Power Systems Design
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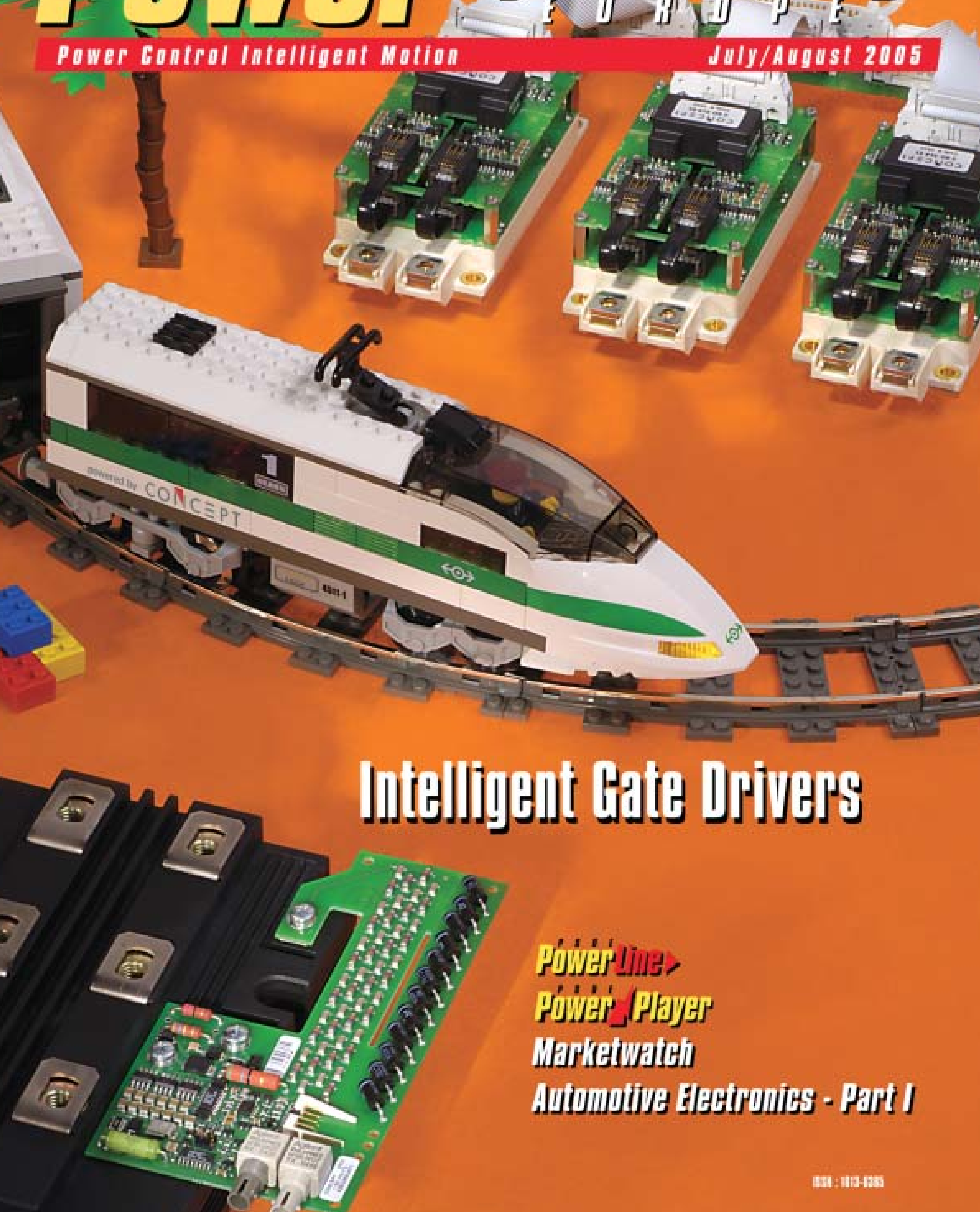
Power Control Intelligent Motion

July/August 2005



Intelligent Gate Drivers

PowerLine

PowerPlayer

Marketwatch

Automotive Electronics - Part I

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Power Systems Design EUROPE

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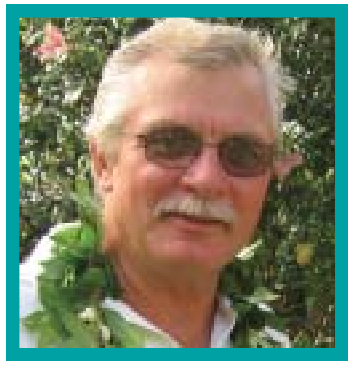
TRANSPAC 2005 - Keeping the Power ON!



Aloha,

Transpac, 2,300 nautical miles of blue water ocean sailboat racing from Los Angeles, California to Honolulu, Hawaii. What does this have to do with a design magazine dedicated to power electronics? Bear with me, as I promise there is a connection.

This year's Transpac was the 100th anniversary of the race and I was one of the lucky ones that got to participate in this "Race to Paradise". Sailing on the fine yacht "Shaman", a Cal 40 of mid 1960's vintage, I was part of the 5 member crew that competed against 13 other identical Cal 40's in a one-design drag race to Honolulu.

Technology has definitely influenced the face of this race in the last 100 years ago. Most notably the original participants sailed wooden ships and used sextants as their only means of navigation. In this years race each skipper was required to use a sextant to do four sightings. This was part of the exercise to preserve the history of the Transpac.

Today's modern Transpac entries included some of the worlds most expensive and sophisticated sailing yachts including Hasso Plattner's (Founder of SAP) MAXZ86 foot "Morning Glory" and Roy Disney's (Nephew of Walt Disney) MAXZ86 foot "Pyewacket". Both of these boats to mention just a few are loaded with technology from the bottom of their hydraulically controlled canting keels to the tip of their 100 feet plus carbon fiber mast.

And yes electronics played a major role in all the yachts sailing in this event. On "Shaman" alone, we had no less than a dozen electronic systems that we were dependent on not only for navigation and basic living comfort but our survival when we were 1,150 nautical miles (half way point) from the nearest point of land.

Beginning with our sixth crew member "Dell" (our laptop computer) which among other things controlled our navigation and weather routing systems and was our Internet link to the outside world via our Iridium satellite phone, and yes the boat was equipped with a Bluetooth wireless network.

Least we forget our water making system that converted raw sea water into pure drinking water and the refrigeration that kept our fresh food from spoiling. (Freeze dried meals began on day 4).

All of these systems ultimately ran off battery power provided by a bank of onboard batteries which needed to be recharged two to three times per day. Keeping in mind that "Shaman" was our self-contained island at sea, we had only 30 gallons of diesel fuel to use to recharge our electronic systems for the entire 14 plus day race. Not only was power of critical importance to us, but of equal or more importance was our conservation of power through our power management systems and procedures.

As power electronics and power management technology continues to reach and improve all aspects of our daily lives, this is merely one small example of its impact.

Least I forget to mention, we finished in sixth place in the fourteen boat Cal 40 fleet and completed the race in 14 days, 2 hours, 58 minutes and 57 seconds. And for those of you who know me, I did receive my special trophy in Honolulu but that's for another day.

A special congratulations to Hasso Plattner and the crew of "Morning Glory" who completed the race in a record breaking 6 days, 16 hours, 4 minutes and 11 seconds.

www.transpacificyc.org

Mahalo,

Jim Graham
Publishing Director
Power Systems Design Europe & China

Power Sources Manufacturers Association and Ireland's Power Electronics Industry Group Form Alliance to Advance Power Supply Developments

The Power Sources Manufacturers Association (PSMA) and the Power Electronic Industry of Ireland (PEIG) announce that they have entered into a Cross Membership Agreement intended to foster collaboration and information exchange between the two organizations. The collaboration, as outlined in the mutual Letters of Invitation, provides each organization the opportunity to participate in the other's activities and committees. PEIG represents members from throughout Ireland while PSMA brings the International perspective having members in US, Europe and Asia. As part of the alliance, reciprocal Affiliate Membership will be afforded to each organization.

According to Arnold Alderman, Board Chairperson for PSMA, "PSMA believes it is very important to work with other organizations such as PEIG to the benefit of our industry. We hope this agreement will nurture a better understanding and a higher degree of cooperation between our members. All members of PEIG and PSMA are urged to participate fully in the opportunities afforded by this important cross membership agreement."

According to Gary Duffy, Chairman for PEIG, "PEIG is pleased to be forming this alliance with PSMA. We already have many corporate members active in both organizations and this alliance will encourage greater participation and cooperation as our industry strives to address the demands of the 21st century."

www.psma.com

Dr. Justin Chiang VP of System Power

Fairchild Semiconductor announced that Dr. Justin Chiang has joined Fairchild Semiconductor as Vice President of System Power. Chiang will report to Bob Conrad, Senior Vice President and General Manager, Analog Products Group.

Chiang most recently was the general manager of Tyco Electronics Power Components, a $300 million business unit within Tyco Electronics. He was responsible for all aspects of Tyco's power components global business including operations, sales and marketing, and research and development. With the majority of Tyco's power component sales in Asia, Chiang managed a diverse, global workforce of 6,500, which included a large contingent based in China. Prior to serving as general manager, Chiang was director of the Silicon Products Group, Circuit Protection Division of Tyco. Chiang's career at Tyco began when Tyco acquired Raychem Corporation, where Chiang held positions within the PolySwitch Division. He holds a Ph.D. in Chemical Engineering from the University of California at Berkeley and is a graduate of Princeton University. Chiang holds numerous patents and has authored a number of technical articles.

www.fairchildsemi.com

Maxwell to Sponsor Student Automotive Engineering

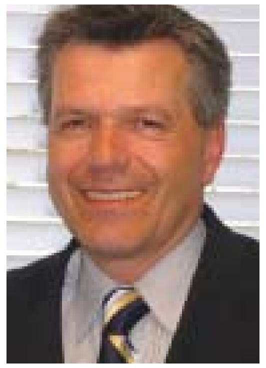
Maxwell Technologies has joined General Motors (GM) and the U.S. Department of Energy (DOE) in sponsoring Challenge X: Crossover to Sustainable Mobility. Challenge X is a new three-year engineering competition series that challenges student teams from 17 North American universities to explore advanced vehicle solutions that will reduce energy consumption and decrease emissions. Launched for the 2004-2005 academic year, the program is a joint effort among academia, government and industry partners that aims to introduce energy-efficient technologies into the marketplace to help reduce our nation's dependence on foreign oil.

Demonstrating a commitment to the development of advanced automotive technologies, Maxwell will provide each of the 17 participating universities with BOOSTCAP ultracapacitors for incorporation into vehicle drive trains and subsystems to reduce fuel consumption and reduce emissions. Ultracapacitors are electrical energy storage and power delivery devices that enhance vehicle performance and energy efficiency.

The students will follow a real-world engineering process based on GM's global vehicle development process at each phase of a three-year competition. Students will re-engineer a 2005 Chevy Equinox using cutting-edge advanced automotive technologies, including advanced propulsion systems, hybrid designs, lightweight materials, and alternative fuels.

www.maxwell.com

Potentia Achieves ISO Registration with Zero Findings



Potentia Semiconductor has achieved registration of its quality management system to the ISO 9001: 2000 standard, following an audit conducted by QMI. Significantly, no 'findings' (errors) were identified during the audit process, meaning that no corrective actions were required.

The management system registration strengthens Potentia's market leadership in digital power management controller chips and supporting software.

Potentia Semiconductor's President and CEO, Danny Osadca said, "For no findings to have been identified for a company founded just three years ago is a truly remarkable achievement, and is thanks to the concerted efforts of staff throughout the entire company. ISO 9001:2000 recognizes that all aspects of the business take a common approach to continuous quality improvement."

He continued, "In applying this rigorous quality standard to all of our management processes, we are providing our customers throughout the world with the assurance that we are following best practice quality procedures and producing the highest quality products."

www.potentiasemi.com

Linear Technology Launches Phoenix Design Center

Linear Technology announced the opening of its newest design center in Phoenix, Arizona.

This marks the company's tenth design center, as it continues to expand its resources for design of high-performance analog integrated circuits. Linear Technology has successfully developed satellite design centers over the past several years in order to rapidly grow the company's analog design staff.

Dave Bell, President of Linear Technology, stated, "The Phoenix Design Center represents a significant addition to our growing team of analog design talent at Linear Technology. The Phoenix-Chandler-Tempe area ranks among the top communities for analog design talent, and we're excited to draw on this extensive resource. We expect the Phoenix Design Center to contribute innovative product designs across all of Linear's product lines, which will further fuel the company's growth."

Linear Technology continues to seek talented analog IC designers as the company grows, and has proven that satellite design centers facilitate expansion of engineering resources beyond the deep talent pool at the company's Silicon Valley headquarters. Linear Technology produces a wide range of high-performance analog integrated circuits supporting its power management, mixed signal, signal conditioning, and high frequency product lines.

www.linear.com

Peter Frey Joins the Management Board

Mr. Peter Frey was asked by Mr. Dirk Heidenreich, CEO of the Semikron group to join the management board of SEMIKRON International GmbH. Since 1991 Mr. Frey was employed in managerial positions as General Manager of Semikron companies in Switzerland and Italy. He was responsible for international sales and marketing since 2003. It was under this leadership that the international group achieved a record turnover during the past business year. The enterprise has 53 companies in 30 countries and employs 2,500 people worldwide.

www.semikron.com

Power Events

- ***H2Expo 2005,*** *Aug. 31 - Sep. 1, Hamburg,* *www.h2expo.de*
- ***Power Supply Design Workshop,*** *Sep. 26 - 29, Atlanta,* *www.ridleyengineering.com/workshop.htm*
- ***EPE 2005,*** *Sep. 11-14, Dresden,* *www.epe2005.com*
- ***Power Systems World,*** *Oct. 25 - 27, Baltimore,* *www.powersystems.com*
- ***SPS/IPC/DRIVES,*** *Nov. 22 - 24, Nuremberg,* *www.mesago.de/sps*
- ***PRODUCTRONICA,*** *Nov.15 - 18, Munich* *www.productronica.com*
- ***APEC 2006,*** *Feb.19 - 23, New Orleans* *www.apec-conf.org*

Intersil Enters Light Sensor Market with Single Chip, Low Power Device

The EL7900 is a light-to-current optical sensor, combining a photodiode and a current amplifier on a single chip

Intersil Corporation has introduced the EL7900, an optical sensor that converts light to current. The device operates in a wide range of lighting conditions from 1 lux to 10,000 lux. This information can be used to determine the amount of ambient light present, which allows automatic backlight or brightness control for backlit keyboards and LCD monitors. This allows devices such as cell phones, laptops or any handheld device to decrease overall system power consumption by dynamically controlling the current sent to the display or backlight.

The EL7900 is easy to use. Traditional light sensing applications have used photodiodes in combination with complicated signal conditioning circuits. The EL7900 provides a simple current output that can be converted into a voltage with a single external resistor. This opens up many new possibilities in motion sensing, intrusion detection and other various medical or industrial sensing applications.

A typical display will consume the same amount of power until a user changes the system settings, which is usually brightness control. In very bright areas like an outdoor setting, users tend to increase the brightness of the display. This increases the power consumption of the system. When the conditions change, like walking into building or operating a laptop on a flight, most users don't change the settings and the system power consumption remains high. By using the EL7900 ambient light sensor, a system can now detect changing conditions and automatically adjust the settings to keep the display at optimal brightness and reduce overall power usage. The EL7900 also consumes little power itself, so there is no overhead by integrating it into the system.

There are several key factors for ambient light sensors. First, the output current must be linear to the light intensity and spectral wavelength sensitivity should be very close to the human eye. The EL7900 excels in both these areas. The device output current is directly proportional to the light intensity on the integrated photodiode and the peak response of 540nm is extremely close to the peak sensitivity of the human eye. The EL7900 is designed to sense ambient light from 380nm to 770nm.

As handheld designers are pushed to extend battery life of their device, innovative methods for saving power are being devised. The new EL7900 provides better brightness management, as well as, an improved solution to discrete photo resistor and/or photodiode use, where linearity is worse, and an additional amplifier is usually needed.

Adding to the family of ambient light sensors, Intersil has also introduced the ISL29000. This is an extremely low power ambient light sensor suitable for the most demanding portable applications. Although it consumes less current, the ISL29000 provides the same linear response and wavelength sensitivity of the EL7900.

The EL7900 and ISL29000 also perform over a wide operating temperature; -40 degrees C to +85 degrees C. This allows for integration into a number of demanding applications where extreme ranges of temperatures are normal.

EL7900 and ISL29000 Technical Summary

Features:

- Integrated photodiode and amplifier
- 2.5V to 5.5V supply range
- Excellent linearity
- Low power consumption
- Ultra-compact package

www.intersil.com/display

High Power Semiconductors: Are They Worth the Effort?

By Eric Carroll, Semiconductor Marketing Manager of ABB Switzerland Ltd

Technologically, the millennium has started well for high power semiconductors with many advances in Turn-off Devices (ToDs), namely: IGBTs (Insulated Gate Bipolar Transistors) and IGCTs (Integrated Gate-Commutated Thyristors). ToDs have been experimentally made up to 10 kV, spectacular improvements in Safe Operating Area (SOA) have been achieved for HV IGBTs and preliminary results suggest that future fast diodes and IGCTs will demonstrate similar capabilities. Switching SOA of up to 1.5 MW/cm^2 of silicon has recently been demonstrated for small IGCTs and new diode technologies are in the offing. Most recently, 30% reductions in conduction losses have been announced for next-generation planar IGBTs. All these developments have occasioned considerable Production and R&D investments in what is traditionally viewed as a small, slow growing market characterised by over-capacity and low profitability – so why is all this happening?

