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Design Tips

ISSN: 1613-6365

Power Systems Design EUROPE

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

Send address changes to:
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Volume 3, Issue 9

The Priority is Power

Hi everyone, having just completed my California editorial tour, I return with a stimulating 'feel-good' factor about our power industry. Maybe it has a little to do with the wonderful weather and indigenous positive attitude of the Californians, but the meetings I had with major companies as well as media folks has done much to reinforce my already strong view that this industry has never been so important to so many parts of the manufacturing of industrial, automotive and consumer goods.

The power supply and management of the raw energy that provides the so called user experience are now an agenda item and climbing rapidly. No more the 'heavy and hot' block that every equipment must somehow house, somewhere inconspicuous and placed so as to adjust the centre of gravity of the overall product design!

On a personal note, the user experience I had with the humble mobile phone charger that came with my now-essential piece of kit was certainly a long way below expectations when I realized the thing was not charging, despite the fact that I had it plugged into the hotel wall-socket all night. The shape of the unit should have told me…this was a linear charger with the usual transformer arrangements and it did not like the 115 volts supply as it was designed only for the European 230v system! A new switching supply was hastily purchased and all was then ok and will be wherever I travel from now on.

The point I make is that all this old stuff is on its way out, together with the huge copper and weight costs to a design. Smart power engineers providing smart solutions are now in demand, in Europe as well as in the US and with the high focus from players large and small that I met in California, there are surely great things to come in our field.

As ever in California, enthusiasm for the power electronics industry's future is unsurpassable, but not without good reason. With the resources now diverted into developing essential solutions in power and power management, new products and technologies are coming thick and fast. I have learnt a lot from my trip and now have many opportunities to seek out upon my return to Europe. I'll write them up and publish in future issues of our magazine.

Of course, as one would expect, everyone claims leadership in power, providing one just looks at the operating space each company is occupying. This is normal and really carries not so much weight to those of us who are exposed to a much broader picture, but it does show that each company has its own set of key credentials and particular area of excellence which, when all combined gives us a very rich resource to fulfill our design requirements.

In this issue we have a selection of features from some of the companies with whom I am talking and interviewing. Many have heroic stories to tell. The power business has never been so prolific and at such a high profile, certainly not in my time - and that goes back further than I care to admit.

The delivery, management and conservation of power is pursued with absolute passion in certain companies. One top international power player likened it to the ability of filling a wine glass without waste from a high-pressure water hydrant! Every company I see has something of great interest when you go beneath the surface of public image which is exactly the place I want us to be. Getting around them all will certainly give me a challenge, but one that will certainly bring us rich rewards in terms of industry update and innovation news.

So please enjoy the issue, tell me about your design experience and importantly for me, give me your feedback on the magazine and help me to make it what you want it to be. In the meantime I'll pull in the features and put them up in subsequent issues for your benefit.

Cliff Keys

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‘Q-Series’ Rectifiers to Replace Silicon Carbide in PFC Applications

Qspeed Semiconductor, an early-phase power semiconductor manufacturer, has announced a new family of power diodes for boost power factor correction (PFC) circuits. Developed using proprietary technology, the new rectifiers have a softer reverse recovery and higher efficiency than any other silicon rectifiers available. In typical PFC circuits, the new family of devices offers system efficiency gains of 0.5-2.0 percentage points when compared with typical ultrafast rectifiers.

Until now, high PFC efficiency has required the use of use silicon carbide Schottky rectifiers at a tremendous price premium to the traditional, lower-efficiency Silicon alternatives. The new Q-Series family now offers engineers an alternative with performance almost identical to silicon carbide Schottkys but at a fraction of the price.

The new Q-Series rectifiers also have the lowest reverse recovery charge (QRR) available at most operating temperatures, and their soft recovery characteristic results in lower EMI emissions than for any other rectifier available, including silicon carbide types.

“The global energy situation has created an environment of increasing efficiency and PFC requirements around the world,” said Michael T. Robinson, CEO of Qspeed. “It has become necessary to use more-efficient rectifiers in a whole range of off-line equipment, to meet current guidelines and regulations and in high-end AC/DC conversion, efficiencies well over 90% are now required just to be competitive. Our new Q-Series rectifiers are the most cost-effective way to meet all of these requirements.”

www.qspeed.com

Infineon Opens First Asia-Based Front-End Fab in Malaysia. Invests US $1 Billion in Power Plant for Industrial and Automotive Chips

Photo-caption: Wolfgang Ziebart, President and CEO of Infineon

Infineon Technologies has announced the opening of its first Asia-based front-end power fab located in Kulim Hi-Tech Park, Malaysia. At the ceremony, the Honourable Dato’ Seri Rafidah Aziz, Minister of International Trade and Industry of Malaysia, gave one of the opening speeches and together with Dr. Wolfgang Ziebart, President and CEO of Infineon, officially opened the new power fab. Infineon invests approximately US $1 billion in the Kulim power fab. At full capacity, the fab will employ about 1,700 people. Maximum capacity will be about 100,000 wafer starts per month using wafer discs with a diameter of 200 mm (8 inch). The new facility will produce power and logic chips used in industrial and automotive power applications.

“Our new fab in Kulim is a strategic investment into our future and an opportunity to address the world’s growing demand for more efficient power controls in industrial, computing and household appliances by enabling variable speed-controlled electric motors with higher performance,” said Dr. Wolfgang Ziebart, President and CEO of Infineon. “This new fab is an important step in continuing our successful business with chips for automotive and industrial power applications.”

With global energy demand continuing to rise and natural resources depleting, power semiconductors make a major contribution to address the increasing need for energy savings. Infineon has a strong position in power applications within industrial and automotive segments. According to market research firm IMS Research, Infineon has been the global market leader for power semiconductors for three consecutive years, holding 9.3 percent of the US $11.35 billion market by revenue in 2005.

Production of Power Semiconductors in Kulim

Complementing Infineon’s existing power semiconductor production sites in Europe, the Kulim plant is part of Infineon’s Power fab network, which includes development and production facilities in Villach (Austria) and Regensburg (Germany).

The core activity of the Kulim fab is to produce power semiconductors which enable efficient energy management, such as CoolMOS and IGBT chips for industrial applications and SMART-Power chips for use in cars. CoolMOS semiconductors allow for completely new system approaches for power supplies, such as in servers, PCs and laptops and for battery chargers in mobile phones or PDAs. Power supply designs with CoolMOS chips continue to shrink in weight and size. Infineon’s IGBT chips enable new concepts of drives in household applications, such as refrigerators, air conditioning systems and industrial applications. Due to their low inner resistance and switching behavior, electrical energy can be utilized more efficiently with less waste heat. For car applications, Infineon’s automotive SMART-Power switches increase fuel efficiency, safety and convenience. They are applied in engine control, ABS and airbag applications as well as in lighting control, electrical window lift, seat adjustment and door locks.

www.infineon.com

Digi-Key and CR Magnetics Sign Global Distribution Agreement

Digi-Key Corporation and CR Magnetics today announced the signing of a global distribution agreement.

CR Magnetics is a manufacturer of current, voltage, power and frequency transducers, relays, current transformers, hall effect sensors and other devices. Digi-Key Corporation is one of the world’s fastest growing distributors of electronic components and currently ships product to more than 140 countries around the globe.

Under the terms of this new distribution agreement, CR Magnetics products are available for purchase directly from Digi-Key and featured in the company’s print and online catalogs. This agreement will enable Digi-Key to fulfill both the design and production quantity needs of its diverse customer base.

www.digi-key.com

www.crmagnetics.com

Microsemi Awarded R&D Contract to Develop Silicon Carbide RF Power Products for Airborne Avionics

Microsemi Corporation has been awarded $1.8 million to allow the company's Power Products Group to develop technology related to the use of silicon carbide semiconductor components in military avionics applications. It is expected that the program will be administered by AFRL (Air Force Research Laboratory). This commitment by the Air Force and the US Congress to further development of the new silicon carbide technology supports future designs of lighter and more efficient jet fighter communications systems. The appropriation follows a contract with Northrop Grumman awarded earlier in the year where Microsemi will provide leading edge silicon carbide products to this leading defence contractor.

Silicon carbide brings several advantages in avionics applications, including increased reliability, extended coverage, point-of-use power conversion, and reduced size and cooling requirements. Silicon carbide plays a key role as military operations become more networked and the demands for expanded bandwidth and high duty (power) operation increase significantly.

According to James J. Peterson, Microsemi President and CEO, "Microsemi is committed to be a technology innovator in the development of next generation silicon carbide products for defence and commercial applications. This commitment is another example of the end customer support that we are receiving in the quest of being a silicon carbide leader."

www.microsemi.com

Power-One Announces Acquisition of Magnetek's Power Electronics Group

Photo caption: Bill Yeates, Chief Executive Officer, Power-One

Power-One has announced that it has signed a definitive agreement with Magnetek to acquire its Power Electronics Group. Magnetek specializes in the application of advanced power electronics technology to meet the needs of the global digital economy. Magnetek's Power Electronics Group sells power supplies and alternative energy products to a wide range of customers and markets.

Bill Yeates, Chief Executive Officer, added, "The acquisition of Magnetek's PEG business unit advances our strategy to penetrate new markets and customers. We are extremely impressed with Magnetek's R&D successes, creativity, and ability to design some of the highest efficiency power products in the world. With this acquisition, we will add digital controls for motors, specialty transportation and system-level applications, and alternative energy, along with a premier customer list."

The Power Electronics Group is comprised of operations in Italy, Hungary, China and the United States with approximately1200 employees and has customers such as Alcatel, Electrolux, Google, IBM, Indesit, Motorola and Siemens.

www.powerone.com

Powervation & Commergy to Collaborate on Digital Power Solutions

Powervation Ltd and Commergy Ltd have entered into an agreement to collaborate on the development of complete digital power delivery solutions for OEM customers in networking and computing applications. Under the agreement, Commergy will have early access to Powervation's digital power controller technology to enable the advance development of digitized power delivery for key OEM customers. Powervation expects to benefit from Commergy's experience in high efficiency power supply design, existing market reach and incorporation into Commergy's leading edge power solutions.

Antoin Russell, CEO of Powervation, commented, "Commergy has a team of power gurus and a track record of designing innovative, high efficiency power solutions for customers in the computer, networking and storage markets. Their model is unique in the industry as their designs are targeted at specific emerging market requirements then licensed to the client for manufacture using their own supply chain. The customer benefits from their innovative design services, fast market entry, security of supply and significant reductions in sourcing costs for the power supply solution."

Garry Tomlins, Marketing Director of Commergy, added, "We have a long-standing relationship with Powervation and are excited about developing products based on their upcoming digital power controller technology. It fits very well with our developing range of high efficiency platforms and in enabling us to provide end-to-end advanced power delivery solutions. The controller has some very exciting new features which we believe offer compelling advantages over comparable digital controllers in the market."

www.commergy.com

www.powervation.com

Power Events

- ***ELECTRONICA 2006**, Nov. 14 - 17, Munich, www.electronica.de*
- ***SPS/IPC/DRIVES 2006**, Nov. 28 - 30, Nuremberg, www.mesago.de/de/SPS/main.htm*
- ***APEC 2007**, Feb 25 - Mar 1, Anaheim, California, USA, www.apec-conf.org <http://www.apec-conf.org/>*
- ***PCIM China 2007**, March 21-23, Shanghai, China www.pcimchina.com <http://www.pcimchina.com/>*
- ***electronicaChina 2007**, March 21-23, Shanghai, China http://www.global-electronics.net/?id=21317*
- ***PCIM Europe 2007**, May 22-24, <http://en.wikipedia.org/wiki/N%C3%BCrnberg_%28disambiguation%29> Nürnberg, Germany http://www.mesago.de/en/PCIM/main.htm*

Reference Design Kit for Energy-Efficient Charger/Adapter with 10 kV Surge Protection

Power Integrations, Inc., has introduced a reference design kit for an energy-efficient charger/adapter based on its LinkSwitch®-LP family of integrated circuits with EcoSmart® technology. The new reference design kit (RDK-83) reduces no-load power consumption by 79 percent compared to existing linear solutions, and features a constant-voltage (CV) charger circuit capable of withstanding 10 kV common-mode / 2 kV differential-mode surges. This level of surge protection is often required in power supplies for products that connect to telephone lines - such as cordless/wireline phones, answering machines, modems and other telecom devices.

Richard Fassler, director of product marketing for Power Integrations commented, “Designing for adequate surge protection helps to minimize damage to products due to lightning strikes and other over-voltage events and thereby reduces the cost of replacement and repairs. With the RDK-83 as a guide, designers can develop switched mode power supplies that will withstand 10 kV surges and operate far more efficiently than supplies based on linear transformer technology.”

The RDK-83 contains a working 7.7V, 210 mA flyback adapter circuit that operates over the universal input voltage range of 85 VAC to 265 VAC. As with all recent PI reference designs, the RDK-83 has a high average active mode efficiency of 66.6 percent, which easily exceeds the ENERGY STAR and California Energy Commission (CEC) specification of 53.2 percent, and no-load power consumption of less than <220 mW at 115 VAC.

Included in the kit are LinkSwitch-LP samples, PCB, an engineering report on the power supply, and a PI Expert™ power supply design software CD-ROM.

The RDK-83 is available today at www.powerintsamples.com.

The company’s breakthrough integrated-circuit technology enables compact, energy-efficient power supplies in a wide range of electronic products, both in AC-DC and DC-DC applications. The EcoSmart® energy-efficiency technology, designed to dramatically reduce energy waste, has saved consumers and businesses worldwide more than an estimated $1.8 billion on their electricity bills since its introduction.

www.powerint.com

Powering the future

By Robert Hinke, Marketing Director, National Semiconductor Europe

Great steps forward have been made over the past years in process technology to enhance performance of power converters; novel topologies and innovative IC control logics that have renovated the standard power supply architectures. Many other innovations are expected in the near future. However which major trends and applications will lead the innovation of power supply technology?

During the last decade electronic equipment has taken a great step ahead offering smaller solutions and higher performances. These dramatic improvements have been mainly driven by microprocessors that quickly moved from the MHz clock speed range to GHz and memory storage units that now contain several gigabytes. This has been made possible by the advances in silicon technology geometries which have moved from a few microns to sub micron today. While the 1.0 micron technology used to operate at 5V, the 0.1u technology operates at only 1V. As the power remains almost the same, the voltages have come down and currents have gone up.

This new technology trend forced power supply solutions to follow, offering more efficient solutions and miniaturized systems that fulfill these requirements.

Furthermore, the much publicized high oil price and severe CO2 emission problems emphasize the importance of more efficient sub-systems, driving advances in power supply architectures and applications.

Europe, always more sensitive to these issues, will certainly take the lead in driving innovative solutions.

National, with its leadership in power management, has the technology and IP to meet these requirements.

If 'efficiency' is the key-word, then

white light emitting diodes (LEDs) must be an important path for the future. High-brightness LEDs use only a fraction of the power needed for bulb technology, have much longer operating lifetimes, and do not endanger the environment. LED technology is used for automotive lighting systems, displays, mobile devices and many other applications.

Lumens-per-watt is the standard used by the lighting industry to measure the conversion of electrical energy to light. As a reference, conventional incandescent light bulbs are typically in the 10 to 20 lumens per watt range, while compact fluorescent lamps range from 50 to 60 lumens per watt.

LED semiconductor suppliers have been racing to produce higher efficiency white LEDs with a target of 100 lumens per watt, seeking energy efficiency alternatives to conventional lighting.

One way to boost efficiency in a lighting apparatus is to use a configuration of multiple LEDs connected in a series of strings, which guarantees the closest matching colour and brightness, driven by a high efficiency constant current source switching driver. A switching regulator offers the advantage of efficiency, reducing the dissipation that drives the LED as well as reducing the heat transferred to the LED itself.

LED semiconductor technology together with dedicated driver solutions will further boost the adoption of LED subsystems in large TFT displays, pendant lights, automotive front lights, and all the other applications where efficiency and reliability are needed. Here, National's family of dedicated regulators combine better efficiency and accurate temperature/brightness control with a high integration level.

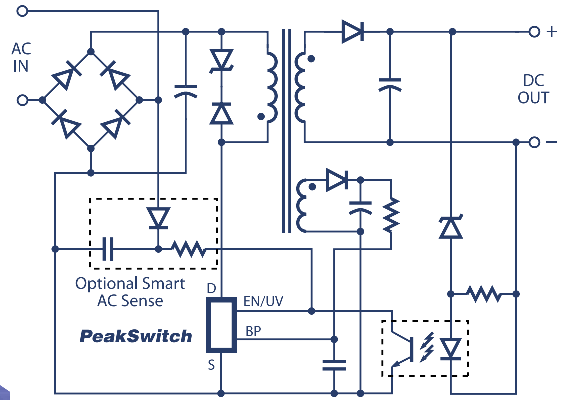
But whatever the application or complexity of the system, the power supply is usually the last part of the overall design, since it can be developed only when all the power requirements of the main blocks are well defined.

Designing a switching power supply embraces all aspects of engineering: EMI, closed loop analysis, power losses, thermal analysis, layout issues, magnetic design.

It can become a difficult task for any system designer. Fortunately, a wide selection of integrated switching regulators such as National's Simple Switcher and software tools like WEBENCH, an online design tool that allows the design of a complete switching power supply in four simple steps for engineers at all levels of expertise.

In addition, we continue to develop training material, power courses and on-line training tools to stimulate the self-development of engineers and raise their knowledge in the vital field of power design.

www.nsc.com



"YouTube" The Power!

By Marijana Vukicevic, iSuppli Corporation

The entertainment and media industry heavily depend on the buying power of end consumers. With more sites being developed to promote alternative bands, music and different forms of art (video clips, short films), new generations are growing up in need of more memory- static and dynamic, for powerful processors and graphic and video cards.

It is about learning what is out there in the world and then doing it yourself. The latest among them is YouTube launched in December last year featuring more than 100 million videos a day. The downloadable video applications are requesting more processing power from PCs, servers and the increasing forms of handheld devices and therefore more electrical power for these PCs and servers.

But what do the video clips and amateur filming have to do with processor manufacturers or power spending? Ultimately, that seems to be the reason bringing Intel and Google together, or Intel and ADI, or Microsoft, Freescale and Intrinsyc who are all working to boost up the efficiency of the components and systems in different areas of computing platforms.

In order to launch one of these media sites, more processing power is needed from a PC at the consumer end. To store the data and respond quickly to the user's requests, more processing power is needed from a server on the provider's side. Ultimately, that means that power spent to run them is critical. Energy costs for servers and for personal computers are becoming more and more of an issue. The estimated bill for a home PC per year in US is between 150 and 220 dollars depending on the PC configuration. With the energy crisis, processor requirements and the increasing number of computers per household, this is sure to rise over

the years. Electricity bills over time can easily exceed the cost of hardware of a personal computer.

The concern over dollar spending is rising among service, media and content providers not only regarding server power usage and optimization but also with respect to the power consumption in personal computers.

At Google, engineers took a closer look at the power supplies in our PCs and concluded that it has been some time since the standards for power supplies in these computers were last updated. It's been more than 10 years since the last time somebody took a real close look at this critical area.

In general, there are four voltage levels generated in power supplies used for PCs - +12V, - 12V, +5 V and + 3.3V. Only one is really needed and that is +12 V with the VRMs (voltage regulator modules) converting it down to the other supply voltages like 3.3V, 2.5V or 1.2V or anything else that could be needed. The other seldom-used three voltages are just a legacy of the previous generation of PCs that were never looked at and changed over the years. Indeed, there also seems to be a question about the + 12V being optimized, since the efficiency of a supply is normally at its highest a little below its maximum rated load.

