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Power Control Intelligent Motion

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Power for Automotive and Hybrid Electric Vehicle Applications

PSDE PowerLine

PSDE PowerPlayer

Marketwatch

Automotive Electronics

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Driving Solutions from Engineering

Well, here we go into the much publicized Automotive theme. I say much publicized, not so much from an editor's perspective, but that of an industry watcher. It looks, on the surface, especially to a marketeer to be a much lusted after segment realizing huge volumes at good AUP. But is it all it seems?

There are characteristics found in automotive not typical of the general semiconductor market. According to Databeans, the consistent demand for automotive electronics is growing faster than the vehicle market itself, as regulations tighten in emission standards and safety requirements, and as consumers invest in the DVD players and audio products made specifically for automotive applications. Sounds like a dream come true...

Legislated regulations and consumer demands continue to drive this market upward. High growth application areas for automotive semiconductors include safety (airbags, cruise control, collision-avoidance, anti-lock brakes) and 'cockpit electronics' (entertainment, telematics, instrumentation, phones). All of these applications have a need for the parts in our power industry, so what could be the real advantages and perhaps drawbacks? As always in engineering, things are not quite so simple and clear cut...Find out in this issue.

We look at the products on offer. Products which are innovative and highly specialized to the automotive specification from a wide variety of suppliers, but what I want to try to do is not just present an array of silicon alternatives but to show real-world problems and solutions. This magazine is made for the design engineer and I want the content to be of use as well as of interest. We all have our 'challenges' to overcome on a daily basis and I would hope that this magazine can be a forum for engineers. To present their own experiences and to share with colleagues in the industry.

After the much looked forward to holiday season in July-August, the kids go back to school and we are, as usual, plunged straight into the rigours of work.

It occurred to me that when I thought about automotive, I just thought about a special class of products optimized for reliability under tough conditions but as I edited our rich selection of contributed articles and news stories I learned there was far more to it than this simple theme. This is where the experts connected with our magazine show their great value and insights for our collective benefit.

I would just like to take this opportunity to extend a warm welcome to two such experts joining our magazine.

Marijana Vukicevic, senior analyst, power management for iSuppli corporation. She will be contributing the Marketwatch section of the magazine starting in this issue and **Michele Sclocchi**, principal application engineer, power management for National semiconductor Europe is the newest member of our valuable steering committee.

In my recent visits to power semiconductor suppliers, I am almost immediately impressed how well aligned they are becoming with the problems faced in engineering... real problems. This has not always been the case. The days of the simple 'silicon vendor' are over, hopefully forever and the new breed of 'solution provider' will ultimately win through.

But back to me. Luckily, my publisher handles all the complicated stuff like circulation profiles (who needs to get it) and Ad revenues (who pays for it) and I just get the good materials using our industry experts (steering committee plus authors) and to deliver this material for our mutual benefit.

Sounds like a dream job. It is. And with the dynamic and exciting nature of the power industry especially, it is definitely at one of the cutting edges of engineering and keeps us all on high alert. Long may it continue.

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ON Semiconductor Names Bob Mahoney Executive Vice President of Global Sales and Marketing

ON Semiconductor Names Bob Mahoney Executive Vice President of Global Sales and Marketing

ON Semiconductor, a leading industry supplier of power solutions, has named Bob Mahoney Executive Vice President of Global Sales and Marketing. Mr. Mahoney takes on his new responsibilities after successfully directing the company's Sales for the Americas as Vice President. During his tenure with ON Semiconductor, Mr. Mahoney has been instrumental to the company's growth of market share and bottom line profitability. Since joining the company in 2003, he has held executive responsibilities throughout the sales organization—including Vice President of Global Distribution and the Electronic Manufacturing Services Industry (EMSI), and Vice President of North America Sales, Computing Segment Sales and Sales Operations.

"To accelerate the growth of ON Semiconductor's power solutions portfolio, the company was internally realigned at the beginning of the third quarter into four market-based divisions—namely the Digital and Consumer Products Group, the Computing Products Group, the Automotive and Power Regulation Products Group and the Standard Components Group," said Mr. Mahoney. "My first order of business is to better align ON Semiconductor's worldwide sales and marketing efforts to meet the engineering needs and manufacturing challenges of our existing and future customers in these focus application areas."

Mr. Mahoney brings more than 20 years of semiconductor industry experience in sales and sales management to his new role as Executive Vice President of Global Sales and Marketing for ON Semiconductor. Just prior to joining the company, he was Vice President of World Wide Sales for Xicor Semiconductor. Previously, at Altera, he was Vice President of Strategic Accounts. During his career, he has also held sales management roles at Analog Devices and National Semiconductor.

Mr. Mahoney holds both a BA and a Masters degree in Business Administration from LaSalle University. He replaces Bill Bradford—who left ON Semiconductor to accept a position with Freescale Semiconductor.

http://www.onsemi.com

Collaboration for 45nm low-power process technology

IBM, Chartered Semiconductor Manufacturing, Infineon Technologies and Samsung Electronics Co., Ltd. today announced first silicon-functional circuits and the availability of design kits based on their collaboration for 45nm low-power process technology. The early characterization of key design elements in silicon, coupled with the availability of early design kits, provide designers with a significant head start in moving to the latest process from the industry-leading CMOS technology research and development alliance. The early design kits are developed through a collaborative effort by all four companies and are immediately available for select customers.

The first working circuits in 45nm technology, targeted at next-generation communication systems, were proven in silicon using the process technology jointly developed by the alliance partners and were produced at the IBM 300-millimeter (mm) fabrication line in East Fishkill, NY, where the joint development team is based. Among the successfully verified blocks are standard library cells and I/O elements provided by Infineon, as well as embedded memory developed by the alliance. Infineon has included special circuitry on the first 300mm wafers to debug the complex process and to gain experience in product architecture interactions.

The development of the design kits incorporates design expertise from all four companies in order to facilitate the earlier transition to the new process by chip customer designers, as well as continue to drive single-design, multi-fab manufacturing capability for maximum design leverage and to bring about ultimate consumer benefit. The 45nm low-power process is expected to be installed and fully qualified at Chartered, IBM and Samsung 300mm fabs by the end of 2007.

www.ibm.com

www.infineon.com

www.charteredsemi.com

www.samgsungsemi.com

China EMS Providers Expand

Electronics buyers who are involved in outsourcing decisions can expect electronics manufacturing services (EMS) providers in China to diversify their manufacturing capabilities in China and expand into less developed areas to take advantage of lower labor rates.

Some EMS companies in China are focusing more attention on automotive and medical electronics. For instance, Surface Mount Technology, a Hong Kong-based EMS provider, has established factories in Changchun City in Kilin Province and Tianjin to add capacity for automotive electronics products. China First Automotive Works Group, China's largest automaker, is a major customer of Surface Mount Technology.

The automotive electronics market in China is expected to grow from about $4 billion in 2004 to more than $7 billion in 2010, says researcher iSuppli.

Some companies are migrating to low cost areas. EMS providers have been located in the Pearl River Delta, Yangtze River Delta and Bohai Gulf. Now some EMS providers are starting to expand into the northeast and mid-western areas of China.

The migration is occurring because of labour and power shortages in the Yangtze and Pearl River delta areas. However, as EMS companies migrate, there are challenges including complicated logistics management because of fewer transport links.

www.pcb007.com/china.aspx

Intersil Promotes Roberto Magnifico to Vice President of European Sales

Intersil announces the promotion of Roberto Magnifico to the position of Vice President of Sales, Europe, located at Intersil's sales office in Lausanne, Switzerland.

Magnifico joined Intersil in 1997 as a marketing manager and progressed to sales director for Europe in 2002. As Sales Director he helped drive sales growth and improve Intersil's overall brand in the region. As Vice President, Mr. Magnifico will play a vital leadership role in Intersil's efforts to re-enter the automotive market and further penetrate key OEM electronics customers throughout Europe.

"I expect that Roberto's continued leadership in the region will allow Intersil to expand its presence in Europe, go after strategic growth markets and engage with new customers," said Peter Oaklander, Intersil's senior vice president of Worldwide Sales. "Roberto's strong sales background, as well as his long tenure with Intersil and in the semiconductor industry, makes him ideally suited for these expanded responsibilities."

Mr. Magnifico has been in the semiconductor industry since 1984. Prior to Intersil, Mr. Magnifico worked for Phillips Semiconductor for nine years. He began his career in 1984 at STMicroelectronics as a product engineer in the Power Audio Amplifier ICs product group. Mr. Magnifico holds a BSEE from L. Settembrini, Milano Tech Institute.

www.intersil.com

Infotainment Set to Boom in China

The Chinese domestic market for infotainment—vehicle entertainment and navigation systems—will be worth at least $4 billion by 2013, according to research by analysis firm Strategy Analytics.

The market opportunity will be dominated for some time by the vehicle OEM business, the firm reported today, and the domestic aftermarket will not become significant until 2007 and onward.

Additionally, there are significant cost reduction opportunities for any international infotainment system vendor willing to invest in China, Strategy Analytics said, and Japanese vendors like Clarion, Pioneer, Kenwood and Panasonic are leading this charge.

"For international automotive infotainment system suppliers, China offers opportunities to reduce component and system production costs, to increase access to international/Chinese vehicle OEM joint ventures, and to respond to the growing domestic Chinese OE market," Joanne Blight, director of the Strategy Analytics automotive multimedia and communications service, said in a statement.

www.strategyanalytics.net

Philips Semiconductors to become NXP

With a change of ownership from Royal Philips Electronics to a consortium of private equity investment companies, Philips Semiconductors will simply become NXP.

NXP stands for the consumer's "next experience," according to CEO Frans van Houten. NXP is also associated with Philips Semiconductors' Nexperia platform where audio and video processing technologies reside.

The NXP trademark will include a "Founded by Philips" tagline as part of its branding. "We want to create the bridge between the 'next experience' and our rich heritage," said van Houten. "We have agreed as part of the disentanglement that we can use the Philips brand link to NXP."

In an interview, van Houton laid out several new business priorities. First, NXP is planning a strategic investment in cellular baseband technologies in order to save what appears to be a lackluster baseband business. The move would also help it gain substantial market share in the mobile wireless sector.

NXP will also make a sizable investment in development tools to increase product quality. "Quality, too often, has become an odd one out," he said, suffering at the expense of the company's pursuit of "cost and time-to-market.

"If you have to re-spin your SoC three times to get it right, you are not only delivering a product to your customers nine months late, but you are also increasing the cost of development," he said.

Citing massive recalls of notebook computers with faulty batteries in recent weeks, van Houten noted, "We will never want to be the reason for recalled products. Quality is very important."

Van Houten said NXP will "raise the development budget" for products, "seeking the best tools." He added, "We will not skimp on quality, and we will aim for zero defect and first-time-right silicon."

www.nxp.com

Power Events

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

New Dual Synchronous Step-Down DC/DC Converter Delivers 300mA/Ch from a 3mm x 2mm DFN

Linear Technology Corporation announces the LTC3547, a dual channel, high efficiency, 2.25 MHz, synchronous buck regulator that delivers up to 300mA of continuous output current per channel from a 3mm x 2mm DFN package. Using a constant frequency current mode architecture, the LTC3547 operates from an input voltage range of 2.5V to 5.5V, ideal for single cell Li-Ion/Polymer, or multicell alkaline/NiCad/NiMH applications. It can generate output voltages as low as 0.6V, enabling it to power the latest generation of low voltage DSPs and microcontrollers. Its 2.25MHz switching frequency enables the use of tiny, low cost ceramic capacitors and inductors less than 1mm in height, providing a very compact solution footprint for handheld applications.

The LTC3547 uses internal switches with an RDS(ON) of only 0.75 Ohm (N-Channel) and 0.80 Ohm (P-Channel) to deliver efficiencies as high as 96%. It also utilizes low dropout 100% duty cycle operation to allow output voltages up to VIN, further extending battery run-time. The LTC3547 incorporates low ripple Burst Mode? operation, offering only 40uA no load quiescent current (both channels) with only 20mVP-P of output ripple. Shutdown current is less than 1uA, further extending battery life. Each channel has independent internal soft-start, enabling design flexibility. Other features include short-circuit and over-temperature protection.

The LTC3547EDDB is available in an 8-lead 3mm x 2mm DFN package.

www.linear.com

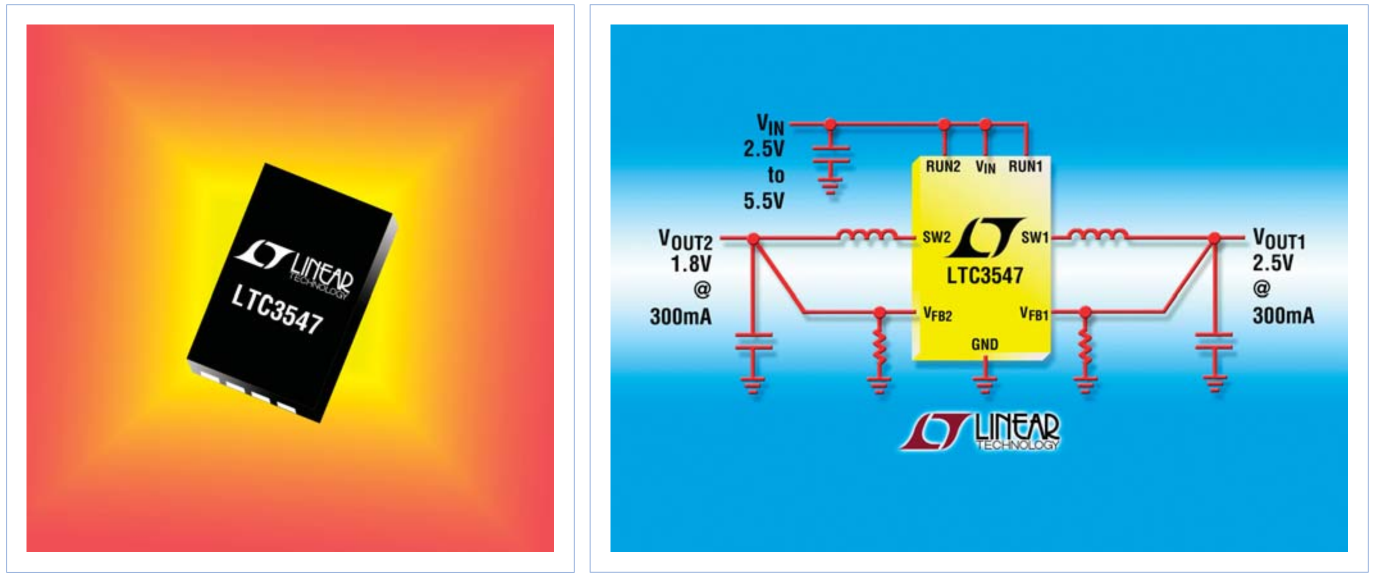


Figure 1. Dual 300mA, 2.25MHz Synchronous Step-Down DC/DC Converter.

Practical Efficiency in Lighting Made Possible by Power Electronics

By Kevin Parmenter, FAE Director, Fairchild Semiconductor

I recently was asked by my son to assist him with a project to reduce the energy consumption of the lighting in the parking and common areas of his condominium complex where he serves as the association manager. As my son is a computer science engineer he needed some practical hardware assistance. Statistics have shown according to the US Department of Energy the average home consumes 25% of its electrical energy in the production of light. The average school, store or commercial building uses 60% of its electrical consumption in lighting. This provides an opportunity for improvement in conversion efficiency for retrofitting with newer more efficient technologies. As my sons condo complex in Scottsdale, Arizona the environment for temperature testing is extreme and the lighting is cycled daily on a photo switch with plenty of sunshine to switch it. This photo switch allows a reasonably controlled environment to test the electric bill difference with the exception of the rising and setting times of the sun changing from day to day over time.

