the Yokogawa WT310 digital power meter (see **Figure 1**) performance was evaluated against the requirements of the IEC62301 Ed.2.0 and EN50564:2011 standards at VSL (the National Metrology Institute of the Netherlands, providing direct traceability of measurement results to internationally accepted measurement standards) and at the Yokogawa European Standards Laboratory.

Figure 1: The Yokogawa WT310 power meter

The Yokogawa laboratory is presented as the only industrial (i.e. non-government or national) organization in Europe to offer traceable power calibration, to national and international standards, at frequencies up to 100 kHz at all power factors from zero to one.

IEC and EN standard uncertainty condition

The IEC and EN standard defines the maximum current ratio (MCR) as the ratio between crest factor and power factor. The significance of MCR is in the creation of test conditions where high crest factors are combined with low power factors. The standards state that, when the MCR is less than or equal to 10, for power values greater or equal to 1.0 W then the uncertainty should be less than or equal to 2% of the measured value; and for measured power values less than 1.0 W, the uncertainty should be less than or equal to 0.02 W. If the MCR is greater than 10, the uncertainty is calculated using the equation:

$$U_{pc} = 0.02 \times [1 + (0.08 \times \{MCR - 10\})]$$

which means that the tolerance range of the uncertainty value becomes broader as the MCR value increases.

Test setup

The tests on the Yokogawa WT310 were carried out using a calibration system based on a high-speed sampling wattmeter, which calibrates power at frequencies from DC to 100 kHz. This system

Measurement	Crest Factor (CF)	Power Factor (PF)	IEC & EN Standard - Required Uncertainty	WT310 Digital Power Meter - Measured Deviation
1	1.41	1.0	±2 %	0.026 %
2	1.41	0.1043	±0.02 W	-0.0003 W
3	11	0.0679	±0.0663 W	-0.0006 W
4	11	0.06757	±0.02 W	0.0002 W
5	11	0.5690	±0.02 W	-0.00007 W

Table 1: WT310 Evaluation results

is excellent for calibrating high frequency power, distorted waveforms and harmonics.

The generator for the signals is a Yokogawa FG320 two-channel arbitrary waveform generator whose output drives wideband amplifiers (DC to 1 MHz), which in turn generate the reference voltage and current. The total harmonic distortion of the voltage signal is smaller than 0.1% at 230 V. The current amplifier is able to drive from 0 to 5 A.

The front end of the test system is the part that converts the voltage and current to the 1 V signal that the sampling system uses for the A/D input. The 230 V AC mains input is converted to a 1 V signal by using a capacitor-compensated resistance divider. To convert the current into a 1 V signal, a special wideband shunt was developed. The 1 V signal is fed to a differential amplifier to avoid common-mode effects.

The core of the sampling system is the NI-5922 high-speed high-resolution A/D converter giving a resolution of 24 bits at 500 kS/s or 16 bits at the maximum speed of 15 MS/s. There are two input channels using the same clock source. Measured parameters such as voltage, current and power are derived using software-based calculations, allowing the power meter to be checked against the sampling system. The accuracy of the total system is many times higher than is needed for the IEC 62301 Ed.2.0 standard.

Measurements

The Yokogawa standby power software was used to read out the values measured by the Yokogawa WT310 power meter. A minimum of five minutes was set and the averaged value was taken. During the five minutes, the applied signals were stable. The voltage was a sine wave of 230 V, and the current range was set to "auto". The WT310 measures the peak current and selects the best current range.

The results of the evaluation of the power meter with various "challenging" signals (i.e. signals with high crest factors and low power factors) are shown in **Table 1.** From these results, it is clear that the Yokogawa WT310 digital power meter not only fulfils the uncertainty requirements of the IEC 62301 Ed. 2.0 and EN50564:2011 standards, but also exceeds them by far.

Certification

The WT310 has recently been certified for standby power measurement by the VSL as well as by Yokogawa's Standards Laboratory. The VSL certificate has certain limitations. To date, for example, it offers accredited calibration for sine-wave signals only. Therefore the VSL certificate is only relevant for specific calibration points on the sine wave. The VSL certificate also includes the comment: "This measurement is not within the formal VSL scope of accreditation for power measurements. They are, however, within the capabilities of VSL and are directly traceable to the Dutch National Standards."

In order to overcome these limitations, further tests were carried out in the Yokogawa laboratory. As indicated above, in practical scenarios it is important to have measurements done not only with sine waves but also with distorted waveforms. In order to show the superiority of the standby power software and the WT310 power meter, these additional tests were carried out with on both sine-wave and distorted waveforms with high crest factors and low power factors (which are mentioned in the Yokogawa certificate). It is also important to note that the power calibration capabilities of Yokogawa are also traceable to national and international standards.

