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May 2009

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Special Report - Lighting Systems

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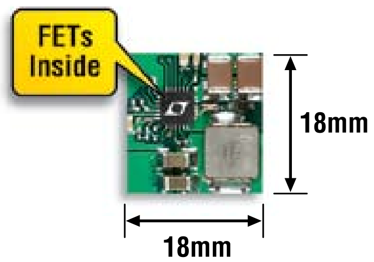
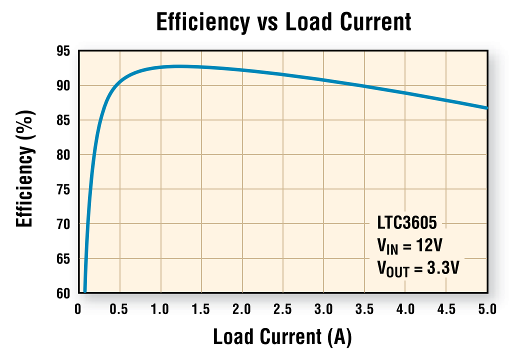
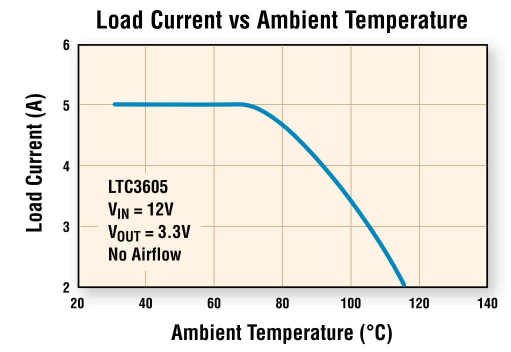
2A to 12A, High V_{IN} Synchronous Bucks



LTC®3605
Demo Board
(Actual Size)





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▼ High V_{IN} Monolithic Synchronous Buck Converters

Part Number	V_{IN} Range	Output Current	Switching Frequency	Synchro-nizable	Architecture	Package (mm)
LTC3601*	4V to 15V	2.5A	800kHz to 4MHz	Yes	Controlled On-Time	3x3 QFN-16, MSOP-16E
LTC3603	4.5V to 15V	2.5A	300kHz to 3MHz	Yes	Constant Frequency	4x4 QFN-16, MSOP-16E
LTC3605	4V to 15V	5A	800kHz to 4MHz	Yes	Controlled On-Time	4x4 QFN-24
LTC3609	4V to 32V	6A	300kHz to 1MHz	No	Controlled On-Time	7x8 QFN-52
LTC3608	4V to 18V	8A	300kHz to 1MHz	No	Controlled On-Time	7x8 QFN-52
LTC3611	4V to 32V	10A	300kHz to 1MHz	No	Controlled On-Time	9x9 QFN-64
LTC3610	4V to 24V	12A	300kHz to 1MHz	No	Controlled On-Time	9x9 QFN-64

*Future product. Contact LTC marketing for information.

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LINEAR TECHNOLOGY

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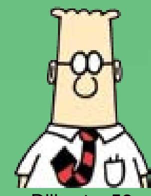

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Volume 6, Issue 4

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Turning the Screw

Welcome to this special lighting issue of PSD. With PCIM (Power Conversion Intelligent Motion), Europe's premier meeting-point for experts in Power Electronics (Exhibition Centre Nuremberg May 12-14) now well underway, we look forward to seeing the latest our industry has to offer. I am hosting a forum exploring "Power Design for Ecological and Economic Success" where I will be joined by leading manufacturers in the industry. This takes place in Hall 12 from 4:00 – 5:00pm on Wednesday 13th May. If you're at the show, join us for an hour. You'll make many contacts see some of the most knowledgeable people in the business.

Many companies in our own industry still continue to swing the axe frantically with the net result that many employees are being thrown into joblessness, neatly dumped onto the responsibility of the state and social services. Not a desirable or dignified approach to the current economic difficulties, or indeed a confidence builder for the current captains of industry.

But despite the current downturn, opportunities for growth in the medical imaging equipment market have been highlighted in the first edition of InMedica's report, "Medical Imaging Production Yearbook". Forecast to exceed $22 billion by 2012, the combined market for ultrasound, X-ray, MRI and CT imaging equipment is forcast to continue to expand in an environment where restrictions in healthcare spending and reductions in reimbursement are ever-increasing. Technologies predicted to have the greatest impact in the medical imaging equipment market over the next few years are those which allow changes to clinical pathways that will eliminate unnecessary diagnostic procedures, dramatically reduce the cost of healthcare and increase diagnostic accuracy for patients.

In 2008 China surpassed the United States to become the world's second largest auto-making nation and is set to displace Japan in 2009 as the planet's largest car producer, according to iSuppli Corp. China manufactured 9.3 million cars in 2008, while the United States built 8.7 million. In 2009, China will build 8.7 million autos, compared to 7.6 million for Japan.

"China's rise to the No.-2 position in global car manufacturing in 2008 marks a major milestone in China's economic ascendancy and the United States' industrial decline," said Egil Juliussen, PhD, director and fellow, automotive research, for iSuppli.

Despite the doom and gloom of today's industry and workplace, we will get through it. I believe the power industry overall is still well placed for a strong recovery and look forward to it when we all make it happen.

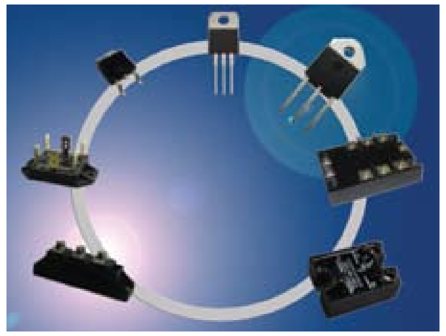
Enjoy the issue, keep the feedback coming and check out our fun-strip, Dilbert, at the back of the magazine.

All the best!

Cliff Keys

Editor-in-Chief, PSDE
Cliff.Keys@powersystemsdesign.com

Exclusive Distribution Agreement



AMS Technologies AG, based in Martinsried near Munich has announced an exclusive distribution agreement with San Diego based C3 Semiconductors LLC. The agreement entitles the Pan European distributor to sell C3 Semis semiconductor products throughout Europe.

C3 Semiconductors LLC is a manufacturer of a wide array of discrete semiconductors such as Triacs, SCR's, rectifiers in TO220, TO218, Dpack, D2pack package sizes. Also power modules, IGBT modules and solid state relays are available. The products are used for solutions in a variety of applications including lighting, motor control, automation and high power control.

C3 Semis was formed to bring a new focus to the semiconductor industry, providing the flexibility to fulfill specific customers' requirements. Due to its expertise C3 Semis is able to construct different circuits in a number of diverse packages and configurations or with special characteristics.

C3 Semis products will be shown at **PCIM 2009** (12th to 14th May, Nuremberg, Germany) at **AMS booth** # **12-512**.

www.ams.de

ABB Wins Ireland-UK Power Transmission Order

ABB has won an order worth $550 million to connect the Irish and UK power grids using technology that will strengthen the reliability and security of electricity supplies in each country, and enable Ireland to expand its wind power capacity.

The Irish transmission system operator, Eirgrid, has ordered a 500-megawatt (MW) transmission system using HVDC Light (high-voltage direct current), an ABB technology with environmental benefits that include neutral electromagnetic fields, oil-free cables, low electrical losses, and compact converter stations. The solution also provides features such as 'black start' capability, a way of re-storing power after a blackout without the aid of external energy sources.

"We are delighted to partner Eirgrid for this project," said Peter Leupp, head of ABB's Power Systems division. "ABB's HVDC Light technology will enhance the stability of both the Irish and U.K transmission grids, and also expand capacity for the use of renewable power."

The transmission link will run underwater for 186 km and underground for 70 km, with minimal environmental impact. The only visible parts will be the converter stations at each end that switch AC (alternating current) to DC (direct current) and back. The cable will be encased in extruded polymeric insulation, providing strength and flexibility needed to endure the severe conditions of the Irish Sea.

Rated at 200 kV, this will be the highest voltage HVDC Light link using this type of cable. The higher voltage enables a transmission capacity of 500 MW, the highest ever for an HVDC Light underground cable. ABB will be responsible for system engineering, including design, supply and installation of the sea and land cables, and both converter stations. The system is scheduled to be operational in September 2012.

Ireland plans to expand wind power generation and this link, between North Dublin and Wales, will ensure that it is able to import power if needed when the wind isn't blowing, and to export power to the U.K. when it generates a surplus.

www.abb.com

First Wind Farm with REpower 6M Turbines

REpower Systems AG has just completed installation of the first wind farm consisting exclusively of REpower 6M turbines at the Westre civic wind farm close to the German-Danish border.

The three turbines, each rated at 6 megawatts with a rotor diameter of 126 metres, are among the largest wind turbines in the world. The new turbine was developed by REpower engineers for offshore deployment at a later stage and assembled at the company's manufacturing centre in Bremerhaven. In the Westre civic wind farm, the first three turbines of this type are to be tested extensively for offshore operation and will also be subjected to a type certification.

In January, the nacelles (cover housings) of the three 6M turbines were shipped from the REpower plant in Bremerhaven to Dagebüll in Schleswig-Holstein and then transported to the construction site. The rotor blades, each one 61.5 metres in length, were transported as a wide load directly from Denmark. The hub height of a 6M turbine in the Westre civic wind farm is 100 metres. A crane with a boom height of 132 metres was required to assist in erecting the turbines.

Matthias Schubert, CTO of REpower, commented, "By now, the REpower team has gained experience in the installation of 17 type REpower 5M turbines; the 6M turbine technology is based on the successful 5M construction series. However, this was still our first time erecting a wind farm that consists entirely of turbines each with a six megawatt output and for this I congratulate the entire project team. This achievement means we have once again taken one huge step forward in the field of offshore wind energy."

Also, the framework agreement between REpower Systems AG and the RWE subsidiary Innogy, signed in February, includes the delivery of up to 250 turbines of the type REpower 5M or 6M for the "Innogy Nordsee 1" offshore wind farm.

Over 200 limited partners from the districts of Westre, Ellhöft and the Danish Lydersholm are participating in the Vindtved GmbH & Co. KG civic wind farm.

www.repower.de

IRIS Certification for Mitsubishi Electric

Mitsubishi Electric Corporation is the first Japanese company to receive the International Railway Industry Standard (IRIS) certification. The IRIS quality standard (International Railway Industry Standard) is defined by UNIFE, the European association for the railway supply industry. The IRIS standard covers project management (from design, development to after sales services), management of tender bids, change management and also reliability, maintenance and safety levels of products. IRIS, an extension of ISO 9001, is unique to the railway industry.

The research, production and testing facility of semiconductor components in Mitsubishi Electric Corporation Power Device Works in Fukuoka, in Kumamoto and Sun-A factory in Nijo have now been successfully audited.

Mitsubishi Electric Europe B.V. offers a wide range of HV-IGBT and Intelligent Power Modules. Mr. Shoichi Nakagawa (Divisional Manager, Semiconductor European Business Group) accepted the certification as a proof of Mitsubishi's lead position in the development & production of semiconductor components.

The successful award of IRIS certification reinsures Mitsubishi Electric's high-quality, certified products and services for the railway industry.

www.mitsubishichips.com

Digi-Key and Bosch Sensortec Announce Global Distribution Deal

Electronic components distributor Digi-Key Corporation and Bosch Sensortec have announced that they have entered into a global agreement for the distribution of Bosch Sensortec's acceleration and pressure sensors as well as its award-winning BMP085 barometric pressure sensor.

In stock and ready for immediate delivery from Digi-Key, Bosch Sensortec's triaxial acceleration sensor family is specifically designed for low-power applications to enhance functionality in mobile phones and consumer electronic devices. The interrupt feature of the sensors offers an additional special advantage for mobile applications such as a battery-saving mode or free-fall detection.

Also in stock and available in different housings, Bosch Sensortec's monolithically integrated pressure sensors provide outstanding accuracy, and their high robustness makes the sensors ideal for applications such as GPS navigation enhancement, in- and outdoor navigation, leisure, sports and health monitoring, weather forecast, vertical velocity indication, and fan power control. The winner of several prestigious awards, the BMP085 is a high precision, ultra low-power barometric pressure sensor for use in advanced mobile applications.

Bosch Sensortec products stocked by Digi-Key are available through its global websites and will be featured in upcoming print and online catalogs.

"We are very pleased to add Bosch Sensortec to our register of trusted supplier partners and offer the advantages of its products to the hundreds of thousands of design engineers who rely on Digi-Key for the quick delivery of the electronic components they need," said Jeff Shafer, Digi-Key vice president, interconnect, passive and electromechanical product.

Frank Melzer, CEO of Bosch Sensortec, pointed out, "Our customers expect worldwide availability and support for our products. We are convinced that Digi-Key is a strong partner for broadening our sales channels."

www.digikey.com

National Semiconductor Acquires Act Solar

National Semiconductor has acquired Act Solar, Inc. a privately held solar energy company that provides power optimization solutions for commercial and utility-scale solar installations.

With the acquisition of Act Solar, National expands its portfolio of power optimization technologies along with the acquisition of new diagnostics and panel monitoring capabilities for solar arrays.

"National Semiconductor is applying its 'PowerWise' capabilities to drive new energy generation and efficiency initiatives in the solar panel marketplace," said Mike Polacek, senior vice president of National's Key Market Segments. "Now with Act Solar we can further improve the performance and efficiency of solar systems, at the same time providing monitoring capabilities not available before. This will make solar installations more efficient and ultimately reduces the cost of solar energy for everyone."

National's SolarMagic™ technology enhances the efficiency and output of solar arrays when the panels are affected by

mismatch issues including shade, debris, different panel types, and panel aging. Recent internal testing showed that National's SolarMagic power optimizers recovered 57% of power lost due to shade, thereby enhancing the solar installation's output and efficiency. SolarMagic power optimizers begin shipping this spring.

Act Solar now becomes part of the SolarMagic family. Its products improve array performance by 6 to 11% using patent-pending technology, complementing central inverters by dynamically re-circulating small amounts of energy as needed. The balance of the array is maintained, assuring maximum power output. The technology utilizes a revolutionary technique for power tracking, which works by injecting energy into the string as opposed to traditional DC-DC voltage converting approaches. Early field tests and historical modeling have shown that this solution can cumulatively deliver 40 to 80% more power over the operating life of a solar panel installation.

www.national.com

www.actsolar.com

Infineon's Comprehensive Low Cost LED Driver Solution

LED's are revolutionizing the illumination market by offering high energy efficiency and very long operating life. Infineon Technologies contributes to faster adoption of this new technology by introducing the low cost LED driver IC BCR 450.

Specifically designed for driving high power LEDs, the BCR 450 in combination with an external transistor features highly precise current control, thermal protection as well as over-voltage and over-current protection functions. As BCR 450 produces no electromagnetic radiation, it is well-suited for applications sensitive against electromagnetic interference (EMI), such as lighting in transportation vehicles including buses, ships, trains and aircrafts, as well as medical applications with communication bus systems. In addition to general lighting systems, BCR 450 also is ideal for applications in architectural and accent lighting, advertising, strobe lights for emergency vehicles, hazard lights and road safety lights.

The BCR 450 was specifically designed for use with high-wattage LED's (for example in the 0.5W, 1W or 3W range) in combination with an external transistor. By simply changing the external transistor, manufacturers of LED lighting have the flexibility to adapt output currents from 100mA to above 1A.

The application circuit with BCR 450 has low component count and is free of inductors, capacitors and free-wheeling diode resulting in a very small PCB space requirement. This includes the elimination of electrolytic capacitors which limit the lifetime of switch-mode driver solutions. Since there is no need for capacitors with BCR 450, the lifetime of the LED system can be extended.

Regarding long life operation of LED lighting sources, Infineon recognized the strong demands for thermal management and implemented an effective thermal shut down feature and over-voltage as well as over-current protection into the device.

In large parts of the illumination market and especially in architectural lighting a homogenous light output in the whole LED chain of light sources is crucial. The human eye is very sensitive towards shifts in light color. The BCR 450 with its output current precision varying only +/-10 percent over the entire operating temperature range strongly supports the homogenous light output requirement for LED lighting fixtures.

"Currently the biggest obstacle for penetration of LED's in the lighting market is the high system price. As Infineon separated the power stage from the intelligent IC, the cost of the BCR 450 LED driver could be optimized. The BCR 450 clearly out-performs current LED driver solutions in terms of price-performance ratio," said Michael Mauer, Senior Director, Discrete Semiconductors at Infineon Technologies. "With our commitment to energy efficiency, we have developed an innovative product that maximizes performance and lifetime of LED lighting systems while reducing board space, design complexity and system costs."

Volume production of the new BCR 450 LED driver IC has already started. It is available in a small 6-pin SC74 package. Infineon offers a comprehensive range of LED driver solutions characterized by robustness and cost-effectiveness, meeting the evolving and expanding requirements of lighting applications.

Further information on Infineon's LED Driver ICs is available at

www.infineon.com/leddriver

Challenging Times for Power Design

By Hans Dieter Huber, VP Industry of Transducer Manufacturer, LEM

Engineers that design power systems are facing greater pressure than ever. Decreasing sales and cost saving programs leads to lower R&D budgets and therefore to less resources.

New products are requested in shorter and more challenging times for a better market position and to improve market share. On the other side, new increasingly complex designs mean that power designers need a wider skill-set than ever before if they are to compete in the power marketplace. Engineers must develop a broad range of knowledge and skills if they are to meet these challenges.

Some of these challenges are driven by available technology: as components become more complex, engineers need greater expertise to use them optimally together to achieve the lowest cost, the best efficiency and quality. Others are coming from the application demand and to transform this into possible technical solutions. A typical example is that of domestic appliances such as washing machines, where the requirement for efficiency and quiet operation has driven the adoption of new motor control techniques, which in turn has created demand for new components to be developed. This dramatic change means power engineers must continually upgrade their expertise.

Take transducers for example. A prerequisite to developing new devices consists of deep understanding of magnetics including simulation tools and sophisticated knowledge of possible and effective design shapes to work well under all the different applications and conditions. In depth knowledge of integrated electronics in specific Asics working properly under harsh environ-

mental conditions is required and even digital skills and a deep understanding of the final application. On the user side, selecting the right current measurement device means choosing between a simple sensor or one with on-board signal processing and a suitable control-loop algorithm. The need to develop expertise in smart motor controls, and to keep up-to-date with the latest product developments and topologies, means that power designers need to broaden their skill-set by adding digital design and software skills to their expertise in motor control and power.

Engineers working on new components have to work closely with customers to deliver enhancements that will provide major breakthroughs in the existing performance parameters for current and voltage sensing in power applications. These breakthroughs will form the foundations on which designers can achieve higher levels of efficiency and functionality in their products.

The other main challenge all designers are facing is the rough current economic climate. This has to lead to adaptation of resources and to redirection of projects towards markets with growth potential in the near term future. The megatrends in the industry for energy savings and for renewables will continue. Whilst the overall market could potentially take a number of years to make a full recovery, renewable energy is likely to bounce back faster than other sectors. This will be fuelled by major investments from various governments and provide a positive outlook for power design. “Green” products are likely to be the main beneficiaries of government support, with technologies that use cutting-edge power design to either reduce energy consumption or enable generation of power from renewable sources receiving state funding in many countries. The bigger investments in energy savings are highly linked to energy prices and will depend a lot on the future outlook of the oil price. Opportunities will be there and will create a new boost of growth for power electronics. To be ready and prepared for the return of the economy with new innovative products will make the difference in the marketplace.

The time to market and the readiness will be the challenge for designers in a more difficult environment and with extended skills. At the same time it gives a lot of opportunities to score.

A more difficult but interesting future will bring new and innovative products developed in close collaboration between suppliers and customers for the benefit of climate and pollution.

www.lem.com

From CFLs to Liquid LEDs

Reported by Shane Walker, Research Analyst, Consumer Electronics Group, IMS Research

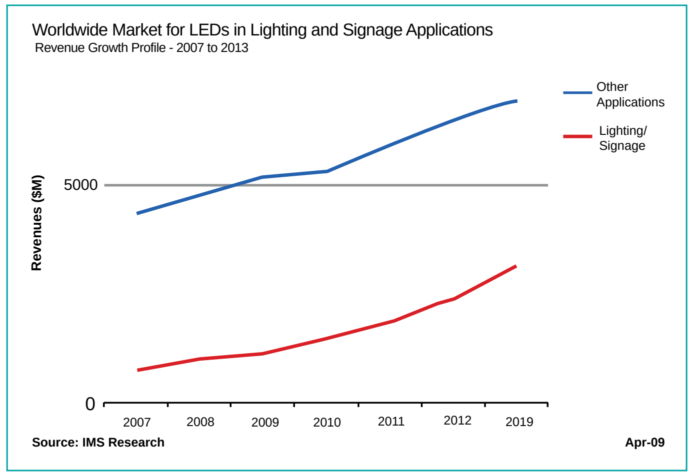
With an 11% market contraction forecast in 2009, it appears that the lighting industry is not immune to the global economic downturn. However, there is a bright spot within the forecast for companies delivering LEDs. While LED lighting is a small part of the overall lighting industry at present, the growth potential is enormous.

Major LED suppliers such as Nichia, Osram, Lumileds and Cree are all well aware that, while LEDs in backlighting applications are worth more dollars at present, indoor and outdoor illumination applications will represent the largest market in a few years as LEDs become brighter and more efficient. Many of these LED applications will also require or benefit from dedicated LED driver ICs. However many LED driver IC manufacturers remain focused on mobile handset and other consumer applications, where the revenue is currently much larger.

In the near term, we expect to see heightened awareness of a new non-IC LED known as a liquid LED. These bulbs are poised as a possible replacement for interior lighting — a market that has not traditionally been seen as viable by LED manufacturers due to cost and overall lighting quality as compared to incandescent and fluorescent bulbs.

Liquid LEDs address the key challenges of high power LED lighting including heat dissipation and light decay, extensive beam angle and high luminance, security and certification, and compatibility with existing standard light fixtures.