For the past several decades lighting options were limited there was incandescent, mercury vapor, fluorescent or high pressure sodium the latter having only magnetic ballasts available. Electronics was unheard of in these applications not all that long ago. The growth of CFL lamps, electronic ballasts and UHB LED lighting has seen rapid growth. In this particular condominium example the complex is approximately 25 years old and no electronics were present in anything except the photo switch. The project

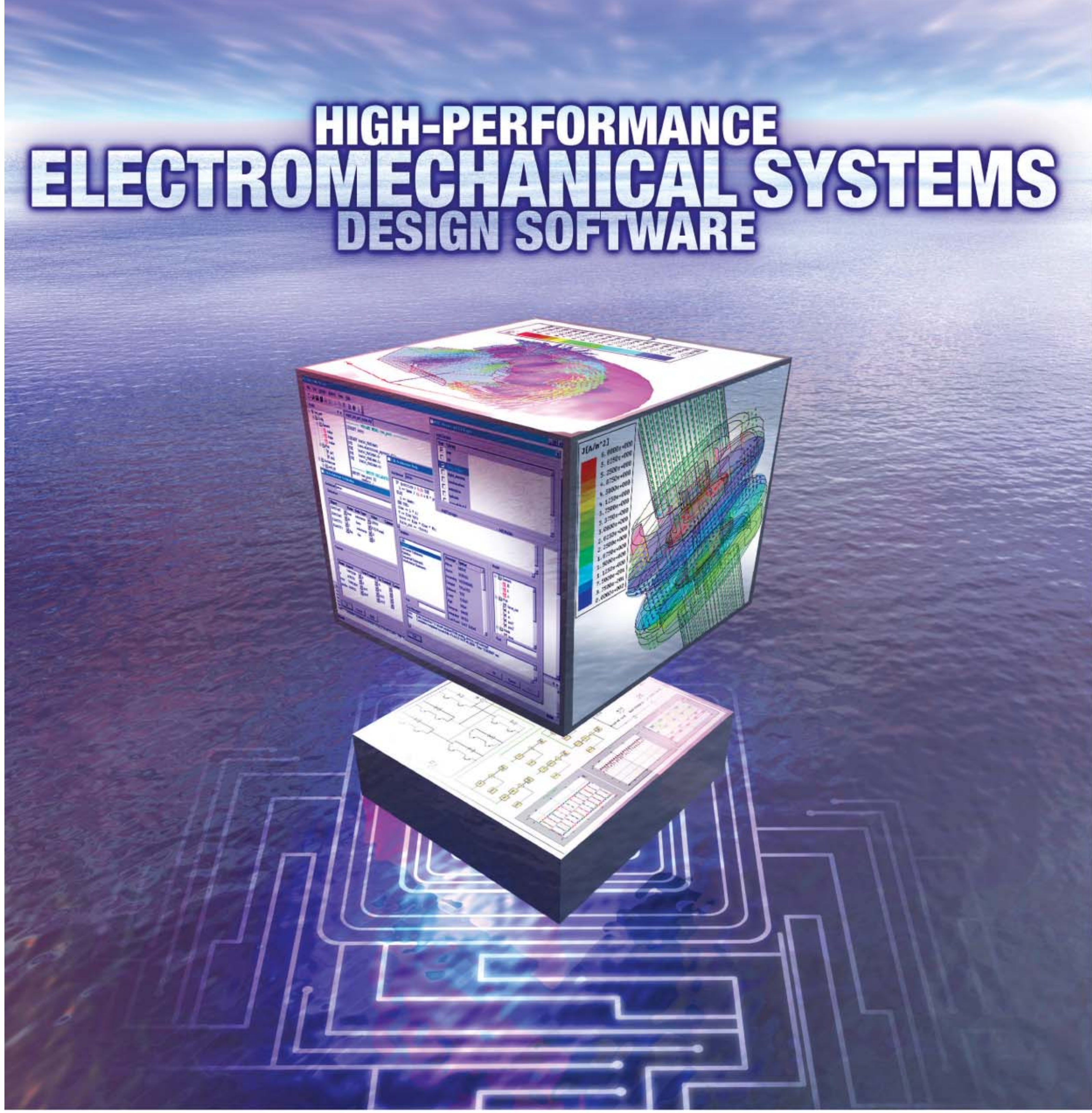
involved replacement of incandescent lamps with Energy Star rated CFL lamps and magnetic ballasts with Energy Star electronic ballasts. Additionally we replaced the linear florescent lamps with higher efficiency lamps in existing fixtures. We made some measurements of the current consumption during these tests to check the “before” and “after” to check the difference in energy consumption. A completely unscientific eyeball test was performed to see what the difference in lighting output was between the before and after was also conducted.

So what were the results? The old bulbs and ballasts were recycled so the glass and metal were recovered and reused – especially the copper is important. The overall energy consumption was predicted to be about 1/3 of what it was previously and measured to approximate that figure using simple DMM current measurements. The light output appeared to be equal to or better than the previous lamps. The Installation was simple because the original fixtures were retained only the lamps and ballasts were replaced (stated differently the same sheet metal was reused) Over the last three months of reading the electric bill the consumption has dropped by approximately two thirds so the installation is generating the same or greater light output on approximately one third of the energy as previously consumed.

In summary the cost effectiveness of this retrofit considering the payback period alone in power savings is highly compelling. With the additional consideration of less maintenance by not having to replace incandescent lights and the new linear florescent tubes are “7 year lamps” it becomes very significant indeed. What does this all mean? With energy becoming more expensive and less available all the time and with green house gas emission being a growing issue we all should be concerned with conversion efficiency. Considering humans are short circuiting the normal sun - to producers and consumer energy cycle in such a manner that we appear to be causing potentially irreversible damage to our fragile planet we can make a difference with power electronics.

This is exciting news for us in the power electronics industry. Our technologies are no longer commodities when we can make a difference such as cutting lighting bills by two thirds and increasing energy to light conversion efficiency dramatically.

www.fairchildsemi.com



Fragmentation Increases in WW Power Management Market

New players cause share to become more diverse

By Marijana Vukicevic, iSuppli Corporation

Despite an abundance of suppliers in the power management semiconductor market, the allure of these products is continuing to attract new competitors to the business, causing market share to become more fragmented, according to iSuppli Corp.

iSuppli tracks 248 significant semiconductor companies and of these, 109, or 44 percent, are identified as suppliers of power management devices. This is despite the fact that power management chips accounted for only $22 billion, or 9.3 percent, of global semiconductor consumption in 2005.

Such supply-heavy conditions might be expected to trigger consolidation among the market players, but in fact the opposite is occurring, with the number of significant competitors in the power management space increasing in 2005, according to iSuppli.

Power management semiconductors present several attractions to potential suppliers:

- Many power management semiconductors are relatively easy to make, and can be fabricated in fully depreciated fabs that would otherwise be under utilized.
- Manufacturers often want to control power management functions critical to the function of their own proprietary chips.
- The wide variety of non-standard applications means that a supplier can succeed simply based on the specialized application expertise of a small number of key employees.
- Many power chips, primarily custom analog ICs, are among the most profitable semiconductors made.

This has led to the fragmentation of the supply base, a phenomenon that should continue for some time, predicts iSuppli.

The top 20 suppliers are seeing their share decline somewhat as new players enter the market. The combined market share declined to 74.9 percent in 2005, down from 75.6 percent in 2004.

Looking at the top 20 players, North American headquartered semiconductor suppliers continue to be aggressive with respect to innovations in digitalized power, and have captured a commanding lead in this area. These suppliers have maintained a significant lead in the power supply market, as evidenced by the market success of power supply focused companies such as Texas Instruments, International Rectifier, Fairchild, Microchip and Linear Technology.

Texas Instruments and several smaller North American headquartered companies now are pushing forward a new set of digital technologies that will quickly and fundamentally alter the competitiveness of many power supply systems. This suggests that these companies will maintain an advantage in this area for some time to come, unless major strides are made in European and Japanese firms soon.

Looking at specific suppliers, number two ranked Texas Instruments (of the United States) distinguished itself by posting the highest percentage increase in power management semiconductors in 2005 among the top 10 players, with a rise of 9 percent. The company gained a half point of market share during the year.

Texas Instruments has the greatest momentum of the large power management suppliers, both from a financial perspective and a technological one. TI is regarded in the industry at the moment as the company with the best execution.

Mitsubishi Electric Corp. gained the most market share of any power management company ranked by iSuppli in 2005, jumping from number 18 to number 15 in the rankings and gaining 0.7 percentage point of market share.

Mitsubishi has made several innovations in industrial and consumer semiconductors, especially Insulated Gate Bipolar Transistor (IGBTs), and gained significantly in the market, mostly at the expense of other Japanese suppliers.

iSuppli anticipates that this momentum will persist as Mitsubishi continues to introduce compelling new packages and power chip technologies.

Marijana Vukicevic is the senior analyst, power management for iSuppli Corp. Contact her at mvukicevic@isuppli.com

www.isuppli.com

Power for Automotive and Hybrid Electric Vehicle Applications

SoftSwing® inverters and customized power modules for leaner and greener operation

Energy is getting more precious, yet we want to continuously be more mobile. A dilemma for the automotive market.

By Peter Sontheimer, Tyco Electronics and Arno Mathoy, Brusa Elektronik AG

The human being is following mega-trends in our world. Boundless mobility as well as the enjoyment of a clean and green environment at home is an essential desire in our daily life. The automotive market reacts according to this situation, well supported by both the increasing fossil fuel cost and the legislative environment, which demands a decrease of CO_2 emission and fuel consumption. One possible concept to answer such challenges is the Hybrid Electric Vehicle HEV. The Electronics industry is asked to react and to come up quickly with suitable solutions for today's and tomorrow's vehicle infrastructures. This article analyzes a particular motor drive inverter with a new topology, which helps to reduce power losses as well as EMI effects. It provides a deep description of the core power element, which shows a power module designed for highest power density and efficiency. The concept leads to better silicon usage and to significant cost reduction in the system.

Conceptual formulation

An inverter is under development for the following applications:

- Automotive drives for hybrid and fuel cell vehicles.
- Hybrid bus traction or generator inverter.
- Drives for Streetcars, Trolleybuses, Metros etc.
- Turbine applications (Turbo-generator, Compressor).
- High speed machine tools.

In automotive applications, the focus lies with the typical cyclic loadings experienced whereas the machine tool market requires in general longest lifetimes in terms of operation durability. As the inverter core electronics are eventually required to be used in mass volume vehicles, the focus is maximum system cost reduction as well as specific harsh mechanical loading capability. The highest reliability as well as power and current densities must also be realized.

Among other components, a power integrated module with lowest inductances are under development in order to achieve testable subsystem levels which can entirely be qualified and can be produced at constant quality levels, reverting to most actual technologies and fabrication processes.

SoftSwing® Inverter

The newly introduced inverter is based on a resonant switching topology, realizing the so called SoftSwing® method. Besides a minimum of construction volume, the target for the inverter design was to achieve extremely low operation losses as well as a highly improved EMI performance. In considering these targets, a couple of design rules regarding the power electronics were considered in order to minimize the system cost, arising while ramping up the device in a mass production style manufacturing site. The system must have a low internal complexity, consequent PCB integration for passives, reduced overall dimensions as well as weight regarding its components, and must be realized with an extremely low inductive design in order to enable highest current handling capability. The key was a high PWM-frequency at low losses.

Functional principle and electrical data

The inverter is operating at 150V..450V level with maximum 600A continuous current I_{rms}. The maximum fundamental frequency supplied is specified to 1700 Hz, whereas the chosen PWM frequency runs with 24 kHz.

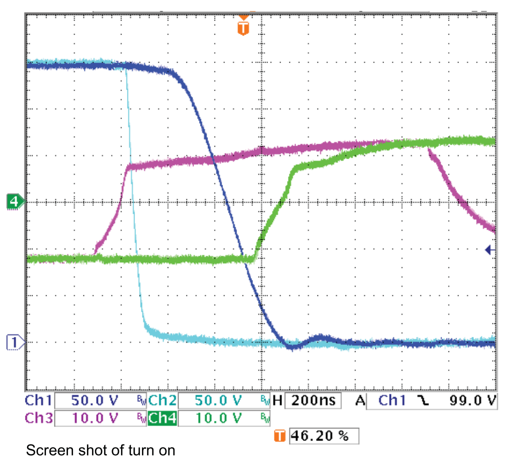
In general, the selected SoftSwing® topology represents a full bridge power circuit as shown in figure 1. By adding a two phase transformer as well as auxiliary capacitors in the circuit, a resonant inverter topology can be realized. The topology leads to significant benefits within the system at circuitry level, inverter level but also at system level of the HEV:

Circuitry level

- Prevents the IGBTs from absorbing the reverse recovery charge when the load current commutes from the free wheeling diodes into the IGBT.
- During turn off, the bridge capacitors prevent the IGBTs from high voltage as the tail current occurs.
- Due to the absence of significant switching losses, the IGBTs can be utilized up to their rated DC-capability.
- Ageing related to periodical thermal expansion of the dye, caused by adiabatic switching loss absorption is completely avoided. SoftSwing® half bridges have proven extremely rugged and tolerant against overload.

Inverter level

- Halves the required IGBT dye size at 25kHz.
- Allows the utilization of the body drain diode in high voltage MOSFET bridges.
- Due to the absence of reverse recovery spikes it generates extremely low disturbance emissions. In particular, DC-link filtering against conducted emissions will be obsolete.



Screen shot of turn on
Magenta: gate of pre-switch
Green: gate of main switch
Cyan: drain of pre-switch
Blue bridge point (drain of main switch)

Figure 3. switching process of the main and the pre-switch.

System level

- SoftSwing® enables a significantly higher PWM-frequency and thus sinusoidal motor-currents up to 2 kHz and even more. This allows innovative, high power density motor concepts.
- High PWM-frequency reduces PWM related motor losses and contributes to energy savings.
- Low du/dt reduces dielectric stress of the motor insulation and enhances thus reliability during the expected lifetime of the vehicle.

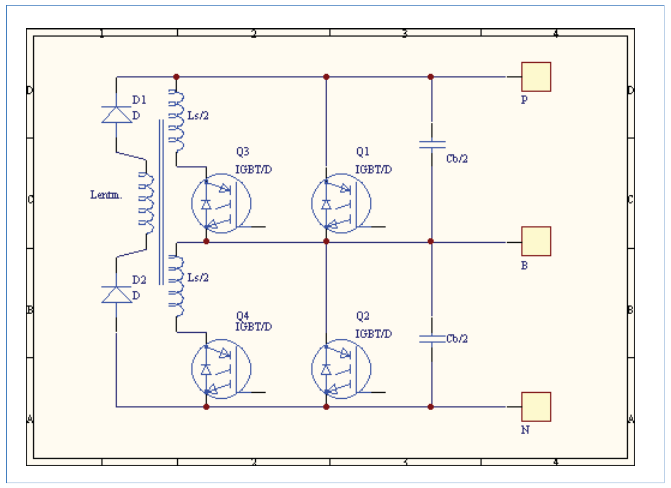


Figure 1. basic SoftSwing® topology.

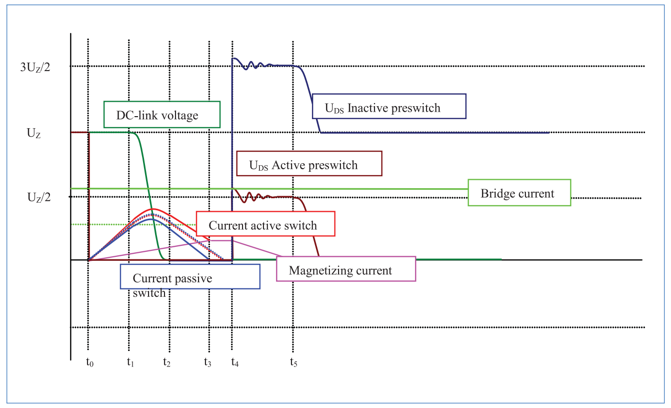


Figure 2. switching process of the SoftSwing® inverter.

Hardware description

Auxiliary elements

The bridge point formed by the two main IGBTs is connected to an auxiliary circuit, consisting of small bridge capacitors and an auxiliary half bridge with small IGBTs and coupled inductors on their drains.

Switching process and characteristics

Figure 2 shows the switching behavior of the SoftSwing® inverter. In case of active switch-on, the external gate stimulus turns on only the auxiliary IGBTs which conducts first (t_0). Now, current ramps up flowing into the inductor. Due to the coupling, the same current ramps up in the other inductor through the free wheeling diode of the passive auxiliary switch.

Once the sum of these auxiliary currents are equal to the load current, the main free wheeling diode is completely prevented from any load current and is about to set the bridge point free (t_1). Now the bridge capacitors and the inductors form an LC-oscillator and the bridge voltage starts to swing around its neutral point, which is in this case the virtual center tap of the DC-link.

If the damping is sufficiently low, the bridge voltage nearly reaches the other rail potential where it is trapped by zero current, zero voltage turn on of the corresponding main IGBT (t_2). From this point, the auxiliary inductors give off their stored energy as their currents start to ramp down.

As the load current is continuously flowing, the main IGBT current must ramp in exchange of the disappearing auxiliary current.

Once the load current is completely commuted (t_3), the inductors need to be demagnetized, for which the auxiliary IGBT has to be turned off (t_4).

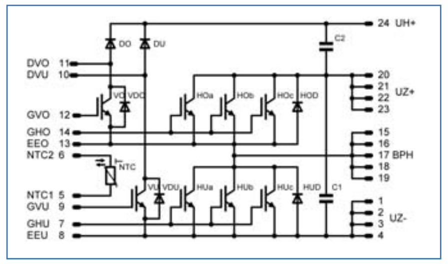


Figure 4. electrical equivalent of the SoftSwing® module.

One solution to perform demagnetization is formed by a well coupled demagnetizing winding. Once the auxiliary inductors are completely demagnetized (t_5) the half bridge is ready for another active commutation.