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Protecting small autonomous robots

Even a robot vacuum needs power safety

By: Barry Brents, TE Connectivity

In recent years the development of information technology, artificial intelligence, sensor techniques and mobile-robot technology has led to intelligent systems being applied to smaller household appliances. One of the most representative products of this trend is the robot vacuum. Since the launch of the very first commercial sweeping robot in the U.S. in 2002, robot vacuums have become increasingly popular around the world (see **Figure 1**).

Figure 1: robot vacuums have become increasingly popular around the world

Because a robot vacuum operates independently, it may be used unsupervised. Consequently, in the event of mechanical or electrical failure, the components must be protected by a timely shutdown to avoid possible damage. For manufacturers of vacuum manufacturers, ensuring reliability by protecting the motors, ports and batteries is a primary concern. Moreover, designers of these applications must comply with various safety standards, including requirements specified in the IEC/EN60950, UL1017 and EN 60335-1.

Principles of Operation

Robot vacuums avoid obstacles in their path by using an ultrasonic ranging sensor which emits ultrasonic pulses in the direction of travel and receives corresponding return acoustic pulses. Ultrasonic emission and reception are controlled by devices with either a microcontroller or a DSP (digital signal processor) as their core. The robot's control system uses this data to determine an optimized path; it then engages the two-step motors and activates the drive wheels, initiating the travel function. As the robot follows this optimized travel path, the onboard cleaning units are activated to perform dust removal and floor cleaning.

In general, a robot vacuum consists of a travel mechanism, a sensor system, a control system, a sweeping system and a power supply unit. The travel mechanism occupies a large part of the body of a robot vacuum, and its size determines the amount of operating space the robot requires. Wheeled systems are generally employed for home-use robot vacuum. Ultrasonic sensors, contact and proximity sensors, infrared sensors, etc., are utilized to allow the sensor system to gather information about complex environments. The control system analyzes this data from the various sensors in order to control the operation of the robot, allowing it to navigate correctly and carry out its cleaning functions.

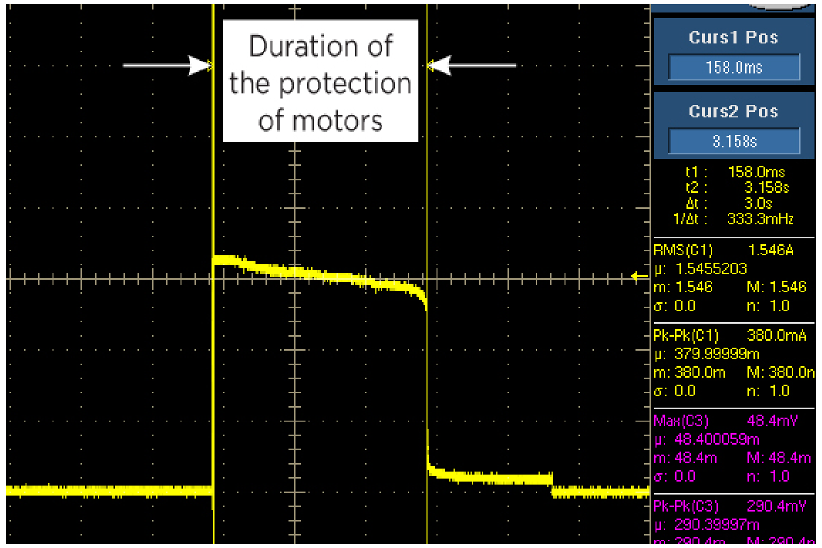

Figure 2(a): Real-time response time of a surface-mount PolySwitch PPTC device protecting a stalled wheel motor.

