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PSDNA Green Power ENERGY EFFICIENCY

Longevity in Light

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

With the huge industry interest in Lighting as the topic themed in this issue, I have been amazed at the growth in the industry and hence the submission of a great deal of good quality content for this issue of our magazine since this time last year. Naturally the figure of Lumens per Watt figure for LEDs is getting ever better, but it' s not just the LEDs themselves but also the circuits that drive them. We all were agog at the constantly specified lifetime of LEDs, usually in the order of 50,000 hours, but this assumes a well designed fixture with adequate heatsinking and a driver/controller circuit that can drive the device within its electrical and thermal specifications. Early fixtures proved disappointing to many users due to the less-than-perfect driving or mounting of the LED. As always, engineering came a long way in a very short time and solved the problem.

But the area of lighting is not merely confined to LEDs, although this does get the most in terms of media attention. Factories and offices as well as homes will not suddenly switch over to LED illumination overnight. Even though the traditional incandescent light bulb is being phased out by enforced legislation, there are other viable and hi-tech alternatives such as Compact Fluorescent (CFL) technologies to enable high efficiency operation, low cost and higher degree of control, particularly in dimming techniques, than available in the past. The other advantage is that CFL (and traditional incandescent) lighting fixtures throw a more evenly distributed light than their current LED counterparts. (See our MarketWatch report from IMS Research).

You should be able to get yourself updated on exactly what's happening in the area of lighting within the pages of this issue and naturally, if you have a compelling engineering story to tell, send it in to me.

Beginning with this issue of Power Systems Design North America, I would like to highlight the first of a regular contribution from David Morrison, Editor of How2 Power. David will talk about design engineering opportunities and how jobs offered in our industry are developing, and will follow the magazine's editorial theme in each issue. This should be a valuable new career resource section. Please join me in welcoming David to our top team of regular contributors.

As we work our way through another year and hopefully out of recession, into a period of sustainable growth, I hope we see more university places taken by students of engineering in all its forms. I would guess it depends who they see as role models for their future. It will hopefully be those firms who hunker down, lead and inspire their talented engineering resources to creatively innovate their way out of a recession into a bright future rather than those who hack their staffing to pieces merely to cut down on costs. It all depends on who pulls the strings.

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

All the best!

Cliff Keys

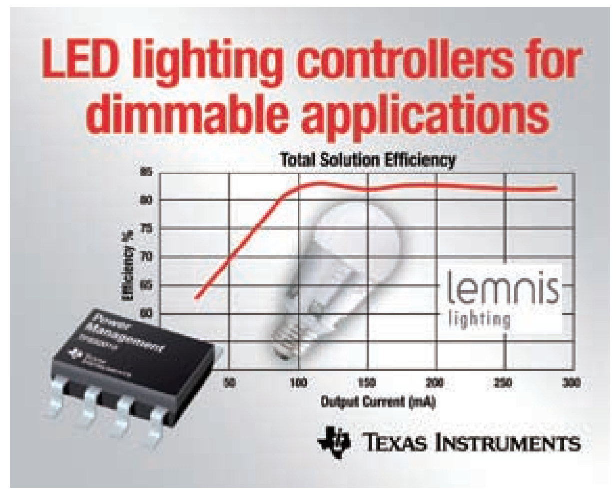
Editor-in-Chief, PSDNA

TI's New LED-Lamp Reference Board

TI has recently launched a leading-edge portfolio of products for today's LED lighting design requirements based on decades of innovation in power management and wired and wireless communication technology. TI helps speed customers' lighting innovation with a broad portfolio of power management devices, and products tailored to the needs of the lighting market, complemented by the company's strong local and online customer support network.

The company has introduced a complete LED lighting driver reference board in collaboration with Lemnis Lighting to help address three important issues: cost, dimming and efficacy. The TPS92010 LED-lamp Reference Board applies TI's semiconductor technology for general LED lighting and Lemnis Lighting's expertise in dimmable lighting applications. The board can help speed adoption of energy-saving retrofit LED light bulbs. The reference board will be available in mid-second quarter and is accompanied by a user's guide that contains the schematics, bill of materials and test results needed to design a dimmable LED lamp.

The reference board is based on TI's new TPS92010 LED lighting controller. The TPS92010 offline LED lighting controller implements quasi-resonant flyback power converters to achieve high efficiency of up to 87%, small size and lower cost for AC/DC LED lighting drivers. The TPS92010's control technique allows designers to develop replacement light bulbs in tight, small form factors, and helps reduce overall system cost. The device's system-level features, such as overvoltage detection and shutdown, prevent system damage caused by an open LED string. Its over-temperature shutdown feature protects against excessive heat in the system.



The TPS92010 is the first of a new family of TI LED controllers designed for general lighting applications, such as residential LED fixtures; retrofit LED bulbs; commercial troffers; downlights; wall sconces; pathway lighting; overhead lighting; and architectural and display lighting.

Building on the successful development of the TPS92010 LED-lamp Reference Board, TI and Lemnis Lighting will continue to collaborate on future cutting-edge driver solutions for LED lighting applications.

Key features and benefits

The TPS92010 LED-lamp Reference Board features a seamless, high-performance dimming interface to TRIAC (triode for alternating current) based wall dimmers. The TRIAC dimming interface circuit maintains high efficiency even during deep dimming (60% efficient at 10% LED current).

The reference board is an isolated driver with low EMI to simplify safety certification and electromagnetic compatibility (EMC) compliance. To order the TPS92010 LED-lamp Reference Board see www.ti.com/tps92010referenceboard-preu.

Availability and pricing

The TPS92010 LED-lamp Reference Board will be available in second quarter 2010 and is priced at $49.95. The TPS92010 offline LED lighting controller is available now in an 8-pin SOIC package and is priced at $0.43 in quantities of 1,000.

www.ti.com

www.lemnislighting.com

Lighting Industry Becomes Re-defined by LEDs

By Paul Scheidt, Product Marketing Manager, Cree LED Components, Durham, North Carolina

The LED lighting revolution has reached the mainstream lighting market with the availability of high-performance LED products. Now it is more important than ever for engineers to consider LED technology when designing lighting solutions.

Less than five years ago, the prospect of a 200 lm/W LED was considered a far reach for the solid-state lighting industry. Many even considered it the theoretical maximum for a LED. Earlier this year, Cree surpassed this significant milestone with an R&D demonstration of a 208 lm/W white LED.

By reaching this milestone at an accelerated pace, the bar has been raised for the achievement of future milestones including higher lumens per watt and the stage has been set for continuing technology developments.

In production LEDs, other new components are raising the level of light output and efficacy across the white color spectrum into the 150 lm/W range and above. This enables a broad spectrum of applications, including general lighting applications such as LED replacement lamps, outdoor area lighting and commercial luminaires.

To address this broad range of markets, LEDs must deliver high lumen output and high efficacy across the entire white color spectrum—including

warm white. This is especially important as LED replacement bulbs begin to enter the market, where meeting consumer expectations of warm color (2700-3000K) is paramount to continue LED adoption.

Traditional light sources are specified by brightness (lumen output) and color temperature. Cree saw the need to make multi-chip LEDs fall into this same specification formula, to more quickly accelerate the LED lighting revolution. With the introduction of EasyWhite technology, lighting designers can now forget (or not learn) binning, color mixing and LED recipes. These new LEDs are optimized for directional lighting applications, including PAR- or BR-style light bulbs, and, to give an example of what's possible, could create a 3000K BR-30 bulb but consume 78 percent less energy than a comparable 75W-incandescent equivalent!

Every advancement in LED performance enables additional LED lighting applications. Similarly, every new LED application opens a new arena for competition. All of this is exactly what the LED lighting revolution needs. Cree has seen the need in for an efficient, high-quality light source in a compact, easy-to-use module that traditional lighting manufacturers could integrate into their fixture designs. Our new LED module is designed to overcome common design issues that manufacturers previously faced when trying to incorporate standard LED solutions into their lighting fixtures. In many cases, LED lighting design can now be as simple as designing a fixture and dropping in our ready-to-go module.

As the technology continues to improve and the costs come down, the lighting industry is being redefined by LEDs. This trend will continue as developments accelerate in LED components, fixtures and power/control circuitry. In order to position LED lighting at the forefront of the market, the lighting industry needs to continue setting the bar for better performance, simpler designs and lower operating costs through energy efficiency and reduced maintenance/replacement.

www.cree.com/products/ledlamps.asp

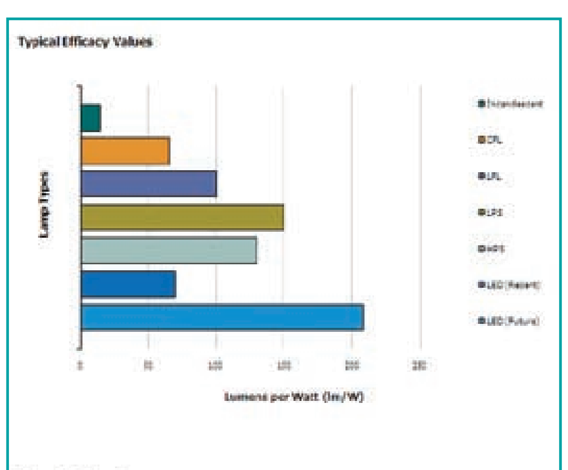
www.cree.com

LEDs Are Straight Shooters (But That's Not Always Good)

By Kevin Furr, Senior Research Analyst, IMS Research

Lighting trade shows are shining a spotlight on the bright future of LEDs. Technology has now elevated LEDs to the point where they can take on the marquis role in light-emission – general illumination, lighting up our offices and streets and homes. Recent trade shows might lead an attendee to believe there is no other source of light, with supplier booths hawking almost nothing else but LED-based lamps and luminaires.

Like yesterday's cause célèbre – the compact fluorescent lamp – new LED-based lighting promises huge dividends in energy savings and longer life. But also as with CFLs, LED lighting leaves something to be desired in some lighting applications. For all its promise, LED may not be embraced in key everyday lighting applications we take for granted. The core problem is directionality – a filament bulb casts light in every direction, but an LED emitter projects light only in one.



That trait makes LED-based lamps a good fit for highly directional applications – recessed lighting, accent lighting, retail downlighting, street lighting. Indeed roadway lighting has proved to be an early target for LED conversion, with LEDs putting out no stray lumens above the horizon – and so not polluting the night skies. In terms of indoor products, the first against the wall in the LED revolution are likely halogen MR and PAR lamps.

But LED lighting is a more debatable replacement for common A-19 bulbs and linear fluorescent tubes. A public accustomed to omnidirectional output lighting up all corners of a room may find the directionality of an LED device limiting and off-putting. Lamps designed with an array of emitters facing a variety of directions are not yet satisfying replacements for the incumbent technologies – and packing so many emitters into such a small space challenges the device's thermal management.

Not so debatable is the potential energy savings from LEDs, a technology that's rapidly improving. A key metric in the lighting world is efficacy, or lumens-per-Watt. Current LED lamps have been clocking in about 70 lm/W, but the emitter efficacy record in the lab has reached 208 lm/W – recently announced by Cree. We may not see that number for a few years in LED-based lamps on the market, but LED products should soon pass the 100 lm/W we see with T-8 or T-5 fluorescent tubes.

Bringing that kind of efficiency to as wide a market as possible may require us to solve the problem of diffusion: clever advancements may yet enable a pleasing and useful omnidirectional diffusion of LED emission.

A second approach is to rethink lighting design, tapping LEDs to put light where needed but with a design users can accept. Omnidirectional filament-bulbs, after all, cast lumens where they are not really needed – in the end, designing replacement LED bulbs for the installed based of sockets may not be the most effective use of LED technology.

www.imsresearch.com

Power Supply Development Diary Part II

Introduction

This article continues the series in which Dr. Ridley documents the processes involved in getting a power supply from the initial design to the full-power prototype. In part II, we focus on the interface between the power stage and controller, and getting the gate drive working properly.

Power Supply Development Testing

The results of initial testing are shown in this article for a two-switch forward converter. This was a project for which the initial prototype breadboard was complete, and it was time to apply control and power signals. As mentioned in the first article of this series, there were a total of 85 process steps involved in moving the power supply from the original non-working condition to a full power board. It would take too many articles to present every detail of each of these steps, so I will focus on the events which I have observed many times before in the industry.

Power Supply Requirements

The specification for the power supply was as follows:

1. Output 1 – 35 VDC @ 10A isolated
2. Output 2 – 35 VDC @ 10 A isolated
3. Maximum power 350 W (only one output fully loaded at a time, application is for audio.)
4. Input – 180 – 265 AC
5. Power Topology: Two-switch forward
6. Controller: Digital controller from TI

Power Stage and Control Interface Schematic

The full schematic of the power stage is shown in Figure 1, together with the signals for interfacing with the control circuit. The power stage was completely separated from the control so that each could be worked on individually, and layouts for each were independent. This is crucial for a digital power supply controller which needs fine-pitch layout versus the heavy copper suitable for the power stage.

It is quite common to find errors in either circuit that can require a new layout – keeping the power and control separate can greatly speed up the development process. For early testing, it is often a good idea to provide a connector between the two, with two separate boards.

For high power work, using either digital or analog controllers, it is best to have only one ground connection between the control circuit and the power circuit. There should be no overlap of ground planes in order to prevent power currents from flowing near the control parts. A single point ground should be established between the two parts of the circuit.

The drive for the gate of an offline power supply should be galvanically isolated for both of the power FETs using a gate drive transformer as shown in Figure 1. This is much better than using an integrated high-side driver. A gate drive transformer has the advantage of providing negative gate voltage during the off-time which provides superior noise immunity from accidental turn on of the FET. A gate drive transformer is

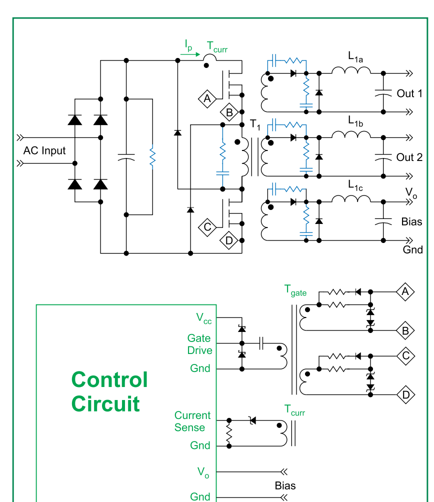


Figure 1: Power Stage and Control Interface Schematic

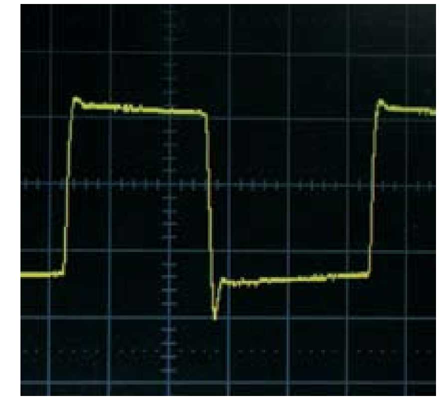


Figure 2: Gate Drive Waveforms with Damaged Gate

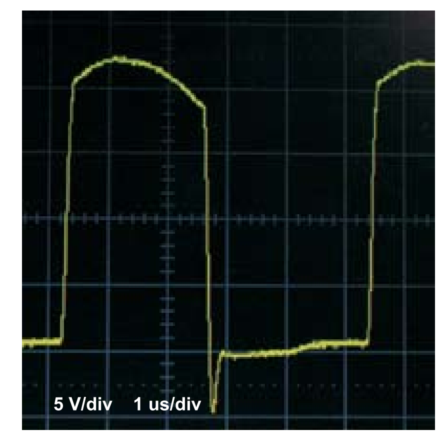


Figure 3: Normal Gate Drive Waveforms

also much better during the development phase when power stage failures are likely to occur. If the high-voltage power FET is destroyed, the damage is usually limited to the secondary of the gate drive transformer, and the control circuit is left intact. This is crucial for finding the root cause of failures.

The current-sense network is also galvanically isolated. The current transformer network shown provides the cleanest signal for current sensing, and its wide bandwidth allows for protection of the power devices as we shall see later.

Event #1 Bypass Capacitors

The first problem encountered was that the digital controller simply did not work properly when hooked to the gate driver. The issue was tracked down to the lack of a bypass capacitor in the proper place for the gate-drive chip. The need for this was documented in the data sheet, but deeply buried in other information.

If you haven't worked in power supply design before, adding bypass capacitors next to your integrated circuits is often just a formality. Quite often, they can be removed without any detrimental effect. However, they are crucial elements of power supply control circuits, especially when power FETs must be driven. Placement of all bypass capacitors for gate-drive outputs, clocks, references, and supply voltages must be very tight to the integrated circuits.

he lack of a gate-drive bypass capacitor also highlighted the difference in thinking of digital and analog engineers. The digital engineer's immediate response to the oversight was to make another board before proceeding. The approach from most analog engineers would be to add a bypass capacitor next to the chip with two lengths of hookup wire and move on to the next test. Experienced power designers know there will be many such issues, and it is best to collect as many changes as possible and rework the PCB when the changes become unmanageable.

Event #2 Gate Drive Overheating

Once the bypass capacitors were properly placed, gate-drive waveforms at 200 kHz were obtained from the control chip. However, both the gate driver and the lower power FET overheated significantly, even with no power applied to the input of the power stage. The FETs were able to switch a resistive load, but something was not working properly.

This led to another significant conclusion for me. An overheated and destroyed gate driver for a digital controller is a substantial repair problem. The high density drivers have pads on the bottom which, when surface mounted, remove the heat very effectively. However, this prevents you from mounting the driver in a socket. After many years experience in designing offline converters, you learn that failures of the control chip and the gate-drive chip are common events. When trying to track down failure mechanisms, it is not uncommon to burn through many chips in a day. If they have to be unsoldered, this can be a very tedious process, severely impacting development time.

At this point, the digital controller part of the project was put on hold. Clearly, it did not make sense to continue debugging the power stage at the same time as working with a digital controller. An analog control board from a previous project was substituted for the digital control to allow testing to continue. The clearly delineated separation of the control and power stage made this substation straightforward.

Only one of the FETs was hot with the gate drive applied. The waveforms on this FET are shown in Figure 2. There was a significant drop in the predicted voltage, but the waveform still looked reasonable if you are not familiar with normal FET operation.

One indication that something is not right is that the waveform is very square. Upon being desoldered from the power board, the gate-to-source resistance was measured at 27 ohms when it should be an open circuit. The gate may have been damaged by static when handling or mounting to the board, or it may have been damaged upon arrival. It could also have happened when the power board and controller were connected together.

Notice the use of back-to-back zeners across the FETs. These were added after the failure was found, a normal precaution for offline converters. Figure 3 shows the proper gate waveforms after the FET was replaced. Notice the higher amplitude, and the curve of the top of the waveform. This is characteristic of the gate drive scheme chosen.

Event #3 Driving Inductive Loads

The digital controller was replaced

with a 3825 controller, one of the most rugged chips on the market. This is a good choice of controller to use to debug a power stage. In order to test the initial operation, the controller from another power supply design was used with wires jumping between the two boards. This allowed testing to rapidly continue without designing a special board.

The initial operation, however, was very unpredictable, with very narrow or missing gate pulses from the controller when connected to the transformer. This was due to a second common problem. Most bipolar technology control chips cannot provide the reactive current needed by a gate-drive transformer. The solution to the problem is shown in Figure 1 – schottky diodes must be added at the output of the gate signal to supply the reactive part of the current.

Other Early Mistakes

When hooking up the power stage with a substitute controller, several other mistakes were made.

#4.The supply voltage Vcc was mistakenly applied to the output of the controller. The 3825 had to be replaced.

#5.An auxiliary ramp summing circuit for current-mode control was applying a negative voltage to the current sense input. Nothing works according to the datasheet if you do this. This is a more common occurrence than you might think when hooking up low-voltage control circuits to high-voltage power stages.

The first of these mistakes was made after trying to achieve too much in one day. Working on power supplies requires a clear and fresh mind to avoid mistakes. In this case, it was easy to fix the controller since it was in a DIP socket. When power is being applied, though, working while tired can be dangerous, destructive, and often very time-consuming.

Summary

The first phase of this project showed up numerous errors and failures that are difficult to predict and anticipate. This is normal in power supply development, and such events must be budgeted in the schedule. If you are a manager, pushing your engineers to work harder and longer hours is not the path to better results. The development and testing of a power supply must be a deliberate and methodical process with sufficient time allocated to work efficiently with a clear head.

Switching to an analog controller during the debugging process was clearly a necessary step to get the power stage operating properly. This eliminated unknowns of a very complicated component, and made replacement after failures fast and straightforward.

