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- RoHS Compliant
Energy-saving inverter designs: 50% less cost, size and time.

Integrated power modules simplify your designs

Smart Power Modules (SPM™) are just what you need to dramatically improve the performance/cost ratio of variable speed designs. Available for motor ratings from 50W to 7.5kW, every SPM includes:

- An integrated drive and protection solution built with our leading power components
- Fairchild’s combined power and motion design expertise
- Best-in-class packaging technology that reduces board space while providing excellent thermal performance

Our SPM series includes solutions for consumer and industrial inverter designs, as well as options for switched reluctance and PFC.

If you prefer to build your own drive with discrete components, all the building blocks inside our SPM, including IGBTs, FRDs and MOSFETs are also available for your motion power path.

If energy and cost savings are your problem, Fairchild has your solution.

For more motor design information, including online design tools and application notes, visit www.fairchildsemi.com/motor

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www.fairchildsemi.com
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 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, 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...
**INDUSTRY NEWS**

**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 focus on high-performance 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 Morison, 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.”

**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 Morison, Executive Vice President of UltraVolt.

**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 ESI-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.

**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. Patras, Jr., Vice President, Electrical Distribution & Lighting.

Noboru Tazaki, Executive Vice President & COD 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

www.linear.com

www.ultravolt.com

www.zetex.com

www.gelcore.com
NXP Semiconductors Appoints Pascal Langlois Senior Vice President of Global Sales

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.

Aimtec Signs Distribution Agreement with Koala Elektronik of Czech Republic

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 Slovakian Republics.

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. This marks the third consecutive year 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.

“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,” 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.”

INDUSTRY NEWS

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.

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

Power Events

* HiFiParts, October 25-26, Hamburg, www.hifiparts.com
* ELECTRONICA 2006, Nov. 14 - 17, Munich, www.electronica.de

Vijay Shankar
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 Recraft, 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 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.

Microsemi Launches New POWER MOS 8™ Generation of MOSFETs

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The first POWER MOS 8 devices:

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PeakSwitch™
Energy-Efficient Off-Line Switcher IC with Super Peak Power Performance

Features:
- Peak power up to 3X continuous power
- 277 kHz peak mode means smaller transformers
- Tight parameter tolerances reduce system cost
- On-time extension reduces bulk capacitance at light load
- Smart AC protection during fault conditions

Applications requiring peak power:
- Inverters
- DC/DC converters
- AC/DC power supplies
- Battery chargers
- HVAC systems
- Industrial applications
- Medical equipment
- Audio amplifiers
- DC motor drives

EcoSmart® Energy Efficiency:
- Easily meets all global energy efficiency regulations
- No40% consumption:<50 mW with bias winding
- <150 mW without bias winding
- Meets 1 W standby requirements

Enter to win a PeakSwitch Reference Design Kit at: www.powerint.com/psde93
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. 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 sync 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.
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.

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.

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
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...
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.

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.

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.

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 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.

Figure 6: Switching power supplies are noisy. LC filters must be used 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 fulfils 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 capability charging 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 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 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

Low Dropout Regulator Selection Table

<table>
<thead>
<tr>
<th></th>
<th>PSR at 1kHz</th>
<th>Output Noise @ 1MHz</th>
<th>L1 (V/mA)</th>
<th>L2 (V/mA)</th>
<th>L3 (V/mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISL9000</td>
<td>50</td>
<td>30</td>
<td>300</td>
<td>42</td>
<td>1.9%</td>
</tr>
<tr>
<td>ISL9007</td>
<td>75</td>
<td>50</td>
<td>450</td>
<td>50</td>
<td>1.9%</td>
</tr>
<tr>
<td>ISL9011</td>
<td>70</td>
<td>50</td>
<td>150</td>
<td>300</td>
<td>6.5%</td>
</tr>
<tr>
<td>ISL9012</td>
<td>70</td>
<td>50</td>
<td>150</td>
<td>300</td>
<td>45</td>
</tr>
<tr>
<td>ISL9014</td>
<td>70</td>
<td>50</td>
<td>150</td>
<td>300</td>
<td>45</td>
</tr>
</tbody>
</table>

ISL9000 Key Features:
- Very high PSRR: 90dB at 1kHz
- Extremely low quiescent current: 42 A (with ICs active)
- Low output noise: typically 30 V/mA@100 A (1.5V)
- Low dropout voltage: typically 200mV @ 30mA
- Wide input voltage of 2.3V – 6.5V
- Integrates two 30mA high performance LDOs
- ±1.8% accuracy over all operating conditions
- Stable with 10-15pF ceramic capacitors
- Separate enable and POR pins for each LDO
- Available in tiny 10x14 3mm x 3mm DFN package