Google argues in a recent white paper that the opportunity for power savings in PCs is immense - deploying new power supplies in 100 million desktop PCs running eight hours a day, it says, would make it possible to save 40 billion kilowatt-hours over three years, or more than $5 billion of power at California's energy rates.

Although Google does not plan to enter the personal computer market, the company is a large purchaser of microprocessors and has evolved a highly energy-efficient power supply system for its data centres

But if manufacturers changed PSUs to only a +12V optimized power supply, surely the efficiency could be increased significantly achieving tremendous savings? Notably, in highly developed countries such as the USA, it is estimated there are on average 1.6 Personal Computers per household…a big number.

The same argument can be applied to servers and here savings could be appreciable, bearing in mind the amount of power that is needed today for datacentres. A sobering example of this can be seen with Google whose spending on electricity bills for servers reaches almost 6% of their capital expense.

With the increasing demand for more thrilling media experiences together with the pressure frequently applied to us all to conserve precious energy, maybe the opportunity is here for our power engineers to save the day.

Marijana Vukicevic is a senior analyst with iSuppli Corp. Contact her at mvukicevic@isuppli.com

www.isuppli.com

Analyzing the Sepic Converter

In the last issue, we talked about the simplest of all converters, the buck converter, and showed how its control transfer functions could be extraordinarily complex. In this issue, we'll go to the other end of the spectrum, and look at a converter that is far more complex, yet is often used by engineers who are unaware of the difficulties that follow.

By Dr. Ray Ridley, Ridley Engineering

The Sepic Converter

The most basic converter that we looked at last month is the buck converter. It is so named because it always steps down, or bucks, the input voltage. The output of the converter is given by:

$$V_o = DV_g$$

Interchange the input and the output of the buck converter, and you get the second basic converter – the boost. The boost always steps up, hence its name. The output voltage is always higher than the input voltage, and is given by:

$$V_o = \frac{1}{D'}V_g$$

What if you have an application where you need to both step up and step down, depending on the input and output voltage? You could use two cascaded converters – a buck and a boost. Unfortunately, this requires two separate controllers and switches. It is, however, a good solution in many cases.

The buck-boost converter has the desired step up and step down functions:

$$V_o = \frac{-D}{D'}V_g$$

The output is inverted. A flyback converter (isolated buck-boost) requires a transformer instead of just an inductor, adding to the complexity of the development.

One converter that provides the needed input-to-output gain is the Sepic (single-ended primary inductor converter) converter. A Sepic converter is shown in Fig. 1. It has become popular in recent

years in battery-powered systems that must step up or down depending upon the charge level of the battery.

Fig. 2 shows the circuit when the power switch is turned on. The first inductor, L1, is charged from the input voltage source during this time. The second inductor takes energy from the first capacitor, and the output capacitor is left to provide the load current. The fact that both L1 and L2 are disconnected from the load when the switch is on leads to complex control characteristics, as we will see later.

When the power switch is turned off, the first inductor charges the capacitor C1 and also provides current to the load, as shown in Fig. 3. The second inductor is also connected to the load during this time.

The output capacitor sees a pulse of current during the off time, making it inherently noisier than a buck converter.

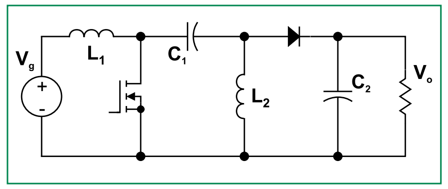


Figure 1. The Sepic converter can both step up and step down the input voltage, while maintaining the same polarity and the same ground reference for the input and output.

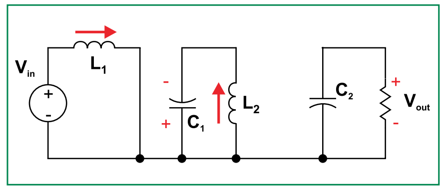


Figure 2. When the switch is turned on, the input inductor is charged from the source, and the second inductor is charged from the first capacitor. No energy is supplied to the load capacitor during this time. Inductor current and capacitor voltage polarities are marked in this figure.

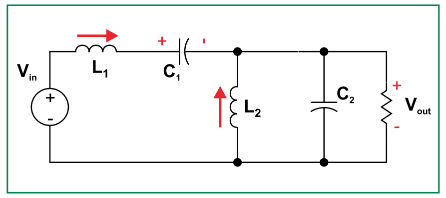


Figure 3. With the switch off, both inductors provide current to the load capacitor.

The input current is non-pulsating, a distinct advantage in running from a battery supply.

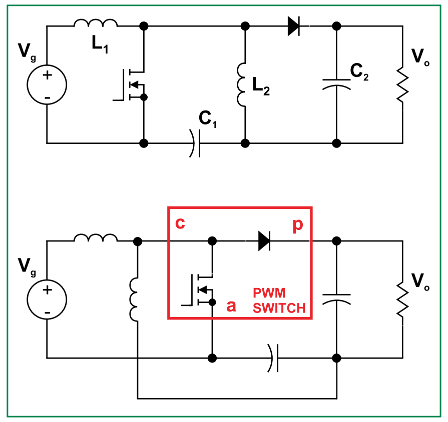


Figure 4. In order to take advantage of Vorpérian's PWM switch model, the circuit elements must first be rearranged. The function of the original topology is retained when the capacitor is moved, and the second inductor is redrawn.

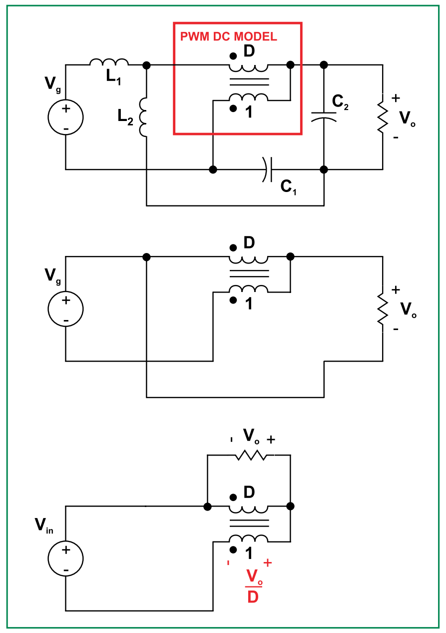


Figure 5. For DC analysis, the small signal sources are set to zero, inductors become short circuits, and capacitors become open circuits. After the circuit is redrawn, it is a trivial matter to write KVL around the outer loop of the circuit to solve for the conversion gain of the converter.

The PWM Switch Model in the Sepic Converter

The best way to analyze both the AC and DC characteristics of the Sepic converter is by using the PWM switch model, developed by Dr. Vatché Vorpérian in 1986. Some minor circuit manipulations are first needed to reveal the location of the switch model, and this is shown in Fig. 4.

First, capacitor C1 is moved to the bottom branch of the converter. Then, inductor L2 is pulled over to the left, keeping its ends connected to the same nodes of the circuit. This reveals the PWM switch model of the converter, with its active, passive, and common ports, allowing us to use well-established analysis results for this converter.

For more background on the PWM switch model, the text book "Fast Analytical Techniques for Electrical and Electronic Circuits" [1] is highly recommended.

DC Analysis of the Sepic Converter

Fig. 5 shows the equivalent circuit of the Sepic converter with the DC portion of the PWM switch model in place. The DC model is just a 1:D transformer. We replace the inductors with short circuits, and the capacitors with open circuits for the DC analysis. You can, if you like, include any parasitic resistances in the model [2], but that's beyond the scope of this article.

After the circuit is manipulated as shown in the figure, we can write the KVL equation around the outer loop of the converter:

$$V_g + V_o - \frac{1}{D} V_o = 0$$

Rearranging gives:

$$V_g = \left(\frac{1}{D} - 1\right) V_o = \frac{D'}{D}$$

And the DC gain is given by:

$$V_o = \frac{D}{D'} V_g$$

Here we see the ability of the converter to step up or down, with a gain of 1 when D=0.5. Unlike the buck-boost and Cuk converters, the output is not inverted.

AC Analysis of the Sepic Converter

You won't find a complete analysis of the Sepic converter anywhere in printed literature. What you will find are application notes with comments like, "the Sepic is not well-understood." Despite the lack of documentation for the converter, engineers continue to use it when applicable.

Proper small-signal analysis of the Sepic converter is a difficult analytical task, only made practical by advanced circuit analysis techniques originally developed by Dr. David Middlebrook and continued by Vorpérian. [1]

If you're going to build a Sepic, as a minimum, you need to understand the control characteristics. Fortunately, Vorpérian's work is now available for this converter, and you can download the complete analysis notes . [2]

The simplified analysis of the Sepic converter, derived in detail in [2], ignores parasitic resistances of the inductors and capacitors, and yields the following result for the control-to-output transfer function:

$$\frac{v_o(s)}{d(s)} \approx \frac{1}{D'^2} \frac{\left(1 - s\frac{L_1}{R}\frac{D^2}{D'^2}\right)\left(1 - s\frac{C_1(L_1+L_2)R}{L_1}\frac{D'^2}{D^2} + s^2\frac{L_2C_1}{D}\right)}{\left(1 + \frac{s}{\omega_{o1}Q_1} + \frac{s^2}{(\omega_{o1})^2}\right)\left(1 + \frac{s}{\omega_{o2}Q_2} + \frac{s^2}{(\omega_{o2})^2}\right)}$$

Where

$$\omega_{o1} \approx \frac{1}{\sqrt{L_1\left(C_2\frac{D^2}{D'^2} + C_1\right) + L_2(C_1 + C_2)}}$$

$$Q_1 \approx \frac{R}{\omega_{o1}\left(L_1\frac{D^2}{D'^2} + L_2\right)}$$

$$\omega_{o2} \approx \sqrt{\frac{1}{L_2\frac{C_1}{D^2}\|\frac{C_2}{D'^2}} + \frac{1}{L_1 C_1 \| C_2}}$$

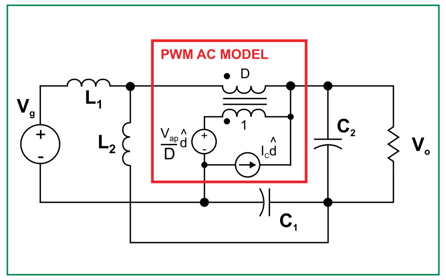


Figure 6. The small-signal AC sources are included in the switch model, and we can either solve the analysis by hand, or use PSpice to plot desired transfer functions. The hand analysis is crucial for symbolic expressions and design equations.

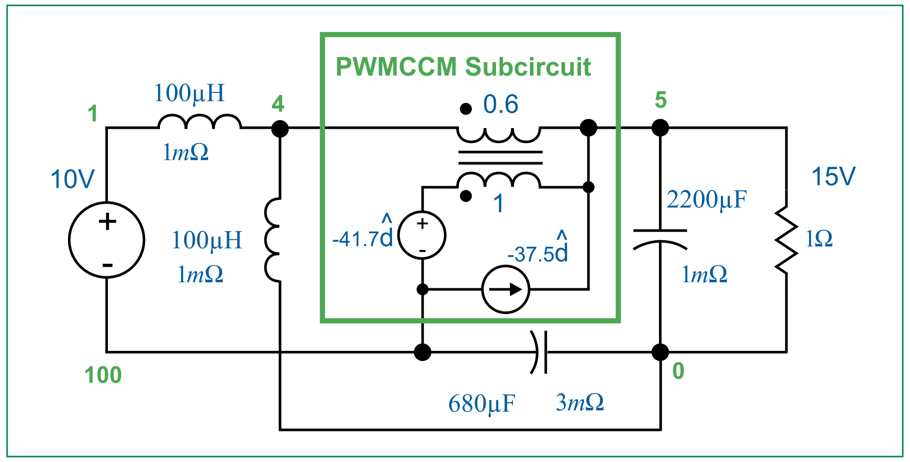


Figure 7. Analysis can also be done with PSpice. This figure shows a specific design example for a 15 W converter. Parasitic resistances are included in the PSpice model.

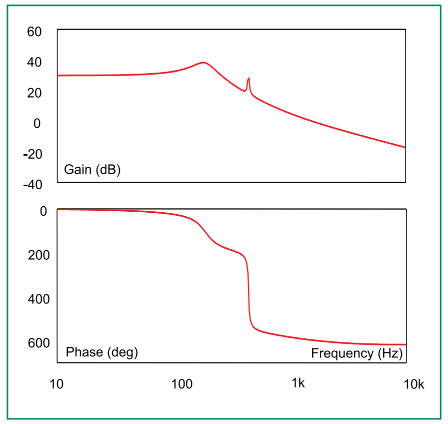


Figure 8. This shows the control-to-output transfer function for the Sepic converter. With low values of damping resistors, the converter has four poles, and three right-half-plane zeros. This results in an extreme phase delay of 630 degrees!

$$Q_2 \approx \frac{R}{\omega_{o2}(L_1 + L_2)\dfrac{C_1}{C_2}\dfrac{\omega_{o1}^2}{\omega_{o2}^2}}$$

As you can see from these expressions, the "simplified" analysis is anything but simple. Including the parasitic resistances greatly complicates the analysis, but may be necessary for worst-case analysis of the Sepic converter. The analysis of this converter involves the use of the powerful extra element theorem, and Vorpérian's book on circuit analysis techniques. [1]

In addition to the inevitable fourth-order denominator of the Sepic, the most important features to note in the control transfer function are the terms in the numerator. The first term is a single right-half-plane (RHP) zero. Right-half-plane zeros are a result of converters where the response to an increased duty cycle is to initially decrease the output voltage.

When the power switch is turned on, the first inductor is disconnected from the load, and this directly gives rise to the first-order RHP zero. Notice that the expression only depends on the input inductor, L1, the load resistor, R, and the duty cycle.

The complex RHP zeros arise from the fact that turning on the switch disconnects the second inductor from the load. These zeros will actually move with the values of parasitic resistors in the circuit, so careful analysis of your converter is needed to ensure stability under all conditions.

PSpice Modeling of the Sepic Converter

The analytical solution above does not include all of the parasitic circuit elements. As you will see from [2], there is a prodigious amount of work to be done even without the resistances.

We can also use PSpice to help understand the Sepic better. Fig. 7 shows the circuit model for a specific numerical application of the Sepic, and it includes resistances which will affect the stability of the converter, sometimes in dramatic ways.

The PSpice file listing can be downloaded from [2] so you can reproduce these results to analyze your own Sepic converter.

Fig. 8 shows the result of the PSpice analysis. The two resonant frequencies predicted by the hand analysis can clearly be seen in the transfer function plot. What is remarkable is the extreme amount of phase shift after the second resonance. This is caused by the delay of the second pair of poles, and the additional delay of the complex RHP zeros. The total phase delay through the converter is an astonishing 630 degrees. Controlling this converter at a frequency beyond the second resonance is impossible.

Summary

The Sepic converter definitely has some select applications where it is the topology of choice. How do designers get away with building such a converter? There are several possibilities. First, the dynamic and step load requirements on the system may be very benign, with no reason to design a loop with high bandwidth. This allows the loop gain to be reduced below 0 dB before the extreme phase delay of the second resonance.

Secondly, in many practical cases, the parasitic resistances of the circuit move the RHP zeros to the left half plane, greatly reducing the phase delay. This can also be done with the addition of damping networks to the power stage, a topic beyond the scope of this article.

Thirdly, some engineers do not build a proper Sepic. In some application notes, the two inductors are wound on a single toroidal core, which provides almost unity coupling between the two. In this case, the circuit no longer works as a proper Sepic. Don't fall into this design trap - the circuit will be far from optimum.

Additional Reading

[1] "Fast Analytical Techniques for Electrical and Electronic Circuits", Vatché Vorpérian, Cambridge University Press 2002. ISBN 0 521 62442 8.

[2] http://www.switchingpowermagazine.com. Click on Articles and Sepic Analysis Notes.

www.ridleyengineering.com

TechTalk

The Benefits of Design Resource Investment

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

I recently had the opportunity to visit Fairchild Semiconductor in Bayern, Germany. Here I was able to get an insight into the operations and foci of the company from the management team including Ole-Petter Brusdal, Regional VP, European Sales and Marketing; Alfred Hesener, Marketing Director, Europe and Dr. Michael Weirich, Application Manager.

The company, market leader in Power products shipping over 20 billion devices every year, has attained a special position in the industry and devotes much resource into providing its customers with the support now needed as motion control and power systems become ever more complex. These new systems require specialist skills to bring customers products to today's highly competitive market in the shortest time possible.

Brusdal commented, "the constant drive in the power semiconductor business -and in particular here at Fairchild, to integrate functions into a single package or module, brings tremendous benefits to the designer in terms of space saving, cost of ownership advantage and a predictable and measured EMI performance. Power options taken and design decision-making have never been more critical. Gone are the days generally where manufacturers of, for instance, consumer goods do everything from design to final assembly and promotion. Now, they tend to focus on their core competence and outsource the higher-level specialist needs. Power has now become such a specialist requirement for the manufacturer to contend with. Fairchild has consistently made significant investments as part of the company's focus, to ensure the power element of the design runs smoothly

for the manufacturer. In many cases, the customer's designer in charge of the whole complex power path for a product simply just does not have the time or the in-depth specialization to be able to deliver the complete system within the 'normal', brutally aggressive timescale needed to break into a new market. It is here that our laboratory at Fairchild, as part of Fairchild's Global Power Resource™ network, will work with the customer to help achieve a planned development cycle, delivered on time".

As an example of this, the Global Power Resource design centre lab in Germany has recently completed designs enabling automobile manufacturers to meet the proposed European daytime headlight (daytime running light) safety regulations with a new ballast design utilizing Fairchild's SEPIC, Single Ended Primary Inductance Converter topology. This new design has proven to be ideal for low voltage DC/DC applications such as automobile headlights and offers a wide range of options in EMI and efficiency. These deigns are highly flexible in terms of input and output voltage as well as output power.

"Fairchild's Global Power Resource design centre in Europe also developed a design, using SEPIC topology, to drive up to seven LEDs with 30V max output and 350mA constant current as well as up to 36 low power LEDs with 120V max output with 70mA constant current output," added Brusdal.

Many of today's autos already use high brightness LEDs of up to 1W. However daytime headlights typically require five to seven LEDs to comply with the expected new standard. Ideally, these LEDs should be connected in series to ensure identical current and brightness of each device. SEPIC topology can transform voltages up as well as down, to easily meet these requirements.

"Fairchild is fortunate to have the calibre of talent in Dr. Michael Weirich and his team to develop these innovative designs using SEPIC topology in a expansive range of low voltage applications, such as daytime running headlights, DC/DC converters and off-line AC/DC solutions," continued Brusdal.

The Global Power Resource centre in Fuerstenfeldbruck- is resourced with expertise and equipment targeted to provide comprehensive power design solutions for electronic applications in the principal European end markets.

Able to turn around designs in as little as two weeks, the centre provides customers in industrial, consumer and automotive markets with fully engineered solutions, including evaluation boards; detailed reports including information for 'Bill-of-Materials' (BOMs) and turnkey designs as well as CAD files that can be incorporated into customers' designs. It is one of seven such centres operated worldwide by Fairchild to develop complete system power solutions in the computing, communications, consumer, industrial, automotive and display segments. Fairchild plans to almost double the number of design labs this year, with

Figure 1: Dr Weirich and Ole-Petter Brusdal explain power designs and company direction at Fairchild.

