Power Systems Design EUROPE

Empowering European Innovation

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MarketWatch

Design Tips

Automotive Electronics

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Shows, Autos and Vampires

Hi everybody. We kick off in our October issue with Electronica well and truly in our sights, for many of us in the industry it is the major event staged every two years in Munich, Germany. It turns what normally is a fairly sedate Bavarian city into a buzzing hi-tech centre where every restaurant and bar is humming with the voices of techies, marketers and, of course, media types like me. It is a great meeting place – ideal for networking for that new job, or just discussing the latest power MOSFET or DC/DC converters on offer. But for many of us it will mark the culmination of a long hard slog. Engineers getting the latest design demos ready, media getting the promotions and features in on time and the marketers planning the contacts they must make and the pitches to prepare.

Have you seen the stuff in the media recently on 'vampires'…not the 'real' kind, but all those chargers and equipment on standby, that people leave permanently plugged-in, drawing current from the mains. I'm as guilty as anyone in leaving my pc, mobile phone, drill, screwdriver and more almost permanently on-charge. If I assume a fair percentage of people are as lazy as I in doing this, the 'vampire' current drawn on a European scale is quite significant. Even if all devices are fairly fully charged the current is still flowing albeit at not such a high level. A recent report from the US proposes that up to 10% could be saved by switching them off when not needed, bit overstated I believe, but still worth a mention.

In this issue we have decided to continue with our highly successful Automotive content. The response from my call for articles has been overwhelming and much high quality material has been received. On top of this, we have some great articles from our contributors as well as comment from the industry. Additionally, we had some significant announcements from Vicor on their new range of power bricks and new business focus, National on power management and Microsemi on their new Mos 8 process, all of which you'll find covered in this issue. I'm expecting even more to be happening in the next weeks as the European industry ramps for Electronica, so please stay tuned.

For the team at PSDE, we've had a bumper response from the industry with contributed material from throughout our power domain. We are fortunate in having a great team to handle the many disciplines in publishing.

To enhance the capability further and to align with our readers' requests based on the feedback I asked for when I was 'new', we are delighted to announce an additional contributing team member, **Dr. Ray Ridley.**

Ray will contribute in every issue. This regular column, entitled 'DesignTips', will complement PSDE's regular technical columns, which include PowerPlayer, Marketwatch and Powerline. He is an inspiring design guru who will, I know, capture our attention every issue and provide much food for thought. Ray's work has influenced the power supply designs of major companies worldwide. He received a Doctor of Philosophy in Electrical Engineering in 1990 from Virginia Polytechnic Institute and State University. Well known for his work on current-mode control, Power 4-5-6 Design Software, laboratory workshops and seminars, Ray provides a unique combination of theoretical concepts and practical applications to the power electronics industry. His column includes practical power supply design tips for the working engineer and begins in this issue of PDSE.

As a further enhancement to our content value, we are very fortunate to announce the previous contributor to Marketwatch, **Chris Ambarian**, formerly of isuppli, now with Qspeed, to our steering committee. Chris brings a wealth of industry knowledge and experience to our team.

The magazine is growing and flourishing only due to your interest and the feedback you give to our responsive team.

So, enjoy the magazine and survive Electronica.

Cliff Keys

Cliff Keys
Editor-in-Chief, PSDE
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Linear Technology Commemorates 25 Years in High-Performance Analog

Linear Technology Corporation celebrates 25 years since its founding in 1981. Growing beyond $1 billion in revenue, with innovative products and industry-leading financial performance, Linear has set the standard for product quality and on-time delivery. Its products continue to lead in technical innovation and are designed into products throughout the world.

Robert Swanson, founder and Executive Chairman stated, "When Linear was founded in 1981, to succeed it had to overcome a lot of what was then conventional wisdom. Investors didn't think there was still much of an opportunity to back a new chip venture, much less an analog chip company during the dawn of the 'Digital Revolution.' The vision of the founding team turned out to be correct. 25 years later we can say with pride, we did it our way and the results speak for themselves."

Lothar Maier, CEO, stated, "Linear has been successful for 25 years by sticking to one overall strategy and that is to only develop, design and market high-performance analog products. After 25 years we have perfected this skill and see no reason to change. We lead the industry by bringing to market compelling products that solve our customers' complex analog needs; this is what Linear Technology does best."

The company's thousands of analog products have proliferated in applications ranging from popular MP3 players and high-end cell phones, to cellular basestations, network routers, automotive electronics, computer, medical and industrial systems.

www.linear.com

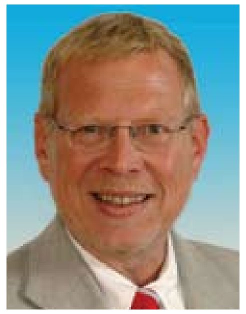
UltraVolt® Announces Representative in Benelux

UltraVolt Inc. announced the addition of Nijkerk Electronics as a new international representative for the Netherlands, Belgium, and Luxembourg. Nijkerk Electronics was founded in 1959 and was one of the original distributors of electronic components in the Benelux region. Among its offerings, Nijkerk represents and distributes a variety of high-voltage components including high-voltage relays, resistors, diodes, capacitors, power supplies, and power systems.

"Nijkerk Electronics' market coverage and its experience in high-voltage applications make it the ideal partner for UltraVolt in the Benelux countries," said James Morrison, Executive Vice President of UltraVolt. "Nijkerk's experience in the marketplace, its strong focus on design-in, niche products, and its extensive customer support infrastructure will help UltraVolt provide our customers in the Benelux countries exceptional support."

www.ultravolt.com

Zetex Semiconductor appoints Dr. Franz Riedlberger as Chief Technology Officer



Dr. Riedlberger, an accomplished semiconductor industry veteran, is to head up Zetex's technology department.

"This is another important milestone for Zetex, demonstrating our determination to put a world-class team in place to excel in achieving our ambitious goals," said Chief Executive Hans Rohrer. "Franz brings a wealth of knowledge to the company, both in semiconductor technology and commercial acumen. In addition, his leading our Technology Group will, I'm sure, attract further great talent into the company," Rohrer concluded.

Riedlberger joins the company following twenty-five years in high tech industry, the last thirteen with Motorola in various engineering and sales management roles. He was co-founder of European ASIC design company ES2-European Silicon Structures.

"I am excited to drive the execution of our ambitious goals together with my team and my peers. Zetex is a visionary company, bringing together excitement, people and technology as a solid foundation to succeed in its target markets.", Riedlberger commented.

www.zetex.com

GE Invests $100 Million to Grow its LED Lighting Business

General Electric Company (GE) through its Consumer & Industrial business and the Nichia Corp. announced a strategic alliance agreement to support GELcore, LLC, based in Cleveland, Ohio.

This agreement combines GELcore's LED system strengths in the Transportation, Signage, Specialty Illumination, and General Illumination segments with Nichia's extensive phosphor and optoelectronics products, such as LEDs. Both companies expect to benefit significantly from each other's expertise and penetrate the high-growth LED general illumination segment.

"This agreement is a true win-win outcome for both parties and clearly demonstrates GE' s commitment to solid state lighting technology. GE and Nichia's combined excellence creates a preeminent alliance that is ideally suited to support GELcore's efforts to accelerate the growth and penetration of LED-based lighting solutions in the $12 billion global lighting segment," said Michael B. Petras, Jr., Vice President, Electrical Distribution & Lighting.

Noboru Tazaki, Executive Vice President & COO of Nichia stated, "This is a historic agreement when you consider that GE, a world leader in traditional lighting technology and LED systems and Nichia, a world leader in phosphor and optoelectronics technology are joining forces to advance LED technology and accelerate the penetration of LEDs into the general lighting industry."

www.gelcore.com

NXP Semiconductors Appoints Pascal Langlois Senior Vice President of Global Sales

NXP Semiconductors (formerly Philips Semiconductors) has named Pascal Langlois Senior Vice President of Global Sales. He will lead NXP's worldwide sales effort across all markets and business units and report directly to CEO Frans van Houten.

"Pascal is a world-class executive who brings great semiconductor industry experience and a proven track record to this important role at NXP," said Mr. van Houten.

Mr. Langlois previously served as Senior Vice President Channel Management and Sales for Multi-market Semiconductors at NXP. Under his leadership, Philips Semiconductors significantly improved its leadership position in distribution and the Electronics Manufacturing Services (EMS) channel by creating one of the largest and strongest partner networks in the industry.

Prior to his role as Senior Vice President Channel Management and Sales for Multi-market Semiconductors, Mr. Langlois served as Vice President and General Manager of Sales and Marketing for the company's Automotive business unit, achieving significant business growth globally. It was also during his tenure that Philips Semiconductors played a primary role in the creation of the FlexRay Consortium, an alliance of automotive, semiconductor and electronic system manufacturers.

Mr Langlois started his career with Arrow-Jermyn and National Semiconductors 22 years ago, also undertaking the role of Vice President and General Manager Europe and Asia at VLSI Technology before joining Philips Semiconductors.

www.NXP.com

Aimtec Signs Distribution Agreement with Koala Elektronik of Czech Republic

Aimtec Inc., a global supplier of ac-dc and dc-dc power converters, announced that it has signed a franchise distribution agreement with Koala Electronik s.r.o. of the Czech Republic. Founded in 1995, Koala Electronik s.r.o's business started with semi-conductors for ATMEL and LCD displays.

Koala is an ISO9002:2000 certified organization with a line card that encompasses electromechanical, optoelectronic, passive and active components for an impressive list of tier one manufacturers. According to a statement released by Aimtec, Koala's strong business development acumen is expected to further Aimtec's brand and expand the company's market share in the Czech and Slovakia Republics.

www.aimtec.com

Infineon is largest supplier of Power Semiconductors

According to initial findings from the latest IMS Research study into this market, Infineon's power semiconductor business significantly outperformed the global market as a whole, which expanded by just 0.6 percent to US $11.35 billion, and achieved a revenue growth of 11.6 percent in 2005. IMS Research indicates that Infineon held a 9.3 percent share of the total US $11.35 billion market in the year 2005. This marks the third consecutive year that IMS Research has ranked Infineon as the number one provider of silicon to this market which IMS Research forecasts to grow at an average annual rate of 6 to 8 percent over the next five years..

"We have been at the forefront of power semiconductor and module development for many years, and this expertise is a strong contributor to our continued leadership role," said Dr. Reinhard Ploss, Group Senior Vice President and General Manager of Infineon's Automotive, Industrial and Multimarket business group. "We are committed to maintaining our leading position in these core competence areas and dedicated to developing power semiconductor products enabling efficient use of the electrical energy available, with excellent price-performance ratios."

The power semiconductor market is driven by the global trend for continued electrical energy demand and declining natural resources. Semiconductors for power electronics - as manufactured by Infineon in Kulim (Malaysia), Villach (Austria) and Regensburg (Germany) - are key enablers for efficient energy management.

Enhanced efficiency in management of electrical power provides a huge potential for energy saving in electrical motor drives, power supplies, computing equipment, consumer products, lighting equipment as well as in cars where power semiconductors are a key component to improve fuel efficiency and safety.

www.infineon.com

Power Events

- ***H2Expo,*** *October 25-26, Hamburg, www.h2expo.com*
- ***ELECTRONICA 2006,*** *Nov. 14 - 17, Munich, www.electronica.de*
- ***SPS/IPC/DRIVES 2006,*** *Nov. 28 - 30, Nuremberg, www.mesago.de/de/SPS/main.htm*

Microsemi Launches New POWER MOS 8™ Generation of MOSFETs

Microsemi Corporation, leaders in high performance analog/mixed signal integrated circuits and high reliability semiconductors, has launched the first 15 devices in their newest generation of POWER MOS 8 products.

These new MOS 8 MOSFET and FREDFET devices are designed for high power, high performance switch mode applications including power factor correction, server and telecom power systems, solar inverters, arc welding, plasma cutting, battery chargers, medical, semiconductor capital equipment and induction heating.

Key Performance Features

- Improved oscillation immunity and reduced EMI
- Low $R_{DS(on)}$
- Low gate charge
- Low switching losses
- Avalanche energy rated
- Lower thermal resistance
- FREDFETs available with fast recovery body diodes

Microsemi engineers employed advanced design techniques to optimize capacitances and gate resistance. The result is a family of devices with improved oscillation immunity, lower peak slew rates, reduced EMI and high dv/dt ruggedness capability. These features combine to simplify filtering and paralleling of multiple devices in high power applications.

In addition, advanced manufacturing processes for the new MOS 8 products have lowered their thermal resistance and enabled higher current ratings for each die size and package type compared to earlier devices. Low capacitance and gate charge specifications enable high switching frequency capability and low switching losses.

All MOS 8 devices are 100 percent tested for avalanche energy capability and are offered only in RoHS compliant packages.

"Our new POWER MOS 8 family utilizes advanced technologies and manufacturing processes to deliver what our customers have asked for in our new generation of MOSFETs and FREDFETs," said Russell Crecraft, Vice President and General Manager of Microsemi's Power Products Group in Bend, Oregon. "Our MOS 8 family will offer the industry's broadest range of high voltage, high power, high performance MOSFETs, FREDFETs and PT IGBTs," he said.

MOS 8 FREDFETs have all of the features and advantages of MOS 8 MOSFETs, with the added benefit of a faster body diode recovery speed of <250ns. These devices provide superior ruggedness and reliability in applications where the body diode carries forward current, such as popular zero voltage switching (ZVS) bridge topologies.

First to be released in the POWER MOS 8 family are ten MOSFET and five FREDFET devices with power ratings from 19 to 75 amps and voltage specifications from 500 to 1200 volts. Additional power/voltage combinations will be introduced throughout the balance of 2006 and into early 2007.

The first Ultrafast Recovery FREDFETs, rated at 500 and 600 volts, will feature a 150ns recovery time and are scheduled for release in the fourth quarter of 2006. MOS 8 IGBTs with 600 & 900V ratings will follow in early 2007.

Volts	Rds(on)	Id (Amps)	Part Number	Device Type	Package Style
500	0.14	42	APT42F50B	FREDFET	TO-247, D³
	0.1	56	APT56M50L	MOSFET	TO-264, T-MAX®
	0.1	38	APT38M50J	MOSFET	SOT-227
	0.075	51	APT51M50J	MOSFET	SOT-227
	0.075	75	APT75M50B2	MOSFET	TO-264, T-MAX®
600	0.21	34	APT34F60B	FREDFET	TO-247, D³
	0.21	34	APT34M60B	MOSFET	TO-247, D³
	0.16	43	APT43M60L	MOSFET	TO-264, T-MAX®
	0.16	30	APT30M60J	MOSFET	SOT-227
1000	0.46	29	APT29F100L	FREDFET	TO-264, T-MAX®
	0.46	19	APT19F100J	FREDFET	SOT-227
	0.4	31	APT31M100L	MOSFET	TO-264, T-MAX®
	0.4	21	APT21M100J	MOSFET	SOT-227
1200	0.8	22	APT22F12B2	FREDFET	TO-264, T-MAX®
	0.68	24	APT24M120L	MOSFET	TO-264, T-MAX®

The first POWER MOS 8 devices:

www.microsemi.com

New Mid-Power 24Vin Maxi Modules and More from Vicor

Vicor, the 'household' name in the industry of power bricks, announces the addition of eight mid-power Maxi DC-DC converters to their successful 24Vdc input family: a 3.3Vout, 200W model and 300W models at 5, 12, 15, 24, 28, 36, and 48Vout. These modules incorporate the company's patented low-noise Zero-Current and Zero-Voltage Switching (ZCS/ZVS) topology which helps considerably in reducing noise and are ideally suited for industrial or process control, distributed power, medical, ATE, communications, defence, and aerospace applications. With switching frequencies up to 1MHz, the 24Vdc family provides rapid transient response well suited for RF applications.

With these new models, the 24Vin Maxi family now comprises 16 models with output voltages from 3.3 to 48Vdc and power levels from 200 to 400W. The converters operate from 24V nominal input, with an input range of 18V to 36V. Efficiencies range up to 88% for the higher output voltages. These models are available in five different environmental grades, with six different pin options and three choices of baseplate.

As part of this major thrust into the market, these new products provide designers who do not need the full-power capability of a 24V Maxi module with a mid-power option, with all of the functionality and configurability of the high power models. In addition, the low-noise ZCS/ZVS, because of its inherent low-emission structure, greatly reduces the design and fine-tuning effort required for power converters to meet agency conducted emissions requirements and also the usual associated high filtering costs.

The company, in its preparation for this major program, has focused internally on a dramatic reduction in manufacturing costs while aggressively developing and introducing new products. This hard-driven company-wide strategy is aimed at doubling the brick business in just four years. The company is committed to meeting and surpassing customer expectations and needs. The business is changing from the long-accepted model and Vicor plans to be ahead of the curve on this and has invested resource to ensure they are in synch with these needs. Heavy investment in R&D together with the close tracking of industry needs at all levels within the company is the way they plan to stay ahead.

In its quest to give the system designer the right tools to complete his design efficiently, Vicor introduced their first issue online design system in year 2000. They plan to launch a new and upgraded version later this year to enable the designer to achieve even shorter development time and at reduced cost.

Designers should no longer need to struggle with their own power supply design and subsequent de-bugging, these new products together with Vicor's major focus on customer service will take care of the requirement in the shortest time and at reasonable cost.

The modules, which are available in RoHS compliant models, are a compact 117 x 56 x 12.7mm in size, with a height above board of 10.9mm. They can be configured in any combination in Vicor's Custom Module Design System at www.vicoreurope.com.

Vicor's comprehensive line of power solutions includes modular, high-density AC-DC and DC-DC modules and accessory components, fully configurable AC-DC and DC-DC power supplies, and complete custom power systems.

www.vicr.com

PSDE Power Player

Digital Solutions for Power Management Applications

By Steve Bakota, Texas Instruments

The most common question from power supply design engineers is simply, "Why should they use a digital pulse width modulator (PWM) controller for loop control? What are the benefits and trade-offs? When will the market for digital power controllers take off and how will it compete with traditional analog PWM controllers in mainstream power supply design?