In the next phase of this article, power is applied and the process of debugging continues.

www.ridleyengineering.com

On the Road

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

Micrel Unveils New 4G Wireless PMIC

I had the enormous pleasure to meet with Micrel's Andy Khayat in the centre of the capital city of London, England. Andy has more than 28 years of high-tech and management experience and has been Director of Micrel's Portable Product Group since 2007. He has responsibility for the business unit's strategic marketing, roadmaps, business plans, product definition, pricing, product launch and promotion, as well as technical support for new design in activities. A very busy guy, he gave me an insight into Micrel's stunningly flexible new 4G PMIC.

Highly integrated and versatile power management solution

Micrel is acknowledged as an industry leader in analog, high bandwidth communications and Ethernet IC solutions and has just launched the MIC2829, a highly integrated Power Management Integrated Circuit (PMIC) for 4G wireless applications. The device represents a complete power management solution providing power to processors, multi-standard RF (such as HEDGE/ LTE or WiMAX) transceivers and power amplifiers, memory, USB-PHY, associated I/O interfaces and other system requirements. Forming the power foundation for forthcoming 4G designs, this product has huge potential in the imminent high volume 4G market.

Designed for 3G/4G (HEDGE/ LTE and WiMAX) USB wireless applications, the MIC2829 is currently available in volume quantities with pricing starting at $2.95 for 10K quantities. Samples can now be ordered on line on Micrel's web site at: http://www.micrel.com/ProductList.do.

Andrew Khayat, Director, Portable Product Group, Micrel, Inc.

Andy explained, "The MIC2829 is a complete 4G wireless system PMIC. This release to the market represents the beginning of a new level of integration for USB and embedded based LTE or WiMAX 4G standard based mobile communication devices. This product is the result of Micrel's focused efforts to revolutionize mainstream wireless PMICs.

The MIC2829 integrates all system power and analog functions supporting 4G wireless baseband, RF and digital/analog sub-systems into one IC. It features Micrel's HyperLight Load™ (HLL) DC converters that greatly extend battery life and Micrel's advanced LDO technologies for ultimate system performance."

The MIC2829 incorporates six DC/DC buck converters, eleven LDOs and digital level shifters for SIM Card support inside a single, compact package. Five general purpose LDOs provide low dropout, excellent output accuracy of ±3% and only require 40 microamps of ground current for each to operate. The remaining six are high performance Low Noise Regulators (LNRs) and provide high PSRR and low output noise for sensitive RF subsystems. Each LNR requires only 20 microamps of ground current to operate.

Four of the six integrated DC/DC buck converters incorporate HyperLight Load™ (HLL) technology. Each of these buck regulators operate at high switching speed in PWM mode (4MHz/

2.5MHz) and maintain high efficiency in light load conditions. The high speed PWM operation allows the use of very small inductors and capacitors minimizing board area while the HLL mode enables 87 percent efficiency at 1mA.

HyperLight Load™ technology also has unmatched load transient response to support advance portable processor requirements. The remaining two DC/DC buck converters support 100 percent duty cycle operation and can deliver greater than 96 percent efficiency. The MIC2829 is available in both 76-pin 5.5mm x 5.5mm LGA and 85-bump 5.5mm x 5.5mm FBGA packages with an operating junction temperature range from –40 °C to +125 °C.

Micrel's flexible foundation for 4G power management solutions

This unique power management solution was made for today's fast developing 4G design and manufacturing industry arena. The company's involved in this business will no-doubt want their own refinements built in to differentiate their offerings to consumers. My knowledge of Micrel' s speed and flexibility in refining its products tells me that this part will form the basis for many future 4G designs. I will feature a full article on the unique technical features of this device in a later issue of the magazine.

www.micrel.com

Inductors for Illumination

Picking the right L for your LED driver

A wide variety of driver circuits is needed to support new LED applications and the demands for high performance are challenging designers to be as creative as possible with new circuit techniques. In order to fully optimize the new circuits, a strong understanding of component performance is necessary. In particular, inductor selection remains a key part of the design process and with the right tools, identifying the best inductor can be one of the most fruitful areas for optimizing LED driver circuits, and with power converters for all applications.

By Len Crane, Director - Technical Marketing, Coilcraft

LED Applications

For DC-DC LED drivers there are uses for buck, boost, buck-boost and SEPIC topologies. There are some requirements particular to driving LEDs, such as the need for a constant current source. In addition, many drivers use pulsed outputs for dimming capability, as well as to achieve higher efficiency, taking advantage of the phenomenon that the human eye does not perceive flicker above a certain frequency. Yet for all the variations, there are many commonalities among inductor based LED driver circuits. Whether they drive a single LED or a string, whether they have dimming capability or not, the essential inductor operation will be a function of the switching frequency, load current, and the input to output voltage ratio. These inputs feed the basic inductor relationship common to all DC-DC converters that is V = L x (di/dt). This relationship, along with different mechanical requirements will determine the type of inductor chosen. It is easy to imagine, for example, that the space constraints may be much different for a high brightness LED flashlight than for an LCD display backlight.

Inductor Specifics

Understanding the tradeoff between inductor size, performance, and cost, begins with a brief review of inductor operating principles. It can be shown that these basic principles translate directly from inductor performance to the data sheet specifications that designers must use to choose between components.

The design task for a power inductor is to maximize the inductance (L) and saturation current (Isat) product, otherwise known as volt-seconds, while at the same time minimizing the losses.

$$L = 4\pi\mu \frac{N^2 A_e}{l_e} \times 10^{-9}H$$

Figure 1

The formula in figure 1 shows that inductance is determined by a combination of material properties and geometry.

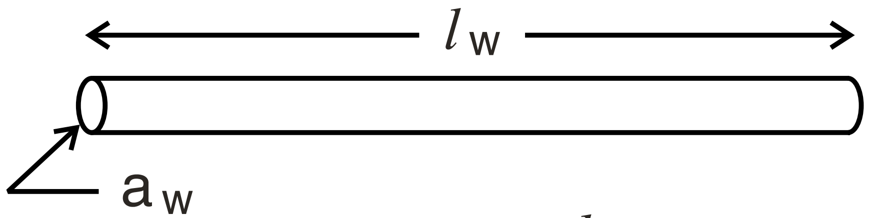
The permeability (μ), is a specific property of the chosen core material, whereas the effective cross-sectional area $a_e$ae and the effective magnetic path length l_e, describe the core geometry. It is important to note that while it seems obvious that a larger core cross-section increases the inductance, it is a little more counter-intuitive that a larger le decreases the inductance. This would be the case in a larger l_e diameter toroid core, for example.

$$Isat = \frac{Bsat \times l_e}{\mu\ (0.4\pi N)}$$

Figure 2

As shown in figure 2 we can describe the saturation current in terms of the same physical parameters as the inductance.

Similar to the inductance, the saturation current (or volt-seconds) depends on geometry (l_e) as well as material properties, namely the saturation flux density (Bsat) and the relative permeability (μ). Note that Isat is inversely proportional to the permeability, directly opposite the effect it has on induc-



$$DCR = \rho \times \frac{l_w}{a_w}$$

Figure 3

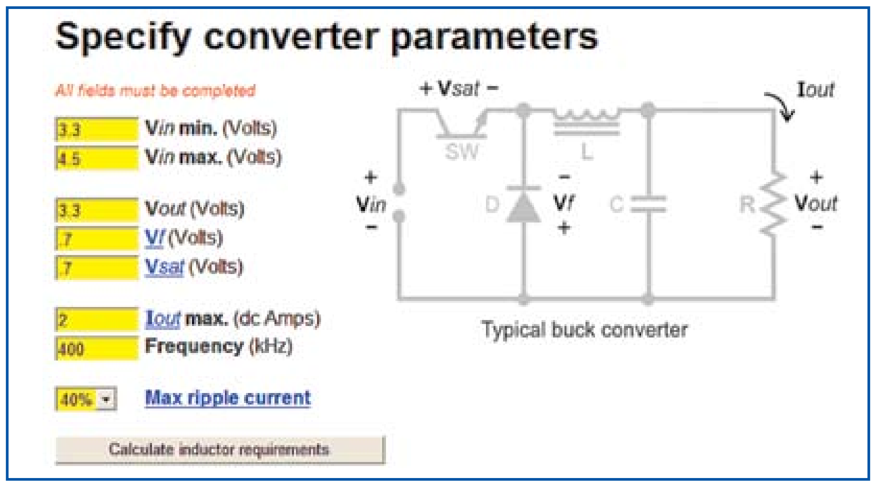


Figure 4

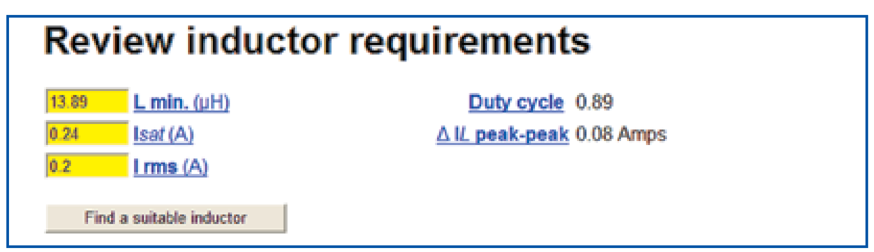
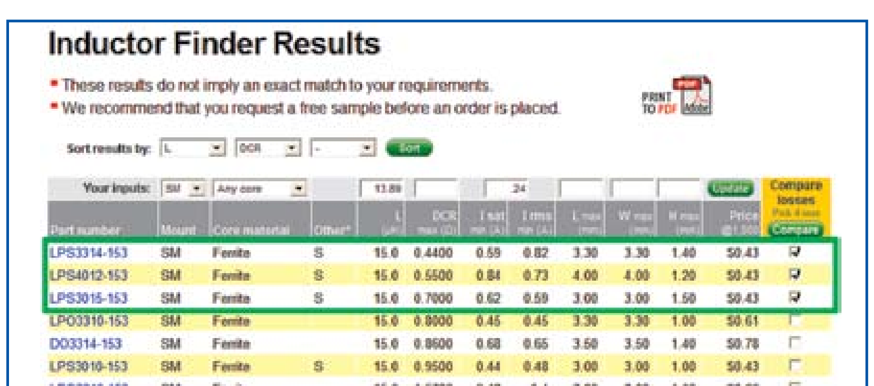


Figure 5



Part number	Mount	Core material	Other*	L	DCR	I sat	I rms	L max	W max	H max	Price	Compare losses
LPS3314-153	SM	Ferrite	S	15.0	0.4400	0.59	0.82	3.30	3.30	1.40	$0.43	☑
LPS4012-153	SM	Ferrite	S	15.0	0.5500	0.84	0.73	4.00	4.00	1.20	$0.43	☑
LPS3015-153	SM	Ferrite	S	15.0	0.7000	0.62	0.59	3.00	3.00	1.50	$0.43	☑
LPO3310-153	SM	Ferrite		15.0	0.8000	0.45	0.45	3.30	3.30	1.00	$0.61	☐
DO3314-153	SM	Ferrite		15.0	0.8600	0.68	0.65	3.50	3.50	1.40	$0.78	☐
LPS3010-153	SM	Ferrite	S	15.0	0.9500	0.44	0.48	3.00	3.00	1.00	$0.43	☐
LPO3010-153	SM	Ferrite		15.0	1.5700	0.42	0.4	3.00	3.00	1.00	$0.66	☐

Figure 6

tance. As this suggests, optimizing the inductance value and optimizing the saturation current rating will be in conflict with each other.

The Isat becomes the specification for how much peak current the inductor must be rated. The average current rating, on the other hand is loss dependent. To completely understand inductor loss, such phenomena as skin effect, core loss, and other frequency-dependent losses must be considered, but a good starting point is to consider the DC resistance (DCR). We commonly think of this as a single value found in a wire table, but it too is a function of both material property and geometry. The material property is the resistivity (ρ), and the length and cross-section of the winding wire are the geometric dimensions.

The DCR, Isat, and L equations demonstrate that these properties correlate differently to the same physical parameters, presenting a challenge to optimize for all three properties. For example, increasing the core cross-section will increase the L and Isat, but detrimentally increase the DCR. Increasing the core permeability will correspondingly increase the inductance and reduce DCR, but conversely Isat will be decreased. The end result is that any design must be a combination of these factors and no one design will provide optimization in all parameters. It is key, therefore, that the designer have access to selection tools that identify the combination of parameters best suited to a particular application. Those tools should include clearly defined specifications and some method for sorting/finding an inductor that best fits those specifications.

Buck Regulator Example

To demonstrate how the required circuit performance can be translated in to the necessary inductor specifications for inductance, peak current, and average current ratings, consider the example of driving a single white LED at .2A drive current and forward voltage of 3.3V, from a Li ion cell over the range of 3.3V to 4.5V. Further, as is typical for a portable device, assume the footprint and component height are limited.

Vin = 3.3 to 4.5VDC
Vo = 3.3VDC
Io = .2A
F = 400kHz
Z = 1.5mm max.
X x Y = 4mm x 4mm max.

For this voltage step-down application, the required input for calculating inductor parameters for a buck converter is shown highlighted in figure 4.

This information and V = L x (di/dt) is all that is required to calculate the required L value, along with peak current (Isat) and the average current (Irms) inductor ratings. Figure 5 shows the result for this example.

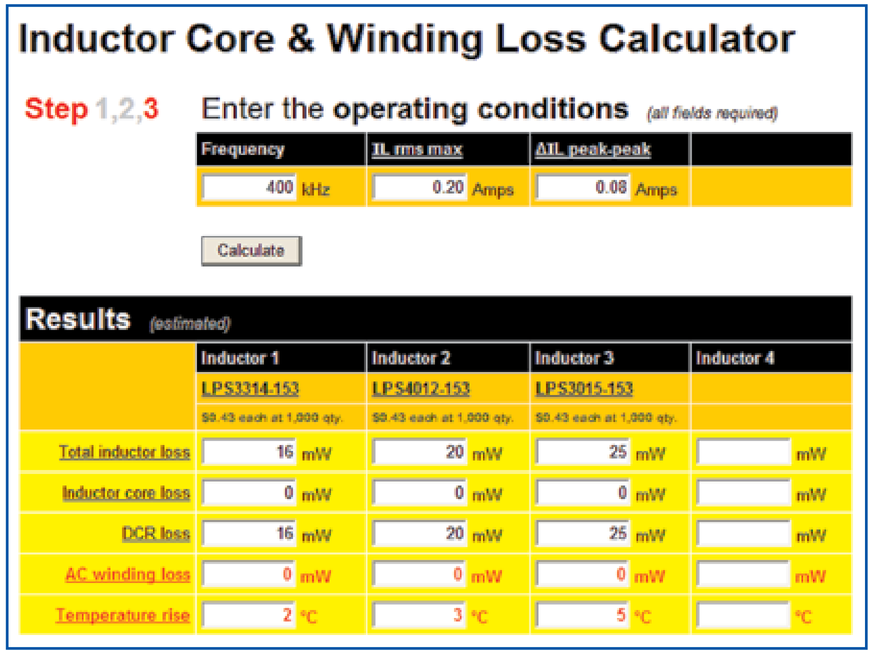
The inductance calculation is based on the amount of inductance required to minimize the desired output ripple current and maintain continuous current conduction in the inductor. The effective output voltage ripple is a result of the current ripple times the ESR of the output filter capacitor. In general, the ripple for LED drivers does not have to be as low as for many other applications.

The Isat specification shows the minimum peak current rating the inductor must have in order to insure against core saturation, otherwise when saturated the inductance will drop and the converter operation will not be as expected. The Irms rating indicates the average current that will flow through the inductor, which in the buck converter is the same as the average load current.

The peak-peak ripple current included in the calculations, will be needed later for calculation of frequency dependent losses.

The inductor specifications having been determined, the next step is to identify a real component that meets these requirements. Based on the L and current specifications, and the physical size constraints, the Coilcraft Inductor Finder tool returns a list of suitable inductors.

Having multiple options is necessary to make an optimal match for the application. Consider the first



Inductor Core & Winding Loss Calculator

Step 1,2,3 Enter the **operating conditions** *(all fields required)*

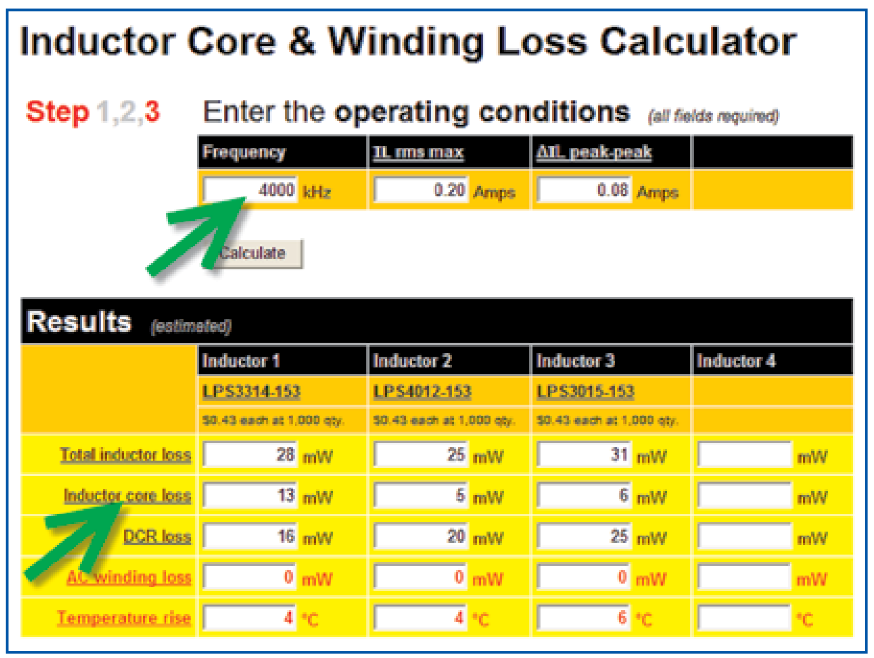
Frequency	IL rms max	ΔIL peak-peak	
400 kHz	0.20 Amps	0.08 Amps	

Calculate

Results *(estimated)*

	Inductor 1	Inductor 2	Inductor 3	Inductor 4
	LPS3314-153	LPS4012-153	LPS3015-153	
	$0.43 each at 1,000 qty.	$0.43 each at 1,000 qty.	$0.43 each at 1,000 qty.	
Total inductor loss	16 mW	20 mW	25 mW	mW
Inductor core loss	0 mW	0 mW	0 mW	mW
DCR loss	16 mW	20 mW	25 mW	mW
AC winding loss	0 mW	0 mW	0 mW	mW
Temperature rise	2 °C	3 °C	5 °C	°C

Figure 7



Inductor Core & Winding Loss Calculator

Step 1,2,3 Enter the **operating conditions** *(all fields required)*

Frequency	IL rms max	ΔIL peak-peak	
4000 kHz	0.20 Amps	0.08 Amps	

Calculate

Results *(estimated)*

	Inductor 1	Inductor 2	Inductor 3	Inductor 4
	LPS3314-153	LPS4012-153	LPS3015-153	
	$0.43 each at 1,000 qty.	$0.43 each at 1,000 qty.	$0.43 each at 1,000 qty.	
Total inductor loss	28 mW	25 mW	31 mW	mW
Inductor core loss	13 mW	5 mW	6 mW	mW
DCR loss	16 mW	20 mW	25 mW	mW
AC winding loss	0 mW	0 mW	0 mW	mW
Temperature rise	4 °C	4 °C	6 °C	°C

Figure 8

three choices. All three parts meet the requirements. The footprint dimensions range from 3.3mm to 4.0mm and the heights are 1.2mm, 1.4mm, and 1.5mm. One could certainly make a selection based on the size, if that is most important for the application. If component height is most important, then the LPS4012-153 is the best choice, whereas the LPS3015-153 is the winner if saving printed circuit board space is more important.

Assuming all of these sizes are acceptable, there are other considerations. Many LED applications are developed specifically for the purpose of

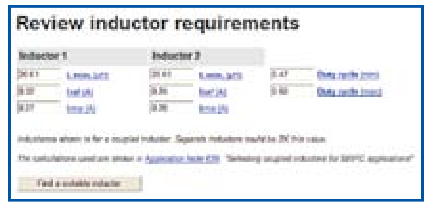


Figure 9

saving energy, so choosing the component with the best average power loss is an important consideration. Of the three parts, the DCR ranges from .44Ω to .70Ω, certainly a wide swing that would suggest LPS3314-153 as the choice for most efficient operation.

Conversely, for many converter designs it is desired to have extra Isat rating in order to accommodate load surges or short circuit conditions, which would place greater emphasis on finding the inductor with the highest Isat rating.

