Power Systems Design
EUROPE

Power Control Intelligent Motion

September 2004

Smart Power Module

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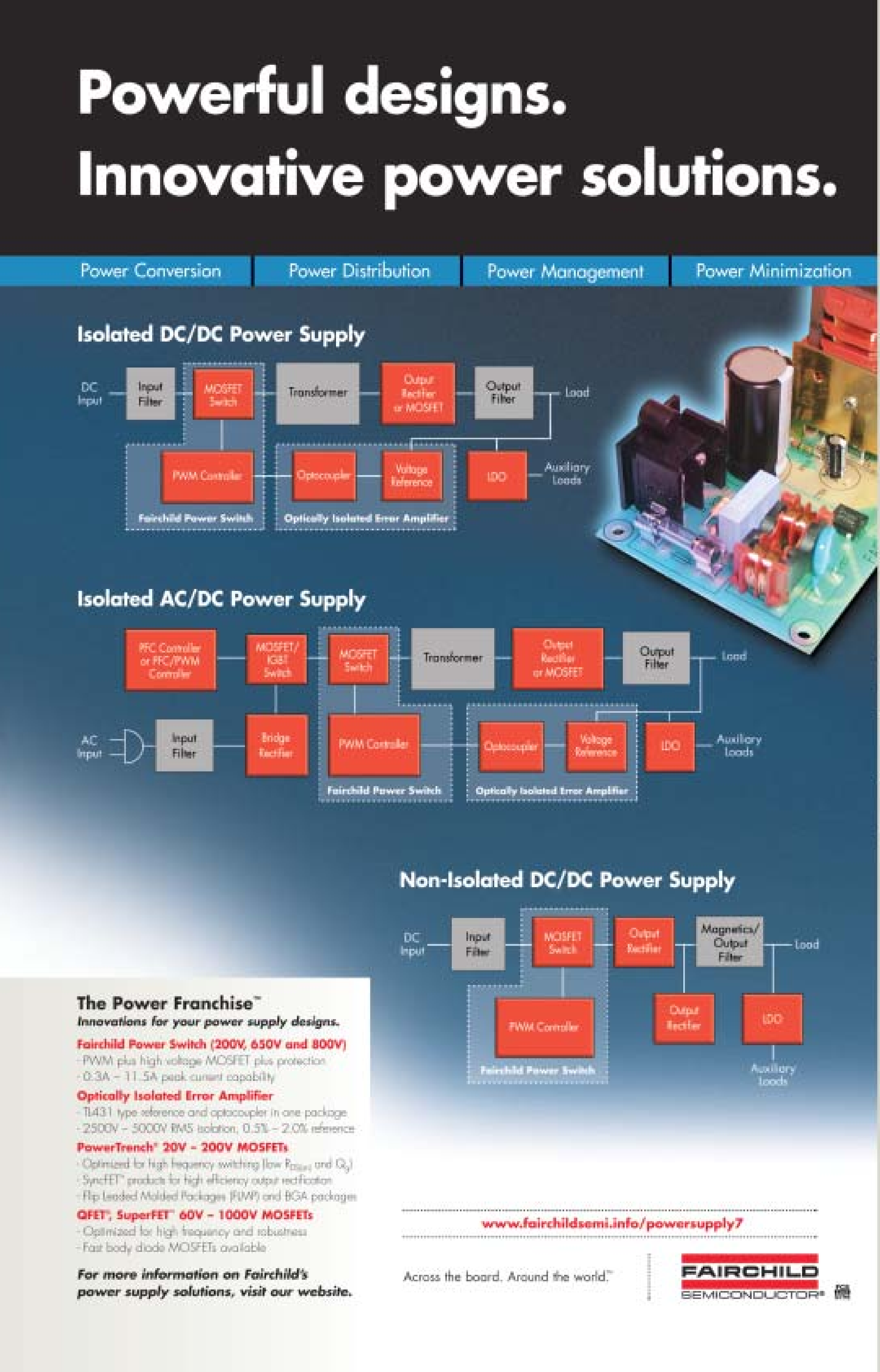
Automotive Electronics: Part II

Electromagnetic Actuator



Power Systems Design EUROPE

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Volume 1, Issue 7

Summer Takes Place at the Beach Now

Europeans received a late good stable weather condition that pushes everybody to the beach.

I am watching the young children building their sandcastles while the tide runs all around them, perhaps some of the kids will be the next generation of engineers. Having wireless LAN may let me work with my laptop direct on the beach. The weather today with wind and water surrounded by nice sunshine in the northern region is like heaven. I am overlooking the Kiel fjord and the beach is only a few steps away with the continuous changing nature of the Baltic waterfront. Europeans have much more interesting views at the beach than our friends in the US. The freedom of “less”, “top” or “bottom” or both.

I remember a gentleman I had worked with on a module program who was the packaging director of a US company made a lasting nose impression on the glass at my favorite fish restaurant amazed at the beach scenery. This kind of freedom is only known in Europe.

In this issue, we continue with Part II of our series on Automotive electronics. Part I which appeared in the July/August issue proved to be Power Systems Design Europe’s strongest issue editorially and in ad pages since we started the magazine in January, our thanks to the industry for such strong support and confidence in our efforts.

Electronics gives the life and functionality to modern cars. Economic aspects are seen in the spot of rising energy cost. Mainly the fuel price is going up and the mileage is critical. We Europeans say liter per kilometer if we are not on the tunneled island called United Kingdom.

Modern electronics using power switches makes drive by wire possible. That means steering can be put anywhere in the car. Left or right side for the driver and his steering wheel or even on the back seats if it makes sense.

That amount of freedom in electronics allows us the freedom in our designs. Hybrid solutions including fuel cell designs in automotive will be pushed by the legislative. The upcoming restrictions will force us to innovation that helps us to continue with individual transportation. Mass transportation will be good for long distance and in big cities. For all the rest we need freedom and our own automobile.

Automotive electronics serves a wide field in modern vehicles. Electronics allows the innovation to more efficient cars for the future. Whether we talk about combustion, electric or hybrid cars. The electronic components makes it happen, that our designs become reality.

Fall is coming along with “Electronica”, Power Systems Design Europe’s October issue will be distributed to that all important show in Munich. I have been invited to serve as moderator at the podium discussions on power electronics. As engineers we continue to learn all our life. It is a never ending process in our profession that differentiates us from other jobs and professions.

Stop by and see me on the show floor!

Best regards

Bodo Arlt
Bodo.Arlt@powersystemsdesign.com

Ansoft Seminars

The GSEM '04: 2004 Global Seminars - Electromechanical Series offers a realistic report on the state of the art in electromechanical design and simulation and presents solutions that address the future demands of electrical, transportation and power electronics and drives industries. Attendees will learn how industry experts use simulation to more efficiently design today's advanced electromechanical features, such as electric-assist power steering, electric pumps, fans, electromechanical actuators and power-processing elements. For details, go to: www.ansoft.com/gsem04.

Ansoft is a leading developer of high-performance electronic design automation (EDA) software. Engineers use Ansoft software to design state-of-the-art products, such as electromechanical components and systems, hybrid-electric vehicles, drive-by-wire systems, power electronics, wireless products, integrated circuits (ICs) and printed circuit boards (PCBs).

Interested parties may submit a 100-word abstract for presentation by emailing gsem04@ansoft.com

Asia and Europe during October and November2004. Please visit: www.ansoft.com/gsem04 for details.

www.ansoft.com

Traction Refurbishment

Westcode Semiconductors an IXYS company is awarded a development contract to upgrade the traction package of the Class 8E locomotives by Spoornet (RSA railways). The proposed design uses Westcode's state of the art press-pack IGBT technology to replace the fast thyristor based converters.

The contract is for the design, development and realisation of an upgrade package for the DC propulsion chopper system. This includes replacing existing obsolete reverse conducting thyristor technology with

Westcode's state of the art press-pack IGBT's, gate drivers and associated power electronics. The upgrade package will retrofit into the existing power cubicle and interface directly to the existing controls and cooling system with the minimum of modifications. The system operates directly from the 3kVDC catenery and will facilitate an increase of load power from 750kW to 1MW. There are currently 99 of the Siemens BBC built locos in service requiring this upgrade.

Contact us at wsl.sales@westcode.com or by telephone: +44 (0)1249 444525

www.westcode.de

Fairchild and Changhong

Fairchild announced the opening of a joint product development laboratory with Sichuan Changhong Electric Co., Ltd.—one of the largest manufacturers of consumer devices in China. The lab enables the companies to collaborate on product development using Fairchild's leading edge power components. Fairchild's power devices are designed into a broad range of Changhong products including color TVs, LCD TVs, PDP TVs, rear projection TVs, DVDs, set-top boxes and air conditioners.

Fairchild and Changhong have established a close relationship over several years. This announcement is an extension of that cooperation. Changhong is known for technical innovation, quality products and significant production capabilities. Fairchild products designed into Changhong consumer devices include Green Mode Fairchild power switches, advanced power MOSFETs, interface switches, diodes, logic devices and rectifiers.

Fairchild's components manage, distribute, convert and minimize power in a broad range of end markets including computing and display, industrial, consumer, communications and automotive segments. New power products are gaining strong acceptance with customers, including Smart Power Modules for electric motors, air conditioners and inductive heating; Green Mode power switches for battery chargers, televisions, display and PCs; MOSFETs for notebooks, displays and plasma panels; IGBTs for ignition control and induction heating; and power supply controllers for microprocessors.

www.fairchildsemi.de

Electric Scooters from Vectrix

The Parker Automation servo motor-based prototypes are now being road tested in European cities.

Leveraging the efficiency of real-time, high-performance control, Vectrix Corporation has selected the TMS320LF2401A digital signal controller from Texas Instruments for its revolutionary electric motor scooters. By pairing TI's leading digital signal processing (DSP)-based motor control technology with a high performance, custom designed brushless servo motor from Parker SBC, part of the Parker Automation division, the new lightweight Vectrix scooter delivers a level of performance and acceleration typically only found in a 250-cc gasoline-powered motorcycle. Vectrix's scooter achieves this gas-like performance without the polluting emissions typically found in two stroke gas engines. (For more information on the LF2401A digital signal controller, please visit www.ti.com/vectrixpr)

The LF2401A controller is ideal for applications that require the high-performance of TI's leading DSP technology along with the peripheral integration and ease-of-use typically found in a microcontroller (MCU). TI's DSP-based controller helps Vectrix's scooter motor operate more efficiently and at a higher level of performance than traditional MCUs or analog designs. This increased functionality and efficiency gives Vectrix a valuable edge in developing lightweight, inexpensive solutions for electrically powered transportation that rival gas-powered options and are environmentally friendly.

www.ti.com

Renesas joins AUTOSAR

Renesas announced that it has joined AUTOSAR (Automotive Open System Architecture), an industry partnership working to establish standards for software interfaces and software modules for automobile electronic control systems. Renesas Technology joined as a Premium Member.

In recent years electronic systems have come to be used ever more extensively in automobiles, a trend that is accelerating rapidly. Such systems are used for applications including engine control, body control, safety control and information systems. As this process has advanced, the share of the software component in the overall development process for automotive control systems has grown substantially. The need is growing for software standardisation as a means to improve the efficiency of the development process, and thereby enable even more extensive use of electronic systems in future. Such standardisation would allow previously developed software to be used in new products as well as in microcomputers and microprocessors from different manufacturers.

AUTOSAR was established in July 2003 to promote the standardisation of software for the automobile industry.

www.renesas.com

Zetex achieves Automotive Standard

Zetex has achieved corporate registration as an ISO/TS16949:2002 certified company, following audits conducted by Underwriters Laboratories Inc. Jointly developed by International Automotive Task Force (IATF) members and the International Standards Organisation (ISO), ISO/TS16949:2002 is recognised as the most comprehensive quality management standard for companies operating in the automotive industry supply chain.

The quality registration strengthens Zetex' position as a leading supplier of discrete and integrated analog semiconductor devices to automotive system integrators and vehicle manufacturers alike. A broad range of Zetex power management products including IntelliFET smart MOSFETs, current monitors and fan controller ICs are employed in a wide variety of automotive applications.

According to WSTS/Bosch, the global semiconductor demand in the automotive manufacturing sector is expected to rise from $13.7B in 2003 to $23.2B in 2008, representing a compound annual growth rate of 11.1%. The research also indicates the growing importance of semiconductors to the sector. As a percentage of the production cost of an average light vehicle, the semiconductor content is forecast to grow from 9.5% in 2004 to over 15% in 2010.

www.zetex.com

Tektronix Oscilloscopes for Education

Tektronix announced that Turkey's first foundation university, Bilkent University, has installed more than 100 Tektronix oscilloscopes into a new laboratory to provide measurement tools for undergraduate student coursework. The Electrical & Electronics Engineering Department of Bilkent University, Ankara, Turkey, attracts a significant portion of the highest performing students in Turkey. The 50-seat modern laboratory was designed to allow students to conduct analogue, digital design, circuit, microprocessor and control experiments. The philosophy employed when designing and setting up the laboratory was to equip each bench with a computer that controls the oscilloscope and a function/signal generator using leading third-party software. This enables students to learn and employ the concepts of modern experimentation easily and effectively. Internet connections to each bench are also provided, which allows students to prepare and submit lab reports via the network and to use Internet resources while they are in the lab. The framework requires digital storage oscilloscopes that have a computer and printer interface, FFT math and high sampling rate.

www.tektronix.com

Power Events

- ***H2Expo 2004,*** *September 15-17, Hamburg, www.h2exp0.de*
- ***Semi Expo 2004CIS,*** *September 27- 30, Moscow, http://wps2a.semi.org*
- ***Automotive EMC 2004,*** *October12, York Racecourse UK, www.AutoEMC.net*
- ***Power Conversion Design,*** *October12-15, Portsmouth UK, www.ejbloom.com*
- ***Ansoft Seminar,*** *October 21,Stuttgart/ Sindelfingen, http://www.ansoft.com/gsem04/*
- ***Electronica 2004,*** *November 9-12, Munich, www.global-electronics.net*
- ***Surface Mount 2004,*** *November 16-18, Brighton UK, www.smartgroup.org*
- ***SPS/IPC/DRIVES 2004,*** *November 23-25, Nuremberg, www.mesago.de*
- ***Embedded World 2005,*** *February 22-24, Nuremberg, www.embedded-world.de*

IGBTs and Modules are good for Vehicles

Continued improvement in packaging and mounting technology allows for more efficient performance in electric automotive motor drives.

Bodo Arlt, Power Systems Design Europe
Editor-in-Chief

IGBTs are dominating all areas in a voltage range from 200V up to 6500V. The IGBT with it's high current density is the perfect candidate allowing to build a high current switch in a small package at a reasonable price. The IGBT is a MOS gate controlled power switch. Cell structure and manufacturing process are very similar to a MOSFET. The IGBT is the workhorse of modern inverter technology. It is the preferred switch because of short circuit capability, speed and improved saturation voltage.

The drive control using IGBTs technology permits sensitive starting, powerful acceleration and finely regulated electric motor braking with energy reclamation. In automotive applications, the demand on the cars' electrical power generation is increasing due to the requirement for more driving comfort, better performance and more features. This while the fuel consumption and emissions must be decreased. Auto makers like Mercedes with its luxury S class have announced to have a hybrid version to gain mileage. The Japanese Toyota with the Lexus Automobiles are pushing the market. Electrical—and Hybrid Electrical—Vehicles are using already IGBT modules. Their bus voltage is between 200VDC and 400VDC with DC currents up to a few hundred amps.

Synchronous or asynchronous machines are used for automotive applications powered by frequency converters. Power modules with a high switching power density combined with low loss designs. To achieve these tasks we need integrated insulation to the heatsink, low thermal resistance and low stray inductance. The power semiconductors, along with the energy storage device, are the two main components, which determine the functionality, reliability, and cost. To compliment the IGBT performance, modules have to include perfect diodes with soft recovery characteristics.

