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Power Systems Design: Empowering Global Innovation

SPECIAL REPORT: LIGHTING, VIDEO, SURVEILLANCE & SECURITY (pg 31)

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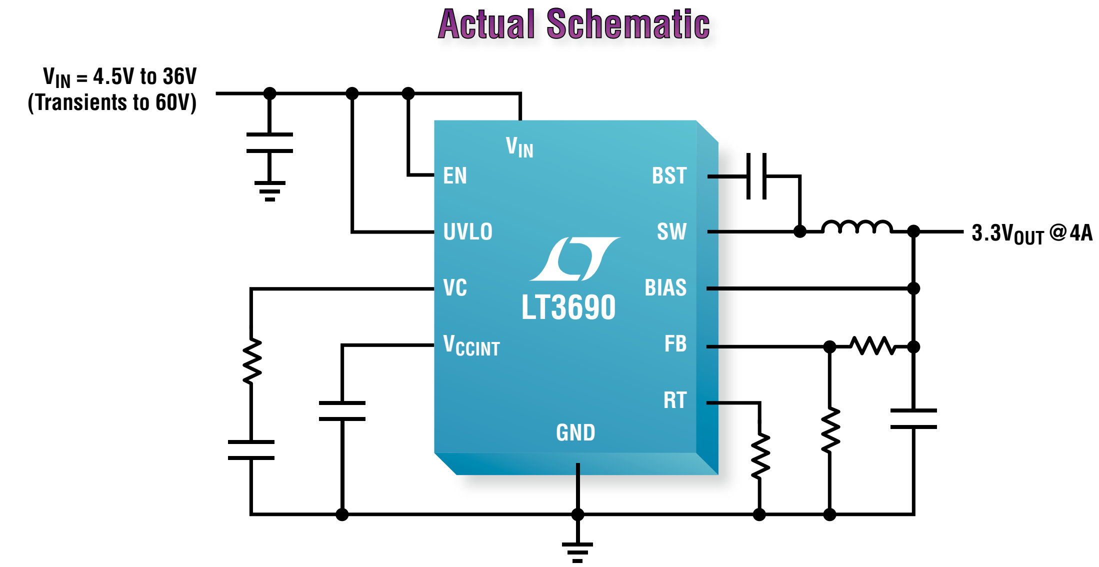

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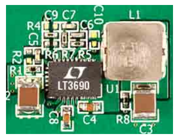

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COVER STORY
High Power Systems (pg 13)

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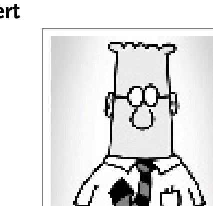

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LIGHTING AND SECURITY

Welcome to this issue of PSD where we carry a Special Report on Lighting, Video, Surveillance & Security, covering the very latest products, technologies and trends in this vital and fast expanding part of our industry.

There have been many advances from the power industry to demonstrate solutions to the regulatory pressures, legislation, need for heightened security and intense competition to help conserve energy and maximize efficiency.

With the traditional incandescent bulbs swiftly disappearing from the supermarket shelves and with even the compact fluorescent offerings looking less inviting, it looks as though the LED is taking its place in the marketplace as the 'Fixture of the future.'

But it has not always been so cut-and-dried. The early offerings which many early-adopters paid high sums of money for, did not deliver on the promise of 50k hours of carefree operation. In fact, the thermal problems had not been fully considered and many fixtures simply burnt out.

Nowdays the lesson has been painfully learnt and the products on the shelves are of much higher quality. Early-adopters can seem trendy but the lesson has been learnt at a cost.

Rising electricity demand, the emergence of the smart grid, and increased interest by consumers and governments in conserving energy, is forecast to dramatically grow the market for energy management systems (EMS) through 2015. While historically seen in limited installations outside of manufacturing and industrial environments, new industries are forecast to adopt EMS, including retail, public buildings, hospitals, and SME. In 2010, IMS Research estimated the world market for EMS to have been worth almost $1 billion globally. Double-digit growth is forecast for sub-metering, networking, software, and services through 2015, when global EMS revenues are predicted to climb over $1.5 billion.

The disaster in Japan has exposed how the focus of electronics manufacturing in a single country can massively impact the highly interconnected global technology industry, reported IHS iSuppli. Because of this, it's worthwhile to consider what could happen if a production disruption were to strike other key electronics production regions where manufacturing is highly concentrated. These regions include Taiwan, South Korea and certain areas of China. As we move forward, the global electronic industry will have to learn how to manage potential disruptions in various regions.

I hope you enjoy this issue and our new online service. Please keep your valuable feedback coming in and do check out Dilbert at the back of the magazine

All the best,

Cliff
Editorial Director & Editor-in-Chief, Power Systems Design
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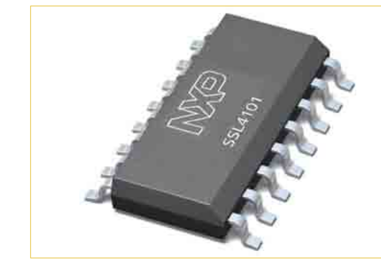
SOLID STATE LIGHTING SOLUTIONS

NXP brings new levels of efficiency to industrial, warehouse and street light applications.



NXP Semiconductors recently announced an addition to its broad GreenChip™ SSL family of products, the GreenChip SSL4101T controller IC, which offers new levels of professional-grade performance for Solid State LED lighting power supplies. The GreenChip SSL4101T enables LED lighting for medium to high power commercial and professional applications with industry-leading performance in Total Harmonic Distortion (THD) of less than 20 percent, a high Power Factor (PF) of 0.99, and high efficiency of 94 percent.

GreenChip solutions for power and lighting

Aimed at improving energy efficiency and reducing carbon emissions, NXP's GreenChip technology lies at the heart of its cost-effective, high-efficiency power and lighting ICs. GreenChip products are suitable for any device that draws AC power and offer many additional benefits, from minimal standby power (as low as 10 mW) to CFL-dimming capability.

The GreenChip III+ is the third generation of green Switched Mode Power Supply (SMPS) controller ICs. The SSL4101T combines a controller for Power Factor Correction (PFC) and a flyback controller. Its high level of integration allows the design of a cost-effective LED lighting application power supply with a very low number of external components. The SSL4101 is designed for the medium power lighting market.

"Today's LED luminaire manufacturers are demanding increased power supply efficiency at lower costs in order to address new LED application segments," said Jacques Le Berre, director of marketing and business development for lighting solutions at NXP Semiconductors. "GreenChip technology lies at the heart of NXP's cost-effective, highly-efficient power and lighting ICs. The newly announced GreenChip SSL4101T offers a professional-grade solution with levels of efficiency of up to 94 percent, which is enabling LED adoption into a wider-range of professional lighting applications such as high bay and low bay lighting found in warehouses; and street lighting, where brightness and dependable illumination are essential."

The GreenChip SSL4101T is based on NXP's unique high voltage process and enables direct start-up from the rectified universal mains voltage in an effective, eco-friendly way. The multi-chip module contains both a flyback controller and a controller for Power Factor Correction, and provides high efficiency at all power levels. The new GreenChip SSL4101T is ideally suited for LED lighting applications that require a very efficient, low THD, high PF, true universal input voltage and cost-effective power supply solution ranging between 10 W and 300 W.

Availability

The GreenChip SSL4101T will be available in April 2011. Pricing starts at US $3.60 per piece. Further information on the GreenChip SSL4101T is available at: http://www.nxp.com/pip/SSL4101T.html
www.nxp.com

POWERING FPGA PROTOTYPING

Reported by Cliff Keys, Editorial Director, Editor-in-Chief, Power Systems Design

I had the pleasure to talk with Doug Amos, Business Development Manager, Solutions Marketing at Synopsys. With 25 years experience in the field of FPGA and ASIC design, Doug has designed or supported countless FPGA and ASIC designs, either as an independent consultant or working with leading vendors. Doug is an expert on FPGA design and FPGA-based prototyping and co-authored the FPGA-based prototyping Methodology Manual (FPMM) in 2011.

FPGA prototyping has been the mainstay for SoC designs for many years. The tools required to optimize partitioning, power and performance, although complex in their make-up, are becoming much easier to use.

The main benefit is in verifying the HW and SW together, well in advance of the first SoC silicon becoming available. "With the high probability of a SoC finding its way into consumer devices such as cell-phones or other portable applications, the power aspects are a major consideration. Prototyping in FPGAs is a vital part of the development of the final chip. Prototypers see their goal as 'interfacing with the real world'. When the first silicon comes back for test and evaluation, this is not the time to start wondering where things went wrong," Doug explained, summarizing the traditional challenges in prototyping in the following 'three laws of prototyping':

1. SoCs are larger than FPGAs
2. SoCs are faster than FPGAs
3. SoCs designs are FPGA-hostile

The many and powerful ways that prototypers overcome these challenges are described in the FPMM, which is available by download from the FPMM website.

With the best tools, boards, devices and IP available today, even the most daunting SoC design can be converted into a good, working FPGA prototype, but this is seen by Synopsys as the minimum requirement. Traditionally SoC designers and FPGA prototypers have been looked at as two separate entities, and yet an optimized outcome can only be achieved when all are working towards the same goal. This is called Design-for-Prototyping. Much more can be done by using a Design-for-Prototyping approach to smooth the way through a SoC project, not least in making the SoC design more FPGA-prototyping-friendly in the first place. This can save weeks or even months in the design cycle and translates directly into revenue for the design house.

Whereas a silicon provider can provide the best fit process and geometry, including libraries that trade-off between power and performance, users can also use advanced techniques such as clock frequency scaling and dynamic voltage scaling. The FPGA prototype, however, is more focused on the functionality of the design and reaching the performance needed to allow the software run in real-time. The tools at the FPGA prototyper's disposal, such as Certify prototyping tools from Synopsys, can aid the fast delivery of a prototype that already has some of the power-mitigation techniques included.

Many of these mitigation functions, such as Gated Clock Conversion and manipulation which would otherwise be a laborious task for the FPGA prototyper, are now completely automated in the tools now available.

In the end, the sooner prototypers can provide a working system, the sooner the HW and SW verification can be completed; Today, the software content is the critical path item, so the time saving factor again, adds to the 'bottom line'.

This is just a snapshot of what I could cover with Doug. It is a vital and interesting area in our industry and PSD will go deeper into this in forthcoming issues. From my perspective I was grateful for Doug's explanations and for the copy of the FPMM that I have as reference.

www.synopsys.com

POE POWERS TRANSITION VIDEO SURVEILLANCE

By Gary Wong

The video surveillance industry has long been dominated by analogue video surveillance products. However, in recent years there has been a strong and sustained trend towards network video surveillance equipment.

IMS Research forecasts that by 2014 global revenues of network video surveillance equipment will surpass those of analogue video surveillance equipment.

This trend is driven by features. Network video surveillance systems can offer a number of advantages over analogue including higher resolution image quality, video analytics and increased scalability and flexibility. A contributing factor to enable increased scalability and flexibility is PoE.

PoE can enable a greater degree of flexibility when designing and planning video surveillance installations. Unlike analogue video surveillance systems, systems integrators/installers are afforded luxury of increased options when positioning network security cameras. Due to PoE, camera placement is no longer restricted by the availability/location of power supplies.

The use of PoE can make a network video surveillance deployment more cost effective than analogue, dependent on the type and size of a video surveillance installation. For a greenfield project, assuming that an IP network infrastructure is already in place, the investment required for additional infrastructure to support a network video surveillance system is minimal. However, to install an analogue video surveillance solution in this scenario, a separate coax (or other transmission medium) infrastructure would need to be established. PoE enabled network cameras, drawing power from the network via Ethernet, can mitigate the requirement for additional investment in power infrastructure for video surveillance.

By utilising PoE, the implementation of power redundancy for a network video surveillance system can be simpler than for an analogue installation. By leveraging the distribution of power over the IP infrastructure, an uninterruptible power supply (UPS) can be deployed in a single point within the network infrastructure.

While PoE is by no means the sole factor driving the transition from analogue video surveillance to IP video surveillance, it does provide compelling benefits for security systems integrators/installers. By 2014, IMS Research forecasts that over 50% of network cameras, in terms of unit shipments, will be either PoE or PoE+ enabled.

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IMS Research

www.imsresearch.com

TRANSFORMER IMPEDANCE MEASUREMENTS

By Dr. Ray Ridley

Dr. Ridley reminds designers of the crucial importance of measuring impedances of every magnetic element that is placed in your power electronics circuit, regardless of the power level. Three impedance measurements versus frequency will speed up your development process, improve the performance of your design, and ensure manufacturing quality.

Magnetic Components
I learned very early in my career as a power designer that transformers and inductors should be characterized versus frequency, regardless of their power level or frequency of operation. This has been part of design procedure for almost 100 years, ever since the use of transformers and motors became widespread.

I have always assumed that all engineers made impedance measurements, but at a recent trip to the PCIM conference in Nuremberg I discovered that most designers do not take the time for this Instead, they rely on just a few static component parameters from their magnetics vendors. Most of the manufacturers of magnetics components also do not make impedance versus frequency measurements since they are usually unaware of the value of such information or they lack the necessary training and equipment to make the measurements.

Transformers and inductors come in many shapes and sizes. Figure 1 shows two magnetic elements – one is a forward transformer for a 60-100 W application and it measures about 3 x 3 cm. This component is dwarfed by the 1500 A inductor for MW applications. Regardless of the power level, the same impedance measurements should be collected for these components.

The equivalent circuit for a two winding power transformer is

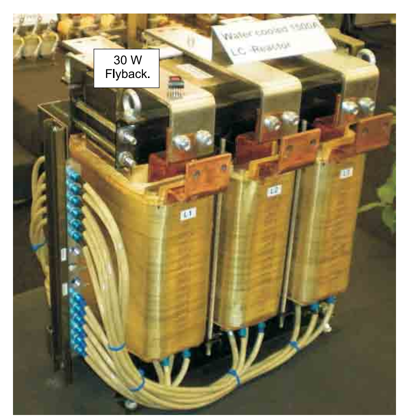

Figure 1: There is a vast range of magnetic components used in power electronics. All of them should be measured across a full frequency range to extract useful design information and important component values.

shown in Figure 2. Notice that many of these components, denoted by a red symbol, are strongly nonlinear. The winding resistances Rp and Rs,vary widely

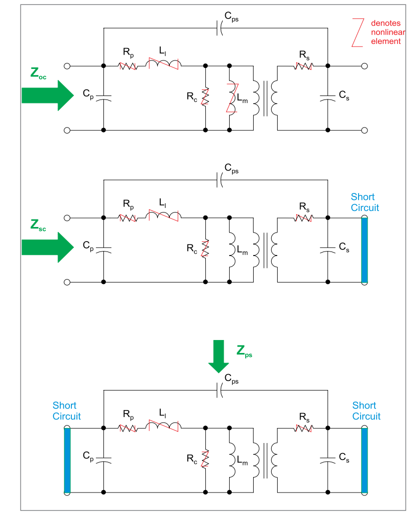

Figure 2: Approximate equivalent circuit of a two-winding power transformer. Three impedances should be measured for this component.

with frequency, sometimes by two orders of magnitude for multilayer windings [5]. The core loss is represented by Rc, and this is a strong function of frequency, excitation level, temperature, and for some materials and applications, the age of the core [3].

