by **Randy Frank** | Contributing Editor

THE POWER BEHIND THE PERFORMANCE

Vehicle requirements push power semiconductors and ICs to the next level.

While hybrid technology has driven the power electronics content higher on hybrid vehicles, competing propulsion techniques of diesel and internal combustion engine have also required new power semiconductor and IC technologies. New loads from power roof actuators, to charging systems for plug-in hybrids as well as existing high-volume applications in body electronics and other systems continue to challenge suppliers to achieve greater efficiency, more integration, increase reliability, and lower cost. With an increasing number of power supplies and motor and actuator controls, several suppliers are dedicated to meeting the challenges.

Many of the newest systems originate in Europe and are frequently found on high-end vehicles with the most electronics content. For Europe, Frost & Sullivan predicts power semiconductor growth from about 2.2 billion units in 2005 to a little less than 3.6 billion units in 2012[1]. These power semiconductors include MOSFETS, IGBTs and bipolar transistors in discrete power semiconductors and converters, regulators and motor integrated circuits (ICs) in power IC technology. Power semiconductors in safety will increase as a portion of the total from about 32% to almost 45% over this period.

At Convergence 2006 in Detroit, MI, suppliers of power semiconductors, power modules and intelligent power ICs promoted and demonstrated their latest efforts to simplify and improve the power control in automotive systems. Beyond discrete MOSFETs and IGBTs that meet automotive operating temperature range and quality requirements, many products developed specifically for automotive applications include a high degree of integration for additional functionality. The products can be monolithic smart power ICs but more and more are multidie units in IC-type packages all the way up to high-power modules to handle higher power requirements. In addition to or, in some cases, instead of custom products, many companies have embraced an application-specific standard product (ASSP) approach for automotive.

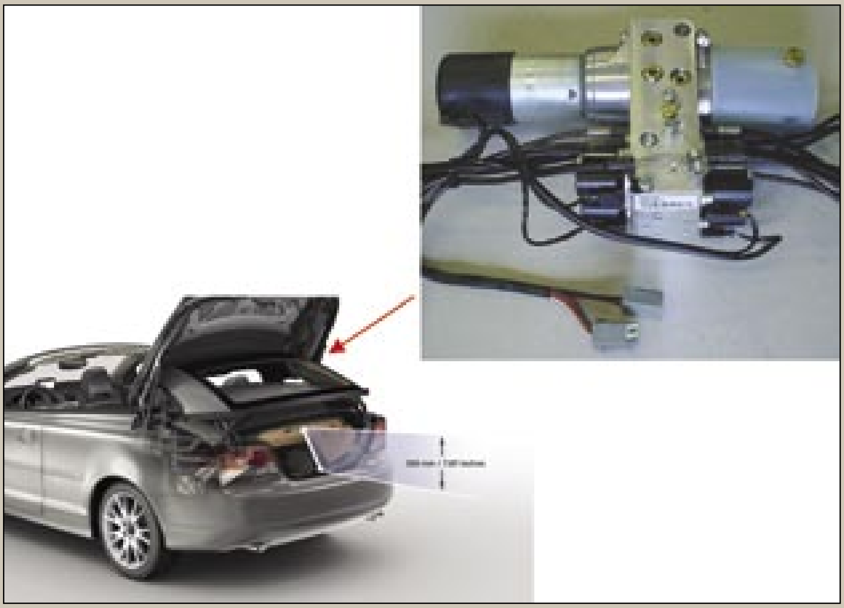

Figure 1. The Volvo C70's folding roof system produced by Webasto uses a combination of hydraulic and power electronics.

POWER REQUIREMENTS PROLIFERATE

The 42 V specification for a next-generation power system was developed based on projections of increasing vehicle loads and power requirements in high-end vehicles. While 42 V systems have seen only limited implementation, the number of vehicle loads has increased. One of the initial driving forces for higher-voltage systems was camless engine technology. Recently, Valeo announced several development contracts with automakers for its camless engine. Using electronic actuation only for the intake valves, a half-camless system, Valeo indicates that the cost of its system in a four-cylinder engine is substantially less than the price premium of a diesel engine over a gasoline engine. Camless technology is projected to provide up to 20% better fuel economy for gasoline engines.

Power requirements and applications continue to increase in body electronics. One example is the power roof assembly in the hardtop convertible Volvo C70. As shown in Figure 1, the hydraulic/electronic system has 11 actuators, four solenoid valves, and a 215 W motor that draws a peak stall current of slightly more than 75 A.