Both IGBT concepts of Punch Through (PT) and Non Punch Through (NPT) have been improved over the years. Reducing the wafer thickness in the NPT side also the transistor cell structures changed to minimised planar cells or trench cells. Outstanding improvement in the IGBT development has been achieved with the Field Stop IGBT.

Pressure contacts have been successful introduced into modules by ABB and Semikron. These modules are designed to take a PCB containing control and gate drive, which snaps on to the module, and is held in place by rugged hooks. A product resulting out of this area is the SKAI, an optimized system for hybrid and electric vehicles, that fulfils the high demands of the automobile industry. Semikron has been named by General Motors "Supplier of the Year" in recognition of the optimized power electronics system developed for GM fuel cell automobiles.

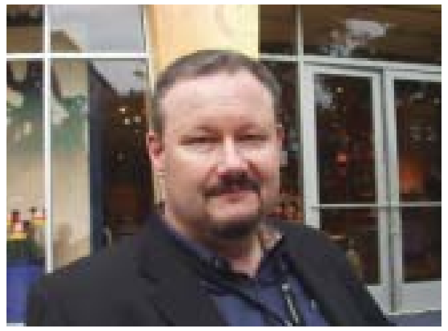
Optimizing thermal resistance in the module design is the designer's goal. Improvement in silicon switches which minimize switching losses and conduction losses in IGBTs has been achieved. With improved silicon thinning processes, thinner die have become a reality. Thinner die equate to a better thermal response. Module manufactures are moving to more dense packages and higher break down voltages. In the past, the major improvements for efficiency have been made by optimizing the silicon. Now the silicon has reached a point where improvement in connecting and packaging technology contribute a higher amount to the total performance of systems. Wire bonding is being replaced for power packaging by alternate technology like solder or pressure contact.

The IGBT had become the switch of choice. Thank you to Frank Wheatley and his college Dr. Hans Becke at RCA. They got the critical important US patent 4,364,073 that had changed the world of power electronics.

Trends in Distributed Power Management

By Paul Greenland, Marketing Director of National Semiconductor's Power Management Products Group

In recent years we have seen a revolution in the distributed power architecture for the rapidly evolving information infrastructure. We start with the introduction of the Intermediate Bus Architecture followed by the advent of digital control and the trend towards the manageability of on-board power.



Intermediate Bus Architecture

Roughly five years ago, power management met an inflection point in system design. The forced air cooling budget for racks in telecom and datacom applications had reached a ceiling. The proliferation of DSPs, FPGAs and digital ASICs, driven by the end-customer's insatiable thirst for bandwidth and content, had increased the number and complexity of loads to the point at which the conventional distributed power architecture, using a single isolated multi-output modular DC-DC converter on each card became inefficient. The answer was to separate the isolation, step-down and point-of-load regulation into two distinct stages replacing the single multi-output brick.

This metamorphosis is not without its challenges; each stage has to occupy less than half the volume of the original solution and the series combination has to have higher overall efficiency. Typically the architecture uses a loosely regulated first stage which performs the isolation and step-down function, with a precision second stage at the point of load. The first stage is called the Intermediate Bus Converter (IBC). The IBC is usually regulated against line voltage variation, load regulation is coarse, typically ±10%. Conversely, regulators at the point of load have tight load regulation, typically < ±1% and are not isolated. The primary distributed bus is -36 V to -72 V dc or +43 V to +53 V dc, for telecom or datacom respectively. The intermediate bus is usually 8 V to 14 V dc.

Digital Power

Economy, flexibility and reliability are the primary motivations for considering digital control. As process geometries have shrunk, digital implementation can often be achieved in a smaller die area, with lower power consumption than its analog counterpart. Digital control offers the promise of improved noise immunity and sophisticated adaptive on-the-fly control allowing the power supply designer to consider power factor correction and resonant conversion topologies hitherto regarded to be too complex for analog control. The transition to digital control is however, a risky proposition. Notoriously conservative power supply designers who have invested years of hard won experience in analog control have to learn to use a whole new vocabulary and toolset. Up to now digital control has been focused on applications where the time constants in the load system have been long enough to permit real-time calculation of pulse width, and reference to look up tables. A good example is battery charging with power factor correction, for instance, the "Rectifier" in a telephone exchange.

Power System Manageability

Complex loads, particularly FPGAs and DSPs require separate supplies for core and I/O. The core processor technology often operates at, or below, one volt, while the I/O is held at a conventional potential by the communication interface standard. Since these sub-circuits are often separated in the IC, by a reverse biased ESD diode, the power rails have to be applied and removed in a particular order, tracking one another to prevent latch-up and potential destruction. Furthermore, sophisticated loads often require "voltage margining" during automatic test procedures and may give an indication of their status and immediate power consumption for energy efficient application. On-board power manageability includes the capability to dynamically configure the power supply to optimize a sensed parameter such as temperature, throttle airflow or improve signal integrity, and to automatically compensate for the sensor's characteristics.

In summary power management is gaining recognition as a true enabling technology, capable of differentiating the performance of the final system. The latest developments in distributed power architectures are prime examples of where timely collaboration with power management semiconductor suppliers can yield sustainable advantage.

www.national.com

Smart Power Module

Powering the motion

Inverter technology is the key to cost-effective and efficient motor drives. As a solution, Fairchild has developed a broad range of Smart Power Modules tailored to variable speed drives. SPM series are designed to bring the customers both high performance and lower cost, and to make electronic motor drives efficient, compact, easy and fast to design, rugged and less risky.

By Sung-il Yong and Bum-Seok Suh, Fairchild Semiconductor

Concerns about the environment and energy conservation have resulted in new regulations and recommendations from government agencies throughout the world. Low power drives both in consumer appliance and general industrial applications have shown a rapid growth in recent years, increasing the need for low power modules. SPM (Smart Power Module) has established a dominant position in these application areas with its compactness, functionality, reliability and ease of user interface.

From 1999, when the SPM series was first developed, to the present, Fairchild has manufactured millions of 600V SPM series with the power range of 400W ~3.7kW in consumer appliances and low power general industry applications.

This article will detail the SPM design concept and its implementation of semiconductor (power devices and control ICs) technology, package technology, and system technology mainly through the newly developed SPM3 and SPM5. Benefits of using SPM inverters will also be discussed.

SPM Design Concept

The key SPM design concept is to create a low power module with both improved reliability achieved by applying the existing IC and LSI transfer mold packaging technology to the SPM. SPM structure is relatively simple: power chips and the IC chips are directly die bonded on the copper lead frame, the bare ceramic material is attached to the frame, and then molded into epoxy resin. In comparison, the IPM is made of power chips bonded on the metal or the ceramic substrate and the ICs and the passive components assembled on the PCB, which in turn is assembled into a plastic or epoxy resin case and then filled up with silicon gel. The SPM greatly minimizes the number of parts count and material types, optimizing assembly process and overall cost. To the left in figure 1 is SPM3 and to the right is SPM5. Their relative sizes are shown next to a US quarter coin.

The second important design concept is the implementation of a product with smaller size but higher power rating. Of the low power modules released to date, SPM3 has high power density with a 3A~30A rated product built into a single package outline.

The third design concept is user design flexibility to enable use in a wide range of applications. For example, there are two major flexibility features in the SPM3 series. First is the 3-N terminal structure where the IGBT inverter bridge emitter terminal is separated. In this type of structure, shunt resistance can be used in each 3-N terminal to easily detect inverter phase current. Second is high-side IGBT switching dv/dt control made possible by the insertion of appropriate impedance cell in the SPM. Depending on how the impedance cell is designed, the high-side switching slope can be adjusted so that critical EMI problems may be easily dealt with.

Figure 1. SPM3 and SPM5 compared to a quarter coin.

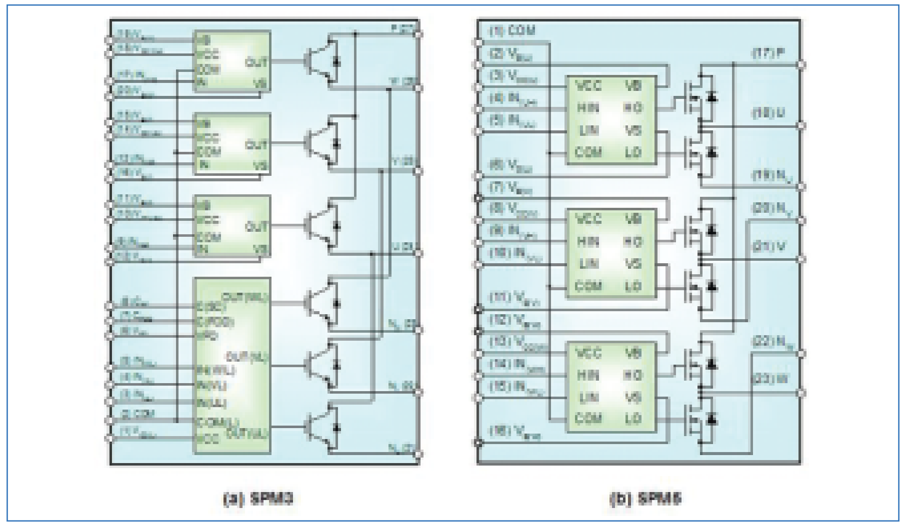


Figure 2. Block Diagrams of SPM3 and SPM5.

The internal block diagram of the SPM3 is shown in Figure 2 (a) and SPM5 is shown in Figure 2 (b).

SPM3 is a 3-phase IGBT inverter with 3 HVICs, 1 LVIC, 6 IGBTs and 6 FRDs.

SPM5 is a 3-phase MOSFET inverter optimally designed for use with low power applications. It has 6 power MOSFETs and 3 half bridge drive ICs built in. The detailed features and integrated functions of SPM3 and SPM5 are as follows.

Features of SPM3:

- 600V/3A to 30A rating in one package (with identical mechanical layouts)
- Low-loss efficient IGBTs and FRDs optimized for motor drive applications
- High reliability due to fully tested coordination of HVIC and IGBTs
- 3-phase IGBT inverter bridge including control ICs for gate driving and protection
  - High-side: Control circuit under voltage (UV) protection (without fault signal output)
  - Low-side: UV and short-circuit (SC) protection through external shunt resistor (with fault signal output)
- Single-grounded power supply and opto-coupler-less interface due to built-in HVIC
- High-active input signal logic resolves the startup and shutdown sequence constraint between the control supply and control input providing fail-safe operation with direct connection between the SPM and a 3.3V CPU or DSP. Additional external sequence logic is not needed
- Divided negative DC-link terminals for inverter current sensing applications
- Isolation voltage rating of 2500Vrms/min
- Very low leakage current due to ceramic heat-sink and DBC substrate.

Features of SPM5:

- 500V, 0.5A, 1A and 250V 1A rating, 3 - phase MOSFET inverter bridge including control ICs for gate driving
- High reliability due to fully tested coordination of HVIC and MOSFETs
- Single-grounded power supply and opto-coupler-less interface due to built-in HVIC
- High-active input signal logic resolves the startup and shutdown sequence constraint between the control supply and control input providing fail-safe operation with direct connection between the SPM and a 3.3V CPU or DSP. Additional external sequence logic is not needed
- 3 divided negative DC-link terminals for inverter current sensing applications
- Typical switching frequency of 15kHz
- Isolation voltage rating of 1500Vrms/min.

Semiconductor Technology, POWER Devices—IGBT, FRD and MOSFET

The performance upgrade of SPM3, which consists of 3-phase IGBT inverter circuits, is basically the result of technological development of power devices (IGBT and FRD). The fundamental design rule of power devices is the reduction of chip size and the increase of current density. The IGBT applied to SPM was newly developed by Fairchild. Through optimized PT planar IGBT design, it maintains the SOA (Safe Operating Area) suitable for motor control application while dramatically reducing the on-state loss (VCE(SAT) = 1.6V) and turn-off loss (EOFF = 60mJ @25∞C). It also implements smooth switching performance without sacrificing other characteristics. The FRD is a hyperfast diode that has low forward voltage drop (an important factor in inverter applications) along with soft recovery characteristics.

In the 3-phase MOSFET inverter SPM5, the MOSFET's internal body diode is used as a free wheeling diode for the implementation of a more compact structure. The MOSFET used in SPM5 was primarily designed to have an outstanding body diode recovery characteristics as well as the implementation of noise immunity and switching performance for motor control application. By optimizing gate resistance, dV/dt was implemented at below 2kV/ms to suppress the resonance of gate signal and to reduce EMI.

Semiconductor Technology, Control IC—LVIC, HVIC

In the SPM inverter, the HVIC and LVIC were designed to have only the minimum necessary function suitable for low power inverter drive. The HVIC has a built-in high voltage level shift function that enables the ground referenced PWM signal to be sent directly to the SPM's assigned high side IGBT gate circuit. This built-in function enables opto-coupler-less interface, making it possible to design a very simple system. In addition, with a built-in under-voltage lockout (UVLO) protection function, it interrupts IGBT operation under control supply under-voltage conditions. Because the charge-pump mode, which interlocks to the low-side PWM outside of the SPM, can be used as the high-side driving power, it can be driven with a 15V single control supply. This is not necessary to have three isolated voltage sources for the high-side gate drive used in inverter systems that use conventional power modules.

Recent progress in the HVIC technology includes chip downsizing through the introduction of wafer fine process technology, input logic change from the conventional low active to high active permitting direct drive by 3V feed Micro-controller or DSP, low circuit current, increased noise immunity and good performance stability against temperature variation.

Package Technology

Since heat dissipation is an important factor limiting the power module's current capability, the heat dissipation characteristics of a package is critical in determining SPM performance. A trade-off exists between heat dissipation characteristic and isolation characteristic. The key to a good package technology lies in the implementation of outstanding heat dissipation characteristic without compromising the isolation rating.

In SPM3, a technology was developed in which bare ceramic with good heat dissipation characteristics is attached directly to the lead frame. For expansion to a targeted power rating of 20A/30A within a single package, DBC (Direct Bonding Copper) technology was applied. This made it possible to achieve optimum trade-off characteristics while maintaining cost-effectiveness.

In SPM5, special epoxy resin was used with optimized thermal conductivity and insulation characteristic. At the same time, the thickness of the insulation layer, which is also composed of resin, has been carefully optimized to meet the required specification both in terms of insulation level and thermal resistance.

Figure 3 shows cross sections of the SPM3 and SPM5 package. As seen in Figure 3 (a), the lead frame structure was bent to secure the required electrical spacing. In Figure 3(b), the lead frame and the DBC substrate are being directly soldered in the DBC-SPM3.