The Liquid Immersed Thermal Management Solution (LITMS) from Liquidleds of Taiwan is designed to replace higher wattage incandescent lamps and lower wattage CFLs for residential applications. What is interesting about the technology is that heat is dissipated at the junction by filling an AC LED bulb with liquid, extending lamp life to approximately 35,000 hours. A thermal conductor in the liquid transfers heat from the LED module through the liquid and to the light cover. The LED light penetrates through the liquid creating wide angle uniform illumination. We tested the bulb in an interior setting and found that a 4W bulb doesn't quite supplant a general service "A" bulb or a CFL, but that a 10W bulb most likely would do the job. In addition, these bulbs do not require a driver as do typical DC LEDs and are therefore dimmable. Currently, the 2W, 4W and 5W bulbs have sold primarily into the Western European markets of Germany, Poland, and France and a 10W bulb is on the way. Distributor costs have yet to be fully disclosed; however, based on information that we have received, price estimates for these bulbs fall between US$10 to US$20 each. This would bring estimated consumer costs back to a reasonable (or semi-reasonable) level, as compared to other LEDs which are still US$95 at retail.



Why would anyone be interested in switching? Let's remember that incandescent lighting converts heat to light at approximately 5% efficiency with an average lamp lifetime of 2,000 hours. While there have been some advances in the technology, such as double filament bulbs, little has been accomplished in terms of overall energy efficiency. Then there are fluorescent or compact fluorescent lamps, which operate at approximately 25% efficiency with an average lamp life of 6,000 to 10,000 hours. Self-contained electronic ballasts with dimming control ICs are allowing fluorescents to compete with incandescent lamps as they will operate similarly in 3-way lamp sockets. However, a principle drawback to fluorescent lighting continues to be the mercury used to create the UV light. Other than dimming capability, recent advances in CFLs include removable ballasts which allow for the separation of the expensive ballast portion of the lamp for reuse.

While it is unlikely that there will be a fundamental shift to LED or Liquidled lighting for residential applications in the near future, it is clear that the energy savings to be had from their use will increasingly improve their standing.

www.imsresearch.com

Frequency Response of Switching Power Supplies – Part 4

Loop gain measurement injection technique

In this article, Dr. Ridley continues the topic of frequency response of switching power supplies. This fourth article shows in detail how an analyzer is connected to measure the open loop gain of a power supply or any other feedback system, while keeping the loop closed and regulated.

By Dr. Ray Ridley, Ridley Engineering

Power Supply Loop Gain

The loop measurement of a power supply is something that should always be made. As pointed out in previous articles, specialized equipment is needed to isolate injected frequencies and measure them one at a time in the presence of large amounts of noise. Loop measurement requires some skill to implement but it provides powerful design guidance during the development phase of a power supply, and a very sensitive measure of a final production assembly.

Fig. 2 shows a switching power supply with feedback loop. The output voltage is compared to a reference, and the difference is amplified through the feedback error amplifier. The output signal of the error amplifier is used by the PWM

modulator to set the duty cycle of the power switch. The loop gain measurement consists of the gain (in dB) of the power stage, plus the gain (in dB) of the feedback compensator.

Fig. 2 shows how this could conceptually be measured with the loop physically opened and a signal with dc offset injected into the compensator.

There are two problems with trying to measure the loop gain in this way. First, with a high gain feedback amplifier, it is impossible systems to apply exactly the right dc offset to the injected signal

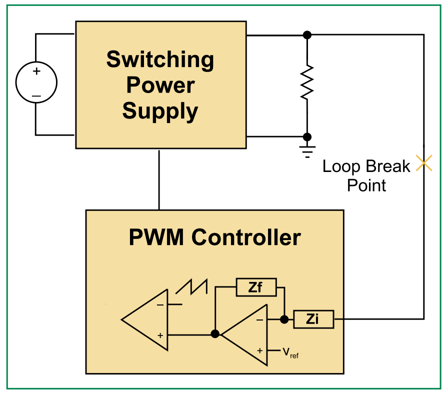


Figure 1: Power Supply with Feedback Loop.

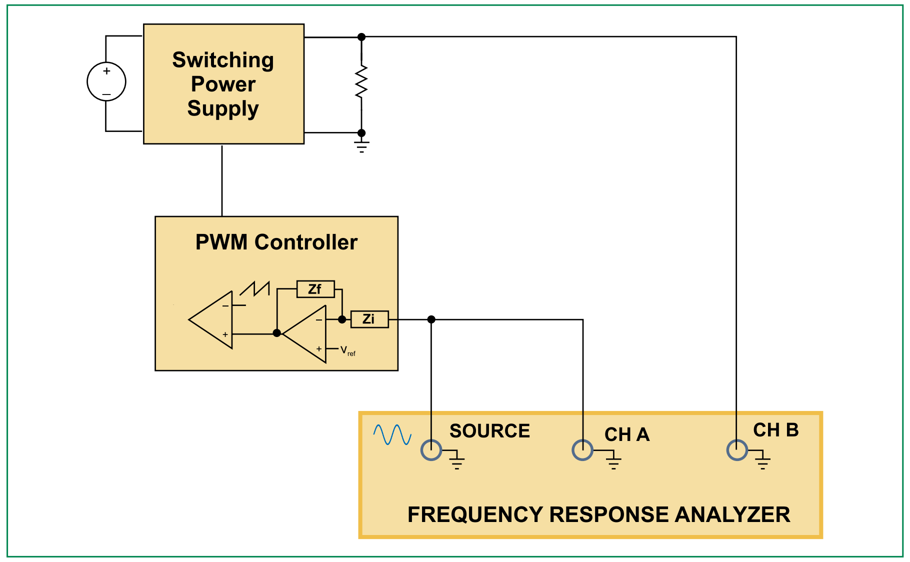


Figure 2: Open Loop Gain Measurement with the Loop Physically Broken.

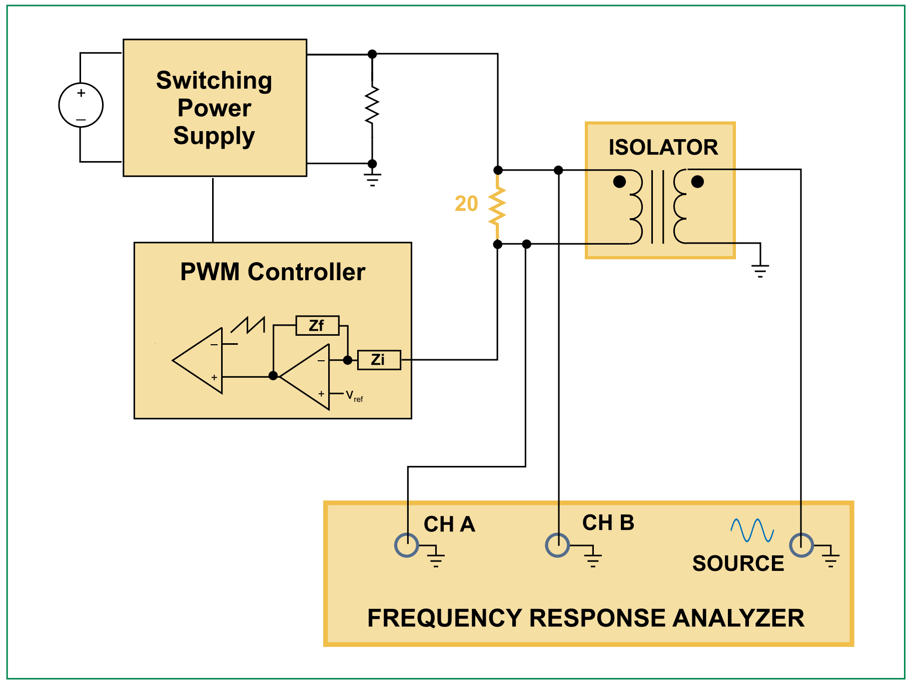


Figure 3: Open Loop Gain Measurement with the Loop Electronically Broken.

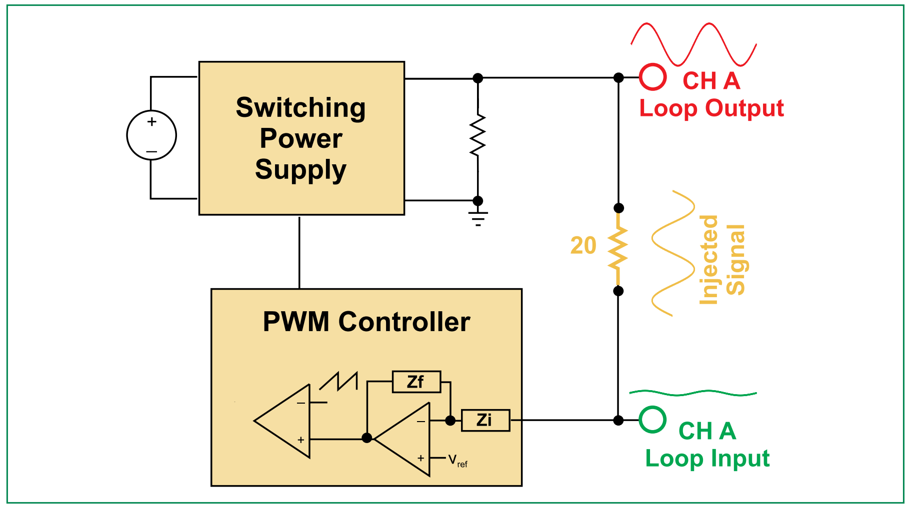


Figure 4: Loop Injection at Low Frequency, Gain Greater than 0 dB.

to prevent the error amplifier from saturating.

Second, the gain of the loop changes by many orders of magnitude over the full frequency range, and the size of the injected signal with this measurement technique would also need to change by the same amount to keep perturbation signals relatively constant.

Breaking the Loop with the Injection Signal

Fig. 3 shows how we overcome the measurement problems for a high loop gain. In this circuit, a 20 ohm resistor is inserted into the feedback loop from the output of the power supply into the error amplifier. The value of this resistor is not critical, but it should be low compared to the feedback resistors of the compensation network.

The test voltage is injected differentially across the resistor via a transformer isolator as shown. The transformer should have a reasonably flat response over the range that the loop will be measured. This is typically from 10Hz up to beyond the switching frequency. For power factor correction circuits, it may be necessary to go as low as 0.1Hz. An upper band of 10MHz may be needed for high-frequency converters.

With this technique, the loop is kept closed in order to regulate the output voltage, but the voltage impressed

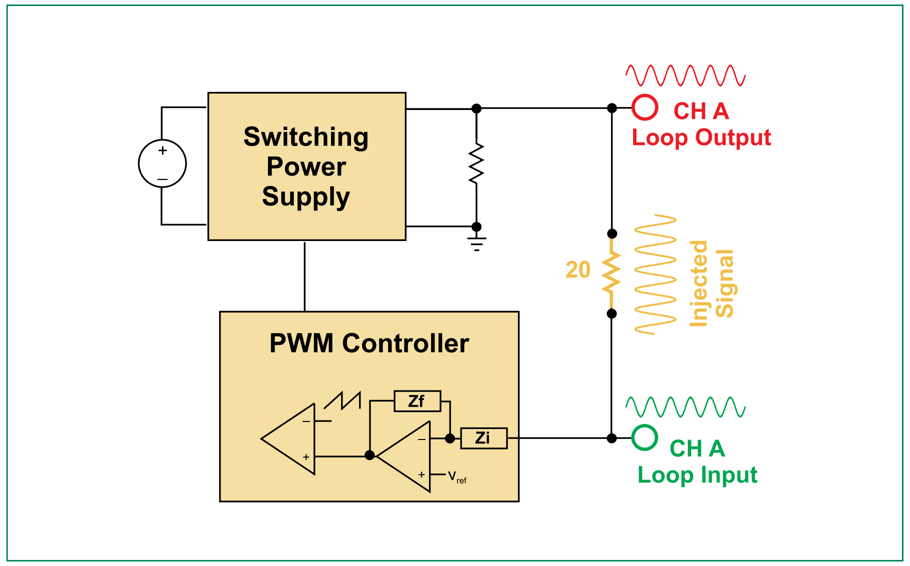


Figure 5: Loop Injection at Medium Frequency with Gain about 0 dB.

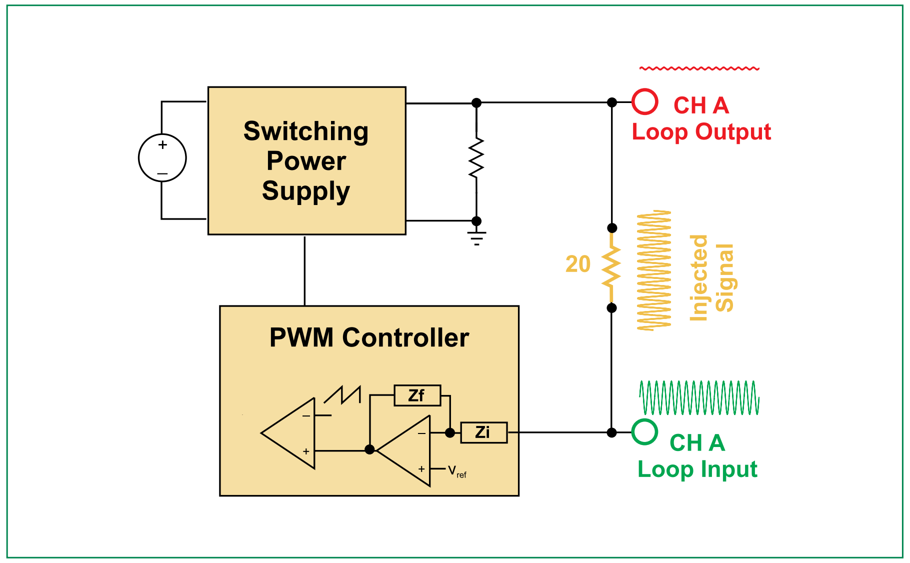


Figure 6: Loop Injection at High Frequency with Gain Less than 0 dB.

across the resistor allows the measurement of the open loop gain. In effect, we are electronically breaking the loop, forcing a difference between the loop input and output signals on either side of the resistor. The loop is only electronically opened at the injection frequency, and kept closed and in regulation at all other frequencies.

The injected signal is set by the frequency response analyzer. However, it is the power supply loop gain that determines the size of the input and output signals. At all times, the injected signal will be the difference between the input and output signals. The signal will be distributed on either side of the injection resistor relative to ground depending on the loop gain of the power supply. This is illustrated below.

Loop Injection at Different Frequencies.

Fig. 4 shows a signal (gold) injected across the 20 ohm resistor. Since the loop gain is high at this injection frequency, most of the injected signal appears at the output of the power supply loop, as shown by the red waveform. The input of the loop, shown in green, is attenuated by the value of the loop at that frequency, and very little of the injected signal is seen here. At all times, the vector sum of the input and output signal will equal the injected signal. The relative phase of the two signals is given by the phase of the loop gain at that frequency.

Note that all of the signals in Figs. 4-6 are shown to be free of noise in order to illustrate the concept of loop injection better. In reality, all of these signals would be immersed in noise as discussed in [1].

Fig. 5 shows the signals at a frequency near the crossover frequency of the loop gain. The input and output signals on either side of the injection resistor are now approximately equal, and the phase shift between them gives the phase of the loop gain at crossover.

Fig. 6 shows the signals at high frequencies beyond the crossover frequency of the loop gain. At this frequency, the input signal is large, and the output signal is small, but the vector sum is still equal to the injected frequency.

Throughout the frequency range of injection, the output signal can never be bigger than the injected signal. This solves the second problem encountered when trying to inject into the open loop system of Fig. 2: the injected signal does not need to be changed over many orders of magnitude to keep the perturbation signal sizes constant. It still requires adjustment with frequency in most cases for optimal measurements. In the next article of this series, the size of the injected signal and its effect on loop measurement will be considered.

Summary

Loop gain is an essential measurement on all switching power supplies since it will provide information of stability, closed-loop performance, long-term ruggedness of the control, and a sensitive measure of many parts involved in the power supply construction. This article describes the industry-standard technique for injecting into a power supply loop for proper measurements.

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www.ridleyengineering.com

Eltek Valere Micropack Powers Next Generation Edge Broadband Networks

I interviewed Morten Schoyen, Chief Marketing Officer, Eltek Valere, who presented the company's new Micropack, a DC power system designed for use with smaller loads such as service provider demarcation equipment. This new DC power system is designed to extend high speed telecommunications networks.

Reported by Cliff Keys, Editor-in-Chief, PSDE

Eltek Valere, headquartered in Richardson, Texas, US, was formed from the June 2007 merger of Eltek Energy and Valere Power. It is a $600 million provider of DC power systems to telecommunications and industrial markets worldwide. The company has more than 2,000 employees worldwide with offices in 25 countries and sales to more than 100 countries.

Telecommunication providers are increasingly implementing new broadband and entertainment solutions into the homes and businesses of customers. These capabilities require power solutions that are suitable for smaller environments, but are still manageable and work with battery back up.

The small form factor of Eltek's system has proven to be a great success factor. Smaller, more cost effective sites require specialized equipment and expertise. This new system is not only physically small, it is also convection cooled, requiring no fans or forced air cooling. Another great feature is that set up and configuration is done on site. The installation and commissioning process is very straightforward and simple and has proven to be a major success factor with customers.

The new Micropack system supports load ranges between 250W and 1000W, making it an ideal solution for broadband extension and other high-speed data and telecom applications.

Morten told me, "With the rollout of content based services and high-speed business networks, today's telecom market demands smaller power supplies in bigger numbers, the Micropack enables carriers to bring power to the customer premises through a flexible and cost effective solution."

The Micropack power system consists of the Micropack 250W rectifier, the Compack controller and distribution, that all mount on a DIN rail and is fully on-site configurable. The system includes two or four plug-in positions for the rectifier, which has a wide input operating and temperature range and is convection cooled for reliability and for harsh environments.

The system also includes one position for the controller, which is an Ethernet based, "all-in-one" plug-in monitoring and control unit.

A big hit already with customers, this new system has generated much interest and enthusiasm with broadband providers and the company expects great success in high volume projects to be forthcoming.

The complete Micropack power system is available immediately from Eltek Valere and its resellers worldwide.

www.eltekvalere.com

New Eltek Valere Micropack System.

Lighting up Future Designs

I talked with Jay Lee, Director of the Lighting Segment for Fairchild Semiconductor. With over 20 years in the semiconductor industry, Jay gave me his insight into the fast developing lighting industry and told me what Fairchild has in store for designers in this exciting segment.

Reported by Cliff Keys, Editor-in-Chief, PSDE

Jay set the scene by telling me that the lighting market continues to experience a shift from incandescent lighting, which operates at only ten percent efficiency to other forms of lighting, which offer ever increasing gains in efficiency. There is indeed speculation that incandescent lamps will completely be phased out by 2010. Alternative forms of lighting offer higher levels of efficiency and longer lifetimes. High brightness (HB) LEDs offer significantly higher efficiency and promise consumers as much as 50,000 hours of use, compared to incandescent lamps that offer only 1000 hours. To guarantee high efficiency, the power supply for these devices also needs to deliver high efficiency - and to conserve space, the power supply needs to be in a small form factor. Semiconductor solutions play a vital role in this area with innovative products that can reduce board space, drive higher levels of efficiency and minimize standby power consumption.

What LED driver products have your company developed for lighting applications?

Fairchild Semiconductor has developed products for several topology solutions such as Primary Side Regulation (PSR), single stage PFC, Quasi-Resonant Converter (QRC) and LLC Half-bridge Resonant converter (LLC), all of which are pursuing high efficiency, simplification and high integration for LED lighting applications. These solutions can provide customer's with easy and precise selection according to their working environments and design concepts.

How have your products influenced the development of LED lighting?

As a global leader delivering energy-efficient power analog and power discrete solutions, we play a key role in increasing the energy efficiency with our technology. We draw on our resources as a power leader driven by consumer and business demand. LED driver products are often derived from our existing power solutions while others are created with LED driver-specified performances and adjusted functions to maximize energy saving and product lifetime.

From Fairchild's perspective, what potential new technologies do you think will drive energy efficiency for LED driver products in the next 2 years?

The most important factor for increasing energy efficiency is in utilizing topologies and optimizing transformer and discrete products. LEDs are utilized for energy saving compared to conventional lighting sources. Currently Fairchild offers its LLC and QRC technology with high integration and simplification (Green FPS™ e-Series™, T-Series, QR FPS and PFC+QR Combo) which are able to support high efficiency well into the future.

Which LED application areas will grow fastest over the next 2 years? What type of strategies will your company adopt to address these application areas? What effect will this have on your investment and R&D strategies for LED drive products?

Indoor and outdoor LED lighting are expected to be areas of incredible change because this field has enormous potential; both in the replacement of conventional fluorescent/ halogen systems as well as the potential phase-out of incandescent lamps.

In addition to high efficiency, our PSR solution covers low power applications with its ease of implementation and the most accurate Constant Current (CC) using Fairchild's built-in proprietary TRUECURRENT™ technology. For dimming systems used for energy saving and mood control, we plan to implement "Phase Modulator" & "Phase Angle Demodulator Systems (PADS)" as full kits and are investing to establish our own IP, circuits and systems.

We have appointed a dedicated team to drive our lighting strategy. This is an important area for us. We have invested and will continue to invest significantly in R&D with company-wide commitment to give designers the best products and topologies to succeed in this promising high growth market.

www.fairchildsemi.com

Right Tools for the Job

I spoke with Larry Vivolo. Larry is Director, Low Power Solutions Marketing at Synopsys. With the recent announcements from the company which are reported below, I wanted to investigate the company's power strategy. He gave me a valuable insight.

Reported by Cliff Keys, Editor-in-Chief, PSDE

With the growing awareness of power at System on a Chip level, what can Synopsys offer to the design community?