Datashet, samples, and more info available at www.intersil.com

InterSil Linear Regulators

High Performance Analog

Shhhhh... We’re Trying to Focus Here

Intersil’s new family of Low Dropout Regulators provide the industry’s best PSRR (Power Supply Rejection Ratio) for superior noise performance AND ultra low Iq. With this combination, digital images on your RF/noise sensitive applications just got a whole lot clearer.

As digital still cameras and cell phone camera modules move toward higher megapixel resolutions, the need for superior PSRR becomes more critical. With a PSRR of 90dB, low Iq, and a 3mm x 3mm solution size, Intersil’s ISL9000 is the LDO you’ve been waiting for.
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 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 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 1. LTC4001’s Minimized Power Dissipation Capability Compared to that of a Linear Charging IC](#)

[Figure 2. Simplified PowerPath Control Circuit.](#)
A low-loss ideal diode provides power 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) 2mm x 2mm 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, MPs/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 complete high voltage, high efficiency battery charger into one IC for portable devices. They are offered in a low-profile (0.75mm) 2mm x 2mm 6-lead 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.

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 voltage 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/2x, 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 chargers offer temperature sensing for the IC, its surrounding external components, and for the battery itself.

Another advantage of accepting low-voltage power sources such as 5V adapters and USB is the ability to accept low-voltage power sources up to 36V (40V max) such as 12V wall adapters, automotive adapters and FireWire/IEEE1394 ports. This may be observed in Figure 3’s block diagram.

Figure 3. LTC4089’s Typical Application Circuit.
Table 1: Representative Linear Technology Battery Charger ICs.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Topology</th>
<th>Battery</th>
<th>Vin up</th>
<th>Vcc 2</th>
<th>Vcc 3</th>
<th>Smart PowerPath</th>
<th>USB</th>
<th>Standalone</th>
<th>Package</th>
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<tbody>
<tr>
<td>LTC4065A/5</td>
<td>Linear</td>
<td>Li</td>
<td>750mV</td>
<td>5.6V</td>
<td>7V</td>
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<td></td>
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<td>no</td>
<td></td>
<td>3x4 GN-22</td>
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<tr>
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<td>7V</td>
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<td>no</td>
<td></td>
<td>4x4 GN-16</td>
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<td>4A</td>
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<td>32V</td>
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<td>no</td>
<td></td>
<td>SSOP-16/24</td>
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<tr>
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<td>Switchmode</td>
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<td>4A</td>
<td>28V</td>
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<td>no</td>
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<td>LTC410</td>
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<td>4A</td>
<td>38V</td>
<td></td>
<td>INFET</td>
<td>no</td>
<td></td>
<td>SSOP-24</td>
</tr>
<tr>
<td>LTC411</td>
<td>Switchmode</td>
<td>Li</td>
<td>4A</td>
<td>36V</td>
<td></td>
<td>INFET</td>
<td>no</td>
<td></td>
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<tr>
<td>LTC4101</td>
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<td>28V</td>
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<td>no</td>
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<tr>
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<td>28V</td>
<td>32V</td>
<td>INFET</td>
<td>no</td>
<td></td>
<td>SSOP-24</td>
</tr>
</tbody>
</table>

* Dual input: USB & wall adapter

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.

- 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 multimedia 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 ball 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, fastest charging and low power dissipation, as well as USB compatibility and high input voltage capability for portability. At the same time, design is being integrated to save board space, reduce manufacturing costs and increase product reliability. This progression towards enhanced efficiency and performance 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 progression to enhanced mobile and battery-powered products. For example, mobile phones have grown to include new features, such as camera and video recording. These features require more power, which means that the battery cells must be larger and the whole system must be more reliable.

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.

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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 (HBM). 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 probe, most manufacturers opt for Level 4 testing, in which the contact and air discharge voltages are 8kV and 15kV respectively. This waveform used for testing rises to its peak voltage (and a maximum current of 30A) in less than
applications. but can achieve the sub-nanosecond and suffer from higher leakage current, 1-5ns. The latter clamp at over 100V current leakage, and response times of medium clamping voltages, modest and MLVs. The former provide low-to-such as specially-designed TVS diodes only by low-capacitance components (0.10pF) and can therefore be served require lower capacitive loading of be 10pF. 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 2.0, 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 1,655Gbit/s; HDMI typically operates at a rate of 750Mbit/s. These specifications put designers in a bind, because transmission speed is not optimal: 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.