They have been using analog PWM controllers for switching power supply designs since the SG1524 was introduced in 1976. As the need for monitoring, management and communication arose, designers started to use microcontrollers in their designs to perform these functions. The integration of these two technologies is the first step seen delivered by semiconductor power controller suppliers.

Many believe for this technology to hit volume adoption, key criteria need to be met: the performance must be as good as an analog controller-based solution, design tools must be intuitive, and the controller should deliver advanced features to the original equipment manufacturer (OEM).

Digital controller-based power supplies must achieve performance as good as or better than existing analog PWM controller technology. Customers aren't willing to compromise on reliability, power density, transient response (closed loop bandwidth), efficiency or stability of output over line/load/temperature.

The technology must have tools that are intuitive and valuable to designers. Today's power engineers have a thorough understanding of the analog building block of the PWM controller and are able to add external circuits that achieve

the desired power design. With digitally controlled PWMs, this same flexibility needs to be provided but not at the price of learning how to write 'C' or assembly code. These Graphical User Interface (GUI) tools are very important for market success of digitally controlled power.

Digital controller adoption must implement intellectual property (IP) offering system benefits beyond that of analog controllers. A popular area of research includes adaptive supply control which tunes the loop to the characteristics of the load on the supply. Advancements in loop control would lead to improved transient response and efficiency over a broader range of power requirements with lower cost of external active and passive components.

TI is working closely with customers using their digital signal controllers in power applications such as uninterruptible power supplies (UPS), rectifiers and conducting system level development to truly understand the challenges of designing digital controller power supplies.

Development tools had to provide maximum flexibility whilst not complicating the design challenge, configured with a GUI, so no programming is required.

TI designed a 1kW telecom rectifier with a single controller on the primary side, to optimize performance allowing customers to measure, model and implement changes to their loop in a simple GUI working in Bode Plots and Poles and Zeros (not Z transforms). This is very powerful when applied in the customization of a supply, simply by making changes in registers and when 'tuning' the control loop for variations in components.

The industry is exploring what digital control technology can deliver to maximize value for customers. Adoption will accelerate as suppliers continue to develop new techniques that take advantage of digital technology and continue to improve their design tools.

The size of the market for digital controllers will be driven by the technological advances that vendors demonstrate. Hot topics in research today are in the same areas where analog PWM controller vendors have been focused: improved efficiency, faster transient response and higher power densities. The key for digital controllers is to go far beyond integration not practical in analog.

Customers are not interested in whether the loop is closed digitally or in analog, but in how the controller will benefit them and their end product. As with any technology, success will come down to features and value.

www.ti.com

Energy Crisis Not a Problem for Digital Control of Power

Demand rises in concert with increases in energy rates

By Marijana Vukicevic, iSuppli Corporation

While many businesspeople fret that their enterprises are being hurt by the high cost of energy, those in the Digital Control of Power (DCP) industry actually are getting a boost from rising energy rates, according to iSuppli Corp.

iSuppli defines DCP as the utilization of digital techniques to control the power-switching functions within a power supply. DCP silicon is being adopted at a much faster pace than expected in power-management applications. While several factors are contributing to this trend, one significant element is the rising cost of energy.

The amount of heat produced by some network/telecommunications equipment is so great that additional powerful air-conditioning systems must be used to prevent overheating of facilities. With electricity rates so high, energy bills are approaching the level of hardware costs for some networking operations.

DCP can mitigate such heat issues by enabling more efficient operation of power systems in communications gear, in turn reducing energy costs.

With the network/telecommunications equipment segment the largest initial market for DCP, this demand is having a significant impact on the growth of the technology. The market for DCP silicon in network/telecommunications will rise to $639 million in 2010, up from $144 million in 2006, iSuppli predicts.

A second factor propelling the acceleration of the DCP market is the proliferation of new features in mobile phones.

Mobile phones are far more functional than they were five years ago—or even

just one year ago—sporting features from PDAs to digital video cameras. These mobile phones are making use of more powerful processors to support this functionality. Greater functionality and faster processor speed imply that more energy is used, generating more heat.

This requires greater power efficiency and tighter management, things that can be accomplished with DCP.

Because they have more features, it is the high-end mobile phones that are seeing the first adoption of DCP technology in power management. Market revenue for DCP silicon in mobile phones is expected to more than quadruple to $215 million by 2010, up from a small base of $48 million in 2006, iSuppli predicts.

Hoping to cash in on this growth, semiconductor suppliers are entering the DCP area, or are increasing their participation in the market.

Previously skeptical companies now understand the viability of DCP, including some of the strong, established analog IC sellers. For example, analog IC house Linear Technology Corp. in April announced it is partnering with DCP pioneer Primarion Corp. Several other semiconductor companies now are spending significant resources on DCP hardware and firmware development.

While the potential of DCP is great, the technology is paving the way for an even more exciting innovation—the Power Operating System (POS).

POS encompasses very sophisticated control of power through software, firmware and hardware. In order to communicate, a power supply must have intelligence to talk to the brain of the POS—intelligence that can only be implemented through DCP. POS offers the most sophisticated means of solving the issues power conversion faces in the critical fields of network equipment and mobile handset, offering unprecedented levels of control and efficiency.

The easy availability of system information brought by the POS will change decision processes and resourcing in IT organizations, iSuppli believes.

Thus, while the latest energy crisis is a problem for many, it is a boon for the power-management industry, as high electricity costs boost demand for DCP and POS solutions.

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

For more information on DCP and POS, read Vukicevic's latest report: The Spring of Digital Control in Power Management. For more information, please visit: http://www.isuppli.com/catalog/detail.asp?id=7907

www.isuppli.com

Will Switching Power Supply Design go the Way of Linear Regulator Design?

Design Tips is devoted to the complex and intriguing issues that continue to make switching power supply design a challenging field of expertise. I hope to illustrate, through each design tip, the need for diligence in designing power supplies.

By Dr. Ray Ridley, Ridley Engineering

Outside the power supply design community, there is a common misperception that power supply design is easy. Many companies minimize the time and attention given to their pre-production designs, without regard to the costly consequences. This has become obvious over the past few years with a flood of product recalls over power and heat issues.

There is no doubt that power supply design is a mature industry. Semiconductor companies are integrating standard functions into advanced chips with more capability inside the chip, and fewer parts on the board.

As the switching power supply functions become incorporated inside the chip, however, we lose design flexibility and access to crucial functions. I'll talk in a future column about the parts that are being integrated, and why I personally prefer access to many of them with discrete designs. For now, we'll focus on just one of the overlooked functions—the feedback control loop.

Linear Regulators

Integration of discrete power circuits occurred once before—thirty years ago. This was an era before switchers, when the

industry was dominated by linear regulators. Sophisticated designs were generated by experienced engineers to optimize parameters such as the minimum dropout voltage, transient response time, thermal characteristics, and efficiency.

Designers were highly knowledgeable in transistor characteristics, thermal design, and feedback analysis. Since all regulators use error amplifiers to precisely set the output voltage, feedback analysis and measurement were part of the design procedure for an optimized system.

Later, standard solutions arrived in the industry, leading to integration of the linear regulator. Since then, few of us build our own. In the process, access to the feedback loop has been lost, but no one seems to be concerned about this. Why not? The integration of the linear regulator went fairly smoothly, and there are three reasons for this: 1) predictability, 2) consistency with line and load variations, and 3) low noise.

Feedback for the linear regulator is quite straightforward. The small-signal model is a current source feeding a capacitor and load resistor. The only variation in the design of a control loop for the system is in the impedance of the output capacitor. Apart from this, the system is predictable, and can easily be simulated and modeled. Modeling results typically agree closely with measurements.

Once the linear regulator design is

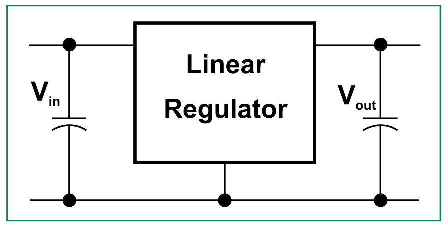


Figure 1: Once designed with discrete components, the three-terminal linear regulator is now almost always fully integrated. There is no longer any access to the control loop.

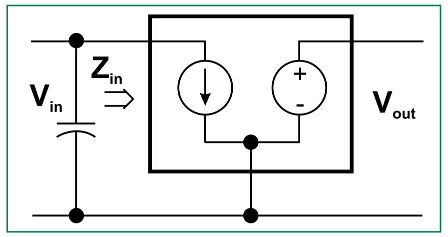


Figure 2: As long as the linear regulator control loop is stable, the circuit model looks like a current source on the input (infinite impedance) and a voltage source on the output (very low impedance). Very little noise is introduced into the system.

placed in the system, it can be modeled as shown in Figure 2. The input impedance of the linear regulator is a current source. Regardless of changes in the input voltage, the current draw is fixed, equal to the output voltage divided by the load resistance. The output of the regulator model is just a voltage source.

Since the linear regulator does not generate any significant noise, we have no need to introduce any complex filtering on the system board. As a result, placement and integration of linear regulators on the board is a job that is almost trivial. A power electronics designer is not needed.

Does the future hold the same fate for the switching power supply? Will integration of the controller functions with power devices and auxiliary circuits render the switching power supply design a simple process?

Well, let's not rush to conclusions. As we'll see below, even the simplest switching power supply can have tremendous complexity.

PWM Switching Regulators

The most basic of all switching regulators is the buck converter, shown in Figure 3. It consists of just four power components, and a feedback loop, shown in red. It looks very simple, but as power designers have realized for decades, there is a great deal of hidden complexity in this system.

Once you are past the first step of turning the semiconductor devices on and off, a circuit remains that generates large amounts of noise. In addition it needs a feedback loop designed around it for a stable, regulated output. This is not always an easy task, especially if you are dealing with synchronous rectifiers or isolated converters.

We'll talk about the turn on and turn off issues later. Meanwhile, let's look at the control loop issues. The first step in dealing with control of any system is to properly understand its plant characteristics. For the buck converter in Figure 3, we are interested in power stage behavior. We can measure a transfer function that shows this by looking at the ratio of V_o/V_i while injecting a swept sinusoidal source into the system. This can be accomplished by either a simulation program, or on the hardware as described in reference [1].

The blue and red curves of Figure 4 show the result of this for a buck converter operating at high and low line input. It's basically just an LC filter characteristic with its gain dependent on the input voltage.

If the load is reduced sufficiently, the converter will enter discontinuous mode. This is shown in the green curve (this does not happen with synchronous

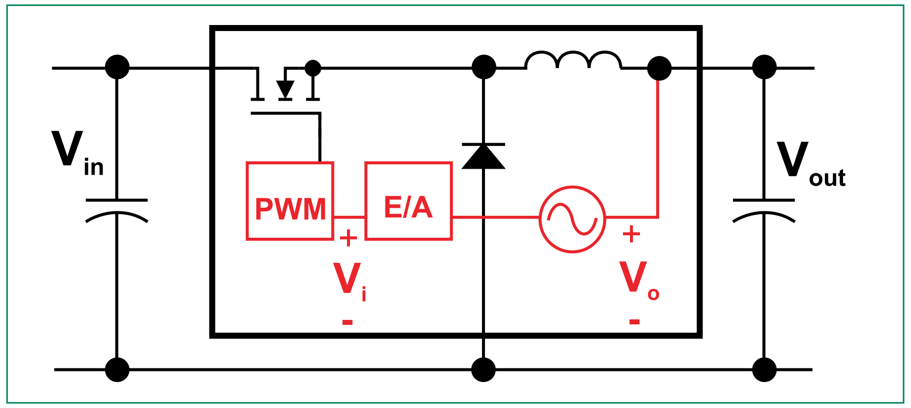


Figure 3: The apparently simple buck converter power stage consists of a switch, diode (or synchronous rectifier), inductor and capacitor. Feedback components are shown in red, with signal injection for transfer function measurements.

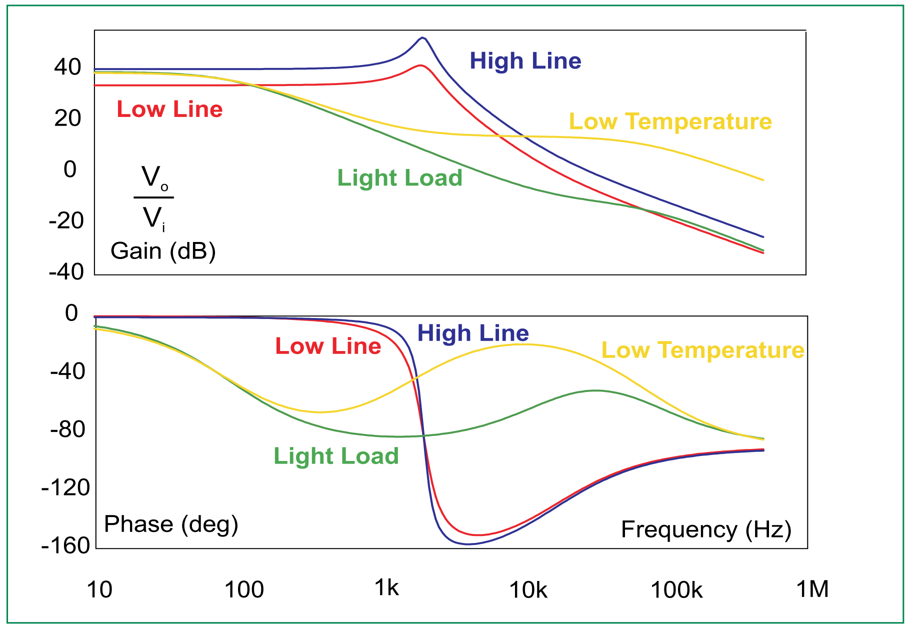


Figure 4: This bode plot shows how much the control characteristics can change with variations in input line, output load, and temperature. At a typical crossover frequency of 10 kHz, the phase of the converter can vary by as much as 120 degrees, presenting a formidable challenge to the designer.

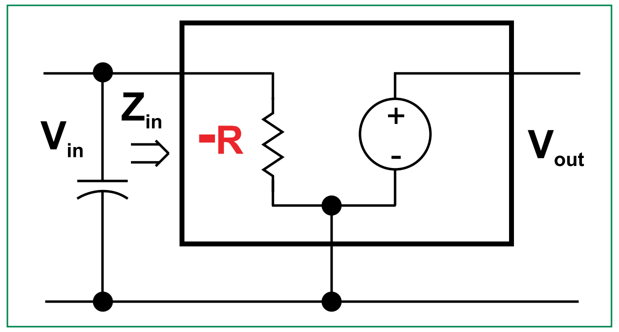


Figure 5: Even if you manage to stabilize the buck converter by itself, it can become unstable again when you apply proper filters to eliminate noise. The negative input resistance can destabilize the passive components on the rest of your circuit board.

rectifiers). There's a big change in the characteristics. Further change can occur if you have electrolytic capacitors in your system, and the temperature is reduced below freezing.

The resulting range of gain and phase curves with all these variations is much worse than a linear regulator loop would ever see. This includes only the basic effects that can occur with switching regulators. Many more variations occur with multiple outputs and noise issues [3].

Now let's take a look at what happens if you succeed in building an acceptable control loop with these variable characteristics. A simplified model is shown in Figure 5. The input impedance of the power supply looks like a negative resistor, which is quite different from the current source of the linear regulator. A negative resistor is a troublesome component in a system, frequently leading to oscillation. With input filters, it can actively excite the LC filters needed for the power supply under certain conditions [2], so great care must be paid to the choice of filter components.

The effect of the filter can be seen in Figure 6. In the green curve, there is a small blip in the gain and phase of the power supply. The design is still OK, but it's interacting with the filter. In the red curve, there is severe interaction, and the power stage suddenly has an additional 180 degrees phase delay in the control characteristic. This power supply will most likely be an unstable design.

There are many more situations that can be created, but hopefully the point has been made. Switching power supplies will never be drop-in designs, like linear regulators. Proper engineering is critical to incorporate the switcher reliably into the system.

The design of a switcher is still a complex task that needs proper engineering attention. Make sure that you budget time and money accordingly, and bring the proper expertise into your project.

Additional Reading

[1] Control function measurement techniques can be found at http://www.ridleyengineering.com/downloads/AP-200Notes.pdf

[2] Read about the effect of filters on switching regulators: http://www.switchingpowermagazine.com/downloads/Evolution of Power Electronics.pdf

[3] For more reasons for convert instability, read: http://www.switching-powermagazine.com/downloads/9 Six Reasons Instability.pdf

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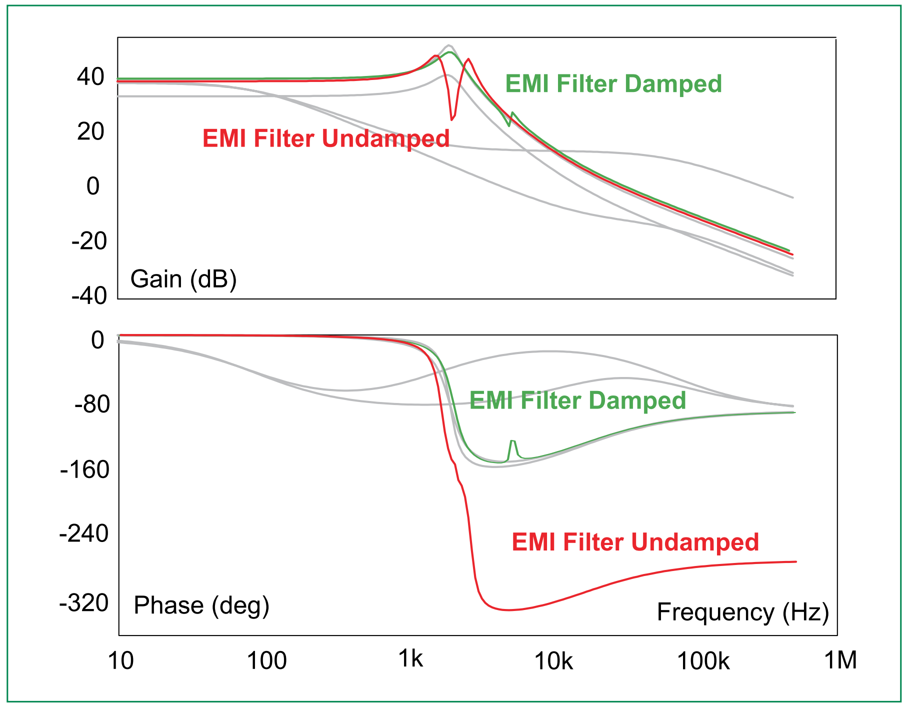

Figure 6: Switching power supplies are noisy. LC filters must be to attenuate the noise. The green curve in this figure shows the effect on control characteristics with a reasonably well-designed filter. The red curve shows what happens when the power supply is unstable. Notice the additional 180 degrees phase delay where the input filter creates a pair of complex RHP zeros in the control loop. The total variation in phase at 10 kHz for the complete range of the power supply is now over 300 degrees!