There are many traditional applications for high power electronics such as Transportation, Uninterruptible Power Supplies and Low Voltage Drives. These markets are large, mature (Compound Annual Growth Rates of 7%) and served by many suppliers. The next three paragraphs should illustrate the motivation for these accelerated developments.

Medium Voltage Drives

The MV network for motors ranges from 2.3 kV to 13.8 kV with the bulk of the market situated around 6.6 kV. Though an average MV motor rating may be only one MW, ratings of 30 to 90 MW are becoming common for applications such as gas compressors. The high voltages and powers encountered in this domain were, until now, a barrier to the widespread use of drives. In 2005

the market for MVDs will reach 0.5 BUSD –albeit one tenth that of LVDs - but characterised by a 30% CAGR. These drives are built with new HV IGBTs and (predominantly) with IGCTs, which currently enjoy a CAGR of over 50%.

MV motors have been operated without drives for 100 years, so why the rush? Apart from improved process control, there is a more pressing rationale: energy saving. It has been said that for every dollar spent on an MV motor, it will consume 175 dollars in energy during its lifetime. A drive can halve that consumption by adapting motor speed to load requirements. There are several hundred thousand industrial MV motors around the world, only 5% of which have drives today. It has been estimated that a programme of systematic MVD usage will spare the world over 50 thermal power stations over the next 20 years – no small contribution to the Kyoto Protocol objectives!

Energy Management

High Voltage DC is used to transmit electricity over long distances. This is done with thyristors in converters rated up to 3 GW but more flexible systems using series-connected IGBT press-packs are now being built with inverter ratings of over 300 MW to serve applications such as city in-feeds and network interconnections. Other applications using IGCTs include Static Compensators, Dynamic Uninterruptible Power Supplies, Dynamic Voltage Restorers and Battery Energy Storage Systems with ratings in the tens to one hundred MWs.

Power Generation

Traditionally, semiconductors were not used in generation other than for excitation but the quest for renewable energies, of which the foremost is Wind Power, is changing this. With over 15 GW installed world-wide and a present growth rate of 10 GW p.a., Wind Power is the fastest growing high power market. Though many systems still use low voltage IGBTs, there is a trend towards higher powers (up to 5 MW) and Medium Voltage, which require large HV IGBTs or IGCTs.

A Final Note

The dowdy High Power Semiconductor Industry has known difficult times of late. Regularly eclipsed by its lower power cousins serving their exploding power-management markets for PCs, hand-held devices, automotive, flat panel displays etc. and confronted with slow growth and over-capacity, many western companies have divested themselves of their semiconductor subsidiaries. ABB has stayed the course, paid the price and can now be proud of its leading role in developing technologies in tune with market needs.

www.abb.com

Hybrid Vehicles Drive Auto Power Chip Market

Part one of two-part series

By Chris Ambarian, Senior Analyst, iSuppli Corporation

Automotive is already one of the most important markets for semiconductors. The auto segment has been a growing and steady consumer of chips for decades, and electronic systems now account for about 15 percent of the average base cost of a motor vehicle.

However, as vast as the automotive chip market is today, it is poised to become an even larger consumer of semiconductors and electronic systems in the future. The automotive semiconductor market will grow to $23 billion by 2009, up from slightly less than $15 billion in 2005, iSuppli Corp. predicts.

Automotive Market Powers Up

Power management is projected to become an increasingly important component of those total semiconductor numbers. Power chips are projected to grow to account for 12 to 13 percent of total automotive semiconductor spend-

ing by 2009, up from 10 percent in 2005.

The figure below presents iSuppli's forecast of automotive semiconductor content growth broken down by power and non-power devices. One factor contributing to this rapid growth in power semiconductors in the automotive market will be hybrid drive trains. Purchases of hybrid vehicles are projected to grow rapidly in the next several years. Hybrid autos contain a much higher amount of power and control chips than non-hybrid vehicles.

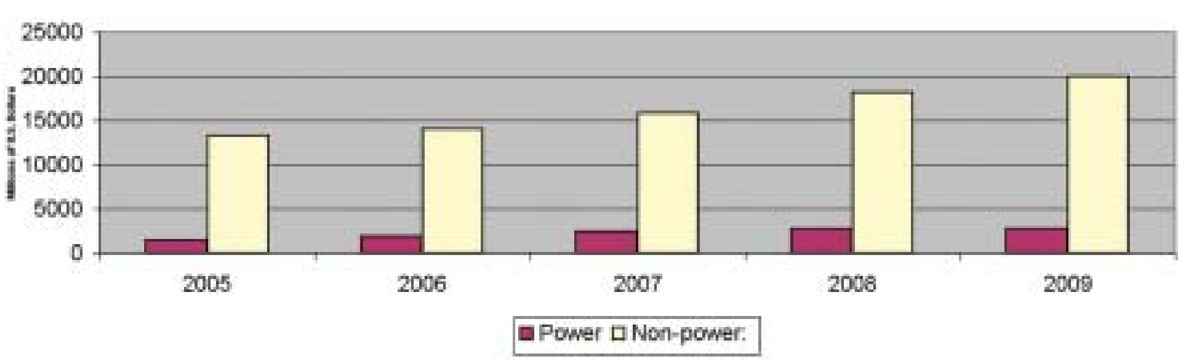
Electronics amounts to 45 to 50 percent of the base cost of a hybrid vehicle, nearly three times that of non-hybrid vehicles. Much of that cost is power management. From a power management perspective, there are three fundamental challenges in hybrid drive trains: power, isolation and drive and control scheme. Each of these areas presents unique challenges.

Inverter Switching Issues

In hybrid drive trains, power refers to the main inverter switching function. The challenges in inverter switching reside in choosing which power transistors to use and determining how to package them. At present, Insulated Gate Bipolar Transistors (IGBTs) are the transistor of choice for this function and they are employed by every maker of hybrid vehicles.

	2005		2006		2007		2008		2009
Power	$	1,511	$	1,932	$	2,418	$	2,719	$ 2,778
Non-power:	$	13,337	$	13,996	$	15,896	$	18,158	$ 19,961

Figure: Automotive Semiconductor Market Revenue Forecast by Power and Non-Power ICs (Revenue in Millions of Dollars)



Source: iSuppli Corp. July 2005

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The IGBT is a proven technology, which is important in the automotive industry where it is normal to require 10 years of established reliability for a component to even be considered. However options among IGBTs are limited at this point.

Toyota, far and away the market leader in hybrid vehicles, uses its own IGBTs for much of its production, and Mitsubishi's for the rest. Mitsubishi's devices are packaged in specially-designed injection-molded variations on the standard types of IGBT modules seen in the market since the 1990s.

Within the next few years, Fuji Electric and perhaps Hitachi also will target this market, with some small probability of an offering by a German supplier and an even smaller probability of a competitive product from a U.S. supplier. Japan has positioned itself well as the leader in IGBTs for hybrid drives for the next several years.

As dominant as IGBTs are today, new transistor technologies are on the far horizon that should factor heavily into the future of hybrid vehicles. Two possible candidates stand out: a new device structure called the Grounded Trench MOS Assisted Bipolar Mode Field Effect Transistor (GTBT) and the eagerly-awaited power MOSFETs made on Silicon Carbide (SiC) material.

The GTBT, patented by Nissan Motor but developed by Sanyo for consumer applications, is a device with a nominal on-state voltage drop of one tenth that of an IGBT. This device went into production in 2003, but in consumer applications only.

It will be many years before such a device structure is proven to be appropriate for driving motors and can be switched at sufficiently low losses as to make it advantageous for use in hybrid drive trains. However, with a forward drop of 0.2-Volts, the GTBT has a major head start.

Along with the GTBTs, SiC Field Effect Transistors (FETs) also are strong candidates for future use as power transistors for the inverter-switching function in the drive trains of hybrid vehicles.

Because SiC is a high-bandgap material, it is possible to make high-voltage devices with very low drops. Also—and perhaps more importantly—SiC chips have superb thermal properties. These properties include a good thermal expansion coefficient, thermal resistance of one tenth that of silicon, and a very high maximum junction temperature—higher than any commercial package presently can withstand.

In demanding uses, such as the automotive environment, such a device theoretically would be nearly ideal. Still, about one more year of work is needed to begin to get these devices started down the path of commercially-viable yields—and then of course there's that 10-year prove-out period.

Still, some promising research and development is taking place at various North American companies, and Rohm already has quietly sampled SiC FETs in the Japan market. Again, Japan seems to be at the forefront in motor power devices, and the North American and European suppliers had better hurry up if they don't wish to be shut out completely.

Christopher Ambarian is a senior analyst with iSuppli Corp. Contact him at cambarian@isuppli.com

Part two of this article will appear in PSDE September issue.

www.iSuppli.com

Intelligent Gate Drivers for Recent IGBTs

Challenge to control latest IGBT chips

IGBT drivers are key components of every IGBT converter. Like the IGBTs, these drivers also have a major impact on the overall performance of a system.

By Heinz Rüedi, CT-Concept Technologie AG

The IGBT drivers offered on the market can be roughly divided into two categories: driver cores that contain the core functions of an IGBT driver, and complete solutions, known here as Plug&Play drivers, that are already matched to a specific IGBT module by the driver manufacturer.

Driver Cores

Driver cores contain the core functions of an IGBT driver such as:

- Insulation between input and IGBT
- Driver output stage
- Insulated power supply (DC/DC converter)
- Short-circuit detection and protection
- Under-voltage monitoring
- Status feedback

Figure 1 shows the SCALE IGBT family of driver cores from CT-Concept Technologie AG that have eminently proved their worth on the market in large item numbers for over five years. These cores differ essentially in the power of their integrated DC/DC converter, their output current and the number of their drive channels. The SCALE driver cores are offered for insulation voltages of between 1200V and 3300V.

Although these driver cores considerably minimize user effort, a high development outlay is still needed to integrate them into a system. On the other hand, the user of the cores has a major influence on the dynamic control capability of the IGBTs. For optimized driving, for instance by means of active clamping, a considerable effort is required to set the parameters correctly and verify them under various operating conditions.

Plug&Play IGBT Drivers

The Plug&Play drivers represent complete solutions that are matched to specific IGBT types and designs by the driver manufacturer. The user is relieved of any development effort for the selection, dimensioning, integration and matching of these drivers.

The Plug&Play drivers contain the same basic functions as the driver cores as well as additional ones such as active clamping, needed for the optimum driving of the IGBTs. These extended functions save the user considerable time and boost the reliability of the system design.

Depending on the electrical and mechanical demands made on the driver by a specific IGBT module, various Plug&Play solutions have been produced. These will now be considered.

Dual and Six-Channel Plug & Play Drivers

A first practical approach is offered by Plug&Play drivers based on a standard driver core. These solutions are comparable to the driver boards a user can create from a driver core: here, however, the driver manufacturer has done this work for him. Such a solution is always preferred for lower and mid-sized item

Figure 1. Family of SCALE IGBT driver cores from CONCEPT

Figure 2. Plug&Play driver boards for 140x130mm dual module with electrical and fiber-optic interface.

Figure 3. Plug&Play driver solutions for EconoPACK+ and EconoDUAL+ module.

Figure 4. Plug&Play driver solutions for high-voltage IGBTs (3300V, 4500V and 6500V reverse voltage).

numbers when a driver core suitable for the application from an electrical and mechanical viewpoint is available. The use of a driver core also simplifies the development of the driver and the required test infrastructure for the driver manufacturer, as an already tested driver module is used for the core functions. Figure 2 shows the 2SB315, a Plug&Play driver solution for 140x130mm dual-IGBT modules of the kind offered by various IGBT manufacturers. The 2SB315 Plug&Play driver boards are available either with an electrical or a fiber-optic interface.

Although another series of Plug&Play drivers is based on the circuit technology of existing driver cores, autonomous layouts are required to match these drivers to specific IGBT module geometries in a constructively optimized way, see Figure 3. The 2SD312EI is a dual-channel driver for IGBTs in the EconoDUAL+, SEMiX3 and SEMiX4 packages. The 6SD312EI is a six-channel driver matched to the EconoPACK+ and compatible packages. Except for the number of drive channels, both these drivers are based on identical circuit technology.

All the dual-channel drivers presented above have the same user-friendly interface to the control electronics. Three dual-channel drivers of this kind can also be connected together on the control side simply and with no additional components to obtain a connector assignment identical to that of the 6SD312EI. The EconoPACK+ and EconoDUAL modules are currently offered by several manufacturers with reverse voltages of 1200V and 1700V and rated currents from 150A to 450A. In the 140x130mm modules, the manufacturers now offer rated currents from 600A to 1200A per power switch at these reverse voltages. CONCEPT is offering individually optimized Plug&Play driver solutions for all these IGBT modules from different manufacturers. So a single standardized interface to the control side covers the complete range from 150A to 1200A, which facilitates the development of a whole series of equipments of various output powers for the user.

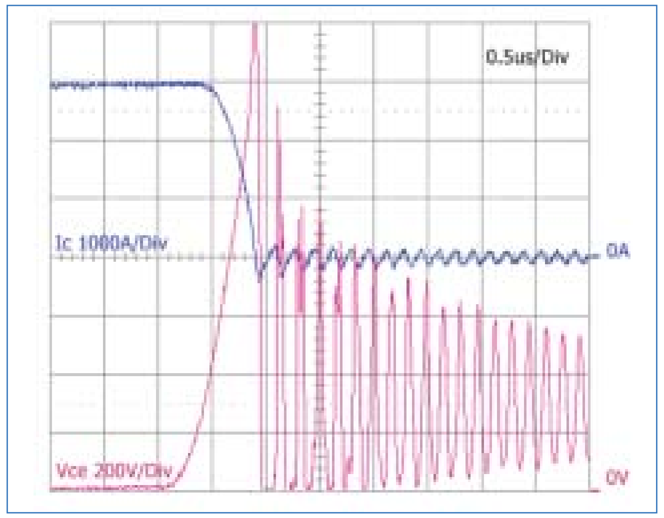

Figure 5. Turn-off behavior for FZ3600R17KE3 at Ic=3000A and 300V DC link voltage without di/dt control.

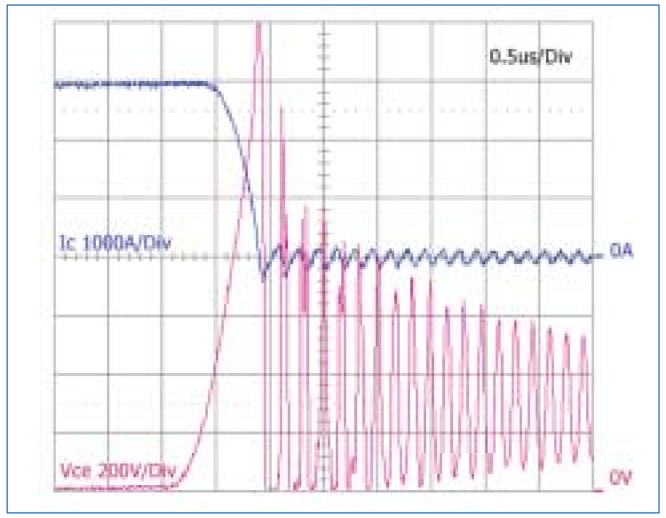

Figure 6. Turn-off behavior for FZ3600R17KE3 at Ic=3000A and 300V DC link voltage with di/dt feedback (with 1SD536F2 driver).

Single Switch Plug&Play Drivers

Single-switch IGBT modules are offered for even higher powers. The range extends from 1200A to 3600A at reverse voltages of 1200V and 1700V. Modules up to 1200A are available for 3300V IGBTs, 900A modules for 4500V IGBTs and 600A modules for 6500V IGBTs. Handling such high-power modules makes extremely tough demands on a driver, with the problem areas looking very different depending on the manufacturer, voltage class and IGBT chip technology used.

Figure 4 shows a selection of Plug&Play drivers for IGBTs of voltage classes 3300V, 4500V and 6500V. All these drivers offer the standard functions as well as active clamping.

By supplying high-power modules equipped with trench-gate IGBTs, the IGBT manufacturers have issued a new challenge to driver circuits. So the turn-off behavior can no longer be affected in the required way by a simple driver circuit that turns off the driver module i n a conventional way.

Figure 5 shows the conventional turn-off of a 3600A / 1700V module (FZ3600R17KE3). During the turn-off time, the turn-off di/dt becomes increasingly steeper and ends in the current being practically cut-off. The high di/dt at turn-off leads to high voltage surges, strong oscillations and thus also to EMC problems. For a 3000A load current in the selected test set-up, a reverse voltage of 1600V is already reached at the IGBT at a DC link voltage of 300V. This problem can be resolved by keeping the gate voltage in the active region of the MOS channel of the IGBT until the collector current goes to zero. Both controlled and regulated solutions are conceivable. An exclusively controlled solution is difficult to dimension with a view to optimizing the switching losses if the circuit is designed to handle the entire range of currents and temperatures as well as fluctuations of the parameter tolerances of the controlled IGBT.