Tradeoffs and limitations

The commuting time of course affects the PWM. Generally the current-depending turn on delay has to be considered at the control part. In addition, the demagnetizing time limits the minimum turn on time to approximately 3% of the PWM cycle time.

Standard gate drivers cannot perform well, in particular if they operate with a fixed dead time. Any dead time will add more turn on delay and is thus counter-productive to SoftSwing®.

Power Module realization

In order to reach better performance values and to achieve a defined and electrically isolated thermal interface to the inverter periphery a module technology was selected. The power switches define the core-element within the application and significantly help to increase current density within the system as well as to decrease system cost in mass production volumes.

The module is realized on a DBC plate w/o a solid Cu-cooling plate. For a better thermal interface to the cooling medium AlN material was chosen. For applications with lower power demand, Al2O3 DBC can be equally selected, although the chip can't be used to its full extent in this case. In the following the AlN version is discussed. Figure 4 shows the electrical equivalent of the power module.

600V module:

In order to achieve the required performance levels, the module contains for the main power bridge paralleled high speed IGBTs of the 2nd gen, designed for fast switching applications, with a given nominal current of up to 50A each. The supporting transistors are single duos composed of 3rd gen IGBTs and of high efficiency fast recovery diodes.

1200V module:

The main power bridge contains Tyco's PhantomSpeed IGBTs, a second generation transistor with extremely high switching speed capability with a given nominal current of up to 25A each, whereas the support switches are composed of 3rd gen low loss transistors. High efficiency Emcon diodes complete the circuit.

Three such modules represent a complete power kit of 40kW continuous electrical power (V_{DC} = 75%V_{DCmax}, I_{AC}= I_{ACcont}, cosφ = 0,9). The integrated capacitors are SMD components, specified for the required power and voltage levels. An SMD thermistor is integrated as well.

Following versions are completed:

All values given at TJ = 25°C unless described differently

Module Type	Component type	Characteristic	min	Value typ	max	Condition
V23990P655F	Main switch IGBT	Collector-to-emitter breakdown voltage $V_{(BR)CES}$	600 V			I_{CES}=500µ m U_{GE}=0V
		Collector-to-emitter saturation voltage V_{CEon}		2,6 V		I_C=50A U_{GE}=15V
		Gate threshold voltage $V_{GE(th)}$	3 V	4 V	5 V	U_{CE}=U_{GE} I_C=1000µA
		Zero Gate voltage collector current I_{CES}			0,04 mA	U_{CE}=600V U_{GE}=0V
		Gate-to-emitter leakage current I_{GES}			100 nA	U_{GE}=±20V
		IGBT Thermal resistance, chip case R_{thjc}		0,23 K/W		
	Main switch FRED	Reverse voltage $V_{(BR)DSS}$	600 V			
		Forward current I_F		150 A		
		Max reverse current I_r			0,027 mA	U_r=600V
		Forward voltage V_f	1,2	1,6	1,9	I_F=10A
		Diode Thermal resistance, chip case R_{thjc}		0,27 K/W		

Module Type	Component type	Characteristic	min	Value typ	max	Condition
V23990P655F	Main switch IGBT	Collector-to-emitter breakdown voltage $V_{(BR)CES}$	1200 V			I_{CES}=1500µ m U_{GE}=15V
		Collector-to-emitter saturation voltage V_{CEon}		2,1 V		I_C=25A U_{GE}=15V
		Gate threshold voltage $V_{GE(th)}$	5 V	5,5 V	6,5 V	U_{CE}=U_{GE} I_C=1000µA
		Zero Gate voltage collector current I_{CES}			3 µA	U_{CE}=1200V U_{GE}=0V
		Gate-to-emitter leakage current I_{GES}			120 nA	U_{GE}=±20V
		IGBT Thermal resistance, chip case R_{thjc}		0,23 K/W		
	Main switch FRED	Reverse voltage $V_{(BR)DSS}$	1200 V			
		Forward current I_F		75 A		
		Max reverse current I_r			0,027 mA	U_r=600V
		Forward voltage V_f		1,6		I_F=75A
		Diode Thermal resistance, chip case R_{thjc}		0,2 K/W		

Table 1. basic target characteristics of the selected power dice.

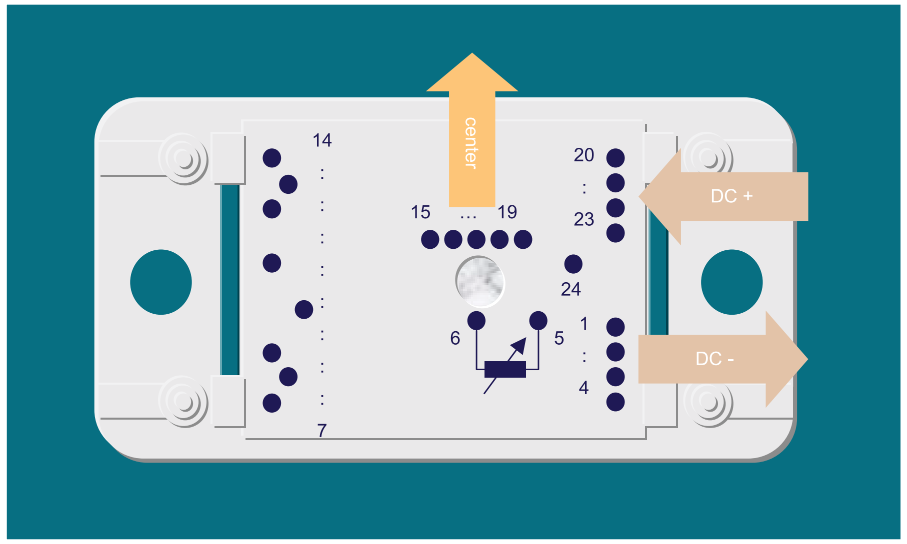


Figure 6: 450V SoftSwing® Inverter.

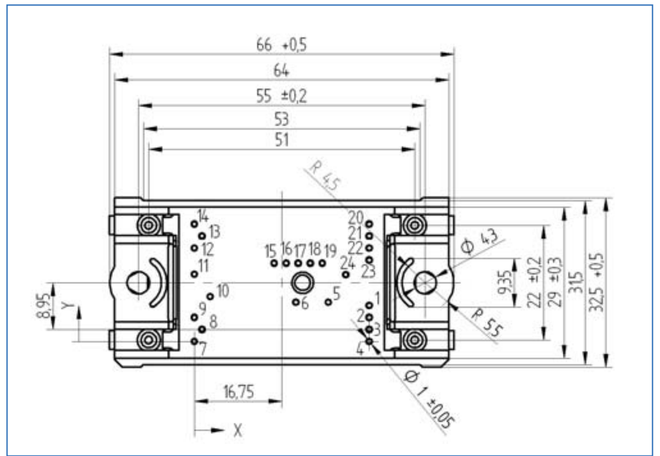


Figure 7: Module dimensions and pin-out.

One important aspect regarding the module development was to achieve the lowest induction design. Figure 5 shows the selected pin arrangement and outline of the module as well as the power flow through the module.

Mechanical dimensions and concept

SoftSwing® inverter

As of today the inverter is designed in a solid Al-metal housing, whereas the housing bottom is completed as a water cooler. The outer dimensions are unrivaled small for this power level:

- 88 x 240 x 360 mm, max. power 106 kW (V_{DC} = 75% V_{DCmax}, I_{AC} = I_{ACmax}, cosφ = 0.9, 450V inverter).
- 88 x 240 x 580 mm, max. power 212 kW (V_{DC} = 75% V_{DCmax}, I_{AC} = I_{ACmax}, cosφ = 0.9, 900V inverter).

This leads to extreme performance key figures of 11.1 kW/kg or 13,94 kW/dm³ regarding the 450V inverter and of 14.1 kW/kg or 17,3 kW/dm³ regarding the 900V inverter. Figure 6 shows the 450V inverter, comprising an integrated terminal box, which can easily be adapted to alternative connectors.

Power Module

The power module circuit was integrated in "flow 0" housing with a DBC area of 39 x 28mm. The housing itself relies on a 17mm mounting height with integrated clip-in functions as mechanical support to avoid redundant mechanical stand-alone parts on the heat sink. To avoid pin stress caused by vibration, a defined mechanical connection of PCB, power module and heat sink is required. The flow 0 housing concept ensures robustness regarding vibration stress and a stable thermal interfacing to the heat sink [Mechanics and Electronics as Instrument for Minimized Drive Applications, Ralf Ehler, Michael Frisch, PCIM Europe Conference 2004].

A flexible pin terminal structure enables the realization of an application optimized pin-out, by not exceeding outer dimensions of 66mm x 32.5mm x17mm, whereas PCB thicknesses of 1.0, 1.5 or 2.0mm respectively can be chosen. Figure 7 shows the top view of the module and its dimensions.

Summary

The SoftSwing® inverter is able to perform at extremely high power levels and bares significant benefits to all levels; system, inverter and circuitry level. Power losses are avoided by using the SoftSwing® resonant topology. EMI problems are reduced by power module integrated capacitors as well as smart selection of the terminal technology and under full utilization of the analog components and their potentials. The power module developed for this specific application is designed under a maxim of gaining highest power density as well as lowest stray inductances. High switching frequencies enable even special E-motors with extremely low leakage inductance to perform well. This is in particular beneficial for ultra high speed drives or motors with a high pole pair number. The mechanical concept of the inverter can specifically be adopted to the referring vehicle and to its available installation space. Thus, Hybrid Electrical Vehicles can be designed based on such highly innovative conception; actually a full electric vehicle based on SoftSwing® inverter technology is already realized. Whatever attracts customer's and legislative's desire and intention, be it the reduction of CO_2 emission or fuel, the discussed products provide significant answers to today's vehicle development challenges.

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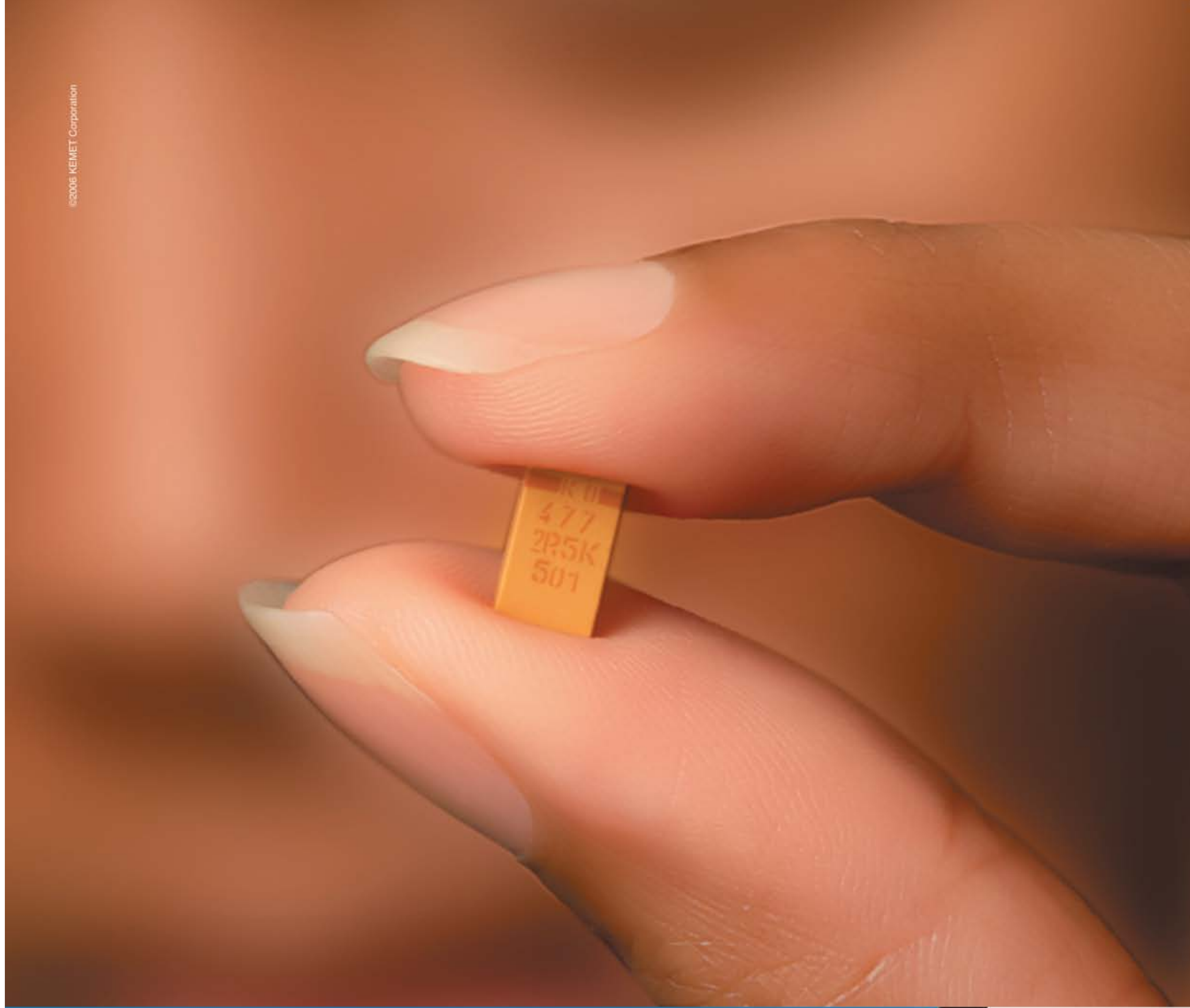

Power Systems Design EUROPE

Automotive Electronics

Part I

Design for Operation in the Automotive Electrical Environment

Harsh conditions need special treatment

Automotive is a brutal environment for electronics. What follows are circuits that are designed specifically to accommodate operation under these conditions.

By Mitchell Lee, Hua (Walker) Bai & Jeff Witt, Linear Technology

While any circuit must operate over a 9 to 16V nominal range, other exigencies include load dump, cold crank, reverse battery, two-battery jump, spikes, noise and an extremely wide temperature range. During load dump, the output voltage of the alternator surges to 60V or more. Cold crank, a name that describes starting the car at low temperatures, causes the battery voltage to sag to 6V or less. Reverse battery is the result of carelessness with cable polarity when jumping a dead battery. Many tow trucks are equipped with two 12V batteries in series to assist with starting a car with a dead battery, in cold weather. This elevates the electrical system to the 28V range, until the car is started and the tow truck driver disconnects the jumper cables. Spikes and noise are no surprise, given that an automotive electrical system comprises high current motors, relays, solenoids, lamps and chattering switch contacts. Furthermore, the alternator, a 3-phase machine with chopped field regulation, at times charges the battery with a very high current.

A passive protection network for automotive electronics is shown in Figure 1. Arrangements identical, or similar to this one, are widely used to protect various systems tied to the automobile's 12V bus. The network protects against high voltage spikes, sustained overvoltage, reverse battery and excessive current draw. Current protection is obvious, fuse F1 blows if the load exceeds 1A for very much time. D1 and F1 combine to protect against reverse battery connections; a high current flows through forward-biased D1 and blows the fuse. An interesting property of electrolytic capacitors is noted at about 150% of the rated voltage: they draw higher and higher current as the terminal voltage is increased, and in the case of C1, it serves as a clamp (eventually blowing the fuse) during sustained input surges. Two-battery jumps at around 28V do not blow the fuse because the 25V C1 rating is sufficiently high so as to draw very little excess current. The inductor adds a small resistance to limit peak fault current, and to limit the slew rate of input transients to assist C1's clamping action in the presence of spikes.

The primary disadvantage of the passive network is its reliance on blowing a fuse for overcurrent, overvoltage, and reverse battery protection. Another disadvantage is its reliance on an electrolytic capacitor for clamping. As the capacitor ages and dries out its ESR increases, impairing the clamping action. Sometimes a large zener diode is substituted for D1

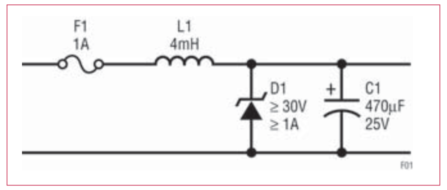

Figure 1. Passive protection network features simplicity.

to assist the capacitor. Active circuits have been devised to overcome these deficiencies.