Power for the Purpose

Considerations in choosing a battery charger IC

With the many constraints of size, dissipation and flexibility on battery charging it's important to choose the part that fullfils all design criteria.

By Steve Knoth, Product Marketing Engineer, Linear Technology Corporation

Battery-powered products such as portable automotive diagnostic meters and USB powered devices as well as non-portable industrial and medical electronics with backup battery systems continue to integrate new functions, transforming them into more convenient and capable products. However, the desire for increased features, portability and flexibility of usage presents a number of design challenges for the product design engineer. These include efficient, fast and accurate battery charging, low power dissipation, stand-alone operation, small solution size, compatibility with both USB and high voltage power sources, and the ability to autonomously manage various input power sources. As a result, battery charger ICs are offered in various topologies including linear and switch-mode and some may also be compatible with smart batteries. Furthermore, they can charge a variety of battery chemistries, from Li-Ion/Polymer to sealed lead acid (SLA) to Nickel-Metal Hydride (NiMH) and Nickel-Cadmium (NiCd). This article will address the issues in selecting the right battery charger IC for your application; it will also explore the various charging topologies available and attributes of each, including design and performance tradeoffs.

Key Design Challenges

The high level of feature integration required of the battery charger IC, when combined with needs to save board space and increase product reliability, exerts pressure on the design of battery-powered electronic devices. Some of the main challenges for the system designer include:

- High current charging capability for faster charging
- Maximization of efficiency and minimization of power dissipation
- High input voltage operation
- PowerPath™ control to switch between multiple power sources or loads
- Compact solution footprint and profile
- Compatibility with USB charging
- Protection of both the battery charger IC and the battery
- Compatibility with smart batteries

High Current Capability & Fast Charging

Most users value the ability to fast-charge their battery-powered devices, leading to a battery charger IC with high current charging capability. Linear charger based topologies may charge "fast"; however, power dissipation needs to be monitored to prevent potential overheating, since the device is essentially a linear regulator with power dissipation being equal to the product of the input-output voltage differential multiplied by the charging current. Switch-mode based charger ICs lend themselves better to faster charging, since their inductor-based topology allows for higher charging currents at higher efficiency, therefore minimizing power dissipation. In addition to speed, high-accuracy charging current reduces variability in charge times for the end device. Examples of fast battery charger ICs are Linear's LTC4010 and LTC4011. These ICs each provide a complete stand-alone NiMH/NiCd battery charger solution without any microcontroller or firmware programming required. They can accurately fast-charge 1- to 16-cell NiMH or NiCd batteries at rates up to 4A from a wide range of input supplies and wall adapter voltages from 4.5V to 34V, with a variety of charge termination options.

High Efficiency Charging with Minimized Power Dissipation

As battery capacities increase, charge currents also increase to maintain a reasonable charge time. Traditional linear regulator-based battery chargers may not be able to meet the charge current and efficiency demands necessary to allow a product to run cool – remember, low efficiency means more heat generation. This situation calls for a switch-mode based charger that requires approximately the same amount of space as a linear solution - but with much lower heat dissipation. Switching regulator based topologies are inherently more efficient due to the nature of the power device's on-off switching action, as opposed to a linear charger's "always on" power device. The Bat-Track™ adaptive output control feature found in some of Linear Technology's battery charger ICs greatly improves the efficiency of the battery charger since the input switching regulator circuit block's output voltage automatically tracks the battery voltage. The LTC4089 is an example of a battery charger/power manager that implements this scheme; more details on this IC will be presented later. The LTC4001 is another example of a high-efficiency battery charger. It is a 2A

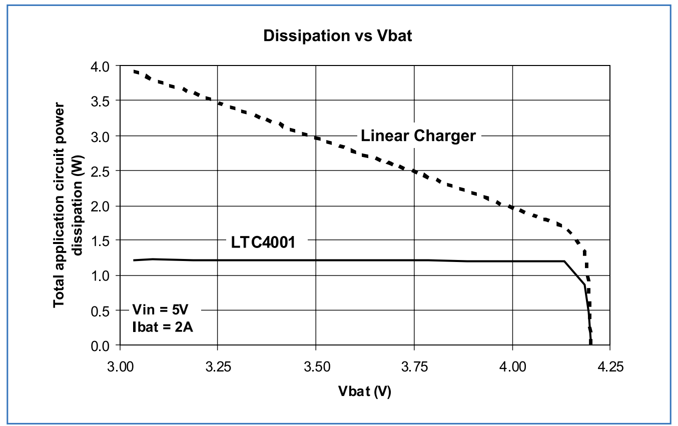

Figure 1. LTC4001's Minimized Power Dissipation Capability Compared to that of a Linear Charging IC

powering from the USB, Li-Ion/Polymer battery or wall adapters with <5.5V input, and in turn may also charge at a fast rate. Nevertheless, an IC with high voltage capability is also less susceptible to voltage input transients, increasing both IC and system immunity as well capable, high efficiency switch-mode battery charger for single-cell 4.2V Li-Ion/Polymer batteries that minimizes heat dissipation without compromising board space, and is housed in a compact 16-lead, low-profile (.75mm) 4mm x 4mm QFN package. Furthermore, the IC's synchronously rectified buck switching topology enables efficiencies as high as 90% at 1.5A charge current, minimizing power dissipation especially when compared to that of a linear battery charger; see Figure 1. The LTC4001's high operating frequency of 1.5MHz and current mode architecture allow the use of small inductors and capacitors, minimizing noise and filtering needs.

High Input Voltage Capability & Susceptibility

Most consumers enjoy the portability of their handheld devices. Therefore, being able to deal with high voltage input sources such as Firewire/IEEE1394, 12V–24V wall adapters, unregulated higher-voltage (>5.5V) wall adapters or automotive car adapter outputs can provide fast charging in locations outside the home or work. With these power sources, the voltage difference between the adapter's voltage and the battery voltage in the handheld device can be very large. Thus, depending on the required charge time and current, a linear charger may not be able to handle the power dissipation. This situation may require an IC with a switch-mode topology to maintain fast charging while at the same time improving efficiency and reducing thermal management issues. Note that a linear charger/power manager may be more suitable when

as reliability. Linear's LTC4002/6/7/8 switch-mode chargers offer high-voltage input operation in excess of 28V and feature the highest efficiency with their synchronous buck switch-mode topology.

PowerPath Control & Ideal Diodes

Many of today's portable battery-powered electronics can be powered from a wall adapter, automotive adapter, a USB port, or a Li-Ion/Polymer battery. However, autonomously managing the power path control between these various power sources presents a significant technical challenge.

Traditionally, designers have tried to perform this function discretely by using a handful of MOSFETs, op-amps and other discrete components, but have faced tremendous problems with hot plugging and large inrush currents, which may cause big system reliability problems. More recently, even discrete IC solutions require several chips to implement a practical solution. An integrated power manager IC solves these problems simply and easily.

PowerPath control allows the end product to operate immediately when plugged in, regardless of the battery's state of charge or even if missing; this is referred to as "instant-on" operation. A device with PowerPath control provides power to the device itself and charges its single-cell Li-Ion/Polymer battery from the USB VBUS or a wall adapter power supply. To ensure that a fully charged battery remains fresh when the bus is connected, the IC directs power to the load through the USB bus rather than extracting power from the battery. Once the power source is removed, current flows from the battery to the load through an internal low loss ideal diode, minimizing voltage drop and power dissipation. Refer to Figure 2 for details.

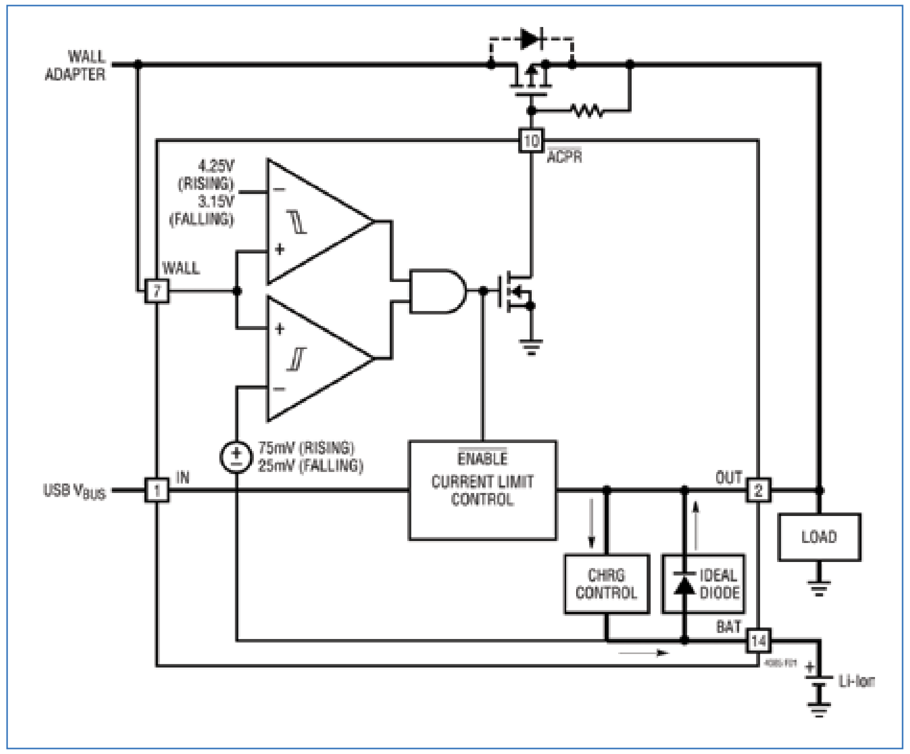

Figure 2. Simplified PowerPath Control Circuit.

A low-loss ideal diode provides power from the battery when output/load current exceeds the input current limit or when input power is removed. Powering the load through the ideal diode instead of connecting the load directly to the battery allows a battery to remain fully charged until external power is removed. Once external power is removed, the output drops until the ideal diode is forward biased. The forward biased ideal diode will then provide the output power to the load from the battery. Refer to Figure 2 for details. The forward voltage drop of an ideal diode is far less than that of a conventional or Schottky diode, and the reverse current leakage can be smaller for the ideal diode as well. The tiny forward voltage drop reduces power losses and self-heating, resulting in extended battery life.

Battery chargers integrated with PowerPath controllers and ideal diode devices (battery managers) efficiently manage a wide variety of input power sources and reduce power dissipation, all with extremely small form factors. Some examples from Linear's portfolio include LTC4089, LTC4085, LTC4066 and LTC4055.

Compact Packaging & Solutions

Space is at a premium in portable devices, as well as in some non-portables.

A compact solution saves board space in space-constrained applications, and reduced component count saves manufacturing PCB pick and place costs and improves system reliability. Tiny, low-profile packaging saves board space and height. A key design tradeoff when weighing topology and size is efficiency. For example, linear chargers do not require an inductor but are less efficient than switch-mode chargers, which require an inductor and thus require more space. Integrated blocking diodes add a layer of protection and save space. Integrated power devices move the thermal management on-chip yet save board space and cost. High switching frequencies in switch-mode topology chargers reduce the size of external components such as inductors and capacitors. Integrated sense resistors not only save cost and space, but they also eliminate the possibility of board layout errors causing accuracy issues. Multiple-input chargers allow design flexibility and reduce PCB routing; the LTC4075/76/77 and LTC4089 are IC examples with separate wall adapter and USB inputs. Stand-alone operation eliminates the need for an external microprocessor to terminate charging, saving space and simplifying design. The LTC4065 and LTC4069 are fully-featured stand-alone chargers offered in a compact, low-profile (0.75mm) 2mmx2mm 6-lead DFN package.

USB Compatibility, Convenience & High Power

There are a number of advantages to offering convenient 5V/500mA (2.5W) USB power and high input voltage power and battery charging capability to handheld devices such as GPS navigators, PDAs, digital cameras, photo viewers, MP3/MP4 players and other multi-media devices. For instance, USB power offers the convenience of not requiring a travel adapter on the road; devices may be powered from a laptop PC or some other device with a USB port, for example. As previously mentioned, high voltage input sources allow charging in various locations, such as in the car. This is important for optimum freedom and portability. Linear's LTC4089 and LTC4089-5 battery charger/managers address these needs. They combine an autonomous power manager, ideal diode controller and standalone high voltage, high efficiency battery charger into one IC for portable devices. They are offered in a low-profile (0.75mm), 22-pin 6mm x 3mm DFN package. For high efficiency charging, their switching topology accommodates various inputs, including high voltage power sources up to 36V (40V max) such as 12V wall adapters, automotive adapters and FireWire/IEEE1394 ports. In addition, they offer flexibility by accepting low-voltage power sources such as 5V adapters and USB. This may be observed in Figure 3's block diagram.

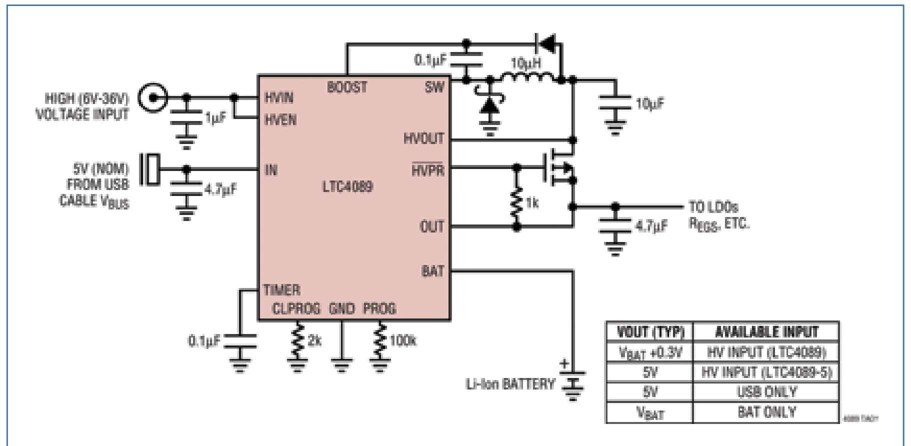

Figure 3. LTC4089's Typical Application Circuit.

Protection for the IC & the Battery

Protection comes in various forms: for the IC, its surrounding external components, and for the battery itself. Onboard thermal regulation prevents the IC from overheating itself and the surrounding components when a minimum threshold temperature is reached. Reverse battery protection protects and disconnects the device and load when the battery polarity is reversed. Reverse current protection prevents battery leakage current backflow into the IC, reducing the chance of damage. Trickle charging refers to two distinct battery charging techniques – a "pre-conditioning" reduced rate charge at low battery voltages to safely prepare a battery for full charge; and a maintenance charge used to top-off nearly full cells (typically Nickel-based chemistries or lead acid batteries). Charge termination and indication options come in many forms, such as by voltage, current, minimum charge such as C/10 or C/x, and fixed or adjustable timer. An onboard battery gas gauge allows the battery's state-of-charge to be monitored. Thermistor input compatibility allows monitoring of the battery temperature, as the thermistor resides in the battery pack in most cases. All of Linear's battery

Table 1. Representative Linear Technology Battery Charger ICs.

Part Number	Topology	Battery	I_{CHARGE}	V_{IN} / abs max	Smart	PowerPath	USB	Standalone	Package
LTC4065/A/9	Linear	Li	750mA	5.5V / 7V	no	no	✓	✓	2x2 DFN-6
LTC4075/6/7	Linear	Li	950mA	8V / 10V *	no	no	✓	✓	3x3 DFN-10
LTC4085	Linear	Li	1.5A	5.5V / 7V	no	✓	✓	✓	3x4 DFN-14
LTC4089	Linear	Li	1.5A	36V / 40V *	no	✓	✓	✓	3x6 DFN-22
LTC4001	Switchmode	Li	2A	5.5V / 7V	no	no	no	✓	4x4 QFN-16
LTC4006/7	Switchmode	Li	4A	28V / 32V	no	INFET	no	✓	SSOP-16/24
LTC4008	Switchmode	Li, Ni, SLA	4A	28V / 32V	no	INFET	no	no	SSOP-20
LTC4010	Switchmode	Ni	4A	34V / 36V	no	no	no	✓	TSSOP-16
LTC4011	Switchmode	Ni	4A	34V / 36V	no	✓	no	✓	TSSOP-20
LTC4100/1	Switchmode	Li, Ni, SLA	4A	28V / 32V	✓	INFET	no	✓	SSOP-24
LTC1760	Switchmode	Li, Ni, SLA	4A	28V / 32V	✓	✓	no	✓	TSSOP-48

* Dual input: USB & wall adapter

charging ICs feature onboard protection, and many ICs have multiple protection schemes.

Battery Chemistry

Batteries come in various shapes, sizes and chemistries, rechargeable and non-rechargeable. The system designer must consider the tradeoffs of each, from the circuit simplicity of "throw-away" non-rechargeable batteries to more complex schemes for rechargeable batteries. The choice of battery chemistry also has many tradeoffs, from size to cost to capacity. The following is a brief summary of the advantages of the various battery chemistries:

-Lead-acid - most economical for larger power applications where weight is of little concern. This is a mature technology.

-Lithium-Ion - offers high-energy density and low weight. Protection circuits may be needed to limit voltage, current and temperature for safety reasons. This chemistry continues to expand with new formulations optimized for different applications and safety requirements.

-Lithium-Polymer - Similar to Li-Ion, this system enables slim geometry and simple packaging at the expense of higher cost per watt/hour.