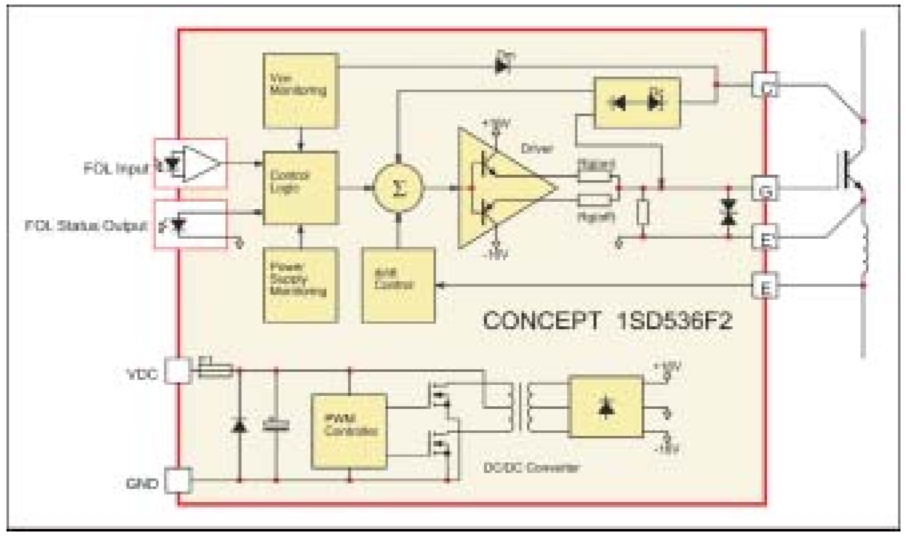

Figure 7. Block diagram of Plug&Play driver 1SD536F2.

The procedure used in the 1SD536F2 (Figure 8, block diagram Figure 7) contains a di/dt feedback to avoid the current cut-off and to attenuate the oscillations without increasing the turn-off delay and dv/dt.

Figure 6 shows the turn-off behavior of the IGBT module with this active turn-off control. The IGBT is turned off with a constant current slope. Under otherwise identical conditions (3000A load and 300V DC link voltage), a significantly lower voltage surge and lower oscillations occur at the IGBT collector. Figure 9 shows the turn-off behavior at double the rated current of the IGBT (7200A) at a DC link voltage of 1100V.

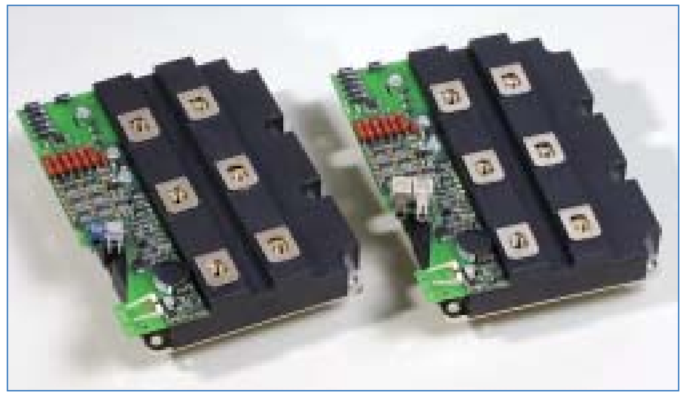

Figure 8. 1SD536F2, Plug&Play driver with di/dt feedback for 2400A and 3600A single switch IGBTs.

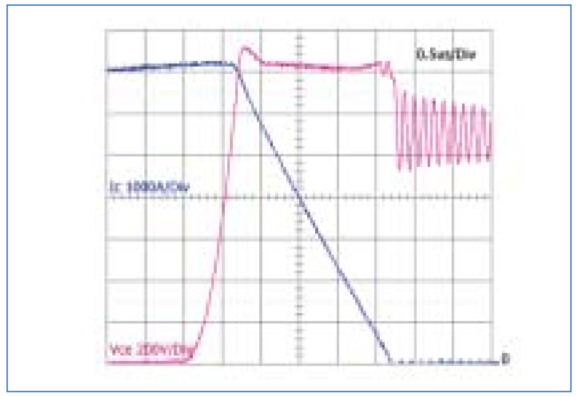

Figure 9. Turn-off behavior for FZ3600R17KE3 at Ic=7200A and 1100V DC link voltage with di/dt feedback (with 1SD536F2 driver)

The obvious argument in favor of this solution is the significant independence of parameter fluctuations of the IGBT and the low turn-off losses. These losses are only slightly higher than in the uncontrolled turn-off previously described.

Conclusion

As a supplement to the widely used IGBT drivers, Plug&Play driver solutions from CONCEPT free the user of time and cost-intensive development work. These drivers give the user a fast and effective solution to the challenges confronting him in the use of today's high-power and high-voltage IGBT modules.

These drivers ensure optimum overall performance for the system implemented with them. Customized adaptations and versions of Plug&Play driver solutions are also offered. In addition to their increased reliability, Plug&Play solutions permit a shorter time-to-market.

www.IGBT-Driver.com

Cost-Sensitive Variable Speed Motor Drives

A simplified current sensing architecture

A practical, low-cost variable speed motor drive, HVIC technology now consolidates the functions performed by numerous large and bulky discrete components such as opto-isolators or Hall effect sensors to be consolidated into a current sense IC and driver IC

By Naresh Shetty, Motion Control Product Manager, International Rectifier

Straightforward Sophistication Needed

Consumer and governmental pressure to improve energy efficiency is driving enhancements to motor drives for ubiquitous applications such as domestic appliances and small industrial systems. Variable speed drives hold the key to reducing the overall energy consumption of such motors. But designers need a cost-effective architecture that will also yield a wide speed range and torque control bandwidth. To achieve this, a straightforward solution to motor current sensing is critical.

The motor current sensing circuit provides important feedback information to enable a MOSFET or IGBT gate driver IC to adjust motor speed, using the motor current information in conjunction with control signals from a host DSP or MCU. Current monitoring is also essential if over-current protection is to be implemented. Over-current protection has traditionally been too expensive for low-end applications.

Processing the Motor Current Signal

Choosing the optimal location to sense the motor current has a profound effect on the complexity and size of the sensing circuit. As illustrated in figure 1 the current signal may display a high harmonic content, depending on where it is sampled. If this is the case, complex signal processing is necessary in order to isolate the required current component. For example, current signals sampled in series with the + DC or –DC bus, as shown in figure 1, are the vector sum of all the IGBT phase leg currents.

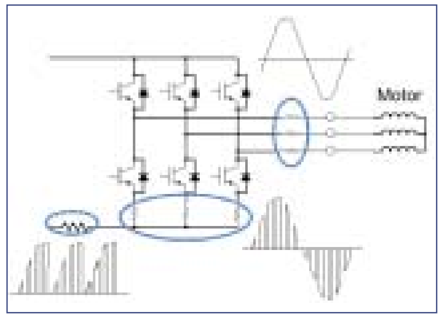

Figure1. Current sensing methods.

Also the signal content is the pulse width modulated envelope, at fixed carrier frequency, of the fundamental variable frequency motor current. Therefore, rather complicated sample and hold plus digital signal processing circuits have to be used to extract useful current information with good linearity and accuracy.

Alternatively, sampling current in one of the IGBT phase legs, also shown in figure 1, imposes lower processing demands but cannot escape from dealing with carrier frequency sampling.

By far the least complex current signal available exists in the motor phase lead. The signal content includes only the fundamental variable frequency motor current. However, there is one significant complication: sensing across a series resistor translates the current into a small differential signal in the mV range, but this is also floating on top of a 600V to 1200V common mode voltage. In addition, the common mode voltage is swinging from –DC to +DC at a dV/dt rate of up to 10V/ns due to the action of the IGBT inverter phase. Historically, this has presented a barrier to implementing low-cost current-mode control.

Direct Phase Current Sensing

International Rectifier's HVIC technology now makes it possible to sense such a differential voltage floating on top of a large common mode voltage containing fast transients, by allowing a low-side grounded CMOS circuit to be fabricated alongside a high-side floating CMOS, separated by an N- or P-channel LDMOS region. The LDMOS performs level shifting to transfer control signals across the high voltage barrier between the low-side and high-side circuits. HVIC therefore enables a monolithic device to support fast and accurate sensing of motor phase lead current, thereby reducing hardware design and processing demands. The level shifting circuit is also immune to fast transients up to 50V/ns. This is well above the typical 10V/ns common mode dV/dt noise from the IGBT inverter.

IR has introduced two new HVICs for high speed, single-phase current sensing: the IR2277 and IR22771, which feature synchronous sampling for motor drive applications.

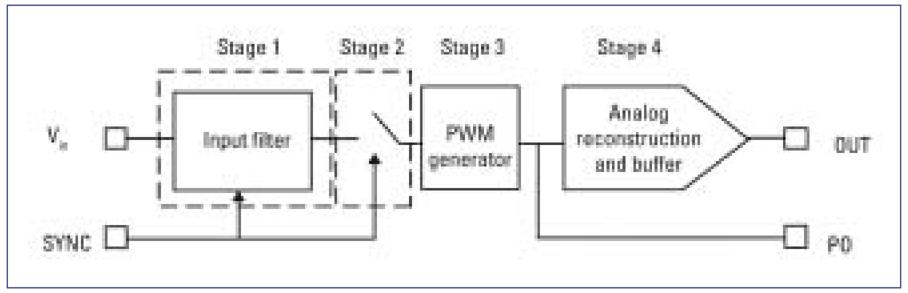

Figure 2. Signal processing blocks in the IR2277.

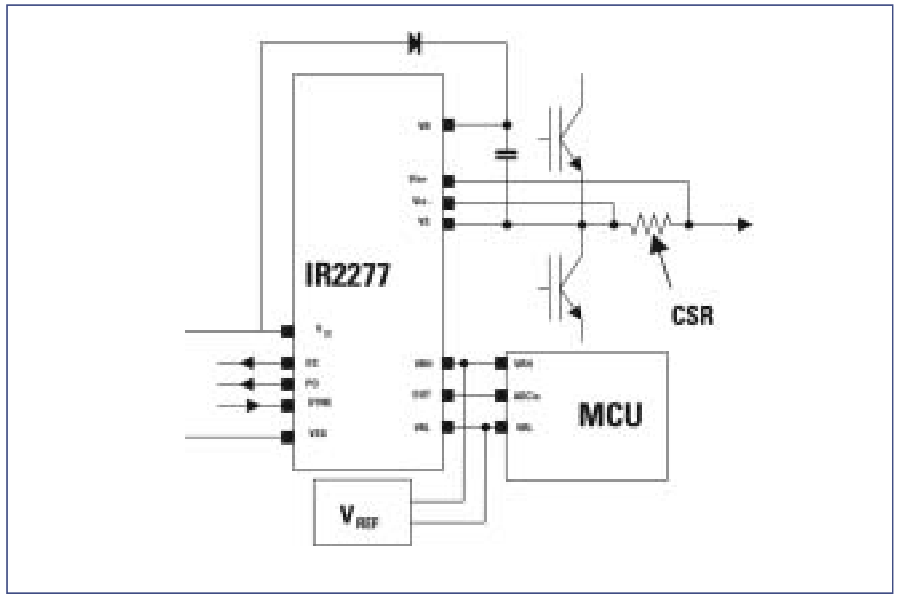

Figure 3. Application circuit for IR2277.

As figure 2 shows, the first stage of each device is an auto-tuning filter that rejects PWM harmonics and thereby reduces sensitivity to current ripple. This is achieved by automatically extracting the PWM frequency from the SYNC signal and putting transmission zeros at even harmonics. The integral on half PWM period then exhibits similar frequency response to that of a single real pole placed at PWM frequency. Hence, high frequency noise is rejected. Furthermore, multiple transmission zeroes are placed exactly on even PWM harmonics resulting in high attenuation.

The second stage samples the result of the first stage at double Sync frequency. This action can be used to fully remove the odd harmonics from the input signal by shifting the SYNC signal 90 degrees with respect to the triangular carrier edges (SYNC2).

The IR22771 converts the small voltage differential into a PWM output, while the IR2277 also provides an analog output in addition to PWM, as shown in figure 2. The PWM output signal and/or analog reconstruction then interface with the torque control loop of the MCU or DSP.

Designing with HVIC

An application circuit for the IR2277 is shown in figure 3. By sensing current directly in the motor phase only the fundamental, variable frequency motor current is processed. The current is sensed as proportional to the analog voltage across an external shunt resistor. The IR2277 then converts this analog voltage into a time interval, which is level-shifted to provide the digital PWM output suitable for DSP and analog-to-digital interfaces without additional logic circuits. The analog output voltage also provided by the IR2277 is proportional to the measured current and is ratiometric with respect to an externally provided voltage reference.

The maximum throughput is 40kSamples/second, suitable for up to 20kHz asymmetrical PWM modulation and maximum delay is less than 7.5usec @20kHz. A noise immune bi-directional level-shifting circuit is used to avoid false common mode dV/dt noise up to 50V/ns.

Chipset for Cost-Sensitive Drives

Both the IR22771 and IR2277 HVICs also generate a fast over-current signal for IGBT protection. When combined with IGBT driver ICs, such as the IR22381Q, which is also built using IR's HVIC technology, these enable designers to implement low-cost protection for IGBTs against line-to-line shorts, ground faults and shoot-through currents. Over-currents arising from these faults can be fatal to IGBTs, but the cost and complexity of discrete protection circuitry has restricted use of such protection features to high-value motor drives.

Hence, in a practical, low-cost variable speed motor drive, HVIC technology now consolidates the functions performed by numerous large and bulky discrete components such as opto-isolators or Hall effect sensors to be consolidated into a current sense IC and driver IC, requiring only a few additional external passive components. These perform basic functions such as sensing, biasing and determining time-constants.

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Optimize Your Power Factor Correction Stage

Implementing the follower boost mode

Applications where some variations of the output voltage can be accepted, features the follower boost mode (FB) that improves the efficiency and dramatically reduces both the size and the cost of the coil.

By Joël Turchi, ON Semiconductor

In addition to its undeniable compactness and ease of implementation, the NCP1653 has another characteristic this article focuses on: flexible, the circuit can operate in traditional mode but also in the so called "Follower Boost" one. After a presentation of this technique, the article proposes a comparison between the two options in term of performance and cost-effectiveness, including experimental results based on the NCP1653 300 W demo-board (designed to work traditionally), that was slightly modified to operate in follower boost.

To force the follower boost mode, only the R3 resistor has to be modified. For sure, it makes sense to reduce the coil to take benefit of the follower boost…

What is the Follower Boost mode?

Traditionally, a PFC stage is actually a boost pre-regulator that outputs a constant dc voltage (390 or 400 V typically). Now, since the downstream converter that loads the PFC stage does not necessarily require a constant input voltage to properly operate, and if your hold-up time specification is not too severe, why not to let the PFC stage output stabilize at a dc level that varies within a controlled range as a function of the load and line conditions? For instance, between 200 and 400 V in a wide mains application?

That is the idea behind the "Follower Boost" mode that makes the pre-converter output stabilize at a level that varies linearly versus the ac line amplitude. This technique aims at reducing the difference between the output and input voltages.

Such an option may appear strange to you until you note that the efficiency of boost converters increases when the difference between the output and input voltages diminishes. Two equations highlight the benefits of this mode:

The formula that expresses the MOSFET duty-cycle:

$$\left(d = 1 - \frac{Vin}{Vout} \right)$$

that clearly shows that the MOSFET duty-cycle decreases when the output voltage is reduced. For instance, if the input voltage is 120 V, the duty-cycle is 70 % when Vout = 400 V and 40 % when Vout is 200 V. In other words, the follower boost limits "d" and hence, the portion of the coil current that flows through the MOSFET. Consequently, this operation mode drastically reduces the conduction losses.

The expression of the current ripple:

$$\frac{Vin}{L \cdot f} \cdot \left(1 - \frac{Vin}{Vout}\right) = \frac{Vin}{L \cdot f} \cdot d$$

shows that the coil current ripple is proportional to the duty cycle and hence, that the follower boost tends to decrease it. You immediately understand that the follower boost allows the use of a smaller inductor for the same specified ripple. Given that in practice, the coil inductance is chosen high enough to limit the ac component of the current to an acceptable level, the Follower Boost mode lowers the size and the cost of your coil. Figure 5 portrays this benefit in a 300 W, wide mains application.

In addition, it is clear that a reduction of the output voltage leads to a diminution of the switching losses. This is the third benefits of the technique.

How does it work?

As shown in the data sheet, the following equation gives the maximum average power a NCP1653 driven PFC stage can provide the load with (1):

$$< Pin > \max = \frac{K}{Rcs2} \cdot \frac{Vac}{Vout}$$

where:
- K is a constant (refer to the data sheet for more details).
- Rcs2 is the pin5 resistor ("R3" of figure1)
- Vac is the rms line voltage
- Vout is the output voltage

K and Rcs2 being constants, equation 1 shows that the power capability depends on the output voltage level. For instance, suppose that K and Rcs2 are dimensioned so that the low line power capability is 150 W if Vout = 400 V, equation (1) teaches us that the PFC stage will be able to provide 300 W only if Vout drops to 200 V.

That is the follower boost principle: we dimension the NCP1653 external elements so that the PFC stage cannot provide the full power unless Vout stabilizes at a target voltage that is low compared to the regulation level.

More specifically, one can deduct that the power capability (see figure 2):

- Is inversely dependent of the output voltage and hence maximum at the lowest Vout level (Vout=VoutLL).
- Is proportional to the line magnitude and then, minimum at low line (Vac=VacLL)

Hence, one must compute Rcs2 so that the PFC stage can supply the full power at low line and at the minimum output voltage you want to set.

Finally one must dimension Rcs2 so that if Pmax is the targeted power capability (2):

$$Rcs2 = \frac{K}{P\max} \cdot \frac{VacLL}{VoutLL}$$

Combination of equations (1) and (2) leads to:

$$Vout = Vac \cdot \frac{P\max}{P} \cdot \frac{VoutLL}{VacLL}$$

where P is the power, as long as the output voltage is below the output regulation level (VoutHL)

$$Vout = VoutHL$$

when the system tends to force Vout to be higher than its regulation level (the regulation block clamps the follower boost characteristic).

This is the follower boost characteristic also portrayed by figure 3.

Experimental results

A performance comparison has been performed between the Follower Boost and traditional modes using the application of figure 1 (300 W, wide mains). The measurements were made on the same boards. Simply as noted in figure 1, the coil and R3 were changed as a function of the tested mode.