There are more opportunities for optimization beyond the values shown in the table. One of the most common decisions to be considered for any dc-dc converter including LED drivers is switching frequency, balancing the smaller component size enabled by high frequency against the generally better efficiency at lower frequency. The Coilcraft Core and Winding Loss Calculator gives a quick and easy way to judge the potential performance gain at different switching frequencies.

Predicted losses can be calculated based on the combination of switching frequency, average current, and peak-peak ripple current. For this example the results are summarized in figure 7.

For these operating conditions, no core loss is predicted nor is ac winding loss. The predicted loss is entirely made up of the DCR conduction loss. This situation suggests that the inductors could operate at much higher frequency before introducing significant core or ac winding loss.

In fact, examining the inductors at 4MHz instead of 400kHz, does show core loss increasing. The three inductors chosen have roughly the same efficiency and any would likely be suitable for this application. The designer is free to make the final selection based on other factors – footprint, height, availability, cost, etc.

Of course in this example, we have simply examined the impact of operating the same inductors at higher frequency. In order to truly take advantage of the higher frequency, the same tools and procedure should be used to re-calculate the (smaller) L needed at higher frequencies and determine the options for using physically smaller inductors.

SEPIC Converter Example

For portable applications, not only is high operating efficiency desired, but it is also important to operate from as wide a voltage range in order to give the longest battery life per charge cycle. In the previous example the minimum input voltage was limited to 3.3V, but for a typical lithium ion

Suitable SEPIC inductors

- Click on a part number to view the complete data sheet.
- We recommend that you request free evaluation samples for testing.
- New Search

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

Part number	Mounting	Other *	L (µH)	DCR (Ohms)	I sat (A)	I rms (A)	L (mm)	W (mm)	H (mm)	Price @ 1,000	Compare losses
Coupled inductors *(1 required)*			20.61 uH	Isat 0.32 A	Irms 0.27 A						Pick 4 Max
MSD1278-223	SM	S,C	22.0	0.0960	6.8	2.81	12.30	12.30	8.05	$0.70	
MSD1278T-223	SM	S,C	22.0	0.0960	8.34	2.81	12.30	12.30	8.05	$0.90	
MSD1260-223	SM	S,C	22.0	0.1160	5.01	2.49	12.30	12.30	6.00	$0.64	
MSD1260T-223	SM	S,C	22.0	0.1160	5.44	2.49	12.30	12.30	6.00	$0.87	
MSD7342-223	SM	S,C	22.0	0.2200	2.1	1.19	7.50	7.50	4.60	$0.64	
LPD4012-223	SM	S,C	22.0	1.6300	0.84	0.48	4.02	4.02	1.20	$0.60	
LPD3015-223	SM	S,C	22.0	1.8900	0.44	0.4	3.08	3.08	1.40	$0.60	
Separate inductors *(2 required)*			41.22 uH	Isat 0.32 A	Irms 0.27 A						
PCH-45-473	Leaded		47.0	0.0350	4.08	3.4	23.80	11.50	11.50	$0.64	
DO5040H-473	SM		47.0	0.0520	7.8	3.7	18.54	15.24	12.00	$1.06	
MSS1278T-473	SM	S	47.0	0.0723	5.66	2.9	12.30	12.30	8.05	$0.77	
MSS1278-473	SM	S	47.0	0.0723	5.32	2.9	12.30	12.30	8.05	$0.69	
MSS1260-473	SM	S	47.0	0.0801	3.3	2.5	12.30	12.30	6.20	$0.63	
MSS1260T-473	SM	S	47.0	0.0801	3.54	2.5	12.30	12.30	6.20	$0.72	
RFB1010-470	Leaded		47.0	0.0820	2.8	3.5	11.00	11.00	11.50	$0.38	
DO5010H-473	SM		47.0	0.0860	4.5	2.6	18.54	15.24	7.62	$0.80	
DO5022P-473	SM		47.0	0.0860	4.7	2.6	18.54	15.24	7.11	$0.80	
PCH-27-473	Leaded		47.0	0.0540	1.88	1.0	16.51	7.04	7.04	$0.54	

Figure 10

source it would be desirable to operate as low as possible on the discharge cycle, typically as low as 2.7V. This places the 3.3V output inside the input voltage range, no longer making this a purely step-down application. One very popular topology for this situation is the SEPIC converter, which uses two inductive elements to provide step-up/step-down capability. In this case the calculations are again based on V = L x (di/dt), with the added stipulation that the two inductances are calculated separately, having some performance analogous to transformer operation in which the input and output windings have different current requirements. While it is possible to use physically separate devices for the input and output inductors, using two windings coupled together on one core as a single device saves valuable pc board area and has the added benefit that only one half the inductance is required per winding to achieve the same performance.

Using the Coilcraft SEPIC Converter Inductor Selector for this example, with input voltage range extended down to 2.7V, provides the needed inductance values along with the current rating for each winding as shown in figure 9.

It is seen in this result that a little more inductance is now required due to the lower input voltage and the different current ratings are shown for the two windings. Note that the Inductor 2 average current is exactly the same as the load current. Similar to the buck regulator inductor, both are series connected to the load. The results shown in figure 10 are for separate inductors. Only one half the inductor value is required if the inductors are coupled on the same core. Figure 10 shows the solutions available for this SEPIC converter, both coupled and separate inductors.

Conclusion

LED drivers require new circuit techniques to meet high efficiency performance goals. In order to meet these goals in applications that are often tightly space constrained, inductor selection can be crucially important. Fortunately for today's user, many inductor shapes, sizes, and types are available, along with the tools necessary to identify them.

www.coilcraft.com

Maximized Manufacturability

Self acting PressFIT module simplifies assembly - maintains reliability

Customers of power electronics increasingly require new, easy connection and mounting technologies. PressFIT technology creates the possibility of solderless mounting combined with an improved reliability.

By Marc Buschkühle and Thilo Stolze, Infineon Technologies AG, Warstein, Germany

To continue this approach, a new module platform based on PressFIT technology has been developed which furthermore offers an extremely fast and robust mounting concept to improve inverter manufacturing, reliability and design. Special emphasis has been put on mechanical robustness. Avoiding the risk of DCB cracks resulting from controllable forces originating from the module design, was one of the main approaches. To demonstrate the robustness, comprehensive mechanical tests were carried out.

Self acting PressFIT: the Smart principle

Regarding current module designs, there are three main improvement areas, which have to be combined into one solution: So the approach is, to get a module which is suitable for a single step mounting process with a high mechanical robustness, in combination with a robust contact system.

The Smart module is suitable for a single step mounting procedure by the use of PressFIT contacts, hence the name "self acting PressFIT". This means that the fixation at the heatsink, the electrical contact and the PCB fixation is done in just one very fast process step, simply by tightening a screw.

A counterholder transfers the force from the screw to the PCB and pushes the contact pins into the dedicated holes. At the end, this pressure part rests onto the module and presses this to heatsink for a good thermal contact. Furthermore the PCB is fixed between the module frame and the counterholder after the mounting process, therefore no additional fixing points for the board are necessary around the module.

This Self acting PressFIT assembly is presented in the full Smart family. The family consists out of three packages, dedicated to the different power ranges. The following tests are carried out with the Smart1 module, but can be also roughly assigned for the Smart2 and Smart3, because of

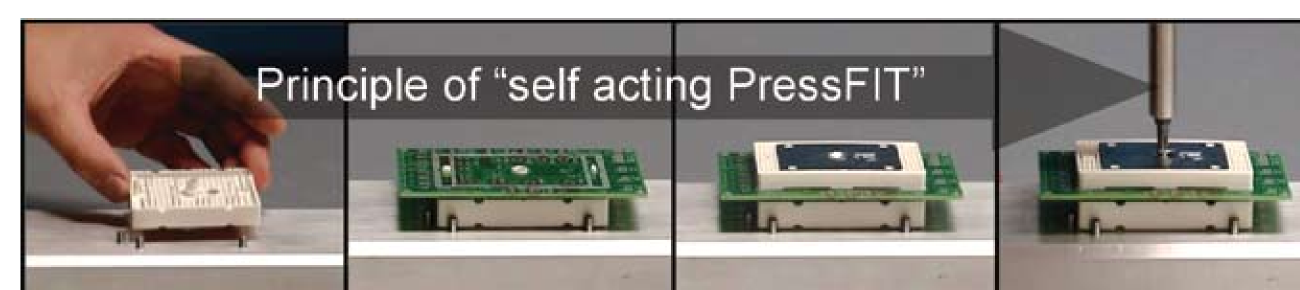


Figure 1: Module fixation and press-in process by tightening a single screw
Further information: www.infineon.com/smart

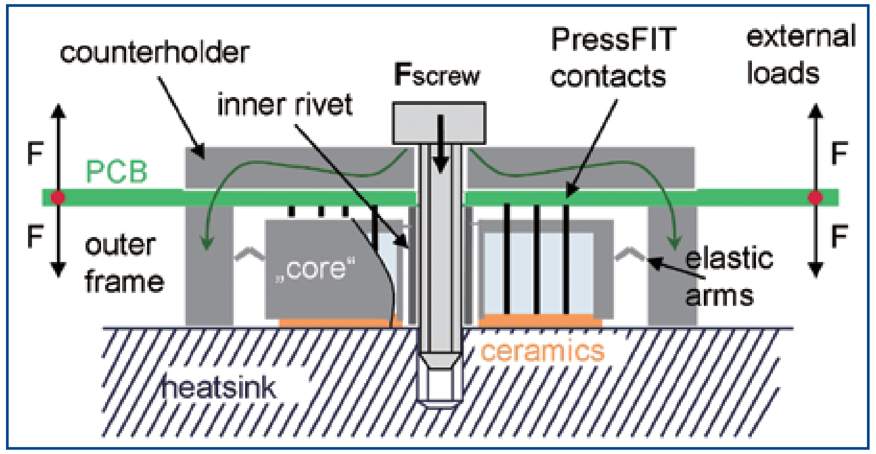


Figure 2: Schematic drawing of a Smart module: The forces of the screw are transferred to the outer part – the inner, decoupled part is protected

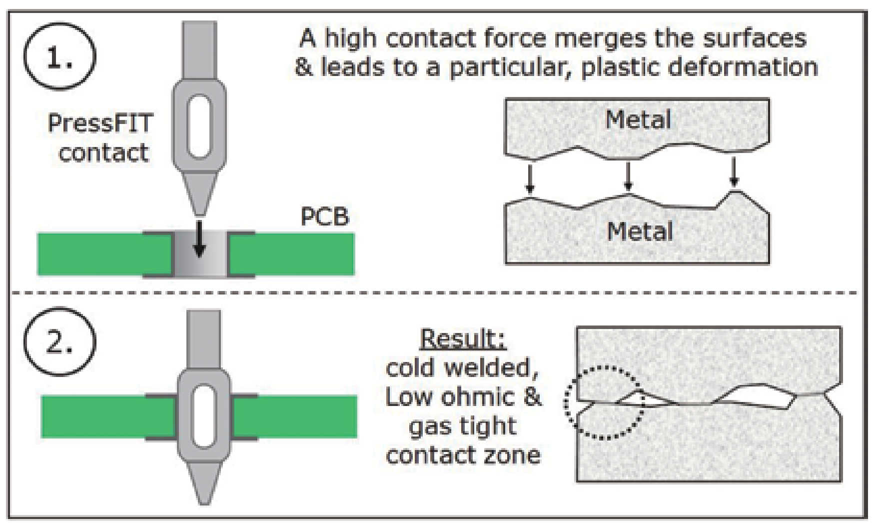


Figure 3: Schematic drawing of a PressFIT connection

the similar mechanical concept.

The mechanical design is benchmark regarding robustness. This is realized by a duplex frame, which prevents the ceramic substrate from all screw forces and also from other external loads. It consists out of an inner module core with the ceramic substrate and an outer decoupled parts frame. The screw force is only applied on the outer frame. The inner part has a vertical degree of freedom. Those two parts are connected with elastic elements which pushes the inner part to the heatsink. Also the PressFIT pins, which are directly distributed on the substrate, push onto the substrate.

High reliable connection to the PCB

To enable the single step mounting process, a solderless connection technology is required. Within the Smart modules, the well proven PressFIT contacts are used.

The reliability of a PressFIT contact is based on the gas tight contact zone, which is very robust against climatic influences and corrosive environments due to the particular plastic deformation in the local contact point which generates a cold welded connection. This results in very low FIT rates, which are approximately one decade below solder connections.

So PressFIT should be the connection method with the highest potential for the future.

No ceramic crack issue

A trend in the market of low power semiconductor modules is to build the modules without the classic baseplate. This means, the module base is designed as the ceramic substrate, where the high power dies are bonded.

In contrast to the smart concept, existing designs suffer the common risk of ceramic cracks due to high resulting pretensioning force of a screw. This results from the fact, that the force is applied directly onto the housing as can be seen. A ceramic crack leads to a safety relevant isolation failure, meaning the module has to be scrapped.

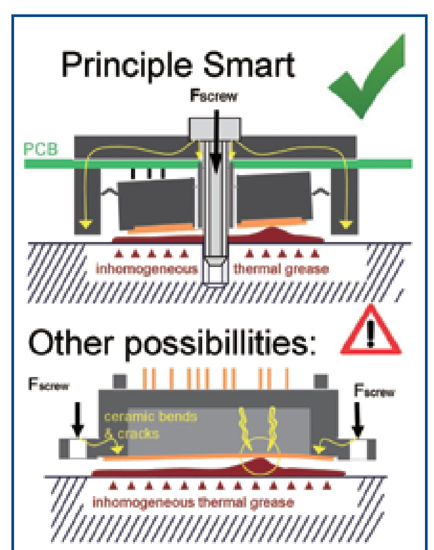


Figure 4: No ceramics cracks with the protecting Smart principle. Crack risk of ceramics in standard module due to direct loads on inhomogeneous thermal grease support

The thermal grease, which is state of the art necessary for a good thermal interface between power module and heatsink, increases the risk of cracks due to its viscosity and velocity proportional absorbability.

Unfortunately and especially if the thermal grease is applied by hand, there are some unavoidable fluctuations regarding the thickness of the grease. For the thermal behaviour of the module later on, these fluctuations are not objectionable, but due to the viscosity and velocity related damping of the grease material, they could be fatal for the ceramics and the isolation capability of the module. This comes from the inhomogeneous mechanical support and the resulting high, local bending stress which can lead to a crack. This risk becomes greater, the higher the mounting speed due to the speed of turning of the screw during assembly.

To ensure the functionality of the Smart principle, some simple tests have been carried out, where the application of the thermal grease has been purposely falsely applied.

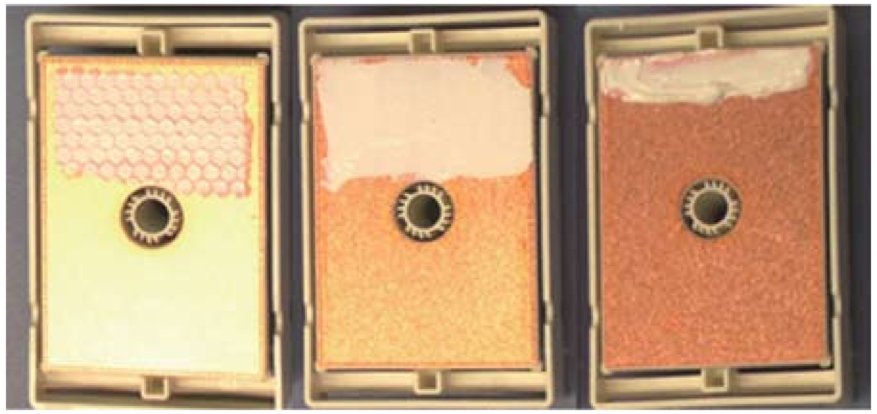


Figure 5: Although with inhomogeneous, wrong applied thermal grease: No damage of ceramics. The wrong application, exemplary shown in 0 could not crack or damage the DCB or the module in any way

Torque and speed of rotation

The request of modern manufacturing is to tighten screws as fast as possible. But as can be seen, a fastening machine is not able to stop exactly at a torque limit at that speed. It has an overshoot effect due to the inertia of the rotating masses. A common corrective action is to use a two step procedure, where the speed is reduced in the second one to values of 100U/min and below.

A Smart module is suitable for a real one-step-mounting procedure with a rotation speed of 500U/min, due to its robust and force-absorbing design.

Within the torque overload tests, thermal grease with a thickness of 100µm was applied. The Electrolube HTC material was chosen, because it has a very high viscosity, which is more critical for the crack sensitive ceramics.

The overload torque was adjusted to a maximum of 12Nm (Figure 6), which is corresponding to a torque of 9Nm at a friction value of 0.10. All modules have been inspected and measured due to their isolation capability before and after the test:

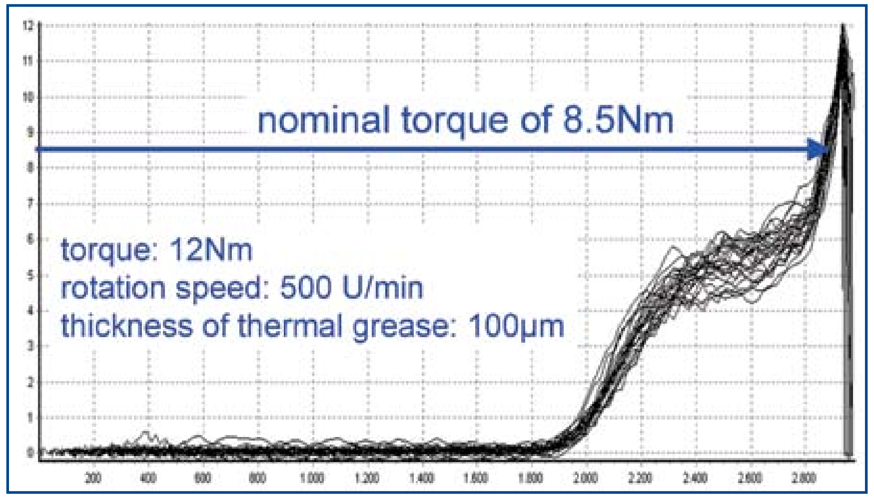


Figure 6: Torque rotation-angle diagram of a Smart1 module

That means there is no DCB crack occurred and also the rest of the device was completely damage-free.

Conclusion

Many tests on the mechanical robustness and behaviour of the Smart1 module have been performed. All show that the Smart principle is a realized approach to cover all of today's main improvement areas in one power module: A solderless, robust single step mounting concept, combined with a reliable and universal contact system. Certainly, the Smart family will be extended to higher power ranges, with the same features and the same robustness.

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Power Systems Design

Special Report-Lighting Systems

Image courtesy of eco-electrician.net

LED Ballast Design

Energy efficiency also reduces electronic waste

In 2009 the EU decided to abandon incandescent lighting step by step, starting with the poorest efficiency bulbs in 2010. Higher efficiency alternatives like CFL lamps or high efficiency LEDs are readily available but attention must be paid to the actual design to confirm that it is as environmentally friendly as possible.

By Dr. Michael Weirich, Applications Manager, Fairchild Semiconductor GmbH, Germany

Environmentally friendly does not just refer to the components themselves but the number of components used and their lifetime - things that are meant by the term ecodesign. Longer lifetime of electronic equipment, resulting in less waste, is achieved by reducing the number of components and increasing their durability. This article explores the design of a primary side regulated (PSR) off-line ballast for LED with constant current output. The low component count and long lifetime makes the design both cost-effective and environmental friendly.

The majority of electronic ballasts for high power LEDs operate in constant current mode. Due to the V-I characteristic of a LED a current limiting element is mandatory for stable operation. Consequently, the most popular approach is to put a number of LED in series and drive them with a current source.

The traditional approach of implementing a constant output current power supply is to measure the load current, e.g., with a shunt resistor and feed this signal back to the PWM controller. Actually, unless one doesn't care about power dissipation and efficiency, the signal generated by the shunt is too small and has to be amplified in some way. This can be done by a simple single stage BJT amplifier or an integrated operational amplifier.

The BJT has an advantage of having a built-in 'reference voltage', the forward voltage VBE of the base-emitter diode. But the latter is not very accurate and has a considerable negative temperature coefficient. If the BJT amplifier is used in cost-effective applications like mobile phone chargers, consequently there is some kind of compensation for this temperature coefficient of VBE as e.g. the PTC THR1 in the schematic Figure 1.

The schematic further shows that there are additional things to consider when designing a current source PSU. At no load current the output voltage would rise to an unacceptable high value. Hence there is an additional voltage regulation loop that is implemented with the reference/error amplifier KA431. Finally, if the output has to be isolated from the mains input, an optocoupler is needed in the feedback path. This optocoupler is an often overlooked component that can limit the lifetime of a PSU.