-Nickel-Cadmium - has moderate energy density. NiCd is used where long life, high discharge rate and extended temperature range are important. It contains toxic metals and is a mature technology.

-Nickel-Metal-Hydride – NiMH has a higher energy density compared to NiCd at the expense of reduced cycle life. There are no toxic metals. This is a growing technology. Current discharge performance approaches NiCd with longer run times.

-Reusable Alkaline - its limited cycle life and low load current is compensated by long shelf life, making this battery ideal for portable multi-media devices.

Smart Battery Charging

The Smart Battery charger IC's primary function is to provide a source of voltage and current for charging a Smart Battery. The Smart Battery communicates with the Smart charger and optionally the host via a data interface called the SMBus. A Smart Battery charger has the following advantages over a fixed stand-alone battery charger:

1) True plug and play operation, independent of battery chemistry and cell configuration. Any Smart battery pack will work with any Smart Battery charger. Batteries with different chemistries, cell configurations, and even different charge algorithms can be swapped with no modification to the charger circuit.

2) Built in safety features. The SBS standards provide watchdog timers and a special "Safety Signal" interface directly between the battery and charger.

3) A reliable battery detection system.

4) Automatic charge management without the need of a host processor.

5) Closed-loop charge system that requires no host processor intervention. A host is welcome to gather gas gauge information if required.

Conclusion

Designers of battery powered products are challenged by demands for small size and convenience, along with needs for high efficiency, fast charging and low power dissipation, as well as USB compatibility and high input voltage capability for portability. At the same time, designs are being integrated to save board space, reduce manufacturing costs and increase product reliability. Linear Technology's large and growing family of battery charger ICs make the product designer's job much easier, featuring a wide selection of attributes and spanning a range of the smallest 2mm x 2mm standalone linear chargers, to fast-charging highly efficient switch-mode chargers to fully-featured Smart Battery-compatible charger ICs. These high-performing ICs enable a myriad of benefits for both the system designer and end user of portable and non-portable battery-powered electronic devices.

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Lightning Strikes Remain Unchanged - But Power Challenges are New

Circuit protection for extreme conditions

Even in the 21st Century, lightning still strikes; power cables still come loose; and circuits remain vulnerable to faults in the devices and assemblies connected to them.

By Huw Muncer, Tyco/Raychem Circuit Protection

For both consumers and engineers, the progression towards enhanced integration and solid state devices with higher speed, better performance and a mind-boggling array of features, is often accompanied by the implicit assumption that electronics is increasingly and inherently robust. This impression is supported by talk of designing for increased reliability, particularly in consumer markets where a reputation for quality is seen as a distinct competitive edge.

With such pressure for innovation, it can be very easy to forget that electronics, far from being tough and resistant to damage, is often delicate and vulnerable.

The bad news is that a whole host of new threats can be added to this range of traditional perils. Components based on advanced semiconductor manufacturing processes are sensitive to ESD (electro-static discharge). Electronics is increasingly deployed in environments which would have been unimaginable 10 or 20 years ago: these include conditions of high temperature or humidity, situations involving exposure to dust, water or solvents and circumstances that involve high levels of shock and vibration.

This state of affairs is worsened by the changing feature set of the electronics itself, and the different techniques for realising those features. The trend towards low-voltage operation means that high currents are encountered more often. And users' expectation to be able to "hot swap" and "hot plug" equipment carries dangers of voltage spikes and sudden charges and discharges.

As a result, circuit protection techniques have had to move forward just as quickly as the equipment that they protect. To the old-style one-shot fuse has been added an array of options including gas discharge tubes (GDTs), multi-layer and metal oxide varistors (MLVs and MOVs), polymeric ESD suppressors and polymeric positive temperature coefficient (PPTC) devices.

The increased range of options reflects not just changing electrical needs, but also a change in function. Whereas the traditional fuse is basically a safety device designed to protect the user, many of the new components are equally important in protecting the equipment itself from damage caused by associated circuits: or in preventing the equipment from causing such damage to interconnected assemblies. This is increasingly important in a world where so-called "connected-ness" is taken for granted. Most equipment today needs to talk to the outside world via some standard interface or another. Such non-safety standards implicitly specify necessary levels of protection, by defining how system components may interact correctly and what happens when things go wrong.

The two main fields of development in circuit protection today are in ESD suppression and "resettable fusing" via PPTCs. ESD is of particular concern at the moment, because new standards such as USB 2.0, DVI (Digital Video Interface) and HDMI (High-Definition Multimedia Interface) specify extremely high-speed signals that can be degraded by the capacitive loading typical of most existing protection strategies.

IEC-61000-4-2 is now almost universally accepted as the most relevant standard for ESD immunity. It specifies a testing regime that simulates the damage caused by an ESD event from the human body, according to a human body model (HBI). Common regulatory requirements, including those in the EU that lead to the award of a CE mark, specify that equipment should conform to IEC 61000-4-2 Level 2, with contact and air discharge test voltages of 4kV: in practice, most manufacturers opt for Level 4 testing, in which the contact and air discharge voltages are 8kV and 15kV respectively. The waveform used for testing rises to its peak voltage (and a maximum current of 30A) in less than

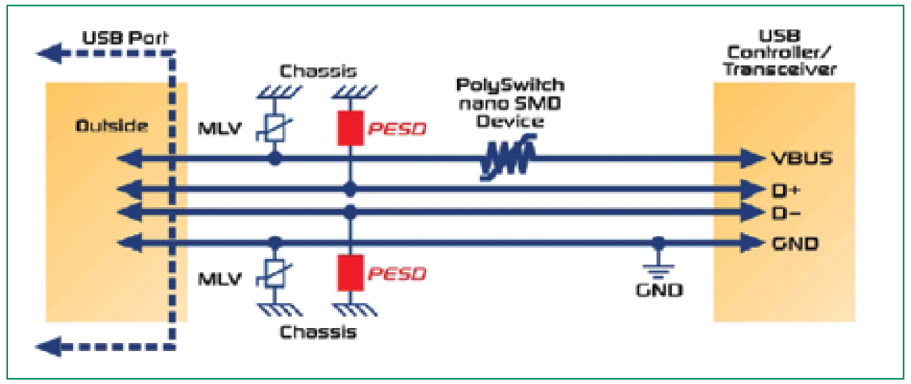

Fig 1. Typical USB 2.0 circuit protection design utilising PESD suppressor devices.

1ns, decaying to 50% amplitude within 60ns.

Whatever ESD protection mechanism is chosen needs to suppress this waveform sufficiently to prevent damage to the equipment. This is commonly achieved using a simple, low-cost Zener diode. Such an arrangement will clamp the voltage to a few volts, with a response time which will be deemed satisfactory at around 1ns. The penalty for such an implementation is a fair amount of leakage current, and a high capacitive loading (50pF or more) on the rails which are being protected.

Such a performance penalty is acceptable in applications such as the audio path of a mobile telephone, RS232 serial port, keyboard or mouse interface. Standard transient voltage suppression (TVS) diodes provide similar performance but with higher clamping voltages, for use in automotive applications, general electronics and white goods. MOVs and standard MLVs, meanwhile, exhibit higher capacitance (at least 100pF), but generally have faster response times (in the sub-1ns range).

Higher-speed applications such as USB 1.1, Ethernet and LCD drivers require lower capacitive loading of below 10pF, and can therefore be served only by low-capacitance components such as specially-designed TVS diodes and MLVs. The former provide low-to-medium clamping voltages, modest current leakage, and response times of 1-5ns. The latter clamp at over 100V and suffer from higher leakage current, but can achieve the sub-nanosecond response times required in some applications.

Protection of the fastest devices on the market today, however, requires a different class of components. Standards such as USB 2.0, IEEE 1394 and DVI impose severe restrictions on the acceptable capacitive loading. DVI transmitting equipment, for instance, can operate at up to 1.65Gbit/s; HDMI typically operates at a rate of 750Mbit/s. These specifications put designers in a bind, because transmission speed is not optional: the usual consequence, then, is to sacrifice a degree of ESD resistance. This risks damage to the sensitive chips that the protection scheme is intended to safeguard, but also puts additional stress on the protection component itself.

The new USB 2.0 protocol provides a further case in point. It allows for data transfer rates of up to 480Mbit/s and supports plug-and-play hot swappable installation and operation. These factors make low-capacitance ESD protection of the bus essential.

Polymeric ESD (PESD) suppressor devices are one recently-developed solution to this problem. The mode of operation of such a device is relatively simple: conductive particles are dispersed in a non-conductive polymer within the body of the component. The polymer maintains a separation between each conductive particle which acts like a “spark gap”. For this reason, PESD devices have both very low leakage current and very low capacitance. However, a high-voltage ESD pulse which exceeds a certain trigger voltage will cause the gaps to spark-over, creating a path of very low resistance. It is this mechanism which leads PESD devices to typically exhibit higher trigger voltages than clamping voltages: the energy needed to start the process is higher than that required to maintain it.

PESD devices provide exceptionally low capacitance (typically 0.25pF): advanced devices such as those recently announced by Raychem can also offer trigger voltages of around 100V and clamping to a few tens of volts. These are improvements on key specifications which to date have limited such devices’ usefulness. A further important parameter is their performance in transmission line pulse (TLP) testing: and IEC 61000-4-2 specifies that devices must withstand at least 100 ESD “strikes”, with a typical figure of 500. Engineers should be aware of the performance impact of multiple strikes when selecting such components.

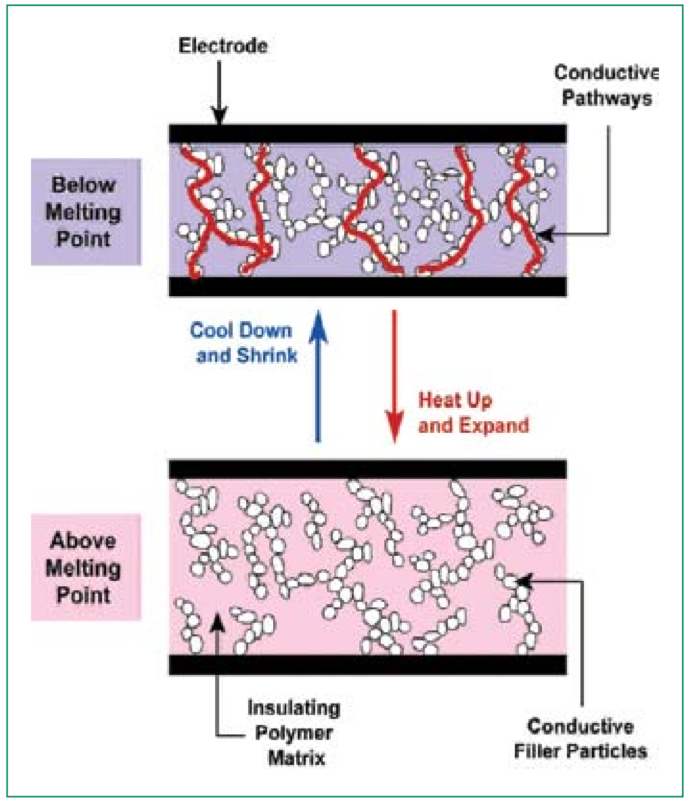

Figure 2. PPTC Crystalline Structure.

As with most of the common techniques for ESD suppression, designing with PESDs requires the engineer to adhere to certain best-practice guidelines. Data signal ground and Vbus transients need to be suppressed for proper operation, typically via a separate MLV. Conversely, good design practice suggests that it is wise to avoid tying the data signal ground line to the chassis ground line at the board level, suggesting the use of decoupling capacitors between Vbus and chassis ground to minimise EMC issues. Finally, as with all ESD suppression devices, PESD components should be installed as close as possible to the source of the potential ESD event.

Polymeric materials are also making an impact in the most familiar of all circuit protection applications, fusing. PPTC devices protect assemblies in the same way as a traditional fuse, effectively going open-circuit when subjected to an over-current (or over-temperature) condition. However, unlike a traditional fuse, when the fault condition is removed and the power is cycled, the PPTC returns to its normal conducting state. Each device is typically specified

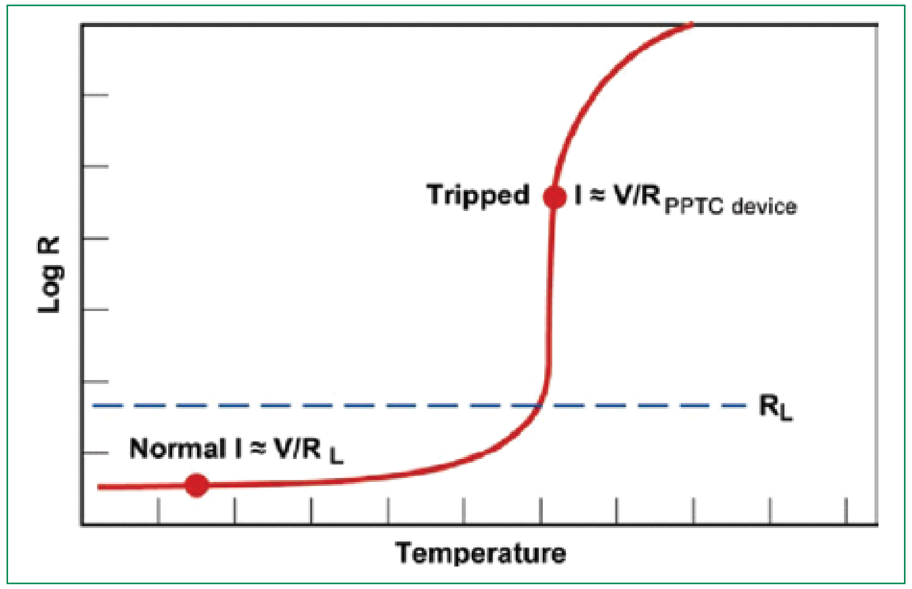

Figure 3. Typical operating curve for a PPTC device.

by a “hold” current, which is the minimum current that the device will pass without tripping at 20° C.

Like PESD suppressors, PPTC circuit protection devices are made from a composite of semi-crystalline polymer and conductive particles. However, whereas PESD devices are normally non-conducting, PPTCs are normally-conducting devices. At room temperatures, the conductive particles form low-resistance networks in the polymer (see figure). But if the temperature rises above the device’s switching temperature (T_{Sw}), the crystallites in the polymer melt and become amorphous. The increase in volume during melting of the crystalline phase causes separation of the conductive particles and results in a large non-linear increase in the resistance of the device.

Because the “fusing” process is temperature-dependent, it can be triggered either by high current passing through the part, or by an increase in the ambient temperature. This means that a PPTC component can be used both as over-current and over-temperature protection. For instance, in a power supply it can be physically located on the transformer windings so that it will trip if input voltage sag conditions cause an increase in transformer power dissipation and hence heat dissipation – even if the increase in current is insufficient in itself to trip the device. Similarly, in a switch-mode power supply, the device can be mounted in contact with critical heat-generating parts such as the MOSFETs.

The resistance of a PPTC typically increases by three or more orders of magnitude (see figure) and the device will remain in its latched (high-resistance) state until the fault is cleared and power to the circuit is removed – at which time the conductive composite cools and recrystallises, restoring the device to a low resistance state. This resettability provides more than just a cut in the need for service calls and maintenance costs: since it is not necessary to provide access for fuse replacement, it also allows a reduction in board space. There may also be safety advantages because service personnel do not need to access areas which contain potentially uninsulated terminals carrying line voltages (or higher).

From at least one point of view,

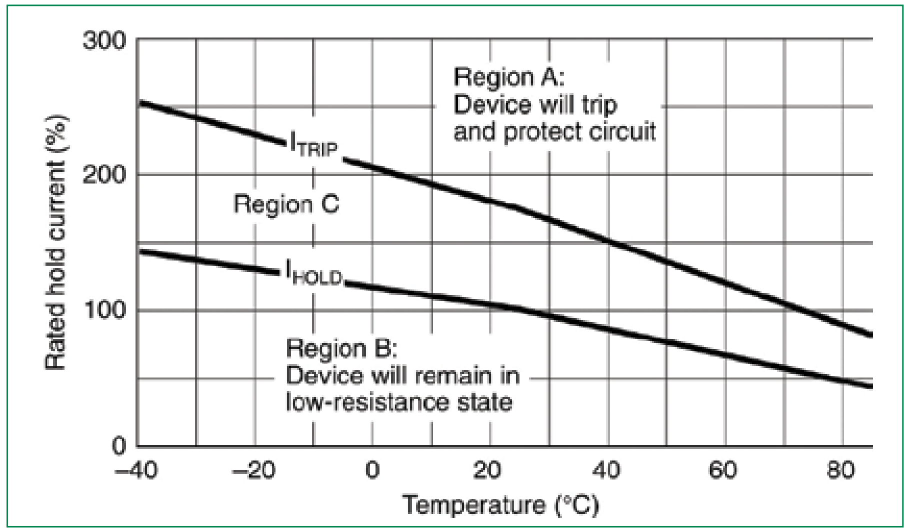

Figure 4. IH and IT vs. Temperature.

designing with PPTCs is simpler than using traditional fuses. The latter can be blown by momentary transients, causing nuisance failures: it is therefore often necessary to set the fuse rating much higher than the system operating current to avoid such events. Under these circumstances, the fuse is more appropriately viewed as a safety device than a circuit protection device, since it will likely be too highly rated to prevent the level of current that might damage the more sensitive system components and ICs. The PPTC, in contrast, can be specified with a trip point much closer to the actual operating current of the system, providing better protection of the electronics and helping to prevent damage when, for instance, external load components fail.

Five other parameters are relevant when considering the use of a PPTC device. The first and most basic of these is maximum voltage capability, since the system voltage is fixed. Next are two measures of current: hold current and trip current. The former is the highest continuous current that the device is guaranteed to pass without tripping at standard operating temperature, and the latter is the minimum current that will trip the device. It is important to consider the derated hold and trip currents (figure x shows a typical characteristic) at the product’s designed-for operating temperature, because, as we have already noted, PPTC devices are thermally activated.

The final two quantities that need to be considered in specifying a PPTC are time to trip, and resistance. This first specification will be dependent upon the amount of fault current through the device and the system operating temperature. The higher the temperature at the time of fault, the faster a PPTC device will trip (see figure 4 for a 265VAC rated PPTC device). Resistance is generally specified at 20°C, in terms of minimum, nominal and maximum values: not as a tolerance percentage as would be the case with standard resistors.