Even vehicle entertainment drives higher power. Class D audio amplification is being used increasingly because of the improved efficiency that pulse-width modulation (PMW) operation provides. While 500 W units are not uncommon, the 2007 Audi S8 has 1,000W Bang & Olufsen stereo system. All of these low voltage vehicle applications require increasingly efficient power MOSFET technology

Perhaps the most common high-power application on today's vehicles is for electric power steering. However, the highest power requirements on vehicles require power modules that combine several discrete power chips and power IC technology. Hybrid electric vehicles (HEVs) require power modules for motor control inverters and dc-dc power supplies. Plug-in hybrids will add an inverter for charging the batteries from a stationary power source while the vehicle is parked.

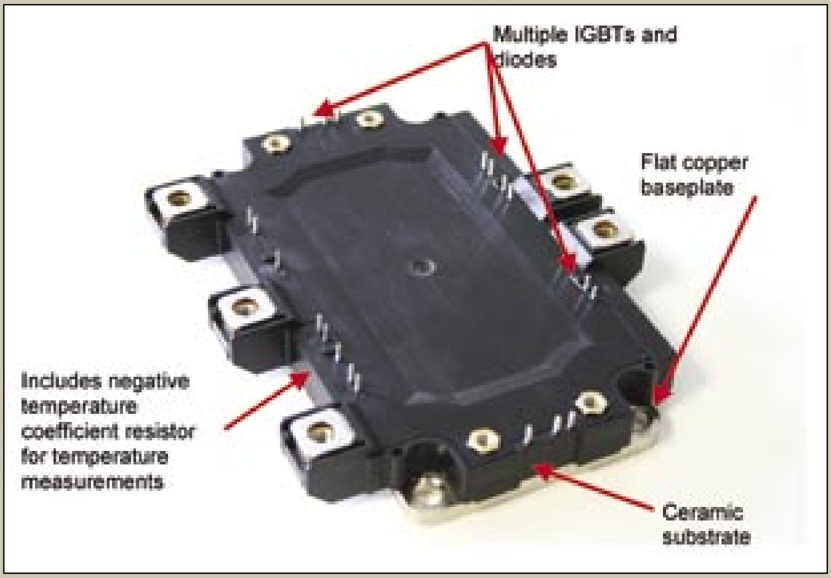

Figure 2. Infineon's HybridPACK1 provides package-level integration for multiple IGBTs and diodes.

VEHICLE APPLICATIONS DRIVE IMPROVED SEMICONDUCTOR TECHNOLOGIES

Infineon Technologies AG's HybridPACK1 and HybridPACK2 address motor control in mild and full HEVs using high-power multidie module technology. The copper baseplate in the HybridPACK1 modules is high-performance direct-bond copper (DBC) technology. Using Trench Fieldstop IGBTs and EmCon diode technology, the silicon uses 30% less area for equivalent output performance, and has 30% Vsat improvement and about 30% lower switching losses. The 9.2 cm x 20.2 cm footprint HybridPACK2 is a six-pack module that delivers 800 A/600 V. The footprint is approximately 25% smaller than current solutions. Pin-finned aluminum-silicon carbide baseplate improves both thermal performance and reliability.

Most vehicles have from 60 to 80 fuses in the fuse/junction box. Lear Corporation employed STMicroelectronics'advanced power management solid-state drivers in its solid-state smart junction box technology (S3JB). The use of the highly integrated ICs instead of fuses and relays provides a 50% to 80% reduction in volume, a 40% to 70% reduction in weight, and a 5% to 20% reduction in systems cost according to Mohamad Zeidan, manager of Electrical Distribution Systems Engineering for Lear.

Fairchild Semiconductor is developing 30/40V MOSFETs and extending its multichip smart power module (SPM) technology to provide the efficiency and high-power density required for EPS applications. The fully molded package uses insulated metal substrate (IMS) technology and can handle up to 200A depending on the thickness of the copper. In general, the company's functional power technology addresses the heat removal, flexibility, performance and size requirements of many automotive applications using multiple-die assembly techniques. For example, the FDMS2380 is a dual-channel unit for transmission control in a PQFN package with three separate heatsink areas and five chips. As shown in Figure 4, the chips include a dual P-channel MOSFET designed specifically for this application, two NDMOS die with integrated recirculating diodes, and a control die for each channel. The MOSFETs are solder attached and the control die are non-conductive epoxy attached to isolate them from the substrate. The unit provides fault protection including thermal shutdown at more than 160 ˚C. In addition, diagnostics in the control chip communicates the status of each driver to the system controller.