While in consumer applications a lifetime of say 10000h is excellent and most applications don't need such a long one, the situation in lighting applications is different. Doubtless one expects the ballast to live at least as long as the light source itself. But since in a lot of applications electric lighting may be used a significant part of the day, one doesn't want to replace the electronics each time the light source is defective but expects a lifetime of up to 50000h from the ballast.

Actually, electrolytic capacitors are the electronic components with the shortest lifetime and in fluorescent lamp ballasts, one with extraordinary long lifetimes and hence, high cost are used. Both the electrolytic capacitors' and the optocouplers' lifetimes are reduced by high temperatures. Unlike fluorescent lamps LEDs must be cooled and often the complete luminary is used as a heatsink. As a result the ambient temperature of the ballast and in turn, that of the optocoupler will be quite high. Thus, it would be advantageous to design LED ballasts without optocouplers.

For constant voltage output there is a well-known solution: the primary side regulated flyback. A primary side regulated PSU works without any direct feedback path from the secondary, reducing part count and cost while increasing reliability considerably. This topology has recently been extended to constant current output.

The actual ballast is designed around the FAN103, a dedicated PSR Flyback controller with patented constant current regulation circuit. The schematic of the ballast is shown in Figure 2 and looks quite unspectacular at first glance. Nevertheless the ballast can deliver up to 22V, enough to drive up to five LEDs in series, at a current level of up to 700mA from a universal mains input. The output current can be selected to be 350mA or 700mA by jumper J101 that changes the value of the current sense resistor. If a bigger transformer is used (EF25 core instead of EF20) and the current sense resistors R102 and R103 are adjusted, even 1A output is easily possible.

A detailed description of the operation of the ballast, that is available as a completely assembled evaluation board, is given in the following section. C101 and LF101 together with C1 form an EMI filter followed by the rectifier bridge D101 and the filtering capacitor C101. Initially C105 is charged via the internal start-up circuit of the controller to the device's start voltage. When the latter is reached, oscillation begins and the MOSFET is controlled by a PWM gate signal. The topology of the PSU is that of a flyback. When the MOSFET is in the off state, D201 at the secondary of the transformer is conducting and the energy stored in TR101 is transferred to C201 and the load. R101, C106 and D102 form the well-known clamping network the limits the voltage spikes due to the energy stored in the leakage inductance of the transformer. In steady state, the controller is supplied from a separate winding of the transformer. The voltage of this winding is rectified by D104 and filtered by C108. A simple linear

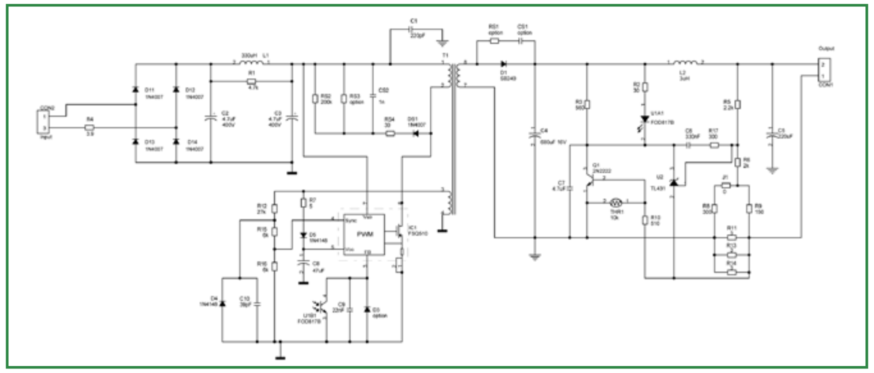

Figure 1: Schematic of a conventional constant current output PSU

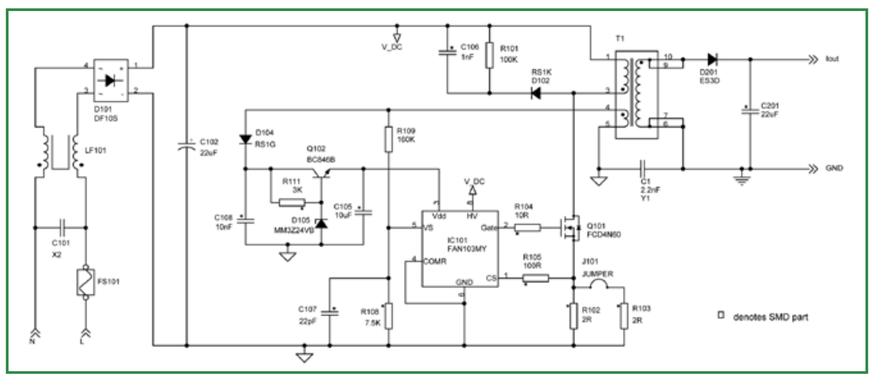

Figure 2: Schematic of primary side regulated (PSR) constant current output PSU

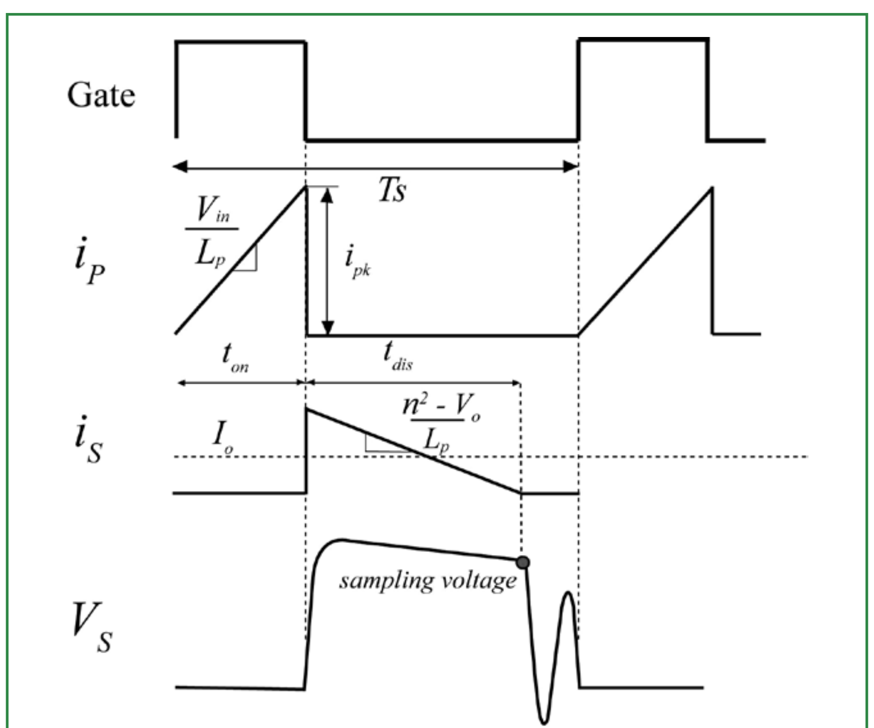

Figure 3: Typical waveforms of the design in Figure 2

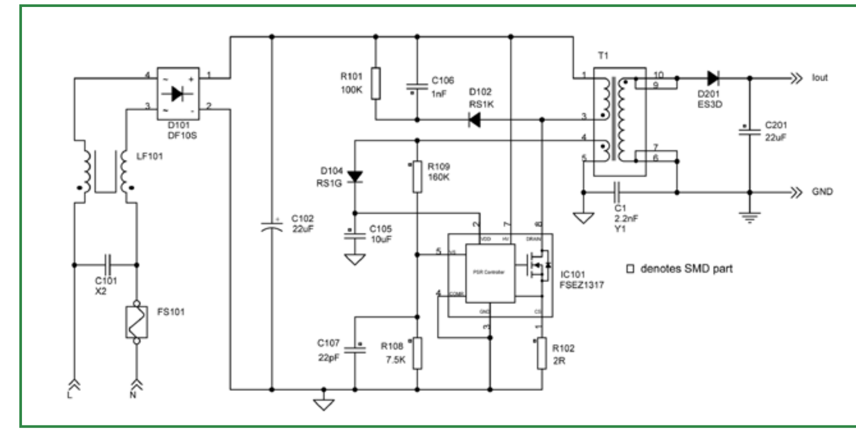

Figure 4: LED ballast with FSEZ1317

regulator consisting of R111, D105 and Q102 limits the voltage at the VDD pin of the controller to 24V maximum. This is necessary since the ballast is designed to operate even with a single LED connected to the output i.e., voltages down to 2.8V in the worst case. The voltage across the supply winding of the transformer will vary with the same ratio of 17V/2.8V = 6.07. Since the minimum operating voltage of the FAN103 may be 7.25V the maximum VDD would be 44V, which would destroy the device.

The voltage of the supply winding is used to do the regulation of both, output current and voltage. In case of high load resistance the PSU is not in constant current but constant voltage mode. The FAN103 uses quite an elaborate method of regulating the output voltage tightly. The voltage of the supply winding, that has almost the same waveform but lower voltage level as the drain of the MOSFET, is scaled by the divider R109 and R108, noise filtered with C107 and feed to the V_S pin. Internally the voltage is sampled and the zero crossing of the current through D201 is determined by monitoring the rate of change of V_S since the sample at this point gives the best estimate and hence regulation of the output voltage.

As load current increases, the output goes from constant voltage into constant current mode. To understand how the latter mode works a bit of math is indispensable. In DCM the output current IO of a flyback is (see Figure 3)

$$I_O = \frac{1}{2}\cdot\frac{t_{dis}}{T_S}\cdot i_{S,peak}$$

Using the transformer winding ratio $n = n_P/n_S$ the formula for the output current can be written with peak primary side current:

$$I_O = \frac{1}{2}\cdot\frac{t_{dis}}{T_S}\cdot n\cdot i_{P,peak}$$

Finally, the peak primary current is given by $i_{P,peak} = V_{CS}/R_S$ and the concluding equation is

$$I_O = \frac{n}{2\cdot T_S\cdot R_{CS}}\cdot V_{CS}\cdot t_{dis}$$

Obviously the first factor is constant for a given design, VCS is the measured voltage at the CS pin and tdis is determined in the same step the zero crossing of ID201 is determined. In order to achieve a constant output current, the feedback loop has to regulate the on time of the MOSFET such that the product $t_{dis}\cdot i_{P,peak}$ is kept constant.

From the equation above it's clear that the output current for a given design is inversely proportional to the sense resistor RCS i.e., double the value gives half the output current.

Having a closer look at the schematic one will recognize that there is only a single electrolytic capacitor: C102. For universal input and the given power level of about 15W a capacitance value around the used 22uF is necessary. But if the input is limited to European power line voltage the latter can be made as small as 6.8uF, a value that is readily available as film capacitor. As mentioned earlier, replacing the electrolytic capacitor results in a ballast with an extraordinarily long lifetime, possibly longer than that of the LED itself.

The component count can be reduced even further by using the FSEZ1317, a Fairchild Power Switch (FPS™), incorporating the controller and a 600V / 1A MOSFET in one package. With this device the output is limited to 350mA. If the output is designed now to drive a minimum of three LED instead of one, the simple linear regulator around Q102 can be omitted as well. The resulting schematic in Figure 4 contains only 19 components in total but nevertheless implements a complete isolated constant current driver for high power LED. It goes without saying, that the reliability of the ballast will be increased at the same time.

Today's designers of electronic devices toned to keep the environmental impact of their designs in view. This does not only concern energy efficiency of the application but reducing electronic waste as well. By developing products with long lifetime and low component count that offer high efficiency, designers can come a step closer to this objective.

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Special Report – Lighting Systems

Lighting Control

Can digital power complement efficient lighting systems?

With the International Energy Agency's first ever global survey of energy consumption for lighting estimating that around 19% of all electricity generated is used to keep mankind from the darkness—that's more power than all the world's hydro and nuclear facilities generate—it's not surprising that there is a huge effort to increase the efficiency of this indispensable, fast-growing use of our resources.

By Patrick LeFevre, Marketing Director, Ericsson Power Modules

One signal of the degree of concern that societies are expressing is the recent banning throughout the European Community of the hugely popular 100W incandescent light bulb, whose invention dates back to 1880 and Thomas Edison.

(Insert) EA0072_lighting

Today's conventional replacement for filament bulbs is the CFL (compact fluorescent lamp), which typically consumes around four to five times less power for a given brightness level. But CFLs are relatively expensive, require an electronic ballast to operate, are difficult to dim, and contain a few milligrams of toxic mercury that creates disposal issues.

As a result, white HB-LEDs (high-brightness light-emitting diodes) are beginning to make real inroads into the general lighting arena. The last decade has seen a huge amount of development of these devices while the historic price issue is being steadily eroded as ever more manufacturing capacity is installed. With commodity parts easily delivering 100 lumens-per-Watt, the energy savings that HB-LEDs confer is dramatic, and hardly a week goes by without yet another announcement of a new achievement in terms of increased efficacy.

Because they are dc current-controlled devices, HB LEDs are relatively straightforward to dim. Given adequate cooling, useful lifetimes of 50,000 hours or more are routinely achievable, especially suiting street lighting and other applications where minimal maintenance is important. It's also relatively easy to maintain or even vary the colour temperature of white HB LEDs, which is one reason for their increasing popularity in architectural lighting.

Given the present state of HB LED development, lighting designers are turning their attention towards complementary technologies to deliver optimal system performance. One particular area of interest lies within the power converters that are necessary to drive large arrays of HB LEDs, where the efficiency of the power system has a profound impact upon the overall energy savings that can be made.

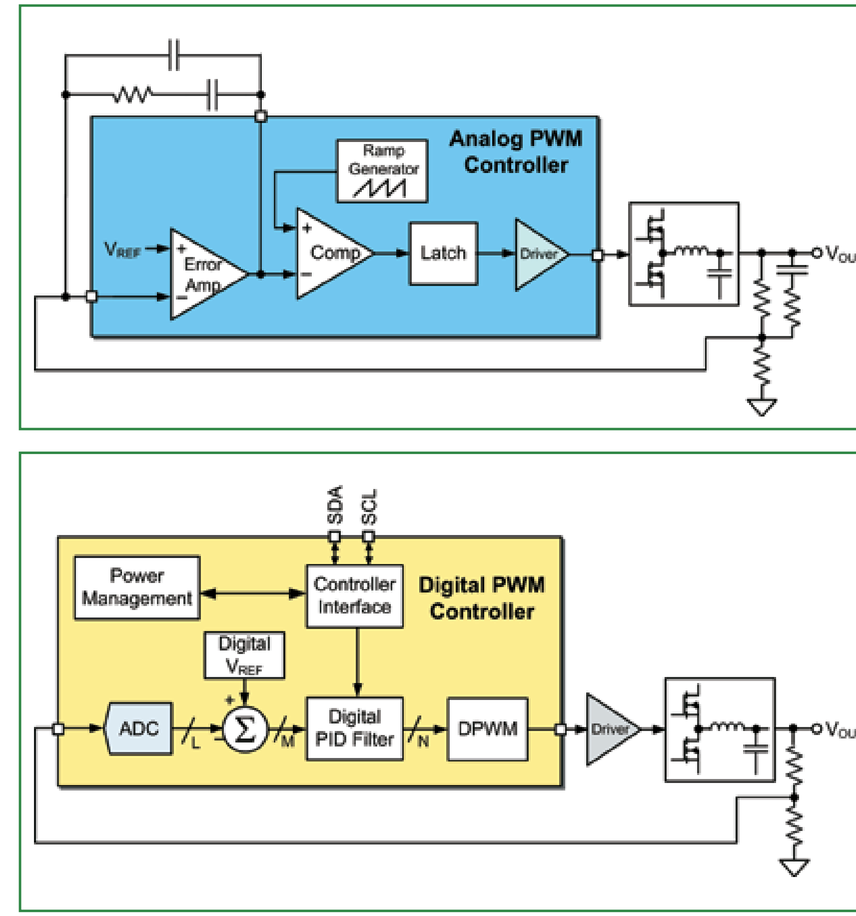


Figure 2: Analog versus digital power converters—core circuits

Digital power increases efficiency and flexibility

Recent research and development in the board-mounted power supply (BMPS) industry—which has not so far specifically targeted the lighting market—demonstrate that digital power control and complementary power management practices significantly improve the performance and power consumption of already very well-developed power supplies. The recent 3E series of BMPS from Ericsson Power Modules embeds several variants of digitally-controlled dc-dc converters, this being the first commercial application for such technology.

While the 3E series targets distributed power architectures in telecoms and high-availability industrial applications, there are numerous similarities between the requirements that the 3E BMPS family addresses and those of a lighting system of any size. For instance, the BMR453—a quarter-brick intermediate-bus converter—provides an isolated output voltage at power levels of close to 400W with typical conversion efficiencies of 96% from 10% - 100% of load level.

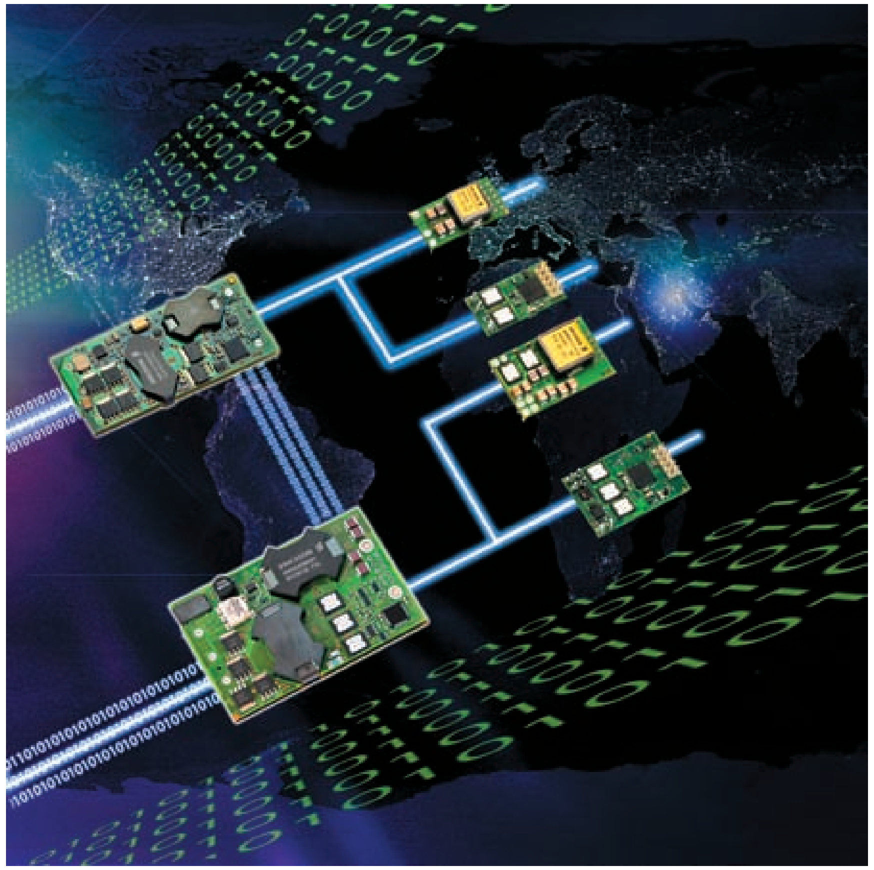
Compared with its immediate predecessor, this represents approximately 5% greater power handling ability and a better-than-1% efficiency increase that applies over a much wider set of operating conditions.

Electrical performance improves too, with the BMR453 maintaining ±2% regulation while a traditional analog counterpart manages only +4%, -10%. Furthermore, the BMR453 integrates all of the power management functions that would otherwise occupy additional circuit-board area, while optimising the coupling between the converter' s control loop and the supervisory functions and consuming negligible additional power. With appropriate adjustments for the new environment, these same attributes are directly transferrable to medium- and large-scale lighting systems. In particular, the availability of a properly integrated power management architecture can complement the digital approaches to lighting system management that larger systems increasing deploy.

Internally, the 3E series dispenses with the familiar analog control loop within the blue box that figure 2 shows and substitutes the digital equivalent within the yellow area:

The hardware implementation necessarily differs between the 3E intermediate-bus and point-of-load (POL) converters, but the same principles apply. In each case, the digital converter continuously samples the output voltage using a high-speed analog-to-digital converter (ADC) that outputs a value that's then compared with a reference value in a digital arithmetic block (Σ in the figure). The digital filter that follows takes this raw correction factor and performs a proportional-integral-derivate (PID) function that controls the output of a digital PWM generator, which varies the duty cycle of the external power MOSFETs to maintain a constant output voltage.

The digital approach has several advantages over the analog one. While the external RC networks that establish the analog converter's transfer function can drift with time and temperature, digital values are immune



to such fluctuations. Better yet, it's possible to vary the digital controller's responses on-the-fly to accommodate a much wider range of input voltage and output load combinations than the fixed time-constants in an analog converter can manage.