Increasing performance and speed of operation – and changing standards – often mean radical changes in the technologies required to implement systems. But sometimes these changes are more subtle. Just as the advent of USB 2.0, DVI and HDMI has led designers to rethink their strategies for ESD protection, the widespread introduction of broadband communications has brought about major changes in the requirements of telecommunications infrastructure, including equipment that is installed outdoors or on the customer’s premises.

In this field one of the major circuit protection challenges is to build in resistance to over-voltage faults of the type caused by lightning or near line plant, and short-term induction from – or worse, contact with – AC power lines. To emphasise the fact that things have not stood still, even in this relatively well-established application, the ITU has within the last two years revised its testing requirements for such situations.

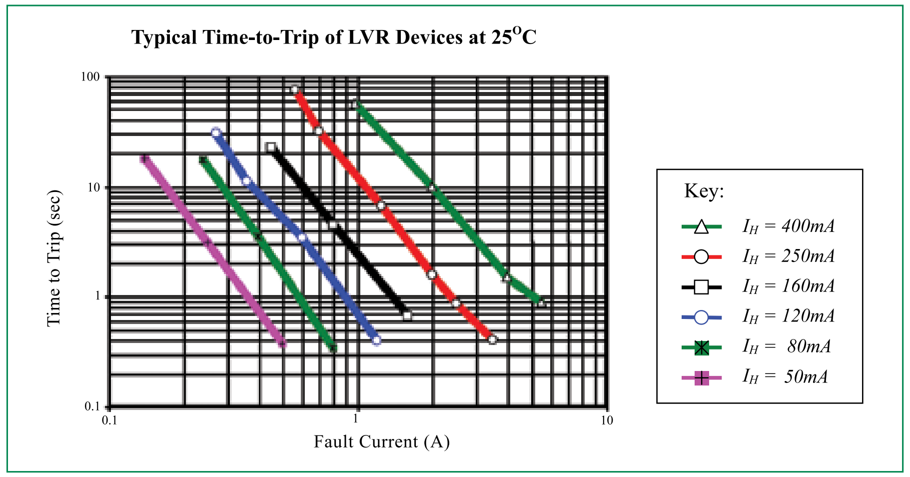

Figure 5. Time to Trip curves for a 265VAC rated PPTC device.

Given modern high-speed transmission rates, the challenges are not dissimilar to those encountered with ESD protection on high-speed lines: to devise effective ways of shunting away extremely large voltage spikes without compromising the system’s ability to transmit and receive at high speed.

In contrast to the case of USB 2.0 and DVI, however, this is one area where it has proved possible to evolve established technologies to accommodate new requirements. The use of Gas Discharge Tubes (GDTs) and thyristors continues to represent the best solution in such applications. GDTs are used in parallel with the components they are protecting: in the event of a voltage surge they switch from their normal high-impedance state to a very low impedance state. GDTs have extremely low capacitance, and so are suitable for use on high-speed lines such as ADSL and VDSL. Thyristors are valuable in similar applications for their very low on-state voltage and relatively small form factor when compared to devices of similar energy-handling capacity.

It seems likely that circuit protection and safety devices will remain in the “unsung hero” category of electronics components for the foreseeable future. However, advancements in the speed and power of our systems are possible only for so long as these particular devices can continue to develop and ensure robustness and safety. All of the semiconductor advances in the world are useless if the components are regularly “zapped” by ESD, and the only conclusion can be that future products look like needing more protection, not less.

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High Current Demands Need Managing

Load sharing techniques for power supplies

High current power supplies are often operated in parallel to fulfill redundancy requirements or to share the stress on individual components. Proper parallel operation is required to share the current equally.

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This article offers solutions to address load sharing, reducing stress on individual supplies, providing dedicated load share controllers as well as integrated multi phase regulators; solutions that ensure low output voltage tolerance as well as improved stability behavior.

This article introduces the concept of parallel power supplies explaining advantages and disadvantages with practical examples.

Internal Load Sharing

For power supplies with large output powers the distribution of the load into two or more parallel power supply paths has many advantages. One example is an application where an input voltage of about 24V is stepped down to an output voltage of 12V. The load current will be 10A in steady state. If no galvanic isolation is needed a typical buck topology will fit best. A buck regulator converting 24V to 12V has an approximate duty cycle (ratio of on and off time of the switching element) of 50%. The Buck regulator has the switching element on the input side of the converter and the LC filter on the output side. So the input current will be large while the switching transistor is on and when it is off there will be no current flowing into the converter. In our example we would have 50% of the time an average current of 10A and the other 50% no current coming from the source when neglecting conversion losses. This extreme input power variation on the input during steady state operation causes many problems. The input capacitors see very large AC currents, the power source is loaded discontinuously, EMI is likely to be excessive and without very good filtering depending on the power source the input voltage will vary significantly.

An idea to deal with such problems is to use multiple buck regulators and to put them in parallel with a phase shift. In an ideal case with two channels with 180 degrees phase shift and 50% duty cycle per channel the input current and with this the input power would be constant. So theoretically an input capacitor would not be needed. Of course reality looks a bit different. As soon as both channels are not operating at 50% duty cycle there will be times while channel 1 is turned on and channel 2 as well or both channels will be off for some time which will interrupt or increase the continuing power coming from the source. So in reality some input filtering is still necessary. But in most cases the filtering can be minimized. Input filtering is especially expensive for high input voltages.

Figure 1 shows a graph of input current ripple with varying duty cycle on channel 2 while duty cycle of channel 1 is 50%. The graph is valid for all phase shift converters. When current sharing is implemented the Iout1 divided by Iout2 is one. Then the input current will behave like the area with the green arrow is in the graph.

The example above uses two phases but the concept can be extended on multiple phases. Depending on the output power and other requirements a 3 or 4 phase system might be beneficial.

National Semiconductor offers the LM5642 dual buck regulator which has possible current sharing included. The controller has an input voltage of 4.5V to 36V and the output voltage can be set with external resistors. Since the device is a synchronous controller with external power FETs it can be used for high current applications with the appropriate transistors.

Whenever current sharing is implemented the control circuitry has to know

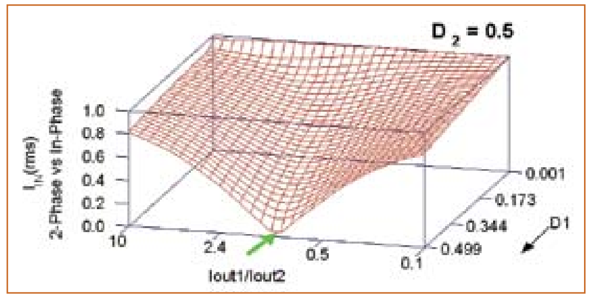

Figure 1. Input ripple current vs. duty cycle and load.

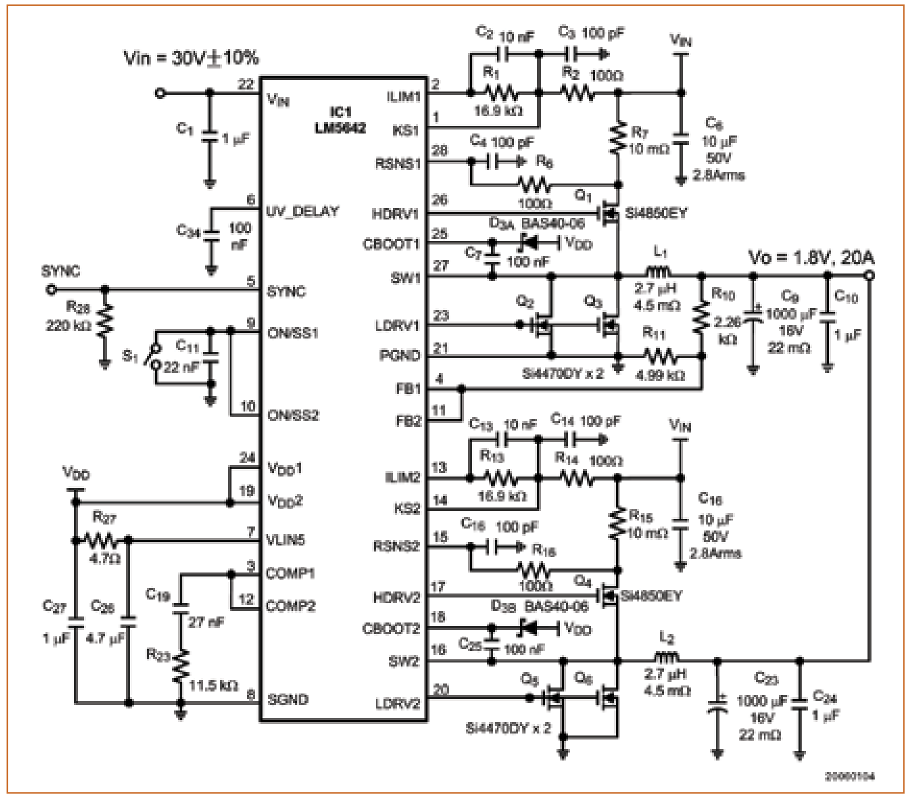

Figure 2. LM5642 current sharing schematic.

the actual current of each channel so that adjustments to each channel can be made to provide an equal distribution of the load on all channels. A good regulation loop scheme for this purpose is current mode control. In current mode control the inductor current is partially sensed by a sense resistor or by the Rdson (drain source resistance while the transistor is turned on) of one of the FETs. This way the information about the current level is known and a current distribution on multiple channels is fairly easy.

The LM5642 offers current sensing with the external FETs Rdson to save the external current sense resistor or with an external sense resistor to have more precise current sensing and by this a more precise current sharing.

External Load Sharing

A much more flexible way to share current in multiple power supplies is using an external controller such as the LM5080 from National Semiconductor. It can be used for internal current sharing as well as external current sharing when power modules (bricks) are used. It is a small device in an MSOP-8 package which can be attached to many power supplies in different topologies. Per power supply one LM5080 IC is needed. The device will sense the current of the individual power supply with a sense resistor. The information is used with an average program method of active load share control. The current may be sensed on the low side or high side. With the current information all the LM5080s in a multi power supply system communicate on the 'sharing bus' to find out what the appropriate current for each power supply will be. The average program method improves stability and has less output voltage variation then other current sharing techniques. There are multiple methods of influencing the regulation loop of each power supply to control the individual share of current. There is the feedback adjust method, the remote sense adjust modes and the reference adjustment operation mode. These modes will be explained in more detail in the next few paragraphs.

To understand the functionality of the device better figure 4 shows the internal setup. The circuitry consists of a remote sense buffer, a CSP mode comparator and a current sharing transconductance amplifier. SHR is the connection for the share bus, TRO is delivering the error current, CSO is the current sense output, CSM and CSP are the minus and the plus connections of the external current sense resistor. RSO is the output which is utilized when driving the low impedance remote sense pin of a power converter. For each of the adjustment methods explained below these pins are connected differently. This implements a great flexibility of the LM5080.

Feedback Adjustment Method

The feedback adjust method influences the power supply's control loop by applying an error current to the feedback divider. Current sensing is done on the high side of the load. It is done with the Vin pin connected to the positive supply bus (the positive voltage where the load is attached) and the Current Sense Minus (CSM) pin. The 'influencing' signal is a current sent out on the TRO pin. It is connected to the power converters trim pin. The trim pin is usually just a connection to the FB Pin (error amplifier input) with a resistor in series. The small signal transfer functions of two parallel power converters are:

IT1 = 0.9 * gm * (Vrs1-Vrs2)

IT2 = 0.9 * gm * (Vrs2-Vrs1)

The IT1 and IT2 are the currents injected to the trim pins of the individual power supply. Gm is the current share amplifier transconductance and Vrs1 and Vrs2 are the voltages sensed across the individual sense resistors. The formulas describe that IT1 and IT2 will 'influence' the power supplies whenever the voltage across the sense resistors is different. This will force the same current on each paralleled power supply.

Remote Sense Adjust Modes

Another adjust method is the positive or negative remote sense adjust mode. They require power supplies with a dedicated remote sense pin. This pin can be a negative remote sense pin as well as a positive remote sense pin. In this mode the RSO and CSO pins are connected together which changes the function of the current sense amplifier to a voltage error amplifier with a gain of one. For better understanding let us disconnect the LM5080 from the share bus and let us see how the current sharing mechanism operates. Voltage

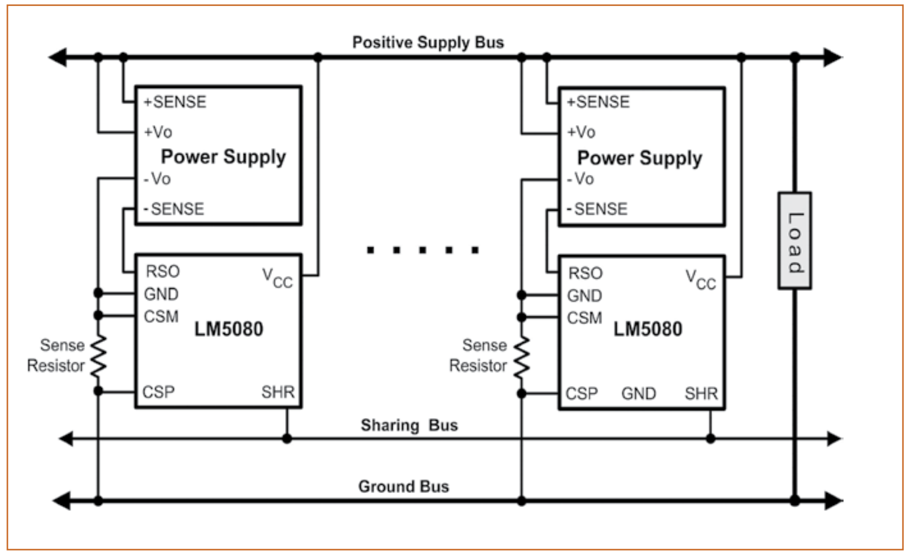

Figure 3. Practical current sharing arrangement.

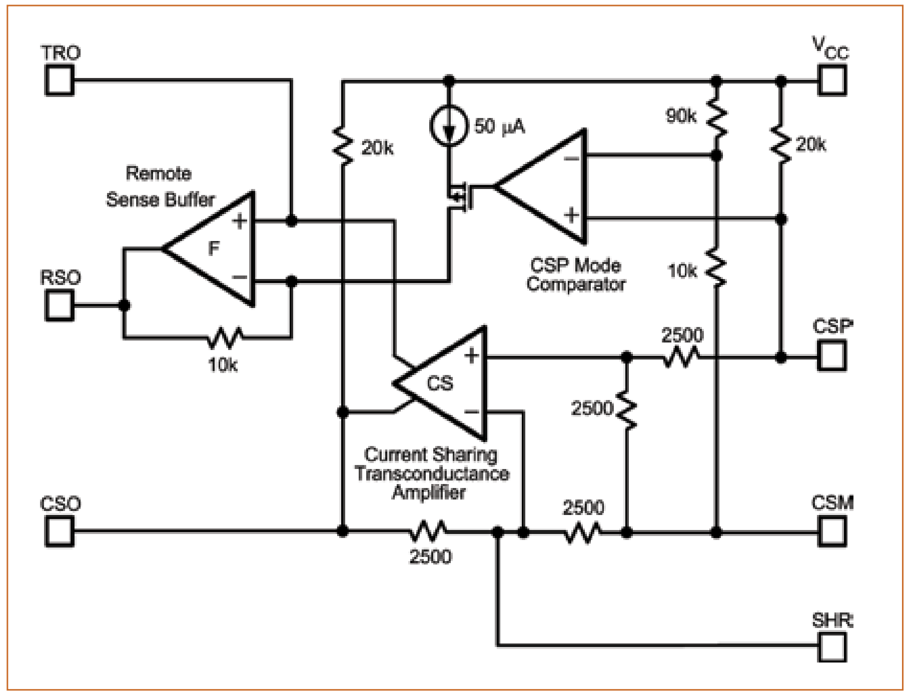

Figure 4. LM5080 internal circuitry.

on the CSP and RSO pins (Vsns) will be the same and are not influenced by the voltage across the sense resistor. This is why the LM5080 would not influence the power supply when no voltage on the share bus is present. Now as soon as a voltage on the share bus is applied, the RSO and CSO outputs will be affected. This way multiple parallel power supplies will force the individual sense resistor voltages (Vrs) to be the same.

The formulas describing the behavior are shown below. A is a certain factor including gain, some external components values as well as the output resistance.

Vsns1 = A/4 * (Vrs1 - Vrs2)

Vsns2 = A/4 * (Vrs2 – Vrs1)

The formulas above describe again a current sharing system with two power supplies in parallel. It can be seen that the individual 'influencing' voltages Vsns1 and Vsns2 are making sure that Vrs1 and Vrs2 are the same and by this that the current in the two power supplies are the same.

Reference Adjustment Operation Mode

The reference adjust operation is very similar to the feedback adjust method. Typically only the current sharing amplifier is used. The RSO buffer can be used additionally to increase the loop gain of the current sharing amplifier. The current sensing is done on the low side. So CSM is connected to the current sense resistor. TRO is sourcing a current into the trim pin of the power supply to influence the regulation.

The small signal transfer functions are the same as with the feedback adjust method described above.

The future of current sharing

Different current sharing possibilities have been discussed and the basic functionality of current sharing explained. Components such as National Semiconductors LM5642 as well as the new current sharing controller LM5080 offer the technical capability to easily implement current sharing. When and how this technology is used depends greatly on the requirements and the cost structures of individual designs. A big plus for current sharing is the possibility of redundancy in case of the failure of one power supply. If the other power supplies are designed to handle the full load for a certain amount of time, the system will not be forced to shut down immediately. In combination with a hot swap controller individual power supplies can even be replaced without the system shutting down.

Current sharing in power supplies will stay very important for some specific requirements and controllers such as the LM5080 will help designers to get better results faster then with complicated and large discrete circuits.