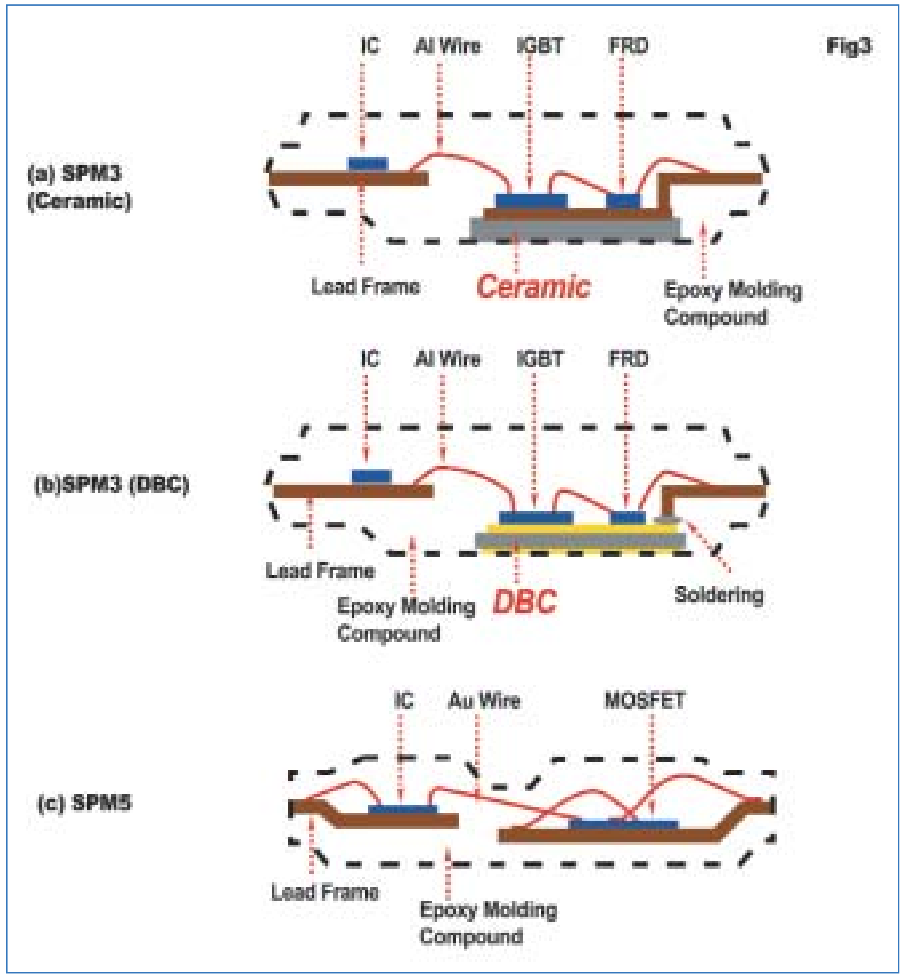


Figure 3. Cross Sections of SPM3 and SPM5

Inverter System Technology

The package has been designed to satisfy the basic creepage and clearance spacing related safety regulations (UL, IEC, etc.) required in inverter systems. In SPM3, 3mm creepage and 4mm clearance was secured in all areas where high voltage is applied. In addition, the Cu frame pattern and wire connection have been optimized with the aid of computer simulation for less parasitic inductance, which is favorable to the suppression of voltage surge at high frequency switching operation.

HVIC is sensitive to noise since it is not a complete galvanic isolation structure but is implemented as a level shift latch logic using high voltage LDMOS that passes signals from upper side gate and lower side gate. Consequently, it was designed with sufficient immunity against such possible malfunctions as latch-on, latch-up, and latch-off caused by IGBT switching noise and system outside noise. Fairchild's SPM design also taken into consideration the possibility of high side malfunction caused by short PWM pulse. Since the low voltage part and the high voltage part are configured onto the same silicon in the HVIC, it cannot operate normally when the electric potential in the high voltage part becomes lower than the ground of the low voltage part. Accordingly, sufficient margin was given to take into account the negative voltage level that could cause such abnormal operation. Soft turn off function was added to secure basic IGBT SOA (Safe Operating Area) under short circuit conditions.

Advantage of SPM-inverter Drives and SPM Inverter Engine Platform

SPM3 was designed to have 3A~30A rated products built into a single package outline. Figure 4 shows the junction to case thermal resistance at each current range of the SPM3.

COVER STORY

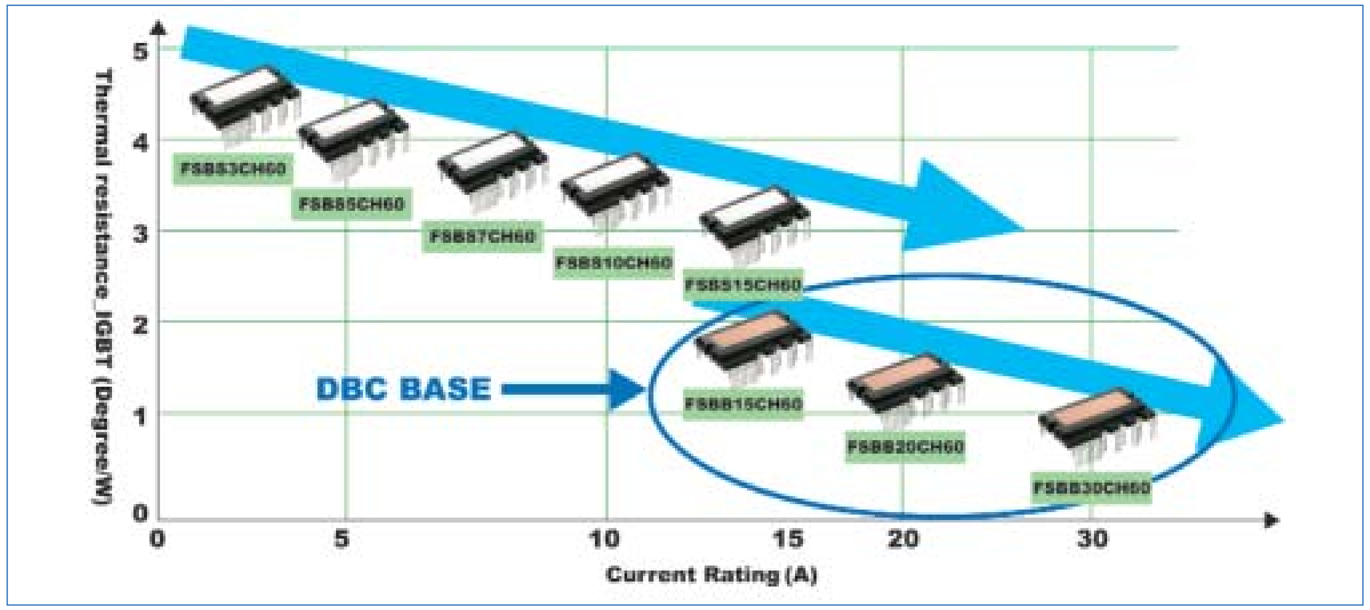


Figure 4. Junction-to-case Thermal Resistance according to Current Rating of SPM3 Line-up.

As seen in the figure, in the 20A and 30A range, intelligent 3-phase IGBT module with high power density (Size vs. Power) was implemented. Accordingly, in the low power range, inverter system designers are able to cover almost the entire range of 0.1KW~2.2KW rating in a single power circuit design using SPM3. Since circuitry and tools can become more standardized, product development and testing process are simplified, significantly reducing development time and cost. Through control board standardization, overall manufacturing cost will be substantially reduced as users are able to simplify materials purchasing and maintain manufacturing consistency.

Noise Reduction

Small package and low power loss are the primary goals of low power modules. However, in recent years, attempting to reduce power loss through excessively fast switching speed has given rise to various challenges. Excessive switching speed increases the dV/dt, di/dt, and recovery current and creates challenges such as large EMI (Electromagnetic Interference), excessive surge voltage, and high magnitude of motor leakage current. Such problems increase system cost and can even shorten motor life. SPM series solve these problems by adjusting the switching dV/dt to below 3kV/usec (typical) through advanced gate drive impedance design.

Thanks to very low on-state voltage of the new generation IGBT and low forward voltage of FRD, an optimized switching speed meeting the low EMI requirement has been realized in SPM while keeping the total power loss at a low level equal to or less than other low power modules.

Cost-effective Current Detection

As sensorless vector control and other increasingly sophisticated control methods are applied to general industrial inverters and even in consumer appliance inverters, there is a growing need to measure inverter phase current. SPM family has a 3-N terminal structure in which IGBT inverter bridge emitter terminal is separated. In this type of structure, inverter phase current can be easily detected simply by using external shunt resistance.

High Reliability

The wire-to-chip junctions and the chip-to-frame junctions have been enforced in a transfer mold package to make it endure severe thermal stress. In particular, the wire-to-chip junction endurance against steep temperature swing caused by rapid load variation has been substantially improved. Power cycle results show that SPM is capable of over ten million power cycles at an average chip junction temperature swing of 25∞C. This makes SPM suitable not only for home appliances, which usually work under a relatively constant load, but also for a typical servo operation characterized by frequent and dramatic load changes.

Conclusion

Today, SPM has positioned itself as strong inverter solution in low power motor control. With its compact size, optimized performance, high reliability, and low cost, the SPM family is accelerating the inverterization not only of low power industry applications but also of consumer appliances. Fairchild will continue its effort to develop the next generation of SPMs optimized for a wider variety of applications and with higher power rating in mind.

For more information on Fairchild's SPM products, please visit http://www.fairchildsemi.com/offers/discrete/spm/index.html

www.fairchildsemi.com

MAGNETICS

Robust Control of an Electromagnetic Actuator

Accurate control of the moving armature

System identification experiments and robust controller design method are presented in the case of a nonlinear electromagnetic actuator.

By A. Forrai, T. Ueda and T. Yumura, Mitsubishi Electric Corp., Japan

The considered control problem requires accurate control of the moving armature. The small contact velocity, known as: 'soft landing', is a very important consideration because high contact velocities correlate with component wear and noise.

Moreover, soft landing of the armature has to be achieved within a limited time. These two requirements are obviously conflicting. Other control difficulties arise from: the nonlinear characteristics of the actuator, control input saturation, dispersion due to the manufacturing and setting process, etc.

Similar control problem arises in the case of electromagnetic valve actuators in combustion engines, and if the armature is controlled around an operating point (magnetic levitation) there are applications such as: high-speed transportation, magnetic bearings, artificial heart, clean room applications in the semiconductor industry, etc.

Modelling and System Identification

The basic structure of the electromagnetic actuator is presented in Figure 1. The related mathematical model of the investigated electromagnetic actuator can be written as:

$$u = Ri + \frac{d\Psi}{dt} = Ri + \frac{\partial \Psi}{\partial i}\frac{di}{dt} + \frac{\partial \Psi}{\partial y}\frac{dy}{dt} \qquad (1)$$

where u – applied voltage, i – current, R – coil resistance, y – air-gap and Y = Y(i,y) is the magnetic flux, which is current and air-gap dependent.

The equation of motion is given by:

$$m\frac{d^2y}{dt^2} = F_m - F_s \qquad (2)$$

where m is the moving mass, Fs is the spring force and Fm is the magnetic

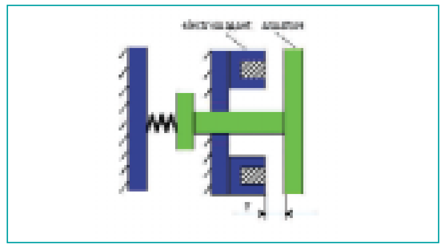


Figure 1. The electromagnetic actuator.

force computed using the magnetic co-energy (the friction can be neglected).

The control problem can be viewed as a general case of a magnetic levitation problem: the nonlinear system can be linearized around an equilibrium point noted by (i0, y0) using Taylor series expansion. The open-loop transfer function is:

$$P(s) = \frac{\Delta y(s)}{\Delta i(s)} = \frac{\beta_1}{i_0(s+\beta_2)(s-\beta_2)} \qquad (3)$$

where b1 and b2 are positive constants and the symbol D suggests small variations around the equilibrium point.

For simplicity let us consider that the armature is controlled around an equilibrium point, then the easiest way to compensate the system nonlinearity is by adding a constant bias current denoted by ib=Ib (or a constant bias voltage in case of voltage control configuration ub = Ub=RIb).

A much robust approach is exact linearization of the plant, in this case the bias current equals the equilibrium current: which is armature position and spring force dependent.

This nonlinear function f can be

$$i_b = i_0 = f(y, F_s) \qquad (4)$$

obtained by measurements and can be implemented in real-time, however, in the industry preference is given to simple compensation laws.

Therefore, we consider the bias current to be the measured current, which under control asymptotically converges to the equilibrium current.

$$i_b = i \quad with \quad i \to i_0 \qquad (5)$$

This approach is called asymptotically exact linearization [2]. From energetic point of view the compensation law covers exactly the Ohmic losses ubib = Ri2, which means that if the system is stabilized around an equilibrium point this nonlinear compensation will not make it unstable. In case of voltage control configuration the compensation law has the form ub = Ri.

The condition of asymptotic convergence i Æ i0 can be assured if the linear control system (around an equilibrium point) is internally stable. Therefore, considering a robust control framework for controller design is essential (robust stability assures internal stability) [3].

The first step in controller design is system identification—a model always must be derived from experimental data. Due to open-loop instability, experimental models for the electromagnetic actuator are obtained through closed-loop experiments only.

Therefore, the first step was to design, through trial and error procedure, a controller, which can stabilize the system, when the nonlinearity has been compensated using asymptotically exact linearization.

The system has been stabilized around different equilibrium positions: y0 = 0.15 mm, y0 = 0.2 mm, y0 = 0.25 mm and y0 = 0.35 mm.

Closed-loop identification has been performed considering an indirect approach: we assume that the reference signal and the regulator to be known, we identify the closed-loop system from reference input to output, and retrieve from that the open-loop system, making use of the known regulator.

The system is identified on the basis of measured input/output data, using well-known Auto-Regressive eXogenous (ARX) model, when the input signal is the Pseudo-Random Binary Signal (PRBS) [4].

Defining the sample period of the PRBS as Ts and noting with M the maximum length period it can be shown that the frequency range of the PRBS is:

$$\frac{2\pi}{MT_s} \le \omega \le \frac{2\pi}{2T_s} \qquad (6)$$

System identification experiments have been performed in two different frequency ranges defined by: 4 rad/sec < wlow < 62 rad/sec, which corresponds to Ts = 0.05 s and 20 rad/sec < whigh < 314 rad/sec, which corresponds to Ts = 0.01 s and around different equilibrium points, when the air-gap was successively 0.15 mm, 0.2 mm, 0.25 mm and 0.35 mm.

Experimental results around the equilibrium point y0 = 0.15 mm are presented in Figure 2.a and Figure 2.b where the measured output (solid line 1) is compared with the estimated output (dotted line 2). Basically there is a good agreement between the real plant and derived plant model.

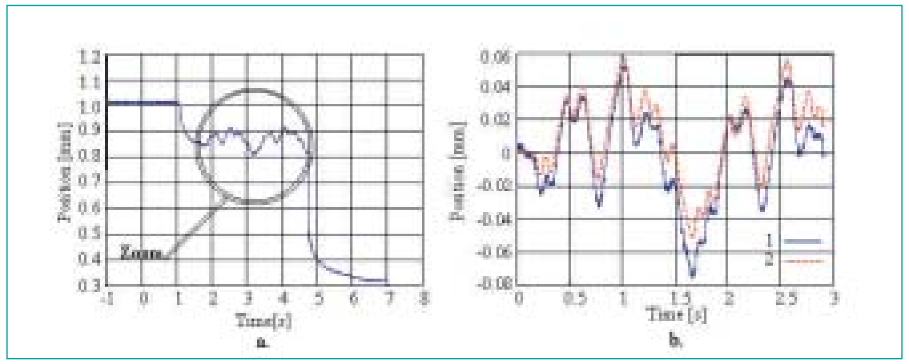


Figure 2. System identification under closed loop.

The identified transfer functions (around different equilibrium points and different frequency ranges) are validated in frequency and time domain and the nominal model is chosen using error minimization. The nominal plant is given by:

$$P_n^r(s) = \frac{120}{(s-1.4)(s+300)} \qquad (7)$$

Robust Controller Design and Experimental Results

In the aim to assure 'soft landing' of the moving armature a positioning control approach has been considered, when the reference input signal is a ramp.

The block diagram of the proposed robust control system with direct voltage control is presented in Figure 3, where the asymptotically exact linearization (AEL) block already has been descried. Moreover, the linearized plant is modified by rate feedback to improve the disturbance rejection properties against the spring force—the modified plant is noted by G(s).

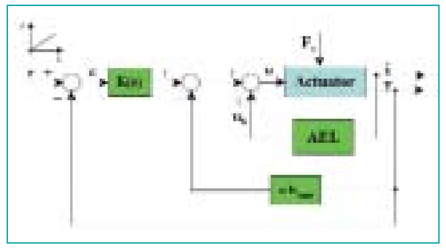


Figure 3. The control structure.

The controller design specifications are summarized as follows:

- The armature speed denoted by v must be between: 1 mm/s < v < 2 mm/s - this will assure 'soft landing' and armature pull-up/release time less than 0.5 seconds;
- The order of the robust controller should be as low as possible;
- The sensitivity function should be minimized as much as possible (its minimization is also limited by the lowest possible gain due to the open-loop instability).