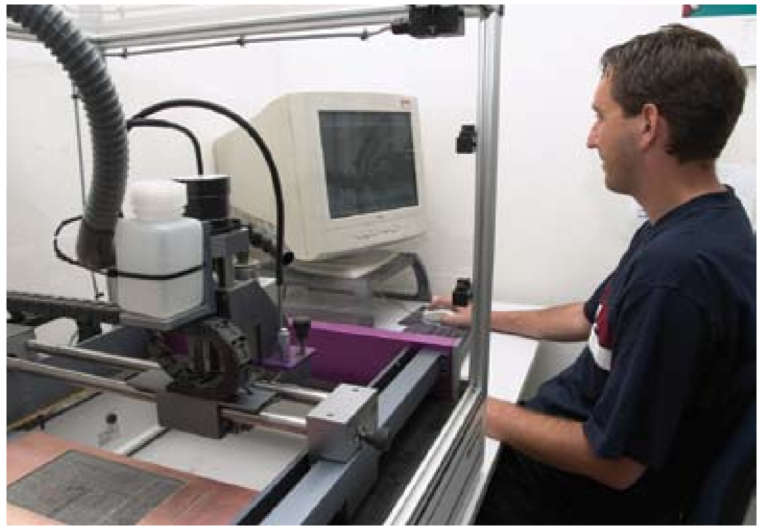


Figure 2: The laboratory milling machine gets a prototype PCB ready in minutes.

the addition of six new facilities located in South America, China and Korea.

Dr. Michael Weirich and his talented team who run the Global Resource centre laboratory in Germany work with Fairchild FAEs and their customer design issues to bring added value and on-time delivery to a market that has already become super-competitive, as in the case of consumer goods. Weirich added, "often, as a result of our lab engineers' and FAEs' proven track record, customers seek pre-production advice and guidance on how they can accelerate a design to deliver new products on-time and in the most cost-effective manner. As anyone in the business will know, talented power engineers are a rare breed these days…and just as it used to be in the early days of DSP design, these guys are very difficult to find and are a great asset to a company like Fairchild here and, of course, to our customers".

Traditionally, designs for appliance applications used triac-controlled universal AC or split pole motors. Energy saving initiatives (now a government legislated issue and a hot topic) are now forcing appliance manufacturers to adopt energy saving motor solutions, requiring more complex electronic drive solutions.

Also, with companies serving the home appliance market increasingly moving away from vertical integration of their manufacturing to focus on competencies, such as brand development, customer service, and logistics, Fairchild's integration of discrete power semiconductors, drivers and controllers into one package allows them to reduce the time and effort spent on design, ensuring they have a solid power electronics section in their appliance.

We discussed an ordinary dishwasher as an example. Earlier models had cumbersome, complex (and sometimes infuriatingly unreliable!), electromechanical controls and several discrete power components. To add features that end customers would perceive as value-added, today's (and tomorrow' s) models need increasingly complex electronic control circuits, with displays and sensors, in order to increase safety and save politically-precious energy and water. New power supplies and motor control designs contribute a great deal to these savings, but inevitably add extra cost in an aggressively price-competitive market. So, it's no surprise that designers of these controls face enormous pressure to provide cost-effective solutions in the shortest possible time.

Fairchild's range of smart power modules (SPMs)- provide a thermally-efficient, space saving solution to many consumer 'white goods' power design requirements - also providing an effective 'lifeline' to the long-suffering designer!"

This modular approach can offer designers significant advantages:

- Reduced number of components, saving logistics and assembly costs
- Higher performance
- Increased reliability
- Less board space or application volume
- Easier and faster design
- Reproducible performance

In addition to the valuable resource provided by the regional design centres that Fairchild has founded worldwide, the company's investment in the Global Power Resource: free-of-charge online design tools, knowledge base and tutorial facilities backed by a comprehensive network of technical support engineering staff available 24 hours per day, 7 days per week, has proved to be a key advantage. This huge investment together with the company's claim to have the broadest and deepest product portfolio in the industry, should prove invaluable to the challenges, problems and inevitable pressures presented to designers for their product developments of the future.

Cliff Keys
Editor-in-Chief

www.fairchildsemi.com

TechTalk

Energy Conservation Makes for Happy Consumers

Reported by Cliff Keys, Editor in Chief, PSDE

Following on from a briefing from Robert Fischer, Product Marketing Manager, National Semiconductor at a press conference in Munich, I was fortunate in discussing further at the company's HQ in Santa Clara, California the potential of the company's PowerWise system which can save up to 70% of the power drained from our batteries in portable equipment.

The pursuit of energy conservation in all aspects of our lives is around us everywhere, whether we are burning fuel in our cars or using up the earth's natural resources in one way or another we get reminded of it from media such as newspapers and TV, even the politicians are using it for their own arguments.

In the world of consumers, it is a harsh reality also, but perhaps from a different perspective. With the advances made in portable devices, particularly in the consumer electronics segment, new content platforms and enhanced features are growing at a much faster rate than current battery technology can follow. All these new enhanced features need to be powered and with consumer expectations of battery life in a new product becoming greater, there is a dilemma for the power that must be solved. It is just not acceptable any more to bring a product to market and expect the consumer to be happy with a few hours use before the product dies. Cell phones have, over the years, become better and better in the sense of power where now a phone can last a week or so without even thinking about recharging.

National has been working towards a solution for hard-pressed designers to develop a system whereby precious energy from the battery is only directed to where it is needed within the product and in the meanest quantity to give satisfactory performance. This means in essence, varying the voltages applied to parts of the circuit to either power down or slow down individual functions in order to maintain a minimum current drain when peak performance is not required from that part of the system. This is called adaptive voltage scaling.

Technology

Adaptive voltage scaling is a technique for determining the minimum supply voltage for a digital processor during operation. It significantly reduces the supply voltage of a digital processor by removing voltage margins associated with the effects of process and die temperature variation inside the processor IC, as well as IR-drop and regulator tolerances in the system. The advanced power controller, together with National' s LP5552, enables customers to easily deploy this technology in their platforms.

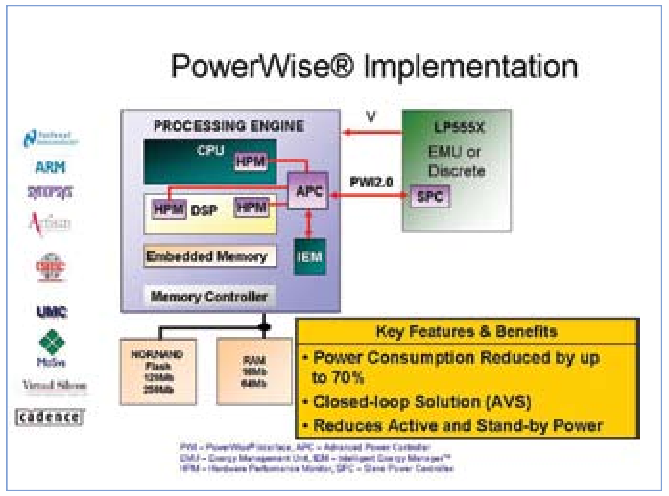
Standards

The PWI open-industry standard 1.0 was developed to provide point-to-point connections in simple systems, such as those with one power management IC and single-core SoC. National's second-generation PowerWise® interface standard provides high-speed, multi-drop bus capability for real-time power management control in more complex systems, such as those in cell phones, portable gaming and media devices with multiple-core SoCs and multiple peripheral devices. The command set and communication protocol of the PWI 2.0 are optimised for advanced power management techniques such as dynamic and adaptive voltage and frequency scaling, the control of multiple independent power domains on modern SoC devices and flexible peripheral device control.

Products

National has now introduced its second-generation, digitally-programmable LP5552 PowerWise® energy management unit (EMU) and advanced power controller (APC2) intellectual property (IP) package for reducing power consumption in battery-powered handheld consumer products.

The APC2 IP pairs with the LP5552 EMU to effect a reduction in power consumption of high data-rate digital processors with frequency-scaling ca-



pability of up to 70 percent.

The APC2 IP is compatible with Intelligent Energy Manager (IEM) frequency-scaling technology from ARM Ltd. The LP5552 and APC2 are compliant with the PowerWise Interface™ (PWI) 2.0 open-industry standard introduced by National and ARM earlier this year.

LP5552 enables a digital processor to adaptively adjust its supply voltage to the minimum level needed which greatly reduces its power consumption. The device includes two adaptive-supply-voltage buck regulators for the processor cores and five additional programmable regulators. The linear regulators power the input/output (I/O) ring, oscillator and phase-locked loops (PLL) and embedded and external memories on low-power SoCs, and can also power other auxiliary devices in the system. The PWI 2.0 interface controls the LP5552's functions for simple interfacing to the digital processor.

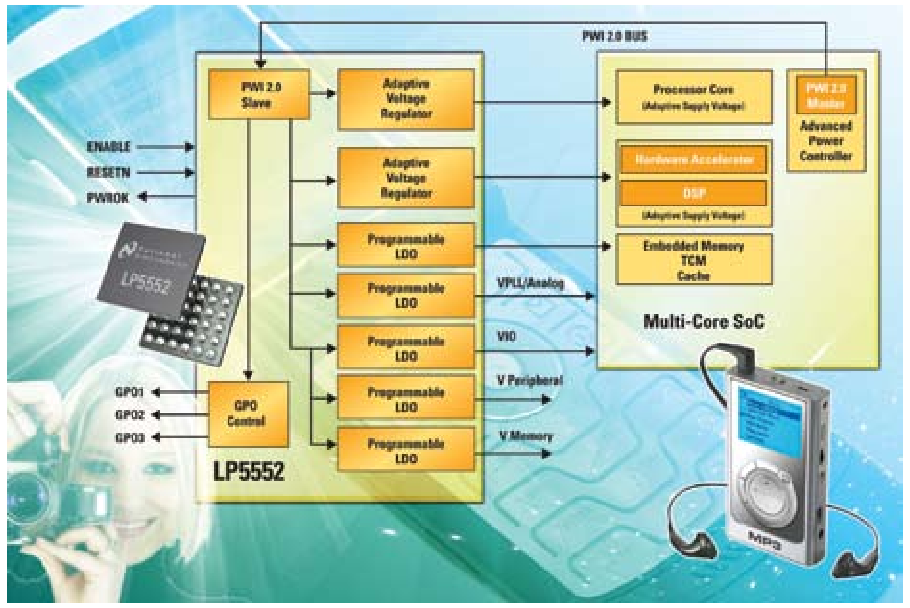
Compliant with the AMBA™ specification, National's APC2 is a synthesisable macro-cell that includes a hardware performance monitor to support adaptive voltage and frequency scaling. Similar to the APC1 announced by National Semiconductor in 2004, the APC2 automatically calibrates for process and temperature variations, and communicates with the LP5552 using the PWI 2.0 interface. In addition, the APC2 concurrently manages multiple voltages and frequency-scaled power domains on a feature-rich multi-processor SoC, as well as bias voltages for leakage reduction with threshold scaling.

The LP5552 supports the PWI 2.0 interface, a 2-pin, high-speed serial power management control interface for advanced processor power management. To enable adaptive voltage scaling, the device includes two digitally-programmable, 600 mA, 0.6V to 1.2V buck regulators with up to 90 percent efficiency and excellent transient performance for rapidly varying digital loads. In addition, it has five programmable low drop-out (LDO) regulators with output voltages ranging from 0.6 V to 3.3V. The linear regulators support output current ranges from 50 mA to 250 mA. Two of the linear regulators contain a low quiescent (Iq) current-retention mode for minimising system power consumption when SoC processors are inactive, but need fast recovery time.

The APC2 advanced power controller, controls voltage in modern, multi-core processor ICs and is embedded in SoC devices such as digital baseband and application processors used in portable applications. The APC2 is provided as configurable soft intellectual property with RTL, configuration and synthesis scripts, test benches, implementation and programming documentation, as well as reference driver software. The IP package is compatible with industry-standard design tools and flows. The APC2 supports up to four power domains each with up to four independently frequency-scaled clock domains inside.

It also supports eight frequency settings, clock stop and power down modes for each clock domain and includes a PWI 2.0 compliant master interface to the peripheral devices as well as AMBA advanced peripheral bus (APB) host interface for configuration and control. The APC2 supports deployment of both table-based dynamic voltage scaling and PowerWise adaptive voltage scaling.

LP5552 is available in a lead-free, 36-bump micro SMD package and operates over the full temperature range from –40 degrees C to +85 degrees C, with input voltages from 2.7V to 4.8V.



Conclusion

These developments in the management of energy will certainly lead to high expectations in consumers of future portable devices. The breakthrough technologies outlined, when adopted universally, will surely lead the way to multi content-rich applications which hitherto have been impractical to incorporate by manufacturers due to the limitations of battery technology. It looks not so much to be a question of 'if' but rather of 'when'.

Cliff Keys
Editor-in-Chief

http://power.national.com

Powering Modern Appliances

Power solutions for today's complex space-restricted white goods

With ever increasing demands on functionality together with directives on energy saving, the power supply and control function has become a vital part of the overall product design. Designers now need sophisticated power products to satisfy these stringent demands.

By Ralf Keggenhoff, Product Marketing Manager Europe HV Discretes and Smart Power Modules, Fairchild Semiconductor

Let's take a closer look at modern white goods. Not only functionality, but also simple handling and energy efficiency are important features for white goods. Household appliances sold in the European Union have to be rated according to Energy Efficiency Class A. In dishwashing machines, the example used for this article, the performance of the actual wash process has to be very good, and the quantity of water used has to be low. The average energy consumption per washing program is approximately 0.9 kW/h. In this application, low water consumption can be achieved by using intelligent control systems that optimize washing programs. The high energy-efficiency requirement can be achieved by the use of low-loss power semiconductors and efficient motors.

Functional aspects

A dishwasher combines water with detergent, heats the mixture and sprays it against the dishes. It pumps out the dirty water and then rinses the dishes with clean water mixed with a rinse agent. After pumping out the rinse water, the dishes are dried by either heating or air drying them. The selector switch offers the choice of a variety of cycles, which vary the length of wash, water temperature and drying temperature. In practice, different washing programs are implemented to consider the pollution or the fill-up quantity. The energy efficient variant is often called ECO-, Spar- or Intelligent Program.

Solutions for Auxiliary Power Supplies

The electrical and mechanical construction of modern dishwashers is very complex. The requirements of modern electronics are primarily based on the needs of different washing programs. Today nearly every home appliance is controlled by a microcontroller. The requirements of auxiliary power supplies are primarily based on the control unit and the trends in electronic motor control methods for the integrated pumps.

Power supplies need to fulfill key requirements in that they must be inexpensive, efficient and reduce part counts. In effect, they need to be a compact solution. Such a low power supply can be easily built with a power switch such as the FPS™. The FPS is manufactured as a multi-chip-technology. The PWM-controller as well as the MOSFET is integrated into a single package (See Figure 1).

Key features of FPS devices include:

- Low standby power consumption (< 1 W) by burst-mode-operation
- Integrated frequency modulation to reduce EMI emissions
- Soft-start function
- Overload protection
- Short circuit protection
- Over voltage protection
- SenseFET™ with specified avalanche rating

FPS devices are usually used in flyback applications. A transformer is needed to isolate the secondary side of this design to guarantee a safe operation. This is particularly needed, especially considering that the human interface has to be isolated from high

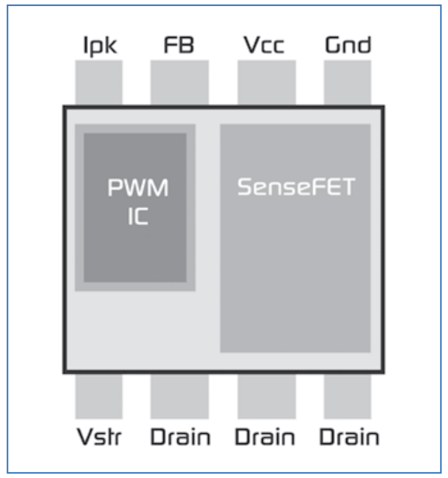


Figure 1: FPS™ principle of the multi-chip-technology

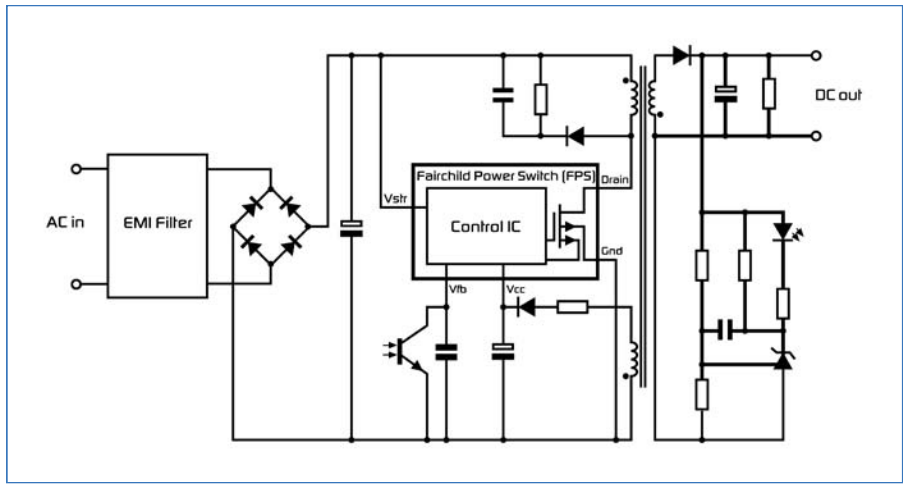


Figure 2: Fly-back application with FPS™.

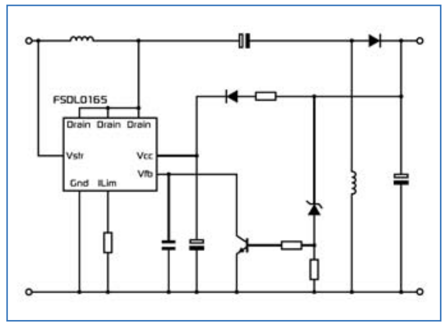


Figure 3: Auxiliary power supply in SEPIC topology.

Figure 4: Motion-SPM™ in SMD packaging.

voltages. Figure 2 shows a typical flyback application.

Other topologies like SEPIC (SEPIC = Single Ended Primary Inductance Converter) technologies can be used in dishwashers with isolated human interfaces to generate the auxiliary voltage sources. The EMI behavior of a SEPIC topology is much better than a Step-down- or fly-back topology.

As shown in Figure 3, two simple inductances can be used in a SEPIC-topology. The transformer-less design is the main difference compared to a fly-back topology where a special designed transformer is needed. This solution can be easily designed to be very compact and it also saves PCB area.

Using BLDC Motors

In the past, universal motors were used for the rinse water pumps in dishwashers. A new trend is to use brushless DC (BLDC) motors for this application. The driving forces behind this trend are lower cost (less copper is used), higher efficiency, higher reliability and the ability to control speed and direction. By changing the direction, self-cleaning of the pump can be implemented.

Electronic control of a motor is more complicated than driving a universal motor. The development of the unique Smart Power Module (SPM™) in Tiny-DIP (Dual In-line Package) by Fairchild Semiconductor offers an efficient solution to drive a BLDC motor. This highly integrated module represents an efficient and power-optimized solution, with little mounting effort and standard manufacturing processes as additional benefits. A Motion-SPM™ in SMD (Surface Mounted Device) packaging is also available (Figure 4). This module offers additional benefits in terms of manufacturing.

The space for the required electronics within a modern dishwasher is limited. It is therefore essential to keep the PCB area as small as possible. The Motion-SPM in SMD helps to fulfill this requirement since power devices as well as driver circuits are integrated into one compact module. The overall size is only 29 mm x 12 mm (Figure 3), which is very helpful when building small solutions, even for restricted areas. The combination of integration and compact packaging make the Motion-SPM in SMD packaging an ideal solution for optimizing space in dishwasher applications.