An active solution shown in Figure 2 is designed for shielding sensitive circuits from the vagaries of a 12V automotive system. The LT1641 is used to drive an input n-channel MOSFET, providing additional protection not featured by the passive solution. First, the LT1641 turns off the load below an input of 9V to prevent malfunctions at low input voltage, and to relieve the system from delivering precious current to non-critical loads during starting, or when the charging system fails. Second, the LT1641 soft-starts the load by gradually ramping the output when power is first applied. Third, the output is protected against overloads and short circuits by current limiting and a timed circuit breaker. The circuit breaker auto-retries at a 1-2Hz rate in the event of a current fault; a fuse upstream of the protection circuit can be sized so as never to blow as a

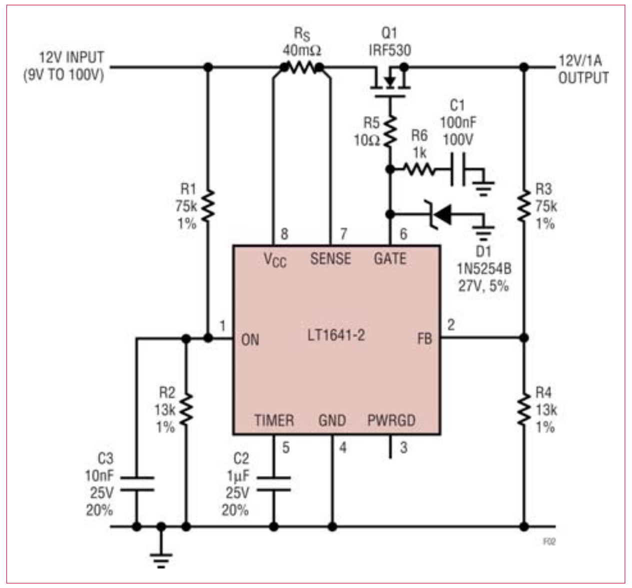

Figure 2. Overvoltage transient protector clamps output at ~24V and disconnects if the input drops below 9V.

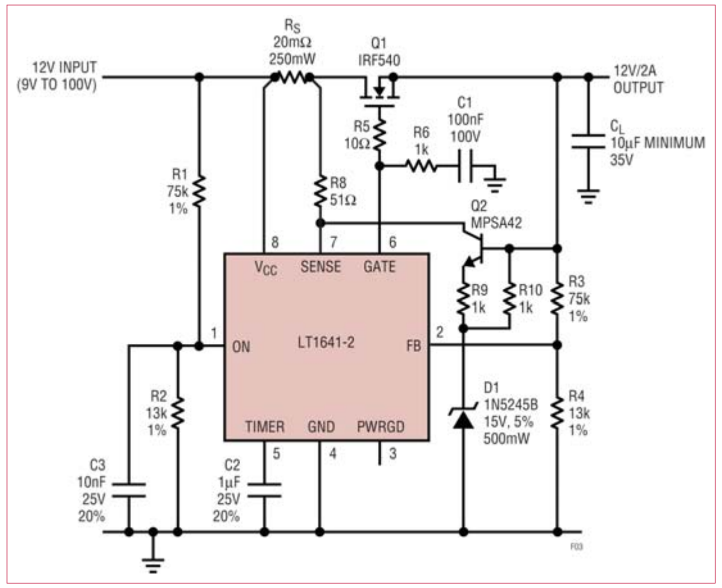

Figure 3. Regulating clamp clamps input surges and protects MOSFET against over-dissipation.

result of a current fault downstream of the LT1641. Finally, the circuit in Figure 2 blocks over-voltages appearing at the input, while at the same time delivering a clamped output so that the load circuitry can continue operating right through the overvoltage event.

Under normal conditions with a 12V input, the LT1641 charges the gate to about 20V to fully enhance the MOSFET and deliver power to the load. A 27V zener diode, D1 is connected from the gate to ground but plays no role in the 9-16V operating range. When the input rises above 16V, the LT1641 continues to charge the gate in an attempt to keep the MOSFET fully on. If the input rises too far, the zener will clamp the MOSFET gate and limit the output voltage to about 24V. The LT1641 itself can handle up to 100V at the input, and is unaffected by the clamping action on the gate. The gate clamp scheme is certainly more precise than the passive solution, and is easily adjusted to suit the requirements of the load by simply choosing an appropriate breakdown voltage for D1.

The circuit shown in Figure 2 works well for loads of up to about 1A, but for higher load currents the technique illustrated in Figure 3 is recommended to prevent over-dissipation in the MOSFET. Excessive dissipation is a risk if the overvoltage condition is sustained, such as when the electrical system is powered from two series connected batteries for an extended period, or even for slow load dump surges and small MOSFETs. The output is sampled by D1 and Q2; if the input exceeds 16.7V, a signal is fed back to the SENSE pin to regulate the output at 16.7V. Regulation is more precise than in the previous circuit (Figure 1), and is easily customized to meet the needs of the load by selecting the appropriate zener.

Total dissipation is limited by the TIMER pin, which keeps an account of the total time spent by the MOSFET regulating the output. If the overvoltage persists for longer than 15ms, the LT1641 shuts down and allows the MOSFET to cool. The circuit attempts to restart after about half a second. This cycle continues until the overvoltage is removed and normal operation resumes. Overcurrent faults are handled in a similar manner to that described for Figure 2.

Reverse battery protection can be added to the circuits of Figure 2 or 3 by simply including a series diode, a conventional p-n diode in most cases or a Schottky if forward drop is important. In critical applications where the power loss in a blocking diode is unacceptable, the simple adjunct shown in Figure 4 will do the job. Under normal operating conditions, the body diode of MOSFET Q2 forward biases and passes power to the LT1641. When that device turns on, gate drive is applied to Q2 turning it on fully. If the input is applied in reverse, the emitter of Q3 is pulled below ground and turns on, dragging the gate of Q2 down and keeping is close to Q2's source. In this case Q2 is held off, and it blocks the reverse input from reaching the LT1641 and load circuitry. A microampere-level current of no consequence flows through the 1M-ohm resistor to the LT1641's GATE pin.

Step-down regulators such as the LT1616 that have maximum input

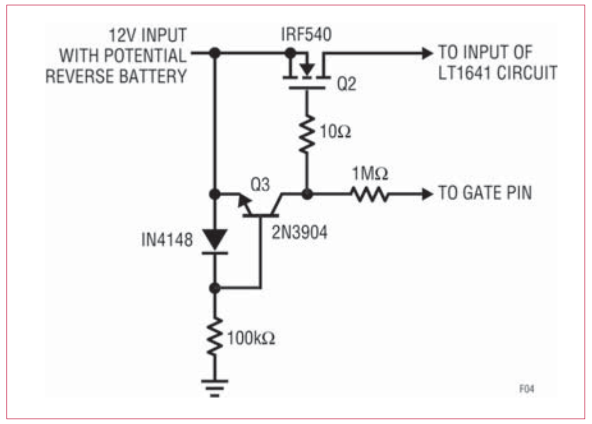

Figure 4. Reverse battery protection for Figures 2 and 3.

voltage rating of 25V or less are not generally considered for automotive applications. Nevertheless, if combined with a low dropout (LDO) linear regulator such as the LT3012B/LT3013B, the voltage deficiency is easily overcome. The small, yet efficient combination shown in figure 5 provides a 3.3V output in an automotive environment. The LT3013B has a wide input voltage of 4V to 80V with integrated reverse battery protection, saving cost and board space without the need for special voltage limiting or clamping circuits. The efficiency of an LDO regulator is nearly V_{OUT}/V_{IN} when operating with a moderate load current. If V_{OUT} is much lower than V_{IN}, the efficiency of an LDO suffers. For example, step a 12V input down to a 3.3V output results in only 28% efficiency. Much better efficiency is achieved in Figure 5 by operating the LT3013B in dropout over the normal input voltage range. In this case, the output voltage of the LT3013B is set to 24V. The output of the LDO will be just 400mV below the VIN, and delivers power to the LT1616 buck regulator with 97% efficiency right in the heart of the normal operating range. During load dump events, V_{IN} may surge as high as 80V, but the LT3013B will be regulate and effectively "limit" its output to 24V for any V_{IN} exceeding 24.4V, well within the rating of the LT1616 switcher. If V_{IN} rises above 24.4V, the LDO efficiency falls, but this condition persists for only a short time and is of no consequence. The LT1616 converts the limited output of the LT3013B to 3.3V. The switcher efficiency is around 80% at a 12V input. During cold crank, the car's voltage can drop to 5V. Under this condition, the LT1616 input voltage is 4.6V, well within its range of operation. Test results of the Figure 5 circuit are shown in Figures 6 and 7.

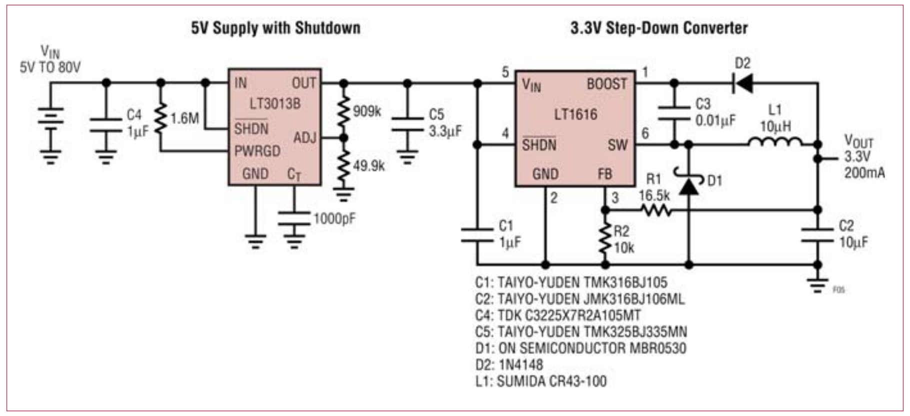

Figure 5. LT3013B serves as a voltage limiter.

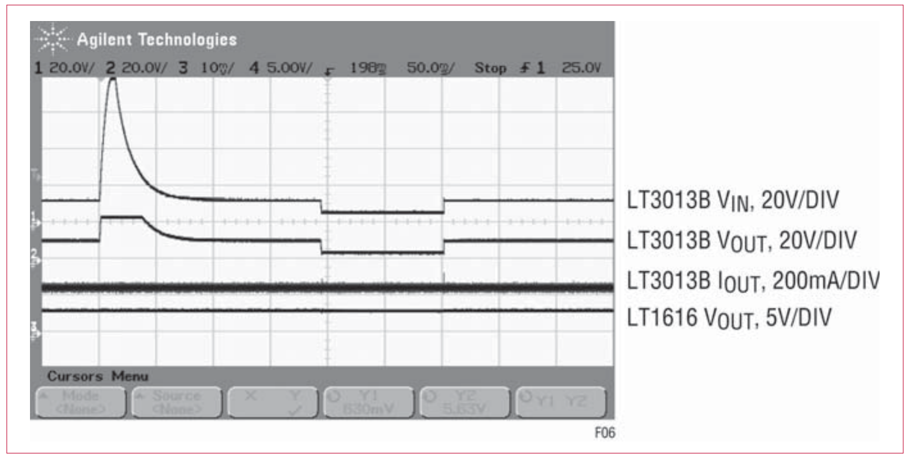

Figure 6. Waveforms of the Figure 5 circuit.

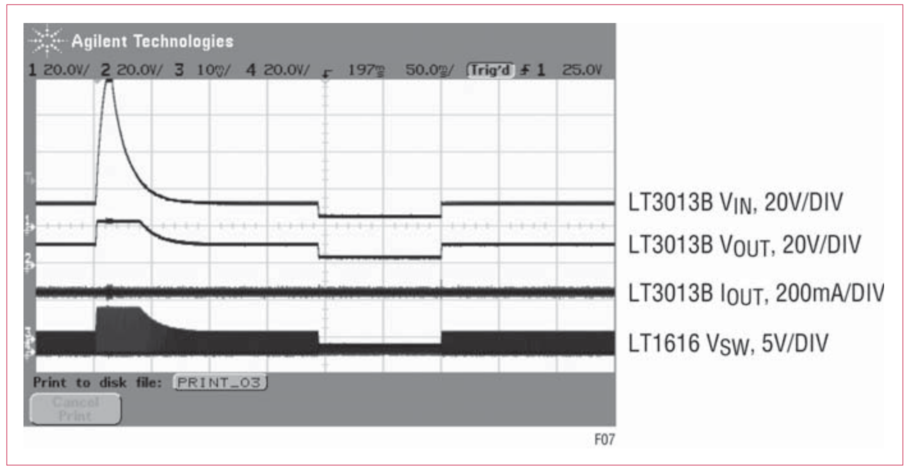

Figure 7. Waveforms of the Figure 5 circuit.

The combination of the LT3013B LDO regulator and the LT1616 switcher regulates the 3.3V output over a wide range of operation conditions typical of an automotive 12V electrical system, without sacrificing efficiency.

A more integrated solution is the LT3437 [1]. The LT3437 is a 200KHz monolithic step-down regulator that accepts input voltages from 3.3V to 80V. Its low quiescent current of 100uA under a no load condition is a must for today's always-on systems. An inexpensive diode can be put in series with the input to offer reverse battery protection.

The challenges of the automotive electrical environment and a traditional passive protection circuit are introduced. Several circuits featuring LT1641-2, LT3013B/LT1616, and LT3474 are designed for operation in an automotive environment.

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Taking the Heat Out of Automotive

Thermal design practice for high power electrical automotive subsystems

With electrical and electronic systems in today's vehicles, driving is easy. But these add heat to an already hot environment. Designers need to cope with this.

By Nico Bruijnis, European Marketing Manager, The Bergquist Company

Major vehicle subsystems such as power steering, brake actuators, valve operation and direct fuel injection are migrating to electrical and electronic implementation, delivering savings in cost, size and weight. But these high-power electric drives also represent significant heat sources in locations close to the engine, brake rotors and exhaust system, where ambient temperatures are already high. For instance, temperatures at the exhaust system and brake rotors can exceed 500°C, and the surface of the engine itself can reach more than 200°C.

Even though component suppliers are qualifying automotive parts up to 175°C, close attention must be paid to maintaining temperatures within this maximum to allow continuous operation at full rated power. Since excessive temperatures will impair reliability, to the detriment of safety and market acceptance, designers of vehicles and electronic or electrical subsystems must prioritise thermal management and cooling of electronics from the earliest stages of vehicle design.

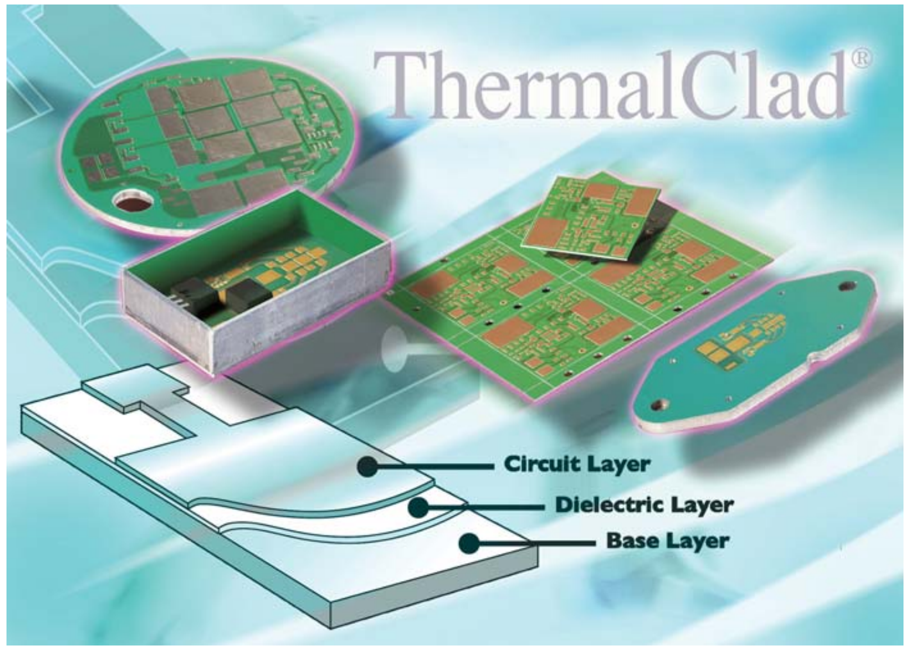
Processing and Control Modules

Electronic engine control units (ECU) have been a feature of new vehicle designs for many years. There has been a clear trend toward more powerful processing capabilities including digital signal processing for smoother and more efficient engine operation, as well as integration of advanced features such as variable valvetrain control. A current, high-end ECU, for example, may include a 32-bit processor, DSP, fuel injector outputs, and several IGBT coil drivers. There is a clear upward pressure on power density, with a corresponding increase in heat dissipation from the module as a whole. Typically, the ECU is delivered as a self-contained unit comprising integrated connectors, and with the die-cast casing acting as an integral heatsink.

While an ECU, particularly at the lower end of the market, may be mounted in the passenger compartment, mounting under the hood (UTH) or directly on the engine saves significant wiring and allows faster and more direct control of engine electrical systems. Thermal design of the ECU is thus more critical with each successive generation of module and vehicle design. The efficiency of the heatsink-casing, which is influenced by size, shape and material characteristics, is critical. So, too, is the need to create an efficient thermal pathway between the major heat dissipating electronic components and the case.