This adaptive algorithmic control technique is what enables the 3E series to outperform its predecessors and save valuable efficiency percentage points, at the same time reducing the heat load that the system must dispose of. Build cost is competitive with analog converters and component count decreases, improving reliability and saving space—especially when taking into account that the power management subsystem and its PMBus serial digital interface now lies on the same slice of controller silicon.

PMBus is the power industry's de-facto standard protocol for managing system elements, from individual power converters to variable-speed cooling fans. The architecture comprises a system master—typically an embedded processor or an external PC whose role is to manage the system—and some number of slave devices that are typically power converters. The hardware interface builds upon SMBus, a two-wire serial digital link that is a more robust version of the ubiquitous I2C that was originally developed to support inter-IC communications. Like I2C—with which PMBus is largely electrically compatible—PMBus has a bidirectional data line and a serial clock line that provides the timing reference, but PMBus adds the SMBALERT# signal that is effectively a fast interrupt line as well as the CONTROL signal that's intended to turn devices on and off. Each PMBus device in a system has a unique physical address, and it's possible to write-protect devices via a hardware write-protect pin.

Being a fully specified protocol, PMBus also features a standard command set together with provision for command extensions that follow a predetermined format. For instance, the 3E series exploits PMBus to make changing a converter's output voltage or turning it on or off as easy as sending standard commands, while parameters such as the converter' s input and output voltage, output current, and temperature are reported in real time, again in a standard format. These features suggest that PMBus has the potential to augment established digital lighting protocols such as DMX512 (digital multiplex, 512 elements) and DALI (digital addressable lighting interface).

Overall, introducing digital power control has the potential to tightly control many different parameters during the life cycle of the entire system, adjusting the energy that's delivered to exactly meet lighting demand while taking into consideration environmental and other factors. As for other industries, digital power and power management will make lighting more efficient, reducing overall energy consumption and preserving global energy resources.

www.ericsson.com/powermodules

New Automotive Display Backlighting

Need LED drivers delivering 30,000:1 dimming ratios

In 2010, the market size for high brightness LEDs is expected to reach $8.2 billion and grow to $20.2 billion by 2015 at a 30.6% compound annual growth rate (CAGR) according to Strategies Unlimited. LEDs used to backlight displays are currently the major driver to this growth. Applications range from HDTVs to automotive displays to a myriad of handheld devices.

By Jeff Gruetter, Product Marketing Engineer, Linear Technology

In order to maintain this impressive growth rate, LEDs must not only offer enhanced reliability, reduced power consumption and smaller/flatter form factors, but must also offer obvious improvements in contrast ratios, picture clarity and color accuracy. Additionally, automotive, avionic and marine displays must maximize all of these improvements while subjected to a wide array of ambient lighting conditions, ranging from bright sunlight to night-time environments. These transistor-liquid crystal display (TFT-LCD) applications range from infotainment systems, gauge clusters and a wide array of instruments. Backlighting these displays with LEDs creates some unique LED IC driver design challenges in order to optimize the displays' readability in such a wide range of ambient lighting conditions. This requires LED drivers that can offer very wide dimming ratios, high efficiency and withstand the rigors of the relatively caustic automotive electrical and physical environment. Finally, these solutions must offer very low profile, compact footprints while enhancing cost effectiveness.

How can such an impressive growth potential in automotive lighting be supported? First of all, LEDs are ten times more efficient at producing light than incandescent bulbs and almost twice as efficient as fluorescent lamps, including cold cathode fluorescent lamps (CCFL) thus reducing the amount of electrical power required to deliver a given amount of light output (measured in lumens), as well as the dissipated heat. As LEDs are further developed, their efficiency at producing lumens from electrical power will only continue to increase. Secondly, in a very environmentally conscience world, LED lighting does not require the handling, exposure and disposal of the toxic mercury vapor commonly found in CCFL/fluorescent bulbs. Thirdly, incandescent bulbs need to be replaced about every 1,000 hours, while fluorescent bulbs last up to 10,000 hours compared to a 100,000+ hour lifetime for LEDs. In most applications, this allows the LEDs to be permanently embedded into the final application without the need for a fixture. This is especially important for backlighting automotive instrument/navigation/infotainment panels that are embedded into a car's interior as they will never require replacement during the life of the car. Additionally, LEDs are orders of magnitude smaller and flatter then their counterparts so the LCD panels can be very thin, thereby requiring minimal space in the interior of the car. Furthermore, by using a configuration of Red, Green & Blue LEDs, an infinite number of colors can be delivered. LEDs also have the ability to dim and turn on/off much faster than the human eye can detect, enabling dramatic improvements in backlighting of LCD displays while simultaneously allowing dramatic contrast ratios and high resolution.

One of the biggest challenges for automotive lighting systems designers is how to optimize all the benefits of the latest generation of LEDs. As LEDs generally require an accurate and efficient DC current source and a means for dimming, the LED driver IC must be designed to address these requirements under a wide variety

Special Report – Lighting Systems

of conditions. Power solutions must be highly efficient, robust in features and be very compact as well as cost effective. Arguably, one of the most demanding applications for driving LEDs will be found in avionic, marine and automotive infotainment TFT-LCD backlighting applications as they are subjected to the rigors of the automotive electrical environment, must compensate for a wide variation of ambient lighting conditions and must fit in a very space-constrained footprint, all while maintaining an attractive cost structure.

Automotive LED Backlighting

Benefits such as small size, extremely long life, low power consumption and enhanced dimming capability have triggered the wide spread adoption of LED TFT-LCD backlighting in today's automobiles, planes and boats. Infotainment systems usually have an LCD screen mounted somewhere in the center of the dashboard so both the driver and the passenger can easily view their location, perform audio tuning and a variety of other tasks. Additionally, many cars also have LCD displays that entertain passengers in the rear seat with movies, video games and so forth. Historically, these displays used CCFL backlighting, but it is becoming more common to replace these relatively large bulbs by very low-profile arrays of white LEDs which provide more precise and adjustable backlighting as well as a service life that will easily out live the vehicle .

The benefits of using LEDs in this environment have several positive implications. First, they never need to be replaced, since their solid state longevity of up to 100K+ hours (11.5 service years) surpasses the life of the vehicle. This allows automobile manufactures to permanently embed them into "in cabin" back lighting without requiring accessibility for replacement. Styling can also be dramatically changed as LED lighting systems do not require the depth or area required by CCFL bulbs. LEDs are also generally more efficient than fluorescent bulbs at delivering light output (in lumens) from the input electrical power. This has two positive effects. First, it drains less electrical power from the automotive bus, and equally important, it reduces the amount of heat that needs to be dissipated in the display, eliminating any requirement for bulky and expensive heat sinking.

Figure 1: Virtual dashboard

Another important benefit of LED backlighting is the wide dimming ratio capability provided by a high performance LED driver IC. As the interior of a car is subjected to a very wide variation of ambient lighting conditions, ranging from direct sunlight to complete darkness with every variation in between, it is imperative that the LED backlighting system is capable of very wide dimming ratios, generally up to 30,000:1. With the proper LED driver IC, these wide dimming ratios are relatively easy to attain which are not possible with CCFL backlighting. Figure 1 shows a typical LCD-based virtual dashboard.

Design parameters for automotive LED lighting

In order to ensure optimal performance and long operating life, LEDs require an effective drive circuit. These driver ICs must be capable of operating from the caustic automotive power bus and also be both cost and space effective. In order to maintain their long operating life, it is imperative that the LEDs current and temperature limits are not exceeded.

One of the automotive industry's major challenges is overcoming the electrically caustic environment found on the car's power bus. The major challenges are transient conditions known as load dump and cold crank. Load-dump is a condition where the battery cables are disconnected while the alternator is still charging the battery. This can occur when a battery cable is loose while the car is operating, or when a battery cable breaks while the car is running. Such an abrupt disconnection of the battery cable can produce transient voltage spikes up to 40V as the alternator is attempting a full-charge of an absent battery. Transorbs on the alternator usually clamp the bus voltage to approximately 36V and absorb the majority of the current surge. However, DC/DC converters down stream of the alternator are subjected to these 36V to 40V transient voltage spikes. These converters are expected to survive and regulate an output voltage during this transient event. There are various alternative protection circuits, usually transorbs, which can be implemented externally. However, they add cost, weight and take up space.

"Cold crank" is a condition that occurs when a car's engine is subjected to cold or freezing temperatures for a period of time. The engine oil becomes extremely viscous and requires the starter motor to deliver more torque, which in turn, draws more current from the battery. This large current load can pull the battery/primary bus voltage below 4.0V upon ignition, after which it typically returns to a nominal 12V.

However, there is a new solution to the dilemmas, Linear Technology's LT3599, which is capable of both surviving and regulating a fixed output voltage through out both of these conditions. Its input voltage range of 3V to 30V with transient protection to 40V makes it ideal for the automotive environment. Even when VIN is greater than VOUT, which could occur during a 36V transient, the LT3599 will regulate the required output voltage.

As most LCD backlighting applications require between 10 and 15watts of LED power. Linear Technology's LT3599 has been designed to service this application. It can boost the automotive bus voltage (nominal 12V) to as high as 44V to drive up to four parallel strings, each containing ten 100mA LEDs in series. Figure 2 shows a schematic of the LT3599 driving four parallel strings, each string comprised of ten 80mA LEDs, delivering a total of 12W.

The LT3599 utilizes an adaptive feedback loop design which adjusts the output voltage slightly higher than the highest voltage LED string. This minimizes power lost through the ballasting circuitry to optimize the efficiency. Figure 3 illustrates the LT3599's efficiency that can be as high as high as 90%. This is important because it eliminates any requirement for heat sinking, enabling a very compact low profile footprint. Equally important for driving arrays of LEDs is to provide accurate current matching to insure that the backlighting brightness remains uniform across the entirety of the panel. The LT3599 is guaranteed to deliver less than 2% LED current variation across its -40˚C to 125˚C temperature range.

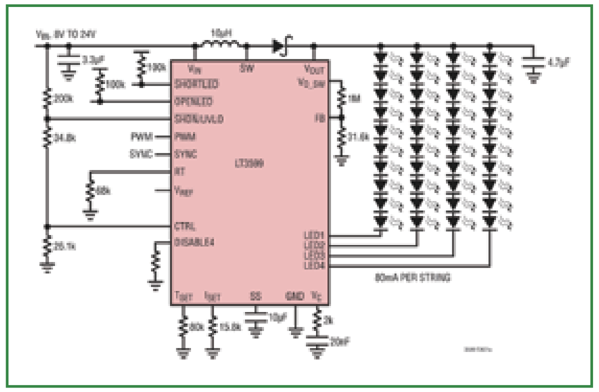
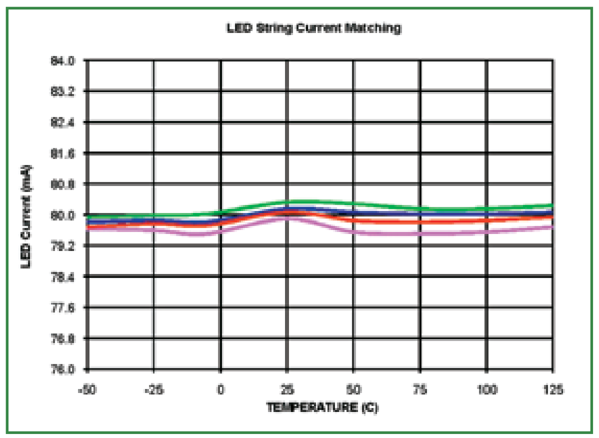
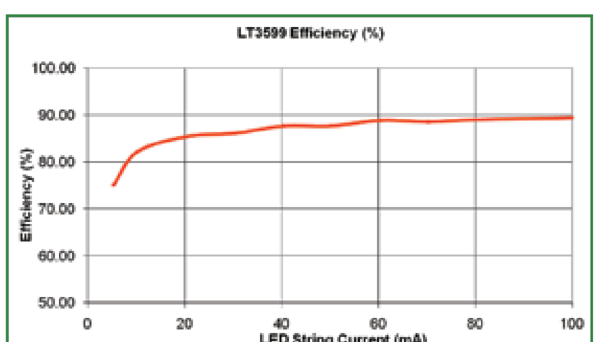


Figure 2: 90% Efficient 12 Watt LED backlighting circuit using the LT3599



(a) LT3599 Current Matching Over Temperature



(b) LT3599 Efficiency vs. LED Current Temperature

Figure 3: LED current matching & efficiency of LT3599 in Figure 2

The LT3599 uses a fixed frequency, constant current boost converter topology. Its internal 44V, 2A switch is capable of driving four strings of up to ten 100mA LEDs connected in series. Its switching frequency is programmable and synchronizable between 200kHz and 2.5MHz, enabling it to keep switching frequency out of the AM radio band while minimizing the size of the external components. Its design also enables it to run one to four strings of LEDs, if fewer strings are used; each string is capable of delivering additional LED current. Each string of LEDs can use the same number of LEDs or can be run asymmetrically with a different number of LEDs per string.

The LT3599's offers direct PWM with dimming ratios as high as 3,000:1 and dimming analog dimming via the control pin, which offers ratios as high as 20:1. In applications which require dimming ratios of up to 30,000:1, these two dimming functions can be combined to reach the required ratio. Certain emerging automotive, marine and avionic applications often require these very high dimming ratios to compensate for a wide range of ambient light that the LCD panel is subjected to.

Furthermore, the LT3599 has integrated protection features that include open and short circuit protection and alert pins. For example if one or more LED strings are open circuit, the LT3599 will regulate the remaining strings. If all of the strings are left open, it will still regulate the output voltage and in both cases would signal the OPENLED pin. Similarly, if a short circuit occurs between VOUT and any LED pin, the LT3599 immediately turns off that channel and sets a SHORTLED flag. Disabling the channel protects the LT3599 from high power thermal dissipation and ensures reliable operation. Other features that optimize reliability include output disconnect in shutdown, programmable under voltage lockout and programmable LED temperature derating. The high voltage capability and high level of integration of the LT3599 offers an ideal LED driver solution for automotive back-lighting applications.

The unprecedented acceleration of LED backlighting applications in automotive displays is driven by a continual demand for higher performance and cost efficiency. These emerging performance requirements must be enabled by new LED driver ICs. These LED drivers must provide constant current in order to maintain uniform brightness, regardless of input voltage or LED forward voltage variations, operate with high efficiency, offer wide dimming ratios and have a variety of protection features to enhance system reliability. These LED driver circuits also require very compact, low-profile, thermally efficient solution footprints. Linear Technology is continually improving their family of LED drivers to meet these challenges head on with LED driver ICs like the LT3599 for display applications. In Addition, Linear Technology has developed an entire family of high current LED driver ICs aimed at myriad of automotive applications ranging from LCD backlighting to turn signals and even headlight applications. As automotive lighting systems continue to demand higher performance LED drivers, Linear Technology will meet these challenges.

www.linear.com

Fluorescent Lamp Dimming

Simple and cost effective dimming solutions

Dimming of fluorescent lamps will normally require the incorporation of a complex, high pin count controller IC into the circuit design. As a result, dimming circuits are more difficult to create than non-dimming alternatives, needing a larger number of components, taking up more board space, and raising the system's total price tag.

By Tom Ribarich, Director, Lighting Systems, International Rectifier, El Segundo, California

These issues are compounded still further when considering compact fluorescent lamps, due to the small form factors involved and the need to be highly cost effective. Here we look at a non-dimming ballast control based on an 8-pin controller IC and explain how dimming functionality can be added without needing to increase the pin count.

With an existing 8-pin, non-dimming lighting ballast controller (for example, the IR2520D from International Rectifier, shown in Figures 1 and 2) only two pins are used (FMIN and VCO) to deal with preheat, ignition and running requirements of the fluorescent lamp. The remaining pins perform standard functions such as IC supply and ground (pins VCC and COM), plus high- and low-side gate drive for the half-bridge (pins LO, VS, HO and VB).

Within a non-dimming ballast circuit, current charges the VCC until it reaches the internal UVLO+ threshold. When VCC goes past this threshold, the IR2520D enters frequency sweep mode, the gate driver outputs (LO and HO) and the half-bridge circuit then starts oscillating at the maximum frequency. The charge-pump circuit then becomes the main supply circuit for the IC, maintaining the VCC at the internal clamp voltage. A small internal current source at the VCO pin slowly charges up an external capacitor causing the voltage on the VCO pin to ramp up linearly. This in turn ramp downs the frequency of the gate driver outputs (LO and HO), and the half-bridge switching circuit from its maximum starting value. The lamp voltage increases as the frequency ramps down towards the resonance frequency of the high-Q, under-damped output stage. The VCO pin voltage continues to increase and the frequency keeps decreasing until the lamp ignites. The output circuit then becomes an over-damped, low-Q circuit. The VCO voltage increases, causing the IC to enter run mode. The frequency level stops decreasing once the VCO pin surpasses 5V and stays at the minimum frequency as programmed by an external resistor on the FMIN pin.

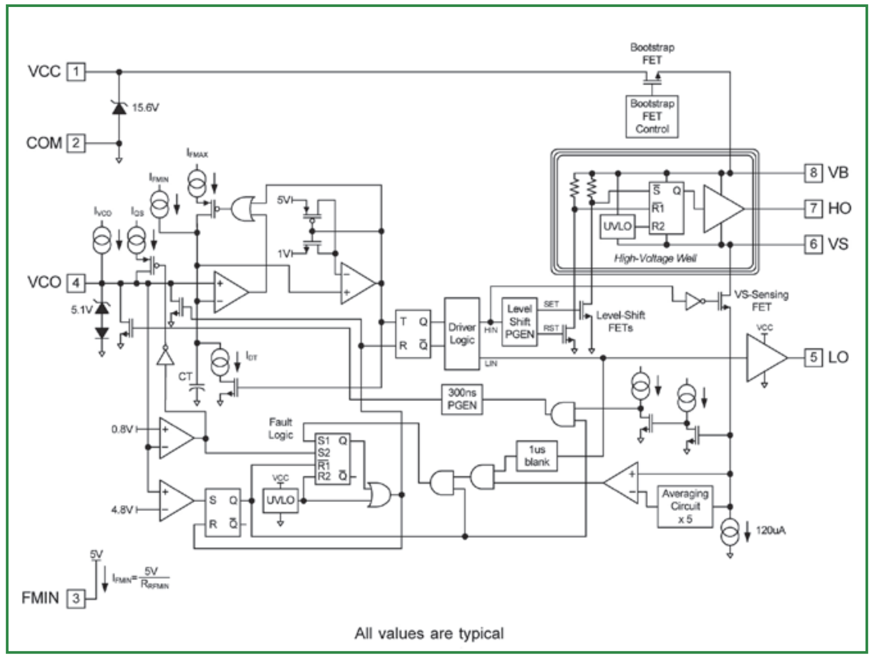


Figure 1: Block diagram of the IR2520D non-dimming ballast IC

With demand for dimming functionality becoming ever greater, but engineers not wanting to sacrifice the advantages of compact low pin count devices like the IR2520D, a way to control dimming through the pins already available needed to be found. As the VCO pin is required to perform the necessary frequency sweep for preheat and ignition, the FMIN pin was left as the only viable option through which this could be accomplished.

Dimming control through a single pin

The dimming of a fluorescent lamp can be achieved by using operating frequency to control the current being applied to the lamp. As the frequency of the half-bridge is increased, the gain of the resonant tank circuit decreases and the lamp current lowers. It is possible to regulate the lamp current to a dimming reference level by continuously adjusting the half-bridge frequency through closed-loop feedback circuit. Dimming is enabled by combining the AC lamp current measurement with a DC reference voltage at a single node. The AC lamp current is measured across sensing resistor RCS and coupled onto the DC dimming reference via feedback capacitor CFB and resistor RFB.

The feedback circuit regulates the valley of the AC+DC signal to COM as the DC dimming level is raised or lowered by continuously adjusting the half-bridge frequency. This causes the amplitude of the lamp current to then increase or decrease so that dimming can be carried out. If the DC reference is increased, the valley of the AC+DC signal will rise above COM and the feedback circuit will lower the frequency in order to enlarge the gain of the resonant tank. This will raise the lamp current, as well as the amplitude of the AC+DC signal at the DIM pin, until the valley reaches COM again. If the DC reference is decreased, the valley will decrease below COM. The feedback circuit will then increase the frequency to lower the resonant tank gain until the valley reaches COM again. The IR2520D's FMIN pin, used to program a single running frequency, has now been replaced with a DIM pin, which measures the AC+DC signal for dimming.

The IRS2530D dimming control IC offers a complete 8-pin solution that contains all dimming ballast functions. The VCO pin includes the frequency sweep timing control for preheat and ignition, and also programs the loop speed for the dimming feedback circuit during dim mode.