The Synopsys Eclypse Low Power Solution provides the industry's most comprehensive set of leading-edge technology, proven methodology, low-power IP, and services, all built on a foundation of recognized industry standards. One unique capability is our Innovator product, which can be used as both a software development and power analysis platform. Innovator provides an environment for engineers to create a virtual prototype, or soft model, of a design. With this model, engineers can compare relative power consumption of multiple variations on a design – enabling them to make architectural trade-off decisions before actual design work has been started. This same solution also enables embedded and system-level software to be developed early in the design cycle. By combining software with power analysis, engineers can develop and optimize power management software as well.

Do you see the current uncertain financial climate slowing progress in the adoption of new design and verification platforms?

The challenging economic climate makes companies more risk-averse, but successful companies know that the answer isn't to stop investing in the future. Instead, a downturn can be an opportunity to focus on important product developments that can deliver greater value today and down the road. More than ever, customers want to get their products out on time, and get it right with high quality.

In verification, both the cost of fixing a missed bug, and the opportunity cost are very high. Verification being a bottleneck to get the product development done on time is a problem that people are willing to invest in. With support for multicore technology in our verification products, Synopsys is enabling its users to get more performance out of their hardware and provide a path of higher return on investment on their machines.

On the design side, energy has become a big focus. The scrutiny goes beyond automobiles and light bulbs. It's about energy consumption at every level, including consumer and industrial electronics. Once the downturn starts to reverse, customer demand is expected to rise again, and the companies best suited to meet that demand are likely to be those that have used the opportunity to optimize their designs for low power. Embracing low power design with a proven end-to-end solution mitigates risk, and may even define the industry leaders.

How does Synopsys contribute to the mass adoption of greener technologies and systems?

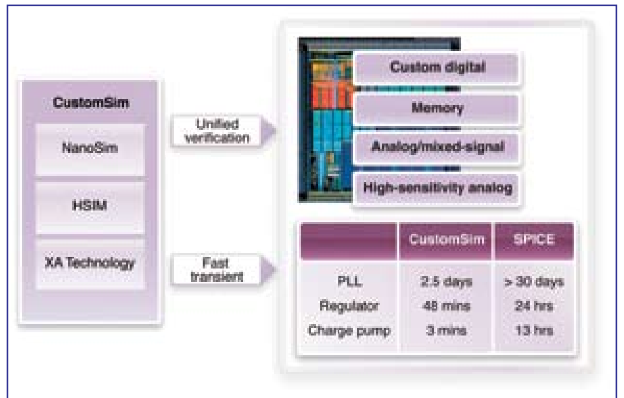
Synopsys has been a leader in low power design for over a decade. Our tools have enabled many generations of computers, networking, entertainment and mobile devices to deliver the maximum functionality and performance with minimum cost in terms of physical design area (dollars) and power (energy). The current emphasis on greener technology aligns with our drive to provide the best possible technology optimized for a particular metric, including power. The recent demand for low power designs has caught some design teams unprepared. With that in mind, our silicon-proven Eclypse Low Power Solution has been optimized to make the most advanced low power techniques available to the masses. The Eclypse solution combines advanced technology, methodology, intellectual property, services and industry standards into a highly automated, comprehensive solution optimized for low power design.

In this highly competitive climate, does it make sense to change to a new (Synopsys) EDA platform? What are the key considerations?

Platform decisions must always be made carefully. With Synopsys' industry-leading solutions, our partners are given the best, most complete set of tools for implementing their critical designs now and into the future. In addition to technology strengths, it's also important to consider factors such as financial stability, customer support, long-term investment in innovation and ability to reduce the total cost of design. Synopsys leads in all these criteria, and our customers know we can be their partner in success today and tomorrow.

How high is power management on your customers' careabouts and how high is it on yours?

Our customers have consistently identified power management issues as their number one priority for several years now. This is not surprising given the increased importance that the market is placing on low power. For many industries, low power design is relatively new, and many design teams have limited experience optimizing designs for low power, particularly using the more advanced low power techniques.



Synopsys has been a leader in low power for over a decade, and we have consistently responded to the needs of our customers by providing advanced low power technology at the right time. The Eclypse Low Power Solution is the industry's most comprehensive low power solution, and low power design and verification continues to be a key focus at Synopsys.

How do you ensure you satisfy or even exceed their expectations?

Synopsys has built our success over the long term by listening to our customers, and providing advanced technology along with a dedicated support organization. Our solutions are silicon proven; we work with key partners, such as ARM, to create methodologies that reduce the cost of design and overall project risk. For low power, we have introduced the Low Power Methodology Manual (LPMM) and recently, the Verification Methodology Manual for Low Power (VMM-LP). It is through this dedication to reducing the complexity and risk of design, combined with our services and expertise, that we are able to deliver the best possible end-user experience.

What are the main key reasons a company will come to you for help?

Synopsys provides silicon-proven solutions that enable our customers to achieve their low power design goals with minimal risk. Whether it's a design engineer who is contemplating power optimization for the first time, or a highly experienced low power engineer who is looking to implement the latest, most advanced low power techniques, the Synopsys Eclypse Low Power Solution provides the right mix of advanced low power technologies and automation needed to create the world's most advanced SoCs. One specific example involves Energy Star compliance. Many of our customers are faced with mounting regulation on power consumption. For example, only one-quarter of available plasma TVs meet the new Energy Star guidelines. When plasma TV manufacturers must redesign their products to conform to these new power budgets, the underlying chips are implemented with solutions like the Eclypse Low Power Solution.

CustomSim Unified Circuit Simulation Solution

Synopsys announced new CustomSim™ circuit simulation solution. The best-in-class simulation technologies of NanoSim®, HSIM® and XA have been unified into a single circuit simulation solution with added multicore capabilities delivering up to 4x performance improvement for large analog and mixed-signal circuits. This comprehensive offering also introduces native circuit checking into the analog/mixed-signal (AMS) domain. The new CustomSim solution forms part of the expanded Discovery™ 2009 Verification Platform.

Shrinking geometries and complex power management techniques have placed a considerable and increasing number of restrictions on the safe operating range of individual transistors and circuits. Designer productivity is negatively impacted by manually having to verify that these electrical rules are not violated. For example, ensuring that individual blocks are not susceptible to leakage power caused by floating gates and DC leakage paths cannot be done by simulation alone. CustomSim provides a comprehensive circuit simulation solution that includes static and dynamic native design checking to rapidly identify electrical rule violations and power management failures, thereby increasing designer productivity and confidence.

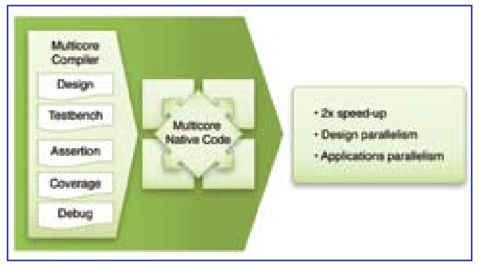
Discovery 2009 - Delivering Faster and Unified Verification Solutions

Synopsys also introduced the latest generation of its Discovery™ Verification Platform, an integrated verification solution for analog/mixed-signal (AMS) and digital designs. Discovery 2009 delivers unprecedented verification productivity with new multicore simulation technologies, native design checks and comprehensive low power verification capabilities throughout the platform. With Discovery 2009, verification engineers are benefiting from significantly higher productivity and faster verification closure for their AMS and digital designs.

Discovery 2009 incorporates comprehensive low-power verification capabilities at multiple levels of abstraction, from RTL to transistor level. VCS with MVSIM delivers true voltage-aware RTL and gate-level simulation, automated assertions, and comprehensive verification coverage, as defined in the new *Verification Methodology Manual for Low Power* (VMM-LP) book. CustomSim accurately verifies complex power management designs at the transistor level by identifying IR drop, electromigration and standby leakage issues that can impact the reliability and performance of integrated circuits.

5x Verification Speed-up with VCS Multicore

Synopsys unveiled new multicore technology within the VCS® functional verification solution, a key component of Synopsys' Discovery™ Verification Platform. VCS multicore technology delivers a 5x improvement in verification performance by harnessing the power of modern multicore CPUs. The new technology removes performance bottlenecks and speeds verification by distributing time-consuming activities across multiple cores.



VCS multicore technology combines the speed-up from parallel computation with the industry-leading Native Testbench (NTB) compiler optimization to meet performance requirement for the verification of large-scale designs. VCS multicore technology helps verification teams address the growing challenges of verifying increasingly complex designs and achieving first-pass silicon success.

www.synopsys.com

Taking a Dim View

Solutions to simplify dimming of fluorescent lamps

There is much in the news these days about LED lighting and the circuits developed to drive then. Fluorescent lamps however, are still widely used and are energy efficient. The drawbacks in the past have been the difficulties associated with adjusting the light output from these lamps. This article looks at the requirements for dimming fluorescent lamps and highlights how a new generation of control ICs can simplify future designs.

By Tom Ribarich, Director of Lighting Design, International Rectifier

Designers employ a variety of techniques to provide users with the ability to dim fluorescent lamps. Common approaches include DALI (digitally addressable lighting interface), triac-based wall dimmers, power line communication, 1VDC-10VDC interfaces and even wireless control. These all, however, require additional wiring at the electronic ballast during installation. Now new IC technologies are set to remove the need for this additional wiring and, therefore, speed, simplify and reduce the cost of dimmable fluorescent designs.

Driving and Dimming Fluorescent Lamps

Fluorescent lamps require a current to preheat the filaments, a high voltage for ignition, and a high-frequency AC current during operation. An electronic ballast circuit must first perform a low-frequency AC-to-DC conversion at the input, followed by a high-frequency DC-to-AC conversion at the output.

Figure 1 shows a block diagram of a ballast for such a lamp, including a dimming circuit that combines a dimming reference signal, a lamp current sensing and feedback signal, and a summing circuit for closed-loop lamp current control.

After passing through an EMI filter to block switching noise, the AC mains voltage is full-wave rectified and then peak-charges a capacitor to produce a smooth DC bus voltage. The DC bus voltage is then converted into a high-frequency, 50% duty-cycle, AC square-wave voltage using a standard half-bridge switching circuit. The high-frequency AC square-wave voltage then drives the resonant tank circuit to produce a filtered sinusoidal current and voltage at the lamp.

During operation the resonant tank, which is a series-LC circuit with a high Q-factor during the pre-ignition phase, becomes a series-L, parallel-RC circuit with a Q-factor somewhere between a high and low value depending on the lamp dimming level. When the CFL is first turned on, the control IC sweeps the half-bridge frequency from the maximum frequency towards the resonance frequency of the high-Q ballast output stage. The lamp filaments are preheated as the frequency decreases and the lamp voltage and load current increase. As the frequency decreases the voltage rises and the lamp ignites when lamp ignition voltage threshold is reached. Lamp current is then controlled to maintain the correct power and brightness level.

Increasing the frequency of the half-bridge reduces resonant tank circuit gain, leading to decreased lamp current and, therefore, lamp dimming. The closed-loop feedback circuit measures the lamp current and continuously adjusts the half-bridge frequency to regulate it to the dimming reference level.

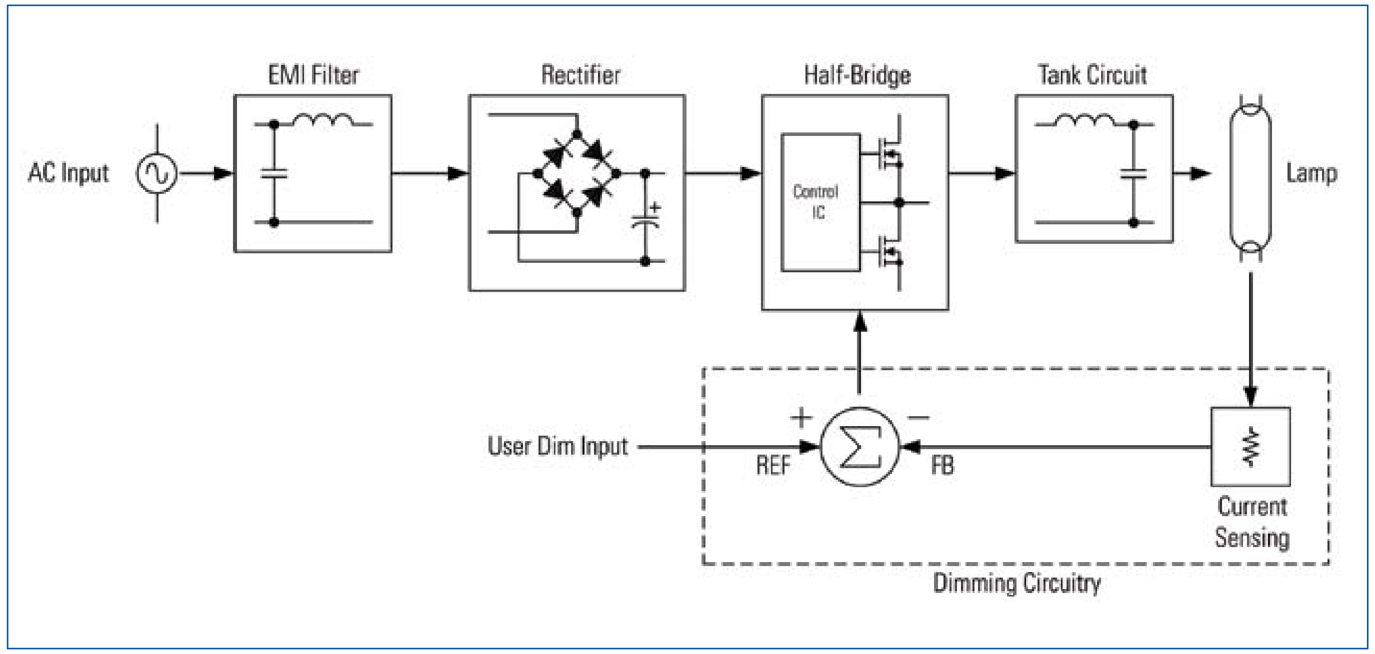


Figure 1: Dimming electronic ballast block diagram.

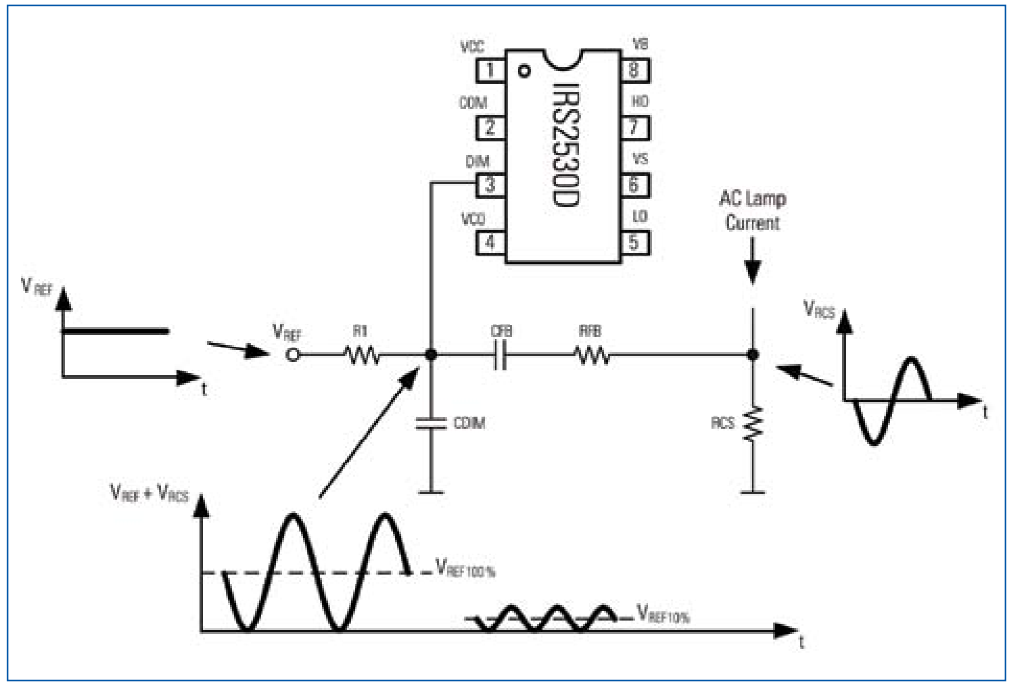


Figure 2: IRS2530D AC+DC dimming control method.

Control IC

Choice of control IC for a dimming application is clearly important and Inter-

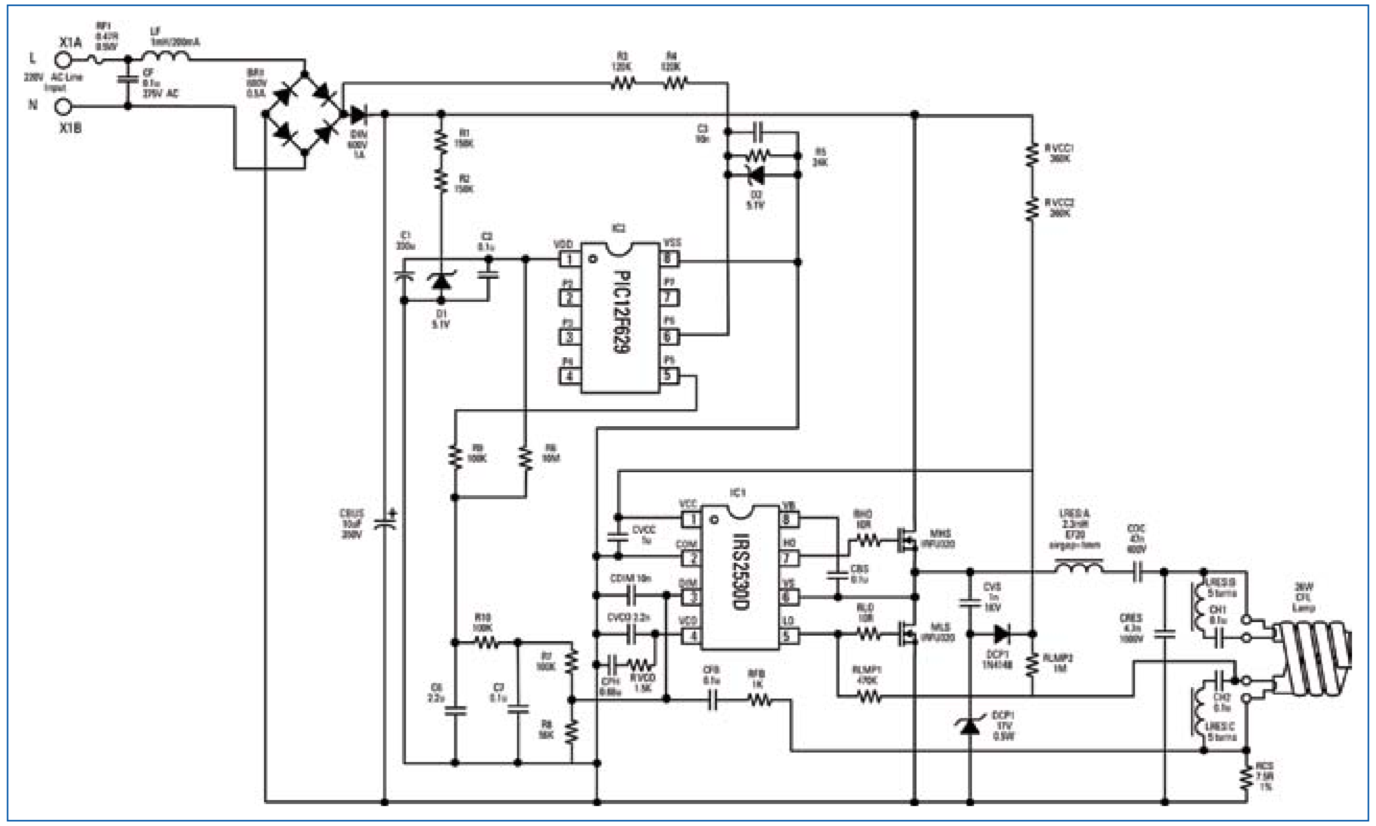


Figure 3: Schematic of quad-level dimming circuit.

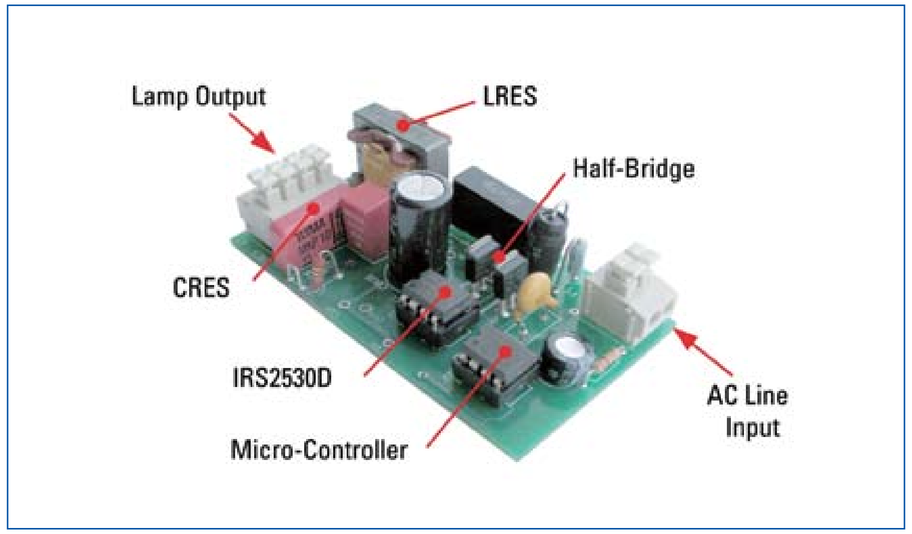


Figure 4: Quad-level fluorescent dimmer reference design.

national Rectifier's IRS2530D provides a good example of the current state of play. This device incorporates all of the functions to preheat and ignite the lamp, and a variety of protection against fault conditions such as open filament failures, lamp non-strike and mains brown-out.