The thermal characteristics of the substrate are increasingly important as designers of automotive electrical subsystems seek to absorb heat from power devices included in the assembly, The substrate must transfer this heat to the module casing, from where it can be dissipated into the surrounding air. Vehicle manufacturers and subsystem designers are considering a number of enhanced substrate technologies. These include Direct Bonded Copper (DBC), Low Temperature Co-Fired Ceramic (LTCC), Thick Film Alumina, Beryllium Oxide (BeO) and insulated metal substrate (IMS). A suitable substrate technology, however, not only displays high thermal conductivity but must also deliver high reliability and current handling as well as supporting flexibility in mechanical designs.

DBC technology, for example, is



already widely used within the automotive domain, particularly in locations where temperatures can increase above 180°C. These not only include ECU positions, but also modules that may be mounted inside certain major units such as the gearbox, for example, to perform transmission control functions.

On the other hand, a DBC substrate can be brittle, and the technology does not provide the flexibility to build custom shapes. An IMS technology such as Bergquist Thermal-Clad does allow designers to specify special shapes such as circular or half-round substrates, to utilise space within the engine compartment and other areas of the vehicle more efficiently. IMS also offers the advantage that it can be shaped in 3-dimensional formats for greater design flexibility and shows higher mechanical stability than most ceramic or bonded substrate technologies. As an IMS technology, Thermal-Clad also allows customers a choice of base layer materials, including aluminium or copper, and a choice of thicknesses to further extend control over thermal conductivity, thermal capacity and the overall size and volume of the assembly. The electrical isolation and thermal impedance properties of IMS are governed by the characteristics of the dielectric layer residing between the electrical interconnect layers and the base material. The dielectric combines a polymer material that determines electrical isolation, stability throughout thermal ageing, and bond strength, with a ceramic filler to enhance thermal conductivity and maintain high dielectric strength. The composition of the dielectric is adjusted to emphasise one or more characteristic, such as high thermal conductivity, to match the requirements of a given set of applications. There is a choice of four dielectrics for use with Thermal-Clad, which allows customers to specify an optimal composition in terms of performance and cost.

Another valuable aspect is that, whereas IMS has traditionally been viewed as a single-layer interconnect, Thermal-Clad technology supports two-layers of interconnect.

Motors and Drives

Successful operation of electrical systems such as EPS, electro-mechanical braking, electrical valve operation and variable speed cooling fans depend on efficient, lightweight electric motors. In these situations, electronic controls deliver the desired controllability, are smooth in operation, and are cost-effective. These motor controllers are now distributed at many locations throughout a modern vehicle, and must be designed not only to dissipate the heat generated internally by processing and power switching but also to include protection from the heat generated by the motor. This is becoming increasingly important as these controllers are now migrating into the motor assembly itself, as part of the trend toward mechatronic solutions.

Among high power automotive electrical subsystems, Electrical Power Steering (EPS), is an attractive goal for car makers. EPS offers savings in cost, weight and fuel consumption compared to conventional hydraulic solutions. Some current models already have full EPS, and most car makers have a roadmap to implement this technology. The required motor output depends on the size and weight of the vehicle, and may range from 300W to around 800W or more. Conduction and switching losses in the MOSFETs of the motor driver, particularly during heavy use of the steering system such as when parking, are dissipated as heat. Again, a large die-cast heatsink is usually used. In the case of EPS, the MOSFET assembly, as well as the electronic control unit if fitted, may be integrated into the motor itself.

Engine cooling fans, on the other hand, benefit from variable speed operation to support a more flexible engine cooling strategy and also enable better management of the overall vehicle electrical budget. Speed control is a key advantage of electronic motor controls, but the driver switching the motor drive current must be able to dissipate losses in proportion to the power of the fan motor. For a small vehicle, this power may be in the range 300-500 Watts. For a larger car, on the other hand, a motor of 800-1000 W may be necessary.

These high power systems require an efficient thermal path from the transistor casing to the heatsink. Air gaps are the greatest enemy in this respect, since the thermal conductivity of still air is very low at 0.0262 W/m-K. This compares with 400 W/m-K for copper: clearly, even a thin air gap between two metallic surfaces will dramatically increase the overall resistivity of the thermal path to ambient. Since air gaps are inevitable where a component attaches too a heat sink or other surfaces, filling these gaps with a thermally conductive material significantly improves overall thermal performance. However, selecting the right gap filling material is critical. For instance, the required thermal conductivity of the material is related both to the thickness of the gap to be filled and the power rating of the motor. The cost of the gap filling material also tends to be greater for high thermal conductivity formulations, which may require the designer to choose the optimum material from a range of alternatives, or to have a custom gap filler developed.

Bergquist has recently completed two projects with major European car manufacturers, in which special gap pad materials meeting custom thermal conductivity requirements were developed. One, to meet the requirements of a small car variable speed cooling fan design, resulted in a gap pad material displaying thermal conductivity 1.5 W/m-K while also meeting the car makers requirements for resistance to cut-through and other environmentally-driven requirements. A similar project for a larger vehicle, on the other hand, required development of a special automotive gap pad material achieving very high thermal conductivity of 3 W/m-K, reflecting the higher thermal transfer requirements of the more powerful motor drive.

The composition and technology roadmap of gap filling materials are such that there is a trade-off between thermal conductivity and cost. Hence, in a high-volume application such as an automotive project, subsystem designers frequently work with Bergquist to customise a solution that exactly suits their requirements. On the other hand, a wide range of off the shelf gap filling pads, such as Gap-Pad™, are available in a variety of pre-cut dimensions including custom shapes and in a choice of thermal conductivity, from 0.8 W/m-K to 5.0 W/m-K. Other gap filling solutions, such as Sil-Pad™ and Hi-Flow™ phase change materials, are frequently used to ensure efficient bonding of power MOSFETs to a heatsink rail and offer additional benefits such as easy assembly. In practice, efficiently bonding a power device to its heatsink allows designers to operate the device closer to its maximum rated current or voltage, or over a greater duty cycle. This offers the designer opportunities to reduce the overall component count, thereby saving size and bill of materials costs, as well as improving reliability.

Best Practice Thermal Design

In general close attention to thermal design, and co-operation with materials partners supplying technologies such as gap filling and thermal substrates to the project, is important to meet the stringent performance, reliability and cost targets prevailing in the automotive environment.

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AUTOMOTIVE/POWER MANAGEMENT

The Lowest Quiescent Current Wins!

How very low quiescent current step down IC converters offer solutions to difficult problems

When you park the car, the battery is still supplying power to certain systems. How can we design to avoid a lock-out upon our return?

By Michele Sclocchi and Frederik Dostal, National Semiconductor

The biggest trend in power supplies over the years has been to maximize efficiency within the monetary budget available to power supply designer. Besides this goal there are of course other optimization parameters like dynamic response, noise behavior or optimized failure behavior. One particular requirement has become of great importance recently particularly from the automotive industry: low quiescent current.

Long battery life is important and depends on the efficiency of the power supply at a given load. If we do not have the possibility to change the load we can only boost the efficiency of the power supply. One way to increase the efficiency especially at low output loads is to decrease the quiescent current of the power regulator IC.

Quiescent current is the current that a certain power supply consumes when turned on but no output power is drawn. In shutdown condition most modern power supplies only consume a few uAs of current. But as soon as little load on the output is attached the power supply has to operate and will consume power. This Power has two main causes. (Figure 1) One is the input voltage times the current that the power regulator IC draws when turned on. This current is used to power internal devices such as the precision reference, the PWM generator the oscillator as well as the Error Amplifier and many more blocks that have to be powered in steady state operation. The second source of the consumed power comes from the feedback resistors which are used to set the output voltage. Here the power results from the adjusted output voltage and the total resistance of RFB1 and RFB2. Voltage square divided by the Resistance. So the higher the resistance of the feedback resistors the less power is consumed. This optimization has certain limits in reality. If the resistance gets to high, noise can easily be coupled on to the FB pin of the power IC. This noise can cause problems in the regulation loop. A practical upper resistance value is a few hundred kilo ohms. If a power IC with a fixed output voltage without external feedback resistors is used, it does not mean that this power loss is non existent. In reality the feedback resistors are just well matched internal resistors. Often the adjustable version of power ICs with external resistors offer more flexibility in selecting the feedback resistors and by this offer a better way in controlling the current lost. On the other hand internal resistive dividers offer optimized resistances and less susceptibility to noise since the high impedance node at the error amplifier is not pined out.

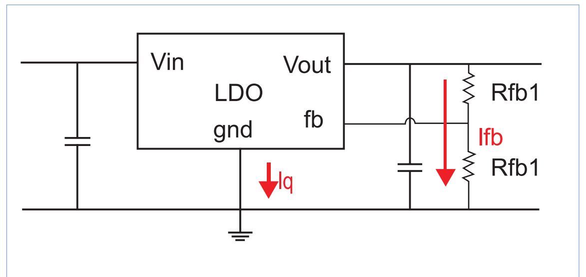

Figure 1. LDO quiescent current.

New requirements in automotive

A rather new development in market requirement came with the soaring electronic content in the automobile. Obviously, the more systems a car battery has to supply power to, the quicker it will be discharge. Once the combustion engine of the car is running and the battery is charging there is not such a big problem. As soon as the car is turned of, but some systems still require constant power we can run into a problem when the car battery is discharged after the vehicle has not been driven for a few weeks or even days. Systems that need constant power are real time clocks, memories, alarm systems including sensors and alike.

A linear regulator approach

For many applications, especially with small output currents as well as low voltage difference between input and output voltage, using a linear regulator could be the best solution. The linear regulator ICs are less complex than switching regulators so they need less power themselves. The overall power loss in a linear regulator consists of three main parts:

1. The power path losses which consist of the voltage difference between the output and input voltage times the load current.
2. The power used to support the functions of the linear regulator. The classic quiescent current. Given in the datasheet of the IC.
3. The power lost in the feedback resistors. Dependent on the value of the feedback resistors and the output voltage.

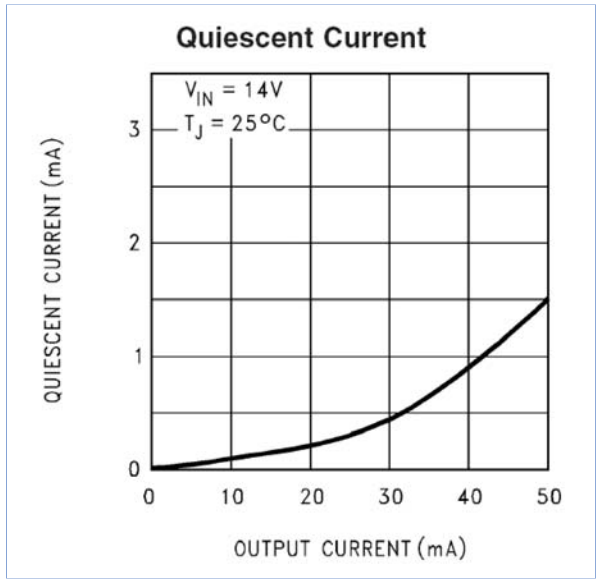

Figure 2. LDO quiescent current vs. output current.

National Semiconductor's LM2936 is a linear regulator optimized for low quiescent current. Its quiescent current is dependent on output load and at output currents of 100uA the quiescent current is less then 20uA. (Figure 2)

The power path losses are very small if the output current is very small. So in many cases using a linear regulator for efficient power conversion at low output load is a very good solution.

A switching regulator approach

Switching regulators generally need much more quiescent current due to the higher complexity of the regulator ICs. Also a switching regulator has to recharge the switching element (usually a MOS FET) every time the switch is turned on. If a certain regulator is switching at a constant frequency the total efficiency at very low output loads is very low. Systems that need high efficiency at low loads as well as the capability to provide high loads often use two parallel power supplies. (Figure 3) One switching regulator to provide high efficiency at high loads and then at low loads the switching regulator is turned off and a low quiescent current LDO is taking over. Such a system

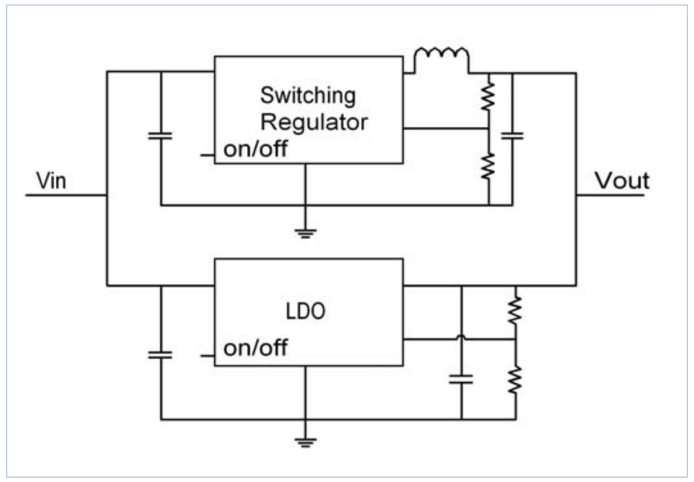

Figure 3. Two parallel power supplies.

works well but requires two independent power supplies, relatively complex control mechanisms and a large bill of material.

New switching regulators such as National Semiconductor's LM26001 combine such a complex solution into one easy design. The LM26001 only consumes a typical 40uA while providing loads of a few hundred uAs of load current. Such a quiescent current optimized design operates in a pulse skip mode so that energy is only shuffled from the input to the output if really needed. This way charging losses of the switching element can be optimized. The LM26001 can deliver up to 1.5A of continuous load current with a fixed current limit, through the internal N-channel switch. The part has a wide input voltage range of 4.0V to 38V and can operate with input voltages as low as 3V during line transients.

The quiescent current is down

With new switching regulators coming to the market like the LM26001 it is possible to support many low quiescent current applications to provide a very well tailored solution. Low quiescent current applications are here to stay so expect more development in this field resulting in a larger selection of semiconductor products coming up.

www.national.com

Essential Design Criteria for Variable Automotive Power Semiconductors

Success can be elusive

In addition to the specific functional requirements of any component designed for automotive applications, three key technical areas need to be considered in detail: Electrical, Environmental and Reliability.

By Bob Christie, European Applications Manager, Allegro Microsystems

Many industry sources are predicting continuing increases in the market for semiconductors in automotive applications. In last year's Power Systems Design Europe automotive supplement Chris Ambarian suggested $23bn by 2009 with power electronics making up 12 to 13% of this. In 2004 Derek Lidow indicated that the expected compound annual grown rate (CAGR) would be 8.3%. With such figures, and the added benefit of longer term stability, automotive electronics can be a very attractive prospect.

However, any component supplier contemplating entering this market should be fully aware of the wide ranging demands that will be placed on them. These vary from broad commercial to detailed technical requirements, including significant delayed return on investment due to extensive automotive qualification requirements, medium level volumes when in production and intense expectation of continuous improvement in quality and price over the lifetime of the product.

Electrical Requirements

In most applications, power electronics will be connected directly to the main vehicle power network. For cars this is nominally 12V but can be as low as 5V during cold engine starting and as high as 24V during double battery starting. It can also exceed 40V during a "load dump" condition if the battery becomes disconnected from the alternator. In addition the many inductive loads, and the inductance of the wiring harness itself during load switching, can inject severe disturbances on the power network. All electronics connected directly to the power network must be capable of surviving these transient conditions. ISO7637 defines the basic requirements for these electrical disturbances and includes five basic test pulses with recommended duration varying from a few microseconds to a few seconds and recommended test voltages up to 150V. Each of the major car manufac-

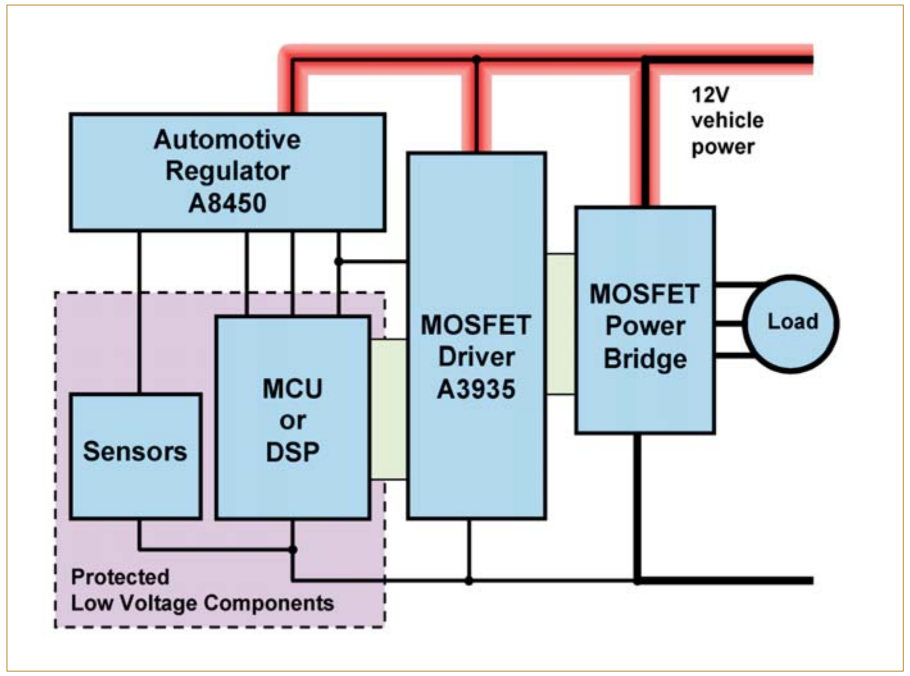

Figure 1. Protecting Low Voltage Components.