The leakage inductance Ll, has significant frequency dependence due to proximity effects. Magnetizing inductance, Lm, will vary depending on core excitation level, and its value can drop drastically during saturation of the core. For ungapped, high-permeability transformers it is also a function of the test excitation level at low frequencies.

The winding capacitances Cp, Cs, and the primary-to-secondary capacitance, Cps, are a function of the surface areas of the windings and the separation presented by the insulation. They can have some variation with frequency, but are usually treated as constant components.

Impedance Measurements and Capacitances
There are three impedances that should be measured for a two-winding transformer. These are the primary impedance with the secondary open, the primary impedance with the secondary shorted, and the primary-to-secondary impedance with both primary and secondary windings shorted. (If you have a step-up transformer, the measurements should be made from the secondary side.) These test setups are shown in Fig. 2, and example measurements are shown in Fig. 3.

From these impedance measurements, we can extract information about the components of the equivalent circuit of Fig. 2, either directly or indirectly. This

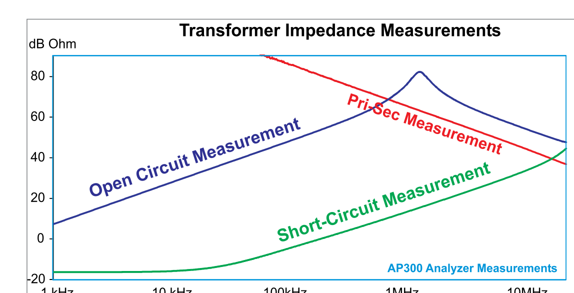

Figure 3: Typical results for the three impedance measurements for a transformer.

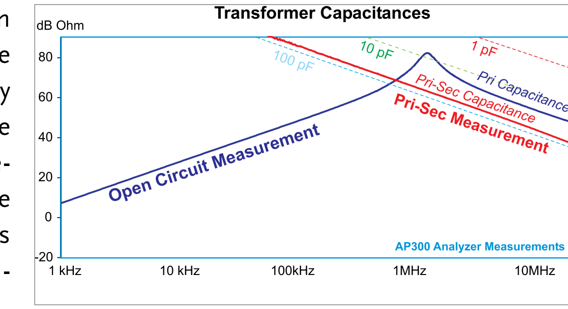

Figure 4: Winding capacitance reference values

is very useful for comparing different transformer designs for the same application, or for assessing components provided by different vendors.

Figure 4 shows reference capacitor values for the high-frequency impedances measured for the transformer. It is important that these capacitances are measured only at the frequencies where the impedances are capacitive. Trying to extract the capacitance values at lower frequencies where the components are inductive will result in inaccurate values.

Your measurement setup must be capable of resolving capacitances as small as 1 pF, since this is the normal limit of the range for small switching transformers and inductors. Even small capacitances can have a big effect on waveforms when looking at the switching waveforms in modern high-frequency devices.

It is very important to control the primary-to-secondary capacitance of a transformer since this has a strong impact on the common-mode noise performance of the converter. This is usually a higher value of capacitance than the primary capacitance, and is a function of the insulation distance between primary and secondary.

Resonant Frequency and Inductances

It can be seen from the open-circuit impedance measurement in Fig. 4 that the resonant frequency of the transformer is quite low, less than 2 MHz for a 100 kHz application. This is not a problem for a forward converter. The value of this resonance does not affect the o(peration at all except for the contribution of capacitive current during turn-on. While we do not care about the absolute value of this resonant frequency compared to the switching frequency, it is very important that it stays consistent from one sample to another in order to guarantee manufacturing consistency.)

What is important is that the resonant dip in impedance caused by the leakage inductance and output capacitance is at a high frequency. For this example, the resonant dip cannot be seen since it is higher than the measurement range of 30 MHz.

Figure 5 shows reference values of inductance for the high-frequency impedance measurements. It is recommended to extract values

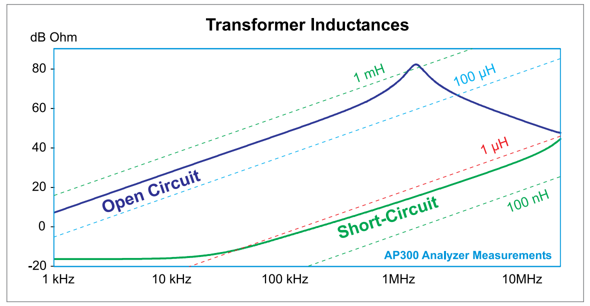

Figure 5: Winding inductance reference values. Notice that the leakage inductance asymptote does not have a 20 dB/decade slope due to a changing inductor value.

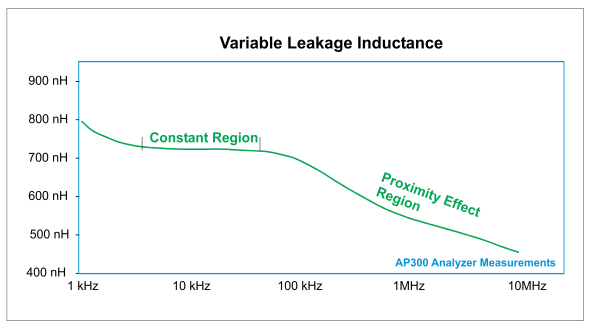

Figure 6: Measured leakage inductance with frequency.

of magnetizing and leakage inductance at frequencies where the components are strongly inductive. For short circuit measurements, this is usually at the switching frequency or higher.

The value of the leakage inductance of the transformer is shown in Fig. 6. The inductance for most transformers is frequency-dependent in the range of the switching frequency, as can be seen in this measurement. It is very important that your transformer leakage inductance is specified at a particular frequency if you want to use this parameter to help control manufacturing variation. I frequently see manufacturing documents where the leakage inductance is too loosely specified to be of value in ensuring properly-manufactured parts.

Summary

Every power inductor and power transformer should be properly characterized in terms of its impedance for a full range of frequencies up to at least 10 MHz for typical switching frequencies. This is a tremendous help in resolving problems with your switching waveforms, EMI, snubber design, and magnetics performance. It is also invaluable in showing problems with manufacturing errors and poor workmanship.

Whether you are designing or using magnetics at 1 W or 1 MW, the importance of making these measurements cannot be overstated. Do not overlook or skip this crucial part of your design and manufacturing process. It will always save you time and money during your product development.

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COORDINATED CIRCUIT PROTECTION

LED Lighting, Video and Security Systems

By Matt Williams

As lighting technologies transition from power-hungry incandescents to cold-cathode fluorescent lamps (CCFLs), and now to LEDs, it is clear that while end-users are willing to pay more for greener light there is an inherent expectation that longer life and improved reliability will be the net benefit of that investment.

In addressing these expectations, design engineers must consider a wide range of variables which influence the performance and lifetime of their product. From power management to power density to overvoltage and overtemperature protection, the uniqueness of LED technology presents new challenges that are not associated with older technologies.

LED technology has advanced rapidly, with improved chip designs and materials facilitating the development of brighter, more energy-efficient, and longer-lasting light sources that can be used in a wide spectrum of applications. In spite of the technology's growing popularity, it remains a fact that excessive heat or inappropriate applications can dramatically affect LED lifetime and performance.

Resettable polymeric positive temperature coefficient (PPTC) devices have demonstrated their effectiveness in a variety of LED lighting applications. Like traditional fuses, they limit current after specified limits are exceeded. However, unlike fuses, PPTC devices have the ability to reset after the fault is cleared and the power is cycled.

A variety of overvoltage protection devices including metal oxide varistors (MOVs), electrostatic discharge (ESD) surge protection devices, and polymer-enhanced Zener diodes can be used in a coordinated scheme with PPTC devices to help improve LED performance and reliability.

LED Driver Input and Output Protection

LEDs are driven with a constant current, with the forward voltage varying from less than 2V to 4.5V, depending on the color and current. Older designs relied on simple resistors to limit LED drive current, but designing an LED circuit based on the typical forward voltage drop as specified by a manufacturer can lead to overheating of the LED driver.

Overheating may occur when the forward voltage drop across the LED decreases to a value significantly less than the typical stated value. During such an event, the increased voltage across the LED driver can result in higher total power dissipation from the driver package.

Today, most LED applications utilize power conversion and control devices to interface with various power sources, such as the AC line, a solar panel or battery power, to control power dissipation from the LED driver. Protecting these interfaces from overcurrent and overtemperature damage is frequently accomplished with resettable PPTC devices.

The PPTC device has a low-resistance value under normal operating currents. In the event of an overcurrent condition, the device "trips" into a high-resistance state. This increased resistance helps protect the equipment in the circuit by reducing the amount of current that can flow under the fault condition to a low, steady-state level. The device remains in its latched position until the fault is cleared. Once power to the circuit is cycled, the PPTC device resets and allows current flow to resume, restoring the circuit to normal operation.

While PPTC devices cannot prevent a fault from occurring, they respond quickly, limiting current to a safe level to help prevent collateral damage to downstream components. Additionally, the small form factor of PPTC devices makes them easy to use in space-constrained applications.

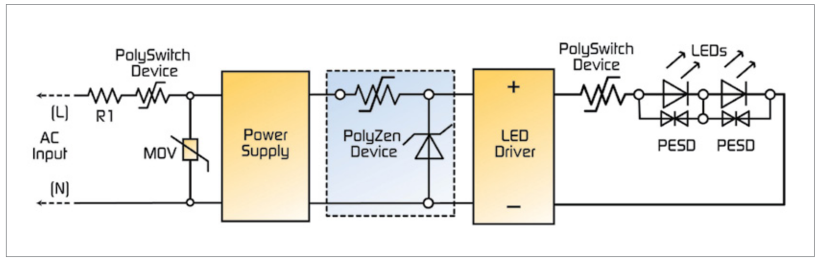

Figure 1: Coordinated protection scheme using PolySwitch PPTC devices and MOV devices for SMPSs (left), and PolyZen, PolySwitch and PESD devices for LED driver inputs and outputs (right).

Figure 1 illustrates a coordinated protection scheme for switch-mode power supplies (SMPSs) and LED driver inputs and outputs. SMPSs offer the size, weight, and energy-saving advantages required for consumer electronics, and have continued to replace linear-regulators in many applications. However, because SMPSs lack the inherent resistance of prior-generation designs, they often require more robust circuit protection. PPTC devices can help manufacturers meet UL60950-1/LPS (Limited Power Source) requirements for SMPSs and help improve equipment safety and reliability.

As shown on the left-hand side of the figure, a PPTC device, such as a PolySwitch™ device, can be installed in series with the power input to help protect against damage resulting from electrical shorts, overloaded circuits or customer misuse. Additionally, an MOV placed across the input helps provide overvoltage protection in the LED module. The PPTC device may also be placed after the MOV. Many equipment manufacturers prefer protection circuits combining PPTC devices with upstream fail-safe protection. In this example, R1 is a ballast resistor used in combination with the protection circuit.

The right side of Figure 1 shows a coordinated circuit protection design for an LED driver and bulb array. A PolyZen™ device placed on the driver input offers designers the simplicity of a traditional clamping diode while obviating the need for significant heat sinking. Developed by TE Circuit Protection, the polymer-protected precision Zener diode helps provide transient suppression, reverse bias protection and overcurrent protection in a single, compact package.

As shown in Figure 1, a PolySwitch

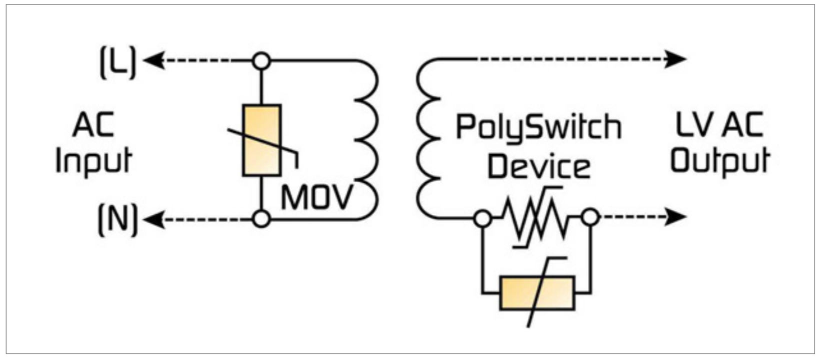

Figure 2. A coordinated protection scheme for Class 2 power sources

PPTC device on the driver output can help protect against damage caused by inadvertent short circuits or other load anomalies. To fully leverage the PolySwitch device, it can be thermally bonded to the metal core circuit board or LED heat sink. To help prevent damage caused by an electrostatic discharge (ESD) event, ESD protection devices, such as low-capacitance (typically 0.25 pF), small-form-factor PESD devices can be placed in parallel with the LEDs.

Meeting Class 2 Power Supply Safety Standards

Utilizing a Class 2 power source in a lighting system can be an important factor in reducing cost and improving flexibility. Inherently limited power sources – a transformer, power supply, or battery – may include protective devices as long as they are not relied upon to limit the output of the Class 2 supplies.

Non-inherently limited power sources, by definition, have a discrete protective device that automatically interrupts the output when the current and energy output reaches a prescribed limit.

A variety of circuit protection devices can help protect Class 2 power sources for LED lighting applications. Figure 2 illustrates how a coordinated circuit protection strategy, employing an MOV on the AC input and a PolySwitch device on an output circuit branch, can help manufacturers meet the requirements of UL1310 paragraph 35.1 overload test for switches and controls.

LED Backlighting Protection

Advanced LCD technology has resulted in larger screens, wider viewing angles, and higher-quality video images. However, as LCD-TV screens grow bigger and brighter, they require more voltage and current to operate, increasing the need for more robust and reliable circuit protection techniques.

LED backlighting enhances the viewing experience, offers more flexible backlight architectures, and enables thinner display designs than conventional CCFL technology. Other benefits include higher efficiency, reduced power consumption, a longer lifespan, enhanced durability, and better contrast ratios for clearer definition on-screen.

As mentioned earlier, LEDs require precise power- and heat-management systems, since most of the electrical energy supplied to an LED is converted to heat rather than light. Power line coupled transients and surges can also reduce LED lifespan, and many LED drivers are susceptible to damage resulting from improper DC voltage levels and polarity. LED-driver outputs may also be damaged or destroyed by an inadvertent short circuit, and powered ports are susceptible to damaging overvoltage transients, including ESD pulses.

Most LED drivers for LCD-TV applications include built-in safety features, including thermal shutdown, as well as open and short LED detection. However, additional overcurrent protection devices may be needed to help protect integrated circuits (ICs) and other sensitive electronic components.