The reliability of a dishwasher is an all-important issue. It is especially important for the electronics within appliances to provide a high reliability. The deployment of the Motion-SPM module greatly helps to increase system reliability.

The statistical failure rate of an application is proportional to the quantity of devices used. This value is defined in FIT-rates (Failure In Time). The FIT rates of single components can be added to get the FIT rates for the complete solution. The higher the FIT-rate, the higher is the likelihood of defects. All SPM modules are pre-tested systems with FIT rates similar to discrete devices. The significantly increased system reliability in using a SMD package for the module can be easily explained by a comparison of the module and a discrete solution (Figure 5), which includes solder joints (e.g., every solder joint is a potential failure risk).

The low number of devices that are needed to build a compact assembly of the drive system are illustrated by the block diagram shown in Figure 6.

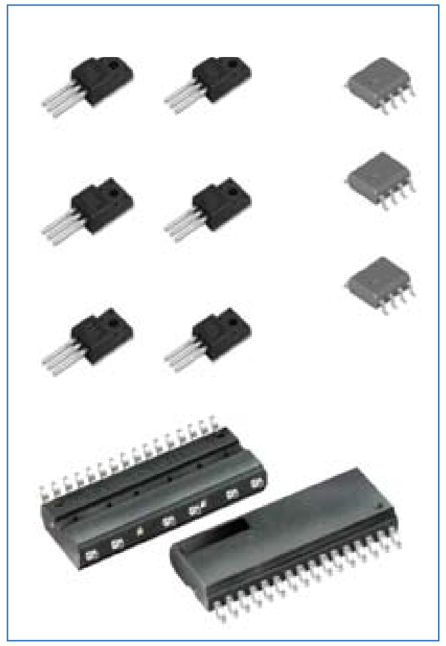


Figure 5: Needed devices for a dishwasher rinse pump application Top, discrete solution; Bottom SMD.

COVER STORY

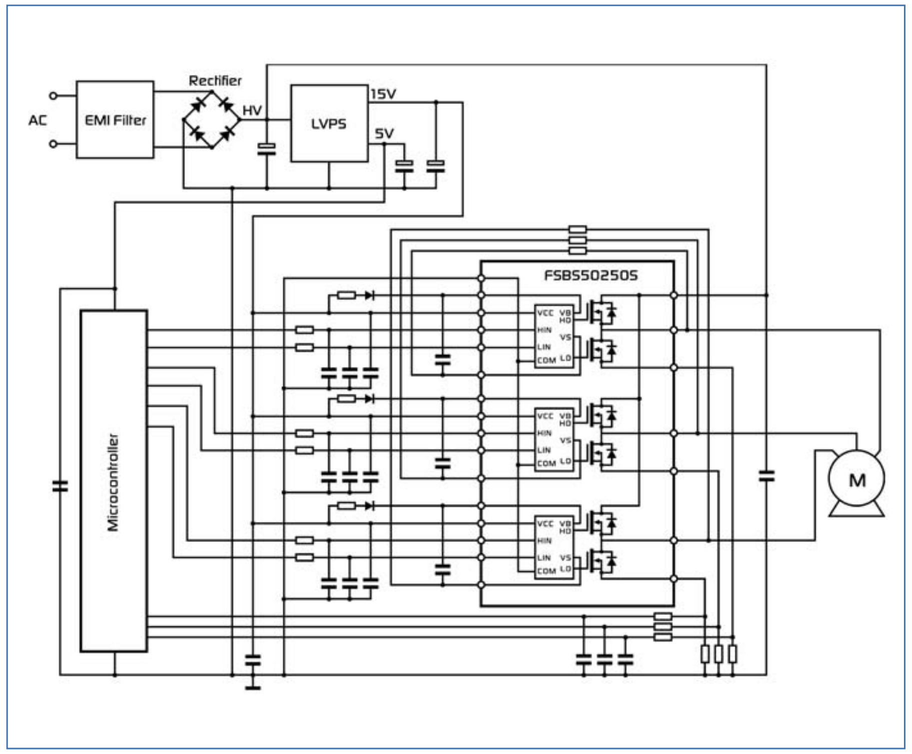


Figure 6: Block-diagram of a dishwasher rinse pump application.

Design aspects

As explained at the beginning of this article, a low-voltage power supply can be easily built with a FPS solution. Additional elements like an EMI filter, an input rectifier, a microcontroller and some passive components to filter the input signals, as well as current-sense resistors, are needed to complete the solution with a SMD-packaged module. This block diagram (Figure 6 shows the external parts around the module in more detail). These devices, which are needed for correct function of the module, include:

- Filter elements for the control inputs of the module which are needed to avoid voltage spikes which can force fail functions.
- Bootstrap-diodes and capacitances to generate the supply-voltage of the upper MOSFETs.
- Resistors and filters for current measurement.
- Resistors for the individual

adjustment of the EMC behavior.

A dishwasher is usually connected to a single phase AC-line. Typical line voltages are 230 V for Europe and 110 V for the US. Consequently, Fairchild developed two types of voltage ratings for the modules. Modules with rated breakdown voltages of 500 V for 230 V AC-lines and 250 V for 110 V AC-lines are available.

Released Tiny-DIP modules (Dual In-line package):

- FSB50250 (2 A, 500 V); motor power up to approx. 80 W
- FSB50450 (4 A, 500 V); motor power up to approx. 120 W
- FSB50325 (3 A, 250 V); motor power up to approx. 80 W

Released SMD modules (SMD package):

- FSB50250S (2 A, 500 V); motor power up to approx. 80 W
- FSB50450S (4 A, 500 V); motor power up to approx. 120 W
- FSB50325S (3 A, 250 V); motor power up to approx. 80 W

As with all power semiconductors, the semiconductors inside the Motion-SPM modules also generate power losses according to the output power. To avoid temperatures above the maximum junction-temperature, the generated heat according to the power losses has to be absorbed. Therefore, it is essential to calculate the losses and thermal behavior of the system.

Design-Tools for Appliance Applications

The www.fairchildsemi.com/design center contains technical information and tools to help designers when using both FPS and SPM devices.

The offline SMPS design tool contains:

- FPS™ Flyback Design Assistant
- FPS™ QRC Design Assistant
- Easy print-out of annotated schematics
- Advanced database
- Interactive tutorials

The Motor Drive Solutions for Appliances Design Tool SPM™ page offers the SPM Tool. This downloadable program provides step-by-step design procedures for motor drive solutions in home appliances. The tool also offers product selection with added features such as a design assistant for calculation the bootstrap capacitor in a bootstrap circuit. The goal of this tool is to simplify design and offer designers flexibility in choosing the right product for the design.

The SPM design tool contains:

- Motor Drives Portfolio
- SPM Cooling Design
- Bootstrap Circuit Design
- PCB Design
- Motors Overview
- BLDC Motors
- Asynchronous Motors
- Single Phase SRM Motors

In addition to web-based design tools, Fairchild's Field Application Engineers (FAE) and world-wide based design centres support designers and assist them to make proper designs.

Advance Packaging for Thermal Efficiency

To build compact solutions, the power density within a module must be very high. The newest manufacturing technologies and modern and low-loss power devices enabled Fairchild to build their Motion-SPM devices with SMD-packaged modules. Due to the high power density within the module, the thermal behavior of the system becomes more and more important. The cooling system has to be designed very accurately. The Motion-SPM with SMD package is a transfer molded device which is characterized by a relatively high thermal resistance. On the other hand, the molded package provides an isolation voltage of 1500 V.

The maximum output power depends on the cooling system. Without external cooling components (heat sink) a maximum output power of 35 W up to 70 W can be achieved. This depends mainly on the PCB design and also on the ambient temperature. The power devices inside the Motion-SPM with an SMD package are connected to a lead frame. To cool these devices, large copper areas on the PCB, especially on following pins, are strongly recommended: P, U, V, W, NU, NV, NW.

The best cooling results can be achieved by using double-sided PCBs with vias which are filled with solder for the thermal connection of both sides. If SMD modules are used it is possible to connect the PCB cooling area to the housing or a heat-sink. An isolation foil with a good thermal connectivity should be used. With this cooling method thermal resistances of 20 – 25 K/W (case to ambient) can be achieved.

If higher power ratings or ambient temperature is needed it is also possible to use an external heat-sink, which can be glued on top of the package. If the application housing is a metal frame this can also be used to cool the device by connecting the metal to the DIP package. The thermal connection should be made by using a thermal paste with a good thermal behaviour.

There are two possible ways to design the application. The first way is to calculate the power losses and, according to the maximum ambient temperature and the losses, the cooling method can be selected. Another way is to calculate the maximum losses due to the thermal behavior of the system. As a result the maximum output power which can be achieved. A detailed thermal calculation is only possible by using thermal simulation programs or thermal measurements.

To get an idea of the thermal requirements and for first results of the power losses, the following equations are applicable:

The losses of single MOSFET in a BLDC application are the sum of static and switching losses.

$$P_{MOS} = P_D + P_{sw}$$

To calculate the static losses the rms current of the motor, the on resistance of the MOSFET and a correction factor (2.2) is needed. Due to the fact that a MOSFET conducts only in a half sine wave the factor 1/2 is implemented.

$$P_D = \frac{1}{2} \cdot Irms^2 \cdot Rdson \cdot 2.2$$

The switching losses are related to the switch-on and switch-off energies (datasheet values) and the applied switching frequency.

$$P_{sw} = \frac{1}{2} \cdot (Eon + Eoff) \cdot f_{sw}$$

Example:

If a FSB50450S is used for a motor-rms current of 1 A at a switching frequency of 20 kHz following losses for each MOSFET can be calculated:

$$P_{MOS} = P_D + P_{sw} = \frac{1}{2} \cdot 1^2 A^2 \cdot 2.4 \cdot$$

$$2.2 + \frac{1}{2} \cdot (85 \mu J + 11 \mu J) \cdot 20kHz =$$

$$2.6W + 0.96W = 3.56W$$

The thermal resistance junction to case for the FSB50450S is 8.9 K/W for each MOSFET. The temperature difference between junction and case can be calculated according to following equation:

$$\Delta Tjc = P_{MOS} \cdot Rthjc =$$

$$3.56W \cdot 8.9 \frac{K}{W} = 31.7K$$

The maximum junction temperature of this module is specified with a junction temperature of 150 °C. The maximum case temperature can be calculated as follows:

$$Tc\max = Tj\max - \Delta Tjc =$$

$$150°C - 31.7K = 118.3°C$$

The maximum case temperature has to be kept below 118.3 °C. This can be done either by using a heat-sink or by using large PCB cooling areas or both.

For applications with a low output power, the switching losses are the dominating consideration. For those applications lower module current ratings are recommended. Up to approx. 35 W output power the FSBS50250(S) is the better choice.

Following selection table can be used for a first selection. The table is created for good cooling systems and for ambient temperatures up to 60 °C.

Output Power:	bis zu 80 W		bis zu 120 W
Input Voltage:	110 V	230 V	230 V
Module:	FSB50325S FSB50325	FSB50250S FSB50250	FSB50450S FSB50450

Table1: Module selection table

Conclusion

The auxiliary power supply of a dishwasher can be easily and efficiently built utilizing a Fairchild Power Switch (FPS), either in a fly-back- or SEPIC topology to source the increasingly important electronics of a dishwasher. The Motion-SPM (available in Dual-In-line or SMD packaging) is ideally suited for the rinse water pump function of a dishwasher. This compact module increases system reliability and helps to comply with government regulations in energy efficiency and emissions requirements. Furthermore, the use of the Motion-SPM in SMD packages reduces space and helps designers of white goods to develop compact and efficient solutions.

www.fairchildsemi.com

Simplified Approach to High Resolution Stepper Motor Control

A combination of low cost, accuracy, simplicity of design and reliability

Toshiba's latest mixed-signal semiconductor driver ICs can help designers to drive down the component count and simplify the design of microstepper motor-based applications.

By Wolf Jetschin, senior marketing engineer, Toshiba Electronics Europe

Incrementally stepping a pre-specified angle each time the driver electronics delivers a control pulse, permanent magnet stepper motors are typically as accurate as conventional servo motors, yet can be used without the encoders and 'closed loop' position feedback electronics demanded by servo-based alternatives. Furthermore, steppers offer repeatable performance, are less susceptible to problems caused by dust or vibration and have the added advantage that when the control pulses are removed, application of zero speed 'holding torque' ensures that the motor automatically holds its final position.

This combination of low cost, accuracy, simplicity of design and reliability - even in relatively harsh environments - has seen steppers become the motor of choice in a wide range of low torque motion control applications where accuracy, repeatability and maintenance-free operation rather than high speed and acceleration are the key design criteria. As a result, stepper motors have become commonplace in office automation, computer peripheral and commercial electronics applications ranging from printer paper feeds and ATM card readers to professional stage lighting and security cameras. Stepper motors

are also ubiquitous in the industrial electronics arena, where the same benefits have made them popular in applications ranging from valve control to X-Y table positioning.

Driving stepper motors

Stepper motors are available in unipolar and bipolar (chopper) configurations. Unipolar motors require a single DC power source, while bipolar variants provide for a simpler motor design and improved performance and efficiency, but demand either dual DC power sources or, more commonly, a power source capable of switching polarity. In both cases appropriate digital drive circuitry is needed to produce the control sequences required to energise the motor coil and create the motor rotation.

There are a number of ways to control stepper motor current from simple square waves to sinusoidal outputs. The latter, based on pulse width modulation (PWM) techniques, are the preferred route for applications requiring higher position resolution and smoother operation. Specifically, using this type of control provides for 'microstepping', in which the 'full step' of the motor can be further subdivided for even better positional control. Both acoustic noise and vibration of stepping motor applications reduce as the microstep input current waveform becomes closer to that of a sine wave.

Traditionally, stepper motor drive designs have been based around a microcontroller for the generation of the step pulses and key control information such as motor direction, acceleration/deceleration and stop commands, and discrete H-bridge circuitry to convert the signals into the current needed to energise the motor coil windings and to step the motor as required. These designs generally require the MCU to have the ability to manage relatively complex stepper motor algorithms, while PWM-based designs lead to the need for further complexity and additional components. When it comes to applications based on multiple steppers – for

STEPPER MOTORS

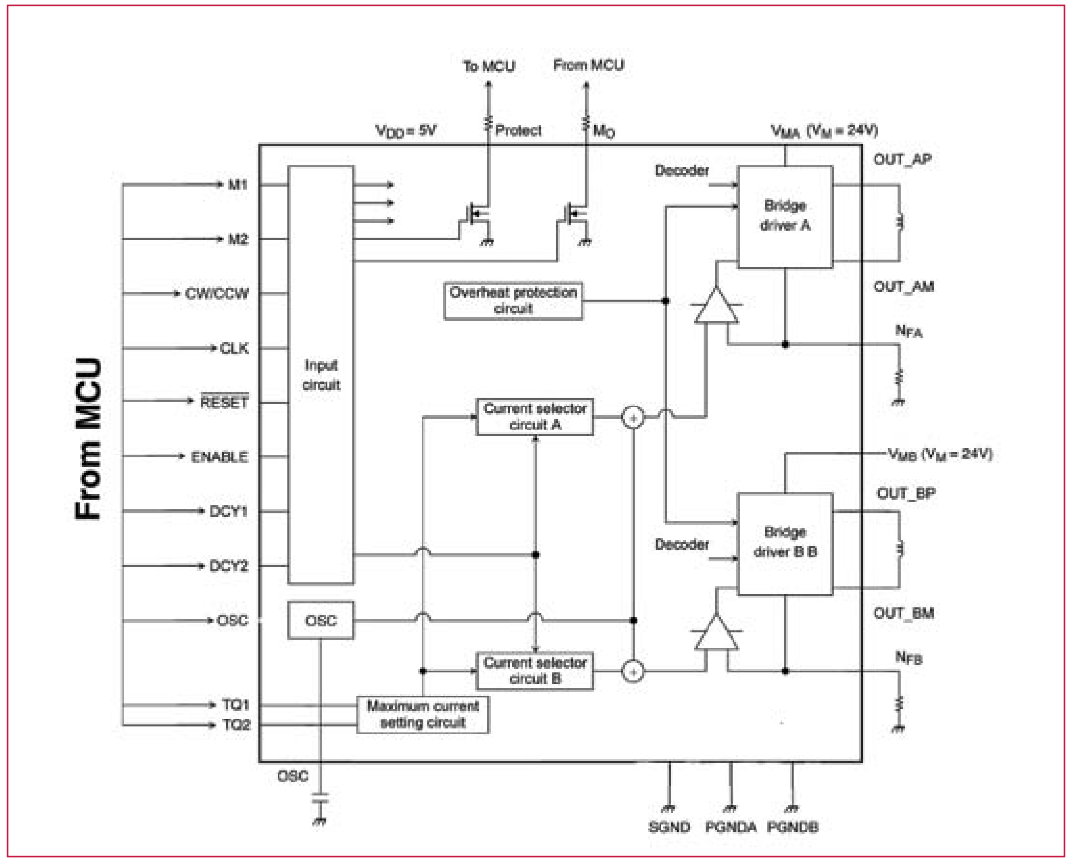


Figure 1. Circuit Schematic.

instance the multiple axis movement of lighting in professional lighting systems – this approach to design has generally demanded one microcontroller per motor, with the corresponding impact on design complexity and overall cost.

The pressure to minimise drive complexity, reduce component count and keep costs as low as possible has fuelled the development of integrated stepper motor drive ICs designed to offload some of the complex processing tasks from the host processor. And now, with the launch of Toshiba's latest stepper motor driver, the level of integration has been pushed still further by combining, in a single intelligent device, the necessary control electronics and PWM functionality with all of the high current circuitry needed to energise the motor coil.

Stepping Motor Driver IC

The Toshiba TB6560 is an intelligent PWM chopper type stepping motor driver IC designed to provide a single-chip solution for the high-quality, sinusoidal input microstep control of bipolar stepping motors. Developed specifically for higher current stepper motor applications, the TB6560 is a mixed-signal device that combines all of the necessary control functionality with a power stage capable of delivering current outputs of up to 3.5A. This level of mixed-signal and power stage integration has been made possible thanks to Toshiba's proprietary BiCD semiconductor process, which allows bipolar transistors and CMOS devices to be combined with high voltage, high current double diffused MOS (DMOS) power MOSFETs on a single IC. By using the BiCD process, Toshiba has been able to create an IC with a high output withstand voltage of 40V and a low typical on resistance per bridge of just 0.6Ω. The result is that high output currents are possible for very low power dissipations.

Figure 1 shows a block diagram of the new TB6560 IC in a typical application circuit. As the diagram shows, the IC including the two H-bridge high current driver circuits, the corresponding selector circuitry, the current setting inputs and the internal oscillator. The IC also incorporates an overtemperature protection circuit, which further minimises the need for additional external components. The end result, is a single-chip device that is capable of the low vibration, high performance forward and reverse driving of the stepper motor using only a clock signal, with each rising edge of the clock signal corresponding to one step of the motor. Because the device provides for selectable phase drives, the TB6560 can be used in applications requiring 2-phase, 1-2-phase, W1-2-phase and 2W1-2-phase excitation modes.

In the application circuit shown, the TB6560 input circuitry takes the signals from the system's host microcontroller, but removes all the complex stepper motor control processing requirements from the host. This means that the microcontroller resources can be deployed elsewhere or, alternatively, less sophisticated (and, therefore, less costly and, possibly, smaller) microcontrollers can be used. In addition, by using TB6560 ICs designers can implement circuits in which multiple stepper motors can be controlled from a single host microcontroller.