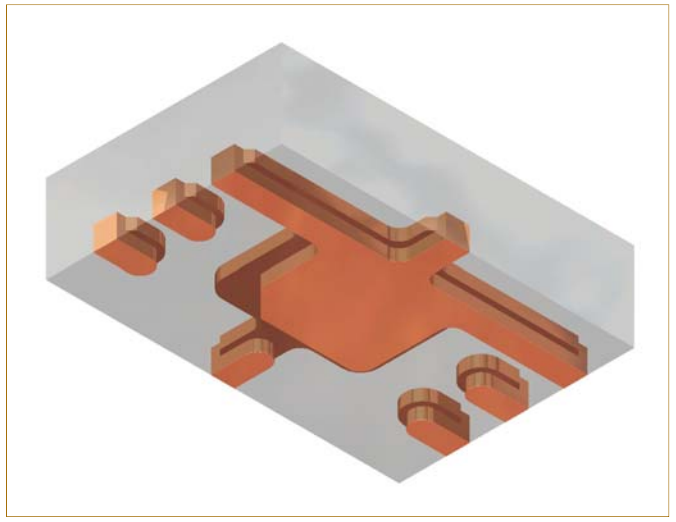

Figure 2a. 3x2 eMLP construction.

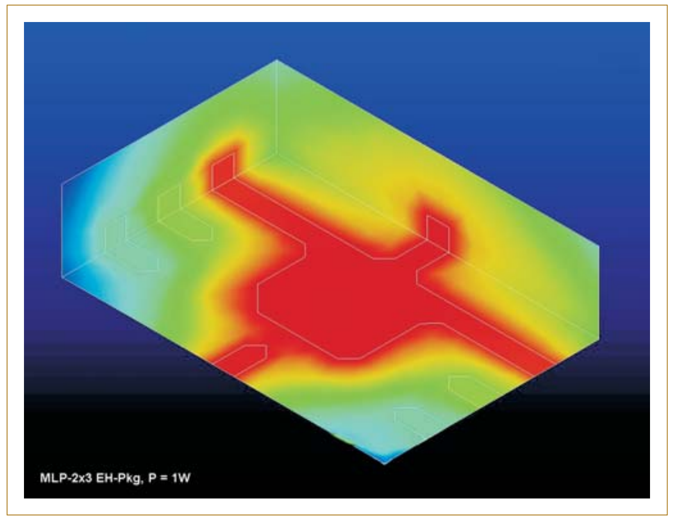

Figure 2b. 3x2 eMLP heat conduction.

turers has their own set of standards based on this ISO standard. Some manufacturers demand load dump capability up to 60V and all include a reverse battery requirement where the equipment must survive a battery being connected the wrong way round in error.

Operating and surviving these voltage requirements requires a combination of system and component design techniques and special processes. An example of such a process is the Allegro ABCD4 process used in a number of automotive MOSFET gate drivers and supply controllers. This process combines small geometry low voltage elements, for design of logic sections, with medium and high voltage components for direct connection to the power network and discrete power devices. The process has been specifically designed to withstand the transient voltages seen when driving brush and brushless DC motors and has is well suited to the automotive electrical environment.

When the use of complex components is required, such as microcontrollers and DSPs, or delicate components such as high power LEDs, then these must be protected by additional circuits. Fig.1 shows an example of a high performance microcontroller system with sensors, which may require several low voltage supplies. 1.8V for the core, 3.3V for the I/O and 5V for the sensors and analog interface. These can be provided by a single automotive switching regulator with multiple linear regulators such as the Allegro A8450. This multiple output regulator is capable of operating from 6V to 45V and provides a protecting interface between the sensitive components and the automotive power net.

As with all electronic components, ESD and EMC are other major considerations. Any component that is connected directly to the wiring harness of the vehicle will usually have to survive 4kV discharges based on the human body model (hbm). In many cases this is increased to 8kV and sometimes even higher at 15kV. Components that are not connected to the wiring harness usually have to be capable of withstanding at least 2kV hbm discharges. At higher frequencies each manufacturer defines their own EMC requirements based on CISPR25 and ISO11452.

Environmental Requirements

Power electronics are generally used to control some form of mechanical actuator. If the actuator is in the engine compartment then the control electronics are increasingly mounted close to or, in many applications, inside the body of the actuator. In this case the power semiconductors must be capable of operating at ambient temperatures down to -40°C and up to 150°C in some applications.

Provided the component has been designed to operate at low temperatures, inexpensive plastic packages do not usually present a problem. The main design challenge, for circuit and package, is at high temperatures. Not only will the load and the engine itself be generating heat, raising the ambient temperature but the power electronics will also dissipate power in the form of heat.

The circuit challenge at high temperature is to maintain the performance of the controller. The packaging challenge is to remove the internally generated heat from the components and keep the temperature difference between ambient and silicon junction at an acceptable level.

Except in a few cases, packages based on special low thermal resistance materials and assembly techniques would be too expensive. Instead the cost and performance requirements can be met using a combination of design techniques to reduce power dissipation and new, near-chip-scale, plastic packages with exposed tabs (e) for heat conduction. For example, fig 2a shows the internal structure of a small 2mm x 3mm eMLP package and fig 2b shows the heat profile in the package when dissipating 1W. Larger pin count MLP packages, miniature quad flat pack and TSSOP packages are all available with exposed pads and provide a cost effective solution to automotive packaging for components such as FET gate drivers and power supply controllers.

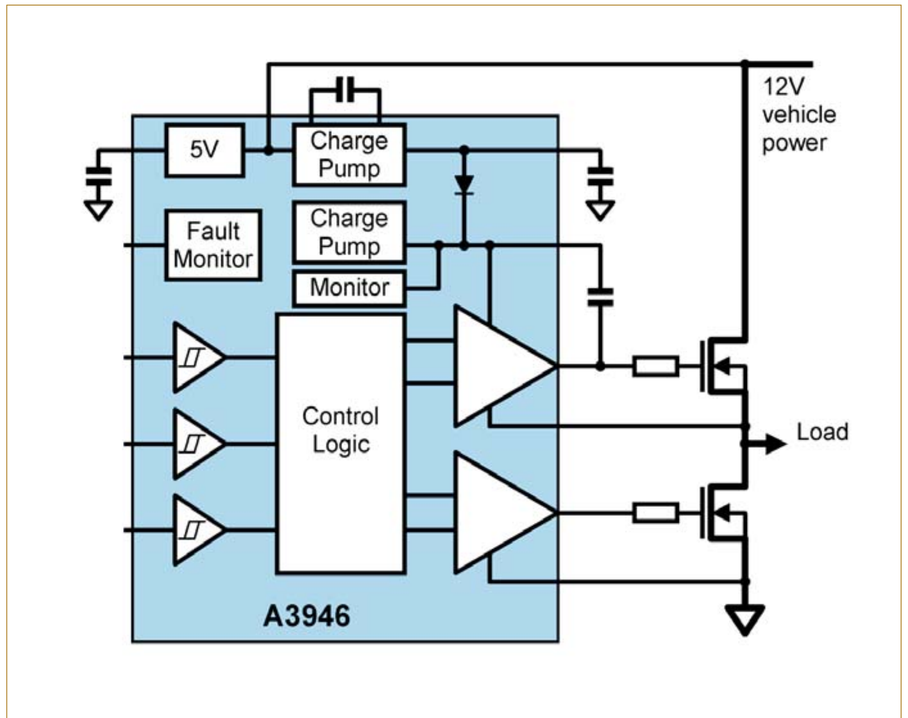

Figure 3. A3946 Half-Bridge gate Driver.

Low on-resistance n-channel MOSFETs can be used to help reduce power dissipation in the controller but only if they are provided with sufficient gate drive under all conditions. The allegro A3946 (fig.3) is an example of a simple half bridge driver with a number of features to ensure that the MOSFETs are always driven at the optimum level. A high-side drive, a low side-drive and associated power supply management and diagnostic circuits are all included. The high-side drive uses a bootstrap capacitor to provide the above supply voltage required to keep the high-side n-channel MOSFET active.

A regulating charge pump maintains a sufficiently high gate drive voltage during low supply voltage conditions to ensure full conduction in the MOSFET and limits the gate drive voltage at high supply voltage to prevent damage to the MOSFET. The A3946 contains several additional ease-of-use features such as automatic bootstrap charge management, system and MOSFET diagnostics, and an additional charge pump to maintain full charge in the gate of the MOSFET under DC conditions. Similar features can also be found on the A3940 Full-Bridge gate driver and the A3930 and A3935 three phase gate drivers.

Reliability

Reliability is probably the most important part of the technical requirement set – and the only part that cannot be guaranteed by design or test. A key differentiation between automotive components and commercial components in use is the high ambient temperatures. The Automotive Electronics Council (AEC) has classified ICs according to their ability to operate and survive these high temperatures. Many power ICs today are rated as grade 1 components able to operate in ambient temperatures up to +125°C. With the trend to locate the power electronics in the body of the actuator, these ambient temperatures in many instances exceed the +125°C grade 1 requirement forcing suppliers to push power IC technology towards meeting grade 0 (Ta <= 150°C) requirements. The end goal of course is to always try to increase the confidence that, during the lifetime of the vehicle, any component will achieve a failure rate as close to zero as possible.

In the first instance, all components undergo full production testing, usually at the extremes of the temperature range, and achieve in excess of 99% fault coverage. In addition, particularly for analog and power components, the test limits are tightened and adjusted based on the average test results over a number of batches (part average testing). This helps remove individual components which are within the specified limits but are outwith the normal distribution of results. In practise this results in a very low failure rate when the components are first assembled into systems.

For lifetime reliability we have to rely on accelerated life testing of a sample of products. For automotive products the Q series of specifications from the AEC define the required sample sizes and test conditions that have to applied. The extreme conditions of temperature humidity and bias that are applied are used to accelerate any possible fault conditions. This allows a statistical estimate of the mean time to failure (MTTF) which, for automotive power semiconductors, is usually in excess of 50 million hours or 6,000 years!

Conclusion

The three topics discussed here demonstrate that supplying power semiconductor components to the automotive market is indeed a major undertaking and not something that can be approached without major financial and technical analysis. Start of production can easily extend to greater than two years from start of design to initial sales revenue and positive cash flow. Once in production the annual volume of any product may be from a few hundred thousand for complex controllers to a few million for discrete active components. Quality must be maintained or improved during the product lifetime and cost is always a topic for discussion. On the positive side, once a component is qualified and in production, provided the product quality is maintained, it can enjoy several years of consistent volume shipments providing stability to the component supplier.

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The Needs and Benefits of Automatic Brightness Control Today's Growing World of LCD Displays

Ambient light affects readability of LCD displays

Poor readability can be annoying. In a critical application, dangerous.

By Roger Holliday, Vice President, Microsemi Integrated Products Group

Explosive growth in liquid crystal display applications continues to exceed expectations. Prior beliefs of many analysts and industry participants, for instance, that liquid crystal display (LCD) televisions would have relatively slow adoption and remain a smaller sibling of plasma TVs have been drastically revised.

On a smaller scale, many simple monochrome information displays have been replaced with impressive, true thin-film transistor (TFT) LCDs in applications such as automotive or communications handsets, where cost once was perceived to be a major barrier. These new applications highlight a number of issues and pose new requirements for the display system designer.

The main points of this discussion center on issues which we can relate to, as electronics consumers, in the year 2006. This article will focus on display ergonomics, comfort, and in some cases safety.

As system designers might note, for each of these benefits there are a number of complimentary technical by-products relating to battery life, lamp life, power savings and others. Most consumers targeted in television advertisements and by "high tech" electronic gadget stores are unaware of these technical issues and their impact. They do however experience a cell phone that is far too bright in a dark night time situation, or a nearly illegible digital camera display in a bright daytime environment.

The aspects of LCD design that will be discussed are as follows:

- Overall display brightness range.
- Ways to take advantage of brightness range and its associated benefits via "Automatic Brightness Control" (ABC).
- Simple do's and don'ts regarding an "autobrite" display implementation.

One of the most critical design criteria in display backlighting is to ensure that the brightness capability range matches the needs of the end product. For example, an LCD TV typically operates in a less dynamic ambient light environment than a hand-held device, such as a cell phone. This dictates that the hand-held display should have a greater overall brightness range capability than a product designed to operate in a constant or "controllable" environment.

Despite this intuitive understanding, brightness range is a commonly overlooked aspect in the design of portable display products. Many digital cameras and various handsets are designed to be legible in a specific "mid level" ambient brightness condition. Operation outside of these conditions can be extremely frustrating, as when attempting to shoot a digital photo at night, or to read a cell phone display in bright daylight. Both of these situations are unacceptable for most consumers – and can be resolved quite easily.

The low ambient light solution simply requires designing a display backlight with a wider dimming range, hence providing a lower brightness operating mode. This minor adjustment increases user satisfaction – allowing photographers, for example, to glance back and forth from subject to display without requiring frequent adjustments of their pupils.

The desired operation in a bright environment is a little more difficult to provide. This requires additional backlighting (lux or nits) capability to be designed into the product in order for the display to compete success-

AUTOMOTIVE/LCDs

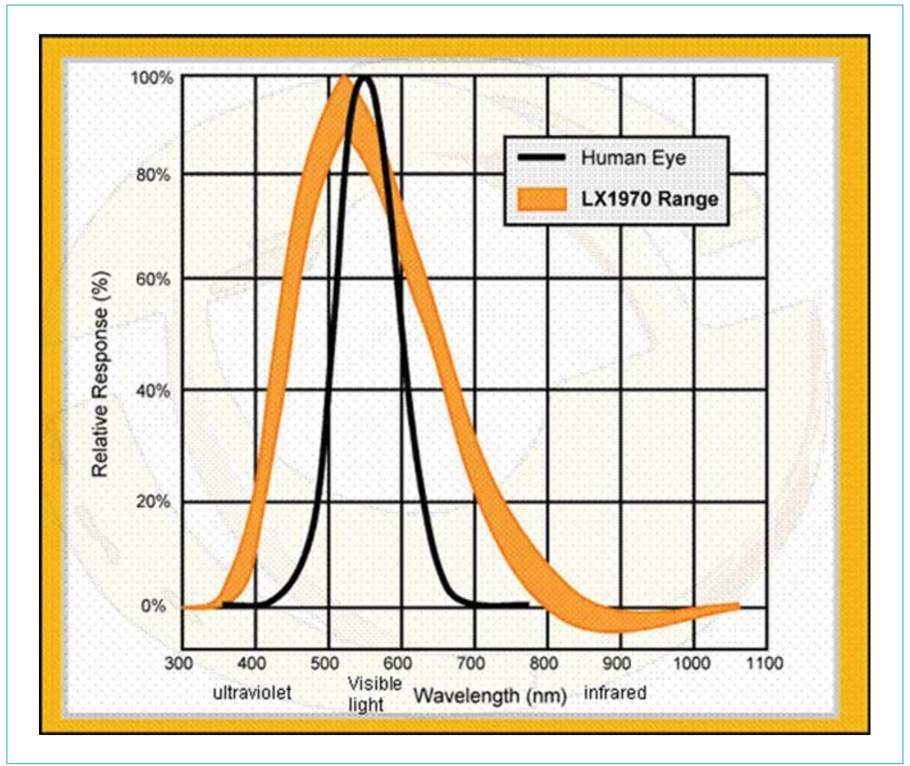

Figure 1. Sensor response is approaching human-eye capabilities, a critical factor for controlling display brightness characteristics.

fully with bright ambient light. This bright condition also affects the light sensitivity of the human eye, and raises the problem of additional power consumption needed to operate in this "hi bright" manner.

High power burn can be offset by a contrasting period of low power, low brightness backlight operation in most hand-held displays. This diligence in reclaiming battery life is much like improving gas mileage by taking advantage of the downhill coast, after driving a steep uphill grade. For it to work, however, users must make appropriate adjustments to their displays to match the ambient conditions. This leads to the subject of Automatic Brightness Control.

Industry data and research performed by display product manufacturers reveals that the majority of the product users, do not, or will not, make significant efforts in adjusting display brightness. This can be substantiated by looking at the day to day use of your own cell phone, notebook PC, or personal digital assistant (PDA).

Most consumers can't even recall how to change the brightness level – or find that changing display brightness takes more time than is warranted for such simple viewing needs s retrieving an appointment or phone number, or dialing a phone number. These transactions are short, so it just doesn't make sense to fiddle with manual brightness adjustments. Repetitive, short-duration use is normal for many display systems. Fig. 1 shows an example of the latest sensor technology's response profiles as compared to those of the human eye.