PPTC devices can also be used to help prevent thermal runaway, which may occur if the monitor's cooling vent is blocked. Due to its ability to detect and respond to overtemperature events, a PPTC device, mounted in the

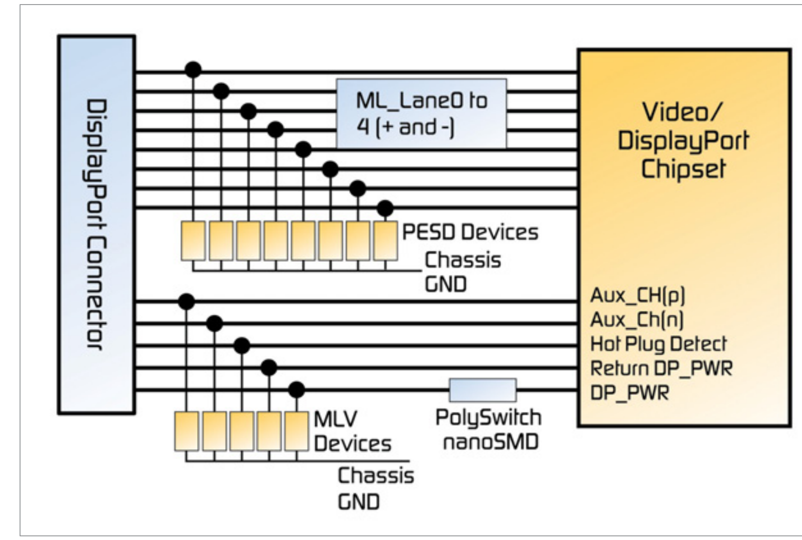

Figure 3. Typical DisplayPort circuit protection design utilizing MLV devices, PESD suppression devices and a PolySwitch overcurrent protection device

appropriate location, can interrupt current in the event the LEDs are operating without adequate ventilation.

In LED backlighting applications the PPTC device is connected in series with the LED to help provide overcurrent protection. To fully leverage the device, it can be thermally bonded to the metal core circuit board or LED heat sink. If the LED is not equipped with built-in ESD protection, a PESD protection device, placed in parallel with the LED, can help protect against damage resulting from ESD surges.

Overcurrent and Overvoltage Protection for I/O Ports

As data rates increase and circuitry becomes smaller and more sensitive, protecting equipment from damage caused by circuit transients becomes even more critical. The HDMI, USB and DisplayPort specifications require that end-user-accessible, powered connectors implement overcurrent protection. The overcurrent protection device must be resettable, without user mechanical intervention, and its preset trip limit must be above allowable current transients in order to prevent false trips.

PPTC devices have demonstrated their effectiveness in a variety of high-speed interface applications. Their low resistance, fast time-to-trip and small form factor have made them the preferred method of overcurrent protection in many powered bus architectures.

Powered ports are also susceptible to damaging overvoltage transients, including ESD pulses. Figure 3 shows a typical circuit protection design utilizing a PolySwitch device for overcurrent protection and PESD devices and MLVs, which help protect against damage caused by overvoltage transients.

Protecting Security and Fire Alarm Systems

Security and fire alarm systems are designed for operation within specified current and voltage ratings. If these ratings are exceeded due to short-circuit or voltage transients, components may sustain permanent damage and the equipment may fail. Power supplies and circuit traces must also be protected against faults that may occur during installation or in the case of a shorted back-up battery.

Modems are frequently utilized in security systems to automatically alert the fire or police department in an emergency. These telecom lines must be protected from damage caused by lightning strikes, power-line crosses or AC power induction. Alarm systems must comply with the UL864 standard, which mandates that soldered-in fuses are not allowed to qualify a power supply as inherently limited. If the system has provisions for connecting to a telephone line it must comply with UL60950 and TIA 968-A in North America, as well as ITU K.21 in Europe and other parts of the world.

Fuses have typically been used for overcurrent protection in security and alarm systems. However, UL864 and UL60950 pose difficult challenges for these

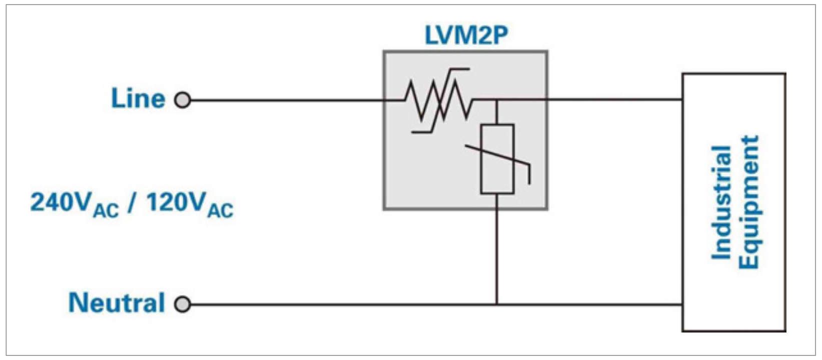

Figure 4. 2Pro device in line voltage protection application

devices, which can fatigue under certain test conditions. More importantly, fuses are single-use components that must be replaced after a fault occurs.

Many equipment manufacturers prefer to use PPTC devices, because, unlike fuses, PPTC devices do not generally require replacement after a fault event, and allow the circuit to return to normal operating condition after the power has been cycled and the overcurrent condition is eliminated. Their small form factor helps conserve valuable board space and, in contrast to traditional fuses that require user-accessibility, their resettable functionality allows for placement in inaccessible locations. Because they are solid-state devices, they are also able to withstand mechanical shock and vibration.

A variety of methods can be used to help protect security and fire alarm systems from overvoltage conditions caused by switching or lightning transients. There are two major categories of overvoltage protection devices – clamping devices and foldback, or "crowbar" devices. By integrating PPTC technology with an MOV, TE Circuit Protection has developed another circuit protection device that can help equipment manufacturers meet the current telecom protection requirements. The 2Pro™ device is a thermally protected varistor that helps provide current limiting during overcurrent events and voltage clamping during overvoltage events. As shown in Figure 4, the device utilizes three leads. The first lead is connected to the PPTC element, the second lead is connected to the MOV/PPTC series connection (providing a path to ground), and the third lead is connected to the MOV.

This integrated device approach helps reduce component count and improve equipment reliability by preventing thermal runaway and maintaining varistor surface temperature at less than 150°C. This helps prevent the device from reaching unsafe temperatures that may result from overvoltage transients. The device's small footprint, resettable functionality and coordinated protection capabilities make it suitable for a wide range of telephony and security system applications.

Summary

A coordinated circuit protection scheme can help designers reduce component count, provide a safe and reliable product, comply with regulatory agency requirements, and reduce warranty and repair costs. Although specific standards address various fault protection needs in LED lighting, video and security systems, it is always good practice to apply protection devices as close as possible to the chip sets' I/O and Vcc pins, as board traces may be susceptible to conducted transients.

As with any circuit protection scheme, the effectiveness of a solution will depend on the individual layout, board type, specific components, and unique design considerations. TE Circuit Protection works with OEM customers to help identify and implement the best approach.

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LOW ESR TANTALUM CAPACITORS

Public Transport Interface power supplies

By Pavla Skopalová

Fare collection and ticketing systems are an essential part of any public transport network. Systems combine software and hardware elements such as onboard computers and driver interfaces for automated travel terminals, ticket and card validation and ticket vending machines.

All components of the integrated system must comply with reliability and functional requirements of the service provider, yet at the same must be time easy to operate and control in varying –sometimes harsh - climatic environments. User-friendly operation – for example LCD screens with active touch screen fields, audible status indication, contactless keyboards etc - increases the power budget necessitating a more complex power supply and filtering solution.

Industrial switch mode power supplies (SMPS) are typically used for voltage regulation such systems. SMPS use various different low ESR capacitor technologies for filtering; the choice is dependant on required capacitance, operating voltage and temperature, circuit impedance and AC current. Important SMPS requirements include: stable output voltage with load current; good temperature stability; low ripple voltage and high overall efficiency.

Figure 1: CAMEL Card validator and PCB detail

The output capacitor plays a key role in switching power systems as it is used to store the charge and for smoothing. Tantalum capacitors are often chosen because of their stability of capacitance and ESR with temperature and power line voltage fluctuations. For example, this technology has proven its suitability for use in harsh automotive environments as an electrically robust component capable of withstanding vibration and repeated bumps. Tantalum capacitors can be found in different parts of the SMPS circuit design, both on the input and output of SMPS. The design of the CAMEL contactless card validator (Fig. 1) produced

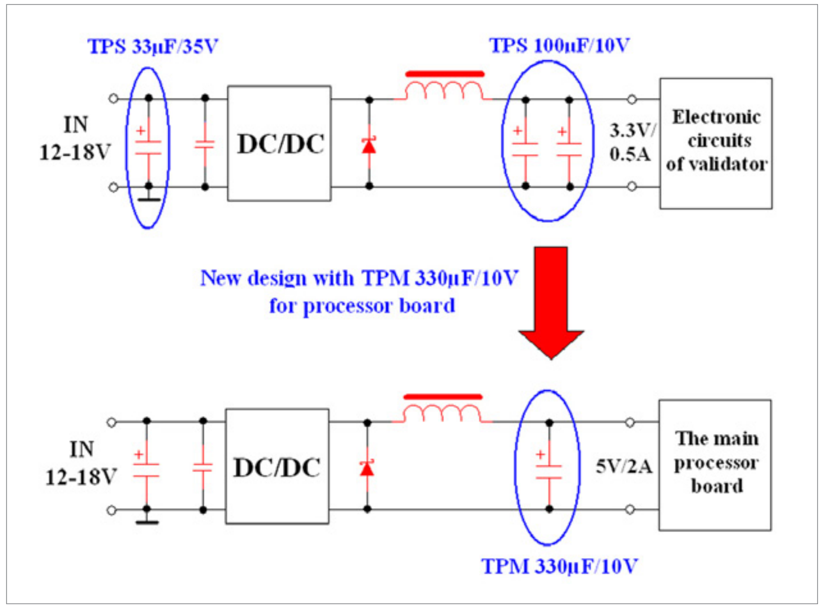

Figure 2: Block diagram of typical power supply unit in the CAMEL card validator

by Mikroelektronika of Czech Republic uses several integrated SMPS.

As the block diagram (Fig.2) of the power supply shows, tantalum capacitors are used either on the input (low ESR TPS D-case capacitors 33µF/35V), or on the output. The parallel

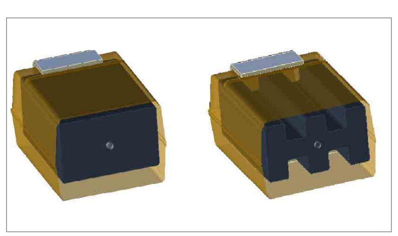

Figure 3: Standard single anode (left) and fluted anode construction (right)

connection of two TPS 100µF/10V capacitors with a 75mΩ ESR limit allows the current to be divided more evenly between both capacitors as compared to using a standard ESR component, therefore electrical stresses are reduced.

The TPS C-case 100µF/10V capacitor uses a special low ESR design of tantalum anode (Fig.3).

The 'fluted' anode design results in a larger outer surface area of the tantalum capacitor anode, which reduces ESR to as low as 75mΩ, delivering both very smooth filtering and also the capability to handle current spikes down to 5V and below. Next generation designs require even higher power performance in a smaller package. To address this requirement, in the prototype of Mikroelektronika's latest card validator the two TPS capacitors on the output are replaced by one low ESR multi-anode TPM E-case 330µF/10V capacitor with ESR down to 23mΩ. Multi-anode construction features several anodes connected in parallel.

This design (Fig. 4) is more robust against current surges and provides an even higher ripple current capability in smaller package sizes which is why it has become accepted as the best choice for industrial power supplies.

Mikroelektronika's CAMEL card validator can be operated using an optical keyboard displayed on the display, which is divided into several active fields imitating the touch screen. Standard ESR 100µF tantalum capacitors in D-case 7343 are used here at lower voltages to supply the pulse needed to switch on the necessary LED diodes.

The CAMEL card validator was introduced in 2007 and has now become well-established. It is available in different hardware versions offering great functional flexibility. Multi-anode tantalum capacitors have been selected for next generation systems - in total 26 tantalum capacitors are used, both on the output as well as input of the SMPS.

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DRIVING LEDs

Choosing the right power supply

By Shane Callanan

LEDs are fast replacing Fluorescent light bulbs and incandescent light bulbs in many lighting applications. In the past these sources could be driven directly from the mains voltage, but this is not possible with LEDs. This paper looks at what an LED is, how to drive it, and also how to choose the right power supply for this requirement.

Like any regular diodes, LEDs are constructed using a semiconducting material which has been 'doped' with impurities in order to create a p-n (positive-negative) junction. Current flows easily from the p-side (anode) to the n-side (cathode), but not in the other direction.

When placed in a circuit supplied by an external power source, current flows, and charge carriers (electrons and holes) flow into this junction from the electrodes which are at different voltages. The electrons and holes are separated by an energy difference known as a 'band gap'.

When an electron meets a hole, it falls across the band gap from the higher to the lower energy level, releasing the band gap energy as a photon of light with a frequency, and hence a colour

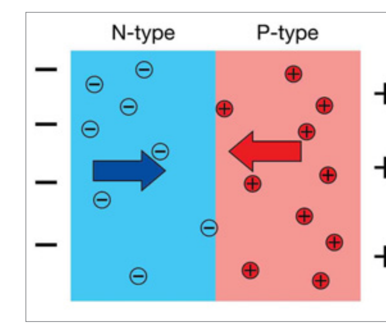

Figure 1: N and P type doping of an LED

Colour	Wavelength (nm)	Band Gap Energy, E (eV)
Infrared	$\lambda>760$	E<1.63
Red	$610<\lambda<760$	1.63<E<2.03
Orange	$590<\lambda<610$	2.03<E<2.10
Yellow	$570<\lambda<590$	2.10<E<2.18
Green	$500<\lambda<570$	2.18<E<2.48
Blue	$450<\lambda<500$	2.48<E<2.76
Violet	$400<\lambda<450$	2.76<E<3.10
Ultraviolet	$\lambda<400$	3.1<E

Table 1: LED Wavelengths and Band Gaps

that corresponds to the band gap energy. This relationship can be expressed using the following equation:

$Eg = hc/\lambda$

Where Eg= Band gap energy
h = Planck's constant
c = Speed of Light

Table 1 shows the wavelengths and band gap energies of a number of coloured lights.

LED manufacturers can 'tune' the band gap energy and hence the wavelength of the light emitted. This is achieved by increasing or decreasing the level of impurities, controlling the composition of the semiconductor. Adding more impurities will lower the band gap energy, and so will increase the wavelength of the emitted light.

The band gap of an LED changes with varying temperature, and the extent of this change can be predicted using Varshni's parameters (empirically measured values which are used in order to calculate temperature dependant band gap energies). This relationship is described in the following equation:

$Eg = Eg|T{=}0\ K - \alpha T2/T+\beta$

Where Eg = Band gap energy
T = Temperature (K)
α, β = Varshni parameters

Since both α and β are constants for a specified LED, as temperature increases, the band gap energy of the LED slightly decreases. As seen previously, decreasing the band gap energy will increase the wavelength of emitted light, will slightly change the colour of the light emitted. This is referred to as temperature dependant spectral shift.

Performance Characteristics of LEDs

The voltage – current relationship of LEDs is given by Shockley's diode equation:

$I = Is(\exp(VD/nVT)-1)$

$VT = kT/q$

Where I = Diode forward current
Is = Reverse bias saturation current
VD = Diode forward voltage
n = Diode ideality factor
VT = Thermal voltage
k = Boltzman's constant
q = Charge on an electron
T = Temperature

Since n, k, q and Is are constant for a given LED at a fixed temperature T, the V-I curve of an LED can be plotted using this equation as in Figure 2.