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Automotive Electronics

Part II

The Next Chapter in Automotive Electronics

Power semiconductor modules for Hybrid Electric Vehicles

The success of the hybrid electric vehicle (HEV) is directly linked to the success of power semiconductor manufacturers to deliver reliable, compact components at low cost.

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In hybrid electrical vehicles (HEV) the battery, motor, and inverter are the core elements of the electric drive train. In the inverter, power semiconductors, usually packaged in a module, are used. This article describes the requirements on such power semiconductor modules in terms of power carrying capability, thermal behavior, reliability, and lifetime in HEV.

The market size in 2005 for power semiconductors was close to 2.4 billion US$ according to an IMS study. More than 60% of such devices ended up in industrial applications followed by consumer goods and transportation with 30% market share. Automotive industry accounted for only 5% of the market. Considering these numbers it is no surprise that most power semiconductor modules on the market have been developed for non automotive applications.

Requirements on power semiconductor modules for HEV

The power rating of a power semiconductor module in a hybrid electric vehicle is directly related to the installed generator/motor power rating. For mild hybrids an installed motor power of 12-16kW based on a battery voltage of 200-300V is mainstream. For full hybrids the power range of the generator with 30-50kW is rather well defined, while the power rating for the motor can vary by vehicle between 30kW for midsized sedans up to 150kW for trucks and SUVs. Associated with the power that needs to be converted are conduction and switching losses in the power semiconductors. The losses can be estimated by equation 1.

Typical values for power losses of

$$P_{loss} = P_{loss\_IGBT\,1..n} + P_{loss\_Diode\,1..n}$$
$$P_{loss\_IGBT} = I_C \times U_{CE} + f_{switch} \times (E_{on} + E_{off})$$
$$P_{loss\_Diode} = I_F \times U_F + f_{switch} \times E_{rec}$$

Equation 1: Power stage loss calculation.

hybrid drive power stages are listed in the table 1.

Application	P_{elec}	P_{loss}
Mild hybrid motor	~15kW	~0,7kW
Full hybrid generator	~50kW	~1,6kW
Full hybrid Motor	~100kW	~2,5kW

Table 1. Typical Inverter losses in HEV applications

Voltage level as well as power demand of hybrid electric drives are in the typical range for industrial applications. Traction applications usually handle higher power and voltage.

Power semiconductors are characterized by a maximum junction temperature at which they can be operated. Exceeding this temperature can lead to damage or immediate destruction. Even during worst case conditions the power losses generated in the power semiconductors must be dissipated by the thermal stack consisting of power module, heat sink and coolant. According to equation 2 there are three ways to improve the inverter system. Increase the temperature rating (T_{j_max}) of the semiconductor, improve the efficiency

$$T_{j\_max} > T_j = \left[P_{loss} \times (R_{th\_jc} + R_{th\_ch} + R_{th\_ha})\right] + T_a$$

Equation 2: Temperature calculation.

Figure 1. Infineon power module for direct liquid cooling (Prototype)

of the power stage by reduction of the semiconductor losses (P_{loss}) and reduce the thermal resistances.

The thermal resistance of the power module is represented by the term R_{th_jc}. It can be improved by choice of material, adequate assembly technologies and placement of the semiconductors. R_{th_ch} can be influenced by the connection of the module to the cooling system. Fig. 1 shows a power module for direct liquid cooling, where the R_{th_ch} can even be eliminated.

The ambient temperature as well as the thermal resistance R_{th_ha} is a function of the cooling system implemented in the vehicle. Typically four ways to cool the inverter are practical.

A.) Forced air cooling (T_a<60°C)
B.) Liquid cooled separate cooling loop (T_a<80°C)
C.) Liquid cooled engine coolant (T_a<105°C)
D.) Liquid cooled transmission coolant (T_a<125°C)

In terms of thermal resistance, liquid cooled systems show significantly better behavior than air cooled systems. Due to the low losses, mild hybrid systems can still be cooled with forced air cooling. Full hybrid systems need liquid cooling to dissipate the power. For industrial power semiconductor modules, forced air cooling is state of the art. Liquid cooling can be found, but the temperature profile is less stringent than in HEV systems. Also the liquid cooling used in traction application is not as demanding.

As with most automotive components, the requirements for power semiconductors vary between different mounting places. For simplification the following categories will be used:

In terms of mechanical requirements, these categories differ by level of shock and vibrations. While boot mounted applications are specified for a vibration level of 5g and shock up to 10g, transmission mounted applications are required to survive 30g in vibration testing and 100g during shock tests. Industrial and traction modules are designed and tested to survive a vibration test with 10g, most modern designs will however be able to pass 20g. Mechanical shock test at up to 100g with industrial and traction modules have also shown good results for certain designs. Still, most modules will need a redesign to pass the requirements for transmission mounted applications.

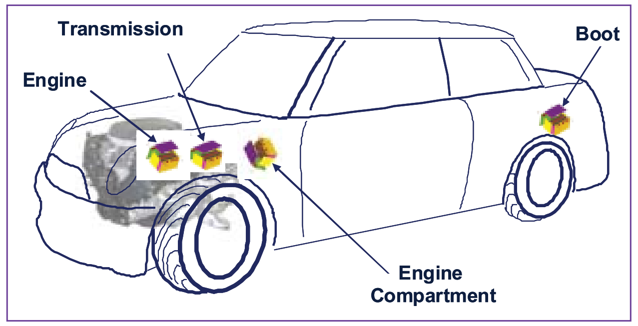

Figure 2. Mounting locations for power electronics in HEVs

Changing loads are typical for the operation of power semiconductors. These generate temperature cycles of which temperature rise and duty depend on the application. In addition to the active temperature cycles generated by the power semiconductor, a high number of passive temperature cycles are applied to the module by the coolant. Both passive and active cycles limit the lifetime of a power semiconductor module. The required lifetime of an automotive is very well described with 15 year non-operational and 12.000 hours operational, but translating this into power cycling and thermal cycling requirements is a difficult task. The actual cycles (number, temperature level and temperature swing) that a hybrid electrical drive will experience depends on cooling system, level of hybridisation, implementation of hybrid strategy, drive cycle, environment, and ultimately the driver himself. For each hybrid electric drive train in a vehicle, power and thermal cycling requirements have to be defined individually as their influence on module cost is significant. As a general rule, boot-mounted inverters with forced air cooling are similar in terms of thermal cycling requirements to industrial applications, while requirements of all liquid cooled applications are closer to those common in traction converters.

State of the art power semiconductor modules

Although there is a wide variety of designs for power modules on the market, when viewed from a vertical aspect (direction of heat flow), two standards can be named today: power modules with base plate and constructions without base plate.

Fig. 3 shows the construction of a module with base plate. Ceramic substrates which are laminated with copper on both sides are soldered to this base plate. The upper copper layer is structured and silicon components are soldered onto it. The top sides of these are connected with wire bonds to the copper layer. Mainly standard modules are made in this way with 70% to 80% of power modules today produced as the principal construction "Standard Module". As a ceramic material, often Al_2O_3 is used; in some special cases AlN and

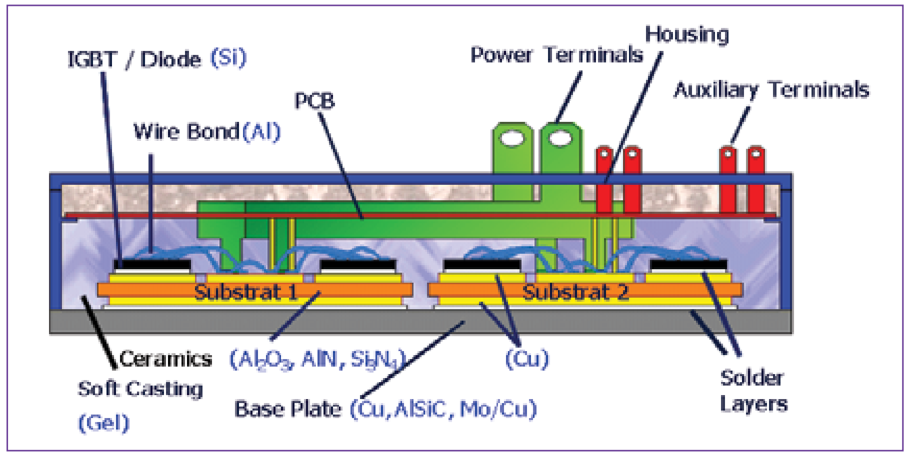

Figure 3. Construction of a power module with base plate

Automotive/Power Semiconductor Modules

Si3N4. The base plate consists of copper in most cases, but in some special high power modules it is made of compound materials such as AlSiC or Cu/Mo.

Today, top side wire bonding and bottom side soldering is commonly used to connect the chip in a power semiconductor module. For accelerated lifetime testing power cycling is used to determine the long term stability of these

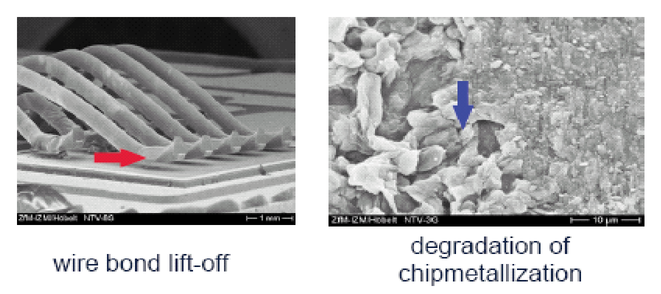

Figure4. Typical failure modes in power cycling tests.

interconnections. Typical failure modes in this test are bond wire lift off, degradation of chip metallization and solder degradation of the chip solder (Fig.4).

The number of cycles that a device survives is related to the temperature swing, the maximum temperature, and the slopes. With process improvements in the wire bonding process as well as introduction of processes after the actual bond process, power cycling capability can be improved. Today, maximum temperature rating, temperature swing and slopes for industrial and HEV applications are similar. Regarding power cycling capability, power semiconductor modules with an improved bonding can fulfill HEV requirements.

While the main fatigue during power cycling in today's power semiconductor modules can be observed in the chip related interconnections, thermal cycling failures have mainly been found in the interconnection of ceramic to copper and solder connection base plate to substrate.

Fig. 5 shows how materials used in the power module expand due to temperature load. The different coefficients of expansion create stress at the connection points which over time leads to a degradation of the joint. A simple way to improve the thermal cycling capability of a module is to match the coefficient of thermal expansion (CTE) of the interconnected materials. This fact triggered the introduction of AlSiC base plates for traction applications. For AlSiC base plates the CTE closely matches the CTE of the substrates. Hence, much higher TC reliabilities can be achieved in modules using AlSiC as a base plate material. To avoid the high cost involved with AlSiC or equivalent solutions like Cu/Mo sandwich designs or Cu/C base plates and still reach the thermal cycling requirements of HEV applications, Infineon worked intensively on an improved solder process for copper base plate as well as an optimization of the substrate.

In numerous thermal cycling tests it has been found, that for typical substrate-to-base plate solder connections, the substrate usually starts to delaminate inhomogeneous and faster if the solder thickness was inhomogeneous. Based on the above observation the solder process was improved by introduction of spacers. With the spacer technology the solder layer is not only more homogeneous but also the solder thickness can be controlled more accurately. An optimized thickness of the solder layer results also in improved thermal cycling behavior.

Due to the RoHS/WEEE directives, great effort has been directed towards the introduction of new lead-free solders. In this context a variety of different solder materials has been analyzed with regard to their TC performance. SnAg3.5 solder which is used for medium power modules already has the best performance of the tested solder alloys. Figure 6 shows thermal cycling results of various solder materials.

Apart from the solder material and its geometric layout, the substrate also still offers improvement potential. While substrate material and layer thicknesses are obvious influence parameters, the layout of top side and bottom side copper is often neglected. The influence of the top side copper layout on delamination is indeed insignificant, but its influence on the increase in thermal resistance for the power semiconductors has to be considered. The lifetime of an application is limited by the increase in thermal resistance rather than by delamination itself. Design of the copper layer on the bottom side can directly influence the delamination. The aim of a bottom side layout should be a reduction in the mechanical stress induced into the corners of solder connection by the substrate. One way to reduce this stress is to extend the bottom side copper over the edges of the actual ceramic material of the substrate.

Thermal cycling limits the lifetime of power semiconductor modules in a hybrid electric vehicle. Traction applications have proven that even the most extreme thermal cycling requirements can be handled, but the costs involved

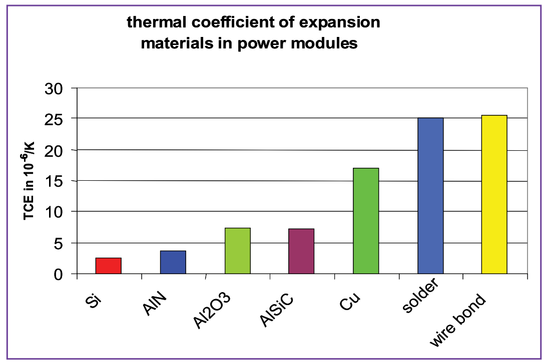

Figure 5. Thermal expansion coefficient of materials used in power semiconductor modules.

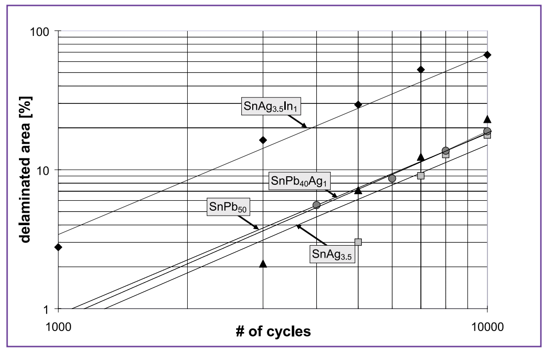

Figure 6. Delaminated area vs number of cycles for different solder materials.

with these modules will not be accepted in HEV applications for long. To design a cost optimized power semiconductor module for an HEV application it is important to know the thermal cycling requirements of the individual system and implement the necessary technologies.

Future trends in power semiconductor modules for HEV

A general trend for power electronics is the increase in power density. This applies also and especially for automotive applications where space and weight are precious. Better cooling, elevation of maximum junction temperature and reduction of losses can be identified as the main levers to improve power electronics for future hybrid electric vehicle and fuel cell electric vehicle application (Fig. 7).

As the coolant temperature in a vehicle is defined by the system and most automotive manufacturers would rather raise it to reduce system cost (e.g. spare the additional coolant loop for the power electronics), better cooling can only be achieved by reduction of the thermal resistances in the system. Eliminating the thermal resistance between module and heatsink by means of direct water cooling can be a solution for the future here. It is the task of the power semiconductor manufacturers to develop new silicon technologies and advanced interconnection technologies. While existing trench-fieldstop concepts like Infineon's IGBT3 and IGBT4 offer the possibility to further increase temperature and reduce losses, traditional wire bonding and soldering technologies seem to be at an end. New low temperature joining techniques like the one shown in figure 8 have already proven to be very reliable.

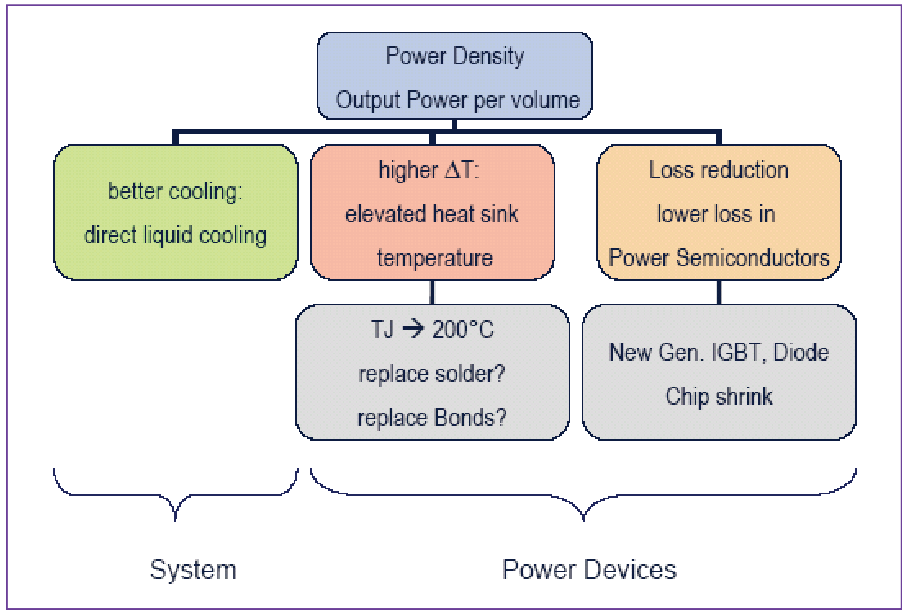

Figure 7. Influencing factors to increase power density.

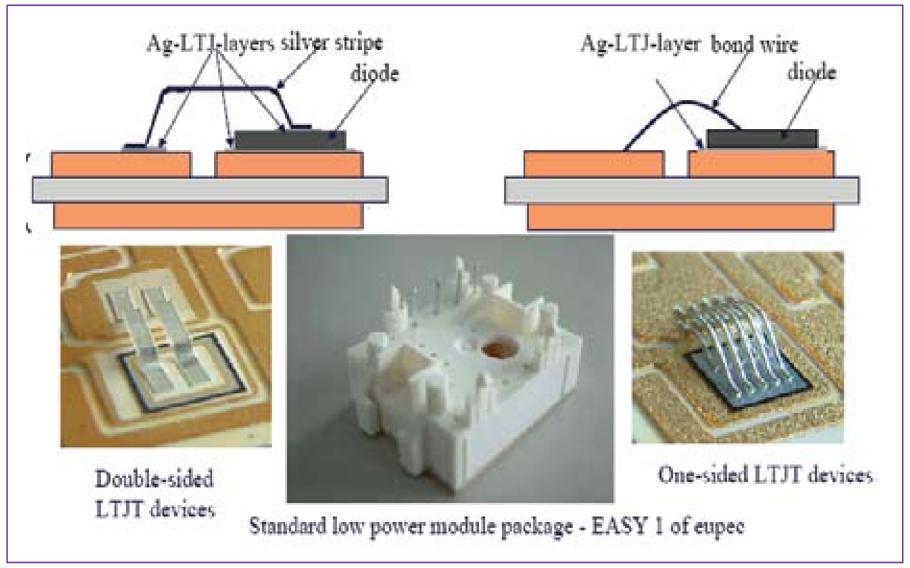

Figure 8. Low temperature joining techniques for high temperature power modules [3]

Figure 9. Optimized power module HybridPACK1 for HEV from Infineon (Prototype).