As part of its analog product offerings for automotive, Freescale Semiconductor provides power actuation and power management analog/mixed-signal ICs. Products like the MC33289 and the MC33689 demonstrate power control in multichip and monolithic designs. The 33289 is a dual high side switch (DHSS) designed to drive inductive loads such as solenoid valves. A surface-mount 20-pin SOICW, houses two discrete 40 mΩ RDSON MOSFETs plus a separate control chip. The switches can be connected directly to a microcontroller (MCU) for load control and monitoring of the diagnostic output.

Power management chips, dubbed systems base chips (SBC) include voltage regulation, input and output drive circuitry, and, frequently, some sort of physical layer for the communications protocol, such as a CAN or LIN transceiver. The MC33689, an SBC with a LIN transceiver, has a 5 V output with reset and overtemperature pre-warning and shutdown. In addition, it has a single 50 mA and two 150 mA fully protected, high side switches with output clamping for switching inductive or resistive loads.

International Rectifier's IR331x family of high-side intelligent power switches (IPSs) provides accurate current feedback to ±5% at maximum load current over the entire operating temperature range. The IPSs address automotive applications in integrated lighting modules, intelligent glow-plug controls, auxiliary positive temperature coefficient (PTC) heaters for HVAC systems, engine cooling fan drivers and interior fan controllers. The 40 V products have a junction temperature shutdown at 165 ˚C, a current sense ratio from 2800:1 to 8800:1, and on-resistance as low as 7 mΩ.

LIGHTING UP

For vehicle lighting and displays, Linear Technology Corporation is among the companies that provide a variety of products for automotive applications, including LED drivers, LCD bias, video drivers and CCFL backlight

ICs. In addition, the company provides a variety of dc-dc converters for boost and buck applications, some with ratings up to 80 V. For example, the LTC3783 is a current-mode LED driver and boost, flyback and SEPIC controller that provides constant color 3000:1 dimming ratio with true color PWM or 100:1 dimming from analog inputs. The IC can be used in a no RSENSE mode for VDS up to 36 V and drives both an N-channel power MOSFET and an N-channel load PWM switch.

In addition to its Siliconix line of trench power MOSFETs, Vishay International introduced a line of the superbright red LEDs earlier this year targeted for automotive usage. The units meet SAE and ECE color requirements for automotive applications and have luminous intensity ratings of >3000 millilumens (mlm), >3500 mlm and >4000 mlm. Units are

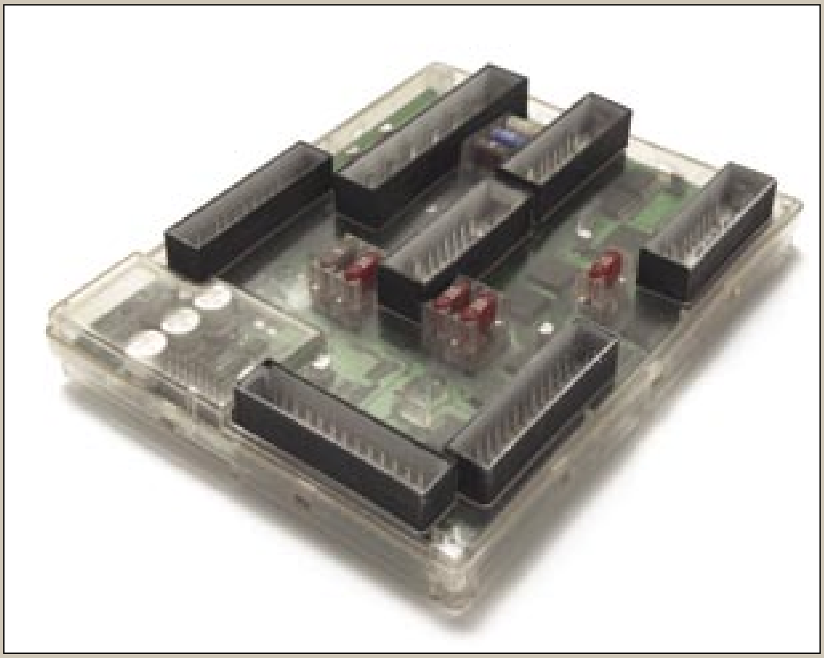

Figure 3. Lear's solid-state smart junction box technology uses only eight fuses and STMicroelectronics smart power IC technology to provide a significant improvement to protecting vehicle wiring circuitry.