Considering a mixed sensitivity approach the robust performance condition (which assures robust stability and performance) is written as:

$$|W_S(s)S(s)| + |W_T(s)T(s)| \le 1 \quad (8)$$

where S(s) is the sensitivity transfer function, T(s) is the complementary sensitivity transfer function and WS(s) an WT(s) are the performance and robustness weighting functions.

The robustness weighting function WT(s) is derived based on system identification experiments. The multiplicative uncertainty model for the modified plant is given by:

$$\Delta_m(s) = \frac{G(s) - G_n(s)}{G_n(s)} \quad (9)$$

where Gn(s) is the nominal plant modified by rate feedback. The weighting function WT(s) is made larger than the multiplicative uncertainty at any frequency |Dm(s)| < |WT(s)|.

The performance weighting function WS(s) is chosen by the designer, taking into account that the reference signal is a ramp, for asymptotic tracking the sensitivity transfer function must have at least two zeros at the origin, this means the order of WS(s) transfer function is at least two.

The robust controller is designed systematically according to the robust control theory and a fourth-order controller is obtained (which can be reduced to a third-order controller). The transfer function of the controller is discretized using the bilinear Tustin transformation with the sampling time Ts = 0.001 s and is implemented on a TMS 320C40 DSP board. The armature current is sensed using LEM current sensors and the armature position is sensed by infra-red sensors, having operating temperature range up to 85∝C degrees.

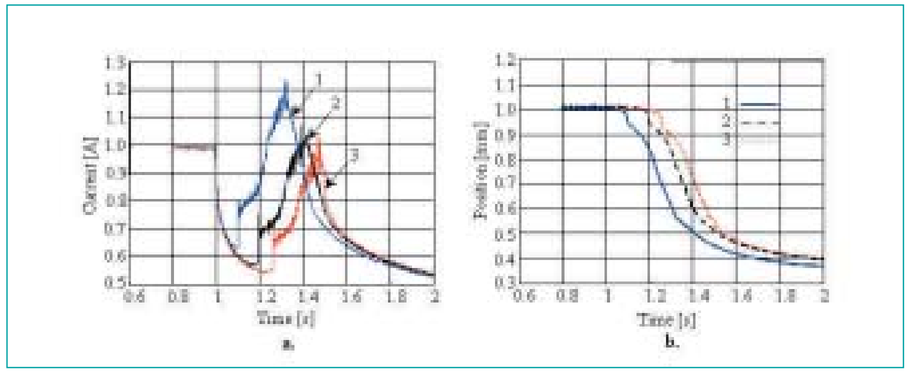


Figure 4. The system response

In Figure 4 is shown the armature current and position variation under control, when the spring force undergoes variations ±5% according to the manufacturing dispersion. The solid line 1 corresponds to the highest spring force, the dashed line 2 to the nominal spring force and the dotted line 3 to the lowest spring force. In all cases soft landing of the armature is achieved, according to the design specifications.

Conclusions

The article focused on system identification experiments and robust controller design applied for an electromagnetic actuator.

The nonlinear system has been linearized using asymptotically exact linearization, which is easy to implement and from passivity based control theory has a nice interpretation—it covers exactly the Ohmic losses.

First, due to open-loop instability system identification experiments have been performed under closed-loop in different frequency ranges and for different equilibrium positions. Next, the robust controller approach has been considered during the controller synthesis. Finally, the designed control system has been implemented on a DSP board and tested experimentally – good robustness and performance ('soft landing') have been achieved.

The performance could be improved, by considering a linear parameter variant controller synthesis approach, which allows a lower uncertainty bound and higher control bandwidth.

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Power–Management Semiconductor Market Hits its Stride in 2004

Sales boosted by robust increases in mobile-PC, automotive markets

With the semiconductor and electronic-equipment markets set for robust growth in 2004, the power-management chip segment also is on its way to a great year.

By Derek Lidow, iSuppli

Global revenue for all types of power-management semiconductors will reach an estimated $20.1 billion in 2004, up 24.3 percent from $16.2 billion in 2003, according to iSuppli Corp. Revenue will grow to $29.5 billion in 2008, rising at a Compound Annual Growth Rate (CAGR) of 12.7 percent from 2003. However, revenue growth will slow in 2005 and nearly stall in 2006 before beginning another growth cycle, conforming with electronics and semiconductor industry trends.

iSuppli believes 2004 will represent the peak year for growth in the power-management semiconductor realm in the current cycle. This year also will mark the zenith of the present semiconductor cycle, with worldwide chip revenue rising 24.4 percent in 2004. Electronic equipment sales also will peak this year, rising 10 percent.

Revenue growth in 2004 for power-management semiconductors is being aided by high Average Selling Prices (ASPs). Sellers have the upper hand in the power-management area in 2004, and have been able to increase prices.

Power-management semiconductors benefit from broad usage in all electronic segments of electronic equipment. Thus, there is a close correlation between power-management semiconductor sales and end-equipment revenue.

Power Goes Mobile

However, beyond the general growth of the semiconductor and electronic-equipment markets, various product areas are driving increased sales of power-management semiconductors this year and further in the future. A major dynamic driving power-management semiconductor sales growth is the increasing number of battery-operated products on the market, such as mobile PCs and wireless handsets, which have more stringent power-management requirements. Beyond mobile products, power-management semiconductor sales are being boosted by the proliferation of electronics into new areas that have growing power needs, such as the automotive market.

Notebook PCs will enjoy 29 percent unit growth in 2004, compared to only 6 percent for desktops. Notebook computers have greater power-management requirements. Thus, the migration to notebooks means the PC market will

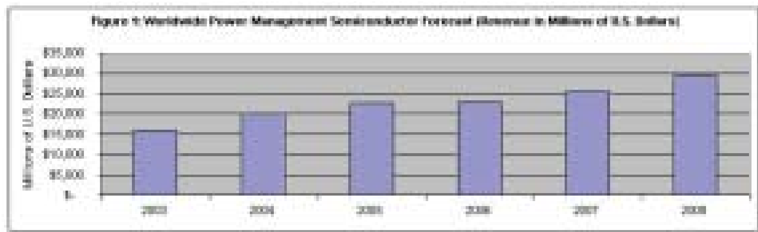

Figure 1. iSuppli's forecast for power-management semiconductors.

increase its demand for power-management semiconductors in 2004 and beyond, iSuppli believes.

Meanwhile, sales of power-management semiconductors to the automotive market will rise to an estimated $2.9 billion in 2004, up 31.7 percent from $2.2 billion in 2003. Revenues will nearly triple from 2002 to 2008, iSuppli predicts. Automotive power-management semiconductor revenues will grow to $5.3 billion in 2008, rising at a CAGR of 18.5 percent from $1.9 billion in 2002.

Sales growth of some power-management components to the automotive market will be boosted by the rising popularity of hybrid vehicles, which are powered by gas and electric engines. Such autos use between $500 and $1,000 of power electronics in each vehicle, generating a huge opportunity for component suppliers.

Power-Management Semiconductor Product Outlook

The fastest-growing major segment of the power-management semiconductor market is power ICs. Within the power IC category, the voltage regulator and reference segment dominates, with more than $4.3 billion in revenue.

The voltage regulator category consists of three different types of ICs: linear regulators, switching regulators and voltage reference and other devices.

Voltage regulator revenue will rise to $5.5 billion in 2004, up 26.9 percent from $4.3 billion in 2003, iSuppli predicts. Revenue will rise at a 17.5 percent CAGR from $4.3 billion in 2003 to $9.7 billion in 2008.

In the power discrete area, power transistor revenue will reach $7.6 billion in 2004, up 26.5 percent from $6 billion in 2003. Revenue will grow to $10.5 billion in 2008, rising at a CAGR of 11.8 percent from 2003.

Within the power-discrete segment, power MOSFETs will post a notable performance in 2004, with sales rising to $4.98 billion for the year, up 30.5 percent from $3.8 billion in 2003. Power MOSFET revenue will reach $7.3 billion in 2008, rising at a CAGR of 13.9 percent from $3.8 billion in 2003.

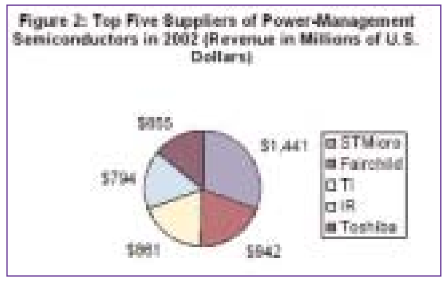

Figure 2. iSuppli's ranking of the top-five suppliers of power-management semiconductors in 2002.

Competitive Developments

With demand coming from multiple, fragmented markets, and divided evenly between discrete and IC device types, the power-management semiconductor area has no clear dominant supplier.

The names of the top-10 power-management semiconductor suppliers were unchanged from 2001 to 2002. However, there was some changing of chairs among the top competitors. STMicroelectronics solidified its number-one ranking in 2002 on the strength of leadership positions in both power ICs and power discretes. Fairchild Semiconductor moved up to the number-two rank, up from number three in 2001, also based on a good balance of strength in power ICs and discretes. At the number-three ranking, Texas Instruments moved up one place from the prior year. TI achieved this level without any participation in power discretes, but it leveraged its leadership in power ICs by growing revenue at twice the industry average rate.

International Rectifier, with its strong focus in the power MOSFET area, but with a much weaker position in power ICs, maintained essentially flat sales in 2002 and slipped from the number-two position in 2001 to the number-four spot for 2002, while the power-management market grew 7 percent.

Power Up

Power-management ICs occupy an enviable market position. Their prospects are limited only by the level of sales growth in electronic equipment and the increase in the need for power management in products. With both of these areas set to increase over the next few years, the power-management IC market is in for continued growth over the long term.

Derek Lidow is president and chief executive officer of the market research firm iSuppli Corp., based in El Segundo, Calif. Contact him at

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Power Systems Design EUROPE

Automotive Electronics

Driving Technology: Part II

Trench MOSFETs Feature Rugged, Efficient Switching

The right device for automotive electronics

The Q101 specification defines the minimum stress test-driven requirements and references test conditions for qualification of discrete semiconductors (transistors and diodes) for the automotive environment

By Anthony Murray, International Rectifier

Integrated starter alternators, synchronous rectifier alternators, electrical power steering systems, and brush and brushless dc motor drives employ power semiconductor switches to control turn-on, turn-off, speed and direction of travel. These power semiconductor switches must operate reliably in the harsh automotive environment, regardless of noise transients and voltage variations. Meeting this need is a new Trench HEXFET (MOSFET) family. To ensure reliability, all members of this Trench MOSFET family are tested according to the AEC Q-101 specification that guides electronic component selection and testing for the automotive environment.

Trench MOSFETs employs the same schematic configuration of the older planar MOSFETs, as shown in Figure 1. The new Trench MOSFETs offer significant advantages over the older generation Trench MOSFETs and also some improvements over the older planar MOSFET technology. To understand the new Trench MOSFET improvements,

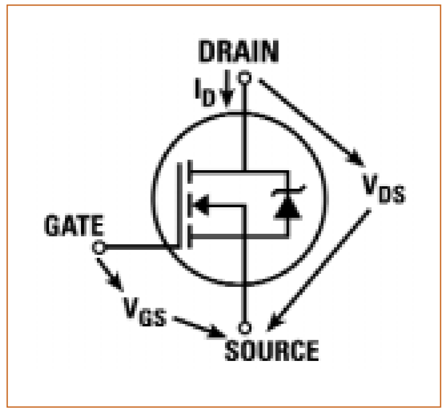

Figure 1Trench MOSFET schematic.

we have to investigate several parameters critical to the performance of power semiconductors employed in automotive applications:

- Blocking voltage (BV_{DSS})
- Maximum avalanche energy (E_{AR})
- On-resistance ($R_{DS(ON)}$)
- Maximum junction temperature ($T_{J(max)}$)
- Continuous drain current (I_D)
- Safe operating area (SOA)
- Gate charge (Q_G)

Blocking voltage is the maximum voltage that can be applied to the MOSFET. When driving an inductive load, such as a motor, this includes the applied voltage plus any inductively induced voltage. With inductive loads, the voltage across the MOSFET can actually be twice the applied voltage. Blocking voltage ratings of International Rectifier's new Trench MOSFET family are 30V, 40V, 55V, 75V and 100V.

The automotive environment can produce repetitive high voltage transients caused by fast current changes, such as starting the engine, which may force MOSFETs into an avalanche condition. There are two possible failure modes caused by the avalanche condition that can destroy a MOSFET. The most destructive is "bipolar latching" that occurs if the device current causes a voltage drop across its internal device resistance, resulting in transistor action and latching of the parasitic bipolar structure of the MOSFET. A second failure mode is thermal, which occurs if the avalanche condition raises the device

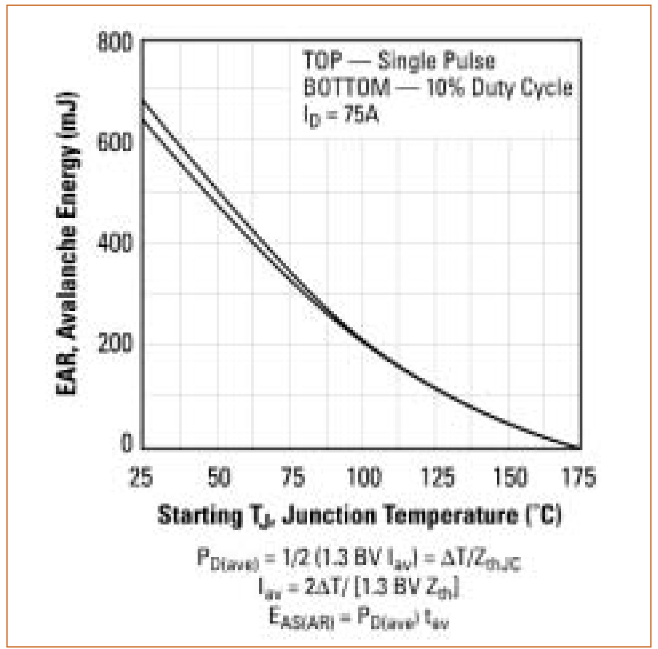

Figure 2. Maximum avalanche energy vs. temperature for the IRF2804 rated at 40V BV_{DSS}.

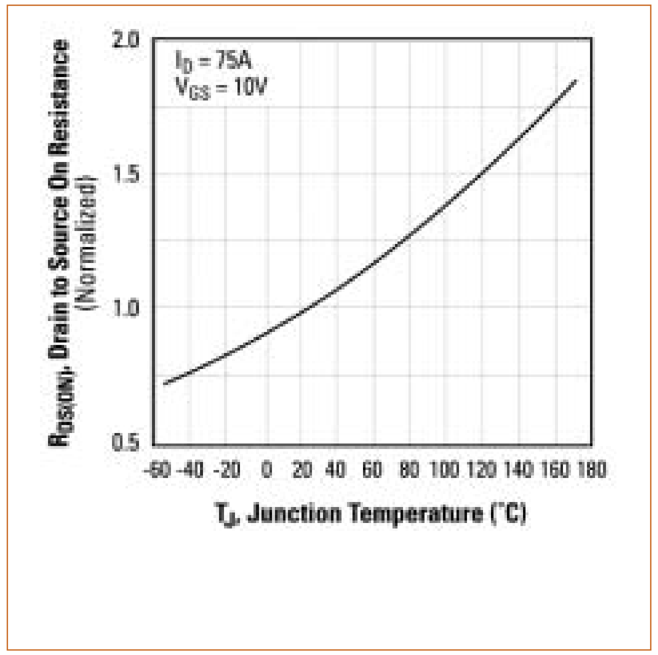

Figure 3. Normalized on-resistance vs. temperature for the IRF2804 Trench MOSFET.

temperature above its maximum junction temperature.