First results show already an increase of power cycling capability by a factor of 4 for one sided low temperature joining technique. A power cycling test with double sided low temperature joining techniques has not shown any degradation even after 66750 cycles with a temperature delta of 130°C. The same technology can be used to connect base plate and substrate. For substrates as well as base plates new materials are under investigation.

Conclusion

This article described the requirements of HEV on power semiconductor modules and compared them to what is feasible with technologies applied in power semiconductor modules designed for industrial and traction applications. Thermal cycling requirements were identified as a cost driver for the design of a module. As the thermal requirements are strongly influenced by the system design an accurate specification as well as a cost analysis on system level is advisable. Only a direct contact between the automotive industry and the power semiconductor manufacturers can lead to an optimized system (Fig. 9). The success of the hybrid electric vehicle is directly linked to the success of power semiconductor manufacturers to deliver reliable, compact components at low cost.

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Power Electronics Fuels Automotive Development

Advanced electronic systems for the auto industry

With stiff laws and strong enforcement on emissions, safety and consumption, manufacturers are looking to the power electronics industry to comply.

By Dr.-Ing. Hans-Peter Hönes, Engineering Manager, Field Applications Europe, Fairchild Semiconductor

Mobility has become an essential part of our life and the car is playing a dominant role. Today's cars incorporate more and more electronics. The semiconductor content has tripled between 1995 and 2005 and is estimated to further rise to 425% in 2009. Hydraulic and mechanical actuators will be more and more replaced by electric components. The share of electric and electronic equipment is expected to rise from an average of 15…20% today to 35% in 2015. This is driven by legislative activities in order to reduce fuel consumption and emissions as well as by introduction of new features for improved safety and convenience. Beside the reduction in weight by replacing hydraulic and mechanical components with their electrical counterparts, the higher efficiency is also an important factor in driving this trend. A major role plays also in the expansion of the crash zone by reduction of mechanical components under the hood, especially for compact and mid-size cars. High power systems such as starter/alternator or hybrid vehicles are also gaining ground especially in the US.

Feeding the Beast – Direct Injection Systems

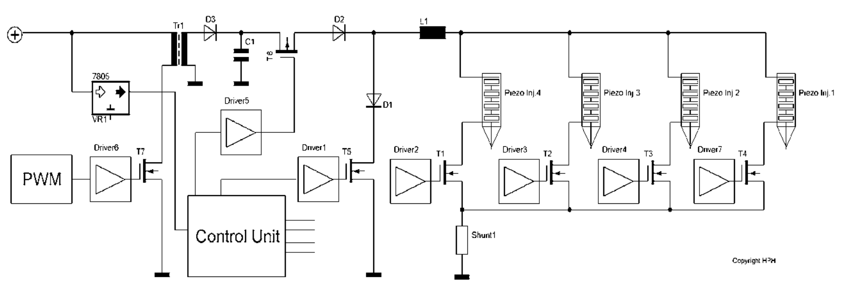
The introduction of high pressure common rail systems using solenoid injectors was a major milestone in the evolution of the diesel engine resulting in lower noise and better performance. From an electronic engine control module point of view, gasoline and diesel engine modules become more and more alike. The difference in piezo direct injection modules for diesel and gasoline engines lies mainly in the output power of the injector stage and the associated software. The replacement of solenoid injectors with piezo technology does have several significant advantages:

Piezo injectors are much faster, reducing deadtimes and allowing more accurate control of the amount of injected fuel. This also makes stratified injection possible leading to lean burn engines. Fast reaction also allows more injections per cycle, reducing rapid pressure changes in the cylinder and nearly eliminating the 'typical' diesel noise.

The problems with injector aging and reliability issues in the ceramic stack at the beginning of volume production, have now been solved and piezo injectors become mature.

Fig.1 shows the architecture of a piezo direct injection module. Actual modules are using Fairchild's low voltage HUFA planar and FDB trench series of low voltage MOSFETs as well as 250-300V B, C or QFET™. RURDxxx ultrafast rectifiers, FAN70xx/73xx drivers and IGBTs are designed-in as well. Next generation modules will most likely use the latest UniFET™ technology.

Piezo Direct Injection System



Low Side Switches T1...T5:	High Side Switch T6:	Diodes D1...D3:
IRFW634B, IRFW644B	IRF9640	MUR860
IRFW654B, FQB11N40	SFP9640	FFB06U40S
FQB14N30, FQB27N25	FQB9P25	RURD460S
HGT1S7N60A4DS	HGT1S7N60A4S	RURD660S
HGT1S12N60A4DS	HGT1S12N60A4S	ISL9R460S3S
FGB3N60LSD	FGD3N60LSD	ISL9R860S3S

Figure 1. Generic schematic of a piezo direct injection system.

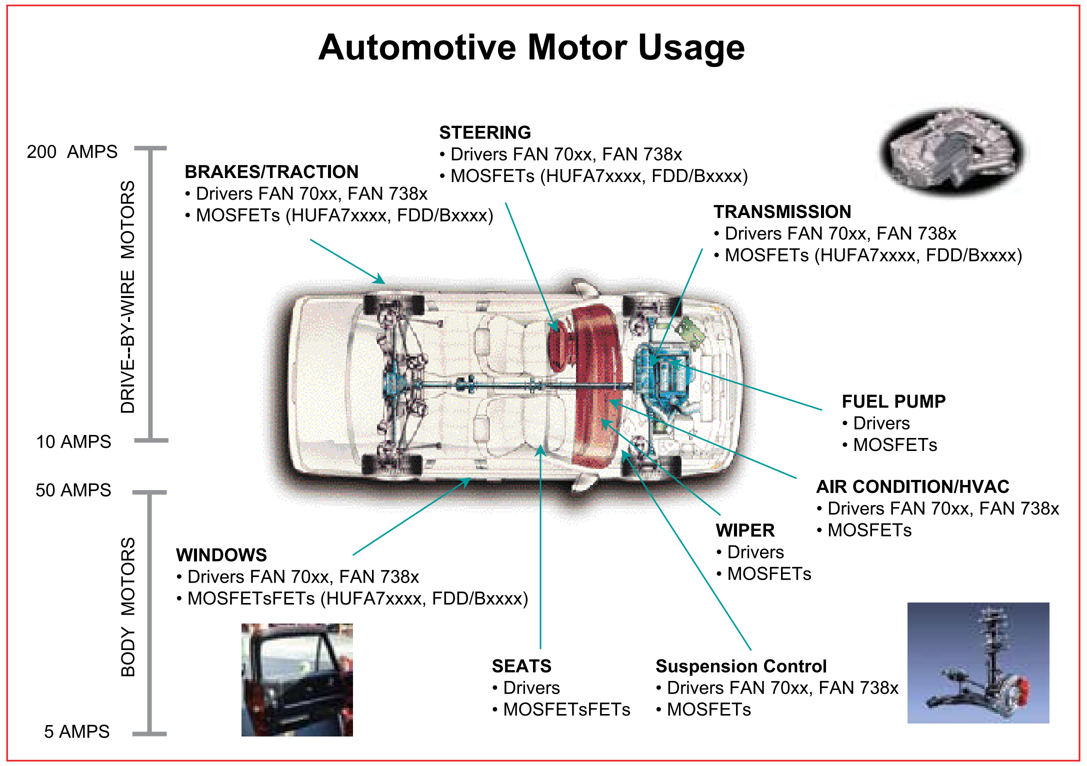


Figure 2. Automotive Motor Usage in Body and Drive-by-Wire Applications.

Hidden changes – Drive-by-Wire and Motor Applications

Hydraulic and electrical actuators in the car are becoming replaced by electrical components. A silent evolution is ongoing. Apart from the weight reduction through the replacement of mechanical and hydraulic components, an additional driving factor for this trend is the significantly higher efficiency of the complete system. One further aspect is the increase in the size of the crash zone because of the reduction of mechanical systems under the hood. This plays a role mainly in compact cars. The first cars following this trend were introduced in model year 1998.

Application examples include the replacement of the belt driven hydraulic pump for power steering by electric pumps, speed controlled fans for engine cooling and closed loop controlled compressors for air conditioning. Apart from a better efficiency, the electrically assisted steering provides a more exact control and therefore, safety. Since the power requirement for electrically assisted steering is lower than that found in classical hydraulic systems, it could now also be implemented in compact cars. A range of electric motor applications is shown in Fig. 2.

The accurate control of engine cooling using electrical pumps and increased cooling performance of a brushless direct current (BLDC) driven blower fan allows a reduction in the amount of cooling fluid required. This saves weight, the engine reaches the operating temperature earlier and temperature excursions under different load conditions are reduced. A shorter time for warm-up results in lower emissions and an increase in engine life. The introduction of a BLDC cooling fan with optimized control into the BMW 3 series in 1998 alone saved up to 3% fuel consumption with reduced noise.

Further fuel savings are expected by the use of electrically powered, power controlled compressors for air conditioning. In most of today's systems, the compressor is belt-driven by the combustion engine and the output power is dependent on the rotational speed of the engine. Using a separate, electric motor-driven compressor, the power output can be exactly matched to the cooling needs.

Implementing combustion engine independent, electronic controlled drives for all the aggregates allows the linking of all these systems with an electronic communications network such as Controller Area Network (CAN), FlexRay or Byteflight. This allows a low cost implementation of new features for safety and convenience. Examples include advanced cruise control, which also keeps speed constant downhill; the addition of a radar system to keep the distance between cars in a safe range, depending on speed and road conditions, as well as electronic stability control (ESP), which extensively uses bus networking with ECU and ABS resulting in a higher level of drive performance and safety.

A relatively new feature is the Brake Assistant. The pulsation felt when an ABS system kicks-in makes many drivers release the pedal. This is just the wrong reaction since it reduces brake pressure and does not allow the ABS to achieve the shortest distance to standstill. In the case where the system detects an emergency braking, the full pressure remains applied even if the driver releases the pedal. Expected for a long time, but still not in production is the fully electric activated brake. Hydraulics are eliminated here completely, the brake is directly activated by high dynamic spindle motors.

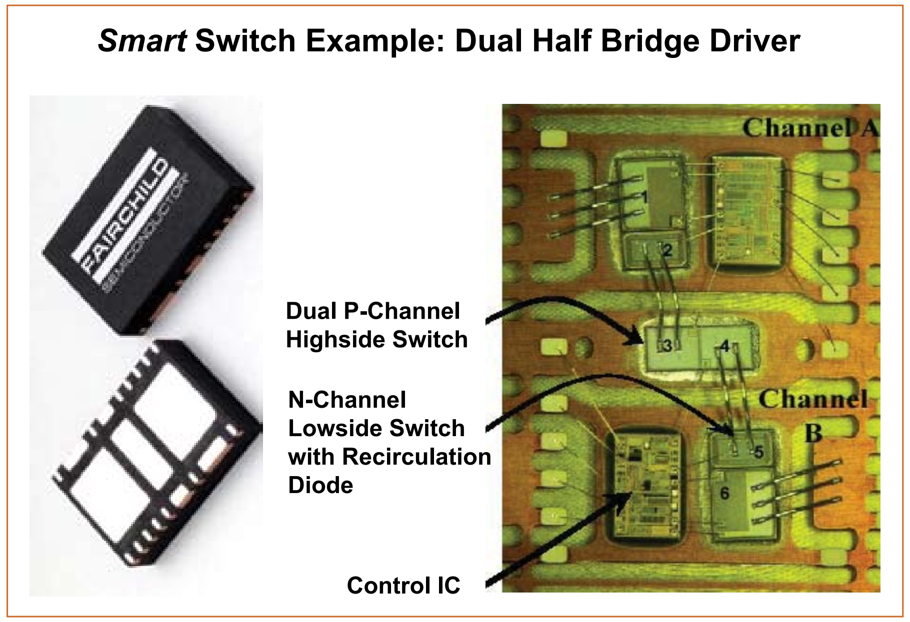


Figure 3. Smart Switch Example: Dual Half Bridge Power Driver.

There is neither a mechanical nor a hydraulic link between brake pedal and the actuators, but just a single wire. Despite long discussions regarding potential risk, this concept is being pushed forward by Siemens VDO with their concept of Electronic Wedge Brake (EWB), which needs significantly lower actuator power. Liberal redundancy in the system should overcome safety concerns.

Drive by Wire concepts will also help to reduce the cost of the control modules since the basic concept of the electronic control module will be similar for different applications. The power stages have to be adapted to the different drives. Software modifications will not only allow adaption of the drive characteristics specific to particular models or applications but also to car-individual or even driver-specific configuration.

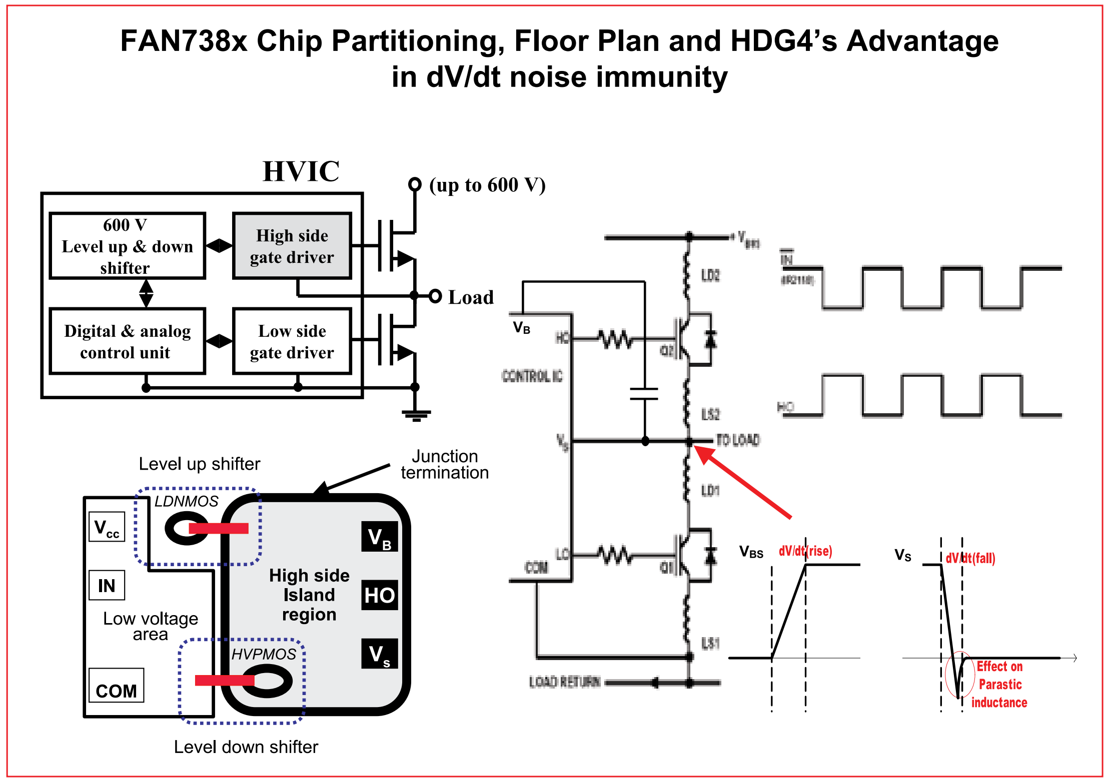


Figure 4. FAN738x Chip Partitioning, Floor Plan and HDG4's Advantage in dV/dt noise immunity.

Silicon Solutions for Automotive Systems

Electric motor applications in the automobile can be classified into low power and high power applications:

Low power is considered below 5A. At this level, the power stages are normally monolithically integrated with control and protection circuits. Even the integration of a microcontroller core and the bus interface is possible.

High power systems control currents above 5A, which include functions at the 10-30A level such as seat positioning, wiper and window lifters up to several hundred amperes for starter/alternator systems and HEVs.

Many of these medium current applications need protection and diagnostic functionality. A monolithic approach for these types of system is either, for technical or commercial reasons, not feasible. A MOSFET process uses between 4-6 mask steps whereas smart-power BCD processes utilize 15-26 mask steps. Since the cost is mainly related to wafer processing time, it is quite obvious that even for moderate power levels a multi-die concept is more cost effective than a monolithic integration. This approach allows the use of the most advanced technologies for both the power stages and the control circuit. As a consequence, the lowest possible power loss per die area can be achieved. High modularity, flexibility and a fast time to market are further advantages. A concept integrating two half-bridge power stages with control, protection and diagnostic functionality into one package is show in Fig. 3.

For high power applications such as starter/alternator or HEVs, the paralleling of several MOSFETs or IGBTs is necessary to cope with current requirements. Here, dedicated custom built modules are used and a "known good die" concept is the key for success. Bad experiences in the early days of hybrid activities have demonstrated that industrial modules types cannot withstand the harsh environment encountered in the operation in cars.

The vast majority of Fairchild's MOSFETs for the automotive market are produced on 8" wafers. SMIF micro environment technology with clean room class 1 allows maintenance and even the replacement of production equipment without interruption of the manufacturing flow. The achievable defect density is still a benchmark for the power device industry and the state-of-the-art stepper based lithography guarantees very narrow distributions.

With the introduction of the UltraFET™ planar process, a stripe design replaced the hexagonal cell design, which significantly improved the relationship of effective channel to die area. This basic concept was also used in more advanced trench processes like the UltraFET trench and power trench-IV. Today a minimum of 2.4mOhms in TO-263 and 5.2mOhms in TO-252 at 40V is achievable.