When a voltage is first applied to VCC (14V, typical) the IC exits UVLO mode and enters preheat/ignition mode. The half-bridge begins oscillating at the maximum frequency and the internal current source at the VCO pin begins charging up an external capacitor (CVCO) linearly from COM. The output frequency decreases as the VCO voltage increases and the lamp filaments are preheated by secondary windings from the resonant tank inductor. As the VCO

Symbol	Description
VCC	Supply voltage
COM	IC power and signal ground
FMIN	Minimum frequency setting
VCO	Voltage controlled oscillator input
LO	Low-side gate driver output
VS	High-side floating return
HO	High-side gate driver output
VB	High-side gate driver floating supply

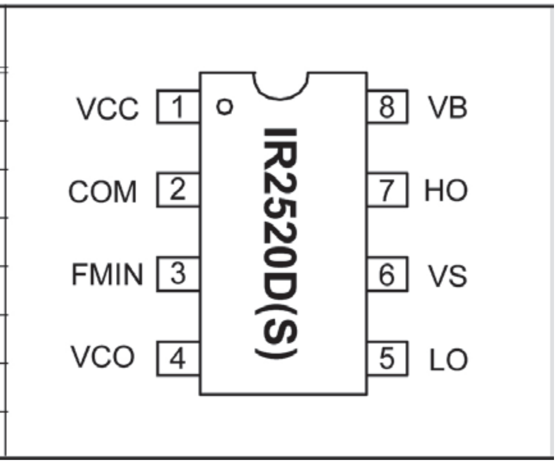


Figure 2: Lead assignment for IR2520D

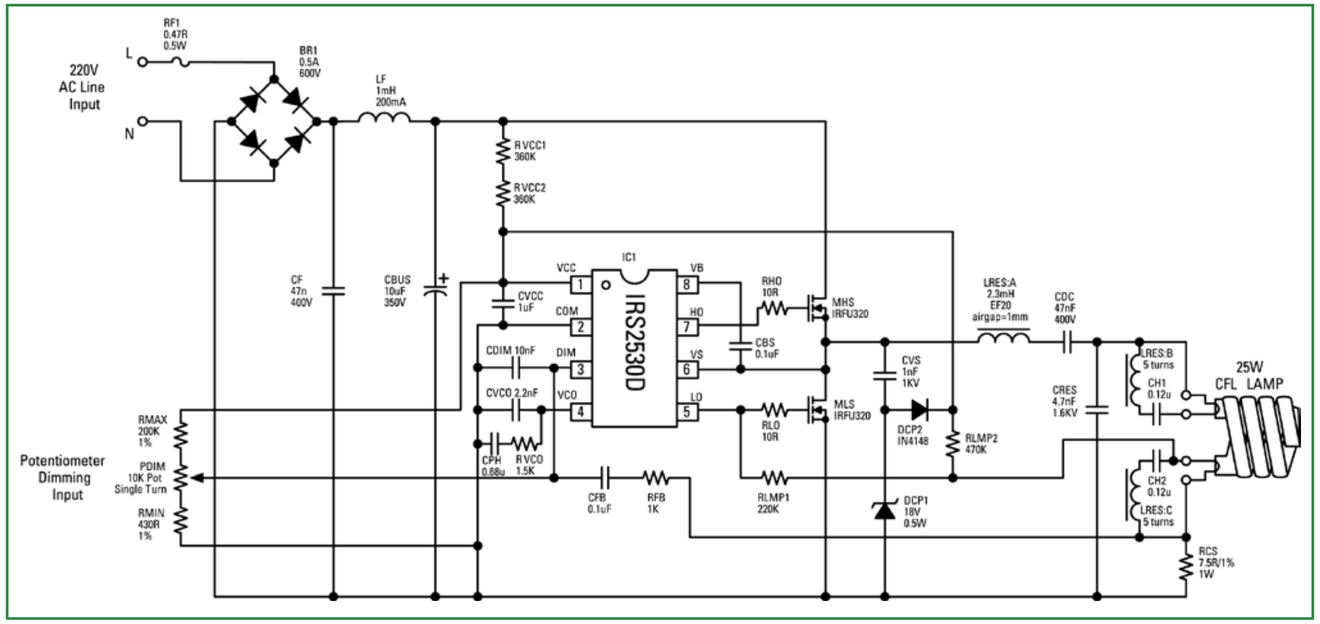


Figure 3: Dimming mini-ballast circuit using the IRS2530D

voltage charges up, the frequency decreases towards the resonance frequency of the resonant tank circuit and the output voltage across the lamp increases. The lamp ignites when the output voltage exceeds the lamp ignition threshold voltage, lamp current begins to flow, and the IC enters dim mode.

A schematic showing a complete dimming mini-ballast circuit is described in Figure 3. It is designed to run from a 220VAC line and to drive a 25W compact fluorescent lamp. The 220VAC/50Hz line input voltage is full-wave rectified (BR1) and then goes through the EMI filter (CF and LF) before being smoothed by the DC bus capacitor (CBUS). The half-bridge switches (MHS and MLS), which are controlled by the IRS2530D, allow preheating, igniting and dimming of the lamp. RVCC1 and RVCC2 provide the micro-power start-up current for the IC's VCC supply, and the charge pump (CSNUB, DCP1 and DCP2) takes over as the IC supply once the half-bridge begins to oscillate. The resonant tank circuit (LRES and CRES) provides the transfer function for generating the high voltages needed for lamp ignition and low-pass filtering for dimming. Secondary windings from the resonant inductor (LRES: A, B) are used to heat the filaments of the lamp during preheat and dimming, and also separate the lamp current from the filament current allowing for a single current-sensing resistor (RCS) to be utilized for sensing the lamp current. The AC lamp current measurement across RCS is coupled to the DIM pin through a feedback capacitor and resistor (CFB and RFB). A potentiometer dimming input circuit is used (PDIM, RMIN, RMAX) to convert the potentiometer resistance to the dimming reference voltage for the IRS2530D through the DIM pin. Protection against ballast fault conditions (failure to strike, open filament, and low AC line/brown-out) are incorporated into the IRS2530D to further reduce component count.

There is a clear need for simple and cost effective dimming solutions which take up the minimum of real estate and do not require a large number of components. The 8-pin IRS2530D offers the means to develop dimming circuits in a quick and unproblematic manner. Furthermore, it has the potential to bring dimming features to a broader spectrum of applications, thus allowing marked energy savings to be realized.

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Meeting LED Expectations

Maximizing the use of LEDs for general illumination

The past year has seen significant advances in LED packaging and manufacturing technique as well as LED price reduction. Thanks to these achievements, the expectations based on using LED as an alternative light source for general illumination are now much closer to realization.

By Irene Signorino, Director of Marketing, Microsemi Corporation, Irvine, California

The past year has seen significant advances in LED packaging and manufacturing technique as well as LED price reduction. Thanks to these achievements, the expectations based on using LED as an alternative light source for general illumination are now much closer to realization. Among such expectations significant energy savings as well as longer life expectancy will drive long-term cost savings for consumers while other features like creative color management and optimized dimming will provide a more comfortable experience. However, the full potential of LED used as light sources for general illumination will only be realized if intelligent LED driver systems are used. These drivers are fully optimized to support those LED characteristics that are dramatically different than those of cold cathode fluorescent lighting (CCFL) and other traditional light sources.

If a non-optimized LED driver system is selected, lighting-fixture designers and users are likely to be disappointed by the performance and by the actual product life of LED lighting fixtures. They will experience flickering and cold, un-tunable light, as well as poor energy efficiency and premature fixture failures. They will also not be able to extract full value from the currently much more expensive LED fixture as dimming and other intelligent integration into networks will not be possible.

The first reason why optimized power supplies are necessary is due to the fact LEDs behave very differently from traditional light sources, and therefore have unique driving requirements in terms of power supply.

LEDs are complex, sophisticated semiconductor devices whose tightly interdependent photometric (luminous flux and efficacy), electrical (current, voltage, power) and thermal (junction temperature) characteristics often behave in a highly nonlinear manner. LED behavior can be particularly hard to predict as temperature changes. For instance, as temperature rises, the LED spectrum shifts to longer wavelength, but the absolute value of this change varies for red, green and blue LEDs. Meanwhile, there is an opposite shift, as LED current rises, to shorter wavelengths.

The first step toward optimizing LED performance and life expectancy is to understand that existing, off-the-shelf non-optimized power supplies are not good choices for driving LED fixtures. They are usually designed to provide constant voltage to the load, but LEDs are current-driven devices whose brightness is proportional to their forward current. So, while a constant DC current source can be used to power the light fixture, it will also not ensure the maximum efficiency or brightness control and will for sure not protect the fixture in case of an over temperature event (all features that can be built into an optimized driver).

An optimized LED driver system can significantly improve fixture performance and life expectancy by directly affecting light efficacy, life expectancy and light quality.

Light efficacy, or lm/W, is directly dependent on the electrical efficiency, or power output versus power input, that the LED driver can deliver. Life expectancy is covered by Energy Star standards and defined as time in operation before the light output decreases typically to 70 percent of the initial value, which varies by application and operating conditions.

Most LED manufacturers promise at least 50,000 hours of operation before failure (the value keeps improving), but

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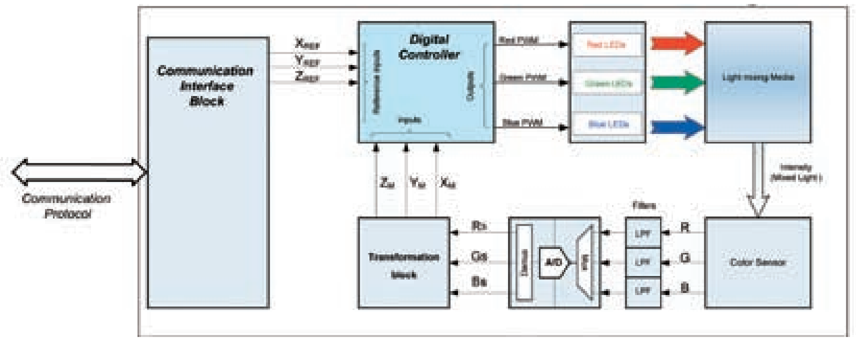

Figure 1: Color management system for RGB luminaries

many LEDs that use sub-optimized power supplies are failing. The two main failure causes are either the use of electrolytic capacitors in the power supply or the lack of control over the maximum temperature the system can see. It is important for LED driver suppliers to include estimates of mean time between failure (MTBF) and specific system operating conditions in their life-expectancy claims.

The LED driver system must also be designed to provide the best possible power factor (PF), or the ratio of real power in Watts to complex power in Volt-Amperes (VA)

PF is particularly important for maximizing energy efficiency. When PF is low, the electric utility must supply more current for a given amount of real power use. Governments generally set minimum national PF specifications that are reflected in international standards for energy efficiency. PF is the product of two components – displacement power factor (DPF), and distortion factor, which was referenced earlier in this article and is also known as THD. The first component, DPF, is defined as the cosine of the phase shift angle phi (ϕ), and can otherwise be described as the phase shift induced between the sinusoidal input voltage and current, due to either the inductive or capacitive nature of the load. The second factor, THD, results from the non-linear characteristics of the load. Optimized intelligent LED driving systems are focused primarily on controlling THD in order to meet PF requirements.

The second reason for selecting optimized LED drivers is the opportunity to add to the most basic driving capabilities other functions that can enhance even further the value extracted from the LED fixture both in terms of energy savings, user experience

Dimming capability (automatic or user-controlled) is critical for realizing the full potential of LED fixture. Dimming adapts light to various applications. The human eye is adept at detecting flickering and jittering, so proper LED dimming is imperative and is directly controlled by the LED driver. Dimming an LED light source poses specific challenges that are very different as compared to dimming traditional light sources. In fact, TRIAC dimmers and other traditional approaches simply do not work well with LED light sources, because they don't consider the unique features of LED semiconductors. The wrong dimming method can cause radio frequency (RF) interference, power harmonics, audible noises, flickering and other interference. An intelligent LED driver should minimize these problems without having to re-wire the existing infrastructure.

Another feature that can be added with an intelligent LED driver is color control or color management. Color management, is what enables LED lighting to be truly differentiated from earlier technologies, by enabling new applications in which the user has full control over color mixing, selection and sequencing. An intelligent LED driver system with integrated color-management control system plays an enormous role in ensuring high color accuracy while meeting color maintenance requirements.

When choosing a color-management system, it is important to understand that LED-based white light can be created either by using phosphor-based white LEDs or by using RGB LEDs. The RGB-based white light can have variable color point, which is particularly beneficial for high-end luminaries and various types of architectural lighting. Microsemi has developed a very high-performance, extremely accurate color management system for RGB luminaries that includes an RGB color sensor, a color manager and LED drivers (see Figure 1).

With this type of RGB-based system, the targeted white color point can be represented by color temperature (CT) and luminance level (Yref), or by tri-stimulus values (Xref, Yref, Zref). The accuracy of color management depends on the performance the RGB color sensor. The sensor should be capable of the response times that are required for CIE color-matching functions, as illustrated in Figure 2.

Unfortunately, commercially available RGB sensors do not provide these response times. For this reason, Microsemi has developed a special procedure which compensates for the mismatch between RGB color sensor response times and those required by color-matching functions. This is done during the calibration process. The output of color sensor [R, G, B] is sent through low pass filters (LPF),

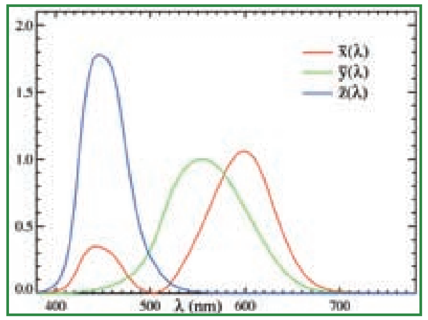

Figure 2: CIE 1931 color matching functions

which are connected to the input of the color manager. The calibration block of the color manager then converts [R, G, B] value of the color sensor to the tri-stimulus value.

Next, a digital controller compares reference data to measured data and, using a digital proportional integral (PI) algorithm, develops RGB pulse width modulation (PWM) signals for the LED drivers. For higher accuracy, a 12-bit PWM algorithm is used. LED drivers control the luminary RGB LEDs, which the mixed light will represent as a targeted white point temperature. In a sophisticated LED fixture, the color temperature can be changed under the user's control through a communication protocol such as PLC, DXM412 or DALI. To improve system accuracy, the temperature sensor can be connected to a color manager, which can adjust the influence of the temperature on LED spectral characteristics.

Despite tremendous advances in manufacturing and packaging, LED fixtures demand high-performance intelligent drivers in order to deliver the performance and life expectancy that users demand. The latest driver solutions take a system approach to optimizing light efficacy, life expectancy and light quality by solving key challenges related to PF, dimming, and color management. Users expect warm, non-flickering, tunable light plus superior energy efficiency, and optimized LED drivers that are designed and specified over realistic operating ranges will contribute to significantly better, "greener" overall performance. These intelligent drivers also will enable the longer life that is critical if LED technology is to deliver the necessary return, over time, on its higher initial fixture investment, so that it can support the necessary technology-deployment payback models.

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LED Lighting Circuit Protection Strategies

Improving reliability and lifespan

As government agencies, industry and consumers look for ways to reduce energy costs, light-emitting diode (LED) lighting technology is expected to boom. LED technology has advanced rapidly, with improved chip designs and materials facilitating development of brighter and longer-lasting light sources that can be used in a wide spectrum of applications.

By Faraz Hasan, Global Marketing & Business Development Manager, Appliance/Industrial/Lighting, Circuit Protection Business Unit, Tyco Electronics

Today, LED lights are quickly replacing conventional lighting based on the following advantages:

• Low energy consumption – retrofit bulbs range from 0.83 to 7.3 Watts
• Long service life – LED bulbs can last up to 50,000 hours
• Durable – LED bulbs are resistant to thermal and vibrational shocks and turn on instantly, making them ideal for applications that are subject to frequent on-off cycling
• Help meet safety and green initiatives – LEDs remain cool to the touch and contain no mercury
• Fully dimmable – LEDs do not change color when dimmed, unlike incandescent lamps that turn yellow
• No frequency interference – no ballast to interfere with radio and television signals

In spite of the growing popularity of the technology, LED light manufacturers are challenged by the fact that LED luminaires are very heat sensitive; specifically, excessive heat or inappropriate applications can dramatically affect their performance.

LED luminaires require precise power and heat-management systems, since most of the electrical energy supplied to an LED is converted to heat rather than light. Without adequate thermal management, this heat can degrade the LED's lifespan and affect color output. Also, because LED drivers are silicon devices they can fail short. This means fail-safe backup overcurrent protection may be required.

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 short circuits. Most LED drivers 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.

Resettable polymeric positive temperature coefficient (PPTC) circuit protection 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 integrated overcurrent/overvoltage devices 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 illustrates a coordinated protection scheme for switch-mode power supplies (SMPSs) and LED driver inputs and outputs. 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 resettable PPTC devices with upstream fail-safe protec-

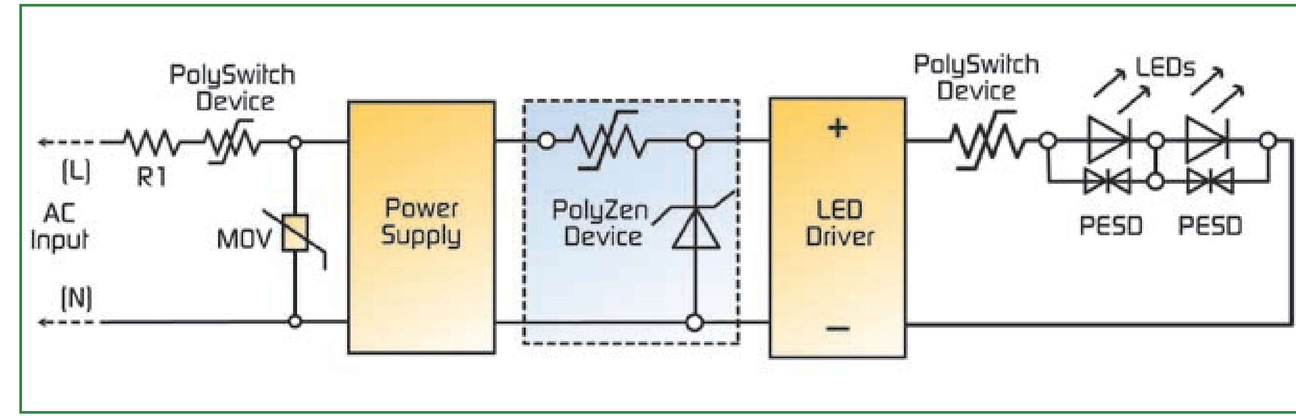

Figure 1: Coordinated protection scheme using PolySwitch PPTC devices and MOV devices for SMPSs (left), and PolyZen, PolySwitch and PESD devices for LED driver inputs and outputs (right)

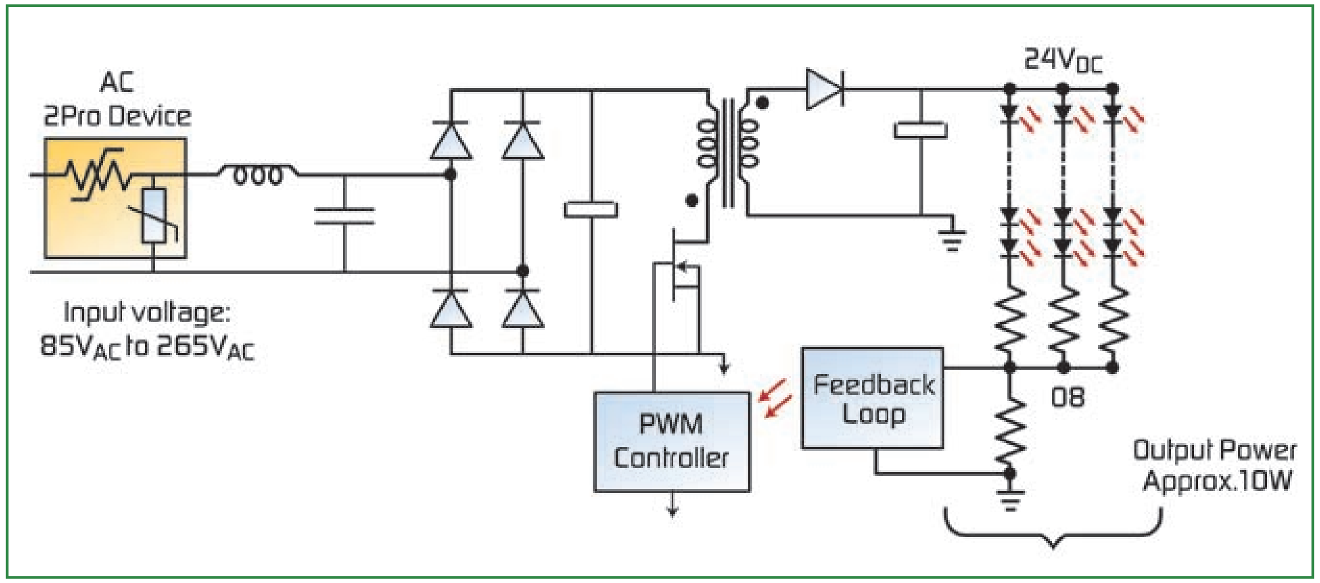

Figure 2: Typical lighting application uses an AC 2Pro device for low-power AC/DC flyback converter protection

tion. In this example, R1 is a ballast resistor used in combination with the protection circuit.