In addition, a lack of interest in changing display brightness is supported by the excellent design of the human eye – with its ability to adjust its aperture to block or receive additional light for viewing comfort as necessary. Since the eye isn't concerned with saving battery power, it allows you to leave the display at a constant brightness by making the adjustments within the eye instead.

The only way to take advantage of all the benefits achieved with variable display brightness is to automate the adjustment process. Simply remove the responsibility from the user to ensure that display brightness always corresponds to the ambient light. The many benefits include extending battery operation, system heat reduction, and the potential for extended lamp life.

Two other benefits can justify automatic brightness control. First, by getting a close match between display brightness and its environment, you

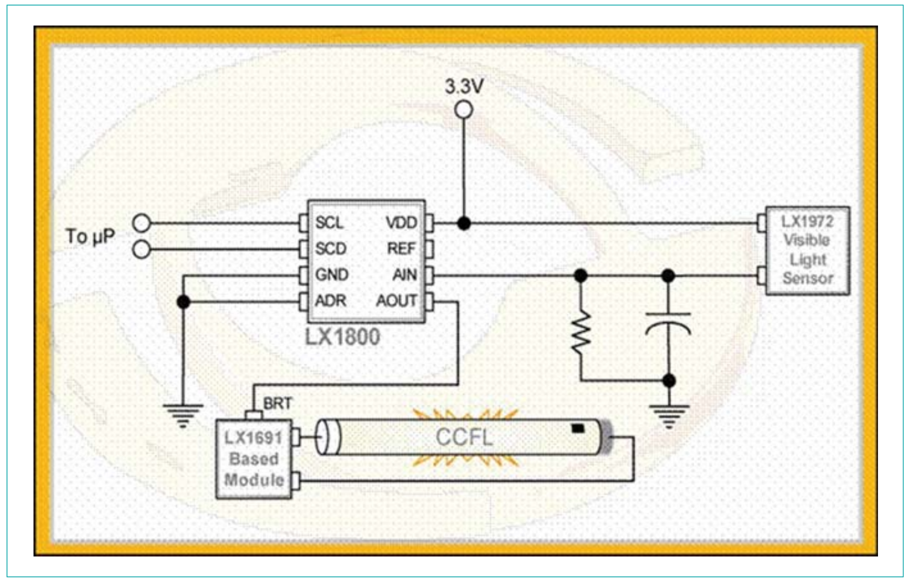

Figure 2. Simple circuitry can provide complete automatic brightness control modes. In this application, an LX1800 integrated circuit has been added for additional digital microprocessor control. Brightness levels automatically adapt to changing automotive ambient environments.

minimize the continual adjustments made by the human eye when it shifts its focus on and off the display. This focusing adjustment process slows as we age, becoming a potential safety concern for a number of display-based products – especially pertaining to vehicular applications or applications involving non-continuous use. Non-continuous use refers to applications where the user frequently looks both at, and then away from, the display in a repetitive fashion. (Unlike a continuous use TV or computer screen.) In many such applications, automatic brightness control can reduce product liability and thus is viewed as extremely attractive to the manufacturers.

The final point of interest in automatic brightness control is its potential for creating a more environmentally friendly or "green" product. The industry is all too familiar with the regulatory and compliance conditions we encounter on a day to day basis. As the volume of LCD products continue to increase, we can envision hundreds of millions of multi-lamp, high wattage, LCD monitors and televisions in operation at any give time. In this environment, interest will be high for system design concepts capable of achieving power savings as high as 50 percent under certain conditions. An example of this is when sleep modes were incorporated into PCs, in order to achieve "green" status. There is no necessity to run an LCD television in your family room during movie night, at the same brightness level needed for airport flight status monitors operating in a brightly lit airport.

Of course, any discussion of implementing automatic brightness control, is meaningful only if the performance and cost criteria objectives can be met. The key is a new generation of optical sensors capable of providing high performance, low-cost, implementations of automatic display brightness modes. Of critical importance, these new sensors have the ability to detect and respond to light wavelengths that correlate very closely to the response characteristics of the human eye itself. These sensors eliminate several problems encountered with prior technology.

Because earlier sensors were extremely susceptible to infrared and ultraviolet light they often provided false readings, based upon these non-visible light sources. The result was unusual, and unpredictable, brightness adjustments at the system level as the displays adjusted to unseen infrared or ultraviolet characteristics originated from such sources as the sun, incandescent light bulbs, fluorescent lamps and even heat. Thus poorly designed systems would set up an erroneous display brightness based on high UV and IR content.

In addition to the improved spectral response, these new silicon sensors such as the Microsemi LX1972 (Fig. 2) also offer extremely good temperature stability. This is essential as most cold cathode fluorescent lamps (CCFLs) or light emitting diode(LED) backlit displays experience substantial temperature swings as they operate. Poor temperature response will result in changes in display brightness based on temperature and not light conditions. A light sensor should not be a "thermostat."

In respect to the issue of cost/performance, it is important to note that a complete LCD automatic brightness control system, as described, can be implemented for less than one U.S. dollar. This design requires no optical filters, can be user adjustable and includes both the light sensor and all supporting discrete components.

Conclusion:

As engineers, we need to design systems that have brightness ranges capable of operating in the environments in which they are intended to be used. Display systems with a fixed brightness level are as logical as an audio system with only a preset, fixed, volume level. They are not acceptable from either an engineering or user standpoint.

The second point is that these backlighting schemes need to be low cost and simple to encourage wide use – since we know that in many applications the correct display brightness range and its benefits will only be realized if its control is automatic. If this concept is widely adopted, it has the potential to enable huge electrical power savings from the proliferation of display devices throughout the world. Not to mention that it also will ensure that when you turn on your camera, notebook or phone, it will boot up at a comfortable, optimal efficiency brightness level regardless of the operating environment – and stay that way.

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AUTOMOTIVE/SENSORS

Pre-empting Problems in the Automotive Environment

Current monitoring in automotive applications protects the auto as well as the occupants

With the uptake of electronics in the automotive industry to provide more comfort, safety, reliability and information to the end user, sensors are used in key applications for monitoring purposes.

By John Constantopoulos, Business Development Engineer, Texas Instruments GmbH

Examples of these developments include:

1) Automatic transmission, where electronic control of the hydraulics in the electromechanical system is executed by linear solenoids that vary the hydraulic pressure applied to the actuators attached to the clutch packs.

2) Automatic window lifter, where the current flowing during the motor control of a window lifter is monitored so as to detect a motor stall which could take huge currents and destroy the motor-controlling MOSFETs very quickly.

The figure below shows a simplified diagram of using a current monitor during Motor control.

Current is thus an important indication of a solenoid's state. The most effective method of measuring a solenoid's current is to measure the voltage across a resistive shunt connected in series with the solenoid, battery and switch. There are several different ways to configure this circuit for switching and voltage measurement.

Low-Side vs. High-Side Measurement

Low-side (negative or ground potential) measuring circuits generally offer the simplest solutions because the resulting signal is already ground referenced. One method to achieve this is to insert a small resistance into the ground plane between the supply's ground and the load to be measured (See Figure 2). The resulting proportional voltage developed across that resistance can be used directly or amplified. One consequence of placing resistance in the ground plane is that any voltage signal that crosses the shunt resistor (Rs) will have an offset relative to ground, the negative rail is now at the potential of Vshunt, which will change with the load current. This will be unacceptable with most analog signals. An important property of the current measurement circuitry is that it should be able to accept Vshunt, a signal of typically tens of millivolts from ground. This issue can be minimized by using an input offset.

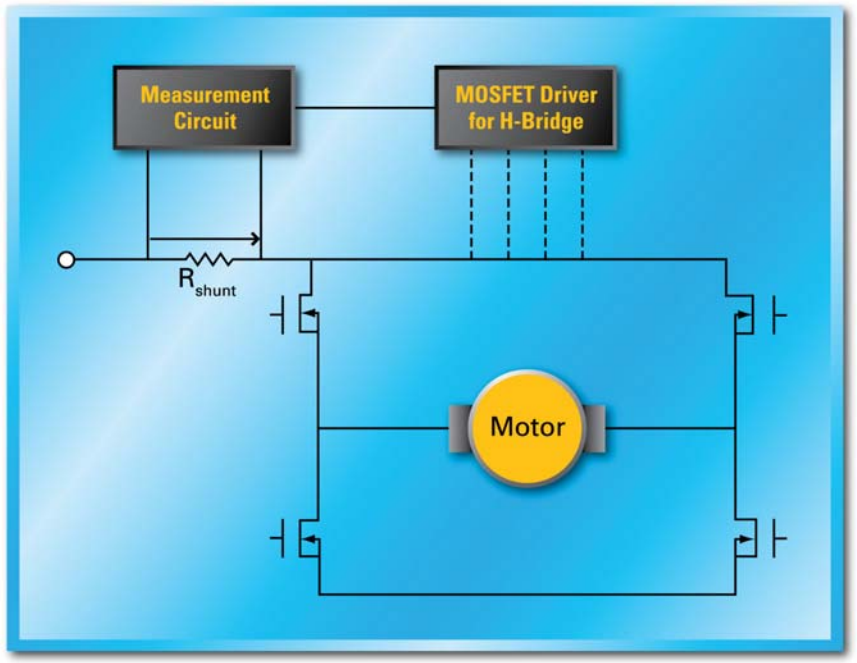


Figure 1. Simplified Block Diagram of Current Measurement for Motor Control.

In some applications, the loss of true ground cannot be tolerated because of the inter-circuit offsets created, as already outlined. Sometimes, regardless of whether the effects of disrupting the ground plane could be ignored or tolerated, it is not possible to adopt this method. Where a system uses a common ground in the form of a metal chassis, as found in the automotive environment, components that are connected mechanically to it may not have the first method as an option. It is then necessary to measure the current in the supply (high-side).

Dedicated High Side Monitors

The INA19x and INA27x family from Texas Instruments with voltage output can sense drops across shunts at wide common-mode voltages from – 16V to +80V, independent of the supply voltage. This wide common-mode range is ideal for withstanding automotive fault conditions ranging from 12V battery reversal up to +80V transients, since no additional protective components are needed up to those levels. This enables the INA19x and INA27x to be used in a variety of automotive applications.

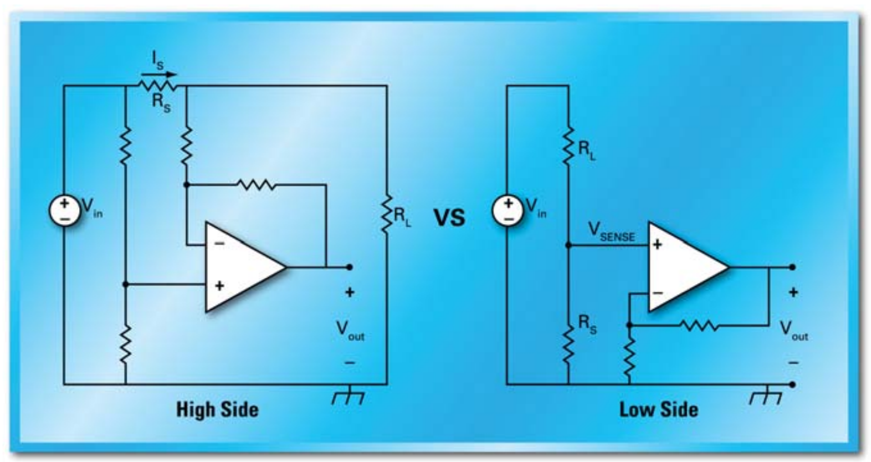


Figure 2. Schematic of Differential High and Low side drivers.

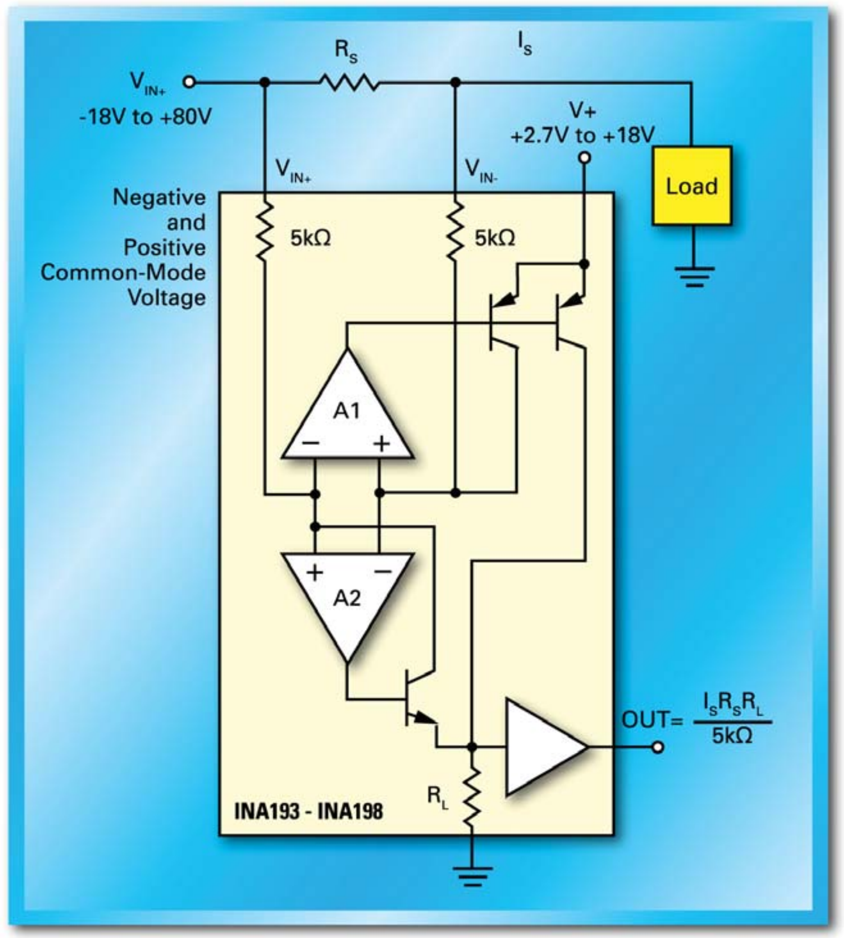


Figure 3. Schematic of INA19x family.

When the common-mode voltage is positive, amplifier A2 is active, and the circuit will convert the differential voltage $((V_{IN+}) - (V_{IN-}))$ measured across the shunt resistor Rs into an output current (I_O) which is then converted back into a ground referenced voltage through R_L. V_{IN} is impressed across the internal 5kΩ resistor which in turn results in a current V_{IN} /5kΩ To maintain a stable feedback condition, where the two input terminals of the op amp are maintained at the same voltage, the op amp's output must bias the output transistor so as to draw this current out of the node, and pass it down to R_L where it is converted back to a voltage and then amplified by the built-in output buffer.

When the common-mode voltage is negative, amplifier A1 is active. The differential input voltage, $(V_{IN+}) - (V_{IN-})$ applied across R_S, is converted to a current through a 5kΩ resistor. This current is sourced from a precision current mirror whose output is directed into R_L converting the signal back into a voltage and amplified by the output buffer amplifier. The relationship between load current and the resulting voltage (V_{out}) can be expressed as:

$$V_{OUT} = \frac{I_L \bullet R_S \bullet R_L}{5k\Omega}$$

The main demands placed on the op amp are that it may have an offset voltage significantly lower than the magnitudes of V_{IN} being measured, and that its input common-mode range extends to V_{IN+}. An output range that comes to within a diode drop of ground is also necessary. These requirements are all met by using an op amp with rail-to-rail I/O. As an example, consider the implementation of a 0A to 1A current sensing application using this circuit and a 20 mΩ shunt resistor. In this case one would like an output voltage range of 0V to 2V to correspond to the input range. By setting V_{OUT}= 2.0V, R_S= 0.02Ω, and I_L= 1A one can solve for the ratio of R_L/1kΩ.

$$\frac{R_L}{5k\Omega} = \frac{V_{OUT}}{I_L \bullet R_S} = \frac{2.0V}{1A \bullet 0.02\Omega} = 100$$

A gain of 50 can also be set if the shunt resistor is chosen to be 40mΩ. This provides the designer with more flexibility, as the gain is dependent on only one resistor.