As shown by figure 4, the Follower boost mode improves the efficiency without significantly degrading the THD. In addition, as shown by the following figure, the coil size is dramatically reduced. By the way, one can note that if needed, the coil could be made a bit less "squeezed" in order to minimize its losses and further improve the efficiency.

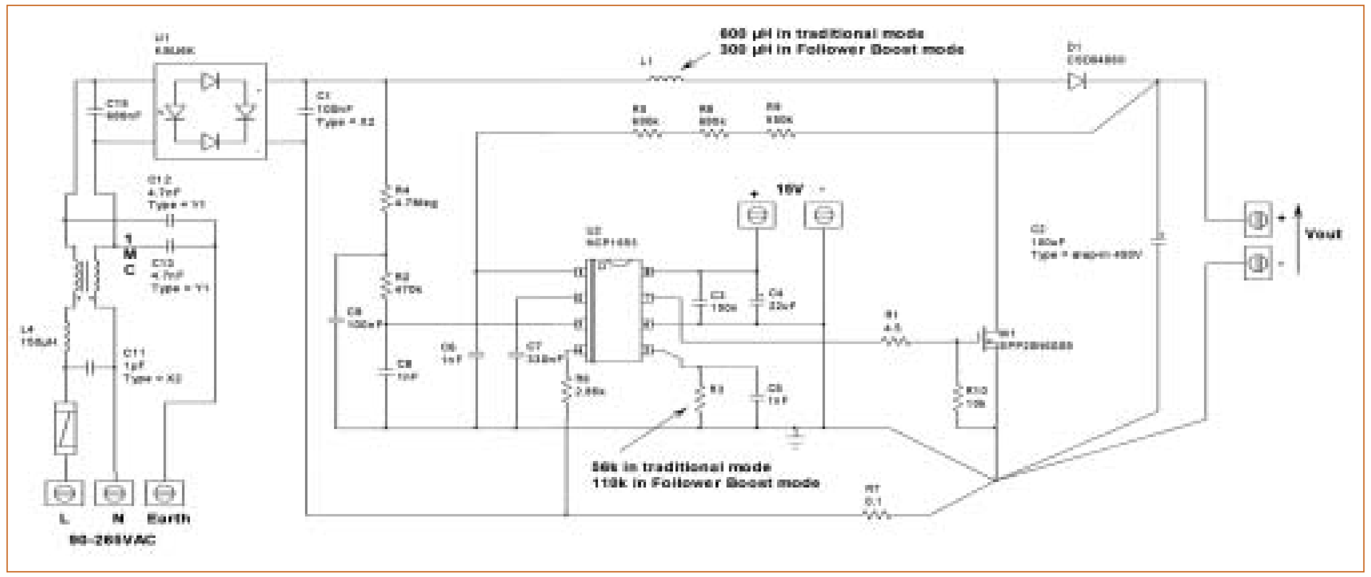

Figure 1. 300 W, wide mains, application schematic.

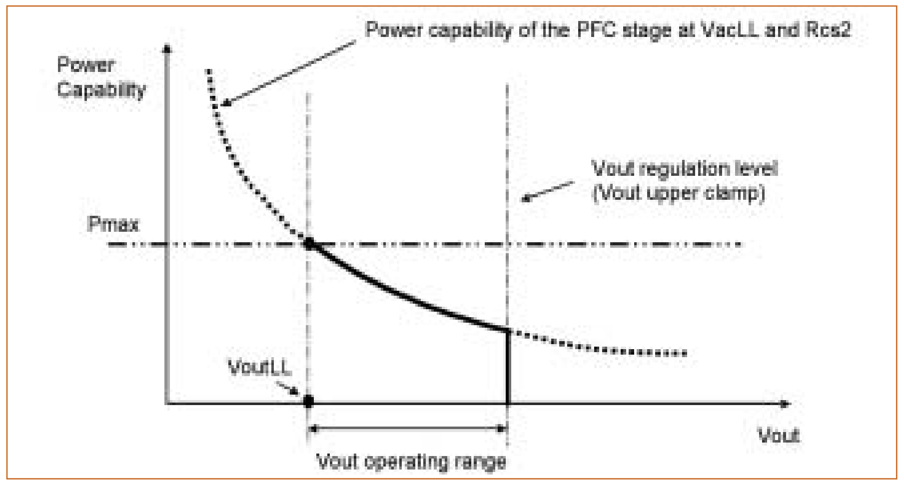

Figure 2. Power capability of the PFC stage as a function of the output voltage level.

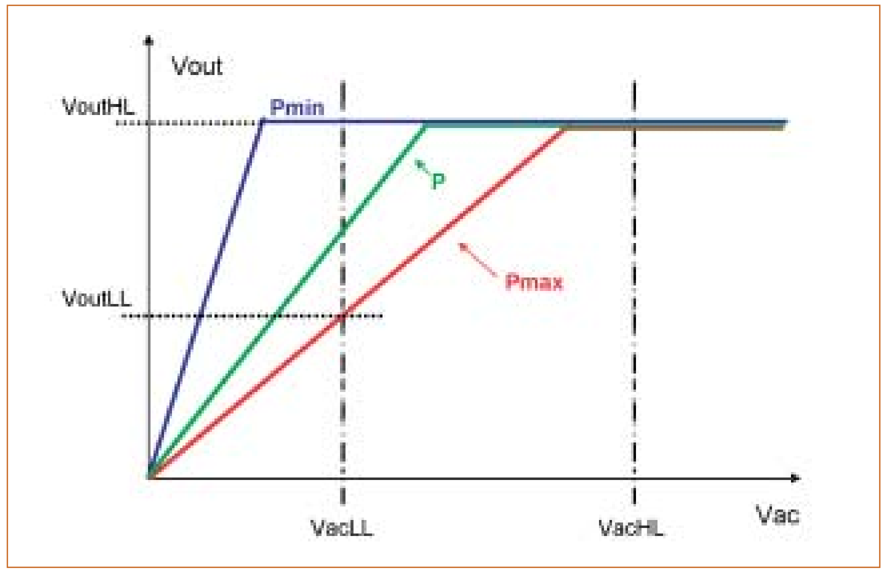

Figure 3. Follower boost Characteristic.

Vac=110V		Follower Boost			Traditional Mode	
Pin (W)	Vout (V)	eff (%)	THD (%)	Vout (V)	eff (%)	THD (%)
86	384	89	11	385	91	10
164	378	92	6	380	92	7
288	337	94	4	374	93	4
330	282	94	6	370	93	4

Vac=220V		Follower Boost			Traditional Mode	
Pin (W)	Vout (V)	eff (%)	THD (%)	Vout (V)	eff (%)	THD (%)
82	386	94	19	387	92	14
123	385	94	16	387	95	11
163	384	94	14	386	93	9
220	382	95	11	386	95	8
310	371	96	9	385	95	9

Figure 4. Performance Comparison between Follower Boost and traditional mode.

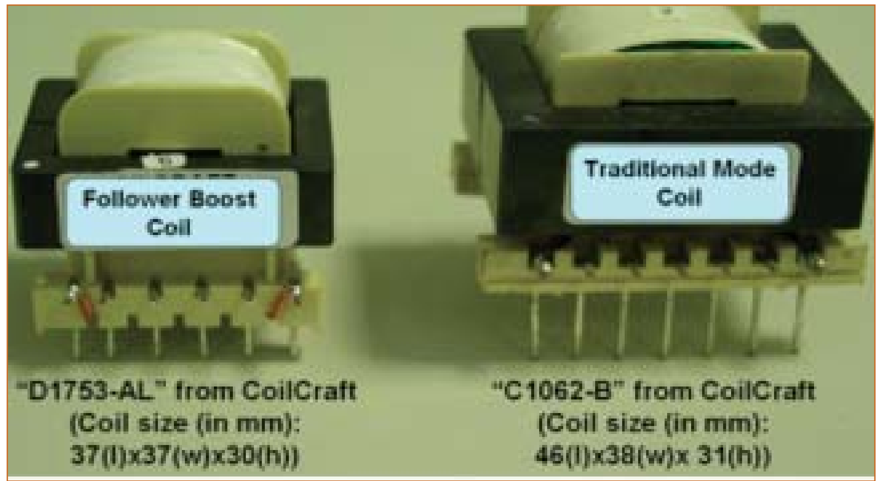

Figure 5. COILCRAFT coils used for the comparison.

Is it difficult to implement?

The design is straightforward:

- Download the NCP1653 design worksheet available at http://www.onsemi.com/pub/Collateral/NCP1653%20WORKSHEET..XLS
- You want to operate in tradition mode: enter the regulation level you target ("Vout") and enter the same value in the "VoutLL" cell and the Excel spreadsheet returns the maximum Rcs2 value you need to implement
- You want to implement the follower boost: select the minimum output voltage you can accept in your application and fill "VoutLL" accordingly. For instance, enter 200 V and the Excel spreadsheet gives you the Rcs2 value to implement.

That's it! In both cases, the Excel spreadsheet also computes the coil inductance and other key dimensioning elements.

Conclusion

The NCP1653 can operate in traditional mode. However, in applications where you can accept some variations of the output voltage, it features the follower boost mode (FB) that improves the efficiency and dramatically reduces both the size and the cost of the coil. The output voltage range is programmable: according to your needs, you can select a wide or a narrow spread. The NCP1653 worksheet (that is available on the web - refer to http://www.onsemi.com/pub/Collateral/NCP1653%20WORKSHEET..XLS) automatically computes the value of the single resistor that adjusts your target FB characteristic.

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Fully Clamped MOSFET for Cordless Power Drills

An active voltage clamp has been developed

The MOSFET was analyzed under the most severe condition for the system, that is, at locked rotor. Then the circuit was powered with an input DC voltage of 18V and all the measurements were performed with the device mounted on its original arrangement.

By Rosario Gulino, STMicroelectronics

To improve the performances of a power drill, a new MOSFET by ST with. Based on the well proven Mesh Overlay Strip Process, the latest version of "NS" series has achieved a very high performance in terms of ruggedness and thermal behaviour. The very simple "5-mask process" allows us to be competitive in the MOSFET market. In particular, the built-in Zener diode ensures exceptional robustness against voltage spikes, and withstands repetitive inductive switching current avoiding operation in breakdown mode.

Cordless power drills

The cordless drill is ideal when there is no power supply nearby. Hand-held power tools have become essential equipment of the modern handyman's and contractors' toolbox. Power drills are the most purchased hand-held power tools. There are various types available on the market working at different voltages, variable speeds, chuck sizes, torque settings and recharge times.

Some power drills also incorporate a hammer action facility, mechanical gears and a quick stop brake. Properly adjusted on identical scrap material, a clutch allows you to have control on the screw avoiding going too deep. This is a very important feature for beginners.

A reversible drill is a must if one plans on using the drill with screwdriver bits. Figure 1 shows the topology of a cordless drill powered by a battery.

The controller is made up of a very simple PWM. The PWM and, as a consequence, the rotation speed are controlled through approximately seven steps in a discontinuous mode. The last step makes the motor spin at full speed in which case the MOSFET is short-circuited by a mechanical switch. No feedback loop has been introduced to control speed and torque.

The circuit is supplied typically by a 20V rechargeable battery. The system works in three different ways depending on the operation to be achieved.

When the motor is in off-state, the battery is disconnected from the circuit. When the motor has to run at variable speed, the battery is connected to the board and the controller operates the switch by changing the duty cycle of the driving signal, thus regulating the speed of the motor.

In the operation mode, when the motor runs at full speed, no current flows through the switch and the battery is connected directly to the motor.

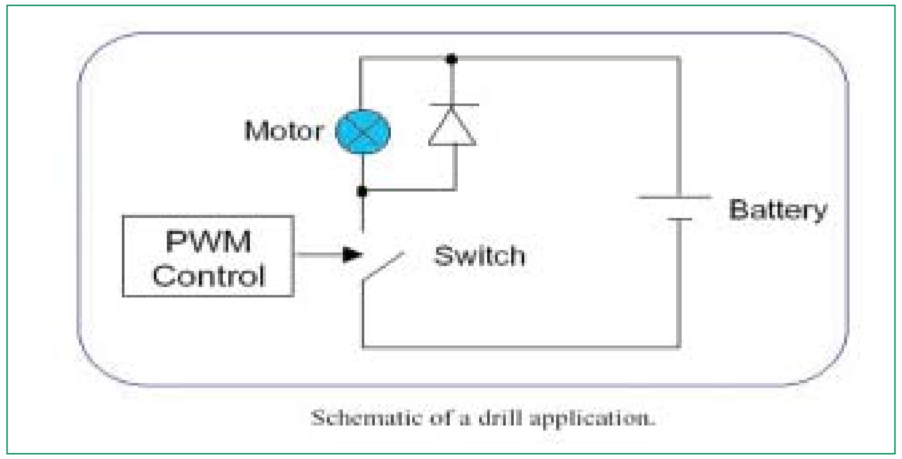

Figure 1. Schematic of a cordless power drill.

P/N	I_D [A]	BV_{DSS} [V]	R_{DSON} max [mOhm]	Package
STP75NF75	75	75	11	TO-220
STP60NF06	60	60	16	TO-220
STP62NS04Z	62	40 clamped	15	TO-220

Table 1. Main characteristics of MOSFETs at 25°C ambient temperature.

P/N	Energy at turn-off [mJ]	Energy at turn-on [mJ]	Conduction energy [mJ]	Total Energy [mJ]
STP75NF75	4.70	2.35	9.47	16.52
STP60NF06	3.85	2.24	11.35	17.44
STP62NS04Z	3.63	1.24	14.56	19.43

Table 2. Summary of the results of the tests performed on a power drill.

Another type of operation is characterized by a locked rotor; such condition is the most severe for the power device due to the amplitude of the current through the motor and through the MOSFET itself. To avoid that the energy stored in the winding of the motor is discharged through the MOSFET a freewheeling power diode is inserted across the motor.

MOSFET requirements

Since a drill is powered by a 20V battery, to avoid the operation in breakdown mode it is necessary to use a low voltage MOSFET with a breakdown voltage higher than 55V – 60V. 75V devices are required when the battery voltage is higher than 20V. In Table 1 the main characteristics of three different devices are shown.

These MOSFETs are the most popular ST's devices used in a power drill application. When using the STP62NS04Z the drain voltage is clamped at turn-off, therefore, it is possible to employ MOSFETs with breakdown voltages lower than those of standard devices that at given voltage would work in avalanche. In turn this implies the possibility of using lower on-resistance products and this advantage can be translated in terms of conduction losses during the operation. Since the integrated drain to gate Zener diode has an intrinsic breakdown voltage (V_Z) lower than its BV_{DSS}, the clamped MOSFET will never go in breakdown. In fact, the V_{DS} voltage will be limited at V_Z and the MOSFET will work in linear mode.

On-board analysis

A way to characterize the devices' performance is to measure the energy losses of the MOSFET at each cycle of the operation. The circuit was analyzed under the most severe condition for the system, that is, at locked rotor. Then the circuit was powered with an input DC voltage of 18V and all the measurements were performed at ambient temperature (25°C) with the device mounted on its original arrangement. Under these conditions, our attention focused on parameters such as gate-to-source voltage V_{GS}, drain current Id and voltage across drain and source V_{DS}.

The figures below show the waveforms regarding the turn-off commutation for all three devices. The current flowing through the device during the locked rotor test is around 75A peak. During turn-off the drain voltage reaches about 52V for both devices, which is lower than the intrinsic breakdown voltage.

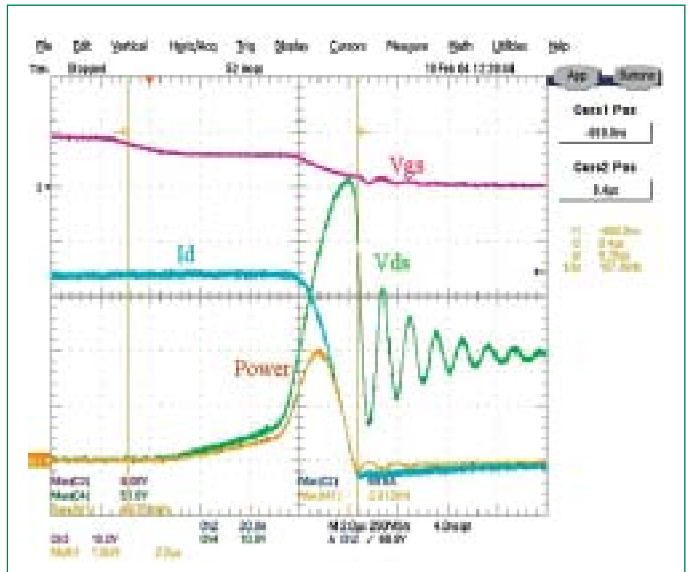

Figure 2. STP75NF75 turn-off waveforms.

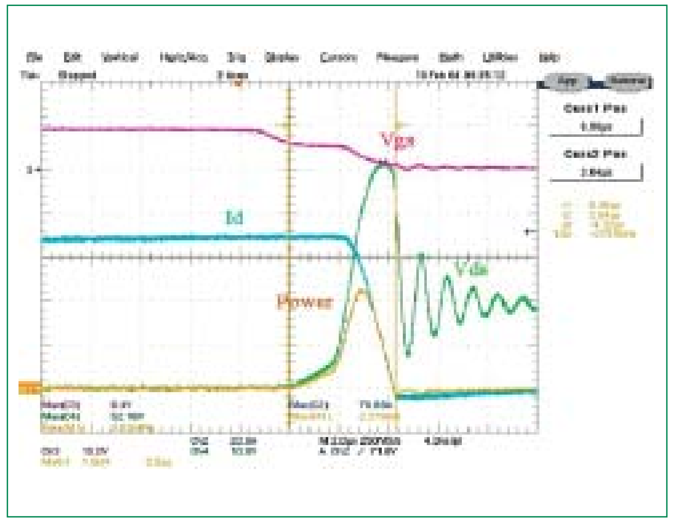

Figure 3. STP60NF06 turn-off waveforms.