Figure 2 shows how the AC lamp current measurement across the sensing resistor RCS is coupled onto the DC dimming reference through a feedback capacitor CFB and resistor RFB. This allows the dimming function to be realized by combining the AC lamp current measurement with the DC reference voltage at a single node. The IC's feedback circuit continuously adjusts the half-bridge frequency so as to regulate the valley of the AC+DC signal to COM as the DC dimming level is increased or decreased. This causes lamp current to increase or decrease for dimming.

Quad-Level Dimming

Now let's consider how a device such as the IRS2530D can be used to implement a four-level dimming design that will help to reduce the problem of additional ballast wiring mentioned earlier.

Figure 3 shows a schematic of the quad-level switch dim ballast design that combines an EMI filter, a full-bridge rectifier and smoothing DC bus capacitor, the IRS2530D "*DIM8*™" dimming control IC, a switching half-bridge and resonant tank circuit to preheat, ignite and run the lamp. In this design a microcontroller is used to set and store the dimming level, and a pulse detection circuit to detect when the AC input voltage turns on and off.

The lamp arc current is detected through RCS after ignition and coupled onto a DC reference voltage to provide an AC signal with a DC offset at the DIM pin of the IRS2530D. During DIM mode, the IRS2530D adjusts the oscillator frequency in order to maintain the amplitude of this feedback signal and control the lamp current for dimming. The frequency of the HO and LO gate driver outputs is set by the voltage at the VCO pin of the IRS2530D and the Capacitor CPH is used to program the frequency sweep time for preheat and ignition of the lamp.

At turn-on, the voltage at the VCO pin will ramp up from 0V causing the frequency to decrease from the maximum frequency down to the minimum frequency. As the frequency continues to fall towards the resonance frequency of the tank circuit, the lamp voltage increases until the lamp ignites. The lamp arc current begins to flow and a feedback signal is produced at the current sense resistor RCS. If ignition fails then the IRS2530D will shut down, going into a low VCC current fault mode.

The DC dimming reference at the DIM pin is derived from an RC-filtered square wave voltage generated by the microcontroller. This microcontroller controls the four dim levels by using a fixed frequency signal at four separate duty-cycle modes of 100%, 66%, 33% and 10%. Highest brightness level is achieved with the highest duty cycle.

Pin 6 of the control IC is connected to the AC line input voltage through a fast delay circuit, which is used to detect fast on/off cycles of the AC line input. When the AC line is switched off the IC - which can continue to run for more than one second after removal of the AC line thanks to the VDD supply capacitor - detects this and starts a timer. Restoring power within one second reduces the output square-wave duty-cycle and, therefore, the dimming by one step (unless the dimming level is already at minimum then it cycles back to maximum). If the AC line is removed for more than one second, the dimming level will not change. After the supply capacitor has discharged below the minimum operating voltage of the control IC the microcontroller will shut off.

Summary

Implementing a ballast circuit based on the IRS2530D dimming control IC, a microcontroller and a pulse detection circuit as described above provides an elegant solution for delivering four different levels of brightness by sensing the on/off switching of the AC mains voltage. The IC itself incorporates complete ballast control, dimming feedback loop and fault protection, simplifying overall design and leaving the engineer free to concentrate on other aspects of the design.

To help designers evaluate and implement quad-level dimming solutions as described here, International rectifier is offering a complete reference design (Figure 4) based on a two-layer PCB with small form factor that is suitable for driving a 26W fluorescent lamp.

www.irf.com

IR Thermography

A useful 'extra eye' into the thermal performance of a design

The design of reliable power electronic converter systems depends partly on an accurate knowledge of the power stage component operating temperatures under extremes of load and input voltage. This article demonstrates how the use of modern infra-red (IR) imaging techniques can significantly enhance the design qualification process and show up potential problems at a very early stage in the product development cycle. The techniques highlighted are applicable to any power converter system or electronic product where knowledge of component operating temperatures is important for reliability modelling and lifetime prediction.

By Dr. Iain Mosely, Technical Director, Converter Technology Ltd.

One of the main limiting factors affecting the power capability and reliability of any electronic power converter system is the operating temperature of key power stage components. Excessive component temperature will reduce product operating lifetimes and could result in early field returns.

Traditionally, thermocouples are used to measure the operating temperature of components. Whilst thermocouples can give very accurate temperature measurements, they do have a few potential drawbacks:

• Thermocouples can pick up noise if they are placed near to power components with high dv/dt switching waveforms present and this can give misleading measurement results.

• Thermocouples will sink a small amount of heat away from the device they are attached to. For physically small components, this can lead to measurement inaccuracy.

• Thermocouples are often only placed on components which are expected to show a reasonable temperature rise. Other components may not be monitored at all and this could lead to problems if a design error leads to a high operating temperature on a component which hasn't been monitored.

IR thermography is a non-contact measurement technique which uses a calibrated infrared camera to form a thermal image of the system under test. As the measurement technique is non-contact, the noise susceptibility and heatsinking effects sometimes encountered with thermocouples are no longer an issue. More importantly, an entire PCB can be imaged which immediately shows up any hotspots or problem components that may have otherwise been overlooked.

An example thermographic image of a power converter is shown in Figure 1. The power converter used has an issue with a snubber TVS diode which can be seen to be running at >150°. Using the thermal imaging camera is this example would immediately alert the designer to a potential problem with the PSU before it reaches the pre-production or production stage. The real value of thermography in power electronic design is this ability to rapidly flag potential design issues at a very early stage.

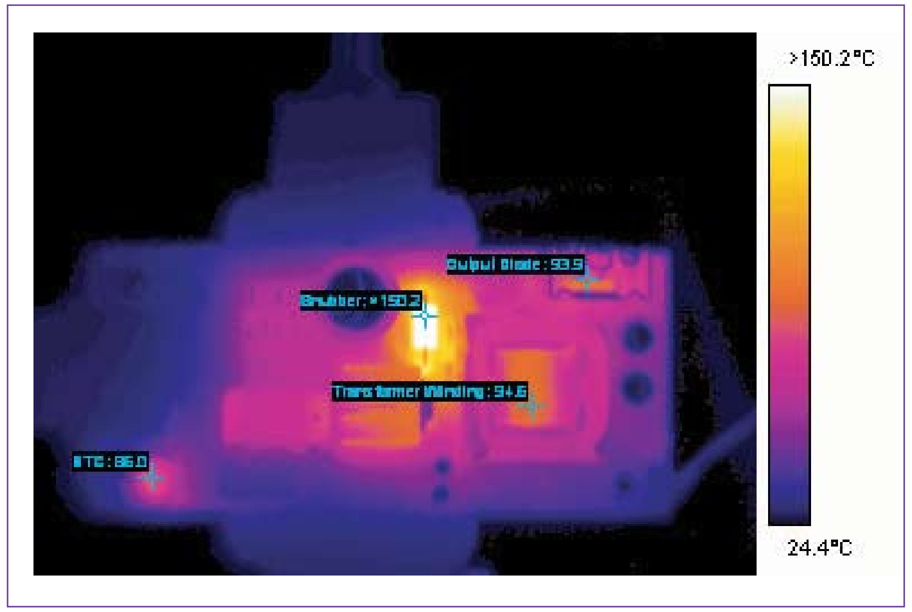


Figure 1: Example Thermographic Image (Note the excessive temperature of the snubber TVS).

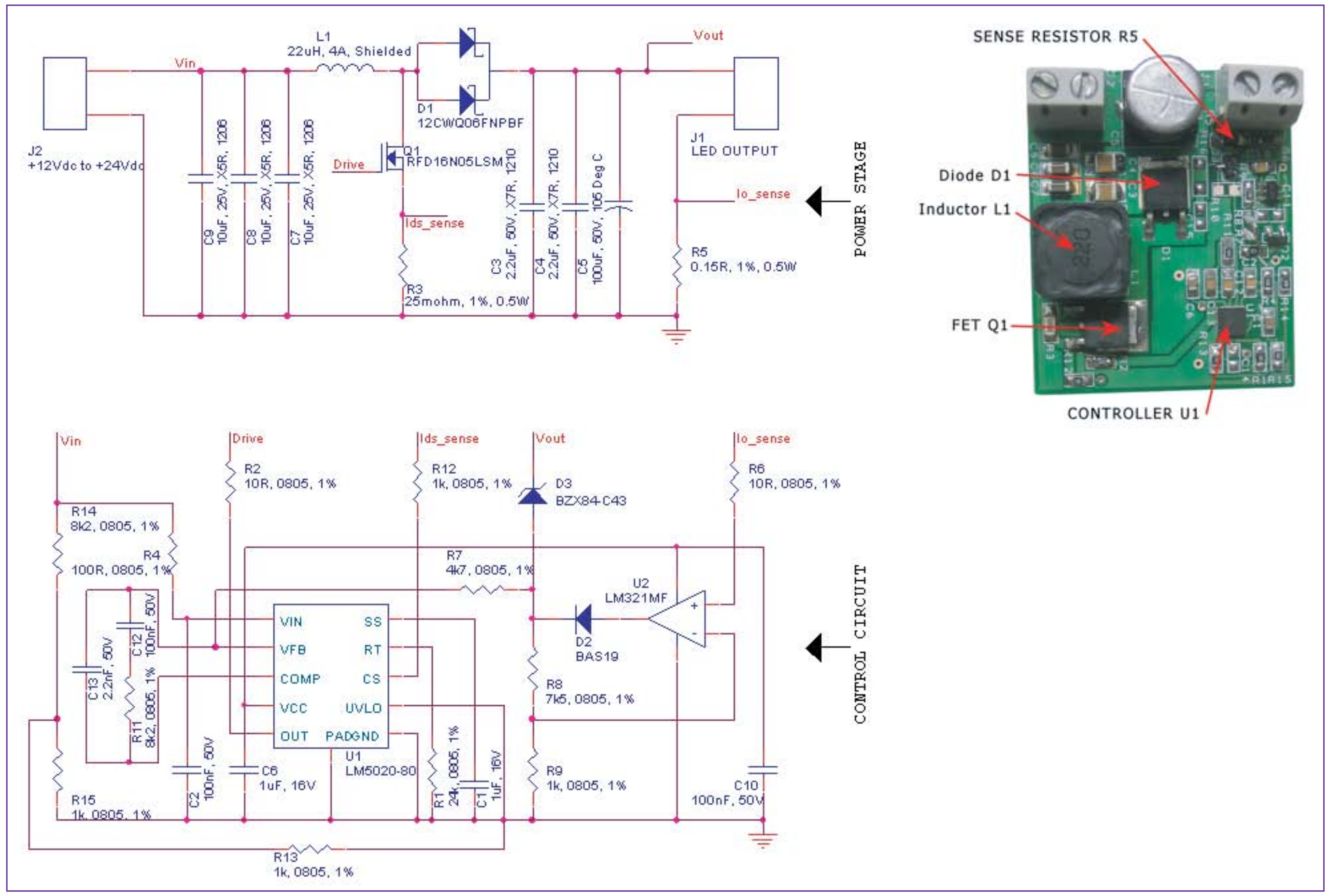


Figure 2: RD009 Schematic and PCB Prototype.

In some situations, it isn't possible the 'see' the component under test and in these cases, thermocouples are still required for temperature measurement. Examples include buried transformer windings or fully assembled products. A good approach to practical thermal analysis of a design would combine the benefits of both approaches and use both IR thermography and thermocouples.

Background on Thermography

IR thermography is a technique which uses a camera designed to detect electromagnetic radiation in the infra-red band. The camera produces a thermal image of the system under test which can be used to quantify device operating temperatures. For the design or test engineer wanting to use thermographic techniques, it is important to remember a few key points when taking measurements:

• If the component being thermally imaged behaves as an 'ideal black body radiator' then it does not reflect or transmit electromagnetic energy. In this case, the measured electromagnetic energy in the infra-red band is that due to the temperature of the component alone and it is said to have an emissivity of unity. In practice all electronic components will have an emissivity less than unity and this should be taken into account when using the camera to take accurate thermal measurements. The thermal camera controller software should allow the user to set the emissivity of a given surface and most power semiconductors will have an emissivity of between 0.9 and 1.

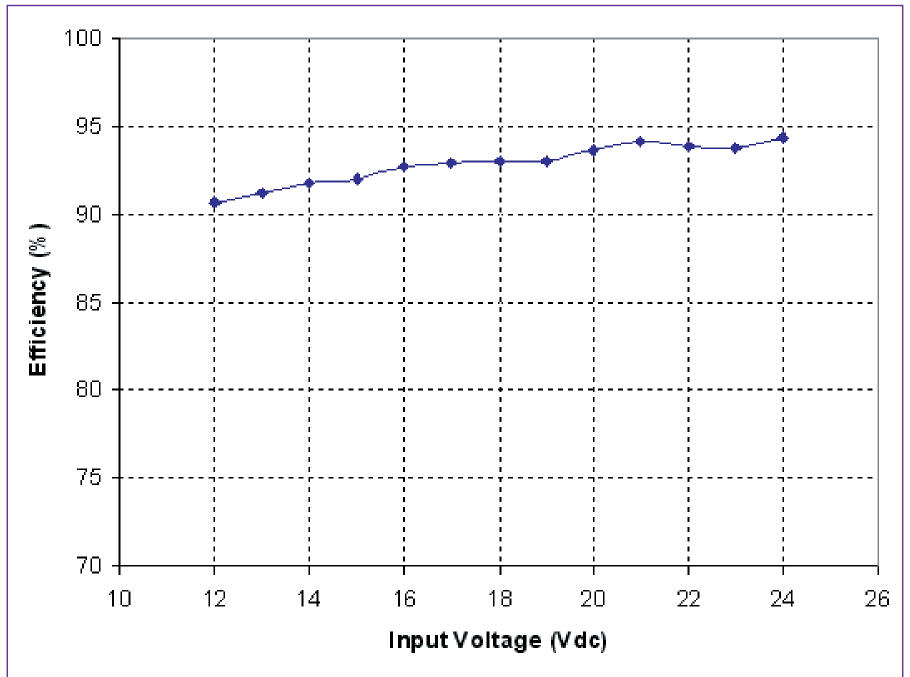


Figure 3: RD009 Full Power Efficiency Profile.

Input Voltage	+12Vdc	+24Vdc
	Operating Temperature (Deg C)	
Inductor L1	73	49
MOSFET Q1	77	53
Resistor R5	88	83
Diode D1	63	51
IC U1	58	60

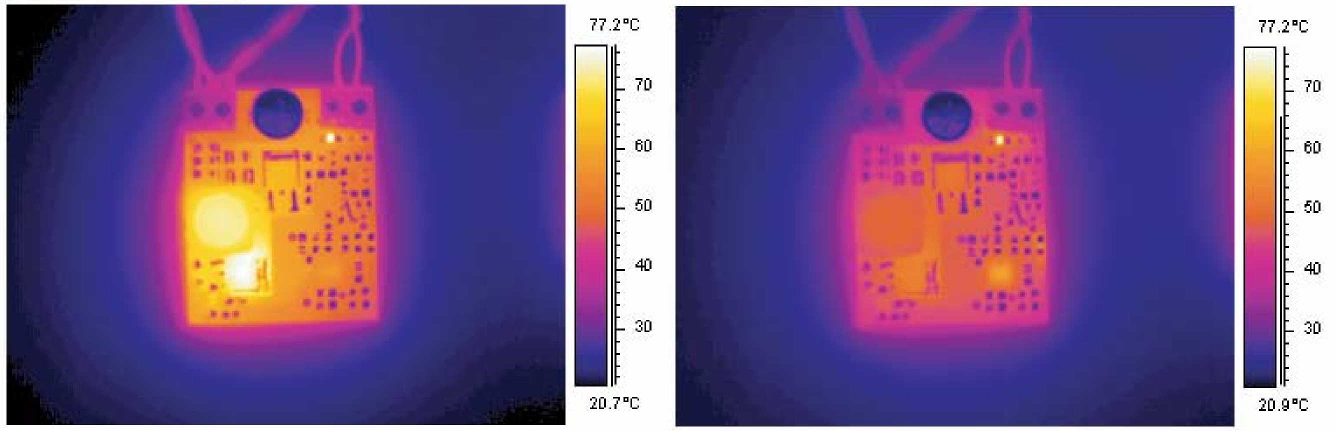


Figure 4: RD009 at full power with 12Vdc input (left) and 24Vdc input (right).

• Shiny surfaces such as the tops of electrolytic capacitor cans or solder will have an emissivity much lower than unity.

• The more dull and black a surface is, the closer its emissivity will be to unity.

The accuracy of this technique does depend on a number of different parameters and a good background on the science of thermography can be found at FLIR systems[1].

Case Study

A 35W LED ballast reference design, RD009[2], was used for a case study to demonstrate the useful insight which thermography can bring to power electronics design. The camera used is an FLIR A320G which gives good resolution and accuracy. RD009 is a high efficiency, constant current boost converter which runs from an input voltage of 12Vdc to 24Vdc. The output provides a 1A constant current into a series LED string with combined forward voltage of up to about 35V. Figure 2 shows the RD009 schematics and PCB prototype board which uses an all SMD construction with components mounted only on the top side of the board.

The conversion efficiency of RD009 is high at >90% but does vary with input voltage as shown in Figure 3. The distribution of loss over the power converter circuitry depends on the input voltage. With low input voltages, MOSFET Q1 will be running with a high duty cycle and therefore will be supporting a higher RMS current than it would do with a higher input voltage. In addition, inductor L1 would be supporting a higher RMS current with lower input voltage and will run warmer than at high input voltage.

These effects can clearly be seen in the thermal image of Figure 4 where, with 12Vdc input, the MOSFET and inductor run warmer than with 24Vdc input. Although the loss in D1 and R5 is likely to remain fairly constant with input voltage, their proximity to L1/Q1 does result in them being heated by the loss in L1/Q1. The effect of emissivity can be seen clearly in the image of Figure 4 with the shiny top of capacitor C5 and the soldered ends of the SMD components appearing to be operating at low temperature. In practice, these components will be operating at about the same temperature as the local PCB care should be taken when interpreting the thermal images, especially for components with shiny surfaces.

Conclusions

IR thermography is a powerful tool for PSU component temperature analysis and the speed at which an entire design can now be thermally evaluated helps the design engineer to identify any potential problems at a very early stage in the design process. Whilst thermocouples are still required for some situations, the combination of traditional techniques with modern IR thermography provides the best of both worlds and ensures that designs can be released in the knowledge that components are operating within specified temperature limits.

References

[1] www.flir.com

[2] Converter Technology LTD (2007). Reference design RD009 (35W LED Ballast), www.convertertechnology.co.uk/

www.convertertechnology.co.uk

Benefits of Digital Power Conversion and Management

DSCs: The product lifecycle perspective

This article describes the benefits of using Digital Signal Controllers (DSCs) in digital power conversion and power management, during the design phase of the product lifecycle.

By Magal Srinivasprasad, Sr. Product Marketing Engineer and Mohammad Kamil, Sr. Applications Engineer, High Performance Microcontroller Division, Microchip Technology Inc.

Power supplies have been a vital part of many telecom, consumer and industrial products for many years. The power supplies in these products must work to the peak of their performance, without compromising on extensive reliability to ensure proper end-equipment functionality. Power-supply designs have transitioned from linear to switch-mode, to improve the performance and efficiency, and decrease the cost. In order to keep up with the technological advancements while providing performance and reliability, power supplies need to be digitally intelligent. This has caused a paradigm shift to digital power conversion and power management. Therefore, from the product lifecycle perspective, digital power supplies play a vital role. Research has shown that decisions made during the design phase determine 70% of the product's costs, while decisions made during production only account for 20% of the product's costs.

Figure 1 show the typical product lifecycle. The first phase is a Requirement phase, where customer wish lists are converted to marketing requirements and then to product requirements. The second phase is a Design phase as shown in Figure 2, where circuit design, simulations, board layout, software architecture and coding are done. In the third phase, the product Prototype is built. The fourth phase involves software/hardware integration and testing of the product. In the fifth and sixth phases, the product is produced and commissioned.

Requirements of digital power supplies

Power-supply requirements are becoming more challenging every day, due to various added features, without increasing the cost and size. Energy-efficiency initiatives, in the form of government regulations, demand higher efficiency and noise-free power supplies. This is combined with the end customer's demands for higher reliability and hassle-free operation. Manufacturers want higher yields in production by reducing the variety and number of components with design-to-cost objectives. To achieve better production yield and target costs Design For Manufacturability (DFM), Design For Testability (DFT) and Design For Serviceability (DFS) are also important.

When the above requirements get translated to design requirements, along with input/output specifications, the results include:

- Increasing power density by increasing switching efficiency and reducing component count
- Implementing in-rush current control and Power Factor Correction
- Multiple output voltages and adaptability to load changes
- Output voltage sequencing with power management
- Remote monitoring and control capability
- Paralleling of outputs for N+1 redundancy
- Reduced effect of component tolerance/drifts and End Of Life (EOL) prediction, to achieve higher reliability & performance
- Protected Intellectual property

Design and development of the digital power supply

This phase consists of Hardware and Software design and development.

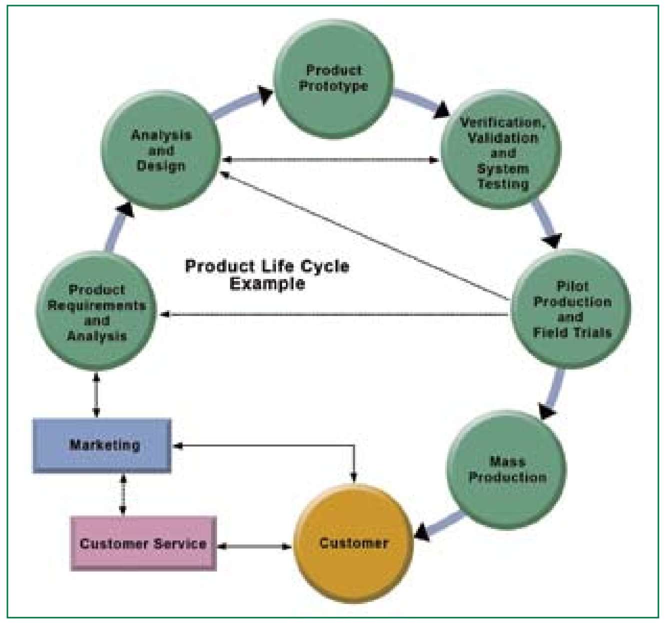


Figure 1: Product lifecycle of a digital power supply.