As with most of the common techniques for ESD suppression, designing with PESD devices 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...
by a “hold” current, which is the mini-
mum 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 tempera-
tures, the conductive particles form
low-resistance networks in the polymer
(see figure). But if the temperature rises
above the device’s switching tempera-
ture \( T_{\text{th}} \), 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 resis-
tance of the device.

Because the “fusing” process is
temperature-dependent, it can be trig-
gered 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
an over-current and over-temperature
protection. For instance, in a power sup-
ply it can be physically located on the
transformer windings so that it will trip
if input voltage sag conditions cause an in-
crease 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 \( \text{at} \ T_{\text{th}} \), 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 resis-
tance of the device.

Figure 4.1H 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 operat-
ing 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 only 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 de-
vice. 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 con-
sider the derated hold and trip currents
(figure 4 shows a typical characteristic
at the product’s designed-for operat-
ing temperature, because, as we have
already noted, PPTC devices are ther-
mally 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 de-
vice and the system operating tempera-
ture. The higher the temperature at the

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

interface of fault, the faster a PPTC device
will trip (figure 4 shows 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 design-
ers to rethink their strategies for ESD
protection, the widespread intro-
duction 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 on 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.

Given modern high-speed transmission
rates, the challenges are not dissimilar
to those encountered with ESD protec-
tion on high-speed lines: to devise ef-
fective ways of shunting away extremely
large voltage spikes without compromis-
ing 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 estab-
lished technologies to accommodate
new requirements. The use of Gas
Discharge Tubes (GDTs) and thyristors
continues to represent the best solu-
tion in such applications. GDTs are used
in parallel with the components they are
protecting: in the event of a volt-
age 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 electronic
components for the foreseeable future.
However, advancements in the speed
and power of our systems are pos-
sible 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 regu-
larly “zapped” by ESD, and the only con-
clusion can be that future products look
like needing more protection, not less.

www.circuitprotection.com
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.

By Michele Sclocchi, Principal Applications Engineer Power Management Europe; Frederik Dostal, Applications Engineer for Power Management, National Semiconductor

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 coming from the source.

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

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.

Whenever current sharing is implemented the control circuitry has to know 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.

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.

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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.

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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 with some 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.

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 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 (Vin) 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.

\[ Vsns_1 = \frac{A}{4} \times (Vs_1 - Vs_2) \]
\[ Vsns_2 = \frac{A}{4} \times (Vs_2 - Vs_1) \]

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 Vs1 and Vs2 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 CSO 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 than with complicated and large discrete circuits.
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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 semiconductor modules, 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 mid-sized 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 semiconductor. The losses can be estimated by equation 1.

\[ P_{\text{loss}} = P_{\text{conduction}} + P_{\text{switching}} \]
\[ P_{\text{conduction}} = I_a \times (E_{\text{on}} + E_{\text{off}}) \]
\[ P_{\text{switching}} = I_a \times f_{\text{switch}} \times (E_{\text{on}} + E_{\text{off}}) \]

For industrial applications a voltage level of 600V is common in traction converters. And power and 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 being produced as the principal construction “Standard Module”.

As for material cost, often SiC is used; in some special cases AI and...
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 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 inter-connected materials. This fact triggered the introduction of ASIC base plates for traction applications. For ASIC base plates the CTE closely matches the CTE of the substrate. Hence, much higher TC reliabilities can be achieved in modules using ASIC as a base plate material. To avoid the high cost involved with ASIC or equivalent solutions like Cu/CoG sandwich designs or Cu/Cu 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 traction application. Traction applications have proven that even the most extreme thermal cycling requirements can be handled, but the costs involved 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 vehicles 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 automotive industry and 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.

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 180°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
The requirements 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.
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

M obility 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 42% in 2009. Hydraulic and mechanical actuators will be more and more replaced by electric components. The share of electronic 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. Besides 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 hydraulic systems, 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 are becoming 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 have now been developed and with piezo injectors with their electrical counterparts, the hydraulic and mechanical components are designed-in as well. Next generation modules will most likely use the latest UniFET™ technology.

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 1999.