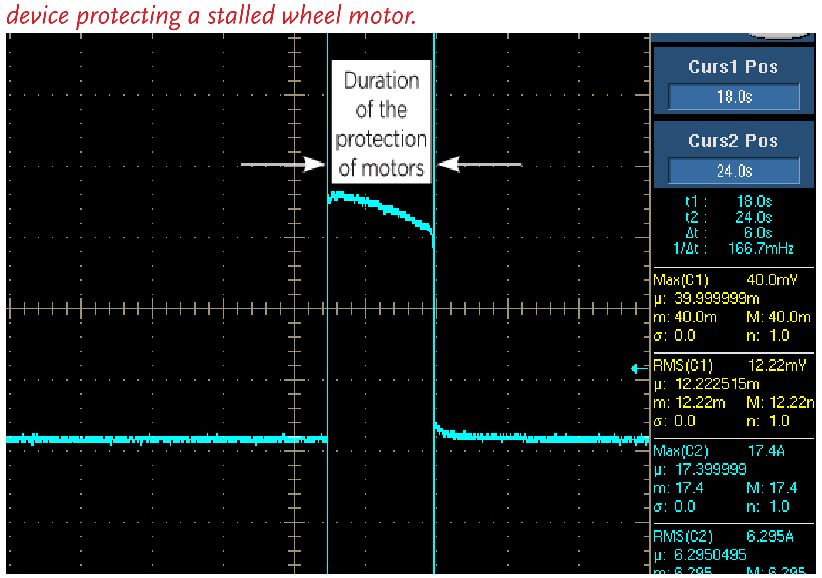

Figure 2(b): Real-time response time of a radial-leaded PolySwitch PPTC device protecting a stalled dust-removal motor.

The sweeping system generally consists of master floor brushes, side brushes and vacuum cleaners. Master floor brushes and side brushes are used to sweep up dirt and debris using mechanical force, while vacuum cleaners are used to remove smaller dust particles from the floor.

The power supply comprises the components that provide power to the various parts of the smart sweeping robot. Since the sweeping robot operates autonomously, the power supply is a rechargeable battery. This not only allows for unmanned control but also improves the equipment's functionality and flexibility. When fully charged, the robot can operate nonstop for several hours.

Preventing a Stalled Motor

While floor cleaning is in progress, the motorized parts of the robot vacuum can become entangled with debris, causing the motors to stall. When this happens, voltage is still being supplied to the motor even though current can no longer flow, which causes the temperature of the motor to rise rapidly. When the temperature exceeds the rating of the motor coil, the coil can burn out and the motor can fail. This not only inconveniences the consumer, it can also add to the cost of warranty repairs incurred by the manufacturer.

Polymer positive temperature coefficient (PPTC) devices are well suited for protecting motors during overcurrent events. Like traditional one-use fuses, PPTC devices limit the flow of dangerously high current during fault conditions. Unlike fuses, however, these devices reset after the fault is cleared and power to the circuit is cycled. With this approach, once the cause of the stall has been removed, the customer can expect that the robot will return to normal operation with no further maintenance requirements. PPTC devices help enable this functionality since their resistance can be restored to a low value after a motor malfunctions. Moreover, compared to many dual-metal breaker products, PPTC devices enable greater design flexibility, longer service life and reduced electromagnetic interference (EMI).

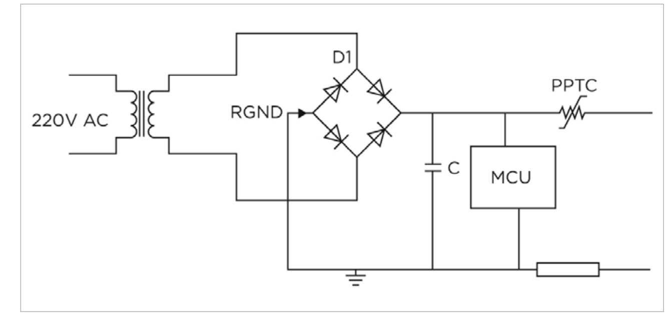

Figure 3: Circuit diagram showing a PolySwitch PPTC device in a charging port of a robot vacuum.

Design requirements
The design requirements for robot vacuum's drive system are as follows. The maximum working current of a driving-wheel motor is 0.3A. The minimum temperature of the environment around the PCBs of the vacuum is 10°C, and the maximum operating temperature is 50°C. The maximum voltage of the charged batteries is 22.5V. Each motor requires protective components, attached to the motor surface, capable of providing protection by shutting off the current within 10 seconds of fault detection.

Figure 2(a) illustrates the real-time response of a PolySwitch surface-mount PPTC device (miniSMD-C050F) being used to protect a stalled wheel motor. As shown in the graph, the protection response time is 3.0 seconds, which is far less the 10 seconds generally required in these applications. **Figure 2(b)** shows a PolySwitch radial-leaded PPTC device (RUEF400) being used in a dust-removal motor stall. The real-time response time in this graph is 6.0 seconds; again, much lower than 10-second response-time requirement.

In the same way, the appropriate PPTC devices in the PolySwitch family can be selected and attached to the respective motor surfaces to protect the master floor-brush motors and side-brush motors from damage from over-current conditions.

Protecting Power-charging Ports and Rechargeable Batteries
Since a robot vacuum operates autonomously, it uses a rechargeable battery for its power supply. This allows for unmanned control and also improves the product's functionality and flexibility since, when fully charged, a robot vacuum can operate nonstop for several hours. Although convenient for the user, having the charging ports exposed means that designers must provide circuit protection to help protect against external short circuits and other failures.