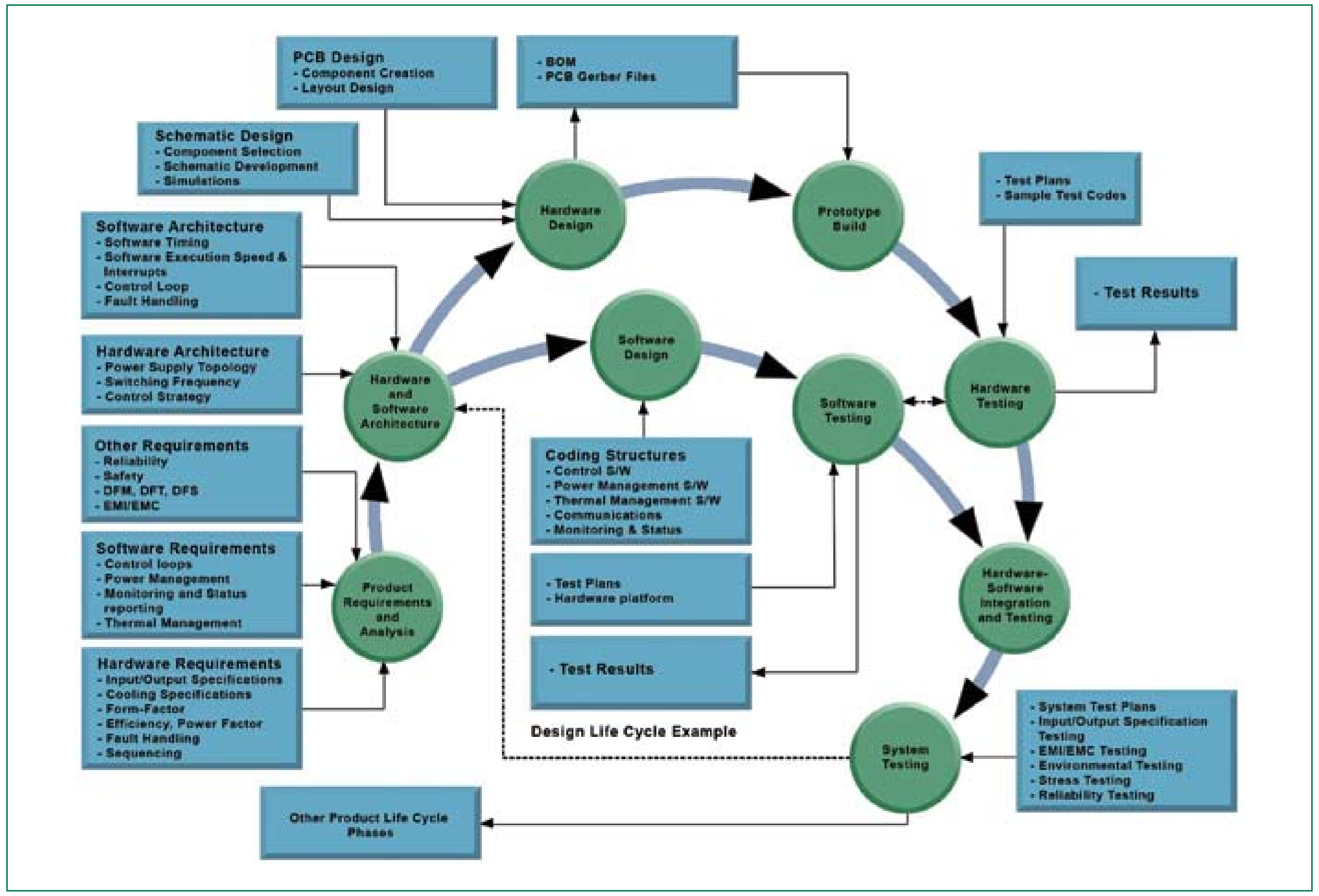


Figure 2: Design lifecycle of a digital power supply.

Hardware design involves selecting the hardware architecture, component selection and developing circuit diagrams. Hardware architecture, for power supplies, means deciding on the power-conversion topology or combination of topologies, such as half-bridge, Full-bridge, Push-Pull, etc. For example, the Phase Shift Full Bridge Zero Voltage Transition (ZVT) conversion topology is best suited to minimize switching losses and improve the efficiency in higher-wattage power supplies. After the control strategy and power architecture are finalized, simulations are carried out for the proof of concept. Results from these simulations act as the basis for selecting critical components. While selecting components, cost, switching frequency and form factor play a major role.

Selecting a digital signal controller (DSC)

A compact power supply with increased power density requires the converter to switch at a higher frequency and achieve higher efficiency. This, in turn, requires innovative topological architectures, such as a variable-frequency resonant converter, to achieve zero voltage and current transitions. Different topologies require different PWM modes to be supported by the DSC. To meet these requirements, the DSC should have flexible Pulse Width Modulation (PWM) modes, with a high-speed, high-resolution PWM that can operate at a high switching frequency.

The DSC must also have a fast Analog-to-Digital Converter (ADC), with flexible data conversion modes such as simultaneous, Synchronous/Asynchronous sampling to optimize the control loop. High-speed analog comparators built-in into the DSC help to detect faults without any delay and take corrective actions quickly. A peak current-mode control algorithm requires high-speed analog comparators with a built-in Digital-to-Analog-Converter (DAC) reference. To enable efficient power-supply operation, Intelligent Power Peripherals (PWM generator, ADC and High-Speed Analog comparator) should be tied to each other without the intervention of the CPU.

Hardware design

For better utilization of available energy sources, the power supply should have Unity Power Factor (UPF), hence input current should be in phase with the input voltage and Total Harmonic Distortion should be near to unity. A single DSC can be used to achieve UPF and secondary output voltages, thus eliminating the cost of a separate controller to achieve UPF.

Passive in-rush current control reduces overall efficiency, hence it is desirable to have active in-rush current control to maintain high efficiency and also reliability. This can be achieved by implementing peak current mode control of the input-capacitor charging current, using Intelligent Power Peripherals.

For trouble-free operation of the end system, properly sequenced multiple outputs are needed. This can be achieved using one DSC, without adding any external sequencer circuits.

Adding communication features,

remote monitoring & control and thermal management to an analog power supply requires an additional microcontroller and many discrete components. On the other hand, the same DSC that is used for power conversion can be also be used to manage the above functions, saving cost and board space.

High-voltage/current tracks and control signals should be properly routed on the PCB to avoid cross talk. The digital pin remapping feature on some DSCs helps in optimizing PCB layout.

Software design

The software design phase consists of developing the control loops needed for the power conversion. Here, complex compensation circuits are replaced by software loops. Self calibration, communications, power and thermal management features are done in software. To achieve optimum control-loop gain and phase margins, execution of control loops is given highest priority. Time available after the control loops is used for other tasks. Therefore, the execution speed of the DSC becomes very important, and deterministic interrupt response plays a major role in optimizing the power-supply performance. In digital power supplies, control loops are software-based; additionally, tuning is relatively easy and optimum stability points are achieved very quickly without re-spins of the PCB. Ready-made peripheral libraries and code examples from semiconductor manufacturers come in handy and save development cycle time.

Achieving design to cost objectives

DFM, DFT & DFS become key elements during the design and development stage. DSCs help in developing value-added features at a reduced cost

Along with other DFM guidelines, it is very important to reduce the number and types of components. DSCs with Intelligent Power Peripherals reduce the usage of external components.

Software features can be written to introduce a self-testing feature, which consists of JTAG boundary-scan tests or a self-test capability. This helps to identify the location of faults and reduces the overall testing time.

Service costs can be minimized with the help of software that includes a self-calibration feature, which helps to nullify the component errors from aging by adjusting the control co-efficient. Software features can also help determine end of life. Communication features help in reporting faults and status, remotely.

Summary

In summary, low-cost DSCs with Intelligent Power Supply Peripherals have features finely tuned to the demands of the new age of intelligent power-supply needs. Digital-power control techniques enabled by DSCs provide advanced capabilities that enable high efficiencies at low cost.

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New 1.2V rated MOSFETs

Saving space and power for ultra portable devices

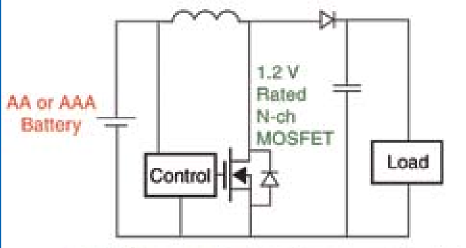
One of the toughest challenges facing electronic system designers today is to make portable devices smaller and thinner while maximizing battery life between charges and adding new features and functionality. Achieving this goal means saving space and power wherever possible. Advances in power MOSFET technology are providing a new opportunity to do just that.

By Hawk Lee, Senior Manager Market Development, Vishay Intertechnology, Santa Clara, California, USA

One of the major trends in portable devices is the migration of power rails for digital ICs down to lower and lower voltages approaching 1V. Until now, however, power MOSFETs have been designed and characterized for operation from gate-to-source voltages of 1.8V and up. Obviously these ratings aren't compatible with these low-voltage ICs.

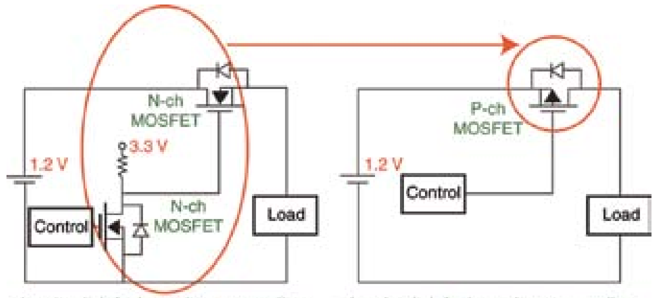
To compensate for this mismatch, designers have had to use a circuit like the one in Figure 1. When the control voltage is low, the control MOSFET is off and the load switch MOSFET sees 3.3V at the gate. This produces a gate-to-source voltage V_{GS} of 2.1V and the load switch MOSFET conducts current to the load. For the off condition, control is high, turning on the control MOSFET. This pulls current through the resistor, and the gate to the load switch MOSFET is then low (near to zero), turning off the load switch MOSFET.

But what if we could avoid having to deal with this 3.3V power rail? In figure 2, just one p-channel with an on-resistance rating characterized at 1.2V is needed. When the control voltage is low, the gate of the load switch MOSFET is 0V, while the source is the system's 1.2V. This produces a V_{GS} of 1.2V, conducting current to the load. For the off condition, control goes high, driving the gate of the load switch MOSFET high and turning the MOSFET off.



<Application example of system powered by AA (or AAA) battery>
Figure 3

A dual MOSFET solution would not work for the circuit in Figure 1 since MOSFETs with different current ratings are needed; the control MOSFET needs a low current rating and the load switch MOSFET needs a high current rating. The circuit in Figure 2 saves one MOSFET and one resistor over the circuit in Figure 1. Therefore, the space, power and cost associated with the extra MOSFET and resistor can be eliminated. When the load switch is off, the resistor in Figure 1 has to be drawing current most of the time. With the elimination of this resistor, the current draw is also eliminated, saving additional power.



<Load switch for low voltage power line> (Conventional) Figure 1
<Load switch for low voltage power line> (New with 1.2 V rated MOSFET) Figure 2

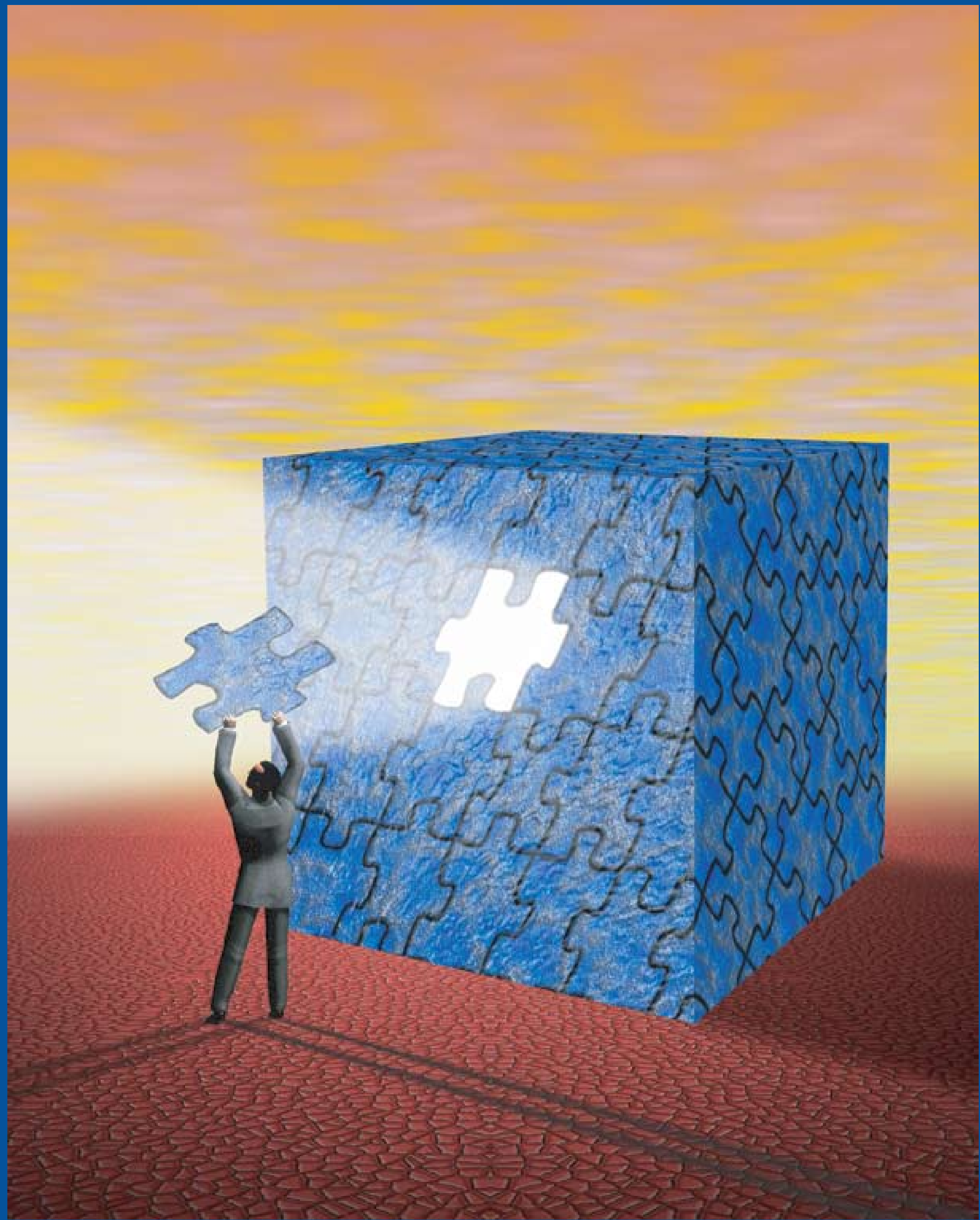
An n-channel MOSFET is well suited for circuits powered by AA or AAA batteries. These batteries provide 1.5V and can degrade down to 1.1V or 1.2V as they age. Designers usually need to use a boost converter to drive a motor, audio amplifier, or IC, as shown in Figure 3. Previously, an NPN transistor might be used in the boost converter. Now, however, an n-channel MOSFET can be used instead, which allows the operating frequency to be increased compared to a circuit with an NPN transistor. The higher frequency, in turn, will allow the use of smaller inductors and capacitors, saving on space and costs.

A family of 1.2V rated MOSFETs is available from Vishay Silconix (www.vishay.com/mosfets/1pt2-on-list/). Their V_{DS} ranges from ±8V to ±20V, with on-resistance at 1.2V are down to 41 milliohms for n-channel devices and 98 milliohms for p-channel devices (or 11 milliohms and 23 milliohms respectively at a 4.5V gate drive). Package size ranges from 2mm x 2.1mm down to 1.2mm x 1mm. These devices not only provide low maximum on resistances at gate source voltages down to 1.2V, they also have improved on-resistance at V_{GS} = 1.5V compared to most devices on the market with a 1.5V on-resistance rating.

www.vishay.com

Power Systems Design EUROPE

Lighting Systems



New LED Applications are Unfamiliar Territory

Tools help designers with inductor selection

New LED developments are making many new lighting applications possible, but some designers must now confront challenges in areas outside their traditional expertise.

By Len Crane, Director - Technical Marketing, Coilcraft, Cary, IL, USA

A product we are all familiar with as consumers, the traditional incandescent flashlight, usually has a very basic circuit design: batteries, a light bulb, an on-off switch, and a way to connect them all. By contrast, opening one of the new LED flashlights now on store shelves reveals a much greater electronic complexity. They use a variety of driver circuits with a wide array of components. It is easy to imagine that flashlight designers have always required a large measure of specialized expertise to produce ruggedized items for uses like sporting and police, fire and rescue applications. But they didn't necessarily need to be experienced with dc-dc converters, let alone components like the power inductors that make up a typical dc-dc converter bill of material.

As the range of new LED lighting applications grows, it is also easy to imagine this scenario repeating itself for a variety of lighting products. It is incumbent on established power component manufacturers to help these new industries adapt existing dc-dc converter expertise into their designs – and do it in ways that achieve the performance and energy efficiency promised by new lighting applications. This article examines the ways an experienced engineer can quickly and easily access existing dc-dc converter expertise including magnetic component detail.

Coilcraft has created several tools to guide the user in the selection of inductors. These tools are available in the new LED Design Center as shown in Figure 1. The tools are arranged to provide the user a choice of starting points.

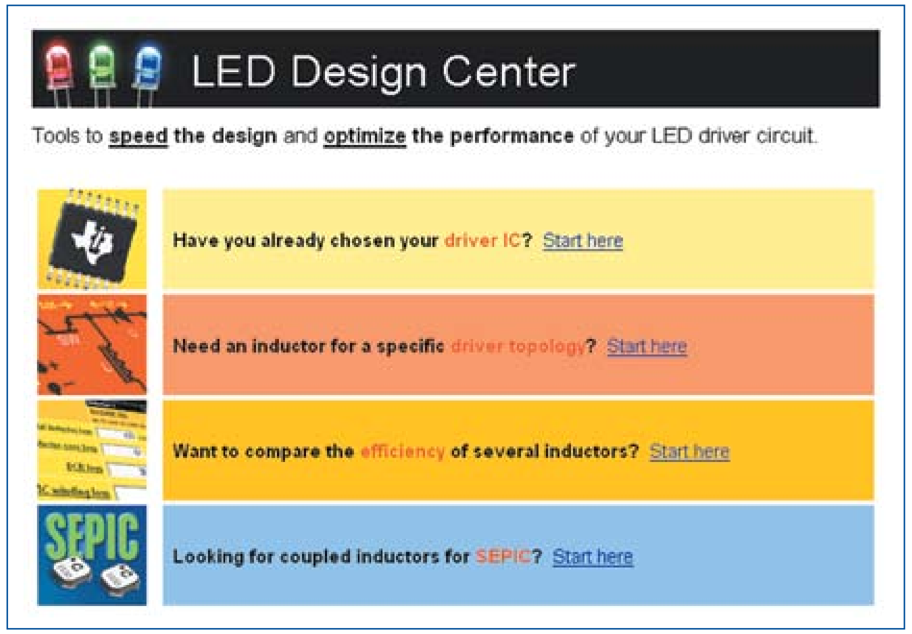


Figure 1: Coilcraft LED Design Center options.

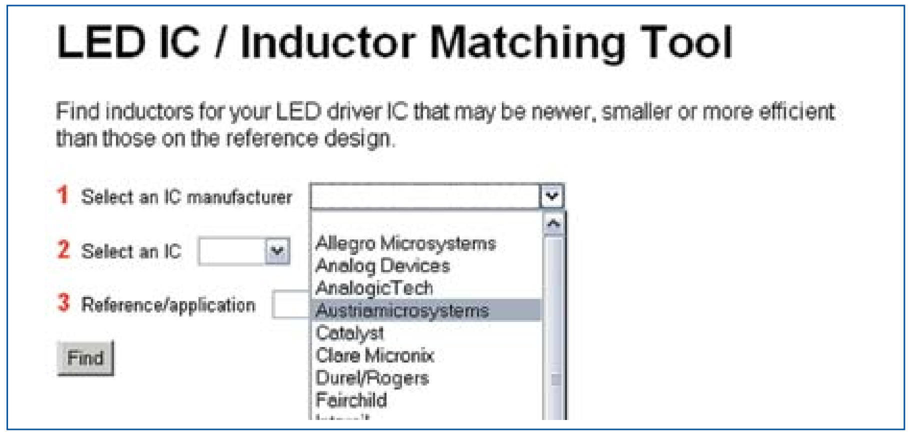
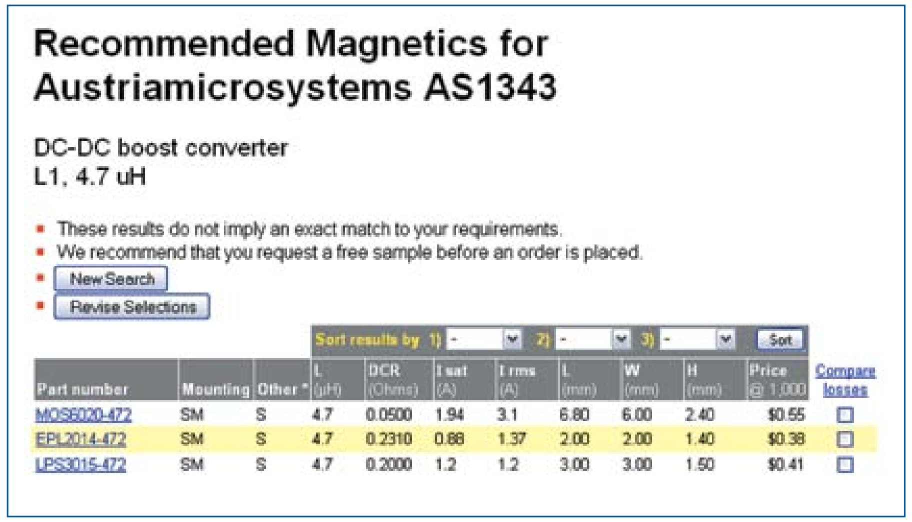


Figure 2: LED driver IC and inductor matching tool.