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 water pump buildings 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

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

Figure 2. Automotive Motor Usage in Body and Drive-by-Wire Applications.
motor-driven compressor, the power output can be exactly matched to the cooling needs.

Implementing combustion engine in dependence of electronic control and monitoring for all the aggregates allows the linking of all these systems with an electronic control and monitoring area (ECU) for a high level of drive performance and safety. Examples include advanced cruise control, which also keeps speed constant downhill; the addition of an ECU to 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.

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.

The vast majority of Fairchild’s MOSFETs for the automotive market are produced on 12” wafers. SMIF micro environment technology with clean room class 1 allows maintenance and even the replacement of individual power devices 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 steered through 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 series of half-bridge power stages with control, and high side driver stage (30-40uA). In addition to the requirements for hybrid cars. 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.

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 diesel particle filters, 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 single 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.
T
day, 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
to decreased performance, but to
consumer preferences.

Other factors influencing this signifi-
cant 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 perfor-
mance. With new and more stringent
legislative mandates, electronic systems
are now used in ignition and engine con-
trol 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 tradition-
ally relied on microcontrollers (MCUs)
and custom application-specific inte-
grated circuits (ASICs) to implement and
control electronic systems and expand
the capabilities of each automotive gen-
eration. But growing component counts,
greater time-to-market pressure, and
higher risk aversion, 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 mili-
tary and aerospace community, FPGAs
now bring high reliability to designers
of integrated automotive systems and can
be an optimal solution for automotive ap-
plications 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 com-
pany is able to put more logic into much
smaller packages, saving space, increas-
ing efficiency and reducing costs.

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

and greater flexibility. Once the normally
exhaustive qualification process is com-
pleted, 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 Data-
quest analysts have identified FPGAs as
the fastest growing semiconductor seg-
ment 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, an FPGA is designed to

suit for in-cab telematics, infotain-
ment, 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 solu-
tions between a variety of automotive
sub-systems. Exceptional reliability and
consistent performance make FPGA au-
tomotive 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 compo-
nents 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 select-
ing 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 nonvol-
tile 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
ersors 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 provid-
ing ‘mission critical’ products, as does
Actel, and are already engaged in ensur-
ing high performance and reliability in
extreme environmental conditions.

Security
As the complexity of automotive elec-
tronics grows and FPGA usage contin-
ues to increase, so does the value of the
designs they hold. Intellectual prop-
erty theft and FPGA tampering pose a
significant liability threat to the auto-
motive 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 chang-
ing engine control settings, which may
have serious consequences to safety
and the vehicle’s warranty. Designers
are, therefore, encouraged to select an
FPGA that has minimum impact on
total system cost while providing higher
levels of overall design security.

Additionally, the threat of compro-
mise 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 compro-
mise of a system that manages gateway
access controls and user authentica-
tion could become a huge security hole
for expensive satellite network or other
costly wireless infrastructure. This is a
place where an intelligent hack of a low-
cost appliance could lead to the com-
promise of an entire communications
network. More importantly, the revenue
model defined for pay-per-use systems
would become totally ineffective, lead-
ing to declining revenue and eventual
failure of the enterprise.

Conclusion
Improved technology, legislated regu-
lations and consumer demands con-
tinue 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 auto-
motive 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 semicon-
ductor and electronics industries, electrical
and electronics content represents
approximately 50 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 to-
day’s higher-priced vehicle might contain
more than 400 components.

Global Automotive Semiconductor Revenue Forecast

Source: Databeans Estimates.
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 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 charge, boost converter, DC/DC converter and load switch applications. The devices are claimed to provide 55% smaller than a 3 x 3mm SSOT-6 MOSFET, 80% lower RDS(on) and 65% lower thermal resistance while providing higher performance.

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

Saves Space

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 I²C 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 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 80 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.

First Automotive Load Driver IC in SOI Technology

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.

Adaptive Power Control

Semitel 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 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 half-bridges to drive DC motors.

Atmel has announced the availability of the new AT86826 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 AT86826 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 position and climate control. With the device’s high voltage capability (up to 40V), the AT86826 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 AT86826 is capable of driving currents up to 1A. The drivers are internally connected to form 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 half-bridges to drive DC motors.

First Automotive Load Driver IC in SOI Technology

http://power.national.com

http://www.fairchildsemi.com

http://www.ssmc.com

http://www.semtech.com

http://www.atmel.com

http://winkler.fairchildsemi.com

http://www.power.national.com
# NEW PRODUCTS

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