Incorporating all PWM generation and decoding circuitry on-chip was a fundamental design goal for the TB6560. This means that a smooth, sinusoidal microstep waveform can be automatically generated from little more than an applied clock input. Two torque inputs provide for flexible torque configuration by setting current at 100%, 75%, 50% and 20% of total current. The 20% setting providing the current necessary for fixed motor position (stop) when full current in the motor coil is not necessary.

A key feature of the new IC is the sophisticated Selectable Mixed Decay Mode (SMDM) technology. This is of particular use to the designer, given that for PWM-based systems it is necessary to discharge the motor coil at the end of each charging cycle. The ability to adjust the discharge scheme by controlling the decay mode provides the opportunity to minimise voltage ripple and, therefore, reduce audible noise and vibration during operation.

In the case of the TB6560 there are four basic decay options (0%, 25%, 50% and 100%), created by modifying the PWM operation based on the fact that output is generated by four PWM blasts. The 0% setting (fast mode) operates without decay in any of the blasts, while the 100% (slow mode) setting induces decay in all four blasts. Inducing decay during the last blast and the last two blasts respectively creates the mixed mode options of 25% and 50% decay. As the ratio of the various decay settings can be adjusted, the current discharge pattern can be modified according to motor load and speed. By choosing the best mix of decay modes, the PWM ripple that appears on the sinusoidal microstepping output can be minimised, reducing both audible noise and vibration.

By using the proprietary BiCD semiconductor process technology to combine all necessary control and driving functionality into a single IC, the new TB6560 technology provides designers with a route to implementing higher current stepper motor applications without the need for discrete high-current bridge devices and additional microcontrollers. By offloading all key motor control algorithm processing requirements from the host microcontroller, smaller and lower cost host MCUs can be used in an application, or system resources can be deployed in other areas. In addition, the device also makes real the possibility of rapid development of microcontroller-free, high-precision stepper motor applications.

Finally, to help further reduce the development time of stepper motor applications based on the new ICs, Toshiba has also developed a comprehensive evaluation board that allows designers to prototype and test key features including decay mode and torque settings.

The TB6560 is available in either an industry standard HZIP25 package (TB6560HQ) rated for currents up to 3.5A, and an HQFP64 package (TB6560FG) that is rated for up to 2.5A.. In addition to the integrated PWM stepper control and output driver bridges, each package option provides an output monitor pin, reset and enable pins and built-in 100kΩ pull down resistors.

www.toshiba.com

Reducing Size and Cost for Intermediate DC Bus Converters

Lower conduction power loss and faster switching with DirectFET

New 200V DirectFETs from International Rectifier provide cost and performance advantages to converter designers. Here follows the experimental proof.

By Weidong Fan and Carl Blake, International Rectifier

IBA (Intermediate bus architectures) proposed three years ago are gaining acceptance as the topology of choice for high-performance systems in data processing and telecom. Industry adoption of this new architecture is a testament to its cost effectiveness. With this architecture, a two-stage approach replaces a singe stage, providing both isolation and voltage regulation. The IBA is especially effective in systems that require multiple outputs voltages.

One two-stage approach uses an intermediate DC-bus converter to provide isolation in the first stage while the second-stage POLs regulate final load voltages. Intermediate DC-bus converters are commercially available with a variety of input to output voltage ratios. The ratios typically are equal to or greater than four. When the input voltage range is between 36V and 72V and load voltages are greater than 24V, a DC bus converter must have a 1:1 ratio. Efficient converters with small transformer ratios, however, require high-voltage power MOSFETs that combine low on resistance, low charge, and low cost. New 200V DirectFETs illustrate the cost and performance advantages available to converter designers.

Experiment setup

A intermediate-bus converter uses an IR2086S full-bridge converter to drive four 100-V MOSFETs on the transformer primary (Figure 1). Two 200-V MOSFETs on the secondary provide self-driven synchronous rectification. Primary and secondary bias voltages derive from transformer windings during operation. A 1μH (microhenry) output inductance, L1, reduces output-current ripple.

The switching frequency increases with input voltage to minimize the magnetizing current across the full input-

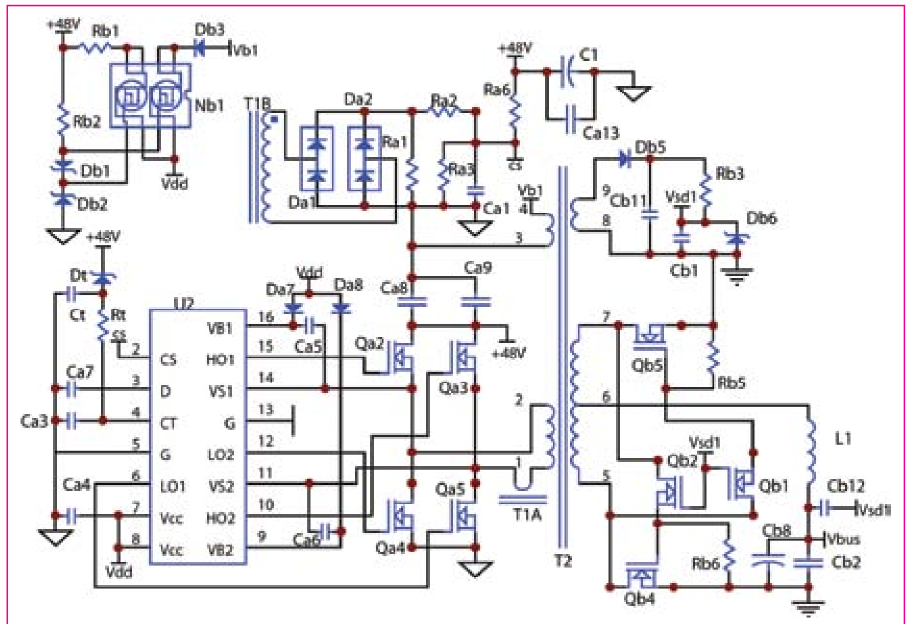


Figure 1: This DC-bus converter serves as the experimental test bed for secondary FET performance comparisons.

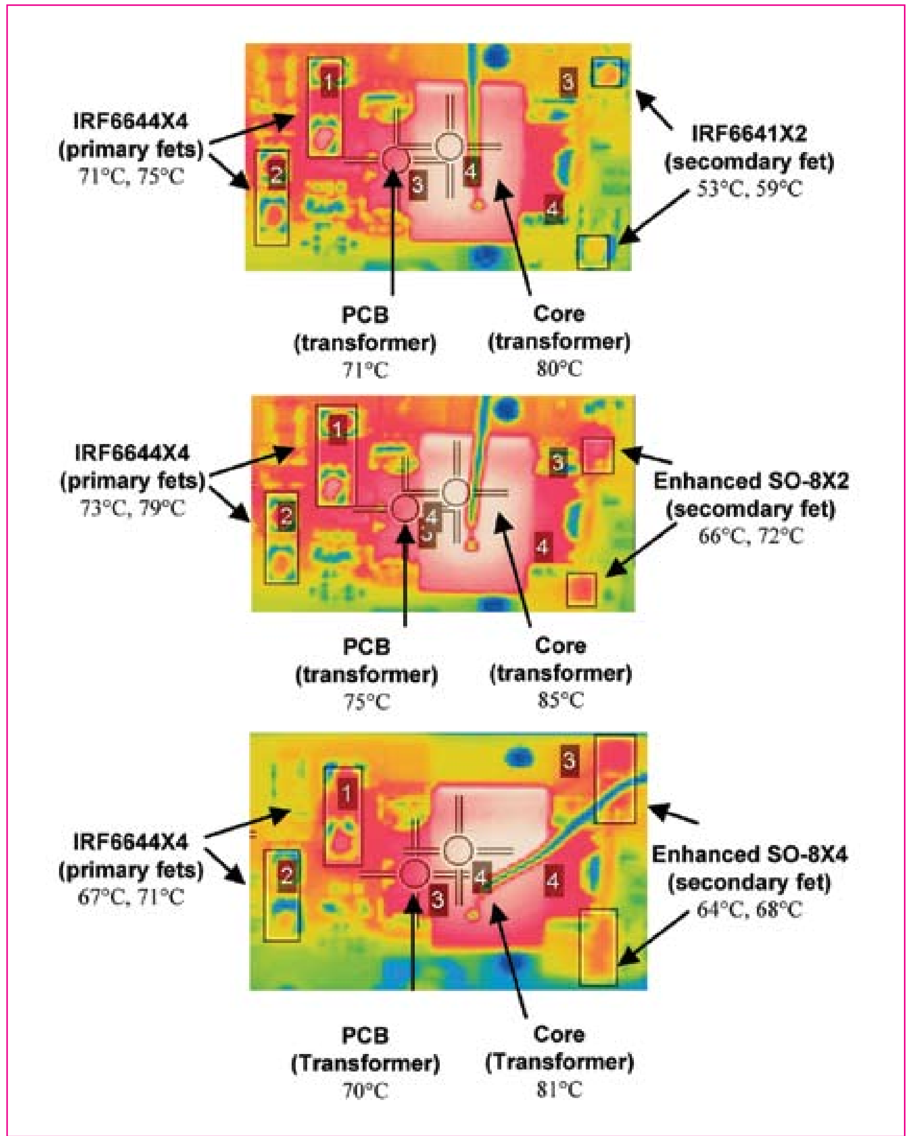


Figure 2: Thermographs of the three configurations provide a quick comparison of losses across the topology.

voltage range with ZVS (zero-voltage switching). In the test converter, magnetizing current linearly increases with the input voltage to a peak corresponding to an input of 54V. Beyond the peak, the magnetizing current falls because Rt increases the current to the controller's Ct pin in response to the increase in input voltage. By selecting Rt and zener Dt, a designer can ensure a low magnetizing current across the full input-voltage range, which reduces both power losses in the transformer and conduction losses in the primary-side FETs.

Results

The circuit configuration allows experiments to test the effect of replacing multiple power MOSFETs on the secondary. Efficiency data and MOSFET case temperatures at 7A appear in Table 1. Thermal asymmetries in the layout result in different operating temperatures for the two FET positions.

Beyond the MOSFET die, advanced packaging contributes to the circuit's parametric performance. For example, a single DirectFET MOSFET in each of the two secondary positions results in 0.4% greater efficiency at full load than does the best available enhanced SO-8 part. In particular, two enhanced SO-8 MOSFETs in parallel provides the same efficiency as one IRF6641 DirectFET.

Figure 2 presents thermographs of three secondary-FET configurations at the full load of 7A. The lowest case temperature was with IRF6641 confirming that replacing two MOSFETs with one provides better thermal performance. The case temperature of the IRF6641 is 10°C lower than that of two enhanced SO-8 devices. The case temperature of the IRF6644 primary-side FET is 4°C lower with two enhanced SO-8 devices on the secondary than with the IRF6641 on the secondary. The configuration with two enhanced SO-8 MOSFETs, however, produces greater output ripple current than does the single-DirectFET configuration. The nearly identical transformer-core temperature readings (80°C versus 81°C) indicate that the two configurations result in the same full-load efficiencies.

Switching waveforms at 7A using the IRF6641 appear in Figure 3. The secondary dead times are 74ns and 80ns. ZVS suppresses the secondary voltage spike. The peak voltages are 150V for both dead times. Switching waveforms at 0A using the IRF6641 appear in Figure 4. The secondary FET's dead time varies with load current from 48ns and 64ns at idle to 78ns and 96ns at full load. Though somewhat counter intuitive, there is no spike voltage at full load but a spike does occur as a result of switching excursions at no load, which requires that the secondary MOSFETs have breakdown voltages of 200V or more.

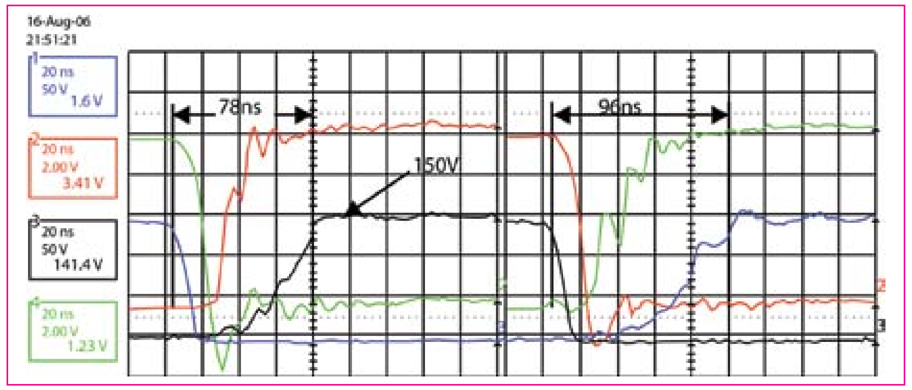


Figure 3: Secondary switching waveforms at 7A using the IRF6641 show the VDS (traces 1 and 3) and VGS (traces 2 and 4).

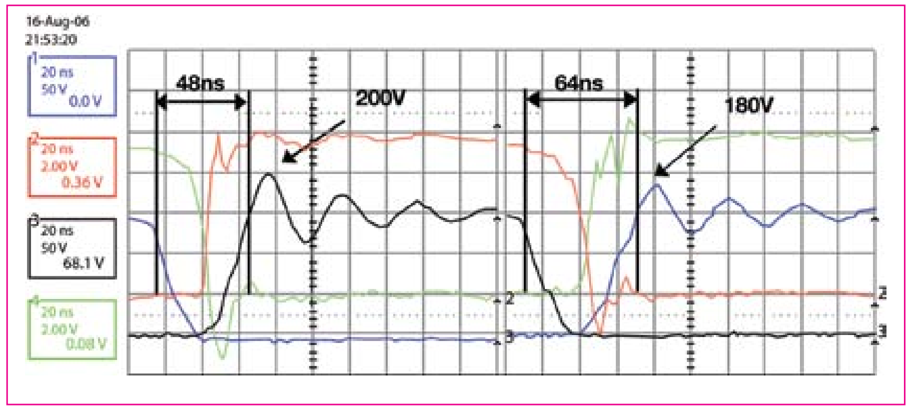


Figure 4: Secondary switching waveforms at no-load using the IRF6641 show the VDS (traces 1 and 3) and VGS (traces 2 and 4).

I out	Enhanced SO-8 (dual)	IRF6641T RPBF (single)	Enhanced SO-8 (single)
7	95.91	95.90	95.51
6	95.80	95.78	95.49
5	95.71	95.43	95.17
4	95.19	94.80	94.54
3	94.00	93.58	93.16
2	91.54	91.01	90.83
1	84.99	83.90	83.93
	Case temperature at 7A		
	64°C, 68°C	53°C, 59°C	66°C, 72°C

Table 1: Efficiency versus load; Case temperature at 7A

Discussion

The IRF6641 has low on-resistance and low charge to meet high performance requirements. Table 2 compares critical parameters of the DirectFET MOSFET to the best available 200-volt MOSFET in an enhanced SO-8 package. The enhanced SO-8 parts have 16% higher Miller charge (Qgd) that causes slower switching than the IRF6641. The enhanced SO-8's on-resistance is 33% higher. Therefore, the IRF6641 not only has lower conduction power loss, but also switches faster. The FET's total charge determines the upper bound for light-load efficiency. Since the transformer drives the secondary MOSFETs, drive current reflects as a load-current component at the primary side. Due to the similar charge of Qg + Qgd (36nC versus 37nC from Table 2), efficiencies of these two devices at a light load of 1A load should also be similar. When two enhanced SO-8 parts are in parallel, the charge of Qg+Qgd will double to 72nC. The load current from driving the secondary parts will increase, which under ZVS results in a higher efficiency at 1A (85% versus 84%).

Under full load conditions, the secondary MOSFETs' on resistance usually dominates the total efficiency. Calculated conduction power losses of the IRF6641 and the enhanced SO-8 parts at 7A are 2.9W (48mW x 7A2 x 1.25 due to the temperature coefficient of RDS(ON)) and 4.9W (72mW x 7A2 x 1.4) respectively. The difference is about 2W, which results in about a 0.4% efficiency difference (Table 1). Using the same equation, the calculated conduction loss of the dual enhanced SO-8 parts is 2.4W (36mW x 7A2 x 1.35) at 7A, which is about 0.5W less power loss than with the IRF6641. The 0.5W power-loss difference should result in a 0.1% efficiency difference at 7A. However, the efficiencies at 7A with the IRF6641 and the dual enhanced SO-8 parts are the same due to dead-time differences.

One of the important factors to determine the secondary dead time is the total charge of Qgd + Qds. The total charge of the dual enhanced SO-8 parts is 52nC (26nC x 2)—significantly higher than the IRF6641's 36nC. The secondary dead time with the dual enhanced SO-8 parts is almost double that of the IRF6641. The long dead time affects the output current ripple in the output inductor. With 64ns dead time the current ripple calculates as 4.4A (69V / 1uH x 64ns), which results in a peak current of 9.2A (2.2A + 7A) through the IRF6641. With a dead time of 128ns, the ripple current is as high as 8.8A, which indicates the peak current through the dual enhanced SO-8 is 11.4A. After considering peak current, the conduction loss with dual enhanced SO-8 parts is about 0.3W less than that of a single IRF6641. The 64ns longer dead time results in additional diode conduction loss, which estimates as 0.2W (64ns x 2 x 7A x 1V / 4us). As a result of the 64ns longer dead time and higher peak current, the power loss with dual enhanced SO-8 parts is about 0.1W (0.3-0.2) less than that with a single IRF6641, which is about a 0.02% efficiency difference at 7A load. Therefore, reducing RDS(ON) by adding another enhanced SO-8 part does not improve the efficiency at the full load of 7A.

PN	$R_{DS(on)}$ @ 10V (Measured)	Q_G @ 10V (Measured)	Q_{GD} @ 150V (Measured)	$Q_{GD} + Q_G$	Q_{GD}/Q_G	$Q_{GD} + Q_{DS}$ @ 150V (Measured)
	(mOhm)	(nC)	(nC)	(nC)	(nC)	(nC)
IRF6641 TRPBF	48	30	7.2	37	0.24	36
Enhanced SO-8	72	27	8.6	36	0.32	26

Table 2: Critical parameter comparison

AUTOMOTIVE ELECTRONICS

Tough Enough?

Aluminium electrolytic capacitors for harsh environments

In automotive applications, shock and vibration frequently cause premature failure of aluminium electrolytic capacitors. EPCOS addressed this problem and now offers designs with significantly higher mechanical stability.

By Norbert Will, EPCOS Development, Automotive Applications, Aluminum Electrolytic Capacitors

Resistance to shock and vibration of 2 to 3 g is sufficient for most automotive electronics applications. Many manufacturers of aluminium electrolytic capacitors quote a vibration strength of 10 g in their data sheets. At first glance, this figure seems quite sufficient with ample reserves. But the test conditions under which this seemingly generous value was determined have little in common with real operating conditions: the tests last no longer than six hours, are conducted at room temperature and the device under test is new.