Starting from the driver IC

The list of LED driver circuit ICs is long and includes all the well known names

Special Report – Lighting Systems



Recommended Magnetics for Austriamicrosystems AS1343

DC-DC boost converter
L1, 4.7 uH

- These results do not imply an exact match to your requirements.
- We recommend that you request a free sample before an order is placed.
- New Search
- Revise Selections

Sort results by 1) - 2) - 3) - Sort

Part number	Mounting	Other *	L (µH)	DCR (Ohms)	I sat (A)	I rms (A)	L (mm)	W (mm)	H (mm)	Price @ 1,000	Compare losses
MOS6020-472	SM	S	4.7	0.0500	1.94	3.1	6.80	6.00	2.40	$0.55	☐
EPL2014-472	SM	S	4.7	0.2310	0.88	1.37	2.00	2.00	1.40	$0.38	☐
LPS3015-472	SM	S	4.7	0.2000	1.2	1.2	3.00	3.00	1.50	$0.41	☐

Figure 3: Inductor solutions found by IC/Inductor matching tool.

Company	Part Number	Vf	Io	Color	Reference
Avago	ASMT-MW00	3.6	0.35	Cool white	www.avagotech.com
Cree	XRCWHT-L1-0000-00601	3.5	0.35	Cool white	www.cree.com
Everlight	EHP-AX08B/CT01H-P01	3.5	0.35	Cool white	www.everlight.com
Lite-on	LOPL-E011WA	3.8	0.35	white	www.us.liteon.com
Osram	LW-W5SM	3.2	0.35	White	www.osram-os.com
Philips Lumileds	LXK2-PW12-S00	3.42	0.35	White	www.philipslumileds.com
Seoul Semiconductor	W10190	3.5	0.35	Cool white	www.seoulsemicon.com

Table 1: Typical white LEDs

such as Allegro Micro, Austria Microsystems, Durel, Fairchild, Freescale, Linear Technology, Maxim, National Semiconductor, NXP, ON Semiconductor, STMicroelectronics and Texas Instruments. Documentation from IC companies typically includes not only the technical specifications for their products but also design examples and application hints. Often complete ready-to-use evaluation or demonstration kits are made available.

In addition to the usual reference design information, companies have implemented special LED design centers as a way to gather the information related specifically to lighting applications. National Semiconductor, for example, offers the on-line WEBENCH LED Designer as part of its renowned WEBENCH Designer tool set. Texas Instruments' web offerings for Power Management Products feature an LED Driver, Lighting & Display Solutions section, and Linear Technologies lists an LED Driver ICs page. These are just examples of the lengths the driver IC makers are going to support the fledgling LED lighting market.

The Coilcraft LED Design Centers collects information on LED driver ICs and connects the user to the appropriate inductors with its Inductor Matching Tool. This tool starts by helping the user select from a list of the IC companies, driver ICs, and specific application of interest as shown in Figure 2.

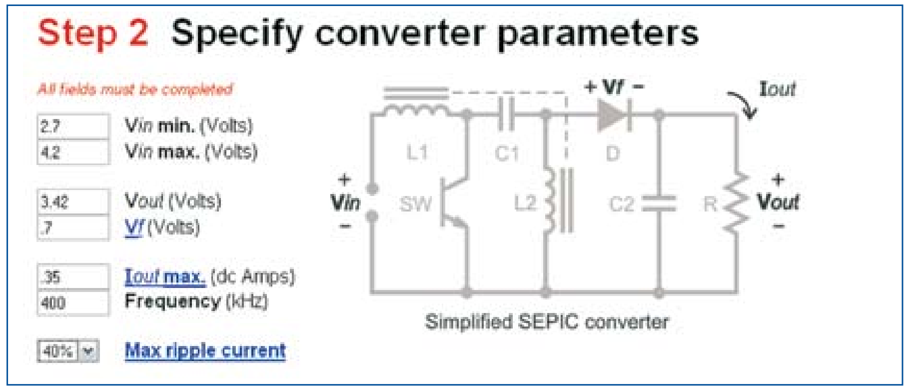


Figure 4: SEPIC input screen.

From the selected information, the tool provides the appropriate inductor information for the application. Figure 3 shows a typical result which features a summary of the inductor parameters and a live link to the complete inductor specification. Because the inductors listed as solutions are pulled from a live database of active part numbers, this tool is more powerful than a simple cross-reference list to the inductors listed in the IC reference design. This feature provides the user with an always up-to-date list of the available inductors, not limited to those inductors identified by the reference design at the time of publication.

Starting with the LED

As the heart of the application, the properties of the LED device itself and the operating requirements are necessarily the starting point for most designs. For example, the basic operating parameters like those shown in Table 1 are easily found from the LED data sheets.

Most web sites from these manufacturers provide a variety of helpful application tips, including lists of technology partners to facilitate the integration of different areas of expertise.

Starting with choice of driver circuit topology

Using the LED specifications provided by the manufacturers, and depending on the available input voltages and the number of LEDs to be driven, the engineer might prefer to specify the driver topology: buck, boost, buck-boost or SEPIC. The Coilcraft LED Design Center can quickly identify the correct inductor for each of those.

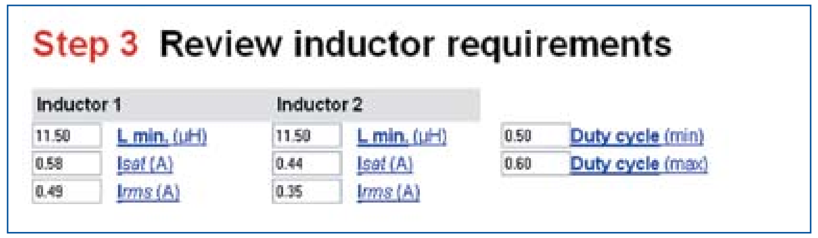
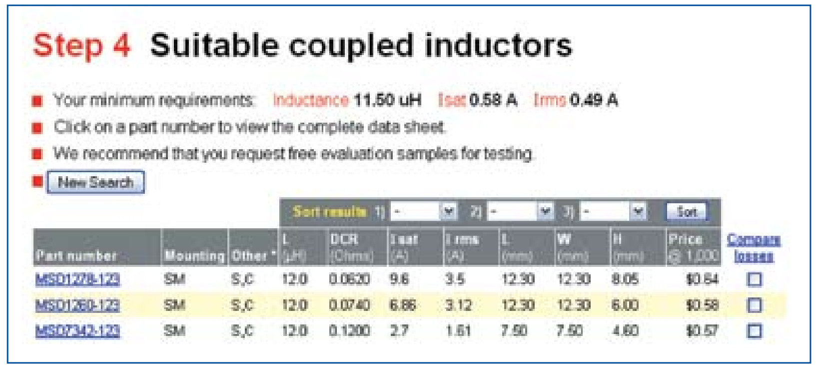


Figure 5: Coupled inductor results.



Step 4 Suitable coupled inductors

- Your minimum requirements: Inductance 11.50 uH Isat 0.58 A Irms 0.49 A
- Click on a part number to view the complete data sheet.
- We recommend that you request free evaluation samples for testing.
- New Search

Sort results 1) - 2) - 3) - Sort

Part number	Mounting	Other *	L (µH)	DCR (Ohms)	I sat (A)	I rms (A)	L (mm)	W (mm)	H (mm)	Price @ 1,000	Compare losses
MSD1278-123	SM	S,C	12.0	0.0620	9.6	3.5	12.30	12.30	8.05	$0.64	☐
MSD1260-123	SM	S,C	12.0	0.0740	6.86	3.12	12.30	12.30	6.00	$0.58	☐
MSD7342-123	SM	S,C	12.0	0.1200	2.7	1.61	7.50	7.50	4.60	$0.57	☐

Figure 6: Standard coupled inductors.

For example, this tool can be used in the selection of coupled inductors for SEPIC converters to drive the white LEDs shown in Table 1. Typically these white LEDs are specified for driving with forward currents of 350 mA, which can be supplied from a single Li-ion battery, the typical power source of handheld devices. The basic requirements for driving a single one of these might be as follows.

Fsw = 400kHz / Vin = 2.7 to 4.2Vdc / Vo = 3.42Vdc / Io = 35mA

The challenge with this design is to operate from as wide a voltage range as possible in order to maximize the battery life per charge. During charging, the Li-ion cell voltage is greater than the output voltage, while at the end of the charge cycle the cell voltage will be less than the desired output. Therefore, neither a buck nor boost regulator will be sufficient for this purpose and so the increasingly popular SEPIC topology is chosen.

The Coilcraft LED Design Center includes coupled inductor selection for SEPIC converters as shown in Figure 4. The SEPIC input screen requests the input/output specifications, the switching frequency and asks the user to select the allowed ripple current.

For a SEPIC coupled inductor the requirements for each winding must be calculated separately to determine the expected peak and average current, which may differ between L1 and L2 depending on the operating conditions. The Coilcraft tool calculates both L1 and L2 requirements and presents the results as shown in figure 5.

The list of standard parts that meet this requirement is then returned (as shown in Figure 6), and the user is allowed to choose, the most suitable inductor for the application, depending on the parameters of most interest.

It is always helpful to offer tools that serve a wide range of experience and expertise, and it is especially important in a developing space that may draw from previously unrelated industries and applications. In the broad field of LED lighting applications, such a variety is being offered by an increasing number of LED, IC, and passive component suppliers.

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HB-LED Lighting Solutions

Illuminating the way forward

The continuing evolution of LED-based lighting solutions has been driven by market factors such as increasing optical efficiency, better color performance, maximized product life, reduction of maintenance costs, and reduced environmental impacts.

By Troy Wu, Director, R&D Division, Everlight Electronics, Taipei, Taiwan

In order to provide lighting customers with the best service for their new LED lighting and luminaire products, Everlight Electronics has invested more than five years in developing high power LED emitters, and is likely to be one of the industry's most important high power LED suppliers. Besides high power LED emitters, Everlight also develops complete LED light engine solutions which integrate the capabilities of LED selections, mechanical designs, optical design, thermal management, LED driver design and assembly, to reduce customer design time and costs.

High power LEDs

High power LED emitters are core components for LED lighting fixtures as their optical efficiency is a key factor to determine the performance of LED lighting fixtures. Currently, the company can offer high power LEDs with 90lm/W at 1W operation, and expects to provide 100lm/W at 1W operation in the second quarter of 2009.

Lumens per package is a key index of high power LED packaging which strongly influences the total cost of LED lighting fixtures. Figure 1 shows the roadmap of lumen output per LED packaging of Everlight high power LEDs. For example, 0.5W LEDs that achieve 40lm at 6500K today are expected to achieve 55lm in 2009 and 70lm in 2010. The expected figures for 1, 3 and 5W LEDs with 90, 200 and 300lm respectively at 6500K today are expected to offer 110, 250 and 360lm in 2009 and 150, 300, 400 lm in 2010.

LED lighting modules

In order to provide convenient LED lighting solutions and reduce costs, Everlight proposes and offers LED light engine solutions which integrate the capabilities of LED selections, mechanical designs, optical design, thermal management, LED driver design and assembly. This means one-stop shopping for LED lighting customers from LED to a complete module that saves both design time and development costs. Figure 2 shows the concept of Everlight LED light engine solutions.

Power Consumption	2008	2009	2010
5W	CC: 300lm WW: 250lm	CC: 360lm WW: 300lm	CC: 400lm WW: 330lm
3W	CC: 200lm WW: 160lm	CC: 250lm WW: 210lm	CC: 300lm WW: 250lm
1W	CC: 90lm WW: 70lm / CC: 750lm WW: 60lm	CC: 110lm WW: 90lm / CC: 100lm WW: 85lm	CC: 150lm WW: 130lm / CC: 150lm WW: 110lm
0.5W	CC: 40lm WW: 30lm	CC: 55lm WW: 48lm	CC: 70lm WW: 60lm

(CC: Cool white, 6500K / WW: Warm white, 3000K)

Figure 1: The lumen output of Everlight high power LED packages.

Figure 2: The concept of Everlight LED light engine solution.

LED light engine reference models

Several standard LED light engine models have been developed based on indoor or outdoor applications. Two examples serve as reference designs and illustrate Everlight's light engine concept: the SL-Dolphin street light and the E-Skyline MI750 high efficiency linear luminaire.

Dolphin Street lamp

Figure 3 shows the photo of an SL-Dolphin street light. Currently 60W, 90W, 120W are available for pole heights up to 8m. The life time of the LED module is L70>35,000hours, a 3 year warranty is available. The Dolphin street lamp is designed for IP65 water and dust proof. The light distribution of SL-Dolphin follows street lighting regulations. As an alternative to choosing the complete SL-Dolphin fixture, customers can select the light source of the Dolphin assembly, called Phoenix (Fig. 4), for their own lighting fixture housing design. The Phoenix can also perform IP65 water and dust proof and L70>35.000 hours with a suitable heat dissipation design based on the metal housing.

Figure 5: E-Skyline MI750.

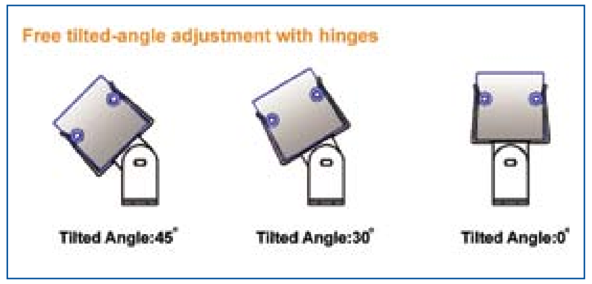


Figure 6: Mounting hinge for E-Skyline MI750.

Figure 3: SL-Dolphin street light.

Figure 4: Designers can select the Dolphin light source, Phoenix, for their own lighting fixture housing design.

E-Skyline MI750

Figure 5 shows the photo of the linear lighting fixture E-Skyline MI750. This is a high quality, high efficiency linear luminaire suitable for indoor decoration lighting and general lighting applications. There are 3 types of beam angle available: 15°, 60° and 120°. The power consumption of E-skyline MI750 is 6W and an excellent thermal management design can keep the surface cool enough (under 50°C) when is operated. The on-board driver design allows for a serial connection of 10 E-Skyline fixtures with only one 60W/24VDC power supply that can easily be bought from the electric shop next door, thereby reducing the power supply costs. A tilt angle adjustable hinge is designed to mount E-Skylines as shown in Figure 6.

The future of the lighting systems industry promises steady growth as regions around the world adopt more efficient and environmentally friendly technologies. Regulation plays its part, but it will be the economic factors together with the quality of electronic and mechanical innovations that designers and manufacturers can deliver, that will differentiate companies in this market.

www.everlight.com

Solid-State Lighting Applications

Selecting drive current and led count

One challenge facing designers in the solid-state lighting industry is selecting the optimal drive current and number of LEDs for reaching performance targets. Some applications require the design to maximize the amount of light from a minimum number of LEDs. In such applications, the LEDs drive current is maximized in order to generate more light output. Other applications require high efficacy with the flexibility of adding more LEDs. In such applications, the LEDs can be driven at a lower current resulting in higher LED efficacy while still delivering the required light output due to the higher LED count.

By Osama Mannan, Technical Marketing Engineer, Future Lighting Solutions, Montreal, Canada

Most LED manufacturers offer low-current and high-current LEDs for variety of applications. Table 1 summarizes maximum drive currents for some of the leading LED manufacturers.

Here we will examine the applications of two LEDs in two distinct cases. For illustrative purposes, the analysis of lower current range LEDs versus higher current range LEDs will be carried out with the LUXEON Rebel and LUXEON K2 with TFFC. However, the same principles will apply to the LEDs from the other LED manufacturers in Table 1.

Case 1 will focus on LEDs used for high lumen output with a low LED count criteria. Case 2 will focus on LEDs used in applications using a high LED count and demanding high efficacy light output.

Case Studies

Three critical factors for selecting an LED are its light output, efficacy, and lifetime. These important variables are significantly affected by drive current, LED forward voltage, junction temperature, thermal solution performance characteristics, and number of LEDs. The Usable Light Tool (ULT), accessible at www.futurelightingsolutions.com/ult can be leveraged to generate performance results for the two selected LEDs under specific operating conditions. In the following comparisons, we will be considering the highest available lumen version of each LED, namely the 100-lumen LUXEON Rebel and the 200-lumen LUXEON K2 with TFFC.

Case 1: High lumen output with a small number of LEDs

In many applications, the main objective is to maximize the amount of light the light source can generate. Moreover, if this light output can be achieved with a minimum number of LEDs, it will greatly reduce the cost and complexity of the overall system.

The Usable Light Tool (ULT) will be leveraged to demonstrate how the LUXEON Rebel and the LUXEON K2 with TFFC compare in achieving that objective. Three LEDs of each were selected at an ambient temperature of 30oC and a heat sink with thermal resistance of 5oC/W. The calculation results for the LED usable light are shown in Figure 1.

Figure 1 illustrates that the LUXEON K2 with TFFC LEDs generate a lumen output of 627 lumens while the LUXEON Rebel LEDs generate 551 lumens. The advantage LUXEON K2 with TFFC has in this case is the ability to be driven at a higher current than the LUXEON Rebel, allowing it to give more light output using a low LED count.

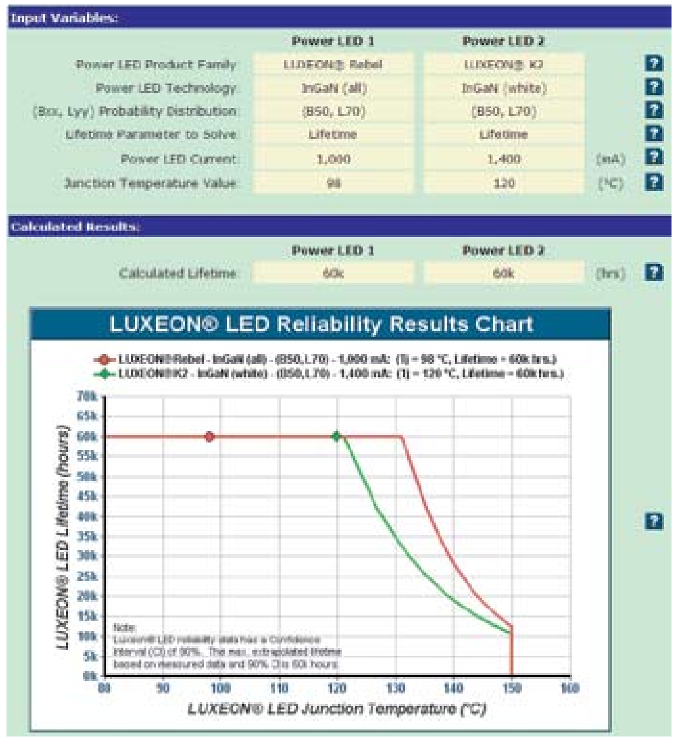
Furthermore, the low count of LEDs reduces the level of power dissipation, thus making it low enough that the 5°C/W can effectively dissipate the power generated by the higher drive current. Increasing the LED count may prevent the LEDs from being driven at significantly higher currents without the assistance of active cooling. As a result, when the LED count is low (typically

LED Manufacturer	Lower Current Product Line (Nominal and Maximum Current)	Higher Current Product Line (Nominal and Maximum Current)
Philips Lumileds	LUXEON Rebel (0.35A, 1A)	LUXEON K2 with TFFC (1A, 1.5A)
Osram	Golden Dragon (0.35A, 0.5A)	Golden Dragon Plus (0.35A, 1A)
Cree	XPC (0.35A, 0.5A)	XRE (0.35A, 0.7A)
Nichia	x083 (0.3A, 0.35A)	x183 (0.7A, 0.8A)

Table 1: Summary of LED Currents.

Input Variables:	LXML-PWC1-0100	LXK2-PWC4-0200	
Power LED Manufacturer:	Philips Lumileds	Philips Lumileds	
Power LED Product Family:	LUXEON® Rebel	LUXEON® K2 with TFFC	
Power LED Color:	Cool White (6500K)	Cool White (6500K)	
Power LED Part Number:	LXML-PWC1-0100	LXK2-PWC4-0200	
Current Optimization Algorithm:	Maximize Current	Maximize Current	
Number of Power LEDs:	3	3	
Ambient Temperature:	30	30	(°C)
Heat Sink Thermal Resistance:	5	5	(°C/W)
Maximum Allowable Tj:	135 (default)	120 (default)	(°C)
Maximum Allowable Drive Current:	1000 (default)	1500 (default)	(mA)
Typical Vf at Nominal Current:	3.15 @350mA (default)	3.65 @1000mA (default)	(V)
Typical Flux at Nominal Current:	105 @350mA (default)	210 @1000mA (default)	(lm)
Calculated Results:	LXML-PWC1-0100	LXK2-PWC4-0200	
Calculated Drive Current:	1000	1411	(mA)
Calculated Forward Voltage:	3.29	3.56	(V)
Calculated LED Power Consumption:	3.29	5.02	(W)
Calc. Array Power Consumption:	9.86	15.06	(W)
Calculated LED Radiometric Flux:	0.554	0.63	(W)
Calculated LED Efficiency:	16.8%	12.5%	(W/W)
Datasheet Junction-to-Case Rth:	10	5.5	(°C/W)
Calculated Junction Temperature:	98	120	(°C)
Calculated Usable LED Flux:	184	209	(lm)
Calculated Usable Array Flux:	551	627	(lm)
Calculated Usable Efficacy:	55.93	41.65	(lm/W)

Figure 1: ULT Light Calculations for Case 1.