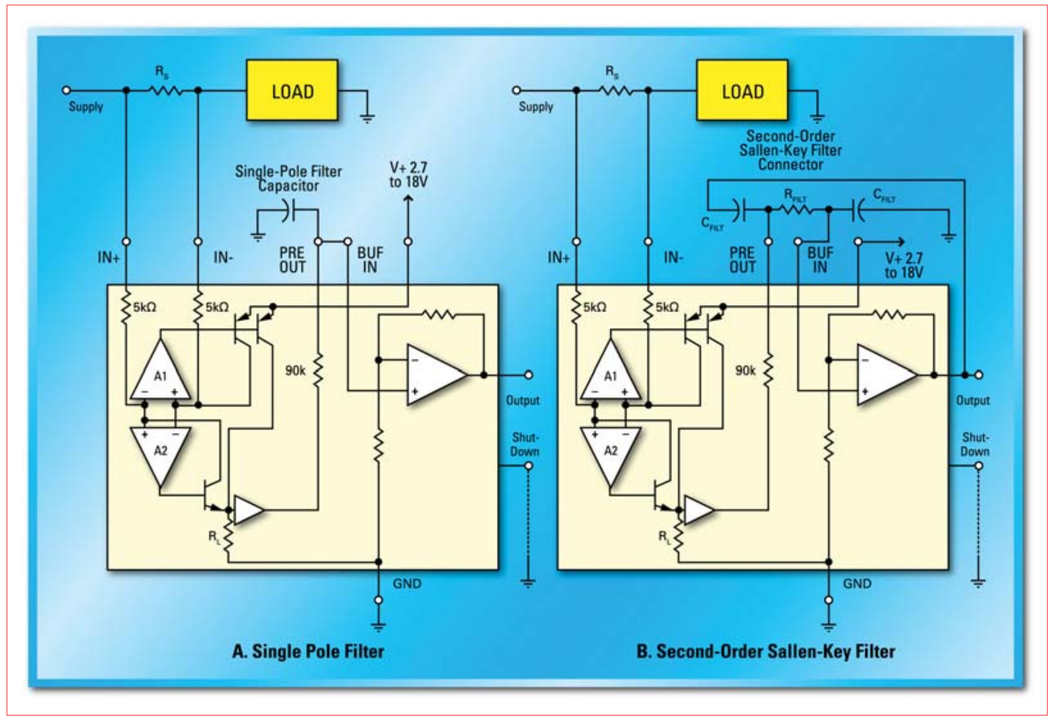


Figure 4(A&B). Filtering Option of INA27x.

Filtering Option of the INA27x

Current measuring is often noisy in automotive and many other applications. It may therefore be necessary to filter the signal to remove any spurious high frequency transients that may occur in many applications, or to extract the mean value of a fluctuating signal with a peak-to-average ratio greater than unity. Low-pass filters can be implemented in several ways using the features provided by the INA27x family, and still preserve the buffered output of the 1st stage. It readily enables the inclusion of filtering between the Preamp Output and Buffer Input. In the simplest case, single pole filtering (20dB/decade) can be accomplished because of the internal 90kΩ output impedance at PRE OUT on pin 3, and a capacitor added from this node to ground, as shown in Figure 4A.

A two-pole filter (roll-off of 40 dB/decade) can also be implemented using the connections shown in Figure 4B. This is a Sallen-Key filter configuration. It may sometimes be useful to remember that a two-pole filter with a corner frequency f_2 and a one-pole filter with a corner at f_1 have the same attenuation at the frequency (f_2^2/f_1). The attenuation at that frequency is 40 $Log(f_2/f_1)$.

Selecting R_S

The value chosen for the shunt resistor, R_S, depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of R_S provide better accuracy at lower currents by minimizing the effects of offset, while low values of R_S minimize voltage loss in the supply line. For most applications, best performance is attained with an R_S value that provides a full-scale shunt voltage range of 50 mV to 100 mV. Maximum input voltage for accurate measurements is 500 mV.

Conclusion

Current sense monitors serve a vital role in a wide range of automotive control systems. They can be used to provide information on the current, position, speed and direction of a rotating motor. In addition, sensors improve the reliability of a system by detecting fault conditions that would damage or destroy a specific application. The INA19x and INA27x high side current-sense amplifiers simplify designs in the automotive environment. Both the INA19x and INA27x are available in SOT23 and SO-8 packages respectively and are specified for the -40°C to +125°C temperature range.

Note: The INA27X is scheduled for release 1Q07.

www.ti.com

Octal high-side driver provides simplified control of automotive loads

AMI Semiconductor (AMIS) has expanded its family of ASSPs (application specific standard products) with a new high-side driver IC to simplify the control of transistor gates, relays, valves, solenoids, LEDs and other loads in 12V automotive environments.

The AMIS-39100 is a highly integrated driver IC, with eight high side (HS) output drivers and a range of functions and features designed to significantly reduce component count and cost.

Each of the eight output drivers can drive a continuous current of 275mA when connected to an inductive load of 300mH. Higher individual output currents are achievable by limiting device current to the total maximum. The drivers will withstand short circuits to the battery or to ground, even in situations where the device itself has lost its ground connection. The drivers also provide over-current limiting and shut-down in the case of a fault condition. Additionally an integrated charge pump and over-temperature protection circuit avoids the possibility of thermal runaway, even at low battery voltages.

Compatible with 3.3V and 5V microcontrollers, the SPI interface is used to control each of the individual output drivers and to provide a route for the integrated diagnostic circuit to feedback error signals. The interface can also be used to read back the status of the built-in thermal shutdown protection function.

"Automotive designers are demanding actuator and controller solutions that help them simplify and accelerate application development," says Tony Denayer, AMI Semiconductor's senior vice president, high voltage communications and ASSPs. "The high level of integration addresses this demand, and complements our existing range of standard components for driving and controlling motors and loads in automotive applications."

The AMIS-39100 incorporates a power-down mode during non-active periods and an integrated slope control function minimizing electromagnetic emission (EME). Operating temperature is rated at -40°C and 105°C and the device is supplied in a compact SO28 package.

www.amis.com

Fastest transient response with highest system accuracy for computing power management

Intersil has introduced a family of four-phase synchronous PWM (pulse width modulation) buck controllers claimed to deliver highest performance/price ratio for four-phase CPU core regulators. Intel VR10/11 and AMD AM2 CPU core solutions using these controllers need many fewer bulk output capacitors. The devices feature Intersil's active pulse positioning (APP™) and adaptive phase alignment (APA™) modulation schemes.

Nominated ISL6312, ISL6312A and ISL6322, these devices provide an integrated precision voltage regulation system for advanced Intel VR10/11(Intel Core 2 Duo and Intel Core 2 Extreme) and AMD AM2 5/6-bit microprocessors. The family features programmable VID (voltage identification) codes for Intel and AMD DAC (digital-to-analogue converter) tables.

Family variations are available for many popular computing applications to enable customers to monitor the CPU load current in real-time and to work with overclocking applications such as performance motherboards using Intel's Core 2 Extreme processor.

All three device types incorporate a unity gain differential amplifier for remote voltage sensing that compensate for differences between remote and local grounds and also integrate three MOSFET drivers and a PWM output for a fourth external MOSFET driver.

The ISL6312, ISL6312A and ISL6322 provide advanced control loop features to optimize transient response to load-apply and removal functions. These include accurate and differential continuous DCR (DC resistance) current sensing for load line programming and channel current balance and also ensure individual channel current and average overcurrent protection (OCP).

The ISL6312A incorporates an added IOUT pin to the basic ISL6312 for output current measurement while the ISL6322 provides an I2C bus input for adjusting four basic regulator functions, such as output voltage, overvoltage protection (OVP) level, operating frequency per phase, and MOSFET driver adaptive dead time control. All devices include open circuit protection on the remote sensing inputs.

Typical target applications are desktops, workstations, servers, single board motherboards, industrial PC motherboards, routers and switches, and voltage regulator modules.

Available in 48-lead, 7 x 7 QFN packaging.

www.intersil.com

Inductor model libraries extended

EPCOS has extended its model libraries for single and dual chokes with new model libraries for power inductors. Included are components that have undergone recent changes as well as new products. The updated libraries can be identified by their version numbers:

Updated libraries	SIMID 0603 (B82496) SIMID 0805 (B82498) SIMID 1210 (B82412, B82422) SIMID 1812 (B82432) SIMDAD (SMD I-core data line chokes B82789)
Extended libraries	DLD (SMD ring-core data line chokes B82790/93/99)
New libraries for power inductors	6 x 6 (B82462) 10 x 10 (B82464) 4.8 x 4.8 (Low-profile B82470) 7.3 x 7.3 (B82472) 12.95 x 9.4 (B82476) 12.3 x 12.3 (B82477)
Library containing all older SIMID types	SIMID

Additions to the SIMID and data line choke (DLC) libraries and other libraries for power inductors will follow. Available for the PSPICE and HSPICE simulation programs in English and German, these useful libraries are user-selectable between Windows and UNIX / LINUX operating systems compressed in ZIP or TAR archives for fast downloading.

www.epcos.com

High-brightness white LEDs for automotive lighting, Sign and Signal Applications

Avago Technologies announces a range of miniature LEDs suitable for operation under the environmental conditions in automotive and electronic sign applications, as well as a variety of home and office applications. The company's ASMT-SWBM long-life, high-brightness surface mount technology (SMT) white light-emitting diodes (LED) are housed in thin, top-mount, single chip packages.

In automotive applications, the ASMT-SWBM can be used in the vehicle's interior such as in backlighting for interior instrument panels and switches.

In addition to high-brightness, long life and compact size, this technology provides manufacturers with the significant advantage of easy soldering using conventional cost-effective surface mount techniques.

"The use of long-life white LEDs by automotive and sign manufacturers has grown significantly over the past three years because of their durability, high-brightness and ease of installation which helps to minimize manufacturing costs and shorten time to market," said Cheng Kai Chong, worldwide marketing manager for Avago Technologies' optoelectronic products division. "These LEDs are designed to meet the demanding environmental requirements set by manufacturers in these environments."

The LEDs are qualified to JEDEC moisture sensitive level (MSL) rating of 2A, supplied in 8 mm carrier tape on 7-inch reels and are a drop-in replacement for the industry-standard PLCC4 LED package.

www.avagotech.com/led

New medical and heavy-duty roadside power supplies introduced

Lambda has recently extended its HWS family of compact single-output power supplies to include models that are approved for use in medical equipment and others which perform reliably in the harshest of operating environments.

Lambda's new HWS-ME medical supplies are available with ratings from 30W to 1500W with the heavy-duty version offered with ratings from 50W to 1500W. All models of HWS feature exceptionally compact construction, typically requiring 60% less space than previous generation products, and all are suitable for operation from inputs in the range 85-265VAC at 47-63Hz, or 120-370V DC (except 1500W models), without the need for switching or adjustment.

HWS-ME power supplies for medical applications have EN60601-1 / UL60601-1 approvals for basic isolation and have leakage current less than 500uA. Models up to 300W also meet Class B EMC requirements and provide a compact and cost-effective choice for use in non-patient connected equipment such as MRI scanners and X-ray machines.

Output voltages for medical supplies rated up to 150W cover the range 5V to 48V, with a smaller range of output options offered for 300W, 600W and 1500W models.

The HWS-HD heavy-duty supplies are ideal for use in roadside cabinets, road signs, ticketing machines, automatic barriers and similar demanding applications and can start up at temperatures as low as -40°C depending upon input voltage and load conditions.

The ability to withstand adverse environmental conditions is further enhanced by a conformal coating, applied to both sides of the printed circuit boards. The units also meet MIL standards for vibration and shock (MIL-STD-810F).

HWS-HD power supplies are available with output voltages from 3.3V to 48V in versions rated at up to 600W, and 12V to 48V in 1500W versions.

www.lambdaeu.com

120W six-channel, low distortion Class D audio reference design needs no heat-sink

International Rectifier has introduced the IRAUDAMP3, a compact Class D audio reference design, featuring the IRS20124S high-voltage analog IC and IRF6645 DirectFET® power MOSFETs to achieve a six-channel 120W half-bridge Class D audio power amplifier requiring no heat-sink.

The IRS20124S features an internal selectable dead-time generation circuit and is immune to noise and supply voltage fluctuations to help achieve a total harmonic distortion (THD) of 0.01% at 60W into 4Ω and 94% efficiency at 120W into 4Ω single-channel. The device has built-in bi-directional current sensing and an integrated shutdown function to protect the output MOSFETs if an over-current condition occurs, such as a short-circuited speaker cable.

The IRAUDAMP3, which has a footprint of just 29.03cm^2 (4.5 square inches) for each two-channel control and switch function, also utilizes IRF6645 DirectFET power MOSFETs with the company's patented packaging technology enhancing performance in Class D audio amplifier circuits by reducing lead inductance, thereby improving switching performance and reducing EMI noise. Their higher thermal efficiency enables 120W operation into 4Ω, eliminating the need for a bulky heat-sink, shrinking size, providing greater layout flexibility at lower overall system cost.

www.irf.com

New EZBright LED Power Chip for Lighting Applications

Cree announced a new EZBright™ LED power chip. The new EZBright1000™ LEDs are twice the brightness of Cree's current power chips. The EZBright1000 power chip is designed for general lighting applications, such as home and office lighting, auto headlamps, streetlights, and garage and warehouse low bay lighting, as well as consumer applications including flashlights, camera flash and projection displays.

"This is an important milestone for power LEDs. For the first time, these chips should enable solid-state lamp makers to challenge the efficacy of not only incandescent, but also fluorescent lamps," said Chuck Swoboda, Cree chairman and CEO. "The EZBright1000 LED power chip is one of several advancements we are working on to help drive LEDs into more mainstream lighting applications."

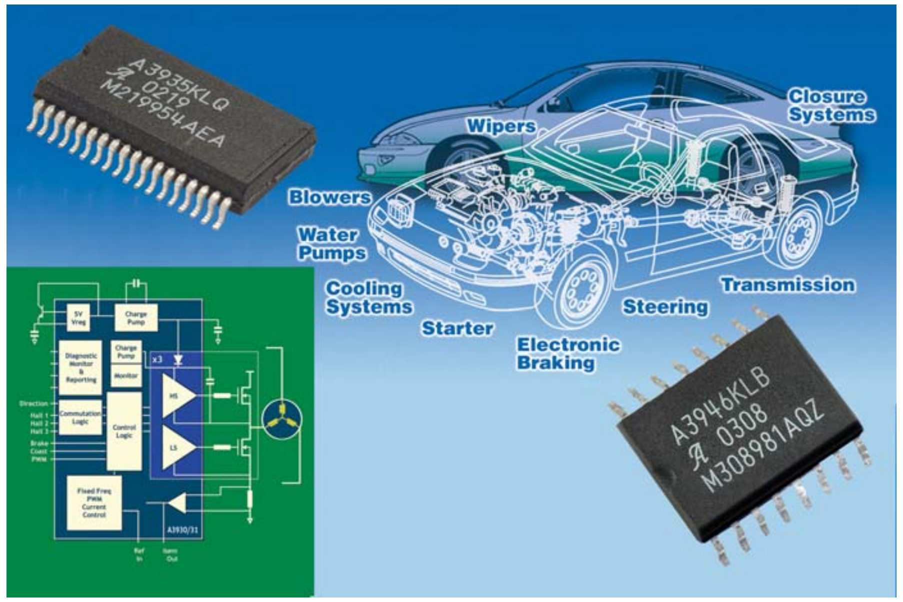
"The blue EZBright1000 power chip, measured as a bare die, exhibits power output up to 370mW at 350mA of drive current and 800mW at 1A of drive current," stated Scott Schwab, Cree vice president and general manager of optoelectronics. "This product should enable our customers to reach new levels of power output and efficiency from a single chip and redefine what is possible with power LEDs."

The EZBright1000 power chip is the third product released based on the Cree EZBright platform, which features a proprietary optical design that delivers an optimal Lambertian radiation pattern, with low emission losses and high efficiency.

EZBright1000 LEDs are now available in commercial quantities.

www.cree.com

Control and drive from Allegro



Allegro Microsystems announces their automotive package.

A3935 controller, designed for automotive applications that require high-power motors. Each device provides six high-current gate drive outputs capable of driving a wide range of n-channel power MOSFETs. The device integrates a pulse-frequency modulated boost converter to create a constant supply voltage for driving the external MOSFETs. Direct control of each gate output is possible via six TTL-compatible inputs. A differential amplifier is integrated to allow accurate measurement of the current in the three-phase bridge.

The A3940 is also designed for applications that require high-power motors. Each device provides four high-current gate drive outputs capable of driving n-channel power MOSFETs in a full-bridge configuration. Bootstrap capacitors are used to provide the above battery supply voltage required for n-channel FETs. An internal charge pump for the high side allows for DC (100% duty cycle) operation of the bridge.

The A3946 is designed for applications that require high power unidirectional DC motors, three-phase brushless DC motors, or other inductive loads. It provides two high-current gate drive outputs: a high-side gate driver which switches an N-channel MOSFET to control current to the load, and a low-side gate driver that switches an N-channel MOSFET as a synchronous rectifier.

The A3930/31 is a 3-phase brushless DC motor controller for use with n-channel external power MOSFETs, and incorporates much of the circuitry required to design a cost-effective 3-phase motor drive system, including integrated commutation logic based on Hall sensor inputs. A charge pump regulator provides adequate gate drive for battery voltages down to 7 V, and allows the device to operate with a reduced gate drive at battery voltages down to 5.5 V.

Packages include SSOP, TSSOP, SOIC and the ultra-compact LQPF-48.

www.allegromicro.com

Companies in this issue

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