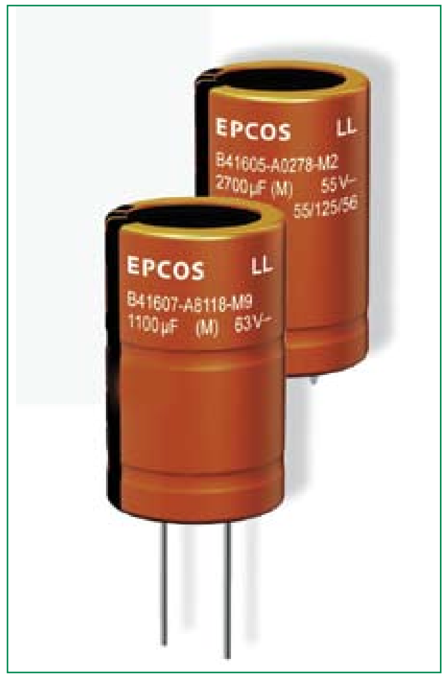
In larger aluminium electrolytic capacitors with can diameters of more than 10 mm, the terminal wires soldered to the circuit board repeatedly prove to be the weakest links despite reinforcement. The cross-section of the wire poses the greatest problem when vibrations occur. For this reason, EPCOS offers the thick, 1 mm wire versions exclusively for all axial-lead capacitors, targeted at automotive applications. But this is not the only measure that enhances long-term stability. If aluminium electrolytic capacitors are operated over extended periods at elevated temperatures, the fixing of the winding in the can turns out to be the weak link in the presence of vibration.

The winding anchorage weakens during continuous operation for two reasons. Firstly, the mounting system, i.e. the aluminium can in combination with the cover disk, can buckle under the effect of high temperatures and the fixing forces, so that the winding is no longer held securely in place. Secondly, electrolyte diffuses from the mounted winding in the long term and the winding becomes softer, so that the bracing within the fixing system suffers accordingly. The tensile or holding force of the classical axial bracing, for which a value of 10 g is usually warranted, derives from the rather elastic region at the end of the winding [1]. If the electrolyte content in this region is reduced, the holding forces will be correspondingly smaller. In an extreme case, the axial bracing can become ineffective. The welded joints between the winding and the feed-throughs, which are vital to operation and should really be protected by the bracing, must then assure sufficiently high residual vibration strength [1].

In general, the bulk of the winding reacts less sensitively to the loss of electrolyte because it is held in place by aluminium strips. The same applies to its diameter. EPCOS consequently fits an additional corrugation to the center of the can in all axial-lead automotive series to give the winding radial stability. The warranted value of 20 g obtained from tests on these axial-lead series is twice as high as that for the standard version. In the long term too, i.e. at the end of their service life, these aluminium electrolytic capacitors rated at 20 g still have significantly greater vibration strength than the standard versions.

Standing up to high radial forces

The normal radial bracing that suffices for axial electrolytic capacitors is not enough to withstand the forces to which larger electrolytic capacitors with diameters of 22 to 35 mm and heavy windings, such as those mounted on automobile engines, are exposed. A special reinforced corrugation is required that does not buckle even under high radial forces at high temperatures. The corrugation shown in [2] has proved effective in such cases. Thanks to its scarped flanks, it can protect the winding from stronger radial counter-forces for the same material thickness without buckling.



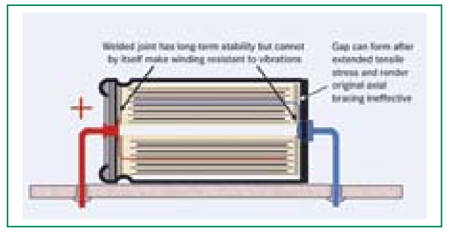


Figure 1: Basic structure of aluminum electrolytic capacitor
When the tensile force of the winding weakens toward the end of its useful life and the capacitor is exposed to vibration, a gap can form between winding and case. The axial bracing buckles – and the welded electrical connection alone cannot ensure the mechanical holding function during vibration.

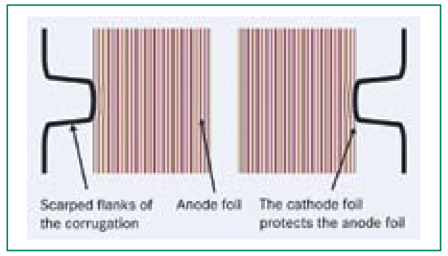


Figure 2: New corrugation in detail.
Thanks to its scarped flanks, the new corrugation can protect the winding from stronger radial counter-forces without buckling and with the same material thickness.

In the parallelogram of forces, the bracing forces are transferred directly to the almost perpendicular corrugation wall without contributing to the large axial forces associated with the conventional flat corrugation. This also enables the new corrugation, which is used in the large-size B41605 and B41607 series from EPCOS, to withstand greater radial bracing forces. This design has passed all vibration tests up to 40 g and 2 kHz. Even after the aluminium electrolytic capacitors were subjected to prolonged thermal pre-stressing for 2000 hours at 125°C, they passed a vibration test at 30 g and up to 2 kHz. The same applies to vibration tests performed after degradation by fast and slow temperature cycling. This corrugation [3] is currently used in all large-size aluminium electrolytic capacitors intended for motor vehicles or machine tools.

Attachment of the aluminium electrolytic capacitor to the circuit board is just as critical. A new design was consequently developed from the original snap-in type. It can be bonded with wires that can be soldered and welded. The decisive factor is that the wires are flexible so that electrical contact is not interrupted even if the aluminum electrolytic capacitor moves relative to its mount [4]. Both the soldered joint on the circuit board and the welded joint on the capacitor feed-through are thus protected.

The exterior of the large-size series is similar to that of single-ended capacitors. In contrast, their internal construction resembles that of a snap-in electrolytic capacitor with a flexible strip contact. Like all EPCOS electrolytic capacitors in cans, this series has fully welded contacts. The new corrugation can also be used for the smaller aluminium electrolytic capacitors exposed to high vibration stress, such as axial-lead and solder-star types. However, the standard corrugation has proved adequate for automotive applications up till now. EPCOS can nevertheless offer customers samples of existing types with the new corrugation added that can satisfy the tougher vibration strength requirements.

Figure 3: Snap-in electrolytic capacitor with additional centre corrugation.
The snap-in models are complemented by the large-size design in which wires instead of snap-in clamps are welded to the feed-throughs. This version is also available with customer-specific bent wires and without insulation.

Tests have shown that the new corrugation design can be used independently of the can diameter. This means that large cans with screw terminals can also be manufactured with centre corrugations in future. Initial attempts are in progress to fit aluminium electrolytic capacitors with corrugations of various designs in order to maintain improvement in their vibration strength.

Profile Large-size Series

Featuring high vibration strength, temperature stability up to 150 °C, high current-handling capability and maximum reliability, aluminium electrolytic capacitors of series B41605 and B41607 from EPCOS are ideal for demanding automotive and industrial applications.

Vibration strength: up to 40 g
Rated voltage: 25 to 63 V
Capacitance: 2100 to 6800 µF
Service life: 20 000 hours at 105 °C

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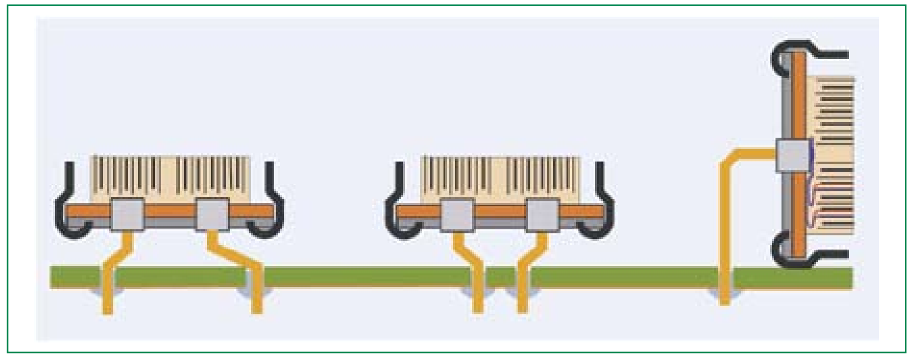


Figure 4: Improved anchorage ensures higher vibration strength.
Independently of alignment, the wires should be bent so that any possible relative movements between circuit board and capacitor do not stress the soldered and welded joints. In contrast with the usual single-ended capacitors, the large-size capacitor is insensitive to axial thrusts applied to the feed-through thanks to its internal strip bonding.

Next Generation Portable Devices Require State-of-the-Art MOSFET Technology

Innovations and improvements maximize efficiency and reduce power consumption

Many design factors affect the performance of new power-hungry portable devices, here we focus on power MOSFETs, the most common power switches for low-voltage applications, to illustrate the impact of the latest silicon breakthroughs on increasing power requirements.

By Yalcin Bulut, Vishay Intertechnology, Inc., Santa Clara, Calif

For efficient designs in portable applications, decreasing power consumption and extending battery life are the most critical factors. As portable devices continue to decrease in size, large batteries with longer life and advanced cooling systems that dissipate heat and power of the components are no longer a viable solution. Even if there were space available for these batteries and fans, the cost of the end product would go up, making the device uncompetitive in the market. And while the battery industry has been making efforts to develop alternative battery technologies with a higher energy capacity than that of conventional nickel-cadmium (NiCd) batteries, from a performance and cost point of view, this new technology simply cannot meet the increasing power requirements of next-

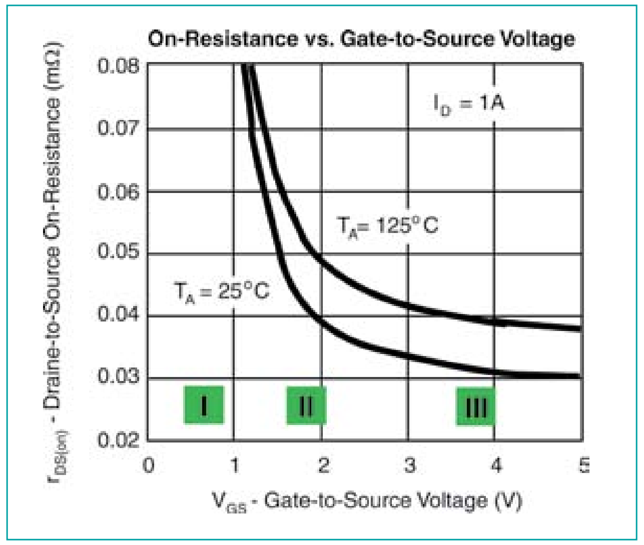


Figure 1: $r_{DS(on)}$ versus V_{GS} characteristic.

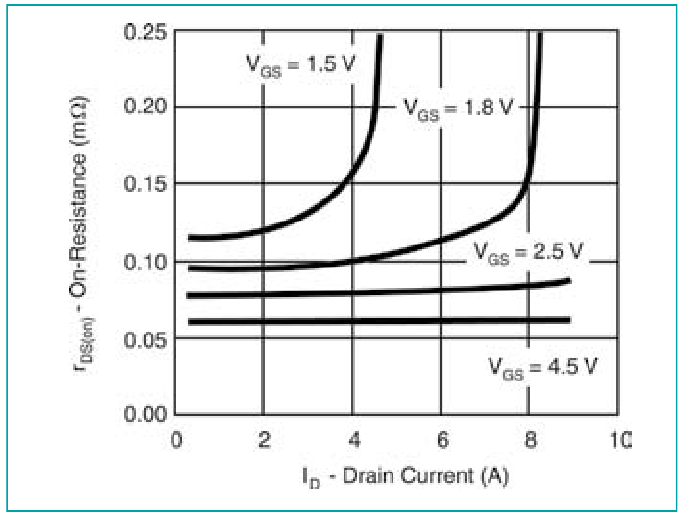


Figure 2: $r_{DS(on)}$ versus Id for different gate voltages. (Source: Vishay Siliconix Si1499DH datasheet)

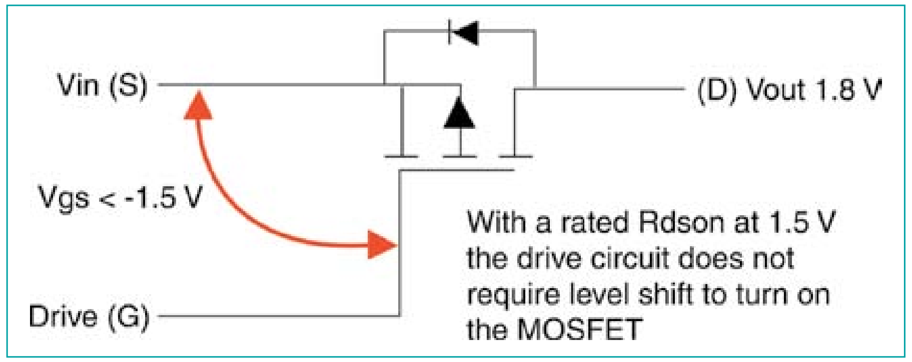


Figure 3. Reducing the $V_{GS(th)}$ point allows the driver voltage to turn on the switch from a lower-output voltage, reducing the need for a level shifting.

generation portable devices.

Lower power consumption through guaranteed on-resistance

Channel on-resistance ($r_{DS(on)}$) is controlled by the electric field present across and along the channel, and is mainly determined by the gate-to-source voltage difference. When V_{GS} exceeds the threshold voltage ($V_{GS(th)}$), the FET starts to turn on. Figure 1 explains the $r_{DS(on)}$ versus V_{GS} characteristic. Region I corresponds to the condition when the accumulative charge is not sufficient to cause an inversion. Region II corresponds to the condition where there is a sufficient charge present to invert a portion of the p region, forming the channel, but not enough that the "space charge" effect is important. Region III corresponds to the charge-limited condition where $r_{DS(on)}$ does not change appreciably as the gate-body potential is raised.

Threshold voltage ($V_{GS(th)}$) is a parameter used to describe how much voltage is needed to initiate the channel conduction. V_{GS} controls the magnitude of the saturated ID, with increases in V_{GS} resulting in lower values of constant ID, and smaller values of VDS necessary to reach the "knee" of the curve (Figure 2).

By using low-threshold power MOSFETs in a signal path, the supply voltage (V_{DD}) can be lowered to reduce the switching power dissipation without affecting performance. That' s why, to address the ever-increasing demand to minimize power consumption and increase battery life, many of the ASICs found in portable electronics systems are designed to operate at core supply voltages around 1.3 V to 1.5 V. Until now, however, the lack of power MOSFETs with guaranteed turn-on operation at such low voltages has made it difficult for designers to take advantage of these low voltages without the use of level-shifting circuitry, which adds complexity while increasing power consumption. Vishay Siliconix has addressed this problem with a family of power MOSFETs that feature guaranteed on-resistance ratings at 1.2 V.

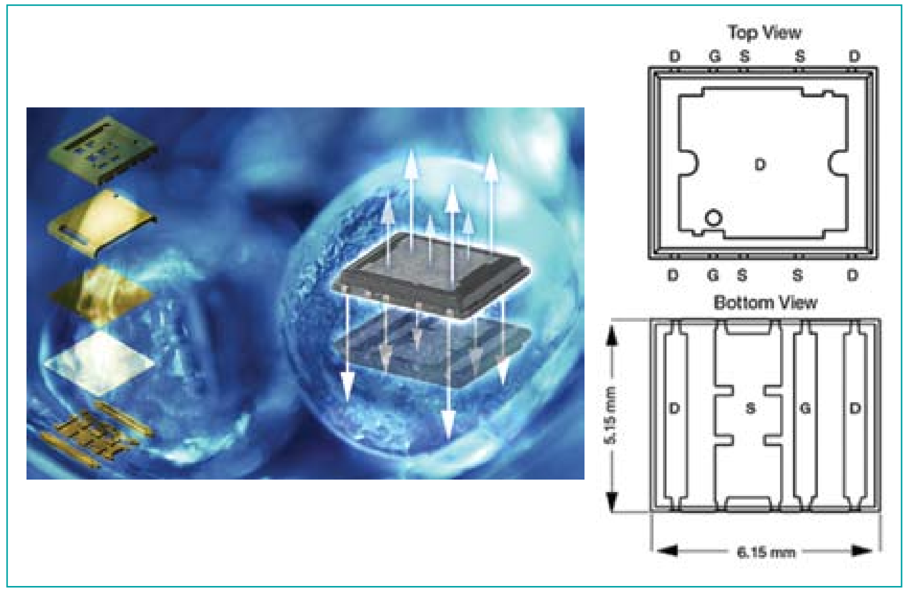


Figure 4: PolarPAK package.

Increased thermal efficiency through advanced packaging technology

As the power density requirements of DC-to-DC converters continue to increase, board real-estate is becoming more critical, increasing the demand for power MOSFET packages with compact footprints and improved thermal and electrical efficiency. Advances in silicon technology have helped to reduce on-resistance ($R_{DS(on)}$) for a given die size to almost negligible levels. Now MOSFET manufacturers are increasing their focus on new package options that provide higher power density levels while reducing conduction losses and switching losses.

Historically, the SO-8 package has been the default MOSFET package used in power-hungry dc-to-dc converters and server applications because a combination of moderate on-resistance and gate charge has been seen as the optimal combination. In addition, the thermal conductivity of the SO-8 size packages has offered an acceptable level of power dissipation, as the resulting temperature rise is relatively low and can be accommodated within the design limits of the PCB. However, as converters become smaller, the SO-8 package footprint area begins to occupy a relatively large portion of the available printed circuit board area. As today's dc-to-dc converters can generate large amounts of power despite their small size, maximum MOSFET space utilization is critical.

A power MOSFET generates internal heat due to the current passing through the channel. This self-heating raises the junction temperature of the device above that of the PCB to which it is mounted, causing a significant increase in heat dissipation. Maximum efficiency in dc-to-dc converters can be achieved

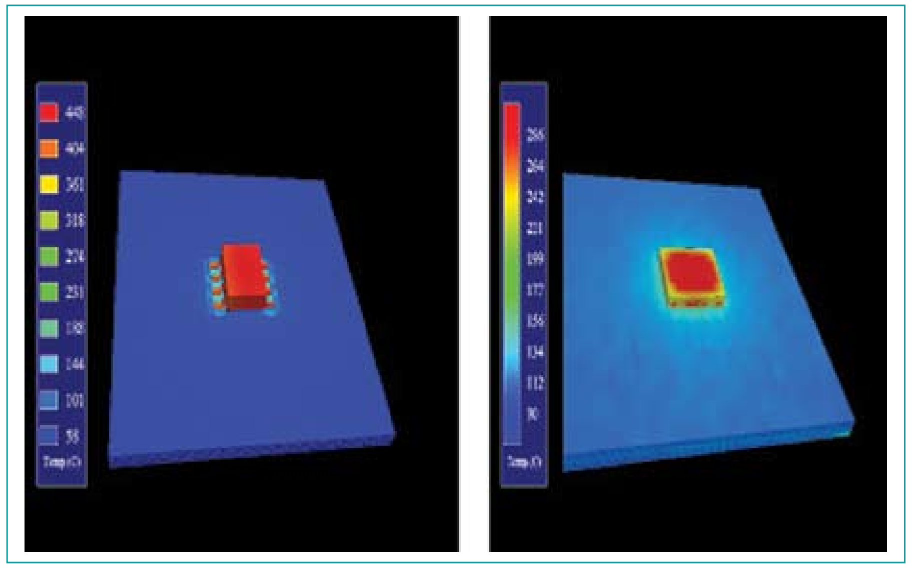


Figure 5: Junction temperature (Tj) comparison of SO-8 and PolarPAK (still air and without heat sink).