Shockley's equation also tells us that the forward voltage of the

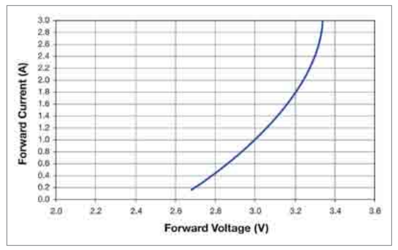

Figure 2: Cree XM-L Current vs. Voltage (25°C)

LED is temperature dependant. For a fixed forward current, as the temperature increases, the forward voltage of the LED decreases. This is because the saturation current Is is also dependant on temperature and can be estimated using the following equation:

$Is(T2) = Is(T1)\exp[ks(T2-T1)]$

Next if we look at the empirical data of the characteristic luminous flux – current curve (Figure 3), and luminous flux – temperature curve (Figure 4) of an LED, we can draw two important conclusions:

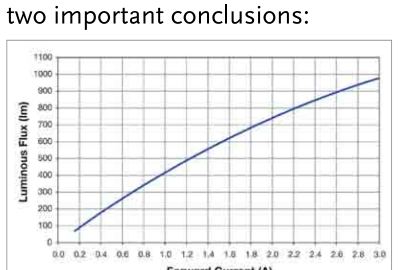

Figure 3: Cree XM-L Luminous Flux vs. Current (25°C)

figures for Cree's XM-L high flux LEDs. When driving the LED at 3 A (and at 25°C), it will emit 976 lumens. The power required to do so

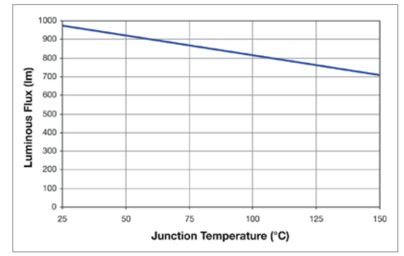

Figure 4: Cree XM-L Luminous Flux vs. Temperature (3A)

is 3 A * 3.34 V, or 10.02 W, resulting in an efficiency of 97.4 lm/W.

However, when the LED is driven at 1.5 A, it will emit 590 lumens. The power required to do so is 1.5A * 3.14V, or 4.71W, resulting in an efficiency of 125.3 lm/W, a significant improvement. This higher efficiency means that there is less waste heat generated by the LED (self-heating) at lower currents which can alter both the wavelength and intensity of the emitted light as well as altering the forward voltage by raising the junction temperature.

2. An increase in temperature will decrease the forward voltage (and power) needed to maintain a constant current. However the lumen output will also fall, and by a greater scale. This means that that even though less power is required to maintain a constant current level; the lower lumen output will mean that the overall efficiency of the LED will fall.

Why use a driver for LEDs

Choosing the right supply is key to ensuring that you get the best performance from your LED. LEDs with their long lifetimes now mean that the perception is that the weakest link is now the power supply. Excelsys has chosen design techniques, market leading components and thermal management techniques in order to provide solutions for customers with lifetime matching figures. We also have incorporated a number of design features which fit in nicely with the LED market requirements.

Constant current or constant voltage driver

We have already stated above that LEDs are current driven devices, so why do companies offer both Constant Current (CC) and Constant Voltage (CV) solutions for LED drivers.

The reason for this is to give the light fixture designers a number of options in optimizing their system. If many strings of LEDs are used in series, then the most efficient way to drive them is to use a constant current power supply, and connect the LEDs directly across the terminals of the power supply. However if strings of LEDs are connected in parallel then you may have an issue in trying to match the current in all the strings. A possible alternative to this would be to place an external component or active device to control the current. This may result in a slightly less efficient overall number of luminaires per Watt, but it allows the user to have full flexibility in ensuring that an identical current flows though many LED strings in parallel.

CC mode and CV mode

Figure 5 to 7 show the characteristic of three distinct mode of operation of a power supply. On each plot the axis are the same.

The X axis shows the load increasing, and the Y axis shows the output voltage of the module. The blue line is the voltage and the green line is the output current.

You will note the performance of Constant Voltage power supply in figure 5. It shows as the terminology suggests a unit that delivers a constant voltage as the load increases. The load current rises as demanded by the system, and will continue to increase to a point where the power supply will go into current limit mode in order to pre-

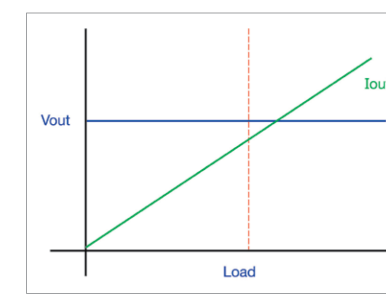

Figure 5: Constant Voltage Excelsys LDV and LXV ranges

vent damage to the power train. In our catalogue this is represented by the LDV and LXV product ranges. A lot of common voltage requirements are covered by these ranges such , and some not so common voltages.

Fig 6 shows how a constant current driver will behave. As the load increases the output current will remain fixed, with the voltage decreasing accordingly. This is

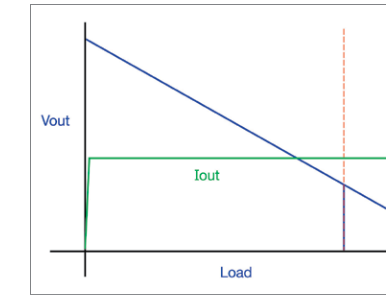

Figure 6: Constant Current Excelsys LDC, LXC and LXD ranges

covered by our LDC , LXC and LXD product ranges.

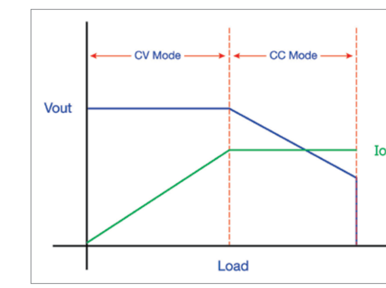

Figure 7: CC and CV mode Excelsys LBD product range

The latest design from Excelsys takes the two mode of operation and combines them onto one design. From figure 7 you can see how the unit will initially behave as a constant voltage unit. Once the load current max is reached, the control loop will then hold the supply current at a constant value and reduce the output voltage accordingly. This type of approach has many benefits to the end designer in that if chosen correctly both CC and CV mode designs can be achievable with one supply.

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HIGH POWER MODULES

The CIBH diode concept

By Th. Schütze & H.P. Felsl, J. Biermann

A new technology for the vertical architecture of free wheeling diodes is introduced, which is optimized for applications with high switching frequencies. To minimize the turn off losses of the diode and the turn on losses of the IGBT, a diode with the CIBH (Controlled Injection of Backside Holes) concept is implemented.

The CIBH allows to reduce the charge stored in the diode by minimizing the wafer thickness and reducing the doping concentration of the backside emitter, whereas an excellent switching softness remains even under extreme switching conditions. The advantage of the CIBH technology for high power applications is shown by investigations in high voltage modules with 1500A current rating and comparisons to state-of-the-art FWDs.

The field of applications for 3300V modules becomes wider. Infineon Technologies has recently introduced a new module which was designed for the needs of applications with moderate switching frequencies and very high stray inductances. But there are also inverter concepts which require higher switching frequencies at moderate values of stray inductances (Figure 1).

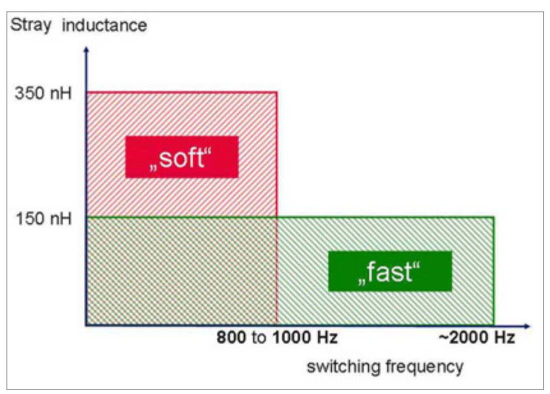

Figure 1: Application range of high power modules. A different optimization of devices is required, indicated by the attributes "soft" and "fast"

For the latter applications the focus of the chip development has to be on the reduction of the switching losses. Special attention was paid to the diode. The stored charge carriers not only determine the turn off losses of the diode but also influence the turn on losses of the IGBT.

The charge in the diode can be reduced by decreasing the device thickness, lowering the backside emitter efficiency and reducing the carrier lifetime. The first two mentioned measures lead to a worsening of the softness of the switching behavior of the diode. To minimize the switching losses of a module, a concept for the diode is desired, which allows a reduction of the device thickness and the backside emitter efficiency by a large extent, but still provides a good switching softness.

The CIBH diode is a concept, which improves the switching softness of the diode under extreme switching conditions like high DC link voltage, low current and high stray inductance, but does not have a negative influence on the trade off between on state losses and switching losses at moderate switching conditions.

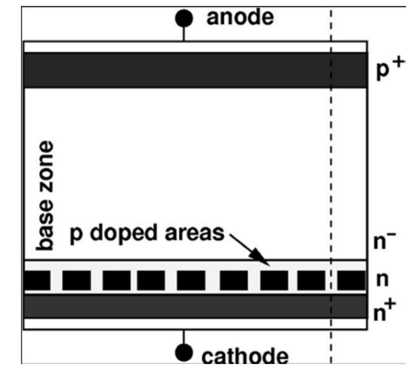

Figure 2: Construction of the CIBH diode

The CIBH Concept

The performance improvement of the CIBH diode is achieved by implanting buried p doped layers at the cathode side in front of the n+ cathode. During reverse recovery the buried p-doped areas inject holes in the base region improving the ruggedness and softness of fast diodes.

Figure 3 shows the cross section of the electric field between the p-doped areas along the dashed line shown in Figure 2 and compares the electric field distribution of the reference and the CIBH diode at the same time during reverse recovery. The reference diode is a state-of-the-art emitter controlled diode with the same thickness. The figure shows that the CIBH diode circumvents the evolution of a high electric field peak at the cathode side effectively by the fore mentioned injection of holes. Plasma providing free charge carriers remains longer at the cathode side due to these injected holes. The plasma removal out of the base region is therefore slowed down and leads to soft reverse recovery.

At the time when the whole plasma is completely extracted out of the base region and the electric field reaches through to the highly p doped areas, the injection of holes increases drastically and no snap-off can occur up to very high DC link voltages which are applied to the diode.

Furthermore a critical Egawa like field distribution, which means that high electric field strength occurs both at the anode and cathode side, will be suppressed by the hole injection compared to the reference diode without p doped areas (Figure 4). Therefore positive feedback of anode and cathode side carrier generation is avoided, which otherwise might results in destruction of the diode. This is the reason for the improved bulk ruggedness which is hindering destructive mechanisms like current filamentation.

Measurements

A high voltage module with 24 diodes in parallel and a rated current of 1500A is investigated. In this large module the advantages of the CIBH concept become obvious. Figure 5 shows a CIBH diode recovery under extreme switching conditions. High values of stray inductance (L_S = 320nH) and DC link voltage (V_{CE} = 2300V) combined with low temperature (T = 25°C) and low current (I_{CE} =

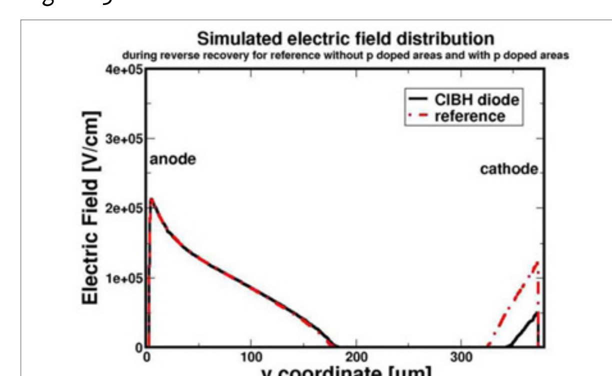

Figure 3: Electric field distribution for the reference diode and CIBH diode at the same point of time during reverse recovery

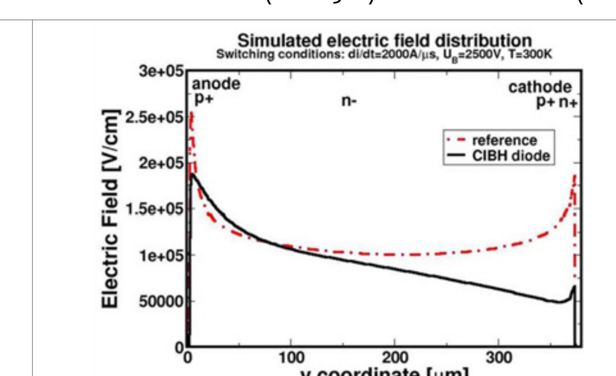

Figure 4: Electric field distribution after plasma extraction, the Egawa like field distribution of the reference diode is effectively suppressed in the CIBH diode till the end of reverse recovery

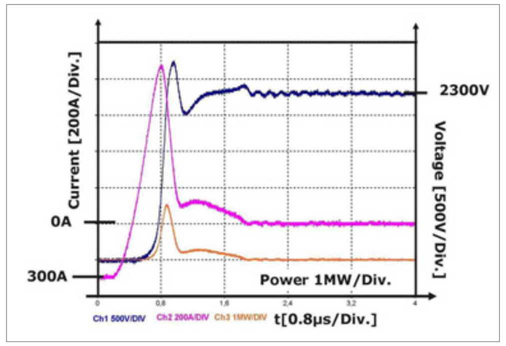

Figure 5: Diode recovery of a 1500A rated current module under extreme switching conditions, VCE=2300V, LS = 320nH, T=25°C, I=300A

300A) lead to a massive current snap off and oscillations at a state-of-the-art fast diode optimized for low switching losses.

In contrast the paralleled CIBH diodes show a very soft switching behavior without snap-off even at a high DC link voltage and with a stray inductance well above the required level. Additional charge carriers which are provided by the hole injection from the structured p-doped areas in the backside of the device can be seen in the recovery current waveform of Figure 5.

This effect we called Dynamic Self Damping Mode. In a self adjusting way this effect suppresses oscillations and provides enough charge carriers to avoid effectively snap off under extreme switching conditions. So the current cut off - self protection allows to design in this diode into applications with high stray inductances.

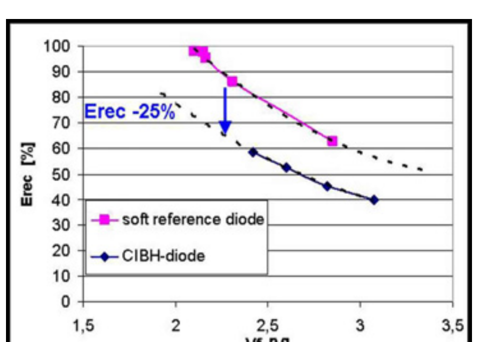

Figure 6: Trade-off diode switching losses vs. on state losses

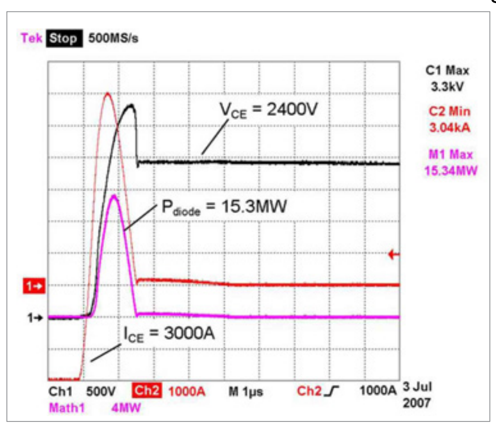

Figure 7: Diode recovery of a 1500A module with excellent robustness; VDC=2400V, I=3000A, LS= 95nH, Pdiode=15.3MW

The advantages of the thin CIBH diode can be clearly seen in Figure 6, which shows a direct comparison to a soft reference diode with high reverse recovery losses. The fast CIBH diode provides the same soft switching behavior as the soft reference diode.