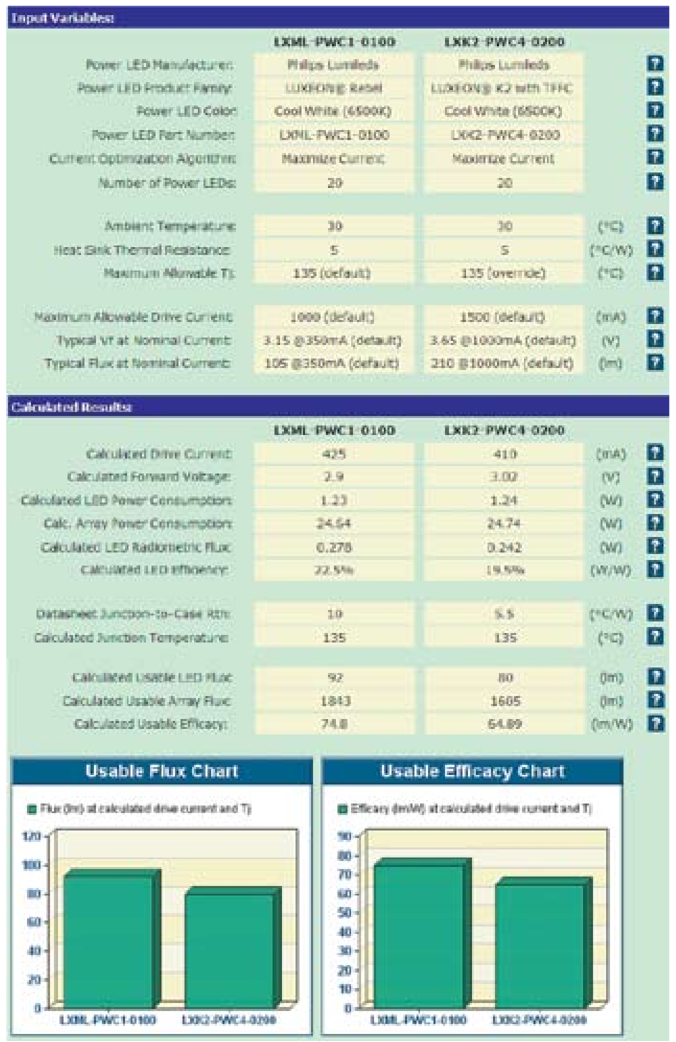


Input Variables:	Power LED 1	Power LED 2	
Power LED Product Family:	LUXEON® Rebel	LUXEON® K2	
Power LED Technology:	InGaN (all)	InGaN (white)	
(Bxx, Lyy) Probability Distribution:	(B50, L70)	(B50, L70)	
Lifetime Parameter to Solve:	Lifetime	Lifetime	
Power LED Current:	1,000	1,400	(mA)
Junction Temperature Value:	98	120	(°C)
Calculated Results:	Power LED 1	Power LED 2	
Calculated Lifetime:	60k	60k	(hrs)

Figure 2: LRT Reliability Results for Case 1.

Input Variables:	Power LED 1	Power LED 2	
Power LED Product Family:	LUXEON® Rebel	LUXEON® K2	
Power LED Technology:	InGaN (all)	InGaN (white)	
(Bxx, Lyy) Probability Distribution:	(B50, L70)	(B50, L70)	
Lifetime Parameter to Solve:	Lifetime	Lifetime	
Power LED Current:	450	400	(mA)
Junction Temperature Value:	135	135	(°C)
Calculated Results:	Power LED 1	Power LED 2	
Calculated Lifetime:	60k	60k	(hrs)

Figure 3: ULT Light Calculations for Case 2.



Input Variables:	LXML-PWC1-0100	LXK2-PWC4-0200	
Power LED Manufacturer:	Philips Lumileds	Philips Lumileds	
Power LED Product Family:	LUXEON® Rebel	LUXEON® K2 with TFFC	
Power LED Color:	Cool White (6500K)	Cool White (6500K)	
Power LED Part Number:	LXML-PWC1-0100	LXK2-PWC4-0200	
Current Optimization Algorithm:	Maximize Current	Maximize Current	
Number of Power LEDs:	20	20	
Ambient Temperature:	30	30	(°C)
Heat Sink Thermal Resistance:	5	5	(°C/W)
Maximum Allowable Tj:	135 (default)	135 (override)	(°C)
Maximum Allowable Drive Current:	1000 (default)	1500 (default)	(mA)
Typical Vf at Nominal Current:	3.15 @350mA (default)	3.65 @1000mA (default)	(V)
Typical Flux at Nominal Current:	105 @350mA (default)	210 @1000mA (default)	(lm)
Calculated Results:	LXML-PWC1-0100	LXK2-PWC4-0200	
Calculated Drive Current:	425	410	(mA)
Calculated Forward Voltage:	2.9	3.02	(V)
Calculated LED Power Consumption:	1.23	1.24	(W)
Calc. Array Power Consumption:	24.54	24.74	(W)
Calculated LED Radiometric Flux:	0.278	0.242	(W)
Calculated LED Efficiency:	22.5%	19.5%	(W/W)
Datasheet Junction-to-Case Rth:	10	5.5	(°C/W)
Calculated Junction Temperature:	135	135	(°C)
Calculated Usable LED Flux:	92	80	(lm)
Calculated Usable Array Flux:	1843	1605	(lm)
Calculated Usable Efficacy:	74.8	64.89	(lm/W)

Figure 4: LRT Reliability Results for Case 2.

Special Report – Lighting Systems

under 6 LEDs), and the objective is to maximize light output, the LUXEON K2 with TFFC is recommended.

Another critical factor in LED performance is lifetime. Figure 2 illustrates LED lifetime calculations for Case 1 with a probability distribution of (B50, L70), which is the average lumen maintenance at a specific current, junction temperature and elapsed operating time. Computer software, LED Reliability Tool (LRT) has been utilized to generate the curves in Figure 2. From the calculation results of the software tool, drive current values of 1000mA and 1400mA, and junction temperatures of 98°C and 120°C, for LUXEON Rebel and LUXEON K2 with TFFC respectively, generated an expected lifetime of 60,000 hours for both LEDs.

Case 2: High efficacy application with a large number of LEDs

Generally, the more current supplied to the LEDs the lower its efficacy (lm/W). As a result, many applications drive the LEDs at a current level much lower than the maximum current rating in order to maximize efficacy. Therefore, in order to achieve a high lumen output, more LEDs need to be used. It can also be assumed that applications needing a large number of LEDs (i.e. street lighting, low bay, wall packs) also include a high efficacy specification.

Following the same procedure as in Case 1, 20 LEDs of each product family were used under the same conditions as in Case 1 (i.e. ambient temperature of 30°C and a heat sink thermal resistance of 5°C/W). The calculation results are shown in Figure 3.

Figure 3 illustrates that the LUXEON Rebel achieves an efficacy value of 74.8lm/W, while the LUXEON K2 with TFFC achieved an efficacy of 64.89lm/W. In addition, the LUXEON Rebel produced more light output. However, these flux and efficacy differences can be attributed to different flux and forward voltage bins.

It is worth noting that both LEDs were driven at currents less than 500mA due to the junction temperature boundary condition of 135°C. While this is an appropriate drive current for the LUXEON Rebel, it is not optimal for the LUXEON K2 with TFFC. Driving the LUXEON K2 with TFFC under 1000mA does not leverage its design robustness. Therefore, from a cost perspective, the LUXEON Rebel is the preferred solution since there is no significant technical advantage to using the LUXEON K2 with TFFC is this case.

Similarly, entering the ULT calculation results for Case 2 into the LRT software, and using the same probability distribution of (B50,L70), also resulted in a lifetime expectancy of 60,000 hours for both LEDs, as shown in Figure 4.

Due to the high thermal capabilities of both the LUXEON Rebel and the LUXEON K2 with TFFC, reaching junction temperatures as high as 135°C did not affect the lifetime of the LEDs, which still sustained an operating lifetime of 60,000 hours, according to the tool, while respecting a confidence interval level of 90%.

The above cases provided information regarding design tradeoffs when selecting the most suitable LED for meeting target specifications. It was evident from Case 1 that utilizing a small number of LEDs (typically under 6) demonstrated how more light output can be achieved using higher currents, making it suitable for more lumens per package. On the other hand, in Case 2, high efficacy and high light output were achieved using higher LED count driven at a lower current.

About Future Lighting Solutions

Future Lighting Solutions is the leading provider of LED lighting components and solution support for lighting designers and OEMs interested in taking advantage of solid state lighting technology. Future Lighting Solutions provides LED lighting knowledge, resources, programs, partners, solutions and logistics support to promote the development of LED products and installations. The company is a division of Future Electronics, the third largest electronic components distributor in the world. Both companies operate in 167 locations in 39 countries in the Americas, Europe and Asia.

www.futurelightingsolutions.com

Out with the Old

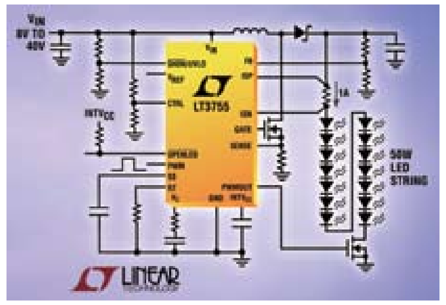
LED driver powers halogen replacement

High brightness LEDs are an inexpensive, robust, and green replacement to halogen light bulbs. The tungsten filament base to the halogen bulb has a short lifetime compared to the robust LED. The safety hazards of the inert gas, the expense of the UV filter encasement, and the handling sensitivity of halogens are all downsides that an LED light bulb does not have.

By Keith Szolusha, Senior Applications Engineer, Linear Technology Corporation

Since halogen bulbs are typically driven with 12V or 24V due to their excellent efficacy at that voltage, buildings have been hardwired with 12VAC and 24VAC transformers for powering the halogen lighting. Replacing existing halogen lighting without starting over from scratch requires an LED that can be powered from a 12VAC or 24VAC source.

Replacing AC-driven halogen lighting with LEDs can be done with a switch mode regulator LED driver designed for AC lighting with high power factor. Although switch mode LED drivers are oftentimes used to regulate a constant LED current through a string of LEDs from a DC voltage source such as a computer battery, a car battery, or a regulated system voltage, halogen replacements run off of 12VACrms and require high power factor.[1]



[1]Power factor of an AC system is defined as the ratio of real power delivered (P) and apparent power |S| as shown in the equation below.

$$\hat{S} = P + jQ \quad |S| = \sqrt{P^2 + Q^2} \quad PF = \frac{P}{|S|}$$

The ideal load with 100% power factor (PF) is a pure resistor. When used with a 12VACrms source and a rectifier bridge (to create 120Hz from 60Hz), the power factor is slightly under 100% using a resistive load such as a halogen or incandescent bulb.

An LED driver with constant (DC) LED current has very poor power factor when used with an AC source in contrast to the resistive load. A constant DC load requires DC power from the input. With an AC source, DC power creates the highest input current when the input voltage is lowest and vice versa. This creates voltage and current input waveforms with a large phase shift and very low power factor. The goal is to create an LED driver with input current in phase with the input voltage. In order to do this, a 120Hz LED current waveform is created to demand the highest input current when the input voltage is the highest and vice versa.

The circuit in Figure 1 is an LT3755 AC LED driver with 98.1% power factor. The topology is buck-boost mode since the wide-ranging input of 0V to 18V (12Vrms) and the wide ranging 4-LED string voltage of 9V to 14V crossover each other. The 12VACrms input is first rectified by D3-D6 to create a 120Hz 0V to 18V PVIN supply. The PVIN and VIN nodes are separated by a diode since the LT3755 works best when the VIN pin is held above 7V, maintaining 7V on INTVcc and driving the power MOSFET M1 with proper gate voltage. The diode allows peak charging of the VIN cap CVIN which is big enough to maintain charge when PVIN drops down to 0V.

LED current foldback with the CTRL pin voltage is used to create a high power factor LED driver. The maximum LED current is set by RS2 at 680mA, but the CTRL pin monitors the PVIN voltage and shapes the LED current waveform to match PVIN. When PVIN drops below the shutdown pin threshold, the IC goes into shutdown, switching stops and the soft-start feature is reset. The LED current trails off as the output capacitors are discharged and soon-enough, PVIN rises above the shutdown pin threshold voltage and the LT3755 starts back up. A light soft-start capacitor allows the LT3755 to get started up quickly and keep the power factor high. With the CTRL pin folding back the LED current at low PVIN, startup is not harsh and inrush currents do not affect the high power factor.

Figure 2 shows the LED string current and voltage waveforms at 120Hz. The scope was used to measure the average LED current and the average LED voltage. Multiplying the two is an approximate method for calculating the LED power. 356mA * 11.175V gives about 4W of LED power, enough for an efficient light bulb replacement.

Figure 3 shows the 120Hz waveforms generated by the LT3755 buck-boost mode AC LED driver in Figure 1. PVIN, VLED, IL1 and ILED are shown – all at 120Hz. 120Hz is a high-enough frequency to not be perceived by the human eye.

The power factor in this circuit is measured using an Agilent 6811B AC power source / analyzer. The 60Hz AC line voltage and current measurements are shown in Figure 4 below.

The LT3755 buck-boost mode AC LED driver delivers 4W of high efficiency LED power at 120Hz with 98.1% power factor. This circuit can be used to replace 12VAC halogen lighting with more robust LEDs. The high power factor of this AC LED driver rivals the high power factor of an incandescent filament-based bulb with purely resistive load properties.

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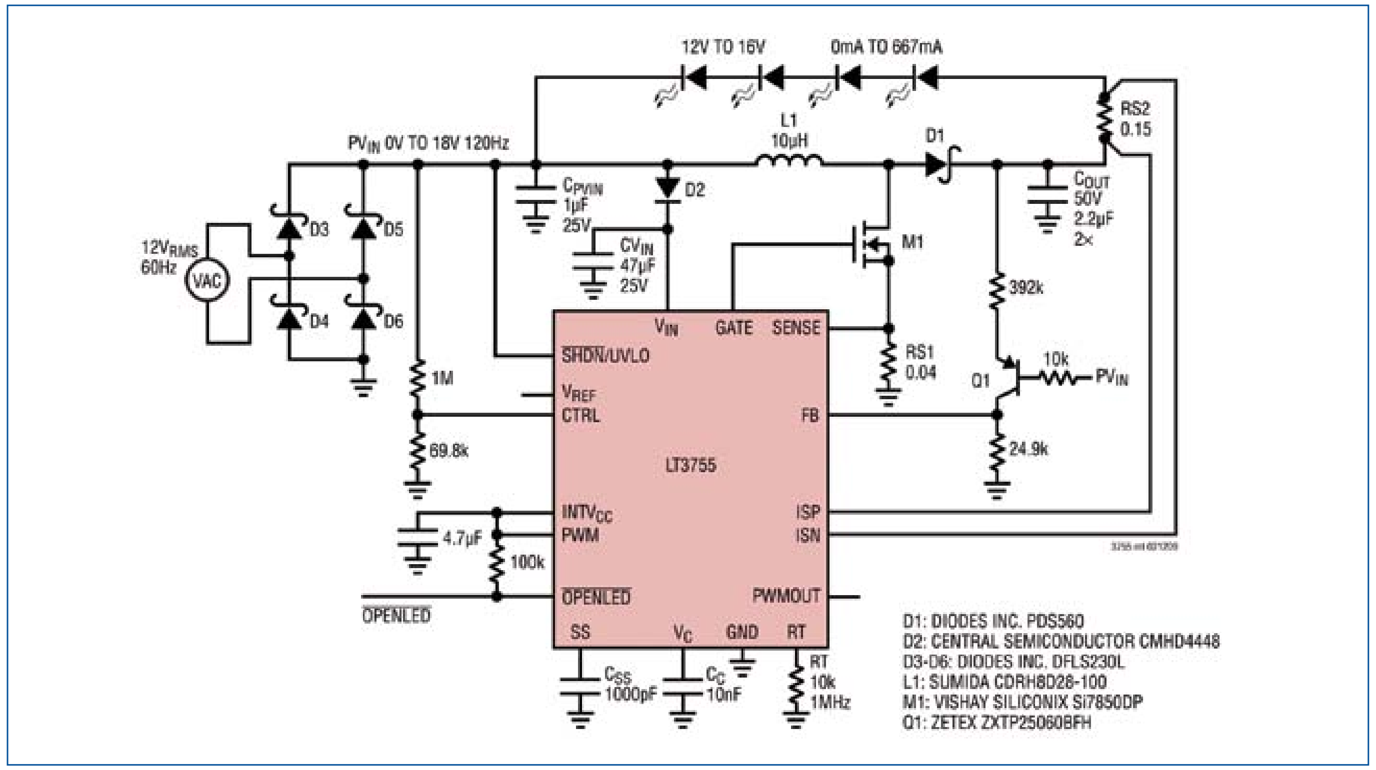

Figure 1: LT3755 AC Buck-Boost Mode LED Driver with 98.1% Power Factor Schematic.

Figure 2: 120Hz AC LED current and voltage waveforms delivering ~4W of LED power.

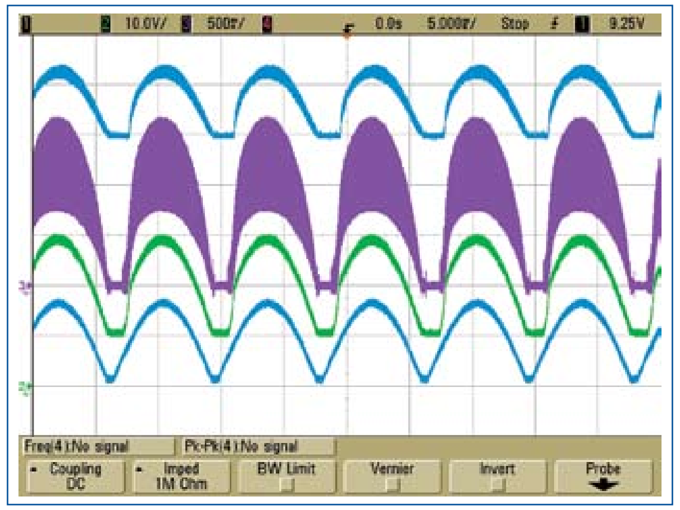

Figure 3: 120Hz AC LED driver waveforms derived from the rectified 12VACrms PVIN.

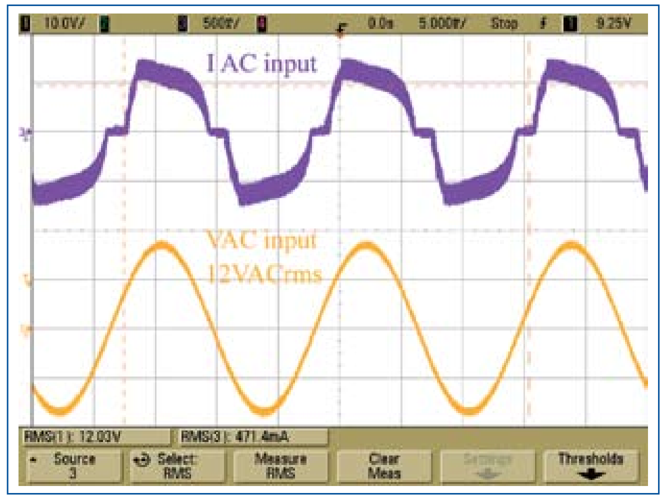

Figure 4: 12VACrms pre-rectifier line voltage and current waveforms with 98.1% power factor.

Special Report – Lighting Systems

Backlighting for Optimized Color

RGB LED driver solution

In order to obtain the best color display in mid-size TFT screens, such as in the popular 7-inch photo frames, RGB LED backlight provides an ideal solution. Using RGB LED backlighting, it is possible to obtain a better NTSC color gamut range, realistic to the human eye. This article discusses the RGB LED driver circuit and outlines a complete RGB LED solution.

By Man Lau, Senior Application Engineer, National Semiconductor, Hong Kong

Since the LCD display is unable to emit light by itself, it must rely on backlight for projecting the colorful images onto the screen. Traditionally, CCFL has been widely used as a light source, but there is now a powerful move towards the use of LEDs with more and more electronic products offering built-in LCD displays illuminated by LED backlights.

Simple, low-end products use white LEDs while higher quality models use RGB LEDs. The white LED is basically a blue LED with a coating of phosphorus which enables the blue light to be converted into red, green and blue lights. If the lights are mixed in the correct proportions, they will be seen by the human eye as white light. Although the circuit design for white LED applications is simple, the color gamut is much more limited than that offered by RGB LEDs.

Basically, white LEDs and CCFL do not differ greatly in terms of color gamut. However, since LEDs offer the added advantages of higher performance, longer life and simpler circuit design, they have a competitive edge over CCFL and hence have a wider variety of applications. Handheld products are a typical example.

Figure 1 shows the color gamut of CCFL and RGB LED backlighting systems. The advantages of RGB LED backlighting are obvious, especially when it comes to applications that are demanding in terms of color accuracy, such as electronic photo frames, which require a full-range color gamut.

Color correction is another important feature. The inherent nature of RGB LEDs enables the user to exercise control over many aspects of the LEDs. The fine shades of a wide range of colors can be easily adjusted making design much more straightforward as individual preferences can be accommodated.