Resettable PPTC devices help provide an effective port protection solution in robot vacuum applications. **Figure 3** shows the charging circuit in the robot vacuum. Since the vacuum's rechargeable battery will not exceed 30V, PolySwitch devices with voltage ratings equal to or greater than 30 Vdc should be used. These low-voltage-rated PPTC devices can be placed on the AC mains charger for secondary-side protection. Based on the working current levels and ambient operating temperatures for robot vacuums, the PolySwitch RUEF400 PPTC device generally can meet the relevant requirements.

Rechargeable batteries provide power for robot vacuums. Various types of batteries can be used, including nickel-cadmium, lithium, and polymer batteries, all of which require protection against electrical surges or failures. PPTC devices are widely used as secondary protection devices in these applications, providing both overcurrent and over-charging protection. The overcurrent function helps protect against abnormally high-charging or discharging currents to prevent damage and ensure battery safety. The over-charging protection function monitors the battery core temperature to help prevent over-charging, enabling disconnection from the charger if such a condition occurs.

Conclusion
Resettable PPTC devices are well-suited for helping to protect the equipment's motors, batteries and charging ports from damage caused by stalled motors, over-charging and other failures that can be encountered during normal operation. The PolySwitch family of PPTC devices offer a various options for low resistance, rapid response time, small size and reset functions can help designers develop safe and reliable products.

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We need net neutrality

By: Alix Paultre, Editorial Director, PSD

Recent experiences with advanced personal electronics like my recent trip to Nuremberg's PCIM with Google glass have only served to emphasize the importance of open and fast wireless data infrastructure. The most powerful devices in the Internet of Things are just random pieces of junk without their enabling infrastructures.

This fact should be a rallying cry for our industry. What use is there to create advanced devices if the gated levels of access in a future web destroy user functionality and de-incentivize them from buying new devices and services? Who benefits from a gated web, at any level? Be it local wireless access, website serving, media streaming, or any other cloud-based functionality, only by enabling devices, systems, and services to operate at their potential peak will manufacturers and organizations be able to get users to appreciate and wish to acquire their products and services.

This is not just a debate about enabling proper functionality and allowing devices to operate well in an advanced cloud-based Internet of Things, although that alone should be reason enough to dismiss those that wish to gate and tier access so they can profit from the pipeline traffic. It is a debate about killing the goose that lays the golden eggs, and trying to leech value from those that created it. The value in the Internet was created by the people who took that tool (it was an information weapon let out of the lab, remember?) and used it to create a marketplace of ideas. Stepping in now once the value has been created simply to be a parasite on the traffic created by others using it may be legitimate business, but it is shortsighted and counterproductive to development.

If we continue and go the way of others who gate and tier and other ways withhold and stifle access to people simply to generate additional profits beyond legitimate traffic fees, we will wind up with an internet that resembles our TV landscape today, content presented only by those with the deep pocket and logistic resources to pay their unrestricted way into your homes. Original, novel, and unpopular content will be bottlenecked into IP ghettoes where only die-hard enthusiasts will put up with the restricted gateways involved.

Not only will content get blander, innovation will be restricted to what the big media companies decide amongst themselves to implement. Small novel creators and exciting new ways to express oneself will become the pro-bono grist for crowdsourced content on the larger sites.

We must take action to prevent the web from becoming a collection of gated communities and crap-filled spam factories pumping uninspired and uninformative "content" that tries to serve everyone but falls short for everyone. If we want to kill the development of the web and the promise of what a well-functioning cloud-based infrastructure could be, then we need to fight for net neutrality now.