However, the power switch alone does not make a power stage. A key element is a driver circuit being the interface between a control circuit and the power switches. This is why the FAN708x/73xx family of half bridge and high-side drivers was created. These drivers using HDG4, a proprietary high voltage process with a self-isolating structure. In comparison to competing devices, the FAN 708x/73xx series of power transistor drivers have better noise immunity using a patent pending dv/dt noise canceling circuit, extended allowable negative output swing down to -10V as well as industry's lowest quiescent current for supply (70-80uA) and high side driver stage (30-40uA). In addition, propagation delays and trigger levels are less temperature dependant, improving the precision of control. Fig 4 shows the chip partitioning, the floor plan and dv/dt tolerance of the new high voltage ICs (HVIC).

The maximum voltage level is specified to 600V, which allows the use not only at standard automotive voltage levels, but makes them also useful for high voltage systems like piezo direct injection, starter/alternator or hybrid vehicles.

Hybrid Cars and Future Drive Concepts

The first high volume hybrid car brought to the market in 1999 was the Honda Insight, followed in 2000 by the Toyota Prius I. The unexpectedly high acceptance, mainly in the United States, was a shock for many car manufacturers who then started intensive activities to catch up. Between 2005 and 2009 as many as 21 new cars are expected to enter the market. Basically there are two types of hybrid systems: Micro or mild hybrids and full hybrids. Micro hybrids using starter/alternator concepts shutting down the engine during idle and regenerate some energy to keep the battery charged. The power levels are about 2-10kW. Mild hybrids use the electric motor as well to boost support the engine, although the vehicle cannot be driven by the electric motor alone. Full hybrids have electric motors powerful enough to drive the vehicle for a certain time without fuel combustion. Basically, all full hybrids have bus voltages between 120V and 300V at power levels of 30-50kW.

Hybrid cars require efficient combustion engines with high power density. The next step is most likely to be the use of optimized diesel engines, especially considering the European market. Two-stroke engines would be an ideal choice with their high volumetric power, but the classical construction cannot cope with today's emission regulations, mainly because of the high HC emissions. This is caused by the overlap of the exhaust gas stream with the incoming fuel-air mixture. Combining a highly sophisticated direct injection system with the simple mechanical construction of a two-stroke engine may lead to a compact, lightweight engine adapted to the requirements for hybrid cars.

Progressing further and considering electronic valve train (EVT) engines, where the intake and exhaust valve are electrically activated, any operating mode either two stroke or four stroke (or even "any stroke"), is possible since there are no limiting boundaries from the camshaft(s). A typical four cylinder engine would require as many as 64 MOSFETs for valve actuation. This leads to one conclusion: For power devices the future looks bright.

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FPGAs Providing Low Power Automotive Solutions

Flexibility and frugal power requirements driving adoption

The traditional MCU has several drawbacks in an industry that needs constant update and change with a major focus on power consumption and design time to market.

By Martin Mason, Actel Corporation, Director, Silicon Product Marketing

Today, several indicators point to continued growth of electronics in the automotive arena. Among these are growing number of vehicle models, the decreased average model lifecycle, and vehicle replacement -due not to decreased performance, but to consumer preferences.

Other factors influencing this significant growth stem from technology. As semiconductor technology advances, component costs become lower and carmakers increasingly use electronics as a competitive advantage or weapon. Electronic systems are used to optimize fuel consumption and engine performance. With new and more stringent legislative mandates, electronic systems are now used in ignition and engine control systems to help reduce emissions as required by law. In the area of safety, features such as air bags, ABS systems, and emergency calling systems are now also becoming a standard requirement.

Technology Selection

Automotive engineers have traditionally relied on microcontrollers (MCUs) and custom application-specific integrated circuits (ASICs) to implement and control electronic systems and expand the capabilities of each automotive generation. But growing component counts, greater time-to-market pressure, and greater demands for performance are requiring alternative technologies, such as low cost, low power, highly reliable field-programmable gate arrays (FPGAs).

Compared with MCUs, the FPGA offers automotive designers greater performance and features (I/Os, programmable Logic, etc.). Similarly, when compared with ASICs, FPGAs provide lower cost

and greater flexibility. Once the normally exhaustive qualification process is completed, FPGAs unlike ASICs, can also be used in multiple programs/projects, thereby helping designers to maximize time and resources associated with automotive qualification activities. For these reasons and others, Gartner Dataquest analysts have identified FPGAs as the fastest growing semiconductor segment for the automotive industry, with over 70% CAGR through 2007.

Engineers have also realized that specifying FPGAs can have positive advantages over the use of an ASIC. For instance, with an FPGA the design team can make late changes. Indeed, products can be upgraded when they are already in service with minimal qualification consequences. In an environment when time to market is increasingly important, and yet companies are highly risk averse, the FPGA solution makes good sense.

Targeted Solutions

The proven low power technology behind Actel FPGAs enables the most demanding high-reliability applications for use in the world's harshest environments. As a well known technology to the military and aerospace community, FPGAs now bring high reliability to designers of integrated automotive systems and can be an optimal solution for automotive applications that require high reliability, firm-error immunity, low power consumption, high junction temperature, single chip, low cost and maximum design security (anti-tampering). With a broad offering of non-volatile solutions for the automotive market and package portfolio, including chip-scale packages (CSP), fine-pitch ball grid arrays (FBGA), and others, the company is able to put more logic into much smaller packages, saving space, increasing efficiency and reducing costs.

The company also offers an extensive portfolio of intellectual property (IP) to support most automotive standards.

FPGA automotive solutions are well suited for in-cab telematics, infotainment, and body control functions, as well as under-the-hood drive train control, and safety systems. Typical applications might include audio, video, multimedia, navigation, safety retention system management, engine control, diagnostic and monitoring systems, and emergency response consoles. Because many industry FPGAs are a single-chip solution, they are also especially well suited for flexible interconnect solutions between a variety of automotive sub-systems. Exceptional reliability and consistent performance make FPGA automotive solutions an ideal fit for point-to-point connections inside and around the perimeter of the passenger cabin and under the hood.

Reliability

The need for high-reliability components is essential to ensure the proper and long-term function of the systems in today's vehicles. While there has been substantial progress made in this area, there are still many engineering trade-offs that are poorly understood, which should be factored into the selection process for advanced digital circuits. When selecting an FPGA, it is important to evaluate the base technology used because it can have a significant impact on the reliability and suitability of an FPGA technology in automotive applications.

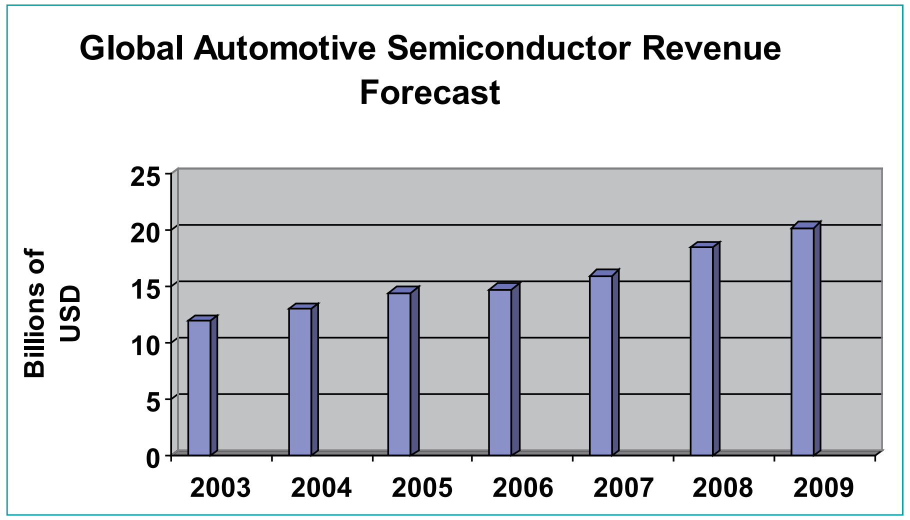
Flash- and antifuse-based nonvolatile FPGAs have fundamental quality advantages over SRAM based FPGA technologies. Both have dramatically low power consumption, which helps mitigate SRAM-based FPGA electro-migration and thermal run-away reliability concerns. Further, SRAM FPGA power and heat dissipation can significantly limit the life of these deep sub-micron semiconductor devices.

Nonvolatile FPGAs do not suffer from errors caused by neutron and alpha particle induced SRAM upsets, or "firm errors. These upsets can lead to FIT rates (number of failures in 109 hours) that are orders of magnitude higher than acceptable industry norms. It can be a tremendous advantage to use an FPGA supplier who has a history of providing 'mission critical' products, as does Actel, and are already engaged in ensuring high performance and reliability in extreme environmental conditions.

Security

As the complexity of automotive electronics grows and FPGA usage continues to increase, so does the value of the designs they hold. Intellectual property theft and FPGA tampering pose a significant liability threat to the automotive industry. While SRAM FPGAs are typically considered susceptible to tampering requiring minimal expertise and equipment, nonvolatile FPGAs are even more secure against attack than the ASIC technologies they often aim to replace. Tampering could include changing engine control settings, which may have serious consequences to safety and the vehicle's warranty. Designers are, therefore, encouraged to select an FPGA that will have minimum impact on total system cost while providing higher levels of overall design security.

Additionally, the threat of compromise is of special concern for designers of telematic systems that serve as an authorization mechanism for fee-for-service products (i.e. satellite radio and location-based services). The compromise of a system that manages gateway access controls and user authentication could become a huge security hole for expensive satellite network or other costly wireless infrastructure. This is a case where an intelligent hack of a low-cost appliance could lead to the compromise of an entire communications network. More importantly, the revenue model defined for pay-per-use systems would become totally ineffective, leading to declining revenue and eventual failure of the enterprise.



Source: Databeans Estimates.

Conclusion

Improved technology, legislated regulations and consumer demands continue to drive the automotive electronics market upward. High-growth application areas for automotive semiconductors include safety (airbags, cruise control, collision avoidance and anti-lock brakes) and cockpit electronics (entertainment, telematics, instrumentation and pay-for-use services). With its long-time focus on reliability, cost and security, the automotive market has started to recognize the advantages that nonvolatile FPGA technologies have to offer.

Sidebar

According to Databeans, Inc., a market research firm focused on the semiconductor and electronics industries, electrical and electronics content represents approximately 20 percent of the cost of the average vehicle. The firm estimates that a lower-priced vehicle built in 2004 had 150 to 180 components, while today's higher-price vehicle might contain more than 400 components.

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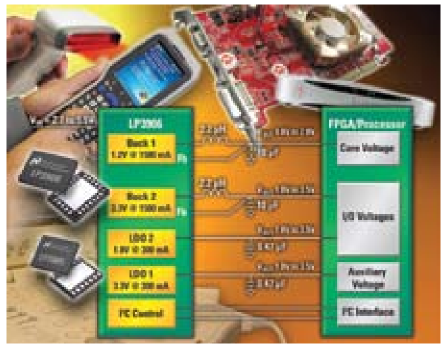
Designer-friendly, Quad-output Power Management Units



National Semiconductor introduces two new, integrated power management units (PMUs) to its family of designer-friendly, easy-to-use PMUs. Optimized to power mid-range, quad-output applications, such as low-power FPGAs, microprocessors and DSPs, the LP3906 and LP3905 PMUs each feature two high-efficiency buck regulators and two ultra-low-noise, low-dropout regulators (LDOs). The high level of integration simplifies system design and increases space efficiency.

The LP3906 PMU features an I^2C compatible interface for programmability. This digital interface provides the flexibility to use the same device for multiple solutions that require different output voltages. By including dynamic voltage scaling with 96 percent conversion efficiency, the power consumption of the powered device, such as a microprocessor, is reduced, thus maximising the power efficiency of the entire system. Example applications for these products include powering an embedded processor, in which each switching regulator can drive the core and input/output while each LDO supplies the analogue and peripheral functions. In FPGA applications, the dual regulators power the core and I/O voltages, and the dual LDOs power the auxiliary voltages that supply the embedded peripherals such as communication engines.

Available in a small, 24-pin thermally enhanced LLP® package that measures 4 mm by 5 mm, the LP3906 PMU provides designers with a simple, highly efficient and flexible solution to efficiently drive core I/O and auxiliary power. It features two integrated 1.5A, high-efficiency buck regulators and two 300 mA linear regulators with an I^2C compatible interface for programmability. The dual buck regulators have a dynamically programmable, wide-output voltage range from 0.8V to 3.5V with up to 96 percent efficiency. This high efficiency is accomplished by intelligent automatic switching between PWM and PFM modes. The dual linear regulators have a dynamically programmable wide output voltage range from 1.0V to 3.5V. The high-speed serial interface for independent control of device functions and settings enables features such as dynamic voltage management, power-up sequencing control and design flexibility.

The LP3905 PMU is available in a tiny, 14-pin thermally enhanced LLP package that measures 4 mm by 4 mm, National' s LP3905 PMU contains two integrated, 600 mA, high-efficiency buck regulators and two 150 mA, ultra-low-noise linear regulators. The dual buck regulators have a fixed and adjustable output voltage range from 1.0V to 3.3V with up to 90 percent efficiency. The buck regulators feature intelligent automatic switching between PWM and PFM modes to achieve the highest efficiency possible for the entire load range. When operating in PWM mode, both regulators have a switching frequency of 2 MHz, allowing use of small external components. The dual linear regulators have an output voltage range from 1.5V to 3.3V, with low dropout voltage and low output voltage noise.

http://power.national.com

Low Voltage MicroFET™ Family Improves Battery Life and Saves Space

Fairchild introduces 11 new MicroFET™ MOSFET products to its range. These ultra-compact, low-profile (2 x 2 x 0.8mm) devices target low-power applications in the <30V and <20V range. These include cell phones, digital cameras, games, remote POS terminals, and many other high-volume portable products where space optimization and excellent thermal and electrical performance is essential for saving battery life and ensuring reliability.

MicroFET power switches combine Fairchild's advanced Power Trench™ technology with an industry-standard molded leadless package (MLP) to deliver significant thermal and space improvements over conventionally used power MOSFETs in larger packages.

Fairchild's MicroFET in MLP offers designers a new package option in addition to SSOT-6 or SC-70 devices typically used in charger, boost converter, DC/DC converter and load switch applications. The devices are claimed 55% smaller than a 3 x 3mm SSOT-6 MOSFET, 80% lower RDS(on) and 65% lower thermal resistance while providing higher performance.

"Fairchild offers the most complete portfolio of products available for serving low-voltage applications. These easy-to-implement, high-performance and space-saving MOSFETs are ideal for all of our customers' low-voltage switching and power management/battery charging systems," said Chris Winkler, marketing director, Low Voltage Power Segment. "In 2005, Fairchild was first to introduce an MLP-packaged MicroFET with the high performance of a traditionally used SSOT-6 device with the footprint of an SC-70. With this introduction of 11 new devices, we're offering our customers a significantly expanded and augmented MicroFET family of products."

www.fairchildsemi.com

Adaptive Power Converter Family Boosts Battery Life in CDMA/WCDMA Phones

Semtech announces the SC250 and SC251, the first members of a DC/DC step-down (buck) power converter family designed to improve battery life by providing adaptive DC power control in CDMA and WCDMA handsets.

CDMA and WCDMA handsets experience wide swings in power consumption. The SC250 and SC251 are designed to work with the phone's baseband processor to enhance efficiency by adaptively controlling the DC power supply to the power amplifier (PA). The SC250 performs a buck conversion to generate an output voltage that is linearly proportional to an analog input control voltage from the baseband processor. The buck conversion process reduces battery current when the PA outputs low power, greatly increasing talk time compared to directly connecting the PA to the battery.

The SC251 performs a similar function, but it utilizes a patent-pending non-linear transfer function that can eliminate the need for a software look-up table. In addition, the SC251 provides the option to switch between two different transfer functions when used with a dual-mode PA. Each transfer function is optimized to match the DC power requirements of the different PA gain modes.

Both devices provide an on-board low-dropout voltage regulator (LDO) that provides a voltage bias that is required for operating a power amplifier, eliminating the need for an additional part.

The SC250 features a 2.3mm x 2.3mm MLPD-W8 package with a low profile of 0.8 mm max. The SC251 comes in an industry-competitive 3mm x 3mm MLPD-10 package.

www.semtech.com

First Automotive Load Driver IC in SOI Technology

Atmel has announced the availability of the new ATA6826 driver IC, the first such product in high-voltage BCD-SOI technology (SMARTIS(TM)) available on the market. The new cost-effective driver IC provides improved performance, a broad range of protection features. The ATA6826 is designed to control two DC motors or up to three different loads via a microcontroller in automotive applications, e.g., body electronic systems such as mirror positioning and climate control. With the device's high voltage capability (up to 40V), the ATA6826 can also be used in 24V supplied trucks or industrial applications.

In contrast to standard BCDMOS bulk technology, the SMARTIS technology uses an SOI (silicon on insulator) substrate. This results in an extremely low leakage current. A significant reduction in crosstalk between power and digital circuits on the same die is achieved, and lower parasitic effects give added value for EMC performance. The chip size reduction (the gate density is equivalent to 0.5-µm CMOS) allowed the design of a cost effective and powerful high voltage power driver IC. The SMARTIS technology also reduces manufacturing costs by simplifying the IC fabrication process through the elimination of high-energy implementation for well doping and simplification of device isolation.

Each of the three high-side and three low-side drivers of the ATA6826 is capable of driving currents up to 1A. The drivers are internally connected to form 3 half-bridges and can be controlled separately from a standard serial data interface. Therefore, all kinds of loads such as bulbs, resistors, capacitors, and inductors can be combined. The IC design especially supports the application of H-bridges to drive DC motors. The operation modes forward, reverse, brake, as well as the high impedance will be controlled by the SPI interface.

The ATA6826 provides several protection features such as over-temperature warning and shutdown, overload, over-voltage protection, and full protection against short circuits. Several diagnostic bits are set in the SPI output register and can be read by the microcontroller. In case of under-voltage at the supply pin, the power-supply fail bit in the output register is set and all outputs are disabled. If the over-temperature pre-warning bit is set, the system developer can implement software routines on the microcontroller to decrease the power dissipation and temperature. If the temperature increases further, the IC shuts down at a certain level to prevent destruction. The device also meets strict automotive qualification demands (protection against conducted interference, EMC and ESD protection) and can withstand transients as specified in ISO/TR 7637.

Samples of the ATA6826 driver IC are available now in Pb-free SO14 packages.

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