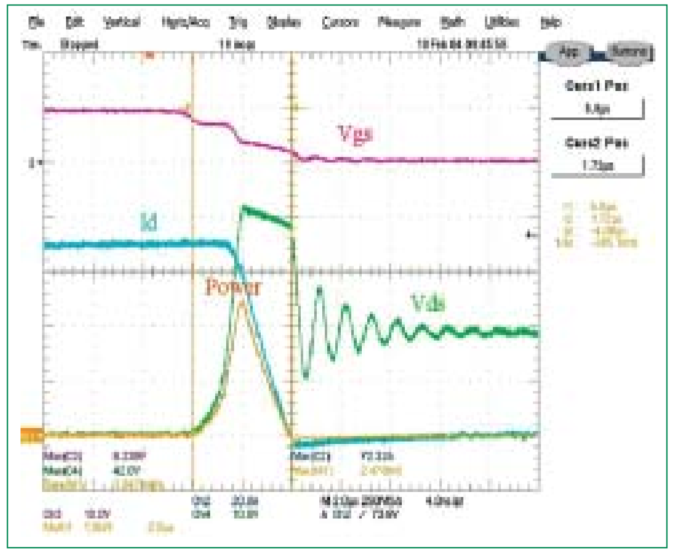

Figure 4. STP62NS04Z turn-off waveforms.

Comparing figures 2 and 3, it can be highlighted that the STP60NF06 device has lower turn-off energy losses than the STP75NF75.

As shown in figure 4, the STP62NS04Z exhibits an active clamp that makes the device turn on again when the drain voltage exceeds approximately 40V during the turn-off. Such kind of turn-off makes the device work in linear region every time the zener voltage is achieved.

The power loss during conduction has been calculated as: $P_{COND} = R_{DSON} \times I_{RMS\_}$, where the current is based on the steady state waveforms as: $I_{RMS} = 47A$.

Results and conclusions

The following table lists the summary of the results of the energy losses during the commutation of the power drill.

The analysis performed on the board proved that all devices work correctly and no problems were encountered. In the application, all devices show a comparable performance. When trying to deliberately destroy the devices during locked motor, it was found that the MOSFET was not the weakest component in the system, but the freewheeling diode and the winding of the motor itself tended to fail because of the high current during such an extreme operation.

In addition, it can be said that the new clamped STP62NS04Z is suitable for use in power tool applications. The total power dissipated is only slightly higher than that of the STP75NF75 (much bigger die) and even lower than that of the STP60NF06 that exhibits much higher losses especially during conduction due to the higher R_{DSON}.

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Power Systems Design EUROPE

Automotive Electronics

Part I

PowerMOSFET in Avalanche Mode

Thermal SPICE simulation

In the automotive segment there are many power electronic applications. Some are complex, such as ABS, ESP and EPS, others are simple DC motor controls such as window lifts and electrical seat adjustment. One trend common to all is the steady increase in the use of trench PowerMOSFET as the power switch.

By Stephan Rex, NEC Electronics

The use of a PowerMOSFET is can usually described by simple on/off switching, e.g. electric motors, or PWM (Pulse Width Modulation) switching if speed and torque control is required. Not only safety-relevant applications such as ABS and ESP, but all other applications demand highest reliability in the PowerMOSFET (AEC Q-101). Failure of the PowerMOSFET can affect the functioning of a whole system, and possibly of the vehicle, with obvious consequences for driving safety.

In applications with inductive loads undesirable side effects can occur. After the PowerMOSFET is switched off, the inductivity of the motor coils, or stray inductance, tends to sustain the current flow (Lorentz force). This can result in voltage peaks that exceed the maximum rated breakdown voltage BV_{DSS} and result in failure of the PowerMOSFET. The two most popular safeguards are the implementation of a simple free wheeling diode parallel to the inductive load or a snubber circuit.

Active clamp operation

With a snubber circuit, the Power MOSFET is often operated in active clamp mode. For a PowerMOSFET operated in clamped mode (see diagram) a Zener diode and a diode are switched between drain and gate. In the event of a voltage peak at the drain connection the Zener diode changes to low resistance which results in a voltage potential at the gate connection. This opens the PowerMOSFET and the energy from the inductivity can dissipate via the opened PowerMOSFET. The PowerMOSFET operates here in a normal conductive state. This operating mode results in only a minimal rise in junction temperature.

Under certain circumstances (space or cost considerations) it is not feasible to use additional devices. In this case, the PowerMOSFET must be rugged enough to withstand unexpected voltage over-stresses for a certain time and not be destroyed.

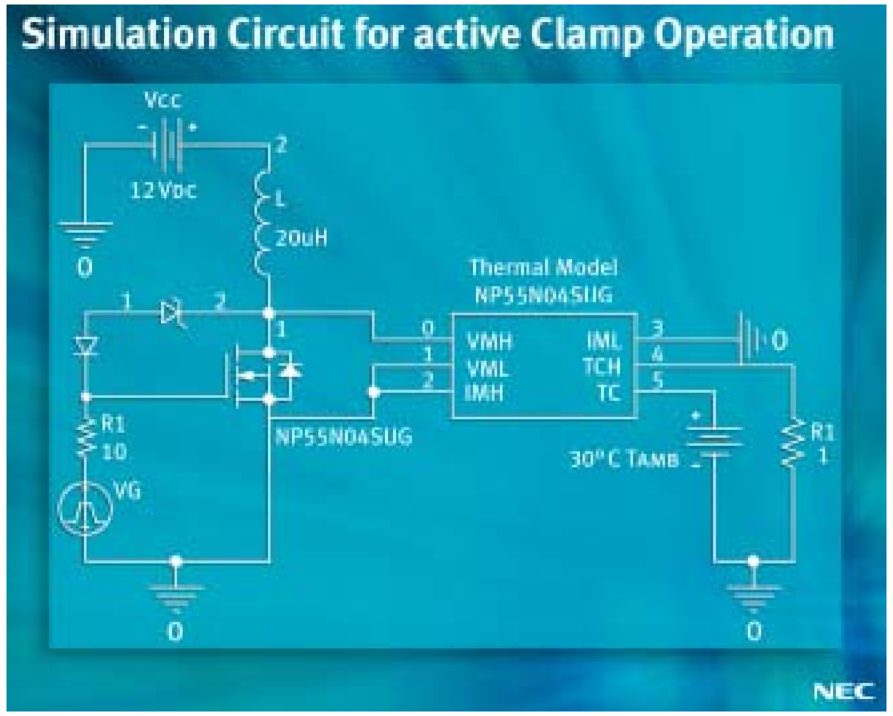

Figure 1. Simulation Circuit for active Clamp Operation.

Avalanche mode

Generally all semiconductor devices are dimensioned for a specific BV_{DSS}. If a component is operated at a higher than rated voltage, the result can be a higher electric field at the internal pn-junction. Due to impact ionization, the high electrical field causes electron-hole pairs to be formed. This multiplication effect is followed by a steep increase in current flow. The reverse current results in large power dissipation in the device, a rise in temperature and possible destruction of the device. Ruggedness in avalanche mode is defined by the capability of a PowerMOSFET to withstand a drain current in unclamped inductive switching (UIS) with a high drain-source voltage being applied at the same time.

Electrical behaviour in single-pulse mode

To appreciate the thermal behaviour in unclamped mode in detail, first the electrical and thermal behaviour of an NEC Electronics PowerMOSFET is described for single-pulse mode. A circuit diagram of an unclamped PowerMOSFET is shown top left in Figure 2. Here the inductivity stands for an arbitrary automotive application, for instance, a simple coil in a motor.

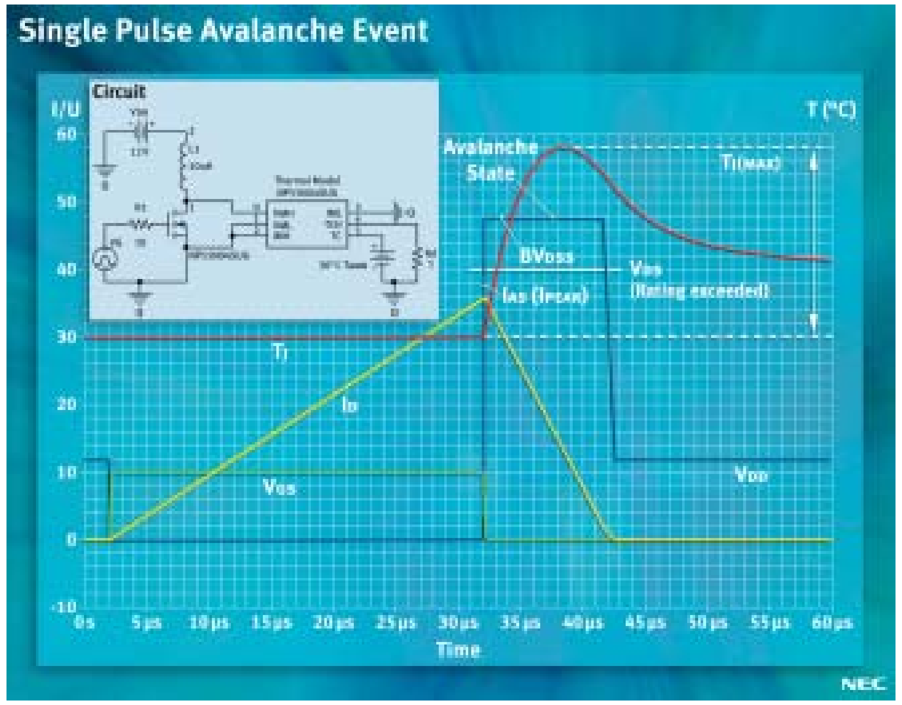

Figure 2. Single Pulse Avalanche Event.

The simulated results of the electrical and thermal behaviour are also shown in the diagram.

A voltage pulse v_{GS} is applied at the gate connection to switch on the PowerMOSFET. This increases the drain current i_D. The rise of i_D depends on the applied voltage v_{DS} and the inductivity L and results in the following relationship:

$$\frac{v_{DS}}{L}\cdot t = i_D$$

At the end of the voltage pulse v_{GS} the PowerMOSFET is switched off.

According to the Lorentz force the inductivity tends to maintain the current flow. At this time the PowerMOSFET is already highly resistive and the voltage across the transistor shoots up. The PowerMOSFET switches into avalanche mode. As soon as the stored energy (also known as avalanche energy E_{AS}) is dissipated in the inductivity, BV_{DSS}, usually given by $BV_{DSS} = 1.2 \times V_{DSS}$, drops again to V_{DD}.

E_{AS} depends largely on the maximum avalanche power $P_{AV(peack)}$ and the duration t_{AV} of the avalanche mode and can be defined as follows:

$$E_{AS} = \frac{P_{AV(peak)} \times t_{AV}}{2}$$

Note that P_{AV} takes the shape of a almost triangular pulse. $P_{AV(peack)}$ is a product of BV_{DSS} and i_D . The avalanche energy to be dissipated can by approximated by:

$$E_{AS} = \frac{L \times I_{AS}^2}{2} \times \frac{BV_{DSS}}{BV_{DSS} \times V_{DD}}$$

Thermal behaviour

Because of the thermal inertia of the PowerMOSFET, a higher dissipation loss is permissible both for repetitive and single-pulse loads in avalanche mode. The transient rise of T_j in avalanche mode can thus be computed as follows:

$$T_{jpuls}(\tau) = \int_0^{\tau} P_{AV}(t)\frac{dZ_{th(\tau-t)}}{dt}\,dt$$

T_j is directly proportional to the avalanche dissipation loss P_{AV} of the PowerMOSFET and the transient thermal impedance Z_{th}. Z_{th} must not be confused with the thermal resistance R_{th} and cannot be interpreted as the element of a thermal auxiliary circuit. It is merely a computed value for determining $T_{j(max)}$. After a pulse width t_{PW} the PowerMOSFET cools down completely. Alternatively, the maximum temperature rise after a single pulse can be approximated by the formula:

$$T_{j(max)} = T_{j(rise)(max)} + T_{amb} = \frac{1}{2} \times BV_{DSS} \times I_{AS} \times Z_{th(t_{AV}/2)} + T_{amb}$$

Often the significance of T_j is not given the attention it deserves. It is urgently recommended that manufacturers' specifications regarding $T_{j(max)}$ are not exceeded (175 °C for NEC's PowerMOSFET NP Series). Exceeding $T_{j(max)}$ can result in catastrophic failure of the PowerMOSFET!

Repetitive avalanche mode

Figure 2 shows the response of T_j as a function of time for repetitive single pulse avalanche mode. The property of T_j can be described as follows: In repetitive avalanche mode, the time between individual avalanche events is insufficient for the PowerMOSFET to return to ambient level. T_j is subject to different laws depending on the time period of the avalanche mode (not a pure exponential function). For a sufficiently short pulse duration t_{pw}, T_j rises only to a value T_{jmax}, which is less than the statistical value given by $P_{AV(peak)} \times R_{th}$ for a continuous load of $P_{AV(peack)}$. The avalanche energy required for T_j to rise to the maximum permissible value after each pulse is always smaller than for single-shot operation. Computing the temperature response in the case of several consecutive pulses requires additional parameters such as frequency f and duty cycle D to be taken into consideration.

In general, the following conclusion can be drawn from the simulation results: the shorter the pulse width t_{PW} and the lower f, the lower will be T_j in steady state compared with the statistical value $P_{AV(peak)} \times R_{th}$. Obviously this applies only if the package temperature remains constant. The average steady-state junction temperature $T_{j(average)}$ can be approximated by:

$$T_{j(average)} \approx T_{amb} + P_{average} \times Z_{th(j-amb)}$$

where the average power loss $P_{average}$ can be deduced from the formula:

$$P_{average} = E_{AR} \times f$$

E_{AR} is the repetitive avalanche energy that is converted to heat in avalanche mode. Normally the power loss is made up of several individual components such as switching losses, gate losses and power losses that occur when the PowerMOSFET is switched on, or losses owing to leakage currents. These components, however, play only a subordinate role in the computation of $P_{average}$ and will be neglected for calculation this time. Of course, NEC models used for PSPICE simulation will always consider all kind of power losses.

Because the time constant of T_j depends on several internal heat capacities (such as cooling paste, cooling body, die thickness or the lead frame used), it is not only difficult but virtually impossible to calculate the exact thermal behaviour. It is possible to approximate the thermal behaviour, but in doing so a number of other factors have to be considered. Firstly, computed temperature $T_{j(average)}$ is an average value and not the actual maximum junction temperature

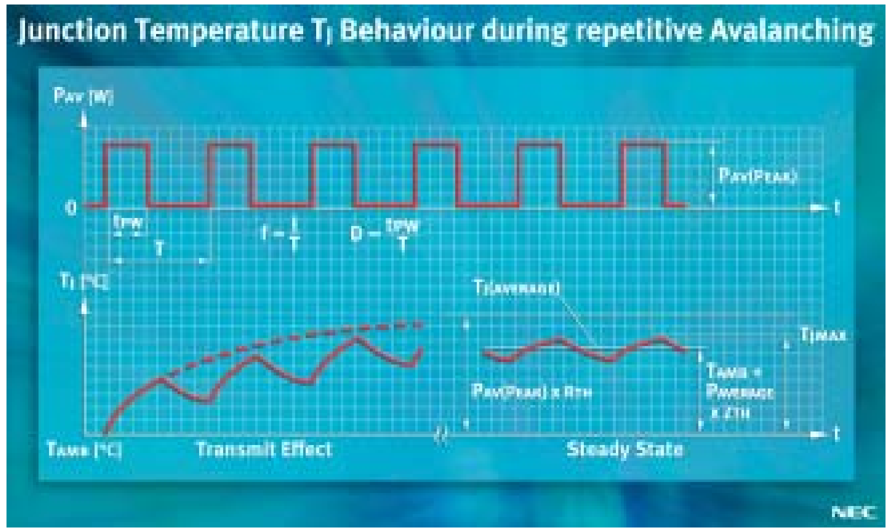

Figure 3. Junction Temperature Tj Behaviour during repetitive Avalanching.

T_{jmax}. Secondly, the approximation of $T_{j(average)}$ does not take into account the point in time at which steady-state operation is reached. Moreover, for some applications it is not necessary to dimension a PowerMOSFET for steady-state operation, because a sequence of a few pulses only results in a minimal increase in T_j and steady-state operation is not a consideration. In short, the questions that need to be answered are how long does it take the PowerMOSFET to cool down again to ambient temperature and how high is the temperature increase after, say, three pulses?

Conclusion

NEC Electronics' electrical and thermal SPICE models offer a simple and time-saving method of estimating the performance characteristics of a NEC PowerMOSFET in avalanche mode. This is important in order to gauge its reliability more accurately. The models make it a simple matter to obtain an overview of different design variants and especially to confirm particular design options.

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OLED – Emerging Display Technology

Power supply requirements and solutions

Advanced displays are becoming an important feature in today's automotive and consumer electronics. Frequently, seeing these innovative displays in action help reinforce a user's perception of a product. The perception ultimately leads to how successful the product will be in the marketplace.