The new Trench HEXFET technology offers an avalanche capability comparable to industry-leading planar technology and up to twice that of some currently available trench products. To ensure satisfactory performance, all the devices in this automotive-oriented family are fully characterized for repetitive avalanche energy (E_{AR}) up to their maximum junction temperature, $T_{J(max)}$. The higher the E_{AR}, the more rugged the device. Figure 2 shows the maximum avalanche energy vs. temperature for the IRF2804 rated at 40V BV_{DSS}.

Trench technology provides the desirable characteristics of high avalanche capability and low on-resistance, or $R_{DS(ON)}$. On-resistance consists of the resistance of the MOSFET die plus its lead resistance, which is a function of the package that is employed. The new automotive-specific, Trench HEXFET power MOSFET technology provides 15% lower device on-resistance per unit area than existing benchmark technologies. And, the new Trench technology allows 10% lower on-resistance temperature coefficient. On-resistance is temperature dependent, as seen in Figure 3, which plots normalized on-resistance vs. temperature for the IRF2804 with I_D = 75A and V_{GS} = 10V (V_{GS} is gate-to-source voltage).

On-resistance is important because it determines the power loss and heating of the power semiconductor. The lower the $R_{DS(ON)}$ the lower the device power loss and the cooler it will operate. This is particularly important in automotive applications where the nominal operating temperatures usually exceed 125°C. Low on-resistance drastically reduces heat-sinking requirements in many applications, which lowers parts count and assembly costs. In many applications, the low on-resistance also eliminates the need to parallel MOSFETs for low on-resistance, which leads to improved reliability and lower overall system cost than previous MOSFET generations.

Maximum junction temperature is a function of the electrical characteristics of the device itself, as well as the package employed. Package thermal properties determine its ability to extract heat from the die. The junction-to-ambient (RqJA) thermal resistance of the device is a measure of its ability to extract heat. The lower the thermal resistance, the more efficient the package is in eliminating heat. In some cases, a heat sink may be required to maintain the device junction temperature below its maximum rating.

Continuous drain current establishes the ability of the MOSFET to drive a specific load. This value can be limited by the MOSFET's package. When operated in the pulsed mode, the MOSFET's drain current can be several times its continuous rating. In the pulsed mode the pulse width and duty cycle determine safe drain current and device power dissipation.

Safe operating area is exactly what the name implies. The maximum safe operating area depends on the drain current and VDS (drain-to-source voltage). Figure 4 shows the maximum safe operating area for the IRF2804.

Gate charge affects the highest reliable switching frequency of the MOSFET. The lower the gate charge, the higher the frequency. Operation at higher frequencies allows use of lower value, smaller size capacitors and

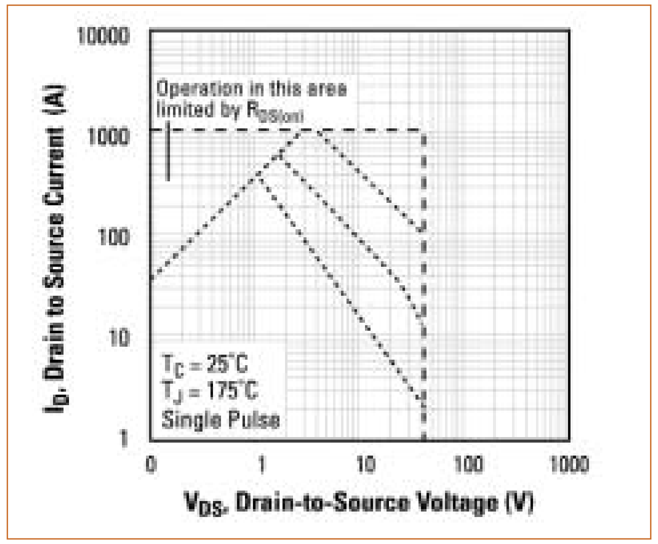

Figure 4. Safe operating area for the IRF2804 Trench MOSFET.

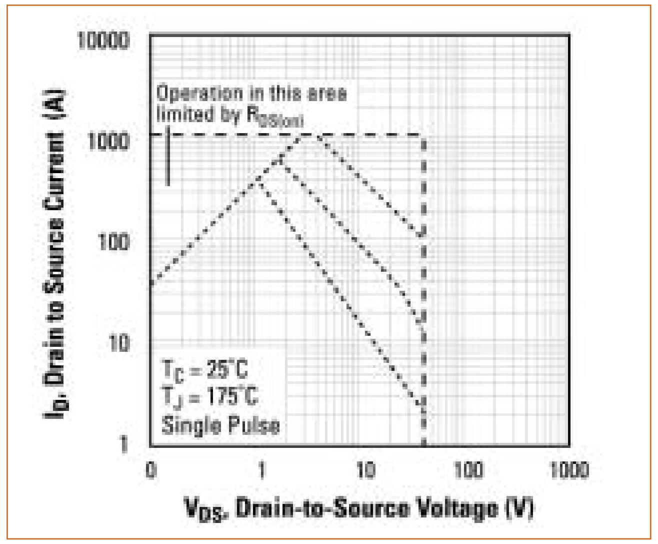

Figure 5. Typical gate charge vs gate-to-source voltage for the IRF2804 Trench MOSFET

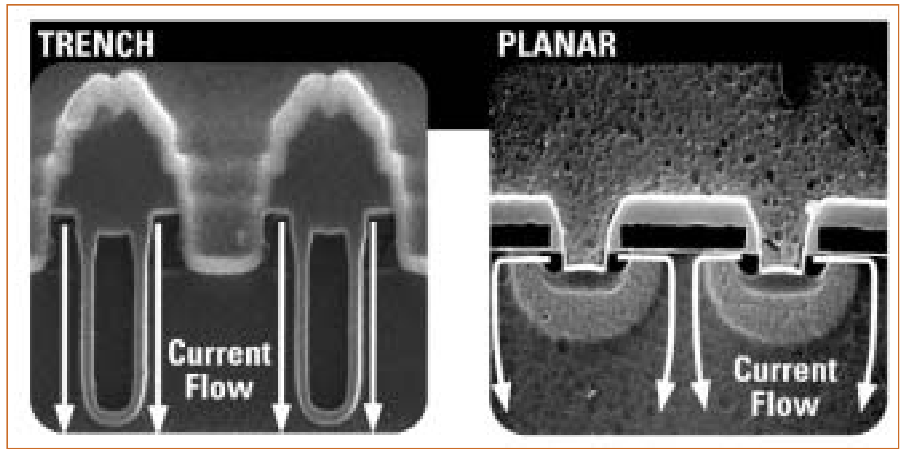

Figure 6. MOSFET cross-sections: a TrenchFET; b Planar MOSFET.

inductors, which can be significant factors in system cost. A low gate charge also makes it easier to drive the MOSFET, however, automotive engineers sometimes need to trade-off switching frequency with Electromagnetic Interference (EMI) considerations, which follow very strict guidelines in the automotive envoirnment. The new devices exhibit lower gate charge than existing planar technologies. Gate charge is a function of V_{GS}, I_D, and V_{DS}, as shown in Figure 5.

AEC Q-101

The Automotive Electronics Council (AEC) consists of two committees that establish the requirements for the Q-101 specification: the Quality Systems and the Component Technical committees. Today, the committees includes representatives from the sustaining members DaimlerChrysler, Delphi Delco Electronics Systems, Visteon Automotive Systems and other associate members. The Component Technical committee establishes standards for reliable, high quality electronic components. Components meeting these specifications are suitable for use in the harsh automotive environment without additional component-level qualification testing.

The Q101 specification defines the minimum stress test-driven requirements and references test conditions for qualification of discrete semiconductors (transistors and diodes) for the automotive environment. It does not relieve suppliers of the responsibility to meet their internal qualification program.

Planar MOSFETs vs Trench MOSFETs

From it very inception, planar MOSFET on-resistance depended on its cell density, that is, the number of cells/mm3. However, there is an upper bound on cell density that limits the lowest value of on-resistance possible.

The Trench MOSFET structure vertically redirects the current flow in the device's channel in a direct path between the topside source and the backside drain contact. Figure 6(a) and 6(b) show the vertical Trench and horizontal planar MOSFET cross-sections, respectively. The TrenchFET configuration avoids the parasitic series-JFET problem inherent in planar DMOS devices. Process refinements have yielded devices with steadily increasing density and lower on-resistance. TrenchFET devices have achieved on-resistance less than 1mW for a 25mm2 silicon die, exclusive of lead resistance.

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Increasing Passenger Car Comfort and Safety

LIN-Bus controlled smart-power chips to control exterior mirrors

A Smart-Power Chip with a Microcontroller-core, embedded in a mechatronic mirror concept solves this problem with only three leads needed to the door module, including: power supply, ground and LIN-Bus.

By Alberto Coen, STMicroelectronics

In the ever increasing need to support safety and comfort in passenger cars, more features are being added to external mirrors. In addition to mirror adjustment and defrosting, which are today standard, electrochromatic controlled dimming, turn indicators, the door's outside (puddle) lights, the folding in of the mirror, and the storing of the mirror position are also become standard in automobiles. The multiple new actuator and sensor functions however result in a significant cost increase, driving up wiring expenses to the door module.

Development trends in the area of exterior mirrors

There have already been different tentative approaches in the area of a mechatronic solutions, without giving up the concept of a central control module. Figure 1 shows some examples of solutions with the resulting effect on the count of the internal connecting leads. This shows the significant reduction in leads achieved by the mechatronic approach.

The mirror has the highest lead count and hence offers the greatest savings

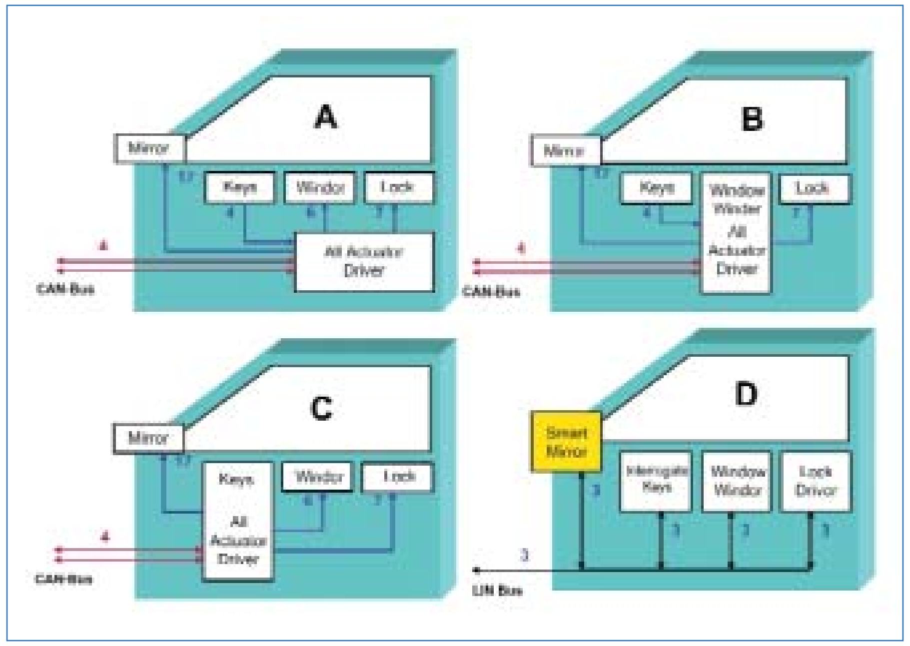


Figure 1. A Actuator driver inside a separate module
B Window winder combined with door module
C Keyboard combined with door module
D Actuator drivers dedicated to actuators (mechatronic)

potential for the mechatronic approach. Experience shows that features that today command an additional price, are tomorrow's standard equipment. This means where today 5 leads are sufficient to provide the standard mirror adjustment and heating, up to 19 leads will be necessary, which can easily become a problem as the hollow spindle of the mirror joint has a limited capacity. Figure 2 shows a typical case for the maximum level of mirror equipment, as

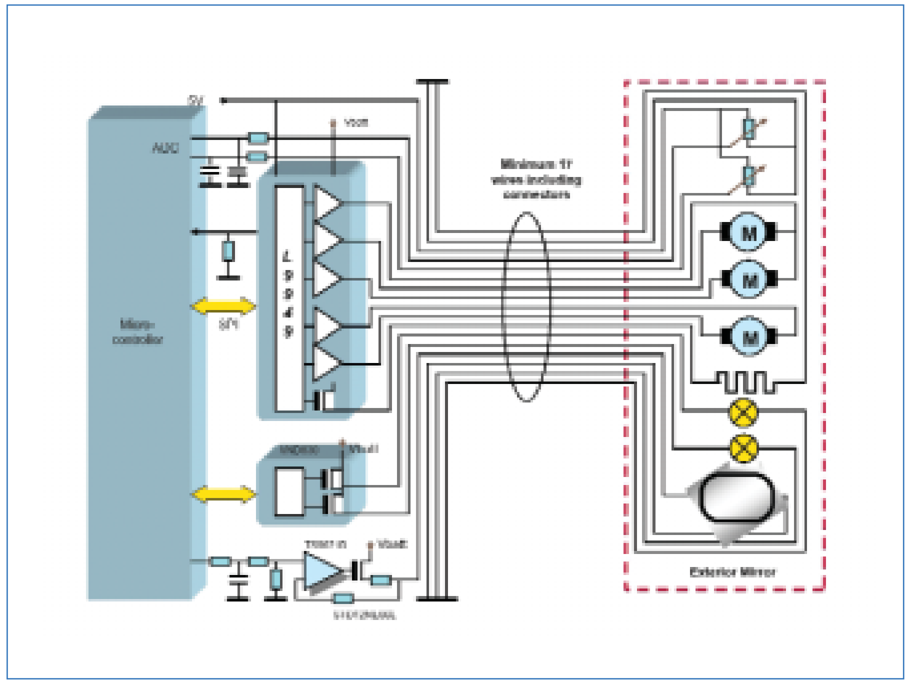


Figure 2. Driving functions for a high end mirror showing significant level of harness complexity.

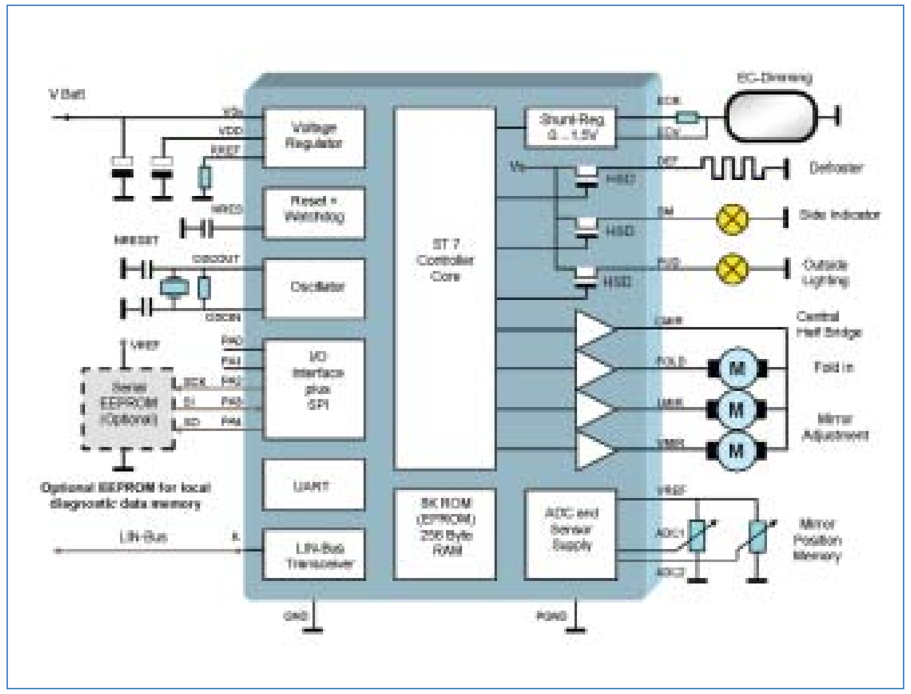


Figure 3. Mirror driver designated as UD13.

well as the effect upon the central door module which naturally also bears the load of multiple options.