LED drivers may be susceptible to damage resulting from improper DC voltage levels and polarity. Outputs may also be damaged or destroyed by an inadvertent short circuit. Powered ports are also susceptible to damaging overvoltage transients, including ESD pulses.

The right side of Figure 3 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 Tyco Electronics, this device's unique polymer-protected precision Zener design helps provide transient suppression, reverse bias protection and overcurrent protection in a single, compact package.

As shown in Figure 3, a PolySwitch 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.

AC Mains LED Lighting Protection

MOVs are typically used for transient overvoltage suppression in AC line-voltage applications. New thermally-enhanced MOVs help protect a wide variety of low-power systems against damage caused by overcurrent, over-temperature and overvoltage faults, including lightning strikes, ESD surges, loss of neutral, incorrect input voltage and power induction. Figure 2 shows how Tyco Electronics' 2Pro™ device helps provide protection for AC mains LED lighting systems.

Under normal operating conditions the AC line voltage applied to an MOV is not expected to exceed the device's maximum AC root mean voltage (VAC RMS) rating and, provided that the transient energy does not exceed the MOV's maximum rating, short-duration transient events are clamped to a suitable voltage level. However, a sustained abnormal overvoltage/limited current condition, such as a loss of neutral, may cause the MOV to go into thermal runaway.

The 2Pro device combines PPTC technology with an MOV component into one thermally protected device to help provide resettability in case of overcurrent or overvoltage events. This integrated-device approach was developed to help manufacturers meet industry requirements, such as IEC61000-4-5 and IEC60950.

Summary

A coordinated circuit protection scheme can help LED lighting designers reduce component count, provide a safe and reliable product, comply with regulatory agency requirements, and reduce warranty and repair costs. 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. Tyco Electronics works with OEM customers to help identify and implement the best approach.

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Keep on Running

Recharging a cell phone battery with ... Batteries!

These days, people can't live without cell phones. This is not a monumental revelation to anyone who has been at an airport, a shopping mall, or a park watching their children play. We close business deals, talk to our friends and family, check email, and browse the web while waiting for a connecting flight. But how do we keep them running when on the go?

By Tom Karpus, Director of Handheld Systems and Applications Engineering, Semtech Corporation, Morrisville NC

The mobile phone has been transformed from what used to be called a "telephone" into a personal communication and data transfer device. All this communicating and data moving takes power, so phone designers and chip companies have poured a lot of effort into squeezing every last mAh (milliampere-hour) of battery life out of each mobile phone function. Talk times and standby times have declined as more complicated, feature-rich products have been adopted by the average user. Advances in phone power management have addressed this issue to some extent, but we still need to recharge our phone batteries when they run out of power.

Anyone who travels knows that it's not always convenient to pack a charger. Even if you have the charging adapter packed for the trip, there is no guarantee that you will have access to a power outlet when you really need it. So what else can you do? Accessories are now available that act as a portable charger for just such an occasion. This is a great idea – it's like carrying a portable electrical outlet and charging adapter all-in-one. Such an accessory can utilize different battery configurations to supply the charging power. One simple, low-cost choice is to use two disposable AA alkaline batteries to transfer energy to your phone's Li-ion battery. These batteries are inexpensive, available at any convenience store, and transferable between different devices (providing the option to raid the kids' games when you need to recharge your phone). Depending on the state of your phone battery, this power transfer system could top off the battery or provide just enough power to maintain an important call when your battery is nearly depleted.

A typical Li-ion battery charges to a final voltage of 4.2V, so a power supply level greater than 4.2V (typically 5V minimum) is needed to supply the charging circuit. Alkaline battery cells range between 0.8V and 1.6V, so a DC-DC boost converter is needed to boost the supply voltage and regulate the output voltage at the 5V needed to properly transfer charge to a Li-ion battery. The combination of a boost converter with a dual AA battery pack can serve as a 5V power supply for battery charging when a wall outlet or USB supply are not available.

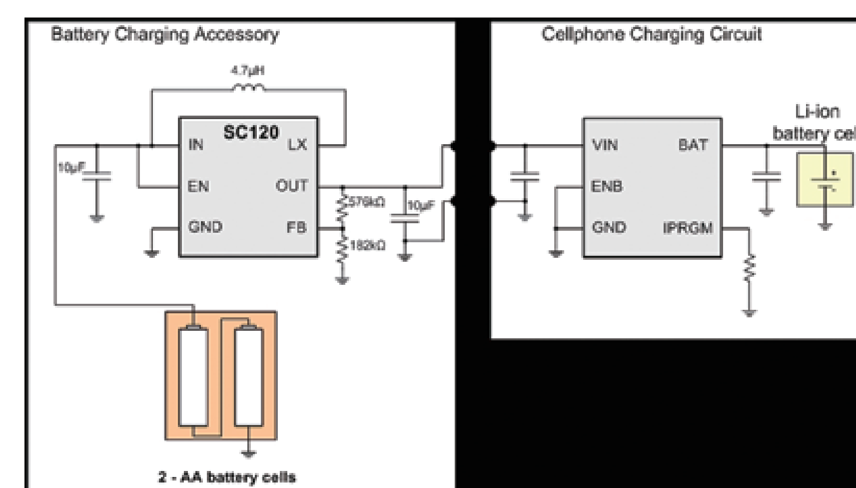

Figure 1: Application circuit for battery to battery charge transfer

A simple circuit can be constructed to provide the 5V needed by the battery charger using a standard DC-DC boost converter IC and some simple external components. Figure 1 demonstrates how this system works. In this example, the boost circuit is contained in an accessory capable of holding two AA battery cells. The 5V output is maintained throughout the duration of the charging operation as the AA batteries discharge. The boost converter used in this example – the SC120 from Semtech – is set to a 5V output by connecting a resistor divider network between the OUT and FB pins.

The charger IC typically resides inside the phone or in a charging cradle for removable batteries. Accessories with similar capability use standard USB connectors to attach to the phone charging system. The phone should limit the charge current internally to 100mA – the standard for low power USB charging. The fast charge current in this example is set to 100mA to illustrate charging performance under these conditions. Charging is terminated when the current into the battery drops to 10% of the fast charge current – in this case, 10mA. Figure 2 illustrates the Li-ion battery voltage and current during the charging process using a 750mAh battery, while Figure 3 shows the voltage and current profiles for the AA 2-cell pack throughout the same process.

Figure 2 demonstrates that normal battery charging occurs. The current is held constant at 100mA and the Li-ion battery voltage approaches 4.2V – the cell voltage at which it is fully charged. Figure 3 illustrates the state of the source batteries as charging occurs. The combined AA cell voltage decreases as charge is transferred to the Li-ion battery, and the battery current increases to maintain the boost output at 5V. In this example, the Li-ion battery was fully discharged at the start of charging, so two AA cells provided just enough power to charge the Li-ion battery to 4V (but not

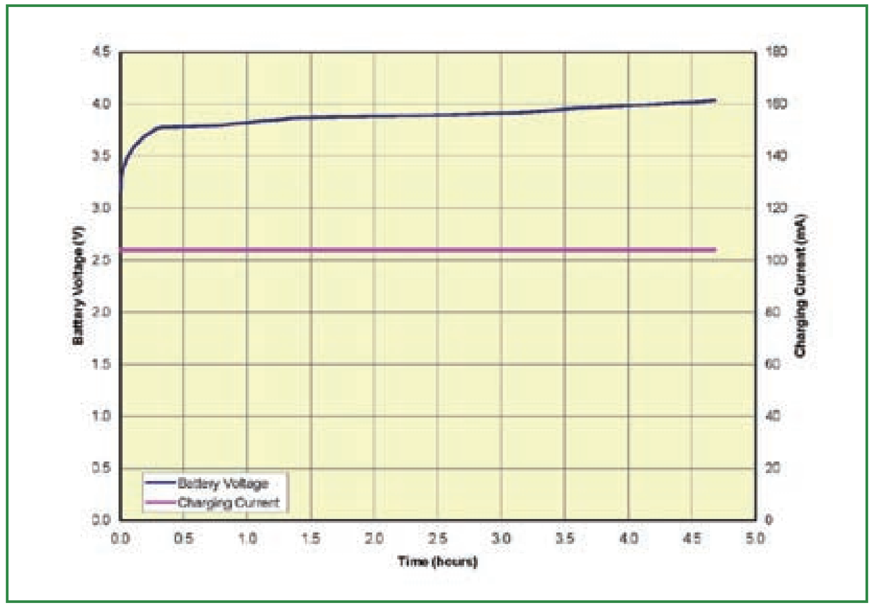

Figure 2: Li-ion battery charging voltage and current curves

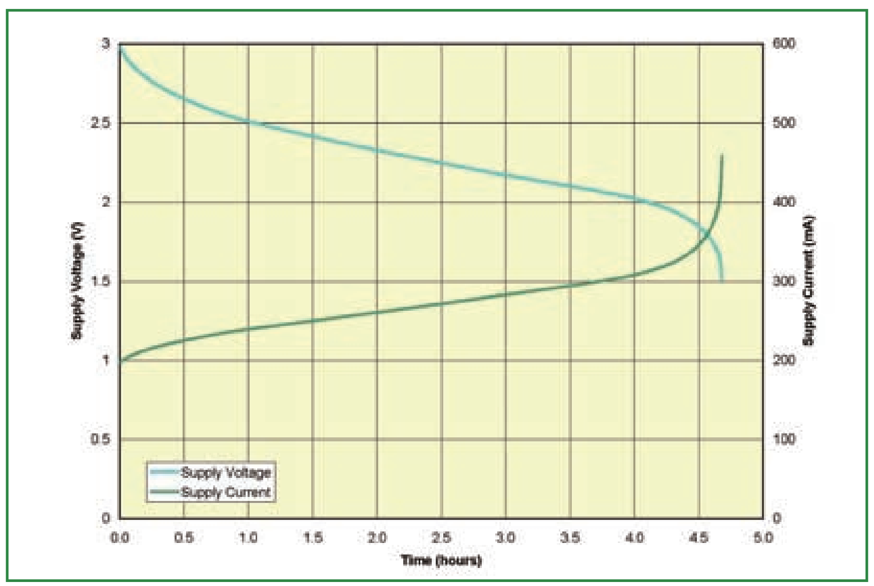

Figure 3: 2xAA alkaline battery cells discharge curves

completely recharge it to 4.2V).

Variations to this system could be implemented using 3 AA cells or a single high-capacity Li-ion cell as the charging supply. Either supply configuration would be more efficient because they would operate the boost converter with less voltage drop. Their increased capacity and efficiency would also give the charger accessory more available charging capacity, which would allow a complete charging cycle or possibly multiple charges. Of course, more battery capacity translates into higher cost. Regardless of which configuration provides the best cost-benefit tradeoff, it is clear that this DC-DC boost converter design approach provides a simple mobile charging solution for the battery powered products that help make busy lives a little easier to manage.

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Special Report – Lighting Systems

Better LED Intensity Control in Video Displays

When a video display application uses a pulse-width modulated LED driver such as the MAX6975, higher PWM resolution is needed to provide gamma (visual effect) correction, LED characteristic matching, and ambient light adjustment to the 8-bit or 10-bit video information. This article will explain how to emulate 16-bit PWM resolution for the video application even though the MAX6975 only has a native PWM resolution of 14 bits.

By Walter Chen, Principle Member of the Technical Staff, Applications, Maxim Integrated Products inc., Sunnyvale, California

For better power efficiency and color consistency, the intensity of an LED is typically controlled by regulating the duty cycle of a pulse-width modulation (PWM) period through an LED driver. A PWM period usually consists of a number of clock cycles equal to the 2 to the power of the number of control bits (2CONTROL BITS).

The control-bit resolution for consumer electronics applications is normally 8 bits. Thus with 8-bit PWM resolution, 256 different intensity levels can be provided and the corresponding PWM period consists of 256 clock cycles. For a typical consumer-electronics clock frequency of 32kHz, a PWM period lasts about 256/32kHz, or 8ms. Consequently, the PWM refresh rate is about 125Hz. Together, this PWM resolution and refresh rate provide enough lighting intensity adjustment, and avoid the flickering effects that can be seen by the human eye. However, for the latest generation HD displays, that resolution is not sufficient and thus the driver resolution must be extended to provide finer granularity.

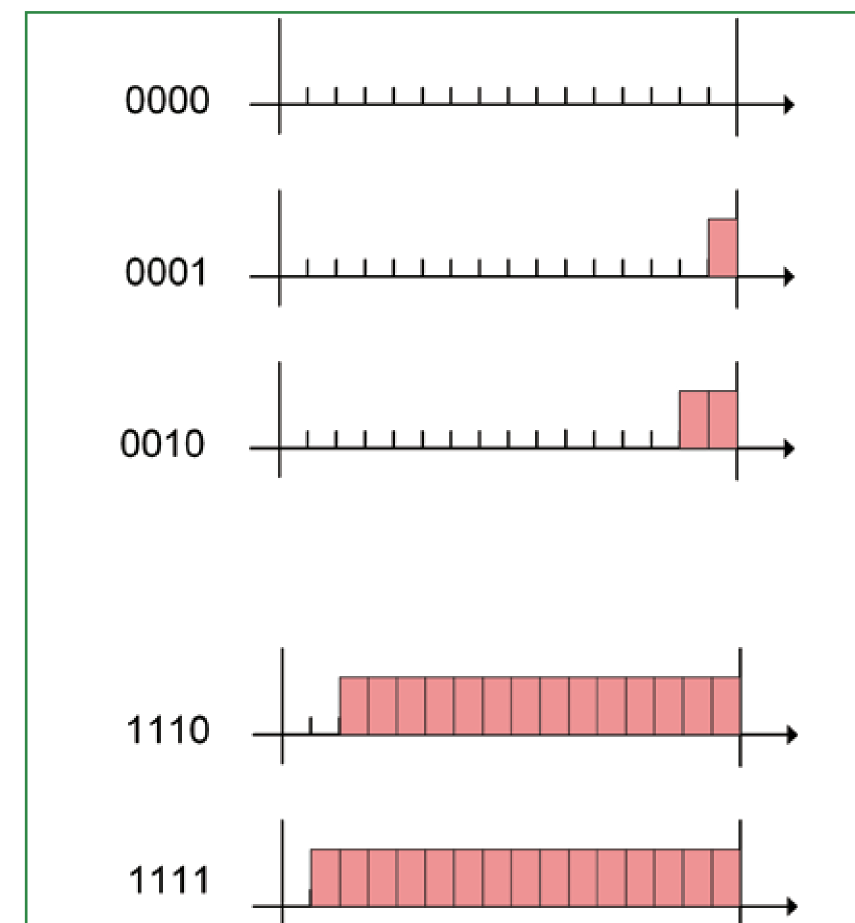


Figure 1: Conventional 4-bit and 16-position PWM waveform.

Providing 16-Bit resolution for an LED driver

It is a challenge to meet the requirements for both the 16-bit PWM resolution and the 2kHz refresh rate of the latest displays. The 16-bit resolution leads to a PWM period with 216 = 65,536 clock cycles. The corresponding clock frequency for a 2kHz PWM refresh rate is 2000 x 65,536 = 131.072MHz. Sending data over a CMOS interface at this speed becomes unreliable, even for reasonable distances. The real issue is that the LED driver's output ports cannot be switched on/off fast enough with the loading of the LED and associated wiring. Without accurate turn-on/off timing, the benefit of 16-bit resolution cannot be realized.

As a compromise, a group of PWM periods of less than 16 bits can be used to emulate a full 16-bit PWM period. By using this approach, the desired 2kHz PWM rate can be maintained at a lower clock frequency since the number of clock cycles is reduced in each PWM period. The visual effects of 16-bit resolution can be maintained, since the human eye cannot distinguish change/flicker once the PWM refresh rate is faster than a few hundred hertz.

Consider the example of a video camera operating at, or near, 1/2000 shutter speed. The camera will capture frames at lower resolution, but this is much better than capturing a black screen for lower refresh rates. Although the shutter speed can be very high, a video camera still captures 60 frames at every second. The averaging effect of these multiple video frames can still resemble a picture close to the desired 16-bit resolution.

The 16-bit resolution can be divided into different MSB/LSB (most/least significant bit) ratios for the emulation. There will be a number of PWM periods with the resolution of the MSBs:

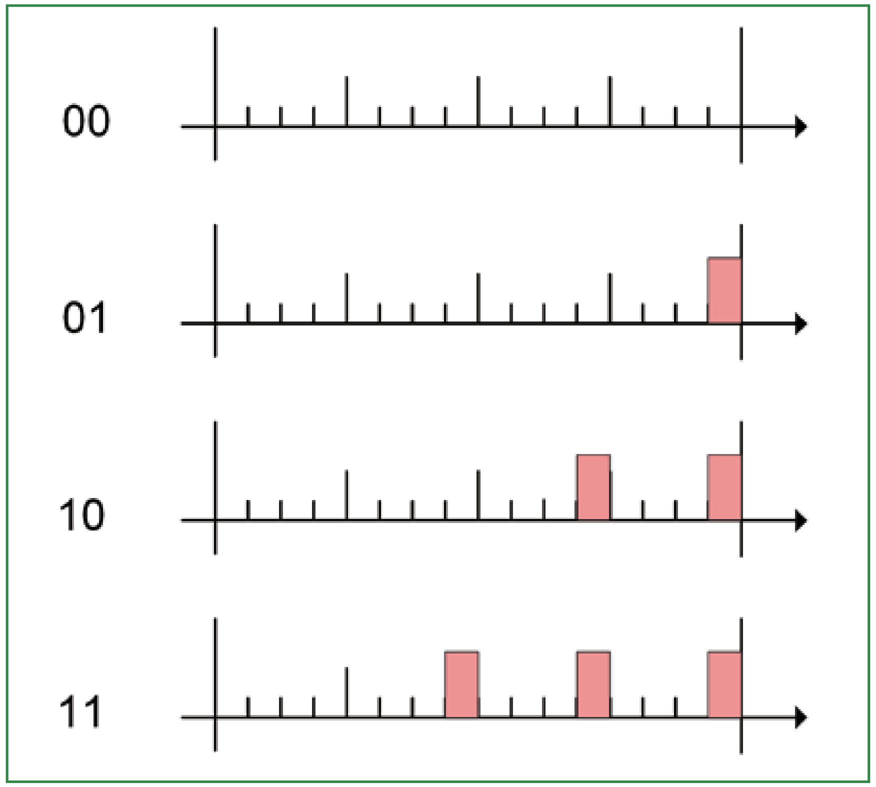
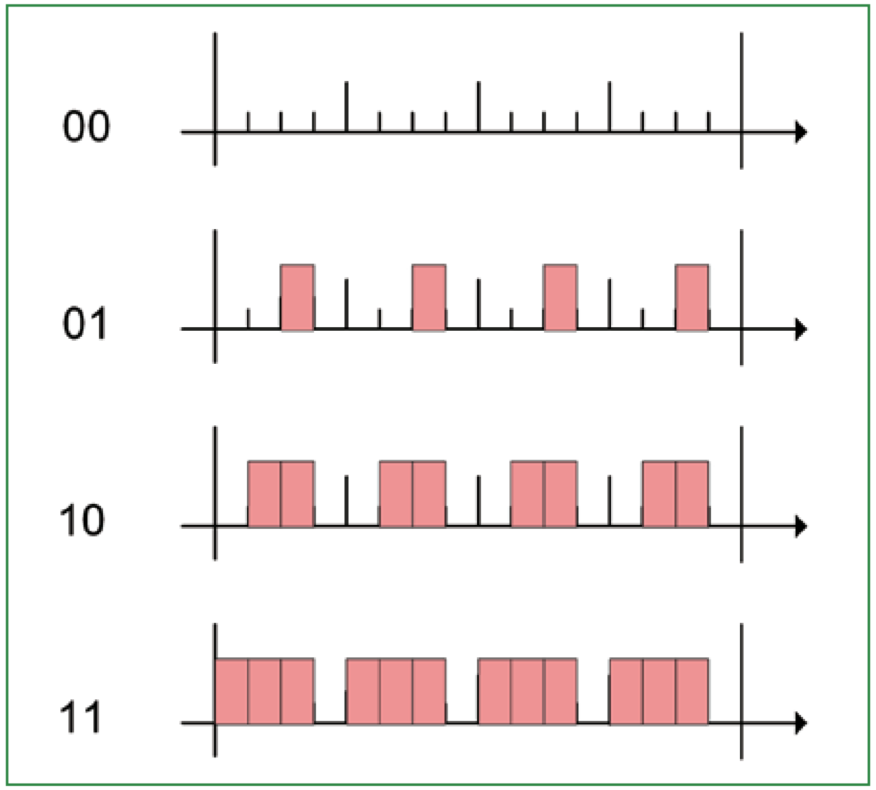


Figure 2: Effect of LSBs for a 2/2 split of a 4-bit emulation.