By Oliver Nachbaur, Texas Instruments

This user perception is especially important for portable equipment like mobile phones and pocket PCs, where full-color, high-resolution displays are becoming a must. New display technologies gaining market share include the emerging **organic light emitting diode** (OLED) display with its excellent contrast ratio, fast response time and wide-viewing angle. As with any new technology, different solutions are being evaluated and manufactured using different LED materials (polymer or small molecules), active or passive matrix control, current and voltage drive technologies, and different bias power supply circuits. This paper will discuss various OLED technologies and appropriate bias power supply circuits. The decision about the OLED technology and driving methodology will also drive the requirement for the power supply circuit. The challenge is selecting the most appropriate power supply circuit supporting the requirements for a portable battery-powered device and the specific OLED display.

OLED technology advantages and disadvantages

Wide viewing angle and high color saturation are strong advantages for OLED displays over technologies like liquid crystal displays (LCDs). In addition, the OLED display does not require a backlight, since it is a self-emitting technology. It also provides faster response time than LCD for multimedia applications. Currently, two OLED materials are used in the market: the small molecule and the light emitting polymer. Both technologies have similar electrical parameters compared to the standard light emitting diode (LED). The emitted light depends on the forward bias current of the LED, whereas the LCD depends on the pixel brightness, dependant on the voltage applied across the pixel. Another advantage of the OLED display is the possibility of using an existing backplane technology, which is the same as for the thin film transistor (TFT) LCD. An active matrix OLED display can use either an amorphous silicon (a-Si) or low temperature polysilicon (LTPS) TFT backplane.

One of the main challenges for existing OLED technology is its lifetime, which is limited due to the differential aging of the RGB (red, green, blue) colors. This is especially an issue when most of the display content is the white color requiring all the three RGB colors at the same time with equal luminance. Because of these color requirements, the first displays on the market were monochrome. Full-color displays were used only for applications when the display was turned-off for most of the product's lifetime. One of the first full-color displays was implemented in a digital still camera. However, for battery-powered portable equipment, full-color displays are still an issue. The OLED display has to compete with the LCD for power consumption. In cases where the LCD does not require a backlight, the LCD power consumption is much lower compared to an OLED display. When the LCD backlight is on, it depends again on the display content whether the OLED requires more power or not. When most of the display content is white, the OLED display still requires more power compared to the LCD, but this becomes less of an issue when the "white" picture content goes down. Another challenge is when the OLED is used outdoors. When outdoors, the contrast goes down and the readability suffers because the OLED technology emits light in response to the photons.

At present, the disadvantages of OLED displays make them more suitable for small displays used in portable devices, but as the technology matures they will be used for larger displays as well. Notebook or monitor displays likely remain too challenging for OLEDs in the near future because of the different aging of the RGB colors when displaying a large amount of "white" picture content. However, the future of OLED technology looks promising for TV panel applications, which do not have large amounts of "white" picture content.

AUTOMOTIVE ELECTRONICS: PART I

Passive matrix displays require single supply boost converter

Currently, the passive matrix (PM) OLED displays, ranging in size from one-to-two inches, dominate the market and are used mainly in mobile phones, with the majority being used for the sub-display of a clamshell phone. These monochrome or two color passive matrix displays are ideal candidates for the still emerging OLED technology. Figure 1 shows a simplified implementation of such a display. The addressing scheme is fairly similar to the PM of a standard LCD, with the main difference being the OLED is a current-programmed device. Therefore the display driver will be different than an LCD driver circuit.

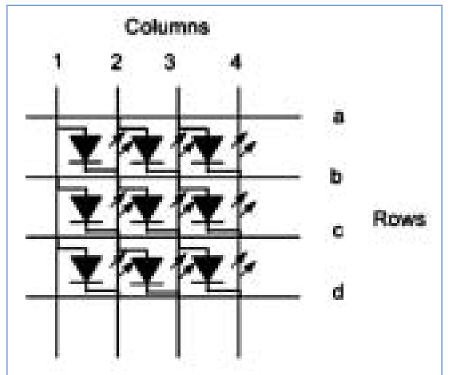

Figure 1. Simplified Passive Matrix OLED configuration.

The required power or bias supply itself for a passive matrix OLED display demands a single positive voltage rail very similar to the PM LCD. The main requirements are low power consumption, high efficiency and small solution size. Since the required supply voltage rail for the OLED driver is in the range of 15 V to 20 V, depending on the display size and resolution, an inductive boost converter is the best solution. A possible solution is shown in Figure 2 using the TPS61045.

An additional requirement to the OLED bias power supply is the input-to-output isolation, which is important when a power supply is selected. A standard boost converter uses an external Schottky diode which provides a direct path from the input to the output and causes the output voltage to be around the same value as the input voltage.

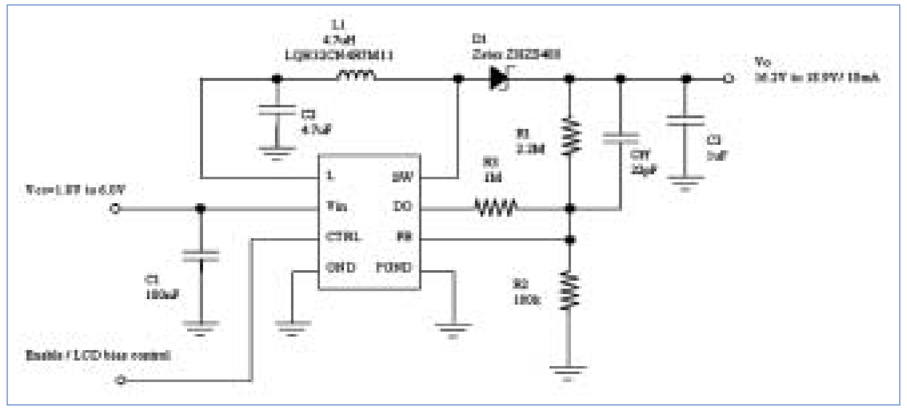

Figure 2. Boost converter providing input to output isolation for OLED Displays.

This becomes a problem when power up and down sequencing is needed and when the leakage current during the "off" mode needs to be minimized. The device shown in Figure 2 disconnects the input from the output using an internal MOSFET switch.

Active matrix displays require positive and negative bias power supply

When higher resolution, display size, higher contrast and fast response time is required, an active matrix (AM) OLED display is used, as shown in Figure 3.

The active switch that turns "on" and addresses the OLED pixel is a thin film transistor (TFT) which is built with the same technology as a TFT LCD display. The current source is simplified by just having one MOSFET in series with the OLED. Some of the implementations use a voltage programming structure and some a current programming structure. All implementations require several TFTs ranging from two up to four and more integrated TFTs. To overcome the different aging of the OLED pixel colors, some solutions integrate a phototransistor to program a higher OLED current to avoid fading of the pixel brightness. Using a low temperature polysilicon (LTPS) backplane with its lower feature size is an advantage when implementing more active components. Currently both technologies, LTPS and amorphous ploysilicon, are being used for the backplane.

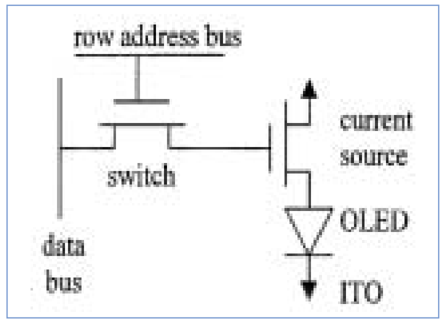

Figure 3. Simplified Active Matrix OLED Display.

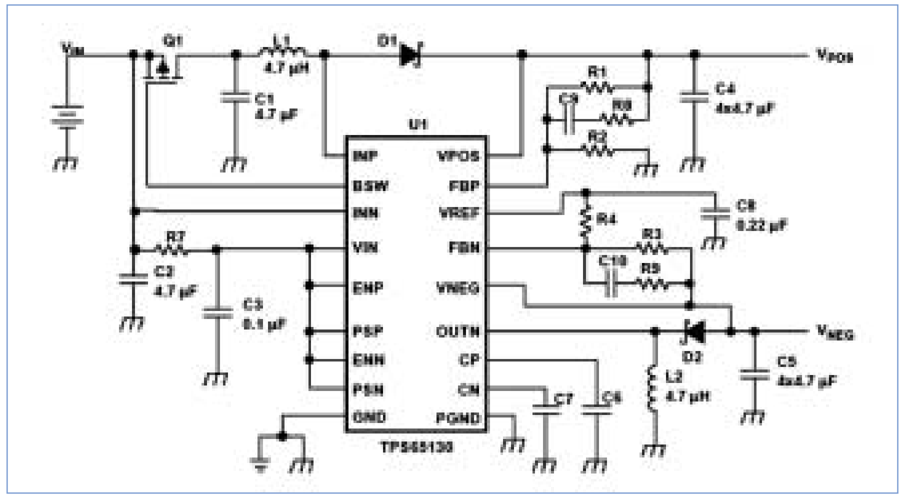

Figure 4. Single IC provides positive and negative voltage rail.

The LCD bias power supply circuit for the AM OLED display has to provide a positive and negative voltage to power the video signal driver as well as provide the bias voltage to turn the row select TFT "on" and "off". Because of the high bias voltages, an inductive boost converter is the most appropriate solution. To minimize the solution size, a fully-integrated boost converter providing the positive rail and an inverter providing the negative rail is used in Figure 4 with the TPS65130.

To minimize leakage current during shutdown and to allow sequencing for the positive rail, a small external MOSFET in a SOT-23 or smaller package is controlled by the IC of Figure 4. The device in Figure 4 operates from a Li-Ion battery (2.7 V to 5.5 V) and provides output voltages up to +15 V and -15 V with an integrated 800-mA/2-A switch current limit. This allows output currents up to 200 mA. To power the OLED display, a small output voltage ripple and fixed switch frequency is important in order to minimize cross-coupling and distortion of the OLED display image. Therefore, the TPS6513x, with its fixed frequency, 1.38-MHz pulse-width modulation is ideal for powering OLED displays. While a tightly regulated output voltage over the entire load current range is especially important for voltage-driven OLED displays, it is less of a problem for current-driven OLED displays. Some displays require higher OLED currents when used outdoors and lower current when used indoors, and require high-efficiency over a wide load-current range. Since a standard boost converter operates only at its optimum efficiency for its targeted load current, the TPS65130 offers a user-selectable "power save mode" where switching frequency and quiescent current is reduced to maintain high efficiency over the entire load-current range.

Conclusions

OLED technology will capture more and more market share as the technology matures. It has large opportunities in mobile phones, digital still cameras and pocket PC displays. Active matrix displays will likely outpace the market currently dominated by passive matrix displays. At the same time, the OLED display drivers will become more advanced and the miniaturization and specialization of the OLED bias power supply circuit will occur as some of the solutions presented in this article has discussed. For the power supply IC technology, the main challenge is to provide high efficiency and smallest solution size at the same time.

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To Integrate or Not to Integrate?

Smart partitioning of functions yields smarter integrated power devices.

The advancements in power semiconductor device technology and power packaging are different from the advancements of integrated circuits. Benefits can be achieved from knowing when and where to partition the different functions of power and signal processing.

By Alexander Craig Staff, Applications Engineer, Fairchild Semiconductor

This is particularly evident in automotive applications where more complex power devices are needed. The terms “smart power” and “integrated power devices” have become overused and poorly defined. For this discussion “smart power” devices or “integrated power devices” will refer to the function and not the technology of the device. In this paper “smart power” or “integrated power devices” are devices that, from a packaged device standpoint, perform both signal processing and power processing. These devices may be simple and offer only logic level feedback to a signal processing device as to the state of the load or the device. Or these devices could be as complex as a complete power converter without the energy storage devices.

The traditional “smart power” or “integrated power devices” use a BiCDMOS process that combines bipolar, CMOS and DMOS devices on one integrated circuit. This process is sufficient for many applications. But with the advancements in power device technologies, the power handling capability of the BiCDMOS process is not as efficient as the new power devices when dealing with larger currents and voltages, or when the space and heat sinking are minimized. The drawback of new power device technologies is that only limited signal processing (non-power) functions can be economically added.

“Smart power” or “integrated power devices” have a wide range of signal processing functions, but the signal processing functions are generally limited and simple when compared with signal processing ICs. For this purpose a “smart power” device is first and foremost a power device. Hence, the basic issues for these devices are similar to those of power devices: heat, flexibility and performance.

Heat

Heat generated by semiconductors cause junction temperatures to rise, which can cause semiconductors to operate in an unsafe environment. Heat removal in a small space is a key issue in most designs. This issue can be dealt with by improving the thermal conduction on the final product or as is done in many designs by simply not generating the heat in the first place. In order to not generate the heat, one needs to use the lowest power loss (heat generating) devices that the footprint (board space) will allow. Equation 1 outlines the relationship between heat generation and junction temperature.

Equation 1:

ΔT= Rth {(Von x Ion)+ (∫ V(t) x I(t) dt)f}

The (Von x Ion) term represents the On-State Component of the device power dissipation and is improved by the reduction of $R_{DS(ON)}$ in power MOSFETs, $V_{CE(SAT)}$ in IGBTs.

The (∫ V(t) x I(t) dt)f, term represents the switching losses or energy absorption power loss such as SCIS, UIS or linear operation. The Rth term represents the thermal resistance junction to ambient.

Two basic power MOSFET structures are used today. The Planar MOSFET and Trench MOSFET are shown in Figure 1.

The MOSFET on resistance can be divided into its major components as illustrated here in Equation 2 & 3.

Equation 2:

RDS(ON) = RChannel + RJFET + REpitaxial + RPackage for a Planar power MOSFET

Equation 3:

RDS(ON) = RChannel + REpitaxial + RPackage for a Trench power MOSFET

The Channel resistance is represented by Equation 4.

Equation 4:

RChannel = L/(W*m*Cox(Vg-Vth))
(Where W and L are width and length of the channel and _ is the surface mobility of electrons.)

The specific resistance for a MOSFET is the on-resistance per unit area of silicon. The specific resistance is a good measure for understanding different technologies. For example the 30 volt Power MOSFET specific resistance trend is shown in Figure 2.

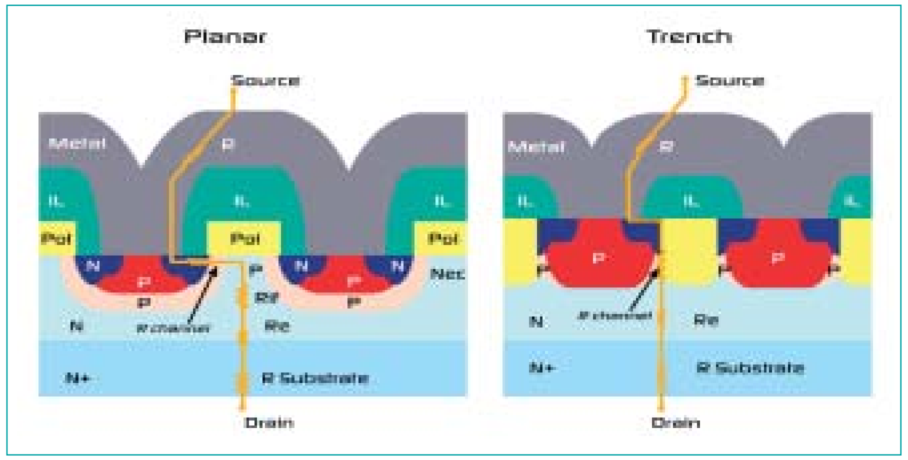

Figure 1. Planar and Trench structures in MOSFETs.

While planar devices have advanced by using smaller geometries and packing the cells closer together, the trench device takes that one step further and places the channel perpendicular to the surface of the device. This placement allows for closer packing of the cells as well as the elimination of some other resistances, notably the “JFET” resistance, and the reduction of the “epi” resistance, as can be seen by the difference between Equations 2 & 3. The onset of trench structures and the resulting improvements in this technology is shown in blue. For an example of specific on resistance limitations of the BiCDMOS process, one needs to understand that several types of integrated power devices are used in monolithic smart power devices. In lateral power devices the drain and source regions are laid out in alternating rows on the die. Quasi-vertical power devices have a vertical MOSFET, but require a termination back to the surface of the silicon. On a normalized basis the leading edge 30v PowerTrench technologies have a specific on resistance of 1.0. A leading edge 30v BiCDMOS power IC process has a specific on resistance of 1.4 X. Once one adds the dual layer interconnect resistance to the MOS device, the driver’s specific on resistance can climb to over 3X that of the discrete device. This biases the BiCDMOS process for applications where fairly complex signal processing functions and lower power handling are required or where the thermal path is such that it can keep the device cool regardless in the generated heat. For example, a device with fairly complex signal processing functions and lower power handling requirements is the FSD210B, which is a single chip 700V SenseFET Power Switch in a 7 lead DIP with a PWM controller and the features including a fixed oscillator with frequency modulation for reduced EMI, Under Voltage Lock Out (UVLO) protection,an auto-restart function for limiting output power during fault conditions, Leading Edge Blanking (LEB) for blanking an unexpected current surge during Sense FETs turn on, several protection circuits such as Over Load Protection (OLP), pulse by pulse current limit, and Thermal Shutdown Protection (TSD), an optimized gate turn-on/turn-off driver, temperature compensated precision current sources for loop compensation, and fault protection circuitry.

For devices that are primarily handling power with limited signal processing, the power process alone will often work. Figure 3 shows a simple function such as a drain to source voltage feedback signal and a gate drive disable control function. This architecture is often needed in automotive injectors and solenoid drivers. The FDSS2407 shown in Figure 4 is a 62V, 132mΩ, 5V Logic Level Gate Dual MOSFET in SO-8 with a 5V logic level feedback signal of the drain to source voltage. Multiple devices can be wired “OR’d” to a single monitoring circuit input. The gate disable function allows the device to be turned off independently of the drive signal on the gate. This function permits a second control circuit the ability to deactivate the load if necessary. It can also be wired “OR’d” allowing multiple devices to be controlled by a single open collector/drain control transistor.