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available with a 25 x 68 or 40 x 90 angle of half intensity.

For controlling up to eight lamps, NXP Semiconductors (formerly Philips Semiconductors) developed an IC with eight power switches in one package that allows control of the lighting strategy. Each switch can address up to a 5 A load and has dynamic protection that avoids oversizing wires. Other functions include bulb failure detection, the ability to PWM all channels at various duty cycles, and minimized shoot through by analyzing the plateau values of the switching signal. In addition, slope control on the switched waveform minimizes electromagnetic interference (EMI) to avoid application problems, especially in high functionality body controllers.

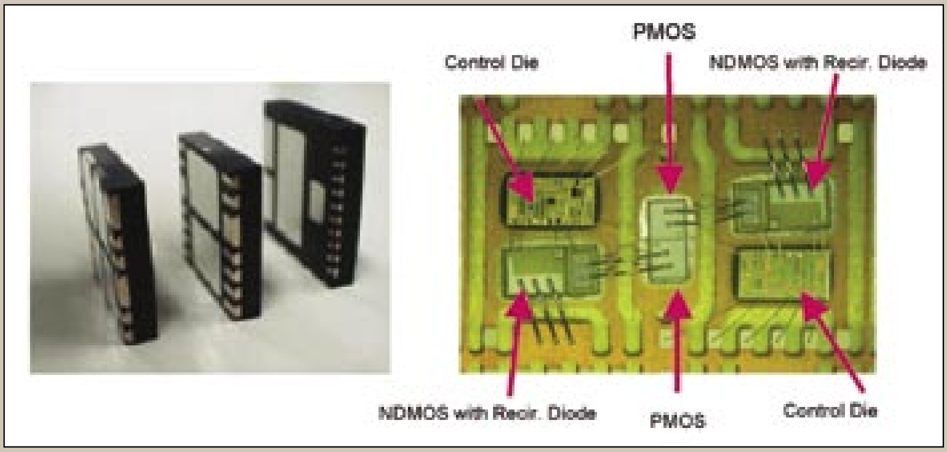

Figure 4. Fairchild Semiconductor's FDMS2380 automotive PWM solenoid driver contains five die in a PQFN package.

Among its automotive capabilities, AMI Semiconductor (AMIS) has a high-voltage 0.35 µm CMOS-based process that operates at up to 80V. One of AMIS' newer products using its I2T technology is an octal high-side driver. The AMIS-39100 ASSP integrates eight driver outputs (275 mA continuous per output), protection, microcontroller interface, charge pump, and diagnostics into single SO-28 package. The unit is designed to control transistor gates, relays and LEDs in automotive applications.

VEHICLE POWER SUPPLIES

In addition to microcontrollers. power MOSFETs, and other automotive semiconductors, Renesas produces ASSPs for automotive applications. The company's M59400FP power supply IC for body electronics applications has built-in power-on reset circuit, watchdog timer circuit, two-channel relay driver function, and 5 V constant-voltage power supply monitoring circuit. The unit has an output drive current of 300 mA max.

Toshiba uses bipolar and BiCD processes to provide motor controllers and drivers for dc and sensorless brushless dc motor control as well as linear and switching system power supplies in body and chassis control systems.

In addition to MOSFETs and IGBTs, ON Semiconductor provides switching regulators, LDOs and drivers for automotive applications.

ELMOS Semiconductor AG develops and manufactures customer-specific integrated circuits (ASICs) in analog/mixed signal CMOS technology including special high-voltage circuits for automotive application. Two new switching regulator families, developed in high-voltage CMOS technology simplify the transition between the different electrical system voltages (i.e., 14 V, 28 V, 42 V). The company's dc-dc converter is used for daytime running lights and multiphase boosters. In addition, ELMOS and Freescale Semiconductor have established a strategic alliance and plan to co-develop ASSPs that combine Freescale's high-performance 16-bit MCU architectures with ELMOS' high-voltage CMOS ASSPs.

With the increasing number of modules in the vehicle, reducing key-off loads is major effort at most carmakers. High-voltage, low-power linear regulators from Maxim Integrated Products target the power supply portion of the problem. The MAX6765-MAX6774 ICs can deliver up to 100 mA of output current, operate from 4 V to 72 V and consume only 31µA of quiescent current.

References:

1. Frost & Sullivan Analyst Briefing, "Power Semiconductors Market for European Passenger Cars--The Road to More Power," http://w.on24.com/r.htm?e=31130&s=1&k=1FF9B0A0D26149E2F9DC4E5FD43BD165.

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