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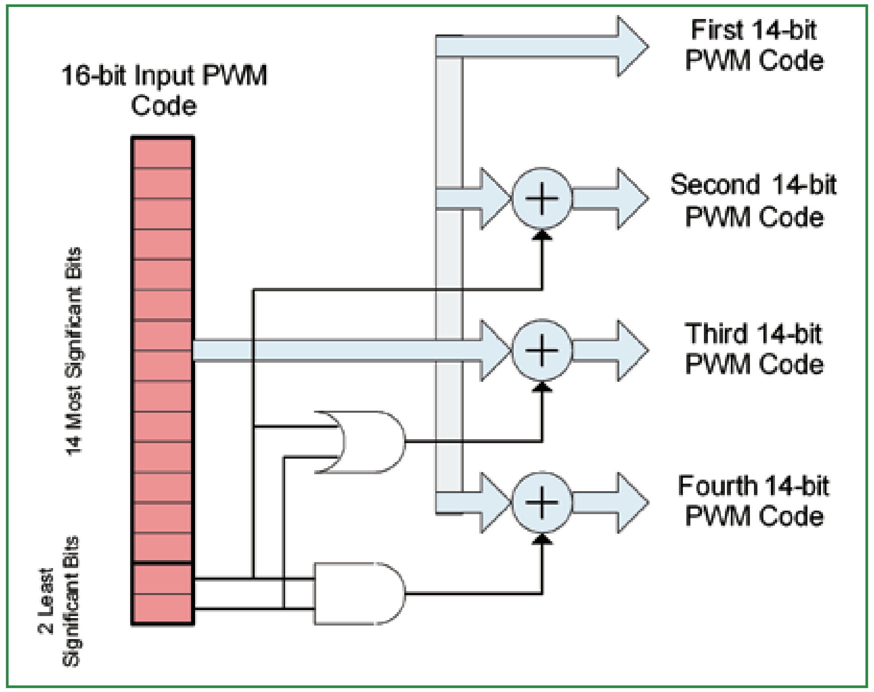

Figure 4: Structure of a 14/2 split 16-bit emulation encoder

2 to the power of the number of the most significant bits (2MSB). The number of periods equals the resolution of the LSBs: 2 to the power of the number of the LSBs (2LSB). There can also be different methods of bit distribution among the PWM emulation groups. A simple approach is to let the LSBs decide if the last clock cycle of each group should be on/off; the MSBs decide the remaining clock cycles. Restated simply, the clock cycles' on-/off-times determined by the MSBs are all the same for all groups.

Test case example

Let's use a 2/2 split emulation of a 4-bit resolution as an example to detail the approach. Figure 1 shows the direct 4-bit implementation of 16-position PWM waveform patterns.

A 2/2-split emulation will create four 4-position PWM groups. The 2 LSBs are used to select at which group the last clock cycle should be on. The 2 MSBs are used to determine the on-/off-pattern of the remaining three clock cycles. Figure 2 shows the effect of the 2 LSBs on the emulation PWM waveforms when the 2 MSBs are 0s.

Figure 3 shows the effect of the 2 MSBs on the emulation PWM waveforms when the 2 LSBs are 0s.

This approach can be used with the MAX6975 LED driver's built-in LVDS interface to emulate 16-bit resolution. It is done with a split of 14/2. A 16-bit video frame will be displayed by four 14-bit video frames of light, by one clock cycle, on/off differences. A simple encoder generates these 14-bit PWM codes using the 16-bit PWM code as input. The encoder uses the 14 MSBs as the base for the 14-bit code, and adds another bit depending on the pattern of these two LSBs. Figure 4 shows the emulation encoder. The first 14-bit PWM code takes the MSBs as they are. The second code adds the MSB of these two LSBs. The third code adds the OR operation of these prior two, and the fourth code adds the AND operation.

There are two small drawbacks for the proposed emulation approach. First, there will be some missing PWM codes at the highest brightness region. As shown in Figure 2, some emulation PWM codes will be fully turned on when selections of the MSBs and LSBs are combined. The full turn-on could not be produced with the MAX6975's original designed operation. The effect of these missing codes, however, will not be noticeable. These codes are near full brightness and not used often. Even when these codes are used, human vision is not sensitive to the slight variation of light intensity when it is that bright.

Second, the information sent to MAX6975 will be four times more or faster if the 60 video frames-per-second display rate is to be maintained. The data interface of the MAX6975 is still fast enough to supply many chips in a serial chain, but the number of chips in the chain will be reduced proportionally. At a clock frequency of 32MHz, 32,000,000/(14 x 24 x 60) = 1,587 x MAX6975 chips can be put in a serial chain to share the same data interface at a frame rate of 60 video frames per second. This number will be reduced to 396, if four emulation frames need to be delivered for each video frame. A video array of 32 x 32, or up to 56 x 56, pixels, can still be driven by a single data interface with all chips in a serial chain.

There is, finally, a small difference compared to the general emulation approach that is also worth noting. Each PWM frame is normally repeated 32 times as subframes for the global intensity control of the MAX6975. Therefore, the MAX6975's 14/2 implementation of a 16-bit resolution will also have each of these four emulation PWM frames repeated 32 times.

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Big Power Challenges in Little Products Create Opportunities for Power Specialists

By David G. Morrison, Editor, How2Power.com

In portable electronic devices, power levels may be small, but the challenges of power management can be monumental. Spurred by consumer demands, manufacturers of devices such as smart phones, portable media players, and laptops are continually driven to make these devices more sophisticated. The next generation of gadgets must always offer more functionality and better performance, while maintaining the same basic form factor and the same—or even longer—battery life.

Since increasing battery size is not usually an option, product designers must resort to advanced power management techniques to minimize power consumption. But that's not the only requirement for portable power management. Designers must manage the operation of multiple supply rails, maintain tight tolerances on supply voltages, deal with very fast load transients, keep noise problems at bay, and minimize design size and cost. Plus, with consumer products, product design cycles can be short, so time-to-market pressures impact the design.

To meet all of these design challenges requires engineers with experience in power system design. In the past, more of these engineers worked for the original equipment manufacturers (OEMs) who designed, built,

and marketed the portable electronic devices. But over time, many of these companies have come to rely on the semiconductor vendors to provide the power system design expertise needed to create the portable devices. So today, many of the opportunities for engineers in portable power design are at the semiconductor companies, which need IC designers and field application engineers (FAEs) to develop and support power management ICs for portable products.

Nevertheless, there are still opportunities for power specialists within portable device OEMs and within the original device manufacturers (ODMs) that work with them. However, roles within these companies are changing, and increasingly these employers are looking more for engineers who understand system-level power issues rather than the details of power converter design.

Understanding how power system design roles are changing within semiconductor and portable device companies may help you to take advantage of engineering opportunities in portable power design. (A sampling of current opportunities in this area can be found in the table that accompanies the online version of this article.)

Customers Expect Complete Power Solutions

As in other segments of the electronics industry, many portable device manufacturers have been letting go of their power supply designers, and relying more on semiconductor companies to help them with power design in their applications. It's no secret that many device manufacturers expect semiconductor suppliers to deliver power solutions as opposed to just supplying the chips. And it's now standard operating procedure for semiconductor companies to offer complete reference designs, evaluation boards, application notes and online design tools to support the use of their power management ICs in the customers' applications. But in many cases, this level of support is still not considered sufficient by device manufacturers.

Kevin Parmenter, the director of advanced technical marketing for Digital Power Products at Exar, explains that "among some device manufacturers the expectation is that the semiconductor company is going to do the design for them and hand them a working solution." Parmenter, who has years of experience in semiconductor applications engineering at Freescale, Fairchild, and ON, recalls a memorable visit to a major computer manufacturer, where an engineer summed up his company's needs. The engineer explained "what the semiconductor industry needs to understand is that they need to stop bringing us a cookbook and groceries, and bring us cooked food, ready to eat."

And it's not simply a matter of the semiconductor vendor delivering a complete, ready-to-build, power management solution after the customer has committed to purchasing their power management ICs. In some instances, the semiconductor vendor must deliver the complete solution before the customer decides to place an order.

Understanding Application Requirements

One lesson here is that the semiconductor vendor makes a heavy investment of its resources to win design-ins of its power chips. Another takeaway is that the chipmaker must have application engineers who understand the customer's application needs as well as (or maybe better than) the customer. As a result, says Parmenter, semiconductor companies like to hire engineers who have worked for their customers and understand the application requirements as well as power supply design.

And while the device manufacturers may be leaning heavily on the semiconductor suppliers for power design expertise, they still need engineers who understand how to address power requirements at the system-level. So, even if they're not expecting their engineers to design power converters from scratch, some device manufacturers still value the combination of power supply design experience and applications knowledge.

An engineer who works for a major laptop manufacturer explained, "What we try to do is understand what outfits like Intel say they need for a power supply and see if we really need the 'Cadillac' they want, or if we can find other ways to do the job. It's not uncommon for us to use good judgment in not taking their advice because that's what adds value." For example, in very high-volume applications, the laptop manufacturer can look for ways to make the power supply design cheaper than what's recommended in the reference design.

Meanwhile, in the area of portable power IC design, semiconductor companies are more likely hiring engineers from their competitors rather than their customers, according to Parmenter. When the business climate is strong, semiconductor suppliers will be competing with one another for IC designers. In addition, they may face new competition from overseas semiconductor companies who want to get a foothold in portable power management by setting up design centers in the U.S. or Europe and hiring away experienced IC designers from other companies.

Technical Challenges Require Interdisciplinary Approach

As handsets and other portable devices evolve, the power management challenges in these devices grow. Within these devices, some processors require a power supply voltage accuracy of 1% over temperature, and they may have 5 or 6 modes of operation that allow for lowering of power consumption, says Parmenter.

"Those modes all require intelligent interaction of the processor with the power system. So the power engineer needs to know something about software, systems, digital, and analog." says Parmenter in describing how the semiconductor FAE's job encompasses many disciplines. Meanwhile, some of the power management ICs developed for portable applications have evolved into very large ASICs. "Some of these power parts are 396-pin BGAs with I/Os tightly packed at 0.4- or 0.5-mm pitches," says Parmenter. That creates layout and manufacturing issues, which naturally the FAEs will be called on to help their customers address.

Steve Schulte, senior staff systems engineer at Qualcomm, notes another technical challenge: Trying to supply clean power in the face of the very fast load transients generated by processors, which have long been a problem in desktop and laptop computers, and are now being generated by cellphone processors. This is forcing designers to resort to some of the tricky power supply topologies, says Schulte.

He also notes that the migration to finer CMOS process geometries in the digital realm creates power design challenges for those who are integrating power control in their microprocessors. This points to another area of opportunity in portable power design which resides within the world of embedded power design on chip.

Other Factors

Power Experience Migrates from OEMs to ODMs. Parmenter points out that the original equipment manufacturers (OEMs) that sell portable electronic devices are relying more on original design manufacturers (ODMs) to develop their products. That means, semiconductor companies are working more now with the ODMs to develop power management solutions for portable applications. This trend suggests that ODMs need to have engineers with system-level knowledge of power issues just as the OEMs do.

Commoditization means less hardware design. Highly commoditized products such as printers tend to be based on chipsets, both for the logic and the power management functions. These power management chips may be highly integrated like the example cited above of a 396-pin BGA. Plus, whichever IC Company is supplying the main chipset for the product, is probably specifying the power components as well. The companies making these products tend to differentiate through software rather than hardware design. As a result, says Parmenter, commoditized products offer fewer opportunities for power designers within the device companies that make them.

On the other hand, portable device manufacturers that sell more specialized, not-yet-commoditized products still view hardware design as a means to differentiate their products. So power supply designers still have a role to play within these companies.

Movement of Jobs Offshore. Since most manufacturing of portable electronic devices is done in the Far East, it's no surprise that some companies in the U.S. or Europe have moved their product design including power system design off shore. However, this trend may be less of a factor for products that are more specialized and less commoditized as discussed above.

Opportunities in the Semiconductor Industry

The larger the semiconductor company, the more likely it is to have their IC designers and FAEs specialize in portable power applications. In some cases, a particular IC design center will focus on portable power chips. With regard to FAEs, there's probably more variation as some companies may opt to have their engineers focus on portable power applications, while others may ask them to support a specific product category such as cell phones.

Some companies ask their FAEs to support power supply design across a wider range of applications. And at smaller IC companies, it's likely that the FAEs will be required to be generalists who support the design of power ICs and all the non-power chips the company sells. All of these variations will influence the particular knowledge and skill sets that semiconductor companies look for when hiring FAEs to support their portable power products. Beyond the requirements for technical expertise, there will also be differences in the sizes of the territories that FAEs will be asked to support. For example, at smaller companies, FAEs may be expected to support customers over a larger geographic area, which may mean more time spent traveling.

About the Author

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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Green Vote-Catchers?

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

The articles and news reports covered in this issue I believe show clearly that throughout the world, governments, industry and consumers are 'getting real' about the need to conserve energy. We simply cannot go on using inefficient devices and systems which deplete the earth' s resources and at the same time poison the environment in which we and our future generations will live. It' s a well-used theme and one which will stay with us, but if we can sort out the politically motivated hype from the real need, we have a great opportunity to show the considerable talents of our creative engineering community, hopefully, steered by bold and innovative leadership.

I doubt that any government would support this simply because it's the right thing to do, but believe that it is indeed helpful when they actually do help the electronics industry and in particular engineering - and education in engineering - to innovate as only engineers can. With this, our industry can achieve the dramatic potential energy savings as well as providing the technology and products to

provide energy from cleaner sources. Both these areas are where engineering needs to play a pivotal role.

SMA Wins the PV Inverter Race in 2009

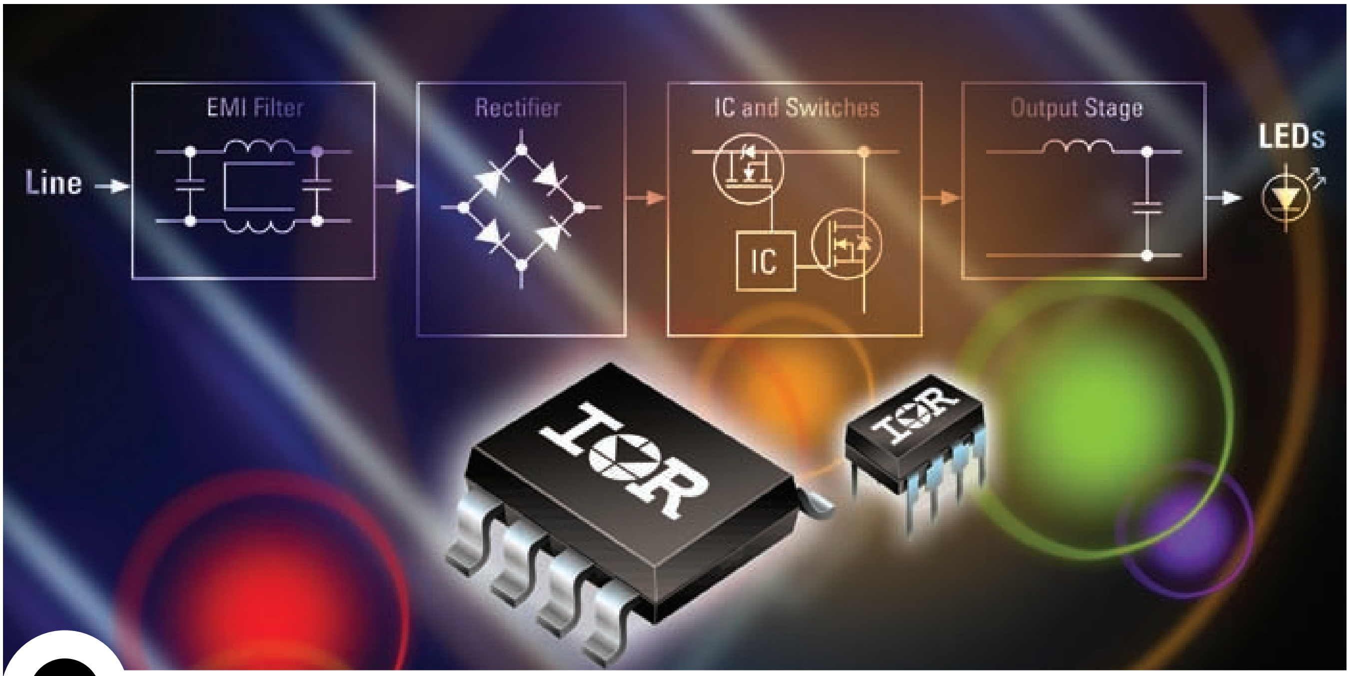
The PV inverter market raced out of 2009, with record shipments of more than 8GW, 30% more than 2008, according to ongoing analysis from IMS Research. Demand rebounded strongly in Q3 after a weak start to the year and has remained high since.

Unsurprisingly, SMA Solar Technology remained the largest supplier of PV inverters in 2009 and increased its share of shipments to an estimated 42%. However, despite a record fourth quarter for the company, its share actually decreased quarter-on-quarter for the first time in the year. In the third quarter it shipped almost half of all PV inverters used worldwide.

Q4'09 saw huge demand for all PV products as investors rushed to complete systems before feed in tariffs were reduced in many key European markets. 2.3GW of installations were completed in Germany alone. This incredible demand resulted in 3.5GW of inverters being shipped worldwide in the final quarter. Demand has remained high into 2010 and we now see a complete contrast to the first half of last year with a shortage of components limiting the market, rather than weak demand.

The top 3 suppliers remained unchanged in 2009; Fronius International remained the second largest supplier worldwide and Kaco New Energy maintained its position as third largest. The competitive landscape changed somewhat more below these suppliers with Power-One and Sputnik Engineering emerging as winners, surpassing several suppliers to become the fourth and fifth largest in 2009.

www.powersystemsdesign.com/greenpage.htm



Precise, Reliable, High Brightness LED Driver ICs

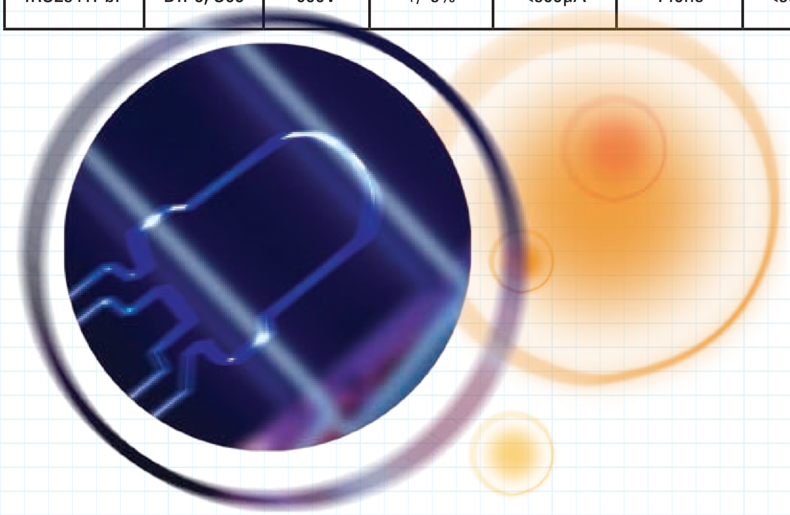
For Constant LED Current Regulation

Part No.	Package	Voltage	Load Current Regulation	Micro-power Start-up	Deadtime	Frequency
IRS2540PbF	DIP8, S08	200V	+/-5%	<500µA	140ns	<500kHz
IRS2541PbF	DIP8, S08	600V	+/-5%	<500µA	140ns	<500kHz

IR's high-brightness LED driver IC's, adapt and compensate to LED parameter variations to enable a highly accurate and inherently stable design.

Features

- 200V or 600V control IC in compact 8-pin DIP or SO package
- Incorporates continuous mode, time-delayed hysteretic buck regulator
- External high-side bootstrap circuit delivers frequencies up to 500kHz
- Micro-power startup of less than 500µA
- 140ns deadtime for continuous current regulation
- Auto restart, non-latched shutdown and PWM dimmable capability



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