In inverters with higher stray inductances it is possible to reduce the diode switching losses by 25% with the same on state losses. This leads consequently to reduced IGBT turn on losses at the same time.

Figure 7 shows a diode recovery which is done under severe test conditions far above the real application conditions. Peak power values above 15.3MW for a FZ-1500R33HE3 module have been reached without destruction. The test conditions are VCE=2400V, ICE=2*Inom=3000A and a module temperature of Tj=150°C. The results guarantee a large safety margin to the data sheet peak power values.

Conclusion

A module with a CIBH diode has been successfully introduced. This diode concept leads to a great reduction of the diode turn off losses and the IGBT turn on losses, but still offers a very soft switching behavior even under extreme switching conditions due to the Dynamic Self Damping Mode. The new diode concept is a breakthrough for FWDs in modern high power / high voltage inverters. In combination with the Infineon trench cell and field stop technology a new benchmark is set in both softness and minimal total losses for high power IGBT modules.

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DESIGNING WITH LDOs

Challenges and Trade-offs for Portable Electronics Equipment

By Eamonn Ahearne

Low drop-out Linear voltage regulators are a vital component in a wide range of applications; perhaps some of the most demanding conditions exist in the portable equipment (media players, digital cameras, GPS systems, portable games consoles) and cell phone markets where the requirement to maximize battery life and to minimize size are just two of a number of factors that create tough challenges.

Typically, the size issue has been addressed by using regulators in CSP or bump die form. However this raises challenges in terms of thermal dissipation and the assembly process. In addition, when creating an LDO regulator a designer traditionally has had to trade off current consumption against noise performance: unfortunately portable products demand both low power consumption and excellent ripple rejection and low noise generation. These challenges and numerous other trade-offs associated with the use of LDO voltage regulators in portable applications are discussed in detail in this article with the aim of providing valuable insight and information for design engineers tasked with designing next generation portable electronics equipment.

Designing LDOs for the Portable Consumer market

Standalone Linear Voltage regulators have always had an important, if somewhat unappreciated place in cell phones, their classic role being to isolate the RF section from the relatively noisy baseband chipsets. Rumors of their demise have abounded for years, with the assumption that increasingly, all embracing PMUs (Power Management Units) would supplant their necessity. However, the constant additions and changes of hardware features such as camera flashes, image sensors, Bluetooth modules etc. have continued to demand the flexibility (in terms of rapidly changing voltage and current options) and calming influence (electrically speaking) that only a discrete LDO can provide. With today's Smart phones, complex hinges and sliding panes have made the prospect of running all power rails from a single PMU unattractive, with the result that some of the more complex phones can have as many as five discrete LDOs, powering elements such as touch screens, keypads, image sensors and RF sections.

Power Consumption vs. Noise

Two of the most important features that designers have looked for in choosing LDOs for cell phones have been their dynamic performance and their size. In terms of their ability to reject external noise (as indicated by their Power Supply Rejection Ratio specification, which is measured

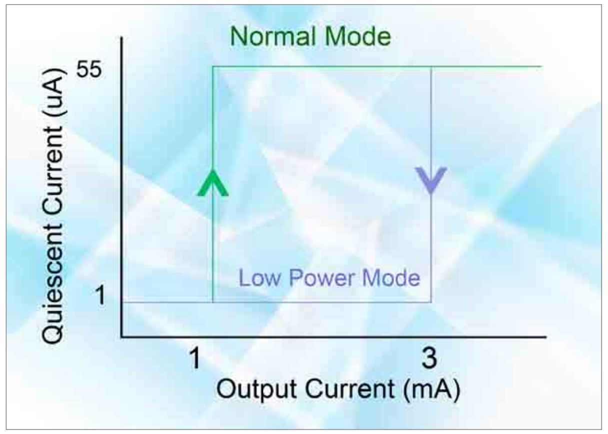

Figure 1: The challenge of dynamic performance vs. current consumption has been addressed by introducing parts that are switchable between low power mode and high performance. A typical example is ON Semiconductor's NCP4587. Looking at products that are currently sampling, it appears that products with noise in the 10 μVRMS range and Quiescent current in the 10-15 μA range will be in production by the end of this year, giving cell phone designers the best of both worlds in selecting their LDOs.

in dB) and to avoid generating internal noise (usually stated in μVRMS) it is interesting to look at the progression of LDOs for use in cell phones through the last 10 years. The earlier products were pure bipolar, with a typical PSRR of 45 dB and noise level above 30 μVRMS. In order to achieve this noise specification, devices usually required a bypass capacitor connected to the internal Voltage reference of the regulator, a topology that became standard for low noise devices.

A leap forward took place with the introduction of BiCMOS which is arguably still the benchmark for low noise LDOs in the wireless domain. A product specification with a typical PSRR of 75 dB (@ 1 kHz) and a noise rating of less than 10 μVRMS was now achievable. Quiescent current remained and issue however with a typical 50 μA maximum consumption over all conditions. Just for reference, there are several CMOS devices on the market with Quiescent currents in the 1 to 4 μA range (at 0 load), but typically with poor Noise performance specifications.

CMOS designers have tackled the challenge of dynamic performance vs. current consumption by introducing parts which are switchable between low power mode (with degraded dynamic performance but low power consumption) and high performance mode (good dynamic performance but at the price of higher current consumption). These modes can either be selected by the user, or automatically switched when the output load is very light. A typical example is the NCP4587 from ON Semiconductor, the performance of which is illustrated in figure 1.

Size does matter

The footprint of a CSP device matched the size of the actual die, without the need for space between the edge of a package and the die to allow for wire bonding. CSP tended to be very low profile (typically around 0.6 mm in height) making it very popular with manufacturers of portable consumer products. However, CSP is very sensitive to the material composition and the mechanical dimensions of the bump. CSP products typically have a die size of approximately 1mm by 1 mm. The bump size has been standardized to around 300 um, and a pitch between bumps of .5 mm .Most CSP products released today with four or five bumps tend to follow the standardized footprint. which effectively restricts them to a 1mm by 1mm footprint, with a typical height of 0.6 mm.

The closest competitor to CSP packaging in terms of size has been DFN packaging (also known by the Amkor name of MLF). As the process of choice for LDO designs has migrated to a 0.25 or 0.18 micron process, the die size has been reduce to the point where, despite the need for clearance, the die can fit in packages as small as 0.8x0.8 mm. Whereas early DFN packages had heights around 1 mm, we now see the XDFN package with a height of 0.4 mm, considerable thinner than most CSP offerings.

There are at least two bonding approaches being taken by manufacturers using small DFN packages (see figure 2). The first uses

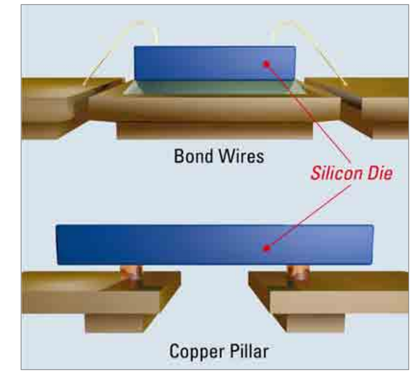

Figure 2: By using copper pillars, a larger die can fit in a device package compared to a traditional approach that uses wire bonding techniques.

conventional wire bonding, relying on small die geometries to get die small enough to fit the package – as an example, to fit a 1.0 mm by 1.0 mm package, a die cannot be much bigger than 0.6 mm by 0.6 mm, depending on how aggressive the associated assembly site rules are. The second approach uses a standard flip chip approach using copper pillars instead of the conventional solder bumps. Copper pillars are grown on the die, which is then flipped over and attached via the pillars to the copper lead frame of the package.

By eliminating the need for wire bonds, this approach allows for a bigger die size – a die close to 0.8x0.8 mm square can be accommodated in a 1x1 mm DFN package using this technique. This is an important difference in the cell phone space, where the sweet spot for output current for LDOs has moved from a 150 mA current output to a 200 mA output current. A majority of space on the die for any Linear Voltage regulator is taken up by the output power device so any technique that allows the use of a larger die size to help in power dissipation is useful.

From the manufacturing standpoint, the cost saving of a smaller die is somewhat offset by the additional cost of the copper pillar process. From the designer's standpoint, in addition to die size, an interesting aspect is that of heat dissipation: which approach can dissipate the heat generated by the LDO in the most efficient manner? Adherents of the copper pillar approach claim that their approach is the most effective in transporting heat from the die surface, but most the packages used in the wire bond approach incorporate a small heatsink pad underneath the package which connects directly the substrate of the die to a heat pad on the PCB, providing a measure of heat transfer.

It is difficult to find exact numbers as manufacturers tend to state thermal resistance numbers which are only valid under specific mounting conditions, but looking at datasheets of a part known to use copper pillars suggests a junction thermal resistance (θA) for a 1mm x 1mm thin DFN 6 pin package of 150°C/W whereas values for more commonly available wire bonded products in a 1mm x 1mm thin DFN 4 are stated anywhere from 181°C/W to 250°C/W depending on the test PCB used. Based on this very narrow sample size, the advantage appears to go to the copper pillar approach, but not by much.

With these developments in shrinking DNF packages, the decision to use CSP or packaged LDOs may soon be becoming a matter of choice rather than of necessity. It is interesting to note the introduction of the ultra think CSP, with a thickness of 0.28 mm, presumably for applications where the height profile of the package is of extreme importance, or where the LDO is going to be actually embedded in the PCB.

Conclusion

Choosing an LDO for a wireless application has usually involved making some decisions from the start: choosing between current consumption and dynamic performance, and between achieving the smallest footprint possible with a CSP package (possibly requiring some additional qualification testing, specialized manufacturing techniques or mechanical safeguards) or more traditional encapsulated packages with larger footprints. With the availability of small geometry BiCMOS processes tuned to Analog design requirements and of smaller, thinner DFN packages, more options are now open to designers of wireless circuit boards.

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Special Report: LIGHTING, VIDEO, SURVEILLANCE & SECURITY

PSD NORTH AMERICA
Power Systems Design: Empowering Global Innovation

Inside:

VIDEO TRANSMISSION SOLUTION

Enabling analog video to stretch over a mile

By Dave Ritter, Senior Designer and Tamara Schmitz

Transmission cables have improved, but the challenge is always the same: get more messages down longer cables faster. It may sound simple, but the longer the cable, the greater the losses. These losses would affect any type of transmission, but they are complicated at higher data rates, like video.

The circuit block that compensates for losses in a system (like cable losses) is called an equalizer. Why is it called an equalizer? Maybe it is this simple: you want the signal coming out of the cable to be exactly the same as the signal going in. Since there are losses associated with cables, the equalizer is included to reverse those losses and make the output signal "equal" to the input signal.

For example, Ethernet in all its forms is only specified to go 300 meters, HDMI on an entertainment center is usually limited to a few meters unless a special cable is purchased and USB peripherals need to be within 5 meters of the desk top. In addition, if you are installing security cameras, they need to be within 300 meters of the console or the picture will suffer.

Buildings are getting bigger all the time. Think of all of the video displays in an airport. Consider the opportunity to run video ads in a supermarket or shopping mall while having the ability to control all the ads from a central hub. What about video feeds from the security systems at these places or at business complexes?

Solutions to Long Cable Degradation

One can use a higher voltage at the input. This higher voltage, just like pre-emphasis, boosts the signal at the source end and hopes that more gets to the far end, but this can be hazardous. Imagine that we wanted to send a video signal down a mile of Cat 5 cable (24AWG twisted pair), and let's say that the attenuation measured at the critical 3.58MHz color subcarrier frequency is 70dB.

To get a volt of signal at the output of the cable, we would need to apply over 3000 volts at the source! Even if we managed the heroic electronics necessary to make a 3000-volt video signal, we would end up driving 30 amps into a skinny 24AWG twisted pair. It would explode in a shower of sparks and molten copper. This leads us to our second solution, equalization.

An equalizer is a circuit that restores a signal that has been degraded by a length of cable. In our example, the signal needs a 70dB boost at high frequencies (the complete video signal takes a bandwidth of 5MHz or so) to make a nice picture. That's still a factor of 3000, but now it is a gain factor instead of a voltage. Let me restate, instead of forcing the source end of the cable to a very high voltage, we allow the signal to drop by 70dB, and then boost it at the output using amplification. In this way, there is no stress to the cable and no exploding wires. A single stage equalizer can easily boost about 14dB. If we put 5 of them in a row, we have our required 70dB of boost. Is that all there is to it? What could possibly go wrong?

In a word: noise. All electronic amplifiers have noise, and if it is too high, it will swamp our video signal. Remember, the noise at the input of a circuit receives the same gain as the signal. (Those of you that remember rabbit-ear TV antennas know what I mean.) In particular, to get acceptable video at the far end, our equalizer noise must be at least 30dB (about 32 times) smaller than the video at the input to the equalizer (fussy people want 40dB or more—which is 100 times smaller).

Remember that the signal at the output is already 70dB below the source level, due to cable attenuation. That's 100dB of dynamic range, or about 100,000:1. So we can avoid exploding wires only by building incredibly low noise equalizers. Fortunately, modern silicon processes are capable of this feat.

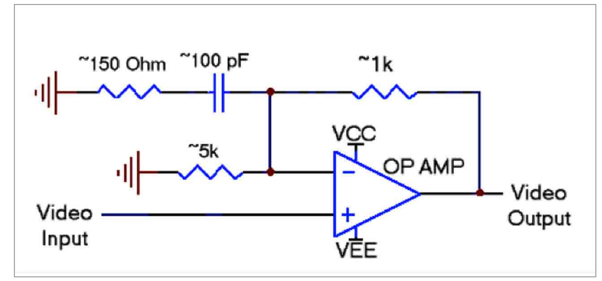

Figure 1: Single Stage Equalizer for 300 meters of Cat 5 cable

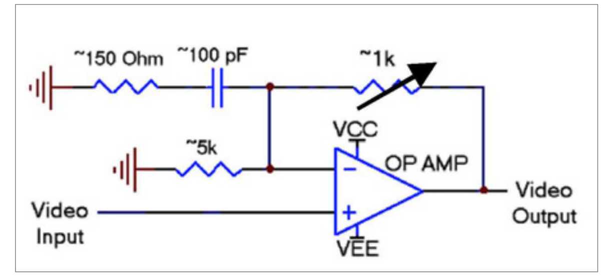

Figure 2: Variable Equalizer for lengths from zero to 1000 feet

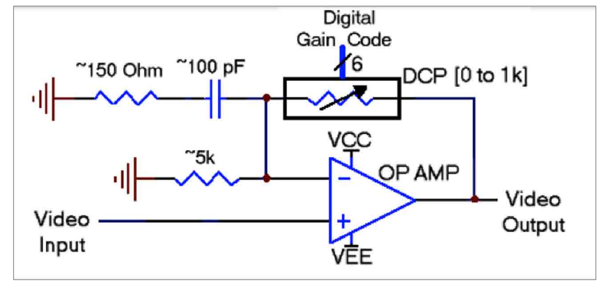

Figure 3: Variable Equalization Stage Using DCP

Equalizer Circuits

To dig a little deeper into the circuit specifics, let's start with the simple schematic of a discrete equalizer stage and build from there. The simple circuit in Figure 1 is designed to equalize 300 meters of Cat 5 cable. It is a high boost circuit, and many discrete video equalizers have been built this way. The amplifier is a low-noise op amp with sufficient gain-bandwidth to create the required 14dB of boost.