Development target- mechatronics

The limited space available in the mirror housing allows only very compactly built electronics, which in the end eliminates a multichip concept with several packages. The way out of this dilemma is the mechatronic mirror concept, in which all signals and actuator functions are already pre-processed within the mirror and only one bus connection and the two supply leads are present. For the target monolithic solution, a 0.6µ BCD (Bipolar Cmos Dmos) technology was selected, which also allows the integration of an "embedded controller", whose architecture is specified according to the ST 7 family from STMicroelectronics. This technology was chosen because it allows the possibility of integrating the power and the digital parts in the same piece of silicon.

The integrated controller monitors and controls all sensors and actuators. All actuator drivers have such a layout that the SMD power package HIQUAD64 can be used without additional cooling, allowing maximum flexibility of mounting. Below, Figure 3 shows the block diagram of the mirror driver designated as UD13.

Table 1 shows the function and loading profile of the mirror actuators. The given values are largely representative for all mirror types and manufacturers.

Control of the mirror motors

The UD13 contains four half-bridges for the control of the motors for the mirror adjustment as well as the folding in of the mirror. Each half bridge is separately controllable from the controller so that simultaneous operation is also possible. The central half bridge, and also the half bridge branch for the fold in motor offers a 200mOhm per transistor (25°C) and is hence capable of driving all known motors with very low power dissipation. In order to safe the otherwise normally used mechanical end switches, the central half bridge allows a bi-directional current measurement with which the blocking of the motor can be detected. The current level can be read out from the controller over the ADC.

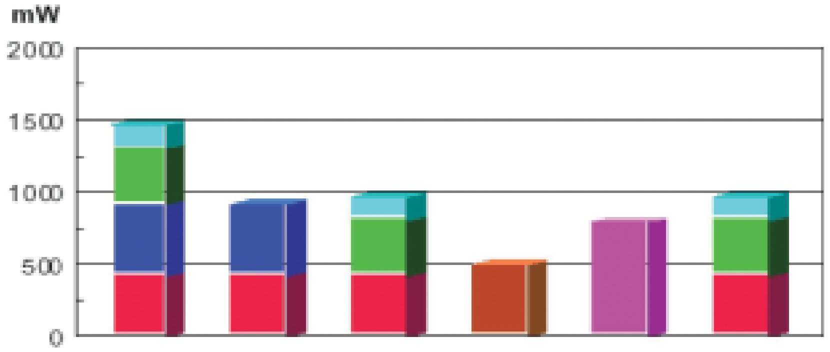
Consideration of the power dissipation

The mirror driver U13 has a total of nine actuator drivers as well as a voltage regulator and the position sensor supply. All drivers in active operation generate a power dissipation, which in total (taking into account the package, ambient temperature and heat removal

AUTOMOTIVE ELECTRONICS: PART II

Function	Load	Load Behaviour	Voltage	Peak Current	Working Current	Typical Operating Time
EC-Control	Chemical Substance	Capacitive & Resistive	0...1,5V 6 Bit DAC	150/350 mA	75 /150 mA	Continuous
Heating	Resistance	Copper Lead or PTC	Vbatt	2,5 A	2,5 A (R) 1,5 A (PTC)	Continuous
Side Indicator	5/10W Lamp	PTC	Vbatt	5A	0,4/0,8A	Continuous (2 Hz PWM)
Exterior Lamp	10W Lamp	PTC	Vbatt	5 A 10 ms	0,8A	up to 30s
Fold in	DC-Motor	Resistive-Inductive	V batt	3 A	0,8A	up to 10s
Central Half Bridge	DC-Motor	Resistive-Inductive	V batt	3 A	0,8A	up to 10s
Adjustment	DC-Motor	Resistive-Inductive	Vbatt	500 mA	250 mA	up to 10s
Mirror Memory	Potentiometer	Resistance 1 kOhm	5V	5 mA	5 mA	Software dependant

Table 1. Function and loading profile of the mirror actuators.



Actuator Priority	EC-Driving	Defroster	Side Indicator	Outside Lamp	Fold in	Adjustment
EC-Driving	420	420	420			420
Defroster	500	500				
Side Ind. (10W)	390		390			390
Outside Lamp				500		
Fold in					800	
Adjustment	160		160			160
Total (mW)	1470	920	970	500	800	970

Figure 4. Maximum expected power dissipation for simultaneous operation of several actuators.

possibilities) may not exceed a specific limit. This limit was set at 1.5 watts to provide the supplier who has to assemble the device in the board with maximum flexibility in his mounting and wiring needs. It also must be considered that not all actuators must work simultaneously. A scenario has therefore been worked out that shows which actuators are given priority under which circumstances. Whether less important actuators are blocked for a short period by targeted activation of specific functions is an exclusive decision of the system developer implemented by means of the software. For this purpose the chip informs the controller of the current junction temperature. If the thermal reserves are sufficiently high, which is usually the case, there are no resulting limitations. Should, through particular operating conditions, a higher power dissipation briefly occur, this will still have no effect as the thermal impedance of the HIQUAD64 package and is still better than 15°C/W after one minute.

The following bar diagram in below Figure 4, shows the maximum expected power dissipation for simultaneous operation of several actuators. It represents, for each actuator:

- which should be activated with priority
- which further actuators may also be activated
- which can be shut off for a specific time

As an example, the turn indicator is chosen. Should this function be activated and the chip temperature is in a limit range, it is no problem to shortly turn off the mirror heating as its thermal time constant completely bridges this interruption.

Considerations for chip technology

UD13 is designed in BCD5. What makes this technology uniquely important is that the signal section density reaches a level where it is economically feasible to integrate an 8-bit microcomputer core and peripheral circuits on a single smart power chip. A circuit like this is much more than a micro with some high power I/Os. Because it is based on a 40V technology, a BCD5 chip can operate directly from a 40V supply, deliver several Amperes output current (limited only by the package) and function at a junction temperature up to 150 Celsius, which is the point where on-chip protection intervenes. UD13 includes a voltage regulator, line interface, power actuators, a micro (core and peripherals) and memories (RAM/EPROM).

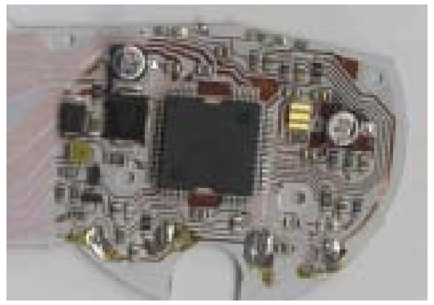


Figure 5. PC-board of mechatronic mirror. Smart power chip is in center position.

Figure 6. Housing shell for motors and PC-board

The technology chosen for the mirror driver chip is a "Mixed Signal + Power Process" solution, which is designated as BCD5 at STMicroelectronics. It offers a comprehensive spectrum of components from analog to digital functions including program memory and power drivers.

The UD013 concept is tightly linked to the mechatronic concept. Mechatronics was born with the goal to combine mechanics and electronics Mechatronics combines application and system relevant functions: actuators, sensors, data handling and control, into a single functional and mechanical unit. The objective of mechatronics is to increase quality and combine it with improved functionality and reduced costs. It requires a simultaneous and unprejudiced design process, evaluation of all technologies, materials and processes and a willingness to build new production structures from the separated production lines of today.

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Automotive & Industrial Applications

High Performance Analog Solutions from Linear Technology

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

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

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

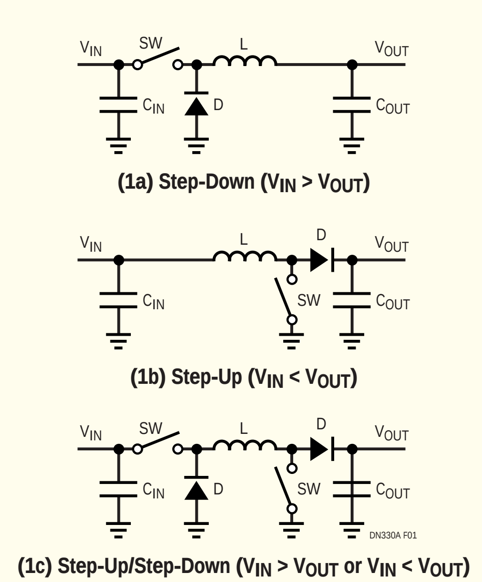

Figure 1. The LT3433 Merges the Elements of Step-Up and Step-Down DC/DC Converters

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

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

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

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

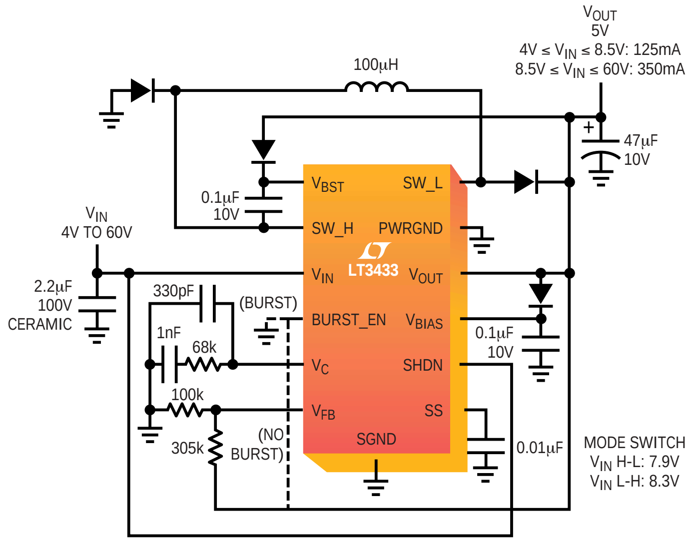

Figure 2. 4V to 60V input to 5V DC/DC Converter

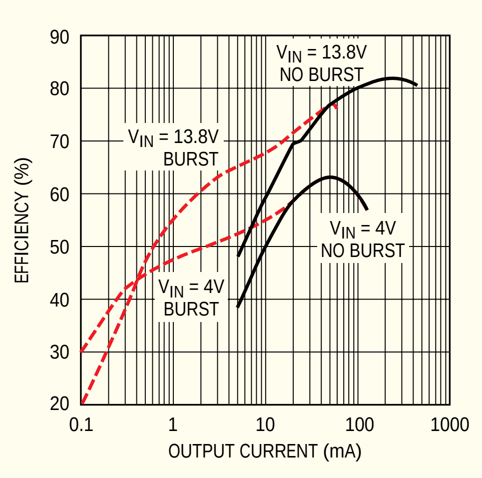

Figure 3. 4V to 60V Input to 5V Conversion Efficiency

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

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

Conclusion

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

www.linear.com

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

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

HIGHLIGHTS

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

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

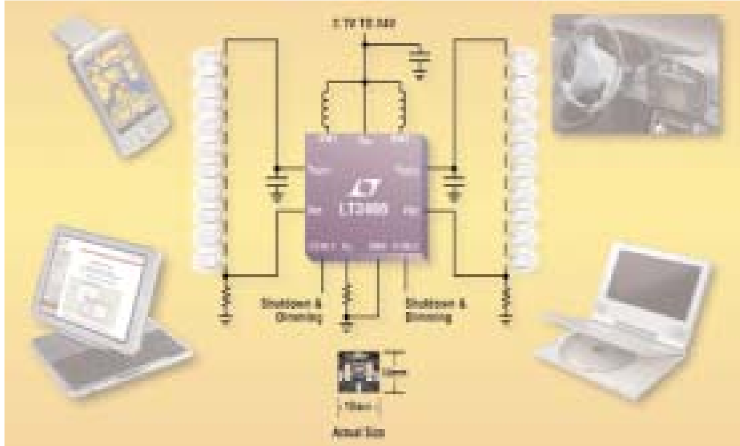

Figure 4. Dual Full Function White LED Step-Up Converter with Built-In Schottky Diodes

Low Supply Currents for "Always-On" Systems

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

Design Options for Automotive Motor Controls

Monolithic IC design for lower current applications

The choices that motor control designers have for the power control portion of brush dc motors have never been better. Brush dc motors are the predominant motor technology in vehicles. With a high-end vehicle having 60 or more motors, a one-size fits all approach does not work.

By Francoise Vareilhias and Lonne Mays, Freescale

With the ability to integrate more efficient power MOSFETs with extensive control circuitry within a sophisticated power integrated circuit (IC) process, such as Freescale's SMARTMOS process, and more efficient power packages with sufficient pinouts for a variety of inputs and outputs, today's IC designers can simplify the motor control system-level design for many different automotive applications.

Issues for the control portion include protection, diagnostics and communications. Issues for the power switching devices include on-resistance, thermal impedance, and power dissipation. The right technology for a specific fractional horsepower motor depends on the motor, desired features, and the network, if appropriate, in which the motor operates.

Multiple Output High-side and Low-side Switches

For lower current applications several power MOSFETs and the control circuitry can be integrated into a single integrated circuit (IC) to control motors and other loads. For example, the MC33880 is an eight-output hardware configurable high-side and/or low-side switch with 8-bit serial input control. Two of the outputs (IN5 and IN6) may be controlled directly by a microprocessor for pulse width modulated (PWM) applications. The circuit controls various inductive loads such as motors or solenoids or incandescent loads by directly interfacing with a microcontroller. Monitoring and protection features include very low standby currents, cascade fault reporting, output-specific diagnostics, and independent shutdown of output. Figure 1 shows two simplified application circuits for the 8-output switch where the outputs control motors, solenoids and lamps.

The circuit is designed to operate between typical automotive voltage extremes of 5.5 V minimum to 24.5 V maximum. It has output voltage clamp

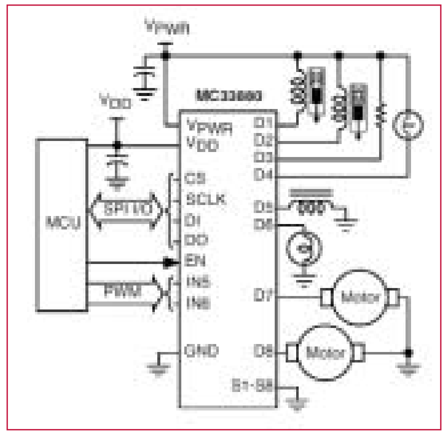

Figure 1a. Two low-side switched (single direction) motors could be small fan motors in a seat cooling and heating distribution system.

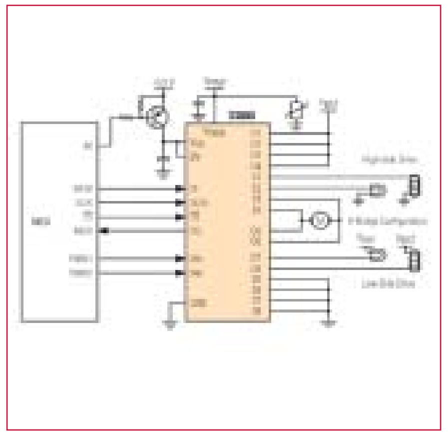

Figure 1b. The reversible motor could be a power antenna or a headlamp wiper or headlamp aiming motor.

of +45 V (typical) for the low-side drive and -20 V (typical) for the high-side drive) during inductive switching.

Fault protection circuitry includes: independent overtemperature protection, short circuit detection and current limit with automatic retry, internal reverse battery protection on VPWR. In addition, loss of ground or supply voltage will not energize the loads or damage the IC. The 8-Bit (4-pin) serial peripheral interface (SPI) that connects the 8 output switches to an MCU for control and fault reporting is 3.3 V/ 5.0 V compatible.

Each of the eight MOSFETs has an typical on-resistance of 0.55 ohms at 25°C and each output is current limited (0.8 A to 2.0 A) to drive incandescent lamps. The circuit draws a maximum 5.0 µA standby current at 13 V up to 95°C. Since, the on-resistance of the MOSFETs have an inherent positive temperature coefficient, all outputs can be tied together providing balanced current sharing.