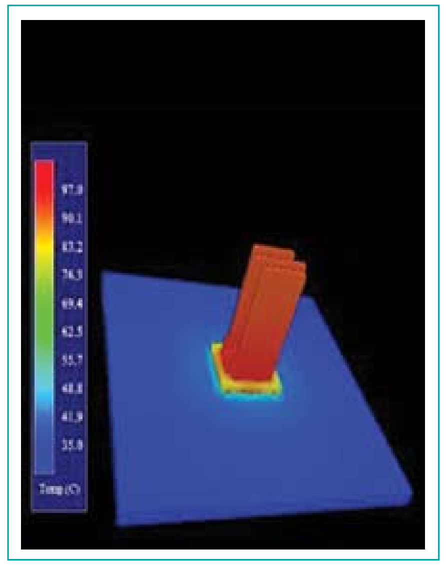


Fig. 6. PolarPAK junction temperature with 400-lfm airflow and heat sink.

by selecting the appropriate package to carry out the switching application, reducing heat build-up in the die area by means of good thermal conductivity within the MOSFET, and effectively using board space with packages that can accommodate a large silicon area. Minimizing the increase in junction temperature will help to minimize the increase in die (silicon) temperature in the power MOSFET package, hence increasing the overall system efficiency.

Vishay Siliconix has addressed this issue by developing a new surface-mount package technology called PolarPAK. This thermally enhanced, low-profile package facilitates MOSFET heat removal from an exposed top metal lead-frame connected to a drain surface, in addition to a source lead-frame connected to a PCB. The package offers double-sided cooling in an encapsulated plastic body that occupies the same space as a SO-8 footprint.

The thermal simulation models below use 2.5 W of power and a 1-in. x 1-in. FR-4 double-sided 0.062-in.-thick PCB with 100 % Cu on both sides. The temperature values in the pictures indicate the junction temperature for 2.5 W at 25°C. Thermal solutions such as airflow, a heat sink with no airflow, and both heat sink and airflow were considered for these thermal simulations.

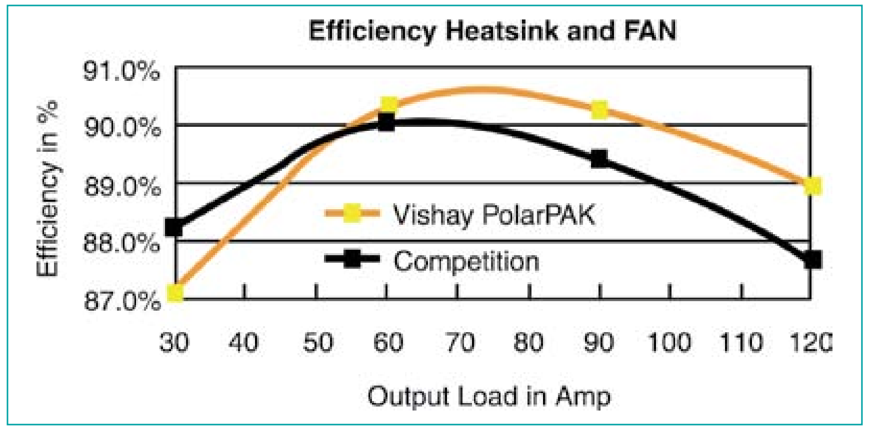


Figure 7. Efficiency comparison.

Figure 5 compares the standard SO-8 package and the PolarPAK package at still air (no air flow) and without any heat sink at the above-mentioned conditions. Under these conditions, the junction temperature Tj of the SO-8 device is 448°C, whereas that of the PolarPAK is about 286°C, demonstrating that for the same footprint size, the PolarPAK package provides a 162° C reduction in junction temperature when used instead of an SO-8 package.

With the use of heat sink and airflow, the PolarPAK package is even more efficient by dissipating more heat out of the topside of the package (see Figure 6). Using 400-lfm airflow and heat sink, the junction temperature for the PolarPAK is reduced to 97°C.

PolarPAK devices also provide superior electrical performance and higher efficiency due to the high cell-density-switching silicon technology from Vishay Siliconix. Using SiE802DF (1.9 mO max at 10 Vgs) as the low-side switch and SiE800DF (7.2 mO max at 10 V) as the high-side switch, it is possible to achieve 89% efficiency at maximum current and 225 kHz (4-phase board with 2 HS and 2 LS MOSFETs on each board). This efficiency is 1.5 percentage points better than other solutions using double-sided cooling.

By minimizing the thermal rise above the board temperature, the new PolarPAK packaging technology simplifies thermal design considerations that keep the on-resistance low, and permits the device to handle more current than any other SO-8 type package.

www.vishay.com

New Power Modules Save on Production Costs

Simple heatsink design and single pass flow soldering

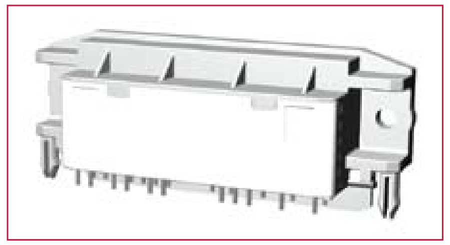
In production, costs are always under the financial microscope. Tyco has developed a range of power modules to simplify construction, assembly and soldering.

By Michael Schulz, Product manager, Tyco Electronic Power Systems

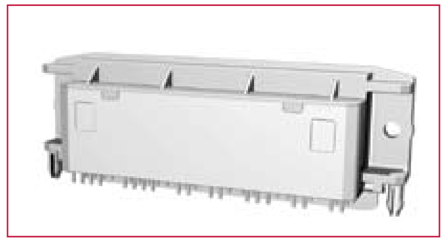
Tyco Electronics has extended its flow90PIM power module family (rectifier + BRC + inverter + NTC) with the flow90PIM 2. Both can reduce soldering efforts and preclude the need for specially constructed heat sinks. To this end, the module features a special design similar to that of discrete power components, enabling it to be mounted to the PCB at a 90° angle. This is a great advantage, particularly for narrow-chassis frequency inverters, for example, as utilized in control cabinets.

Conventionally, a power module design dictates the way it must be mounted. The module is mounted horizontally on the PCB. This can be done on the component side with other through-hole components or on the solder side. Both mounting options have specific advantages and disadvantages. For the former, the module can be soldered in a single pass together with the other through-hole components as depicted in Fig. 1a and thereby cut assembly costs. This mounting option's disadvantage is that it requires the use of special recessed heat sinks.

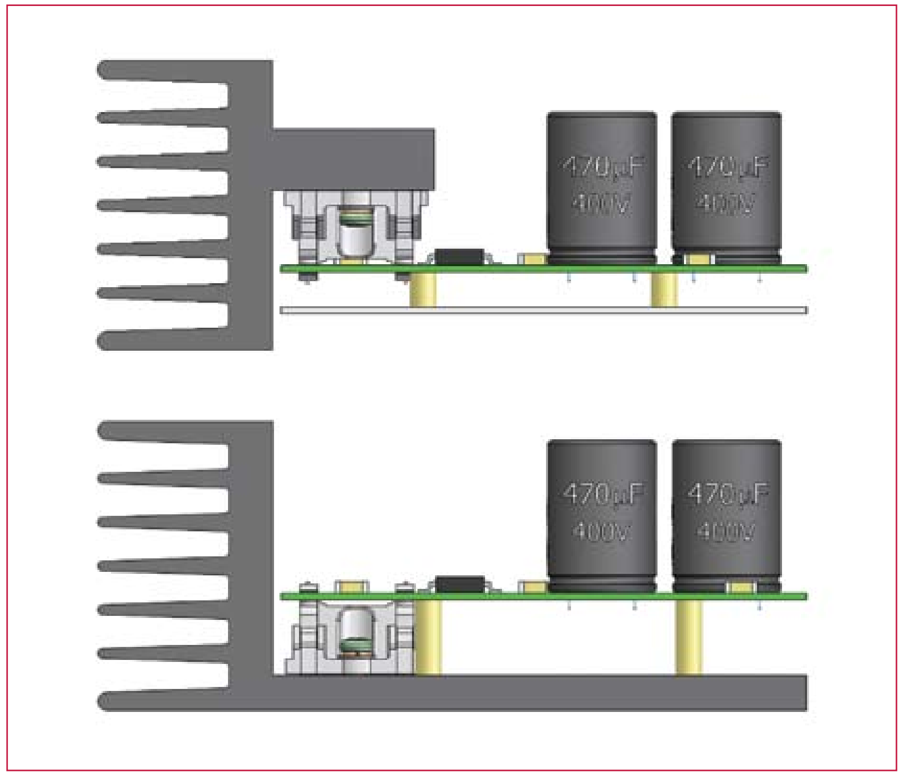
The module cannot however be soldered with other components if it is mounted on the flip side as shown as in Fig. 1b. It must either be soldered manually or by special soldering robots in a separate process. This entails higher manufacturing costs and the risk

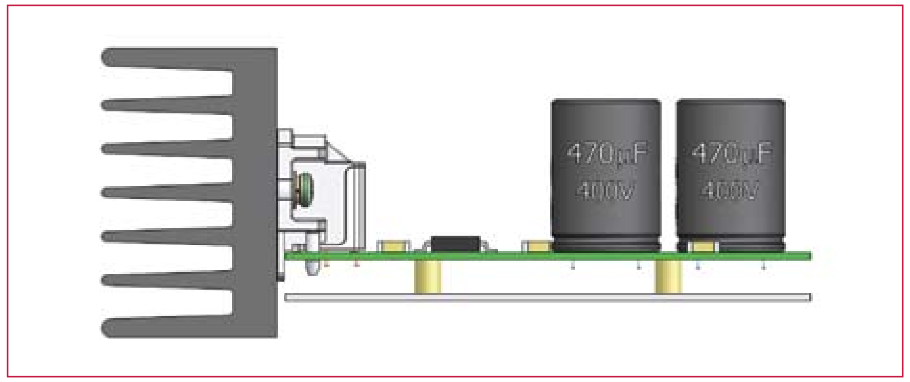


flow90PIM 1



flow90PIM 2





ally, some applications require that cooling is performed on the rear of the housing, that is, at a 90° to the PCB. For example, this is the case with devices designed for use in control cabinets, such as bookshelf inverters. This type of application mandates the use of heat sinks that first conduct heat to the rear of the housing.. As well as entailing relatively high costs for the heat sink, this also appreciably diminishes thermal properties.

For these applications, Tyco Electronics has developed a new family of modules called flow90PIM. What sets this module apart from conventional power modules is its 90° package. It enables the implementation of a direct mechanical connection between the heat sink and PCB at an angle of 90° within the device (see Fig. 2), without requiring additional mechanical components or special heat sinks.

Here, the new power module is now installed vertically on the same side as all other components rather than horizontally as it has been to date. In contrast to Fig. 1, the components are mounted on one rather than two sides, thereby eliminating an additional soldering operation. What's more, specially designed heat sinks are no longer required. This simplifies the manufacturing process and reduces operating costs. In addition, flow90PIM allows end devices such as frequency inverters to be built in a more compact format. This method of mounting modules is especially well-suited for power components in narrow control cabinets where cooling is performed at the rear of the cabinet, as well as for all other applications requiring the heat sink and PCB to be configured at a 90° angle.

The '90' in the part no. refers to the mounting angle between the module and PCB, which can now be implemented far more easily. PIM (Power Integrated Module) designates the topology of the integrated circuit, an input rectifier, a brake IGBT with a free wheeling diode, and six inverter IGBTs and their anti-parallel diodes.

The module is available in 600V and 1200V versions, whereby the design of the module and the circuit array comply with air and creepage clearances. A plastic apron was integrated specifically for the heat sink; it extends beyond the PCB so that circuits may be routed between the connectors and the heat sink in compliance with air and creepage clearances. If the module is not sited at the edge of the PCB, the perforated plastic shield can be removed by simply snapping it off.

Power Spectrum

The flow90PIMs are available with following power spectrum:

Dimensions:
flow90PIM 1: w/h/l 84 x 28 x 21 mm
flow90PIM 2: w/h/l 109 x 33 x 21mm.

Trench Field Stop technology

Trench-field-stop IGBTs are used in flow90PIM 1. This technology serves to attain lower collector-emitter saturation voltages and consequently lower forward resistance, while fast switching performance is ensured. This is achieved using an additional layer between n- substrates and the collector, the so-called field stop, as well as a vertically arrayed gate called a trench gate. The field-stop technology's additional layer enables the overall gauge of the wafer to be reduced, thereby reducing forward resistance as well as the tail current during switch-off. The vertically arrayed gate also improves forward resistance while the IGBTs' short-circuit stability is ensured, a property very important for motor drives. The trench-field-stop IGBT is thus particularly well-suited for applications with switching frequencies up to 20 kHz. Faster IGBT variants or MOSFETs are also used.

Summary

Equipped with an integrated input rectifier, brake and motor inverter, flow90PIM combines the advantages of a power module - for example, isolation, high thermal coupling with the heat sink and enhanced reliability-with the advantages of the 90° mounting option customarily used for discrete components. When mounted vertically on the board, the module can be installed on the same side as other through-hole components, and wave-soldered along with these other components in a single pass. The heat sink is mounted at a 90° angle to the board, thereby eliminating the need for special housings as depicted in Figure 1. Available in 600V and 1200V versions and rated at 6 to 30 A, flow-90PIM 1 is suitable for a wide range of power applications.

www.em.tycoelectronics.com

Designing Wide Range Power Supplies for Three Phase Industrial Applications

Three-phase regulated supplies operate under demanding conditions

With the volatile nature of a three-phase source, special design considerations and techniques need to be applied. The StackFET configuration provides a design solution at significantly lower cost.

By Rahul Joshi, Power Integrations

Industrial equipment operating from a three-phase AC supply often requires an auxiliary power stage that supplies regulated, low-voltage DC to the control electronics. Specifications for these supplies are much more demanding than for the typical single-phase supply. The nominal input voltage is higher, and equipment designed for three-phase input has to tolerate larger input supply-voltage variations. Line surges, extended sags and sub-cycle drop-outs often occur in an industrial environment as a result of large loads being switched off and on, or as a result of fuses being cleared for fault conditions elsewhere on the line. Three-phase applications can occasionally lose a phase or a neutral connection. Industrial equipment is expected to handle all of these conditions without malfunctioning. Applications such as energy meters must work reliably over these extreme conditions.

This article looks at the challenges of designing switched-mode power supplies for three-phase applications, and presents a compact, cost-effective design that operates over a very wide input voltage range.

Design Goal

A three-phase input, off-line switching power supply that has wide input voltage range, high overall operating efficiency, and good immunity to input voltage perturbations.

Most switching power supplies can operate over the universal input voltage range to provide worldwide coverage. For three-phase applications such as energy meters, the power supply must work from 57 to 580 VAC, from all three phases and with the occasional loss of a phase or a neutral connection.

For auxiliary power supply designs, the flyback topology is best-suited, and offers these advantages:

- Use of a single active switch that simplifies circuit design
- Use of a single-wound component in the topology (eliminates large filter chokes on the output)
- Easy-to-create multiple output voltages
- Very low component count and cost

A flyback converter typically requires a minimum MOSFET breakdown voltage of 1.6 times the rectified peak of the maximum AC input voltage. For 580 VAC, a 1200 V MOSFET would be required, adding cost and (normally) ruling out the use of an integrated switching IC that could dramatically simplify the solution (when compared to a discrete design).

An IC such as the LinkSwitch®-TN from Power Integrations incorporates a 700 V MOSFET and controller into a single device, and can eliminate 20 to 30 external components when compared to a circuit using a discrete MOSFET and external control IC. The 700V rating of this IC would normally limit use to single-phase applications. However, by adding an external MOSFET in a cascode or StackFET™ configuration, it is possible to distribute the voltage stress across two devices, resulting in an overall voltage rating equal to the sum of the individual MOSFET voltages.

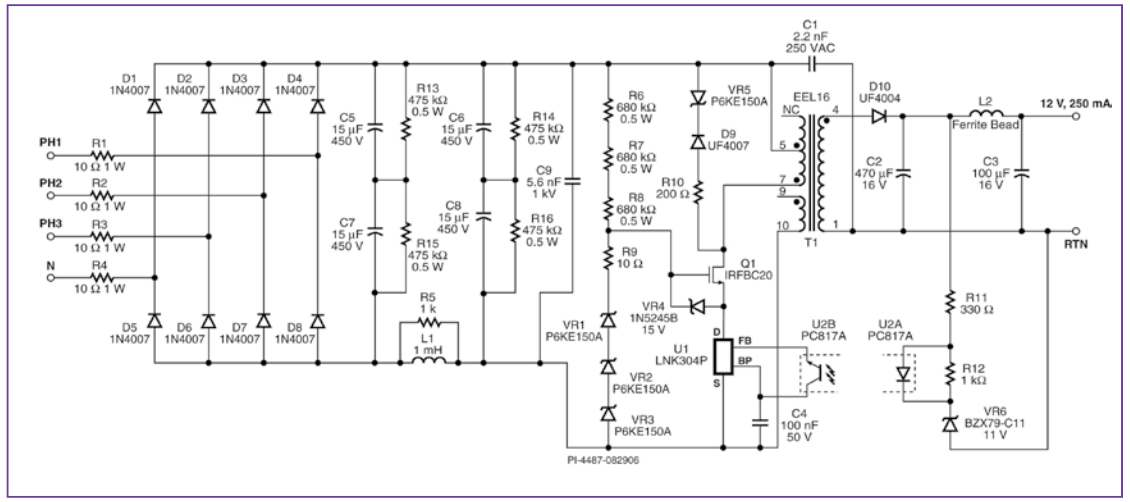


Figure 1. Circuit Schematic.

Note: A standard fixed-frequency PMW controller would suffer from poor efficiency under high-line and light-load conditions, due to the short duty cycle relative to the operating frequency. ON/OFF control eliminates this problem.

Design Solution

The circuit in Figure 1 is a 12 V, 250 mA wide-range flyback power supply that operates from a single-phase or a three-phase input. Using the StackFET technique with a low-cost 600 V MOSFET results in an overall voltage rating of 1300 V and allows supply operation over the desired wide input voltage range of 57 to 580 VAC. The supply will work from 47–63 Hz, single- or three-phase 110 VAC, 220 VAC or 440 VAC. This supply comfortably handles the loss of one or more phases or the neutral, as well as extended sags and surges.

Circuit Operation

The circuit in Figure 1 is based on a LinkSwitch-TN IC, the LNK304P (U1) that is configured as a flyback, to leverage its 66 kHz switching frequency. This reduces switching losses and improves efficiency. The IC's ON/OFF control regulates the output by skipping switching cycles. As the load is reduced, the effective switching frequency decreases, scaling the switching losses and maximizing the operating efficiency.

The AC input is full-wave-rectified by diodes D1 through D8. Resistors R1 through R4 provide in-rush current limiting and protection against catastrophic circuit failure. Capacitors C5 through C8 are used to filter the rectified AC supply. To meet maximum bus voltage of 820 VDC, 450 V input capacitors C5, C7 and C6, C8 are connected in series with balancing resistors R13 to R16 to equalize the voltage. The C5/C7 and C6/C8 capacitor sets are used in conjunction with L1 to form a p filter for EMI reduction. Capacitor C9, which is placed very close to U1 and T1, shunts switching induced noise currents, to minimize differential mode EMI generation. Combining this EMI reduction technique with 1) the jittering of the switching frequency of U1, 2) E-Shield™ winding in the transformer, and 3) the safety Y-rated capacitor C1 across the isolation barrier, allows the design to easily meet conducted EMI limits (as specified in EN55022-B).

The high-voltage DC is applied to one end of the transformer primary, and the other end driven by MOSFET Q1. MOSFET Q1 and the MOSFET inside the LNK304P effectively form a cascode arrangement. When the internal MOSFET of U1 turns on, the source of Q1 is pulled low, which allows gate current to flow through the resistor string R6, R7 and R8 from the junction capacitance of VR1, VR2 and VR3, to turn on Q1. Zener VR4 limits the gate-source voltage applied to Q1. When turned OFF, VR1 to VR3 (connected in series) form a 450 V clamping network that ensures the drain voltage of U1 remains close to 450 V; any input voltage above 450 V will be dropped across Q1. This arrangement distributes the sum total of flyback voltage and DC bus voltage across Q1 and the internal MOSFET within U1. Resistor R9 limits high frequency ringing that occurs when VR1 to VR3 conduct. The clamping network, VR5, D9 and R10, limits the peak voltage that appears across Q1 and U1 (due to leakage inductance) during the flyback interval.