What happens if the cable is shorter than 300 meters? For shorter transmissions, we would need to reduce the amount of boost to match the cable length. Figure 2 shows a simple approach—make the feedback resistor a potentiometer.

But we may wish to control the equalization from a microcontroller or digital logic, so it would be nice if there was a digital input for that variable resistance. We can solve that problem using a digitally-controlled potentiometer (DCP), as in Figure 3.

Building the Whole System

The ability to build this circuit on one piece of silicon gives great advantages in cost, functionality and programmability. Figure 4 shows a simplified diagram of a complete automatic equalizer.

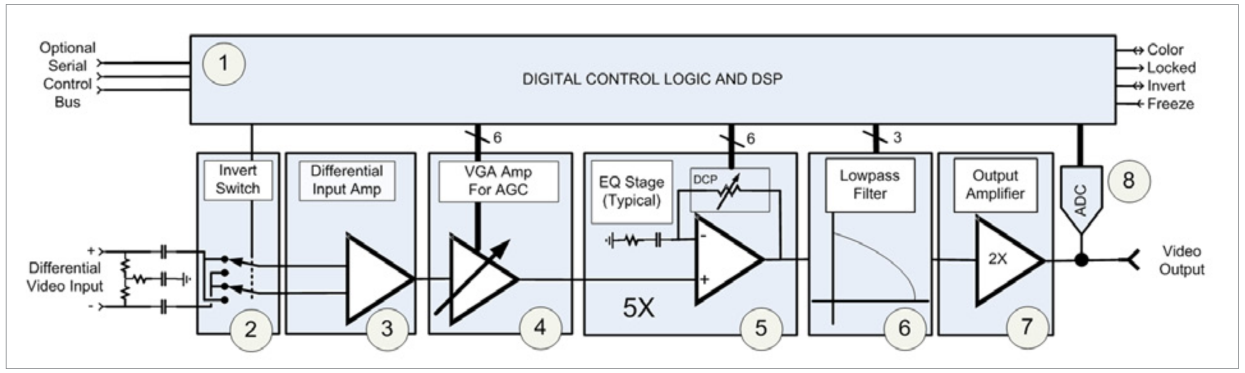

Figure 4: A complete (simplified) equalization system

There are eight blocks, so let's take it a stage at a time and investigate the function of each.

The loop control and user interface are implemented with a modest number of gates of digital control logic (Block 1). The logic determines how much the signal needs to be equalized and how to adjust the equalization. Since no two chips are exactly the same, trim codes for the equalizers and filters ensure that each chip behaves the same.

Block 2 is a simple addition that makes installation easy. Since the video cable in this case is twisted pair, it is possible to swap the wires, effectively inverting the signal. This circuit notices if the wires have been switched and inverts the signal to compensate.

Also, since the video cable is a twisted pair (2-wires), our input stage must be differential. Block 3 shows the differential input amp that receives the signal from the twisted pair wire. At this point the signal has differential video (the intended signal) and common mode noise (corrupting signal from power lines and other nearby equipment). The differential input amp removes the common mode noise, leaving only the video signal.

This video signal is expected to be a 1V peak-to-peak signal. Of course, cameras and other sources may vary. The automatic gain control (AGC) amplifier, Block 4, adjusts for variations in the overall video level. The core of the equalizer is responsible for boosting the high frequencies that were lost in transmission over the long cable. These stages need to be very low noise (they should not generate much of their own noise) and they need to reject any power supply noise (they should block noise from outside sources). Block 5 is simply five of the equalizer stages we discussed in the previous section.

Block 6 is a noise filter. When the equalizer is configured to boost 5MHz, it may continue boosting all the way to about 10MHz before beginning to roll off. This extra boost does not enhance the signal, it just amplifies noise! Therefore, we need to include a sharp cutoff low pass filter to reduce the effect of noise above 5MHz. Once the signal travels through the noise filter, there is one more op amp stage (Block 7) before reaching the output. This output amplifier provides sufficient gain and drive current to interface with other video equipment.

Finally, Block 8 is an analog-to-digital converter. This circuit samples the output and feeds it back into the digital control circuitry. If anything goes wrong, the control circuitry can adjust the other blocks in the equalizer to fix it. For example, if the output starts to droop, the gain amplifier (AGC) could be turned up to compensate.

Visual Results

Figure 5 shows a high quality source image after 1 mile of Cat 5 cable, with and without equalization. Remember that an unaided video signal can travel down around 300 meters of cable. As the length of the cable increases, the color information is lost. As the cable gets even longer, the images smear and text becomes unreadable. With the complete single-chip equalization solution (ISL59605), just described, all the picture details have been restored even after the signal has traveled over 5,000 feet (>1500m).

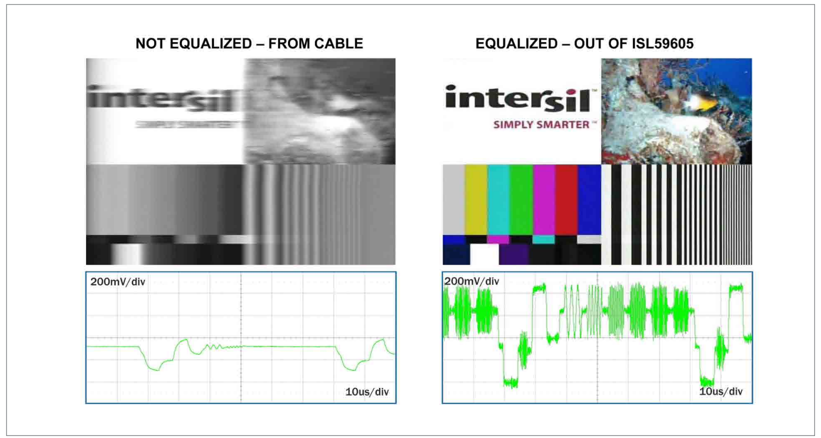

Figure 5: High quality source image after 1 mile of Cat 5 cable, with and without equalization

Conclusion

The ISL59605 (MegaQ) represents the application of advanced analog and digital techniques to the problem of long cable equalization. It provides automatic sensing of video signal parameters and implements appropriate correction and equalization. It requires no user intervention in most applications and provides full bandwidth video output from a variety of cable types and lengths.

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LED STREET LIGHTING

High efficiency, longer life and lower maintenance

By Peter B. Green

High brightness LED street lights are now being installed in pilot projects at many sites. In most cases these are replacing high intensity discharge (HID) and high pressure sodium (HPS) street lamps.

Although HID lamps have long operating life and high luminous efficacy, well designed LED based systems offer the advantage of directing the light in a downward cone providing high illumination at ground level without radiating much of the light sideways. The operating life of well designed LED systems using adequately rated components with sufficient heat sinking can be as much as double that of HID lamps reaching 50000 hours.

LED based systems have the added advantage of controllability and can be dimmed over a wide range unlike HID lamps, which can only be dimmed to about 50%. HID lamps require a high voltage pulse to ignite the lamp. This is typically 1 to 4kV for a cold lamp but increases to over 20kV for a hot lamp, making most HID lamp ballasts unable to provide a hot re-strike. The lamp therefore needs to cool for several minutes before it can be switched on.

LED based street lamps typically consume 120 to 200W of power whereas HID systems require 300 to 400W. The lumen levels however are comparable when measured at ground level not because the LED light source has a greater Lumen per Watt output than HID but because LED optics enable the light to be directed where required.

Switching power supplies for the power levels needed for LED street lighting are usually based on a different circuit topology to lower power LED drivers. Flyback converters although well suited to power supplies below 50W are bulky and inefficient at 100W and above, therefore a multi stage design is normally used instead.

In this type of power supply, the front end consists of a power factor correcting Boost regulator providing a high voltage DC bus. Active power factor correction (PFC) circuitry of this kind is widely used in power supplies and electronic ballasts although there is some penalty in efficiency. The PFC stage typically has above 90% efficiency which increases as higher power levels.

Figure 1: LED street lights

The PFC stage is followed by an isolating step down back end stage designed to produce a regulated current output. This stage could be a single or two switch Flyback converter, Forward converter or half bridge resonant converter.

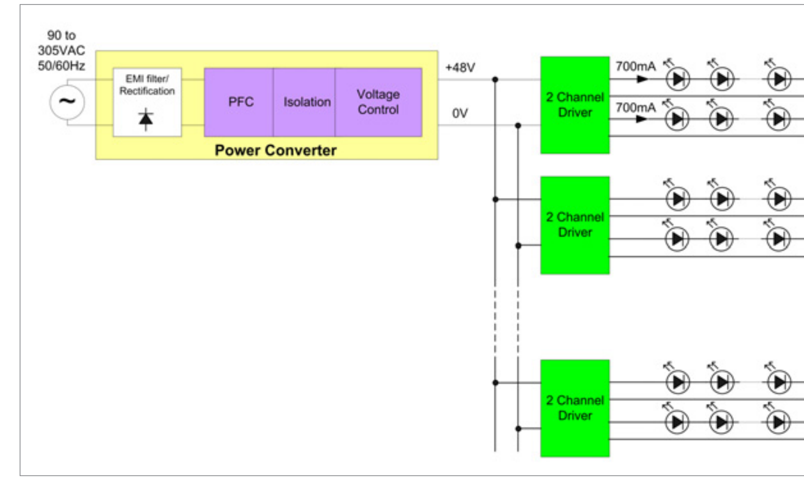

Figure 2: A modular LED system

In some LED street light designs a modular approach is used where the LED panel consists of several smaller panels connected separately to the LED power supply (or driver). Each LED module is driven by a constant current driver. In this type of system the main power supply produces an isolated fixed voltage typically 24 or 48V, low enough to fall within UL safety limits. The output channels to each LED module are then driven by current regulators all supplied from the central isolated low voltage bus. This is described as a multi channel LED driver.

Although modular systems offer convenience and the ability to build light fixtures of different shapes and sizes without the need for many differently rated power supply models, this approach is less efficient than a power supply with a single output. This type of power supply would drive a single panel containing and array of LEDs designed to operate at a fixed current. A typical example might operate at 1.4A with four parallel strings of 350mA LEDs matched so that the forward voltage for each string is very close. The power supply would be optimized for this output voltage and current and regulation could be provided by pulse width modulation (PWM) in the back end stage eliminating the need for additional output current regulators. This allows greater efficiency but less flexibility.

The PFC stage Boost regulator typically operates in critical conduction (or transition) mode between discontinuous and continuous modes, meaning that the switching cycle begins as soon as all of the energy from the inductor has been transferred to the output. Many simple stand alone PFC control ICs are available the operate on this principle, however more complex dedicated ICs able to control this stage as well as the resonant half bridge or Flyback stage are now coming onto the market. The PFC stage provides a regulated high voltage DC bus over a wide range of input voltage and load enabling the LED power supply to operate with high power factor and low THD over a wide range of AC line input voltages (typically 90 to 305VAC), which covers most locations. The second stage is then greatly simplified since its transformer and power semiconductor components can be optimized for a fixed input voltage.

The resonant half bridge is well suited for the second stage of the LED power supply. Unlike the Flyback converter it transfers power through the transformer continuously instead of periodically storing and transferring energy. This allows the transformer to be significantly smaller than the air gapped coupled inductor used by the Flyback. The Flyback is also prone to losses due to leakage inductance where the resonant half bridge uses the leakage inductance to enable commutation allowing zero voltage switching (ZVS) of the MOSFETs. Since the throughput power is controlled by modulating frequency instead of pulse width the dead time remains fixed allowing ZVS operating across the entire operating range. With no switching losses the efficiency can exceed 90%. Forward converters also offer smaller transformer size but an additional output filter inductor is needed and this type of circuit does not provide zero voltage switching.

In both modular and single out-

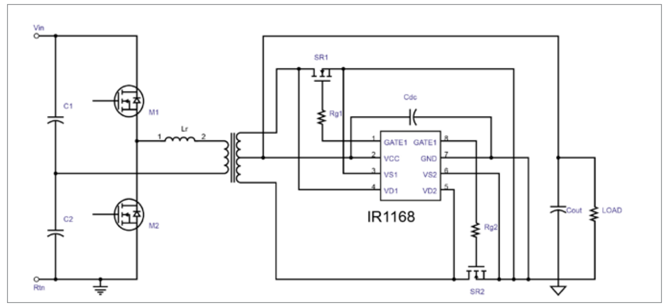

Figure 3: Synchronous rectification

put systems with the output voltage being low the current must inevitably be high, for example at 48V output the current would be about 2A to supply a 100W LED load. The rectifying diodes even if they are Schottky types dissipate more than one Watt each. This can be reduced to negligible levels by replacing these diodes with MOSFETs driven by a synchronous rectifier control IC.

The circuit shown in figure 3 illustrates the resonant half bridge with the step down transformer and a synchronous rectification stage at the secondary to supply the load.

Unlike LED replacement lighting for domestic use, a street lighting system does not need to be dimmable from triac based dimmers but the light output level does need to be adjustable to enable smart functionality such as the adjustment of light levels at different times during the night to optimize energy savings. The control method used might be a form of wired digital control like DALI or analog control through a 0-10V control interface widely used in lighting. Wi-Fi based control is also possible. In each case the light output is most easily adjusted by pulsing the output on and off at a frequency above the visible flicker level which is about 120Hz and varying the duty cycle. PWM dimming is well suited to this type of LED power supply since the half bridge drive and PFC can be pulsed on and off at varying duty cycles to provide smooth and flicker free light level adjustment.

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OFFLINE LED APPLICATIONS

Solution for unique AC offline power LED IC driver design challenges

By Jeff Gruetter

Most new LED lighting fixture applications will be required to run from existing AC offline power sources, generally 90VAC to 265VAC. The ability to drive LEDs effectively from AC offline power presents some unique LED IC driver design challenges.

Power savings capability, long life and additional benefits of high brightness LEDs drive the development and growth of a wide range of lighting applications ranging from 4W screw-in incandescent replacement bulbs to 100W street lamps to commercial high bay fixtures, requiring hundreds of Watts. Most of these LED lighting fixtures will be required to run from existing AC offline power sources, generally 90VAC to 265VAC.

Driving LEDs effectively from AC offline power presents unique IC driver design challenges; The LED drivers must offer maximum efficiency and also provide electrical isolation for safety concerns. Additionally, they must offer Power Factor Correction (PFC) and low harmonic distortion to be practical in a broad range of applications. In many residential applications they must offer dimming capability with existing TRIAC dimmers. Finally, the total solution footprint needs to be very compact to fit into a replacement fixture and also be cost effective to entice both commercial and residential users into changing over.

LED Lighting Math

One of the major driving forces behind the rapid growth of LED lighting is the dramatic power savings they can offer over incandescent or even CFL lighting.

A 60W incandescent bulb delivers approximately 800 lumens, which translates into 13.3 lms/W. Existing LED efficacy ranges from 50 lms/W to 170 lms/W for commercially available product. Future LED efficacy ranges from 200 lms/W to 230 lms/W will be available, but the maximum theoretical efficacy is ~250 lms/W. Let's consider LEDs with 100 lms/W. The electrical power required for the LED itself will be 800 lumens/100 lms/W = 8W. However, the efficiency of the AC/DC LED drive electronics must also be taken into account, which is 85% for a high performance LED driver. Thus, the total required offline power would be 8W/0.85 = 9.4W, resulting in a power savings of 84% compared to an incandescent bulb.