The Power MOSFET die contains these limited functions in silicon as shown in Figure 5.

If a device must have both a high degree of signal and power processing, it is more efficient to split up the silicon into separate signal processing and power processing devices. An example of this is the FDMS2380 shown in Figure 6. This device is a dual intelligent low side driver with a built in recirculation and demagnetization circuits designed specifically for driving inductive loads. The inputs are CMOS compatible. The diagnostic output provides an indication of open load and demagnetization mode. Built-in over-current, over-voltage and over-temperature circuits protect the device. In case of over-current, or over temperature, this product will automatically operate in freewheeling recirculation mode for inductive loads.

In Figure 6, four power die and two high performance BiCMOS control die are combined in a PQFN package. This package allows direct access to the metal lead frame for low thermal impedance and uses both small gold bond wires, hence small bond pads, for

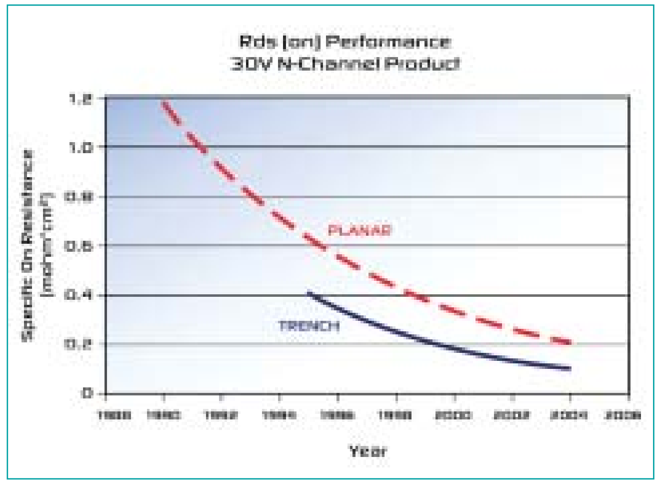

Figure 2. Rds(on) Performance 30 V N Channel Product.

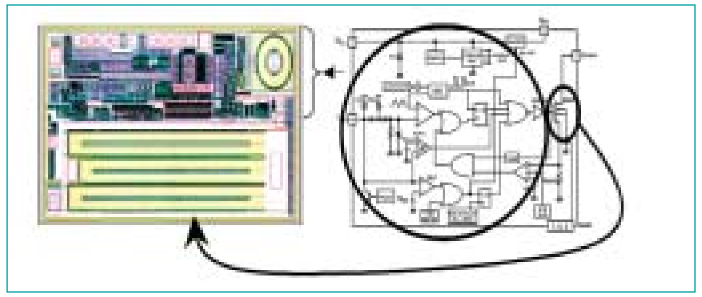

Figure 3. Single chip 700V SenseFET Power Switch in a7 lead DIP.

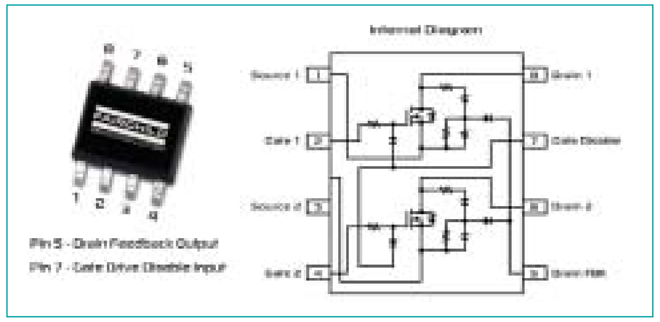

Figure 4. Logic Level Gate Dual MOSFET in SO-8 with a 5V logic level feedback signal.

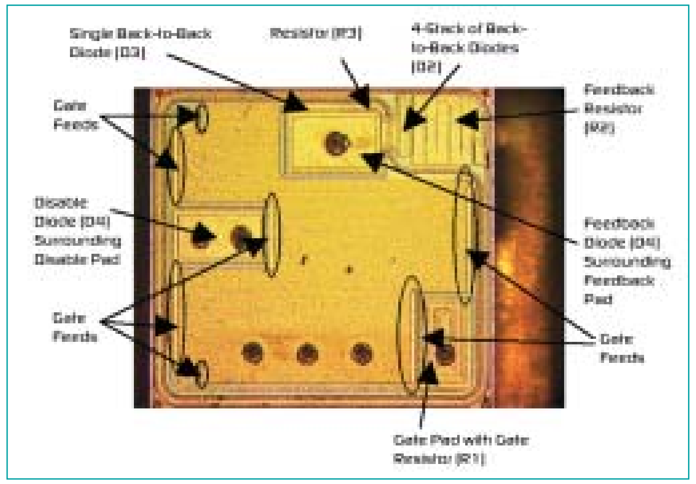

Figure 5. Die picture of the Logic Level Gate Dual MOSFET.

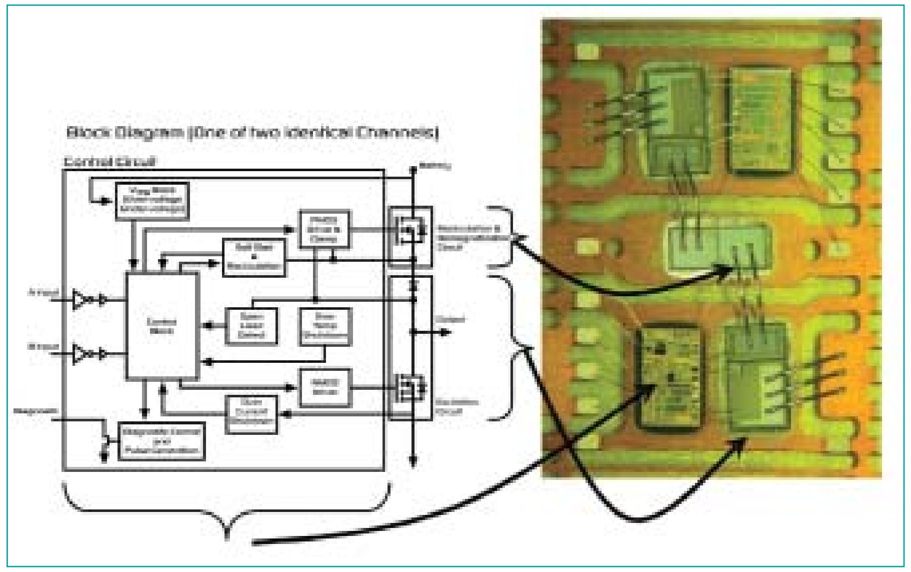

Figure 6. Power die and BiCMOS control die are combined in a PQFN package.

signal lines and large aluminum bond wires for current handling capability. To achieve the desired thermal resistance and die configuration both solder and non-conductive epoxy die attach is used.

Flexibility

Most automotive designs are somewhat customized, yet automotive system designers are under constant pressure to reduce design cycle time. Traditional "smart power" monolithic technologies have complicated fabrication processes, which reduce the speed and flexibility of developing new devices. Since a monolithic development needs to make both power and signal processing on the same fabrication process, iterative designs can be costly and slow. With a multi-chip smart power technology the power and signal device development can occur in parallel. This enables faster development of new products optimized for a customer application. Often an IC Process is optimized for driver functions only (not power), and while the IC portion may stay the same, the power handling requirements often vary. Use of the latest generation power technologies can expand system life by migrating the power section to the latest power technologies.

Performance

Lower $R_{DS(ON)}$ products are needed for less power loss. Low $R_{DS(ON)}$ means less voltage drop across the switch to measure at a given current. Any noise in the measurement method makes accurate measurement difficult. Reduction of noise and accurate sensing of load conditions are important considerations in automotive module design. Multi-die "smart power" devices allow for more accurate measurement of low voltage drops and low currents. With a multi-chip smart power technology excellent isolation between the power and the control silicon is provided. This isolation improves product ruggedness and reliability particularly in harsh electrical environments.

In conclusion

When a function requires a high degree of signal processing capability and a low degree of power performance, a monolithic BiCDMOS process is often the best choice.

When a device that requires a low degree of signal processing capability and a high degree of power performance, a monolithic power process is often the best choice.

When a function requires a high degree of signal processing capability and a high degree of power performance, complex "functional power" solutions can be developed through the use of state-of-the-art power silicon, high performance BiCMOS control functions and new power packaging approaches.

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Automotive & Industrial Applications

High Performance Analog Solutions from Linear Technology

High Input Voltage Monolithic Switcher Provides Continuous 5V from a 4V to 60V Input Using a Single Inductor

Electronic systems must perform under very stringent power requirements in automotive systems. These include load-dump, cold-crank, very low power consumption at light loads and low-noise operation. Additionally, footprints must be very compact and thermally efficient. Linear Technology has developed an entire family of products targeted specifically to meet these demanding requirements.

"Cold Crank" is a condition that occurs when the car's engine is subjected to cold/freezing temperatures for a period of time. The engine oil gets very viscous and requires the starter motor to deliver more torque, in turn demanding more current from the battery. This large current load can pull the battery/primary bus voltage as low as 4V. Upon ignition, it typically returns to a nominal 13.8V. The problem arises when certain subsystems require a constant well regulated 5V output throughout this cold-crank condition. These applications include Engine Control Units (ECU), environmental and emergency system microprocessors which are critical to the car's reliable performance. Traditionally, these requirements were fulfilled by a dual inductor SEPIC (Single Ended Primary Inductor Coupling) DC/DC converter. The disadvantages of a SEPIC topology include a dual inductor configuration which is both costly and physically large and efficiencies in the low 70% range.

Linear Technology's LT®3433 is a high voltage monolithic DC/DC converter that incorporates two switch elements, allowing for a unique topology that accommodates both step-up and step-down conversion using a single inductor.

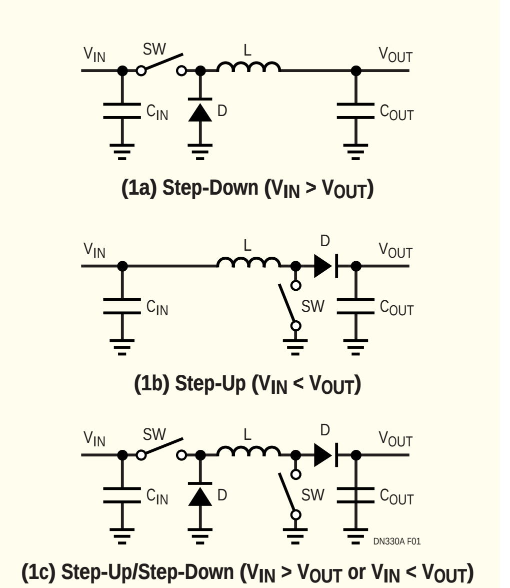

Figure 1. The LT3433 Merges the Elements of Step-Up and Step-Down DC/DC Converters

The LT3433 uses a 200kHz constant frequency, current mode architecture and operates with input voltages from 4V to 60V. An internal 1% accurate voltage reference allows programming of precision output voltages up to 20V using an external resistor divider. Burst Mode® operation improves efficiencies during light-load conditions, reducing the device's quiescent current to 100µA during no-load conditions. A soft-start feature reduces output overshoot and inrush currents during start-up. Both current limit foldback and frequency foldback are employed to control inductor current runaway during start-up and short-circuit conditions.

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Automotive & Industrial Applications

The LT3433 is available in a 16-pin TSSOP exposed pad package which provides a small footprint and excellent thermal characteristics. When the converter input voltage is significantly higher than the output voltage, the LT3433 operates as a modified buck converter using a boosted-drive high side switch. If the converter input voltage becomes close enough to the output voltage to require a duty cycle greater than 75% in buck mode, the LT3433 automatically enables a second switch. This second switch pulls the output side of the switched inductor to ground during the "switch on" time, creating a bridged switching configuration.

During bridged switching, the LT3433 merges the elements of buck and boost DC/DC converters as shown in Figure 1. In the simplest terms, a buck DC/DC converter switches the V_{IN} side of the inductor, while a boost converter switches the V_{OUT} side of the inductor. Combining the elements of both topologies achieves both step-up and step-down functionality using a single inductor, so voltage conversion can continue when V_{IN} approaches or is less than V_{OUT}.

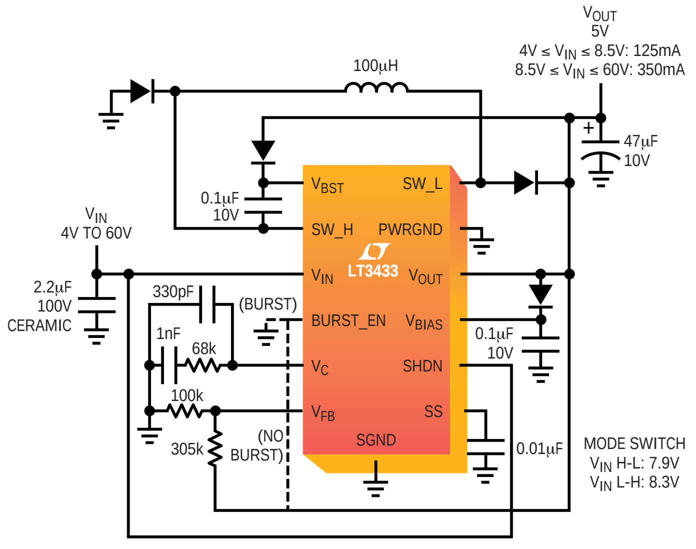


Figure 2. 4V to 60V input to 5V DC/DC Converter

4V to 60V Input to 5V Output DC/DC Automotive Converter

A 4V to 60V input to 5V output DC/DC converter is shown in Figure 2. This converter is well suited for 12V automotive battery applications, maintaining output voltage regulation with battery line voltages from 4V cold-crank through 60V load dump. The threshold for bridged mode operation is about 8V, so the converter will normally operate in buck mode. During buck operation, this converter can provide load currents up to 350mA with input voltages up to 60V. Operating with a nominal 13.8V input, the LT3433 accommodates loads of 400mA and produces efficiencies up to 82% (Figure 3). When the input voltage drops below 8V, the converter switches into bridged operation to maintain output voltage regulation. Because the LT3433 switch current limit is fixed, converter load capability is reduced while operating in bridged mode. With an input of 4V, the converter accommodates loads up to 125mA. Not only does the LT3433 converter operate across a large range of DC input voltages, but it also maintains tight output regulation during input transients. When subjected to a 1ms 13.8V to 4V input transition to simulate a cold-crank condition, regulation is maintained to 1% with a 125mA load.

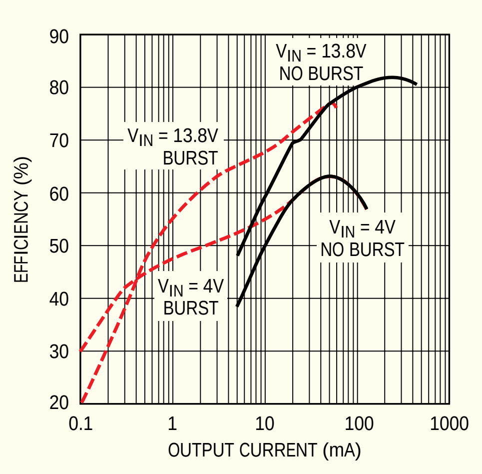


Figure 3. 4V to 60V Input to 5V Conversion Efficiency

Conclusion

The LT3433 simplifies ultrawide input range DC/DC voltage conversion, enabling simple and inexpensive solutions to a variety of design problems. Automatic transitioning between buck and bridged modes of operation provides seamless output regulation for wide input voltage ranges and input voltage transients. The use of a small footprint TSSOP package, a single inductor and few external components reduces board space requirements, increases efficiency and improves thermal performance.

www.linear.com

Dual High Efficiency White LED Drivers with Integrated Schottkys Drive Up to 20 LEDs from a 3mm x 3mm DFN

The LT3466 is a dual, full function, step-up DC/DC converter specifically designed to drive up to 20 white LEDs from a wide input voltage range. Its high efficiency, current mode and fixed frequency operation ensure uniform LED brightness, low noise and maximum battery life. On-chip schottky diodes eliminate both the added cost and space requirements of external diodes. Its two independent converters are capable of driving asymmetric LED strings (up to 10 in series per converter) from an input voltage of 2.7V to 24V, delivering efficiencies up to 81%. Its 3mm x 3mm DFN package and tiny externals provide a very compact footprint for space-constrained applications.

HIGHLIGHTS

- Drives up to 20 white LEDs from a 3.6V Supply
- Up to 81% Efficiency
- Independent Dimming and Shutdown Control
- 3mm x 3mm DFN-10 Package

The LT3466 switching frequency can be set between 200kHz and 2MHz via a single resistor, enabling the designer to minimize solution footprint and maximize efficiency. Because the LT3466 utilizes a constant frequency architecture, noise is minimized, eliminating interference with any onboard RF circuitry. Its 2.7V to 24V input voltage range enables the device to operate in applications visible from Li-Ion-powered handheld devices to automotive backlighting. Also, the LT3466 acts as a constant current source. It delivers the same current to each white LED regardless of fluctuations in the LED's forward voltage drop which vary with temperature, manufacturing tolerances and age, ensuring uniform LED brightness. Although on the same chip, the independent step-up converters are capable of driving asymmetric LED strings with independent dimming and shutdown control of each string. Additional features include internal soft-start/inrush current limiting and open LED protection. The combination of the LT3466's high efficiency, versatility, low noise and extremely small "total solution" footprint make it ideal for a variety of backlighting applications that require many white LEDs in a tiny form factor.