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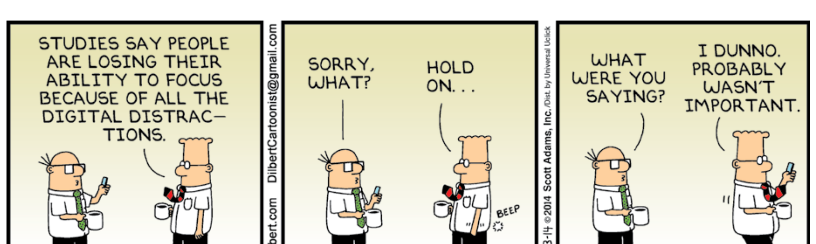
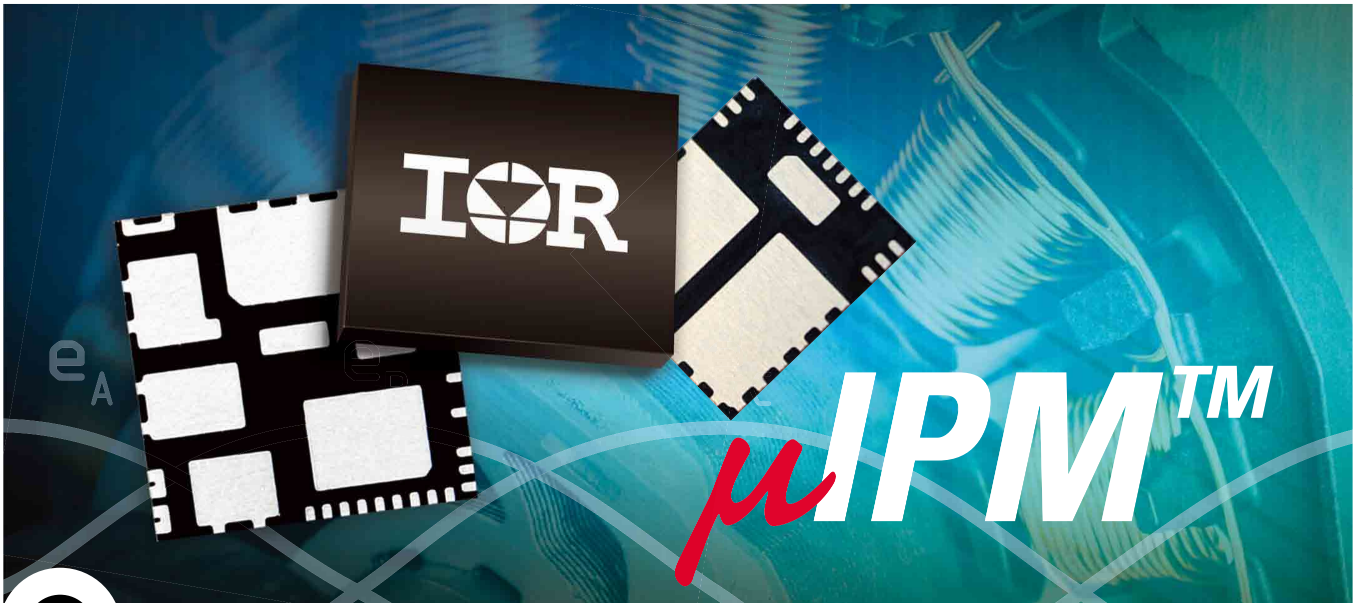




Innovative Power Module Reduces System Size

μIPM™ Power Modules Deliver up to 60% Smaller Footprint

Specifications:

Part Number	Size (mm)	Voltage	IO (DC@ 25°C)	Motor Current**		Motor Power VO=150/75VRMS	Topology
				w/o HS	w/HS		
IRSM836-024MA	12x12	250V	2A	470mA	550mA	60W/72W	3P Open Source
IRSM836-044MA	12x12	250V	4A	750mA	850mA	95W/110W	3P Open Source
IRSM836-025MA	12x12	500V	2A	360mA	440mA	93W/114W	3P Open Source
IRSM836-035MB	12x12	500V	3A	420mA	510mA	108W/135W	3P Common Source
IRSM836-035MA	12x12	500V	3A	420mA	510mA	100W/130W	3P Open Source
IRSM836-045MA	12x12	500V	4A	550mA	750mA	145W/195W	3P Open Source
IRSM808-105MH	8x9	500V	10A	1.1A	1.3A	285W/390W	Half-Bridge
IRSM807-105MH	8x9	500V	10A	1.1A	1.3A	285W/390W	Half-Bridge

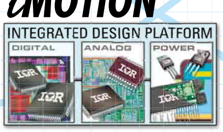
Features:

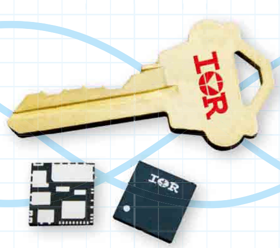
- Integrated Gate Driver IC
- Compact PQFN package offers up to 60% smaller footprint
- Eliminates the need for heat sink
- DC current ratings from 2A to 10A
- Voltage range of 250V – 500V

μIPM™ Advantages:

- Shortens design time
- Shrinks board space requirements
- Simplicity - Eliminates Heat Sink
- Replaces more than 20 discrete parts to deliver a complete motor drive stage
- Slashes assembly time and cost
- Simplifies procurement and inventory management
- Reference design kits available for quick evaluation on any 3-phase motor

iMOTION™ *





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** RMS, Fc=16kHz, 2-phase PWM, ΔTCA=70°C, TA ≈ 25°C