If a more conservative figure of 65 lms/W is used, a net savings of 75% of the power used relative to an incandescent bulb is realized. Looking to the future when LEDs delivering 200 lms/W are available, the power saving jumps to 92%. To meet the current energy star requirements, LED replacement bulbs must deliver at least 75% power savings.

Powering LEDS from Offline Power

Offline power generally ranges somewhere between 90VAC and 265VAC with a frequency between 50Hz and 65Hz. Therefore, manufacturing a LED fixture for the worldwide market would ideally have a single circuit design that could enable it to be used anywhere in the world without modifications, requiring a single LED driver IC that can handle a wide range of input voltages and line frequencies.

Furthermore, many offline LED applications require electrical isolation of the LEDs from the drive circuit. This is primarily driven by safety factors and is required by several regulatory agencies. Electrical isolation is generally provided by an isolated flyback LED driver topology that utilizes a transformer separating the primary and secondary sections of the drive circuit.

As the driving force behind LED lighting's adoption is the dramatic reduction of power required to deliver a specific quantity of light, it is imperative that the LED driver IC delivers the highest level of efficiency. Because the LED driver circuit must convert high voltage AC power to well regulated LED current at a lower voltage, the LED driver IC must be designed to deliver efficiencies above 80%.

For LED retrofit lamps to be feasible with the large base of installed TRIAC dimmers, the LED driver IC must operate seamlessly with these dimmers and ensure that the LED starts properly without any visible flicker.

PFC is an important specification for LED lighting. Because of the costs of larger equipment and wasted energy, electric utility companies will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Because a LED driver circuit (which includes an array of diodes, transformers and capacitors) does not act like a purely resistive load, it can have a PFC as low as 0.5. In order to raise the PFC above 0.9, either an active or passive PFC circuit must be designed into the LED driver circuit.

It is also important to minimize the harmonic distortion levels in LED fixtures to meet the International Electrotechnical Commission has developed an IEC 61000-3-2, Class C Lighting Equipment Harmonics specification.

Accurate LED current regulation over a wide variation of line voltage, output voltage and temperature is critical in lighting applications as variations in LED brightness must be imperceptible by the human eye. Similarly, to ensure the longest operation life of the LEDs, it is important not to drive them with current above their maximum ratings.

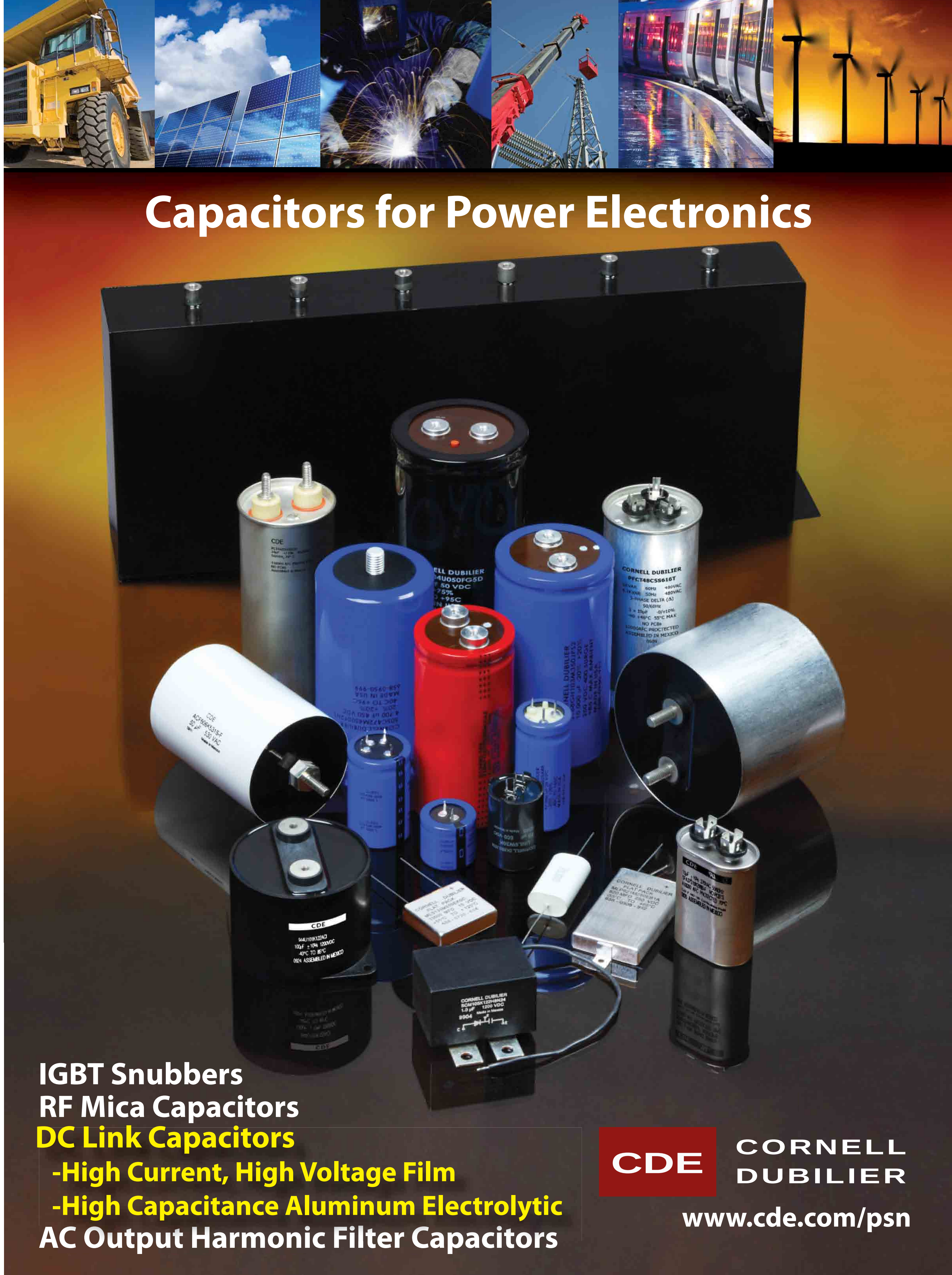
Finally, paying over $30 for a LED replacement is a large hurdle for consumers to overcome. At these prices, the reduced electricity and replacement costs over the lifetime of the LED, does make economic sense but consumers aren't used to making this connection. In general, commercial businesses such as warehouses and parking garages are much quicker to adopt LED lighting.

For direct bulb replacements, the entire solution must fit in the same shape and volume of the original incandescent bulb. LEDs require a heat sink and a much more complicated driver circuit, so fitting both of these in the same volume footprint can be a challenge.

A Brand New Solution

Fortunately, there is a new solution: Linear Technology's LT3799. It is an isolated flyback LED controller with active PFC, specifically designed for driving LEDs from a universal input range of 90VAC to 265VAC. The LT3799 uses a critical conduction mode, minimizing the size of the external transformer. It is ideal for driving a wide range of LED applications ranging from 4W of LED power to hundreds of Watts.

The entire circuit to drive up to 20W of LED current can is shown in figure 2. This particular cir-



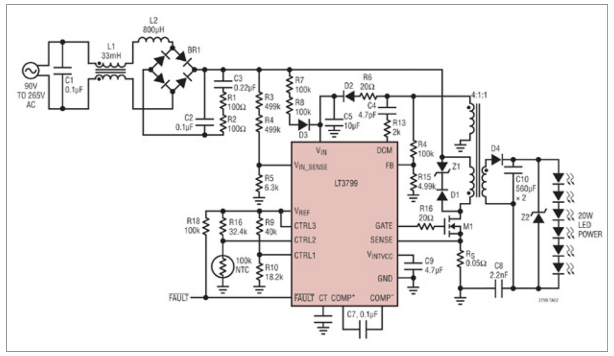


Figure 1: Universal Input, Isolated Flyback LED Controller Circuit with PFC & TRIAC Dimming Using the LT3799

cuit is TRIAC dimmable and can deliver up to 1A of LED current from a universal input range of 90VAC to 265VAC, while delivering efficiencies of over 86% (see Figure 3). With a few changes in externals, this circuit can be optimized further for 120VAC, 240VAC or even 377VAC applications or virtually any commonly found AC input.

The LT3799 utilizes a single stage design with the entire LED drive circuit (including the EMI filter) requiring only 40 external com-

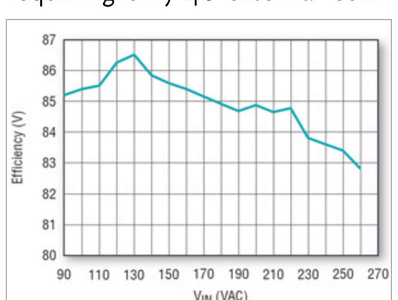


Figure 2: LT3799's Efficiency over the Universal Input Voltage Range

ponents, keeping the solution footprint simple, compact and cost effective. The overall dimensions of the 20W circuit in Figure 2 is only 30mm x 75mm with a profile of only 30mm, making it ideal for a wide variety of LED applications.

The LT3799 provides active PFC of up to 0.98; easily meeting industrial U.S. Department of Energy (DOE) requirements while also complying with the IEC 61000-3-2 Class C Lighting Equipment Harmonics requirement (see Figure 4).

Additionally, the LT3799 offers LED current regulation over input voltage, output voltage and temperature. Looking at Figure 5, one can see that the LED current remains within +5% regulation when the input varies from 90VAC to 150VAC as would be required in most US lighting applica-

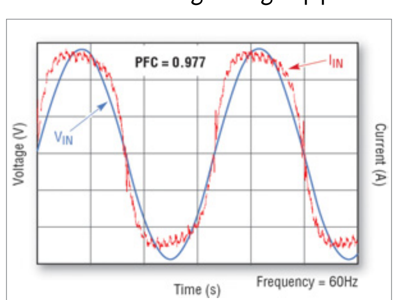


Figure 3: LT3799 VIN & IIN Waveforms with Active PFC

tions. In lieu of an opto-coupler, the LT3799 has a unique current sensing scheme to deliver a well regulated current to the secondary

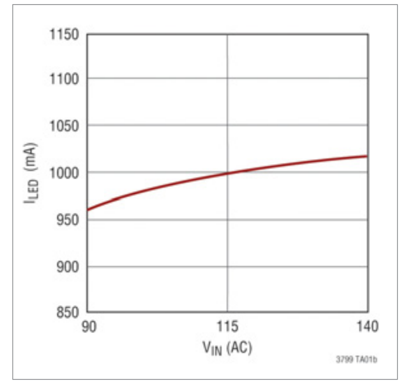


Figure 3: LT3799 VIN & IIN Waveforms with Active PFC

side. This not only reduces cost, but also improves reliability.

The LT3799 can also be used with a standard in-wall TRIAC dimmer without any visible flicker. Integrated open and shorted LED protection ensures long-term reliability for a wide range of LED applications and its thermally enhanced MSOP-16 package offers a very compact LED driver solution.

Conclusion

The unprecedented acceleration of LED general lighting applications powered by offline sources is driven by a continual demand for higher efficiency, performance and cost effectiveness. These emerging performance requirements must be enabled by sophisticated new LED driver ICs. Fortunately, this now exists.

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LED LIGHTING SOLUTIONS

Powered by innovative electronic technologies

By Dan McGowan

Here follows an in-depth look into just how synergistic electronics, optical and lighting industries are yielding new and award-winning technologies to revolutionize the world of LED luminaires.

LEDs are driving a paradigm shift away from traditional incandescent lights toward energy efficient, longer life and sustainable solutions. From street lights to giant video screens, from car headlights to indoor illumination, SSL systems offer compelling benefits and are already making strides toward transforming the industry. Today's advanced LED lighting technologies can deliver the sustainability, scalability, and design flexibility that OEMs need to engineer competitive solutions for the SSL residential, commercial and industrial markets.

Energy savings–a cornerstone of LED technology

Conservatively, LEDs last more than 25 times–ranging up to 40 times longer than incandescents and five times longer than CFLs (compact fluorescent lamps). In addition, LEDs are more physically robust than the average incandescent or CFL light source and are dimmable with the advantage of instant-on capability, with good color rendering and a full color spectrum. They operate silently on a low voltage current, without mercury or lead, and are completely safe for UV sensitive applications.

Intrinsic design and manufacturing challenges of traditional LED technology

Despite these advantages, there are challenges intrinsic to LED technologies. For example, while LEDs run significantly cooler than incandescent lamps, without proper thermal management their effective service life can be shortened considerably due to heat build-up within the LED junction. Conversely, with the proper thermal management, LED fixtures can

Available in serial or parallel wiring options, the new Molex array holder simplifies LED installation. Array holder is shown with and without optional Ingress Protection

last an impressive 50,000 hours at 70 percent lumen maintenance under normal usage.

LED emitters have typically been soldered to PCBs and assembled to integrated fixtures, without a mechanism to replace a failed LED or update the LED. This assembly approach poses several challenges to the fixture manufacturer, being closer to an electronics assembly than a typical lighting fixture. Successfully soldered designs still leave solder joints vulnerable to stress during handling. A cold solder joint can result in scrapping a high cost LED array.

By combining best-in-class electrical, thermal and optical expertise with in-house design and manufacturing capabilities, Molex stepped up to address these practical design issues and needs. The resulting range of Molex LED light modules provides unprecedented design flexibility and freedom for OEMs to differentiate their product offerings. The modular LED lighting solutions are a familiar model long used by distributors, who are now able to broaden their portfolios beyond traditional light sources to include LED sources. Advances in electronic technologies are for the first time making LED luminaires practical and affordable for mass-production.

Helieon® for high-volume applications can deliver energy savings up to 80 percent

Released in March 2010, the Helieon LED light module combines SSL technology from Bridgelux with interconnect technology from Molex. An easy-to-use two-piece design, the Helieon light socket or lamp holder is permanently fastened into the luminaire. The light module is inserted into the socket with a push to make the electrical connections and an intuitive quarter turn to lock the module in place. By emulating a traditional lighting socket, the Helieon system delivers an easy and familiar installation experience. Helieon was designed for lighting OEMs intent on driving mass-market adoption of LED lighting.

Molex and Bridgelux develop and build products designed to meet specific LED lighting applications and market needs

Available in a choice of 800- or 1200-lumen output, Helieon modules are rated roughly comparable to 60W and 90W incandescent bulbs, but use significantly less electricity. Modules come in a choice of 3000K warm white or 4100K neutral white color temperature, and include a choice of 24°, 32°, or 50° beam angles. The module is 80 mm in diameter or just over three inches. With the light module mated to the socket, the assembly measures 27.6 mm or just over an inch thick.

Product options are tailored to match light output levels of traditional light sources, delivering between 500 and 1,500 lumens under application conditions in halogen and fluorescent color temperature options. Helieon modules are available with narrow and medium flood-beam patterns that enable precision effects for a wide variety of lighting applications. Users can readily alter the beam angle, color temperature or light output without removing or replacing the luminaire. Simply switching out the module (with an easy turn) can lend an entirely new look and feel to a lighting installation design.