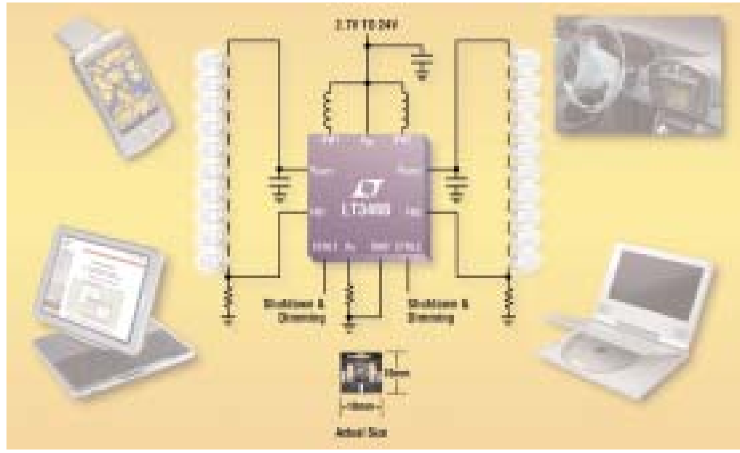


Figure 4. Dual Full Function White LED Step-Up Converter with Built-In Schottky Diodes

Low Supply Currents for "Always-On" Systems

With the adoption of new navigation, security and always-on power systems in automobiles, there is an ever-increasing demand on the battery even when the ignition is turned off. Collectively, several hundreds of milliamps of supply current required to maintain standby power to always-on processors could completely drain a battery in a matter of weeks. For example, after an extended business trip, a high-end luxury automobile would be unable to crank over the engine. Quiescent currents need to be drastically reduced in order to preserve battery life without greatly increasing the size or complexity of the electronic systems. Until recently, the requirement of high input voltage capability and low quiescent currents were mutually exclusive parameters for a DC/DC converter. A car's high voltage step-down converters require 2mA to

LINEAR TECHNOLOGY

Putting an End to Capacitor Termination Failure

Use some kind of flexible termination

With a soft termination such as Flexiterm, PCB manufactures are afforded a lot more flexibility in the layout of the board. Cumbersome manufacturing constraints are removed. In some cases, an expensive board re-design can be avoided.

Jonathan Lennox, AVX

In the modern automotive environment, ceramic capacitors have become widely recognised as a source of critical failures. The most common failure mode for this type of capacitor is cracking of the ceramic material, as a result of flexing of the underlying PCB. The PCB flexes in response to a number of different mechanical stresses. The most significant of these occur during assembly or in the presence of harsh environmental conditions, particularly large variations in temperature. The latter is a particular problem in high-power or power-switching applications.

Such cracking can be destructive and is a potential hazard with all ceramic capacitors, irrespective of the manufacturer. At PCB assembly, cracking most commonly occurs during de-panelisation (after PCB assembly, when individual boards are separated from a larger array), component placement or module assembly (when the board is inserted into the final product enclosure). Parts that are placed near to the perimeter of the board are particularly vulnerable to cracking.

There is plenty of documentation on how to prevent such failures. However, it can take a long time to detect them and uncover why they happened, sometimes occupying PCB manufacturers for many months and costing a great deal of money. If the only solution is to re-design the PCB then this will add significantly to the project turnaround time and cost.

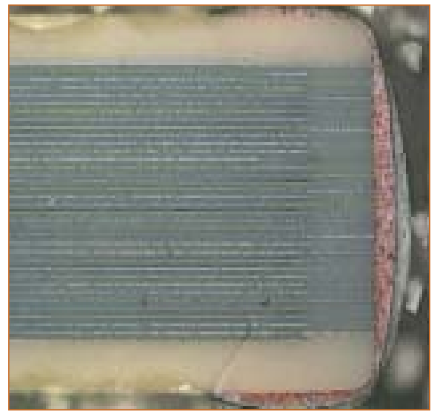


Figure 1. Standard termination MLCC with typical crack resulting from board flexure.

One assumption that can sometimes prove costly is to presume that the more severe failures can be identified at the end of assembly testing, using capacitance and Q-factor testing. This is a critical error since the operation of the device will often not degrade until later, once it has been exposed to a moist atmosphere and the effects of moisture ingress have become apparent. Ceramic capacitors will tend to fail with low insulation resistance (with a short-circuit occurring eventually). As a result, some fractures can be detected by measuring the change in insulation resistance of the device. Such testing is a standard way of assessing the operation of a capacitor but is generally not possible once it has been assembled on the board.

Ceramic capacitors owe much of their tendency to crack to the design of the device, specifically the way it attaches to the PCB. In a typical surface-mount MLCC, the crack will begin at the innermost edge of the point where the termination material joins the ceramic. It will continue in a line upwards towards the outer edge of the ceramic (normally at a point roughly half-way up the height of the material). An example of such a crack is shown in Figure 1.

The solution is either to design the problem out, by re-arranging the layout of the PCB, or to use some kind of flexible termination for the component. AVX, for example, employs a soft-termination system called Flexiterm as an option in a number of its ceramic capacitors. This soft termination works in conjunction with a nickel electrode and a copper termination, eliminating some of the traditional problems and the cost of PdAg capacitors. The copper termination is coated with conductive polymer then plated with nickel and tin.

When the board flexes, the soft termination absorbs most of the mechanical stress, so very little is placed on the component itself. If it is still enough to damage the part, it is far more likely to create an open-circuit failure. This is because tearing will occur at the epoxy layer at the outside of the device before the capacitor itself has a chance to break. This kind of damage is shown in

Figure 2. Flexiterm soft-termination MLCC exhibiting tearing of the epoxy layer at the edge of the device.

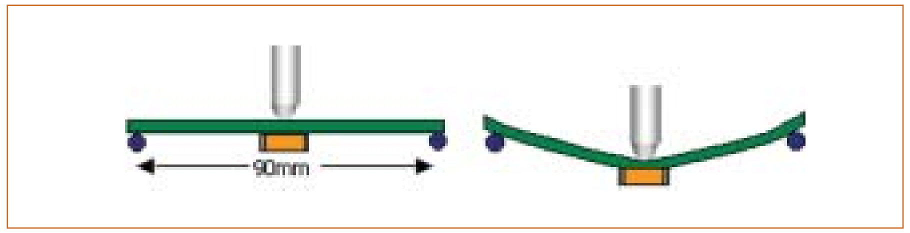


Figure 3. Board-bend test specified for AEC-Q200 qualification.

Figure 2. An open-circuit failure is clearly far preferable to a short circuit, since it eliminates the possibility of component heating and damage to the PCB.

When it comes to assessing the suitability of this kind of termination system for the automotive environment, the Automotive Electronics Council (AEC) specifies a set of tests. The AEC-Q200 qualification defines a number of stress tests for passive components.

AVX has used the AEC-Q200 tests to compare the abilities of Flexiterm and copper terminations to withstand mechanical stress. Two key tests are the board-bend test and the temperature cycling test.

With the board-bend test, a component is reflow-soldered to a PCB and then placed on a pair of supports spaced 90mm apart (see Figure 3). The board is then bent up to a deflection of 10mm at 1mm per second and the results recorded, using either a sensitive current-detection circuit or by inspecting a cross-section of the part, following the test. AEC-Q200 specifies a minimum flex requirement of 2mm.The Flexiterm parts actually provide a guaranteed board deflection of 5mm, providing two to four times the bend resistance of standard capacitor technology.

Changes in temperature cause mechanical stresses to arise as a result of the mismatch between the capacitor and the underlying PCB, in terms of their respective coefficient of thermal expansion values. AVX has also demonstrated its Flexiterm termination in temperature-cycling tests. These test the ability of a component to withstand temperature extremes through alternate exposure to either extreme. To achieve AEC-Q200 qualification, a standard ceramic capacitor (mounted on an FR4 board) has to withstand 1000 cycles from -55 to 125°C. Flexiterm parts can withstand 3000 cycles without damage, demonstrating the high reliability these parts offer in environments where extreme temperatures are present (for example, in the engine of a car being driven in a very cold climate).

The Equivalent Series Resistance (ESR) is an important parameter in applications requiring a high rms current-carrying capability. Tests have been performed to characterise the change in ESR occurring in Flexiterm while undergoing the long-term reliability, operational life and temperature cycling tests defined in the AEC-Q200 specification. The ESR value was found to be unchanged by these tests, confirming that there is no degradation in the quality of the electrical connection provided by Flexiterm, even under the most extreme conditions.

Ceramic capacitors are a major cause of PCB failure because of the cracking that occurs in these devices as a result of board flexing. Cracking is common during PCB assembly and in the application itself, particularly in the presence of harsh environmental conditions such as the temperature extremes that occur in automotive systems. In applications characterised by both high power and high cost, capacitor cracking is especially problematic. The high-power circuits that are used in the automotive environment make such failures all the more destructive.

The position of a component on the PCB has a big influence on the amount of thermal or mechanical stress to which it is exposed. Manufacturers can reduce the possibility of ceramic cracking by designing the PCB appropriately. However, with a soft termination such as Flexiterm, PCB manufactures are afforded a lot more flexibility in the layout of the board. Cumbersome manufacturing constraints are removed. In some cases, an expensive board re-design can be avoided.

www.avxcorp.com

High Frequency Filtered Power Connectors

Anderson Power Products (APP) and Schaffner EMC, leaders in the fields of power interconnect and EMI suppression, have partnered to produce the patents pending, ACARA filtered electrical power connectors. The superior high-frequency attenuation delivered by the ACARA filter connectors prevents radio frequency emission, protecting sensitive computers as well as switching and cellular equipment.

APP's ACARA male filtered connector provides excellent EMC performance to beyond 10GHz. The unique integral feed though capacitor construction incorporates extremely low series inductance, ensuring that the self-resonant frequency is very high. In fact, as frequency increases, the impedance of the feed-through capacitor decreases exponentially.

To ensure user safety, the plastic housing of the ACARA female power connector's plastic housing is polarized to the male filtered, preventing the installer from reversing polarity. Mating of similar ACARA connectors of different capacitance or operating voltage can be avoided using the optional 6 position key. ACARA power connector's positive latch and wire strain relief further enhance the safety of the system. The positive latch prevents accidental unmating, but allows immediate power disconnect for emergency service or repair. The wire strain relief eliminates creep of the wire insulation jacket which can expose bare conductors and result in electrical shock.

ACARA filter connectors are now available in 65, 100, 150 and 250 amperage ratings and in capacitances from 100 to 2100 nano-Farad. The products meet all applicable requirements of UL and EN.

www.andersonpower.com

40A Synchronous Buck Building Block

Internatonal Rectifier has launched the iPOWIR iP2003A — a fully-optimised power "building block" solution for high current, multiphase synchronous buck converters with a 3V to 13.2V input voltage range. The building block is designed specifically for low voltage power rails in servers, desktops and data communication systems.

As part of the iPOWIR family, the iP2003A integrates silicon and passive components into a single, compact land grid array (LGA) package. The integrated silicon includes a synchronous gate driver, high side and low side power MOSFETs, and a synchronous Schottky rectifier for reduced deadtime losses. The device is capable of 1MHz operation with an output current rating of 40A continuous with no de-rating up to a 100°C case temperature.

Unlike standard discrete solutions, the iP2003A enables 1MHz operation which dramatically improves transient performance, saves board area and reduces system cost by enabling the use of a smaller output filter.

Together with a standard multiphase PWM controller, a four phase converter using four iP2003A devices can deliver 160A output current with a 55% board space savings compared to an equivalent solution using thermally-enhanced SO-8 power MOSFETs.

www.irf.com

High-Efficiency Step-Down Regulators

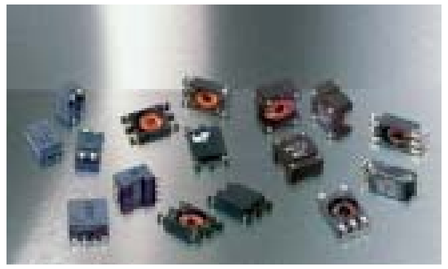
C&D Technologies, has announced three new high-efficiency step-down voltage regulators that are pin- and size-compatible with older and less efficient LM78xx devices. Supplied in industry standard TO-220 SIP packaging, the new 78SR regulators can be used as 'drop-in' replacements that allow engineers to reduce the power consumption of applications without costly or time-consuming circuit re-design. As a result, the devices can be used to increase battery life in portable instrumentation and standby power applications.

The 78SR switching regulators are ideal for new and existing LM7805/LM7812 designs and other applications where maximum load current is 0.5A or less and full load operation at elevated supply voltages is needed. Output options are +5V/0.5A (7805SR), +12V/0.4A (7812SR) and +3.3V/0.5A (7803SR). A 260kHz switching frequency produces efficiencies as high as 95% for the 12V part and 85% for the 3.3V and 5V regulators. Full load operation from 9V, 12V, 24V, 28V or 36V supplies – at ambient temperatures as high as 70°C – requires no heat sinks, no forced air cooling, and no temperature derating.

www.cdpoweronline.com

NEW PRODUCTS

Low Profile – Broadband Attenuation



Common Mode Chokes are perfect components to suppress asymmetric interferences on power lines and Bus-Systems. Without influencing the signal you can attenuate interferences in the MHz-frequency-range. It's mainly for applications like CAN-Bus, USB or Firewire, where the brand new surface mount Common Mode Chokes Series WE-SL from Würth Elektronik work perfect.

These chokes are optimized for broadband attenuation between 1MHz up to 1 GHz. The three new dimensions (WE-SL1, WE-SL3, WE-SL5) are offering multiple options: Very low profile of only 1.65mm, inductance values up to 2 x 4,700 µH, Impedances up to 13,000 _ and currents up to 1.5A.

All of these EMI-Chokes are delivered lead-free and ex stock.

www.we-online.de

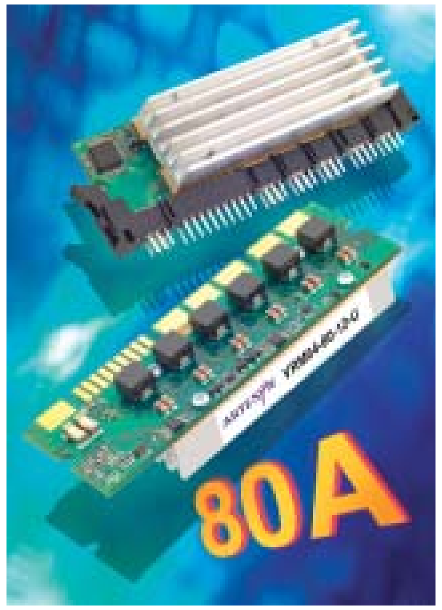
High Voltage Rectifiers for Fast Switching

Faster than 400 Nanoseconds at up to 5000 Volts. The axial leaded diode types HV1.5 to HV5 expand Diotec's range of high voltage rectifiers. The parts are offering blocking voltages of 1.5 kV, 2 kV, 3 kV and 5 kV in standard packages DO-41 respectively DO-15. Forward currents are between 200 mA and 500 mA. Reverse recovery times of less than 400 ns allow for usage even at higher switching frequencies.

Applications for such high blocking devices are e. g. electronic ballasts in lighting applications, but also any other circuits where usual blocking voltages are not sufficient. The parts comply to RoHS directive and complete the existing ranges of standard rectifiers having 2 kV in SMD and up to 16 kV in axial leaded version.

www.diotec.com

Plug-in Processor Power Module



Artesyn has launched a new plug-in processor power module for use with AMD's high performance 64-bit Opteron server processors. Fully compliant with the latest AMD64 processor specification, the new VRM64-80-12-U module has a continuous output current capability of 80A and accommodates fast load transients of up to 100A/µs.

The VRM64-80-12-U is an application optimised non-isolated point-of-load (POL) DC/DC converter which uses highly integrated packaging techniques to create a high current, fast response voltage source with an ultra low profile. The module plugs vertically into a standard board mounted power connector and has a very low installed height of just 29.5mm (1.25in), making it ideal for use in 1U high rack-mounting equipment, such as the latest enterprise servers and routers.

The converter uses an advanced multi-phase buck conversion topology with interleaving to achieve a high equivalent switching frequency of 4.2MHz: this yields a typical conversion efficiency of 84% when delivering 60A at 1.5V, combined with a 100A/µs transient response capability. The topology also helps minimise component count, resulting in lower build costs and an exceptionally compact form factor. The module has a footprint of just 93.3 x 19mm (3.68 x 0.75 inches) - including a fully integrated heatsink - and is a cost-effective, space-saving alternative to embedded voltage regulators on densely packed boards.

http://www.artesyn.com/powergroup/new_vrm_launch.htm

www.artesyn.com

Soft Recovery FREDs

Advanced Power Technology is pleased to announce an extension of the next generation DQ Fast Recovery Epitaxial Diodes. 600V parts were announced earlier in 2005 and APT is now extending the product offering to include 1000 and 1200V product, ranging in current from 8 Amperes to 100 Amperes, in packages including TO-220, T0-247 and SOT-227's, or in chip form. Key Features are:

- Extremely soft recovery – reduces EMI, eliminates the need for snubbers.
- Extremely fast reverse recovery – low switching losses.
- Avalanche energy rated for ruggedness & high reliability.
- Low leakage – thermally stable, low static losses.
- Platinum doping – low leakage and improved reliability at high temperature.

Available in RoHS compliant form by adding a "G" to the end of the part number.

These DQ FREDs are designed for use in Switch Mode Power Supplies, Alternative Energy Inverters, Motor Drives, and other industrial applications. The diodes can be used as Snubber Diodes, hard-switched PFC boost diodes and free-wheeling diodes.Detailed data sheets for these new DQ FREDs are available now. They may be downloaded from APT's website or obtained from the factory.

www.advancedpower.com

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