Reference design

National Semiconductor's LP5520 is an RGB LED driver for backlighting systems of small LCDs. Capable of driving four to 4 ~ 5 RGB LEDs, it is able to meet the backlighting needs of a typical small-size LCD display. Details of the specifications of the LP5520 driver are provided in the data sheet. A typical

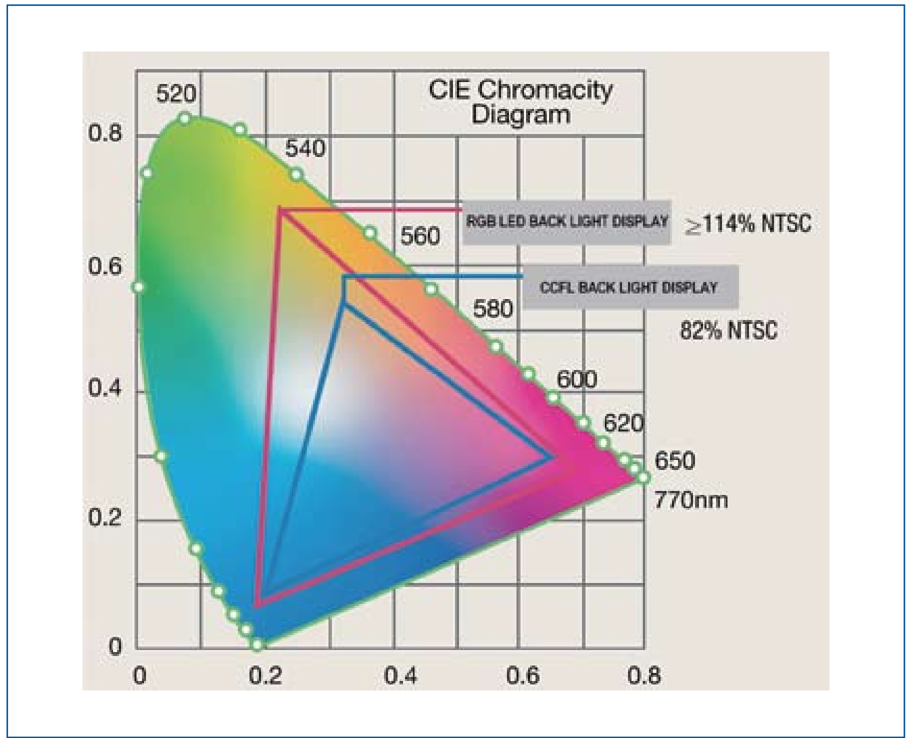

Figure 1: Color gamut of NTSC.

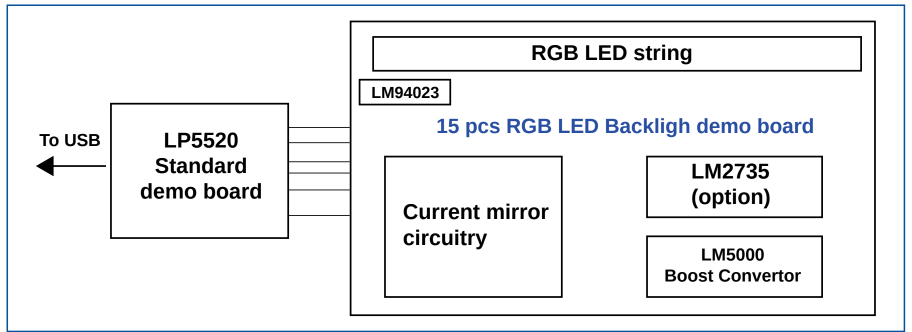

Figure 2: Block diagram of the expanded LP5520 RGB LED driver circuit.

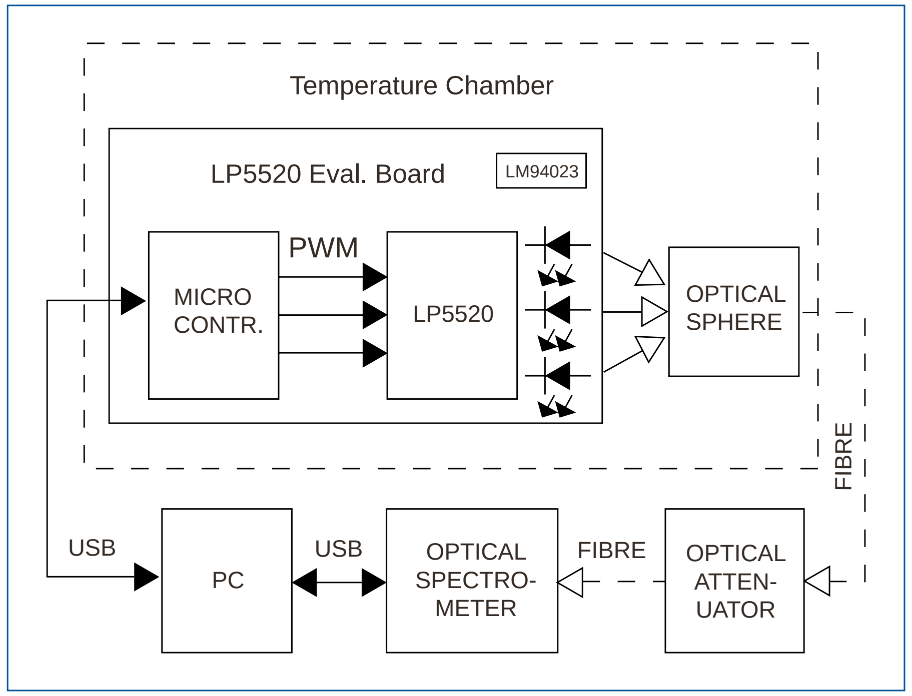

Figure 3: Block diagram of correction circuit.

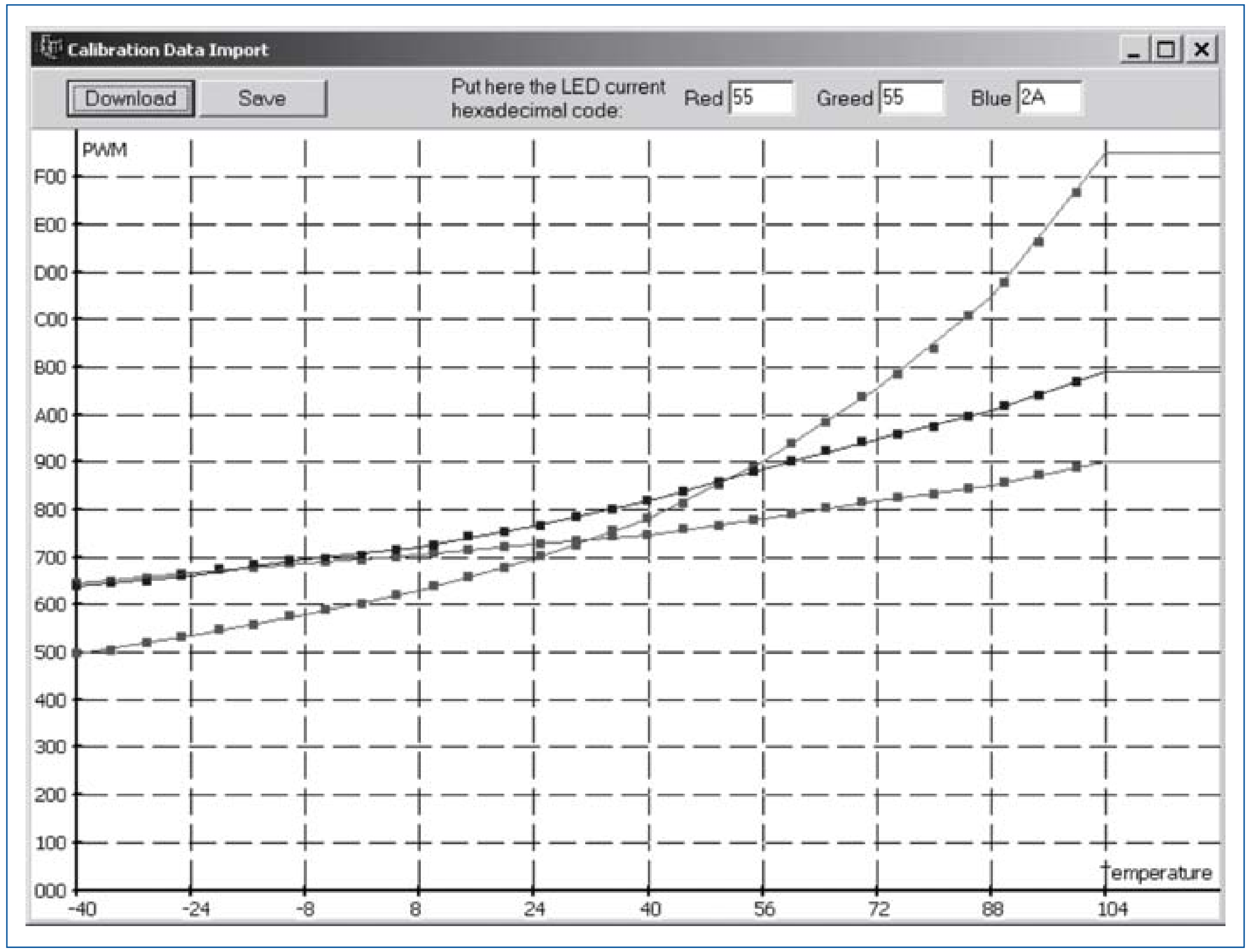

Figure 4: Correction and measurements of sample.

medium-size photo frame is normally 7-inch in size. For a display of this size, its backlighting system requires more than 15 RGB LEDs. In order to take full advantage of the color correction capability and driving power of the LP5520 driver, its typical circuit design has been modified. For example, the LM5000 or LM2735 DC-DC step-up converter and current mirror circuitry are added for higher number of LED application, which enables the entire circuit to drive 15 RGB LEDs. This ensures that the driving current flowing through various strings of RGB LEDs and the driving current provided by LP5520 will remain steady and constant, with no difference between them. Figure 2 is the block diagram of the demonstration circuit.

The LM94023 is an analog temperature sensor. It sends all temperature data back to the LP5520 driver. After receiving the temperature data, the LP5520 driver checks with the EEPROM for the corrected, temperature-compensated PWM values and based on the compensated values, drive the R, G and B LEDs respectively. This will then ensure that the RGB LEDs emit truly white lights.

Calibration of RGB LEDs

In order to emit truly white light, all RGB LEDs must undergo precise calibration. The RGB LED can only emit white light when the intensity of the red, green and blue lights (primary colors) is at the correct level. The intensity of light of each color will vary with the change of temperature while their respective wavelengths, especially that of red light, will also vary with temperature changes. In order to maintain the same light intensity throughout, white balance should be compensated very accurately.

The LP5520 driver allows the respective changes in intensity and wavelength to be compensated according to the values provided by the typical intensity versus temperature function of the RGB LED. Throughout the process of correction, the PWM value determines the intensity of light of a particular color.

Since all LEDs undergo adjustments during production, any slight difference between various parts can be ignored and because room temperature is in the center of the temperature range, the sample performs best at this temperature. As the temperature moves towards the two extremes, the difference in color will be more apparent. Figure 3 shows the block diagram of the correction circuit.

Specific correction steps:

1) Switch to the Manual Operation Mode of the circuit and set the LED current. The LED of each color may have a different current and this means setting the PWM value. Theoretically, in the highest temperature range, the PWM mode operates at its peak duty cycle. In practice, however, the difference in the magnitude of the current must not exceed 50%.

2) Set the first temperature point (the highest temperature that can be measured - it should be slightly higher than 100ºC).

3) For the intensity of the blue light, a default value may be used (e.g. 1500 should be used for 4096 on the scale - this depends on the type of RGB LED used). In order to take full advantage of the PWM range, the PWM value of red light at high temperatures should be around OxF00 (3840). The software program will then ensure that the PWM values of all LEDs be re-set until the white light emitted meets specific color requirements. In order to ensure the highest degree of precision for all measurements, the amplitude of the highest frequencies measured by an optical attenuator on an almost full-range basis is then adjusted.

4) Change the temperature to the next measurement point (5ºC lower). A new PWM value is then used while white balance is maintained throughout by the software program. Once the temperature reaches the pre-set point, the PWM value of each LED is then stored. (The lowest temperature point used is slightly lower than -40ºC, with every 5ºC taken as one step change. The hot box used takes about an hour to cool down from its highest temperature to its lowest.)

5) Based on the measured values, a curve is then plotted (Figure 4).

Conclusion

The use of an internal correction memory enables the designer to use the LP5520 driver conveniently to control the RGB LED and ensure that it will produce a truly white light across a wide temperature range. This will then enable the LCD monitor to display the best possible images on the screen. In addition, the end-user may also adjust the LCD display according to individual preferences.

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Perpetuating and Securing Power…

Reported by Cliff Keys, Editor-in-Chief, PSDE

The power grid is becoming an extremely sensitive topic, both in Europe and in the US. In acknowledgement we will run a special report on this very topic in the September issue in Europe and the September-October issue in North America. Forming the backbone of all industry and vital for consumers alike, this huge arterial network is also coming under attack from infiltrators and hackers. The implications of any serious downtime to the network, whether due to equipment failure or through malicious interference, are too terrible to comprehend. Here, the power industry is the vital element. Look out for the report.

On May 27, 2009 the world's largest solar technology trade fair, Intersolar, will once again open its doors. Since it was first held, Intersolar has established itself as the industry's leading international trade event, attracting manufacturers, suppliers, wholesalers and service companies alike. It takes place for the second time at the New Trade Fair Center Munich (Neue Messe München) from May 27-29, 2009. The show focuses on photovoltaics, solar thermal technology and solar architecture. This year, the show will feature an additional hall, specifically designated for photovoltaic production and technology. Around 1,300 exhibitors, with $100{,}000m^2$ of exhibition space over nine halls, will welcome visitors from all over the world. This is a 30% increase in space, compared to 2008. For details follow www.intersolar.de.

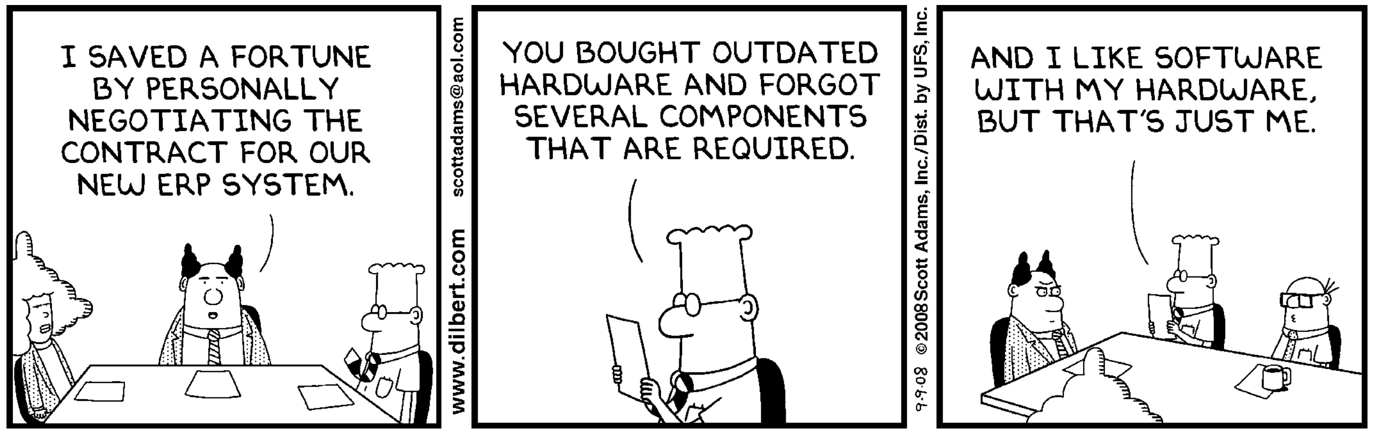
However, according to IMS Research's latest analysis, the global PV market is set to contract for the first time in 2009 in terms of new installations.

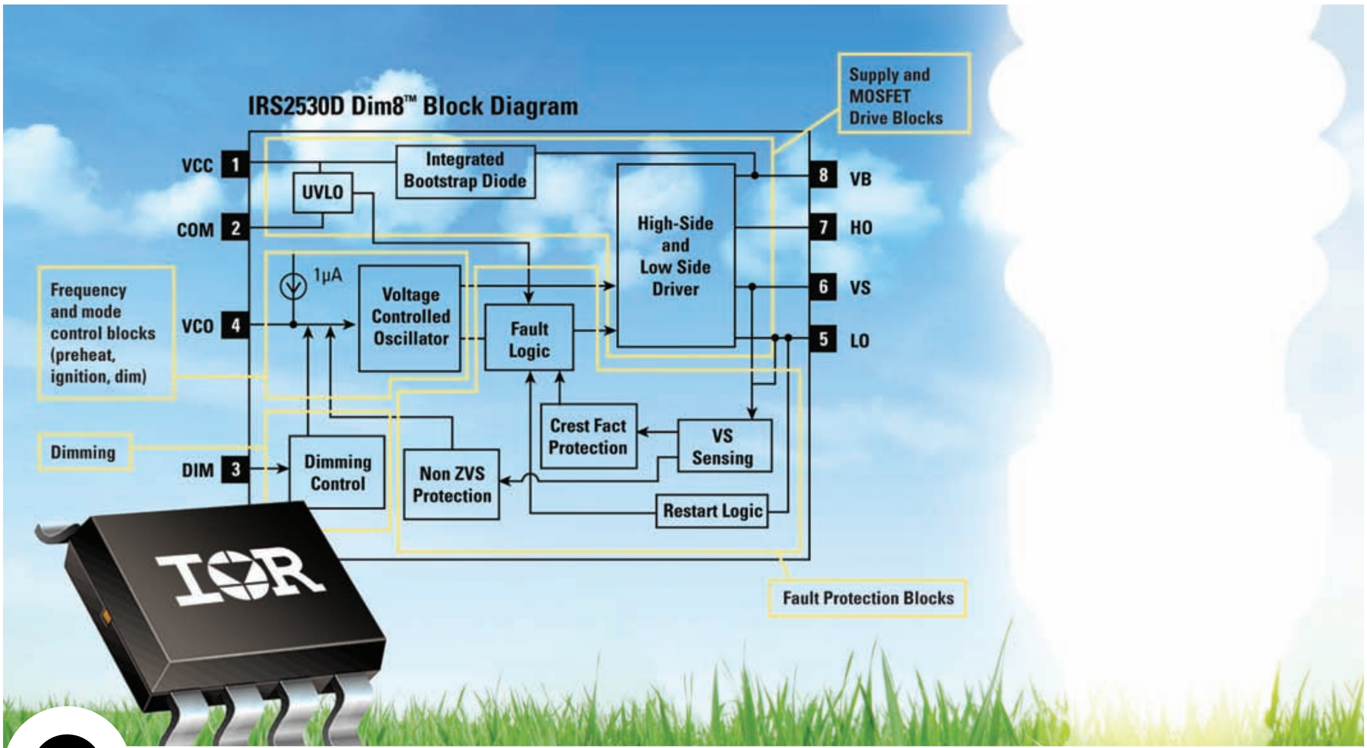
The analysis shows that although the PV market doubled in 2008 in MW terms, a contraction in shipments is anticipated in 2009. This will be caused by the sudden drop-off in demand from Spain, with its newly implemented 500MW cap. This is likely to result in a shortfall of some 1.5-2GW in 2009. Although this will in part be counter-balanced by growth in Italy and Eastern Europe, the dramatic decline of the Spanish market will lead to an overall drop in worldwide shipments.

Research Analyst Sam Wilkinson commented, "Despite credit issues, most major PV markets look healthy and are showing promise of significant growth. However, even if their countries' solar capacities grow at the high levels they saw in 2008, they cannot make up for the unprecedented contraction that the Spanish market will see this year. Many analysts are now predicting a decline in PV module revenues this year."

In spite of this, underlying demand for PV remains very healthy; long term, double-digit annual growth rates can be expected. The market is likely to see dramatic changes in the next few years, with the emergence of new technologies such as micro-inverters; and the development of new and attractive regional markets such as the US, which to date has made up a low proportion of the overall global market. Difficulties in obtaining financing will restrain US market growth this year. However, in the medium term it is anticipated to become one of the largest markets for PV.

www.powersystemsdesign.com/greenpage.htm

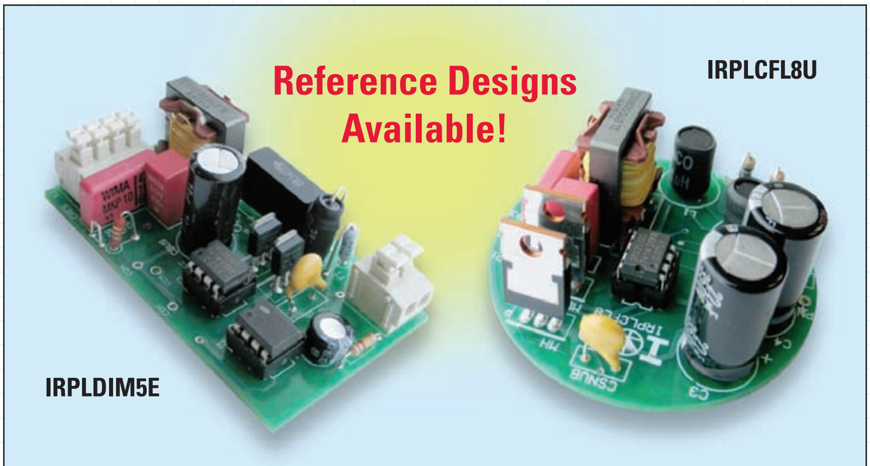




Slash Component Count; Simplify Design

IRS2530D *DIM8™* dimming ballast control IC with half-bridge driver in compact 8-pin form factor.

Part Number	Package	Voltage	Dimming	Fixed Dead Time
IRS2530D	8-lead DIP and 8-lead SOIC	600V	10%	2.0 μs



Requiring only several small external components, the IRS2530D significantly simplifies and shrinks circuit design and delivers a dimming system performance of up to 10 percent for compact fluorescent lamps as well as linear ballasts.

IRS2530D *DIM8™* Features:

- 8-pin dimming ballast controller
- Dimming to 10%
- Flash-free start at all dimming levels
- Fully integrated lamp failure protection

For more information call +33 (0) 1 64 86 49 53 or +49 (0) 6102 884 311
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