Packaging for the eight-output hardware configurable high-side/low-side switch is either a 28- or 32-pin plastic package providing thermal capability of 94∞C/W or 70∞C/W, respectively. The 32-pin SOIC has pins 8, 9, 24, and 25 grounded for improved thermal performance.

Dual High-side Switch with External Low-side FETs

For higher current applications where the dc motor must operate in both forward and reverse direction, a four MOSFET H-bridge with lower on-resistance is required. One common partitioning scheme integrates only the upper legs of the H-bridge, the high side switches, into the IC with the control circuitry.

For example, the MC33486 integrates two 15 milliohm N-channel power MOSFETs with their associated control circuitry and additional circuitry for controlling the external low-side switches. The dual high side switch for H-bridge (DHSB) is designed to monitor the two low side switches for H-bridge control of an automotive DC-motor. It can be directly interfaced with a microcontroller for control and diagnostic functions, is

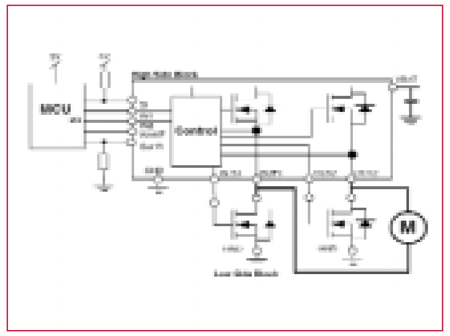

Figure 2. A dual high-side switch for automotive motor control applications, such as the MC33486 uses two external MOSFETs to complete the H-bridge motor control configuration.

PWM capable from DC to 30 KHz and has a self-adjusted switching speed for minimizing electromagnetic emission.

Each of the 2 high-side switches is protected against short to ground and load shorts, and has over temperature detection with hysteresis. Circuitry includes a current recopy feature for the high-side switches to monitor the load current. The control circuitry also has an overvoltage detector which turns off the bridge and protects the load in case of the battery voltage exceeding 28V. The low side control circuitry drives the 2 external low-side switches in the H-bridge and provides short circuit protection. This circuitry, in combination with the high-side protection, fully protects the H-bridge from shorted loads, shorts to battery voltage and shorts to ground.

THE DHSB offers a very low quiescent current in standby mode and can control 10 Amps nominal DC current and handle up to 35 Amps maximum peak current. The device is designed to operate from 8 to 28V but can withstand DC voltages from -0.3V to 40V. It incorporates overvoltage detection and switches off when the battery voltage exceeds 28V.

Both the internal high-side switches and the external low-side switches are protected from overcurrent and are designed for operating junction temperatures from - 40∞C to 150∞C. The standby mode, implemented by the Wake pin, reduces the standby current to less than

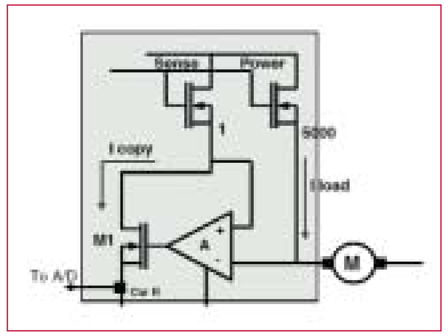

Figure 3. Current recopy in high-side switch for current sensing. The external resistor is not in series with the high current path, so it does not contribute to power losses.

10 _A. A common diagnostic output (St) provides status for both channels.

Packaging for the dual high-side switch is a 20-pin HSOP with 5∞C/W thermal resistance, junction to ambient. This measurement is made with the DHSB mounted on dual-side printed circuit board with 70_m copper thickness and 10cm2 copper heat sink (2.5 cm2 on top side and 7.5 cm2 on the bottom side). The junction-to-case thermal resistance is 2∞C/W.

One of the important design aspects of integrated dual MOSFETs is the use of a current recopy feature that provides a current mirror with the ratio of 1/3700 of the high side output current. This eliminates the additional losses that typically occur when a low value series resistor is placed in the high current path to the motor to determine the current level. However, as shown in Figure 3, it still requires an external resistor connected to the Cur R pin of the mirror MOSFET and then tied to an MCU A/D input for analog voltage measurement. The Cur R pin is internally clamped (Vclst) to protect the MCU A/D input. If a ground shift occurs between the MCU and the DHSS, the amplifier will adapt its output to maintain the same current copy. The shift has to be between +/- 1V.

Monolithic H-Bridge

All of the H-bridge MOSFETs and the control circuitry can be integrated into a single package with a monolithic IC for lower current applications. For example,

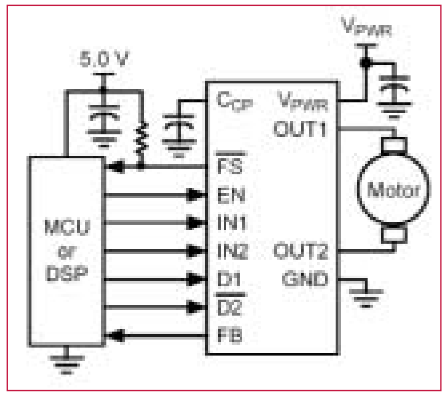

Figure 4. The monolithic H-Bridge MC33887, considerably reduces the number of external components to provide forward and reverse control for a brush dc motor. This simplified application only shows 2 additional passive components.

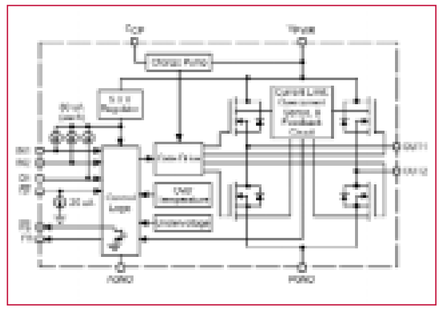

Figure 5. Internal block diagram of the MC33887, a monolithic H-Bridge with a Sleep Mode feature.

the MC33887 is a monolithic H-bridge designed for fractional horsepower DC-motor and bi-directional thrust solenoid control. The application circuit in Figure 4 shows the monolithic H-bridge controlling a DC motor, such as a power door lock. The IC has a sleep-mode feature and incorporates internal control logic, charge pump, gate drive, and four 150-milliohm (typical) MOSFETs. It is able to control continuous inductive DC load currents of 6.0 A.

Referring to Figure 5, the output loads can be PWM controlled at frequencies up to 10 kHz through the internal logic and gate drive circuitry. An output current monitoring circuit, similar to the approach shown in Figure 3 but fully contained within the chip, provides a proportional (1/375th) feedback current output for the microcontroller to monitor the output current and provide closed-loop control.

The fault status output indicates undervoltage, overcurrent, and overtemperature conditions. Two independent inputs provide polarity control of the two half-bridge totem-pole outputs for forward and reverse operation for the motor. An enable (EN) pin is used to place the circuit in a power-conserving sleep mode reducing the current draw (in standby) of 20 mA max to less than 50_A.

Other operational features of the monolithic H-bridge include: speed, torque, dynamic breaking, and closed-loop control. The amount of integration provided by the circuitry requires only 7 additional components (6 capacitors and 1 resistor) in the typical application.

Feature	8-Output Switch	Dual High Side Switch	Monolithic H-Bridge
On-resistance (each switch, max)	850 m_	15 m_	120m_ (typ)
Nominal current	0.4A	10A	5A
Max current	2A	35A	7A
Individual temperature sensing	yes	HS only	yes
Over current detection	yes	yes	yes
Over voltage detection	yes	yes	yes
Fault status	yes	yes	yes
PWM control	2 outputs	<30 kHz	<10 kHz
Package (highest pin count)	32 (70°C/W)	N/A	20 (5°C/W)
Package (lowest pin count)	28 (94°C/W)	20 (5°C/W)	54 (12°C/W)

Table 1. Summary of key features.

Packaging for the fully integrated H-bridge and its associated junction to board thermal resistance can be a 20-pin HSOP (5∞C/W), 44-pin QFN (18∞C/W) or 54-pin SO-EP (12∞C/W).

A summary that compares key features, including packaging aspects, of the three different architectures that have been presented is shown in Table 1. Fault protection and diagnostics are essential features of these types of devices, although how they are implemented can vary.

The motors controls that have been presented were either directly connected to the MCU (MC33887 and MC33486) or used a serial peripheral interface (MC33880). Requirements to connect to CAN and LIN buses are becoming common in more recent motor control applications.

Choose Wisely

While the choice of motor controls is ultimately up to the system design engineer, based on the analysis that goes into designing a motor control IC, the IC supplier can provide assistance that avoids choosing an IC that may not be the best choice for a particular application. Evaluations of the performance of the IC during the development and qualification phases can involve evaluating a variety of motors and applications. In some cases, however, the motor control circuitry could have been specifically designed with only one intended application and the data sheet simply suggests additional applications.

Application concerns such as amount of heatsinking, electromagnetic interference and availability of a reference design are typically discussion points with marketing or application engineers. Additional data not found in the data sheet that is available to support a customer's design approach is frequently a part of the IC qualification package. These are just of few of the additional options available to make future automotive motor control applications easier, quicker and more trouble-free.

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Off-Board Navigation

Bringing low cost navigation to the motorist

Only optimised power consumption together with power management on chip and systems level allows applications like this one. If we play in the automotive world the luxury accessories can only be efficient if they don't reduce the economic aspects.

By Stuart Cording, National Semiconductor

If given the choice, I am sure that everyone would take the option of having a GPS navigation system in their vehicle. The amount of time when travelling that can be saved, and the quantity of frustration when lost that can be relieved can be considered too valuable to be turned down. But, unfortunately, the price tag that this level of comfort commands is just too much for most people. Even the latest range of software and GPS add-ons for the various PDA platforms have still not brought quality navigation aids to the masses. So for now, at least, we must rely on our sense of direction, the support of a fellow passenger with whatever maps are to hand and the quality of the local signs to navigate our way through the unknown.

If we look at the design of a typical built-in or aftermarket GPS Navigation System (Figure 1), we can see the building blocks are made up from several costly components. Firstly there is the processor, which is typically of a 32-bit type allowing the complex routing algorithms to be calculated quickly and efficiently to provide a quality user experience. Next comes a colour display to shows the map of the current location, and possibly a touch screen for user input. A GPS module is of course a must, as is the storage medium for holding the database of maps, locations and points of interest. One large cost which is not shown here is the license fee for the map itself which is the reason why new CD-ROMs for these systems are so costly, and why most motorists do not bother to keep their system up to date. The navigation system in it's current form has more or less remained the same since it was first designed, but with data being available readily from the internet these days, a GSM module would also provide the perfect way to enhance the features of the systems to provide accurate traffic information, points-of-interest, hotel booking features and more. Unfortunately, the cost of doing so remains prohibitive

Ideally, if one of these systems is built into the car, the user could just use their own mobile phone fitted into a cradle to provide that data link. Unfortunately, adding a cradle for a GSM mobile phone is also too complicated for the mass market due to the large number of different and ever changing connectors used by the different phone manufacturers. The RDS system used by car radios can provide traffic data for use by navigation systems, but these are always limited to systems that are embedded into the cars dashboard.

In order to bring navigation systems to the broad market, both as an option when purchasing a new car and as a product for the aftermarket, the cost of the system needs to be brought down considerably. It needs to based on a low-cost microcontroller, whilst bringing the user a broad range of valuable services such as traffic-avoidance routing and traffic-flow updates during the journey. The display of a colour map can removed, as it is not really required, and replaced with high quality verbal direction commands and text based directions from a simple and value for money monochrome type display. And we can also do away with the local CD-ROM or Flash memory map information and instead use a remote server to calculate

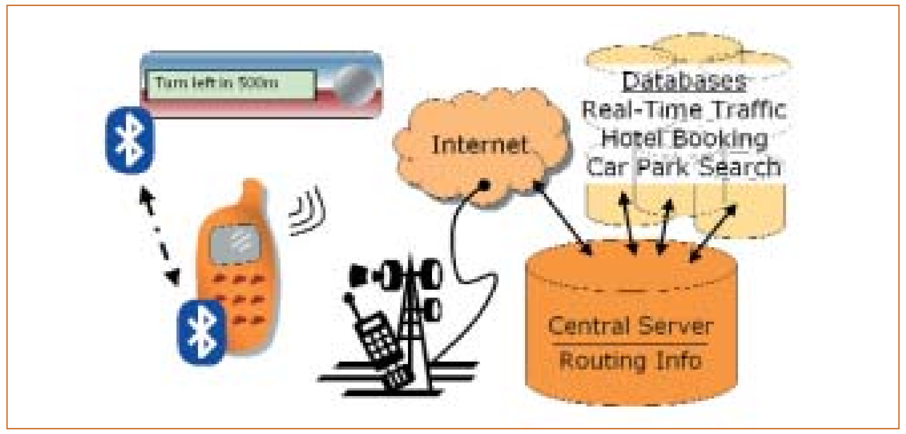

Figure1. Aftermarket GPS Navigation System

the routing for us, using the latest mapping information and a knowledge of road usage according to time of day, allowing users access to the most optimal route. Such a hardware platform is shown in Figure 2. Here we can see that, rather than integrating a GSM module to provide the required data link to the internet, and the associated problems of trying to implement a way of the user using a SIM card for call billing, a Bluetooth interface has been added using the LMX5252 radio. Bluetooth provides GPS Navigation System developers with the most cost effective, shortest time to market and most interoperable solution to this low cost GPS System.

By making use of the Dial-Up Networking Profile (DUNP) of Bluetooth, a GPS Navigation System can use any available local Bluetooth enabled mobile phone to access internet based traffic information. The web-based traffic information could be provided through partnerships with automobile associations that already provide such information (e.g. ADAC in Germany) or through web-sites that are created specifically for the purpose by the hardware manufacturer (see Figure 3). Due to the guaranteed interoperability of the Bluetooth protocol and profiles, the GPS system developer can leave it up to the end consumer to choose how the navigation system will access the internet based traffic information by choosing an appropriate Bluetooth enabled mobile phone and GSM service provider.

National Semiconductors CP3000 family of Connectivity Processors form the perfect platform to Bluetooth enable any current GPS system in such a manner, be it embedded into a car dashboard, or a handheld system. These devices also provide many additional connectivity interfaces that give additional flexibility or provide a means to develop the product further with time. In addition the large addressing capability of the processor can provide ample off-chip memory for immediate storage of downloaded data and traffic information databases.

The CP3000 Connectivity Processors are driven by the powerful, third generation CR16C CompactRISC processor core – a 16-bit RISC like processor. Because of its delicate blend of RISC instructions, keeping code size small, and CISC type instructions, allowing non-interruptible bit manipulation, push/pop and load/store instructions, the CR16C is quite capable of supporting the Bluetooth interface, including profiles, and handling complex applications in small amounts of memory. The ability to store and retrieve up to 8 internal core registers to and from the stack quickly using a single instruction makes RTOS's easier to port, and ensures fast and effective context switches. The three-stage pipeline performs the fetch, decode and execution of instructions, allowing a peak throughput of one instruction per clock cycle. Despite being a 16-bit architecture, with mostly 16-bit general-purpose registers, it can also be seen that the internal data path of the core is 32 bits wide. This allows 32-bit data to be loaded into the four

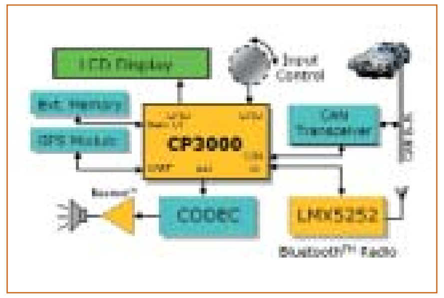

Figure 2. Complex Info input.