The socketed, interconnect Helieon interface enables lighting fixture manufacturers globally to develop products based on the technology, allowing for faster industry adoption. Limited only by one's imagination, Helieon applications might include—down lights, task or accent lights, spot and track lights, troffers and interior-area lighting, retail and display lighting, hospitality lighting, architectural lighting, decorative lighting, and even museum lighting. Supporting industry standardization of the module interconnect technology will help to ensure long-term design opportunities, while protecting the development investment of fixture OEMs and their customers.

LED Array Holder eliminates hand soldering and simplifies LED installation

In 2010, in addition to launching Helieon in partnership with Bridgelux, Molex also launched the solderless LED Array Holder designed for Bridgelux ES and RS arrays. A perfect complement, the LED array holder delivers the same high performance and plug-and-play design in a cost-effective SSL solution. An innovative interconnect system, the LED array holder simplifies the installation of LED assemblies, and facilitates upgrades when more efficient or brighter lights become available. Solderless LED array holders dramatically increase connectivity options for superior design flexibility allowing OEMs to focus on fixture design with fewer constraints and less concern about implementation.

Ceiling light fitting: Molex LED light modules provide unprecedented design flexibility and freedom for OEMs to differentiate their product offerings

The double-ended wire-trap terminal simplifies assembly, allowing flexibility in wire orientation to achieve optimal wire routing. The releasable wire trap enables field replacements and facilitates upgrades to current applications. The one-step solderless screw down connection system eliminates the need for wire-soldering, Surface Mount Technology (SMT) soldering or other secondary processing during assembly, for substantial manufacturing savings and efficiencies. The LED array holder entirely eliminates the need for hand soldering or SMT soldering and expensive SMT equipment.

Secure compression power contacts provide a stable connection even in high-ambient temperature and prevent potential failures due to cold or unreliable solder joints. Other standard features include built-in mounting points for secondary optics. An optional clear LED protective cover, with a snap-lock, protects the LED from dust and assembly process handling.

Because there is no secondary processing required, the Molex array holders help facilitate quick design cycles and ease system-level integration challenges for OEMs. A form-factor smaller than 50mm (1.96") in diameter makes the LED array holder ideal for lamp and other small-fixture applications including MR16 or track lighting. The thermoplastic housing withstands high heat-generating environments.

Leveraging LED printed circuit assemblies for seamless lighting subassemblies

LED printed circuit assemblies offer a dependable and efficient custom lighting solution that works seamlessly with the Helieon product line for LED subassemblies across numerous industries. Connector and LED design integration equates with a complete solution leveraging proven products and technologies to support total LED interconnect needs. In-house functional testing of all printed circuit assemblies helps ensure quality and consistency of intensity and color.

Unparalleled circuit board reliability and design blends electrical, mechanical, thermal, and optical function into a fully qualified LED package. Molex custom LED assemblies support backlighting applications with polyester circuits that support lower power consumption applications and heat sinked polyimide and rigid boards to support high power consumption applications, such as surgical and automotive lighting. A BIN control system regulates consistent lot-by-lot LED luminosity output ranges, which are critical in a quality lighting product.

Intelligent lighting controls for network integration and reduced power consumption

As LED adoption progresses, the integration of lighting control systems with network devices will likely play an integral role in energy cost reduction, allowing end users greater flexibility and control over their environment. Intelligent lighting controls are already making jobs easier, while lowering the carbon footprint. New commercial, industrial and residential buildings are incorporating local area networks directly into lighting systems to monitor maintenance requirements, determine occupancy, and offer daylight controls and light dimming systems—yet a few more simple and effective ways for OEMs to harness electronic technology to drive down LED power consumption.

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THE PROMISE OF SOLID-STATE LIGHTING DEPENDS ON POWER ELECTRONICS ENGINEERS

By David G. Morrison

Solid-state lighting (SSL) or LED lighting promises energy savings, longer lamp life, and other potential benefits in general lighting applications. Spurred on by steady improvements in high-brightness LEDs, government mandates, and growing interest in green technologies, LED lighting is seeing increasing adoption in commercial applications, and to a lesser extent in residential applications.

Lighting manufacturers and others involved in the development of LED lighting are now working hard to accelerate the acceptance of SSL in both markets. They're doing so through their efforts to drive down the cost of LED replacement bulbs, while also developing new styles of cost-competitive lighting products that more fully take advantage of the LED's unique optical, electrical, and mechanical properties.

One aspect of driving down the cost of LED lighting is reducing the expense associated with the LED driver circuit, which is said to account for approximately 20% of the overall cost of an LED luminaire. 1 I recently spoke with engineering executives from two lighting companies about this and other technical challenges they face in the development of power electronics (PE) for LED lighting. Their descriptions of the factors that drive product development explain why PE engineering is now such an integral element of lighting product design.

Tackling Lamp Replacement

According to Guenther Derra, department head for Solid State Lighting at Philips Research, two streams of SSL product development influence the types of challenges faced by electronics designers. The first stream is the development of LED replacements for existing light bulbs.

"This [area of SSL] brings several technical challenges: the electronics have to be compatible with the given electrical infrastructure that has been designed and optimized for the now widely banned incandescent lamps," says Derra. "The electronic circuit, together with the LEDs, the optics and the thermal interfaces have to fit in the same lamp form factor as the original incandescent, halogen or fluorescent lamp. Along the way, costs have to be significantly reduced and light quality and energy efficiency increased."

Mike Harris, the head of the power electronics group at Cree LED Lighting, points out that cost becomes most important in LED products targeting residential applications. "If you look at a Home Depot or a Lowe's [major retailers in the U.S.], there are a fair amount of LED bulbs and lamps that get sold. But clearly the price point from a residential perspective is still not where it needs to be to really see large adoption," says Harris who notes that commercial applications are less price sensitive because the customers weigh energy savings and reduced maintenance requirements when considering the purchase of SSL products.

But despite the gains made in the commercial sector, a key goal in SSL is conquering the residential market.

"I think there's been a pretty big push recently to try to sell the perfect LED bulb and probably the first vendor that gets it right at the right price point will do very well with it," says Harris. "But I think there are certainly still challenges to get to that price point."

According to Harris, the challenges faced in developing the power electronics for LED bulbs and lamps are similar to those encountered in other areas of power supply development. Harris identifies cost, thermal management, size, and product lifetime (though not necessarily in that order) as the key parameters for LED power supply designers.

Harris illustrates the power supply design challenge with a comparison to the compact fluorescent lamp (CFL). With an LED lamp, "you're looking at a 10 to 15 watt power supply that needs to control current, needs to be compatible with triac dimming (phase cut dimming) and be able to do that at a price point comparable to a CFL," noting that a package of CFLs can now be purchased for just a couple dollars.

When asked to compare power supply development in LED lighting to other application areas such as motor drives and ac-dc adapters, Harris observes that all power supply designers face thermal and size constraints to varying degrees.

"I'm not sure that the adapter designers are as challenged on size. They may be on form factor, in terms of a thinness or a profile, but they don't have to necessarily fit into an existing ANSII standard for a bulb and still have room for LEDs and optics," says Harris. Nonetheless, he describes adapter design and LED power supply design as "very similar challenges."

On the other hand, product life may be an area where LED power supplies are held to a higher standard than in most other consumer applications.

"The expectation that you're going to put this into a ceiling and have it last 20 years is probably different from some other power electronic markets, especially at the low price point," says Harris.

While laboring to address requirements of the lamp replacement market, lighting companies are also developing original lighting solutions for new installations. "This stream of product development," says Derra, "allows for new system concepts with new light sources. This is already in progress and will increase in importance in the future."

This area presents its own hurdles. "You can imagine that energy efficiency, light quality and cost efficiency are important technical challenges to address. A major trend worth mentioning is the movement from physical light sources towards complete lighting solutions. The integration of lighting in larger systems requires new power electronics solutions," says Derra.

Better Silicon Is Key to Cost Cutting

Various power supply technologies need to be applied and developed to address the technical challenges faced in LED lighting. This means developing both conventional switch-mode power converters and new topologies, says Derra, but also developing thermal management techniques.

Meanwhile, Harris explains that improvements in silicon are the key to driving down cost in LED drivers. "It's done by more-efficient, better, lower-cost power electronic components and integration. I don't think it [SSL] is different than any other market. The size may be different, the power levels may be different, but a lot of the same challenges that semiconductor companies are solving in other markets apply to the SSL market."

Semiconductor companies have only recently begun to address the demands of SSL applications in earnest. Just four years ago, there were relatively few IC companies developing LED drivers for general lighting, says Harris who notes "the IC vendors were force fitting existing solutions."

"But over the last two years, the number of IC companies that have put substantial resources into LED lighting is tremendous. Out of that you've got a lot of smart people that are creative and they come up with good solutions," says Harris.

For those interested in how design jobs in the SSL field both resemble and differ from power supply design in other industries, see "Profiling the SSL Power Supply Designer" in the online version of this article where you'll also find a sampling of recent job postings for power electronics engineers in the lighting industry.

For additional information on engineering opportunities in lighting, see "Lighting Company Takes a Shine to Power Electronics Engineers," in How2Power Today, February 2010 issue, online at www.how2power.com/newsletters.

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David G. Morrison is the editor of How2Power.com, a site designed to speed your search for power supply design information. Morrison is also the editor of How2Power Today, a free monthly newsletter presenting design techniques for power conversion, new power components, and career opportunities in power electronics. Subscribe to the newsletter by visiting www.how2power.com/newsletters.

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GREENER MEDIA

By Cliff Keys, Editorial Director & Editor-in-Chief, Power Systems Design

A trend in the US is sure to be reflected in Europe for flat-panel liquid crystal display (LCD) TVs featuring light-emitting diode (LED) technology. LED TVs accounted for more than one-fifth of all U.S. TV sets purchased in the final quarter of 2010, according to IHS iSuppli.

LED-backlit LCD TVs made up 22.5 percent of TVs bought in the U.S. market in the fourth quarter last year, up almost 3 points from 19.6 percent in the third quarter In comparison, a full three-fifths of consumer purchases were for LCD TVs featuring the older technology of cold cathode fluorescent lamp (CCFL), LED models are brighter, more power efficient and have thinner profiles, but they are also much more expensive than their CCFL counterparts, which explains the market disparity between the two flat-panel LCD technologies.

The increased share of LED TV models solidifies the steady gains the technology has made since the second quarter of 2009 when it first appeared. In the fourth quarter of 2009, LED models only had 6 percent share, nearly four times less than what the latest totals indicate.

Plasma TV purchases remained flat despite aggressive end-market pricing, with sales growth hindered by the declining prices of LCD TVs in general as well as by consumer perceptions that plasma sports lower-grade specifications.

Marking a major inflection point, the book publishing industry has entered a period of long-term decline because of the rising sales of e-book readers, according to IHS iSuppli. The overall weakening will be spurred by a 5 percent decrease in the CAGR of physical book sales from 2010 to 2014.

While e-book sales will soar by 40 percent during the same period, such an increase won't be sufficient to compensate for the contraction of the larger physical book market. From 2007 to 2009, e-book readers had generated healthy profit margins averaging 35 percent. However, margins collapsed when Apple Inc.'s iPad was introduced in April 2010. To achieve higher profits, e-reader makers must move beyond e-books and offer other items including magazines.

So it looks like a boom time for the LED TV business and for the e-reader market but the demise of the printed book. It will take time but the printed book industry will be sure to take a large hit. Indeed, our own industry media has had to provide both print together with a powerful online service for its readers.

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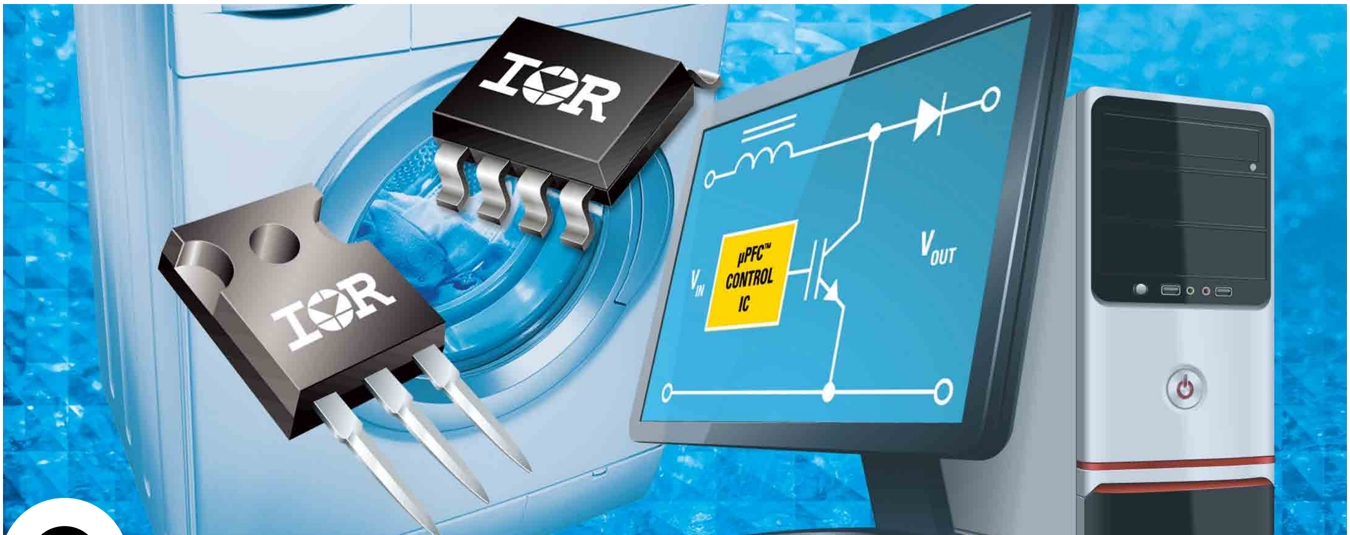

Delivering Real Power

Compact, Powerful CCM PFC from 75W to 4kW+

PFC Control ICs

Part Number	Description
IR1152	Fixed 66KHz switching frequency with brownout protection and dual OVP protection
IR1153	Fixed 22KHz switching frequency with brownout protection and programmable OVP protection
IR1155	Programmable switching frequency and programmable OVP protection

600 V PFC IGBTs for High Power Systems

Part Number	Circuit	I_c @ 100C (A)	$V_{CE(on)}$ (max) (V)	Package
IRGB20B60PD1	Co-Pack	22	2.35	TO-220AB
IRGP20B60PD		22	2.35	TO-247AC
IRGP35B60PD		35	2.15	TO-247AC
IRGP50B60PD1		45	2.35	TO-247AC
IRG4(B/IB)C20W	Discrete	6.5	2.6	TO-220AB; TO-220 FullPak
IRG4(B/IB/P)C30W		12	2.7	TO-220AB; TO-220 FullPak; TO-247AC
IRG4(B/P)C40W		20	2.5	TO-262; TO-220AB; TO-247AC
IRG4PC50W		27	2.3	TO-247AC
IRGP4069		35	1.85	TO-247AC
IRGP4063		48	2.14	TO-247AC
IRGP4066		90	2.1	TO-247AC

The µPFC family of controller ICs radically alters traditional thinking about PFC solutions. The IR115x uses a "One-Cycle Control integrator with reset" technique to deliver the high performance of Continuous Conduction Mode (CCM) PFC with the simplicity and low component count of Discontinuous Current Mode (DCM).

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