The circuit on the secondary of transformer T1 provides output rectification, filtering and feedback. Diode D10 rectifies the output. Capacitor C2 filters the rectified output. Inductor L2 and capacitor C3 form a second-stage filter, which helps to reduce the high-frequency switching ripple in the output. Zener diode VR6 conducts when the voltage at the output exceeds the total drop of VR6 and the optocoupler diode inside U2. A change in output voltage results in a change in the current through the optocoupler diode. This, in turn, increases the current through the transistor inside U2B.

When this current exceeds the FEEDBACK (FB) pin threshold current, the next switching cycle is disabled. Output regulation is maintained by adjusting the number of enabled and disabled switching cycles. Once a switching cycle of U1 is enabled, the current ramps to the internal current limit of U1. Resistor R11 limits the optocoupler current during transient loads, and sets the gain of the feedback loop. Resistor R12 provides bias current to the Zener diode, VR6.

If the FEEDBACK pin is not pulled high for a period of 50 ms, the internal power MOSFET switch in U1 is disabled for 800 ms. Alternately enabling and disabling the switch protects the circuit against output overload, an output short circuit, or an open feedback loop.

No auxiliary winding or bias wind-

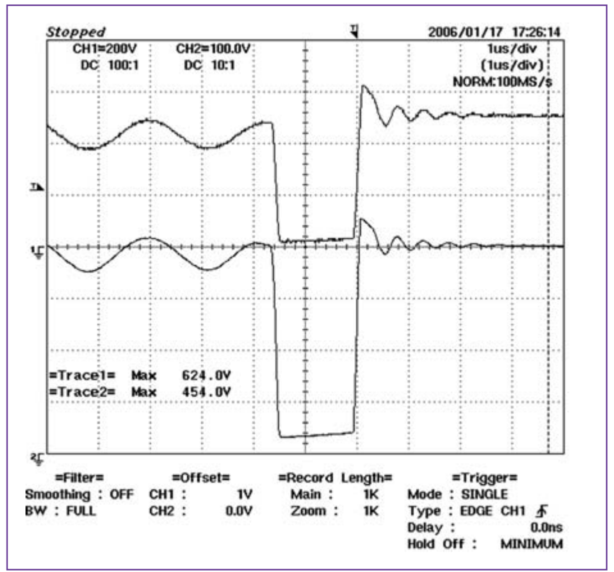


Figure 2. Trace 1 - U1 Drain Voltage (200 V / div) and Trace 2 - Q1 Drain Voltage (100 V / div).

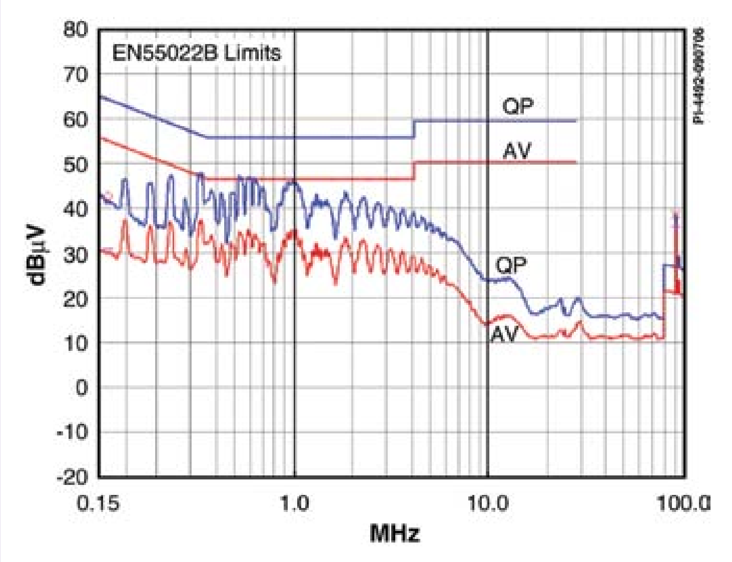


Figure 4. Conducted EMI at 230 V.

ing on the transformer is required to power U1, as it is self-powered from the DRAIN (D) pin. At start-up and during the off-time of the internal MOSFET, the local decoupling capacitor (C4) is kept charged via an internal high-voltage current source.

Circuit Test Results

The oscilloscope plot shown in Figure 2 was captured at an input voltage of 312 VAC (440 VDC bus voltage). At turn off the drain voltage of U1 (trace 2) is clamped to a voltage of 450 V, which is the total voltage across VR1, VR2 and VR3. This clamping ensures safe operation of U1. Trace 1 shows the voltage on the drain of Q1 referenced to primary ground (negative of C8). The actual voltage across the MOSFET Q1 in the OFF state (trace 1) is the difference between the two traces, in this case 170 V.

As the AC input voltage is increased to 580 VAC (820 VDC), the voltage drop across the MOSFET Q1 in the OFF state is less than 550 V, which allows the use of a low cost 600 V to 800 V external MOSFET.

The efficiency characteristic of this design is shown in Figure 3. The curve reveals that the efficiency drops at higher input voltage due to increased switching losses and dissipation in the cascade connected power stage (Q1 and the internal MOSFET within U1). However this is still significantly higher than a regulated linear transformer supply.

The circuit meets conducted EMI requirements with a comfortable margin when tested at 230 VAC, as shown in Figure 4. The blue and red upper lines represent the quasi-peak and average limits, perEN55022 B. The lower lines represent the corresponding quasi-peak and average test results.

Conclusion

The StackFET technique provides a cost-effective solution for auxiliary power supplies in industrial applications. This technique allows the designer to benefit from the simplicity afforded by an integrated switching IC when used for high input voltages required by three-phase AC input.

www.powerint.com

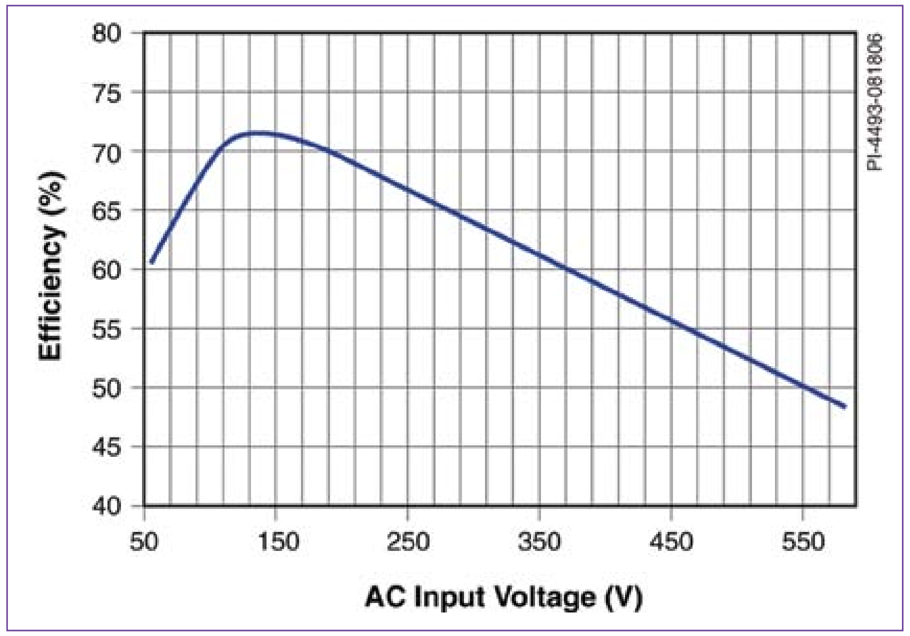


Figure 3. Efficiency vs. Input Voltage.

20V Solid-State photovoltaic relays have 50 percent lower on-state resistance

International Rectifier has introduced a series of photovoltaic relays for applications including power supplies, power distribution, audio equipment, and instrumentation, computers and computer peripherals.

Compared to its predecessor, the PVN012A family offers a 50 percent reduction of AC/DC on-state resistance (RDD-on) and 37.5 percent increase of maximum AC/DC load current rating at full (100%) duty cycle. The new series is also rated for maximum pulsed (surge) load current.

With extremely low on-resistance and high volumetric load current density in such a small package, the PVN012A family exceeds the performance capabilities of traditional electromechanical relays. In comparison, the PVN012A family offers a smaller footprint, high input-to-output isolation, bounce-free operation, solid-state reliability, stable on-resistance over life, and greater input sensitivity.

These new 20V single-pole, normally open, solid state relays utilize a HEXFET® MOSFET output switch, driven by a unique integrated photovoltaic generator circuit. The output switch is controlled by radiation from a GaAlAs light-emitting diode (LED) that is optically isolated from the photovoltaic generator. The new series is available in 6-pin DIP, 6-pin SMT, and in tape and reel.

Specifications:

www.irf.com

Part Number	Package	On-resistance AC/DC [Ohm]	On-resistance DC-only [Ohm]	Load current AC/DC [Amp]	Load current DC-only [Amp]	Input-Output Isolation [VACRMS]
PVN012APbF	DIP-6	0.050	0.015	4.0	6.0	4,000
PVN012ASPbF	DIP-6,SMT	0.050	0.015	4.0	6.0	4,000
PVN012AS-TP	DIP-6,SMT,T&R	0.050	0.015	4.0	6.0	4,000

Dual DC/DC Converter Delivers 1.6A per Channel from a DFN Package

Linear Technology Corporation announces the LT3506 and LT3506A, dual current mode PWM step-down DC/DC converters with two 2A power switches packaged in a 16-lead 5mm x 4mm DFN package. Each channel is capable of delivering up to 1.6A of output current. Their wide input range of 3.6V to 25V makes them suitable for regulating power from a wide variety of sources, including four cell batteries, 5V and 12V rails, unregulated wall transformers, lead acid batteries and distributed power supplies. The LT3506 switches at 575kHz while the LT3506A switches at 1.1MHz enabling the use of tiny, low cost inductors and ceramic capacitors, while delivering low, predictable output ripple.

The LT3506 and LT3506A's low VCESAT (210mV @1A) internal switches offer efficiencies of up 88%, minimizing thermal constraints and maximizing battery run-time. Low voltage outputs are easily attended due to an internal reference of 0.80V. Each channel has independent shutdown and soft-start pins as well as independent power good indicators to ease power sequencing. The channels switch 180 degrees out of phase with respect to the other, reducing input ripple and minimizing capacitance needs. Internal cycle-by-cycle current limit provides protection against shorted outputs while soft-start eliminates input current surge during start up. The low current (<30uA typ) shutdown provides easy power management in battery-powered systems.

The LT3506EDHD and LT3506AEDHD are available in a thermally enhanced 5mm x 4mm DFN-16 package

Photo Caption: 25V, 1.1MHz Dual 1.6A (IOUT) Step-Down Switching Regulator

www.linear.com

26-Watt Power over Ethernet Controller

Texas Instruments Incorporated has introduced a 26-watt Power over Ethernet (PoE) controller that allows Ethernet-powered devices, such as IP surveillance cameras, WiMAX access points and conference IP phones, to use twice as much power from a standard Ethernet cable – without the need of an AC line.

TI's 8-pin, TPS2376-H controller contains all of the features needed to develop an IEEE 802.3af-compliant powered device with innovative safety features including a programmable, 600-mA current limit with thermal shutdown, auto-retry and fault protection. The high-power device also allows a designer to implement a non-standard powered device that draws up to 26 watts of power from power source equipment (PSE) with a minimum of 52 volts of input and over 100 meters of CAT-5 Ethernet cable. The TPS2376-H supports voltage transients up to 100 V at 600-mA. In addition, the device can operate at 24 V over an industrial temperature range of -40C to 85C, enabling support of emerging Ethernet-powered medical and industrial equipment.

Requiring a minimum number of external components, the flexible TPS2376-H is housed in a PowerPad™ package with an integrated 0.6-ohm FET to minimize heat dissipation in the system. The controller's simple front-end architecture gives designers increased flexibility when designing the back-end power stage topology. In addition, the TPS2376-H eases powered device startup capability with adjustable in-rush current limit and an auto-retry feature, which provides automatic start-up on fault. The controller's power conversion functionality includes several additional protection and low-noise features, such as 15-kV system-level electrostatic discharge (ESD) capability, adjustable undervoltage lockout and open drain power good reporting.

Packaged in an 8-pin, SOIC package.

www.ti.com

New Family of LED Drivers to Power High-Brightness LEDs

National Semiconductor has introduced a new family of light-emitting diode (LED) drivers designed to power the new generation of 1W to 5W, high-brightness LEDs found in automotive, industrial and general illumination applications. National's LM3402, LM3404 and LM3405 LED drivers offer the wider input voltage range required by this fast-growing market segment. In addition, these new LED drivers provide a constant current to regulate the LED brightness and low feedback voltage to minimize power dissipation.

"National already offers a wide portfolio of LED drivers designed for low-power portable applications such as those in cell phones and PDAs," said Mal Humphrey, product line director for the Power Management Group at National Semiconductor. "This new family of products extends that portfolio, using our higher voltage and current capabilities to address the high-brightness LED market as well."

Optimized for 1W LEDs, National offers two versions of the LM3402 LED driver that provide wide input voltage ranges of either 6V to 42V or 6V to 75V. For 3W and 5W LEDs, the LM3404 and LM3405 have additional output current drive capability.

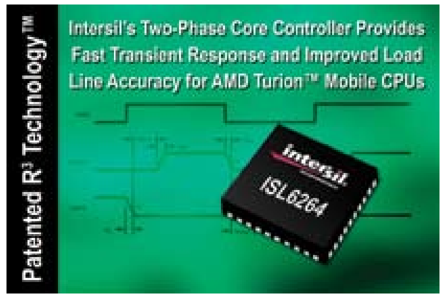
The LM3402 is a compact, constant-current buck regulator with up to 95 percent efficiency that drives up to 525 mA of current. Offered in an 8-pin mini SOIC package, the LM3402 has an enable pin that also can be used for dimming via pulse-width modulation (PWM) inputs and a reduced feedback of 0.2V for current sensing. The LM3402's input voltage ranges from 6V to 42V. For higher input voltages, the LM3402HV offers the same features and a 6V-to-75V voltage range.

Offered in an 8-pin SOIC narrow package, the LM3404 and LM3404HV share the same functionality as the LM3402 and LM3402HV, but have the ability to drive currents up to 1.2A. These products are well-suited to power 3W and 5W LEDs at current levels of 700 mA or 1A, respectively. For more information on the LM3404 and LM3404HV, visit

Offered in an 8-pin mini SOIC package and a tiny 6-pin SOT-23 package, the LM3405 constant-current buck regulator delivers up to 1A of current to drive 3W or 5W LEDs. With a 0.2V reference voltage for constant-current feedback control and a switching frequency that is internally set to either 550 kHz or 1.6 MHz, the device provides a simple, highly-efficient solution for driving LEDs. In addition, it has an input voltage range of 3V to 22V, is internally compensated and has an En/Dim pin for PWM dimming.

www.national.com

Core Controller Improves Transient Response and Load Line Accuracy for AMD Turion™ Mobile CPUs



Intersil Corporation has introduced a two-phase core controller with embedded gate drivers to power AMD's next-generation (64-bit Turion™) mobile CPUs offering improved transient response and load line accuracy with Intersil's patented R3 (Robust Ripple Regulator) Technology™.

Intersil's new R3 controller uses post package trimming to remove all errors associated with assembly and offers 0.5% accuracy across the entire temperate range, which Intersil claim to be the best in the industry. The device uses two interleaved channels to double the output voltage ripple frequency, reducing output voltage ripple amplitude with fewer components, lower component cost, reduced power dissipation in a smaller area.

"The ISL6264 uses Intersil's patented R3 Technology to meet the transient response and light-load efficiencies required by AMD (Turion™) processors," said Majid Kafi, director of Intersil's Notebook Power products group. "Intersil now offers a vast number of products that power the latest CPUs by both Intel and AMD. The dynamic phase adding/dropping optimizes the efficiency of the CPUs, improving battery life."

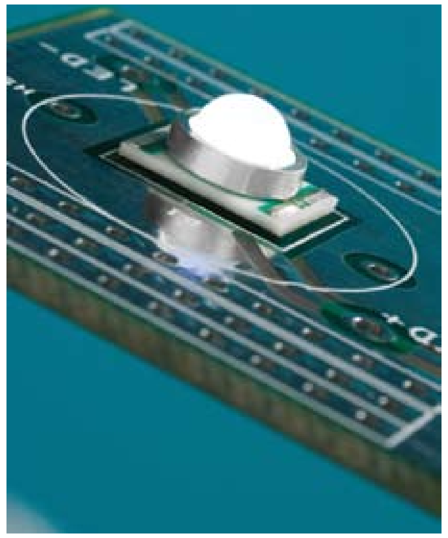
The ISL6264 is a two-phase controller with embedded gate drivers. The heart of the ISL6264 is the patented R3 Technology, Intersil' s Robust Ripple Regulator modulator. Compared with traditional multiphase controllers, the ISL6424 has the fastest transient response due to the R3 modulator commanding variable switching frequency during a load transient.

A unity-gain differential amplifier is provided for remote CPU die sensing. This allows the voltage on the CPU die to be accurately measured and regulated per AMD mobile CPU specifications. Current sensing can be realized using either lossless inductor DCR sensing or precision resistor sensing. A single NTC thermistor network thermally compensates the gain and the time constant of the DCR variations.

The ISL6264 is suitable for applications in notebook PCs, POS systems, LCD PC systems and blade servers and is available in a 40-lead QFN package. Evaluation boards are also available.

www.intersil.com

First 160-Lumen White Power LED Cree



Cree, Inc. has announced new benchmarks for power LED brightness and performance with the release of the newest white Cree XLamp® 7090 power LED. This new XLamp LED, available in volume quantities, produces luminous flux of up to 95 lumens or 85 lumens per watt at 350 mA, and up to 160 lumens at 700 mA, now as efficient as fluorescent sources.

Typical luminous flux for the new Cree XLamp 7090 LED is 80 lumens at 350 mA, yielding 70 lumens per watt. The new XLamp LED was designed to enable general lighting applications, such as street lighting, retail high bay lighting and parking garage low bay lighting, as well as to vastly improve the light quality in consumer applications such as flashlights. LED technology has been sufficiently bright for many general illumination applications for some time. The new XLamp 7090 LED, however, offers the efficiency and reliability needed to make LEDs cost-effective for more of these applications. The new XLamp 7090 LED is the first power LED based on the company' s EZBright™1000 LED chip, which provides the industry's highest performance at 350 mA.

"Cree LEDs are achieving performance levels formerly delivered only by the most efficient traditional lighting sources, including fluorescent bulbs. We have established a new class of LED performance," notes Mike Dunn, Cree general manager and vice president, lighting and backlighting LEDs. "Our goal at Cree remains to aggressively increase the brightness and performance of our LEDs to ensure that LEDs become a cost-effective, energy-saving alternative for all lighting applications."

The Cree LED research and development efforts were enabled in part through funding from the Department of Energy's Building Technologies Program, within the Office of Energy Efficiency and Renewable Energy, and also in part through funding from the Department of Commerce's National Institute of Standards and Technology's Advanced Technology Program.

www.cree.com

Please note: **Bold**—companies advertising in this issue

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