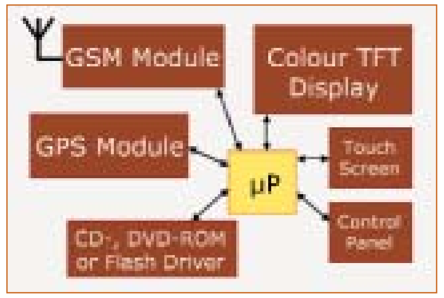

Figure 3. The full Advantage of System Design.

general-purpose core registers that are 32 bits wide, enhancing the cores performance when using relocatable code. With the efficient Index Addressing mode, a mixture of memory types can be used to expand the generous 256kbytes of on-chip flash memory and 10kbytes of on-chip SRAM. The on-chip flash memory also supports single cycle read accesses at system clock frequencies of up to 24MHz.

The CAN interface of the CP3000 communications processor is suitable for navigation systems built into the dashboard of a car. This would allow automotive manufacturers to integrate the GPS system through the CP3BT onto a CAN bus to share data and issue and accept control requests. Additionally, the system could use dashboard displays and control buttons already within the vehicle as its human-machine interface (HMI). The alternative interface for aftermarket GPS systems is the USB interface. This would give consumers the flexibility to connect the GPS system to a laptop or desktop PC, which commonly have USB but no Bluetooth interface at present, whilst still being able to make use of the Bluetooth capability of their mobile phone for traffic information whilst on the move. The audio from the system could also be rerouted through to the audio system that already resides in the vehicle, temporarily muting the radio as it does so.

Because of Bluetooth's high level of flexibility, support of many different connections with many types of electronic products, and the guaranteed interoperability of the protocol, it has to be the interface of choice to extend the capabilities of navigation systems. The CP3000 family of connectivity processors is available to make that choice easier.

www.national.com/appomfp/cp3000

AUTOMOTIVE ELECTRONICS: PART II

Lighting up Automotive Instrument Panels

Wide range of features requested from switching regulators

Depending on where the electronic system operates on the automotive power bus, it is frequently required to perform under very stringent power requirements. These include load-dump, cold-crank, very low power consumption at light loads, and low-noise operation. Additionally, solution footprints are generally required to be very compact and thermally efficient.

By Tony Armstrong, Linear Technology Corporation

Over the past decade, the electronics content in automobiles has made quantum leaps in both the quantities and sophistication of electronic control, telematics and entertainment systems. With the recent introduction of electric and electric/hybrid vehicles, the electronics content extends even further into propulsion systems. On one end of the automotive spectrum, many historically mechanical systems such as throttle control, braking, and suspension control are now being both controlled and optimized by electronic systems. On the other end, entertainment and wireless navigation are fast becoming standard equipment on non-luxury automobiles.

Wide operating voltage requirements coupled with large transient voltages and large temperature excursions combine to make life tough on electronic systems. What's more, the performance requirements continue to become even tougher. Multiple supply voltages are required for different portions of the system. A typical Navigation system can have six or more different supplies including 8V, 5V, 3.3V, 2.5V, 1.8V, and 1.5V. At the same time, as the number of components increases, the space available continues to shrink. Therefore, efficiency becomes more critical because of the space limitations and temperature requirements. At low output voltages and even with moderate current levels, above a few hundred milliamps, it is no longer practical to simply use a linear regulator to generate these system voltages. As a result, over the last several years, primarily due to thermal constraints, switching regulators have been replacing linear regulators. The benefits of a switcher, including the increased efficiency and smaller footprint, outweigh the additional complexity and EMI considerations.

Virtually all luxury automobiles come with in-dash audio, visual and navigational systems, along with the traditional instrument panel. All of these systems need some kind of backlighting to allow for readability in all kinds of ambient light conditions. White LEDs are now commonly used to provide backlighting. In these applications, the white LEDs must be powered by a constant current to guarantee consistent light intensity and uniform brightness. Figure 1 shows the LT3466 powering 50 (two banks of 25) white LEDs from a 12V input supply. The circuit is configured as a voltage tripler to produce output voltages in excess of 90V. This allows a string of 25 LEDs to be connected at each output, resulting in constant current and uniform brightness.

The device is configured to operate at a 2MHz switching frequency by the choice of the 20.5kW resistor. This ensures that the radiated switching noise falls outside the AM radio band. High switching frequency also allows the use of low-profile inductors and surface mount capacitors. Furthermore, in this application the LT3466 delivers 2.4W output power with 83% efficiency. The thermally enhanced 3mm x 3mm DFN packaging (with exposed pad) of theLT3466 enables it to drive as many as 50 white LEDs from a 12V input supply. For optimum performance the inductors can be powered directly from the battery, whereas the LT3466 should be driven from an existing 3.3V rail.

The LT3466 has two independent, but identical, step-up converters capable of driving asymmetrical LED strings. The step-up converters are designed to drive the series connected LEDs with a constant current, thus ensuring uniform brightness and eliminating the need for ballast resistors. It also incorporates internal 44V power switches and Schottky diodes. Switch current limit is guaranteed to be greater than 320mA over the full operating temperature range. A low, 200mV, high accuracy (±4%) reference voltage is provided to program the LED current.

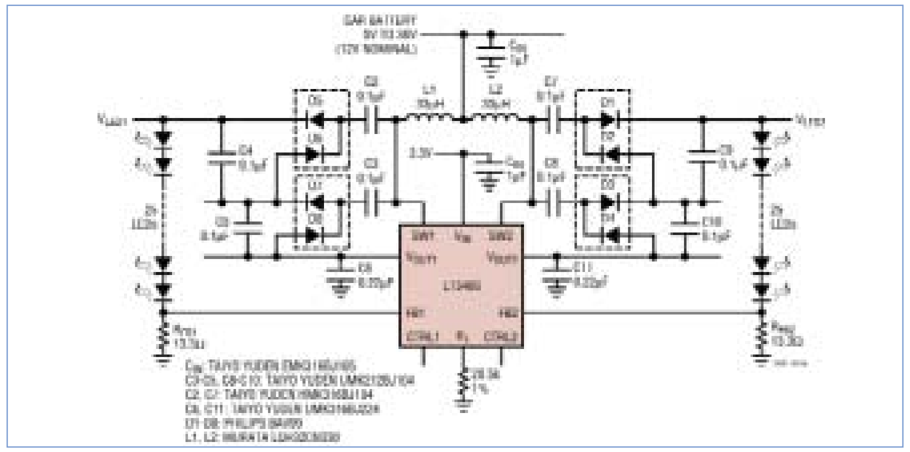

Figure 1. 50 white LEDs powered by 12V input using low profile surface-mount components.

The step-up converters use a current mode topology to provide excellent line and load transient response. Internal feedback loop compensation of the LT3466 allows the use of small ceramic capacitors on the output. The built-in over-voltage protection circuit clamps the output to either converter to 42V if the LED string connected to that output fails open-circuited. Internal soft start is provided for each step-up converter during start-up.

The switching frequency of the LT3466 can be programmed over a 200kHz to 2MHz range by means of a single resistor from the RT pin to ground. Its 2.7V to 24V input voltage range makes it ideal for a wide range of applications. The device features independent shutdown and dimming control of two LED string. The current in each LED string can be shut off by pulling the respective control (CTRL1 or CTRL2) pin voltage below 50mV. Dimming of each LED string is achieved by applying a DC voltage to its respective control pin. When both CTRL1 and CTRL2 pin voltages are pulled below 50mV, the devices enters total shutdown.

The LT3466 is a dual white LED driver with integrated switches, Schottky diodes and a space saving 3mm x 3mm DFN package. The wide operating voltage range and high frequency capability of the LT3466 enables it to meet the backlighting needs for automotive instrument panels and car radio displays. Features like the internal soft start, open LED protection and internal loop compensation reduce the number of external components, thus reducing the overall cost and size of the white LED driver circuit.

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5V Eighth-Brick DC/DC Converters at 92%

Artesyn Technologies has launched two new 5V single output eighth-brick DC/DC converters which provide industry-leading conversion efficiencies of 92%. The new converters are available with current ratings of 10 and 15A now, and 20A in the near future, enabling designers to choose the most cost-effective model for their particular application.

Both converters feature a wide input voltage range of 36 to 75VDC and generate a single 5V isolated output, adjustable over the range 4 to 5.5V via a single external resistor. The converters feature remote sense and remote on/off facilities as standard, and have a typical start-up time of 10ms when driving a resistive load. Synchronous rectification and advanced processor control of both primary and secondary-side circuitry maximise efficiency and transient response.

Artesyn's 5V eighth-brick converters are designed for operation over an ambient temperature range of -40 to +85_C without a heatsink. Their ultra low profile construction minimises air-flow disruption and makes them suitable for both convection cooled and forced air environments. The converters feature under-voltage lockout, as well as non-latching over-voltage protection, and are also protected against short-circuit and over-temperature conditions, with automatic recovery. The converters carry a full set of international safety approvals, including EN60950 VDE and UL/cUL60950.

www.artesyn.com

Off-Line IC Family for Efficient Power Supplies

Power Integrations announced today the expansion of TinySwitch-II, the company's widely used low power family of off-line switcher ICs. The two new device family members, TNY263 and TNY265, extend the cost effectiveness of the highly integrated, energy efficient, low power IC family.

The TNY263 offers a lower-cost, lower power solution compared to TNY264 for universal input adapters up to 3.7 W or up to 7.5 W for 230 V input open frame designs. The TNY265 provides a cost optimum solution for power levels that fall in between the capabilities of existing TNY264 and TNY266 by addressing universal input adapters up to 5.5 W or up to 11 W for 230 V input open frame supplies.

The TinySwitch-II family integrates a 700 V Power MOSFET, an oscillator with simple on/off control, and current limit and thermal protection circuitry onto a single CMOS chip. Other built-in features include auto-restart for short circuit and open loop fault protection, frequency jittering for low EMI filtering cost, programmable line under-voltage detection, and circuitry to eliminate audible transformer noise. Key parameters are designed with very tight tolerances and negligible temperature variation. The internal switching frequency of 132 kHz reduces transformer size, allowing the use of low cost EF12.6 or EE13 cores.

www.powerint.com/greenroom

www.powerint.com

DIP24 DC-DC Converter

Advanced Power Conversion PLC announces a further enhancement to its broad range of DC-DC converters with the new APC-PEN series.

Providing 2.5 W to 6 W of output power in a low profile DIP24 case, the range offers a working temperature between –40°C and +85°C without derating.

Offered in single or dual output versions, inputs include: 9-18, 18-36, and 36-72 V DC wide input 2:1. For applications requiring a very wide operating voltage range wide input 4:1 versions are available with 9-36 and 18-72 VDC.

A very compact and versatile package the APC-PEN series is similar to the APC-TG range but modified to match industry common pinning. The converters can be supplied in either non conductive black plastic or Nickel Coated Copper and efficiency is up to 81%. Additional features of the range include six sided shielding, isolation of 1500 VDC and the modules are short circuit protected with continuous, automatic restart. Outputs options include: 3.3, 5, 9, 12, 15 and 18 V DC single outputs as well as dual outputs with : +/- 3.3, 5, 9, 12, 15 and 18 V.

www.linear.com

2.25MHz Dual 800mA Synchronous Step-Down DC/DC Converter

Linear Technology announces the LTC3407-2, a dual output, high efficiency, 2.25 MHz synchronous buck regulator that delivers up to 800mA of continuous output current from two separate channels. Using a constant frequency and current mode architecture, the LTC3407-2 operates from an input voltage range of 2.5V to 5.5V making it ideal for single cell Li-Ion, multi-cell alkaline or NiMH applications. The LTC3407-2 can generate two independent output voltages as low as 0.6V, enabling it to power the latest generation of low voltage DSPs and microcontrollers. Its 2.25 MHz switching frequency of keeps switching noise out of critical AM and xDSL frequency bands and allows the use of tiny, low cost ceramic capacitors and inductors less than 1.2mm in height. The LTC3407-2 is the most compact synchronous step-down solution available for dual output voltage rails, with its tiny externals and MSOP-10 and 3mm x 3mm DFN packages.

The LTC3407-2 uses internal switches with an RDS(ON) of only 0.35 Ohms to deliver efficiencies as high as 95%. It utilizes low dropout 100% duty cycle operation for output voltages up to VIN, further extending battery run-time. No load quiescent current is only 40uA (both channels) and <1uA in shutdown, ensuring optimal battery life.

www.linear.com

Power MOSFET Modules

Advanced Power Technology Europe announced the addition of 1000V and 1200V MOSFET modules to the existing product range in SP4 and SP6 packages.

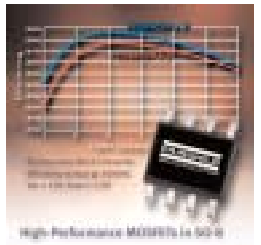
These modules are offered in single switch, Buck, Boost, Dual common source, phase leg and full bridge configurations. Current ratings range from 13A to 160Amps.

Single switch, phase leg and full bridge configurations utilize MOSFETs with high speed intrinsic diodes (FREDFET) for improved diode recovery characteristics and better dV/dt capability. High current single switch modules, with and without a combination of series and parallel diodes, utilize AlN substrates for best thermal characteristics.

The low profile SP4 and SP6 modules exhibit minimum internal parasitic resistance and inductance offering high frequency operation capability. The use of the latest generation PowerMOS 7 1000V and 1200V MOSFETs and FREDFETs allows operating in hard switching mode in the range of 100 kHz to 200 kHz.

www.advancedpower.com

MOSFET Technology Reduces Miller Charge by 35-40%



Fairchild announces its advanced-performance PowerTrench(r) MOSFET process technology that yields exceptionally low values for Miller Charge (Qgd), RDS(on), total gate charge (Qg), and improves gate-drain charge to gate-source charge (Qgd:Qgs) ratio-enhancements that result in superior switching performance and thermal efficiencies when used in synchronous buck applications. The benefits of low Qgd are decreased switching losses and reduced "dead time" for improved regulation. A favorable Qgd:Qgs ratio offers immunity against false gate triggering that result in shoot-through currents between switching MOSFETs when employed as a synchronous rectifier. Low RDS(on) is critical in minimizing conduction losses and low Qg reduces the power consumed to turn the MOSFET on and off each cycle. Two 30V MOSFETs from Fairchild, the FDS6294 and FDS7288N3, exhibit the benefits of this improved fast-switching technology.

With its very low Qgd, the new FDS6294 provides excellent performance in high-frequency, narrow duty cycle switching applications. The extremely low Miller Charge (Qgd) value of 3nC (typical) of the FDS6294 minimizes this transition time, and in conjunction with a low RDS(on) of 11.3m??max, allows the device to offer superior performance to existing solutions. The FDS6294 is available in an SO-8 package.

For more information about these products go to:

- http://www.fairchildsemi.com/pf/FD/FDS6294.html
- http://www.fairchildsemi.com/pf/FD/FDS7288N3.html.

www.fairchildsemi.com

Second–Generation IBIS2SPICE Converter

Intusoft announced the release of its second-generation IBIS-to-SPICE model conversion software. The enhanced program (IBIS2SPICE Converter) offers more power and ease of use than Intusoft's former version released in 1998. The new version supports all 14 IBIS model types, and converts IBIS models up to and including version 3.2.

The converter now uses an updated modeling template, which produces SPICE models that exhibit remarkable accuracy with Intusoft's IsSpice4 simulation kernel. SPICE models are generated for Input, Output, I/O, 3-state, Open-Source, Open-Drain and other I/O structures. Further, the SPICE models can be easily added to the part browser inside Intusoft's ICAP/4 "SpiceNet" design entry system, an integral part of the analog, mixed-signal and mixed-system design automation tool suite.

IBIS2SPICE Converter will be included free of charge with the following software packages: Test Designer, ICAP/4 Professional, ICAP/4Windows Power Deluxe, ICAP/4Windows RF Deluxe and ICAP/4Windows, in Intusoft's upcoming ICAP/4 software release in Q3 of 2004. For Intusoft customers currently on maintenance with any of the above packages, IBIS2SPICE Converter can be downloaded at no charge from the technical support page at: http://www.intusoft.com/support.htm. For all others, a former version is available at no cost from: http://www.intusoft.com/utilities.htm.

www.intusoft.com

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