

# Power management for energy-efficient cars

By Henning Hauenstein, International Rectifier



Today energy efficiency is the key word with regards to new automotive technologies and motoring trends. Since some 27% of the world's energy consumption can be attributed to transportation, it makes sense for companies to spend time, resources and effort improving the technology in today's vehicles. The progress is steering design engineers and end-users towards a more environmentally friendly way of using fuel or energy on the roads.

Looking back 20 years, the trend in electrification of the car has mainly been driven by the wish of the driver to have more comfort and luxury like power windows, electric sun roofs and convertible roofs, high-end stereo, power-adjustable seats, air-conditioning or electro hydraulic power steering which have led to an increased need for semiconductors and electronics in a car. Today the main targets for the electrification of a car are different. Luxury and an improved drive are still important values for buying a car, but the bulk of electronic systems used in cars of today and the future mainly focus on reducing emissions, improving fuel efficiency and reducing the electric consumption of onboard systems.

The best way of achieving this is to replace mechanical and hydraulic systems in a car with more efficient or more intelligent electronic systems. Typical examples are electric power steering replacing hydraulic or electro hydraulic systems and electric motor drives replacing continuously running belt driven systems, like air conditioning compressors, turbo chargers or other pumps and fans. Even lighting applications like the HID (high-intensity-discharge) lamps or LED lights contribute to energy saving by replacing inefficient conventional bulbs. Ultimately the combustion engine will be replaced by efficient electric motors as is already happening today in the power of hybrid and electric vehicles.

## ⇒ Safety with speed

But this latest electrification of vehicles clearly comes with a mandate to the suppliers of the components and electric systems, such as semiconductor suppliers, to develop highly efficient power management solutions in order to make those applications as energy-efficient as possible. Meanwhile, the recent recalls by one of the biggest and most quality-orientated car manufacturers in the world shows the reliability and ruggedness of electronics is at least as important as performance and efficiency. Failures in essential vehicle systems like power steering or braking are simply not acceptable. Therefore, elimination of potential risks and failures must be taken seriously when moving at speed with the electrification of our cars. Systems need to be designed for safety, reliability and ruggedness.

Companies like International Rectifier and its Automotive Products business unit are putting great effort into adding reliability and ruggedness to energy saving automotive solutions. Advanced power management solutions combine advanced silicon with new package technologies that improve performance and ruggedness of automotive systems at the same time. The company provides system designers with packaging solutions and new ways of designing ECUs, motor drives or power supplies.

Silicon technology today excels with very good switches like the newest trench technology based MOSFETs and IGBTs. However, the packaging technology often uses very conservative methods of soldering the Si-die to a substrate or lead frame and contacting its front surface with wire bonds. In 2002, IR began to explore new ways of interfacing silicon via a simple package to the electric circuit in a way that the interfaces for current and heat flow are minimized. The result was the DirectFET1 technology which eliminates the need for wire bonds. Enabling technology consists of a solderable front metallisation of the

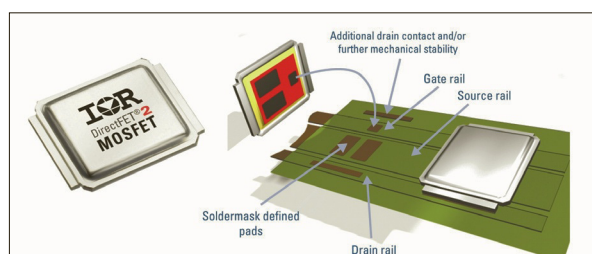


Figure 1: DirectFET eliminates the wire bonds to achieve best electrical and thermal performance.

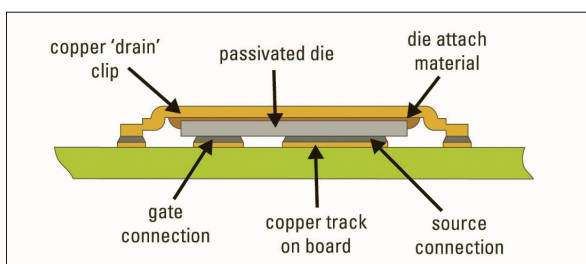


Figure 2: The concept of DirectFET minimises material, interfaces.

silicon switch that allows the direct soldering of the MOSFET housed inside a simple metal can directly to a PCB (Figures 1 and 2). In addition, this concept also contributes to the quality and reliability of an automotive system since it eliminates the dominant failure mode in automotive power cycling: the so-called wire bond lift-off.

The Direct-packaging concept is ideal for automotive applications that need a combination of outstanding performance, quality, ruggedness and extended reliability. In the meantime, IR optimised the DirectFET concept, resulting in the release of the automotive-qualified DirectFET2 product line. The automotive die is housed inside a small metal can which allows customers to design for ECUs and power stages. The DirectFET2 switches can be cooled in many ways, e.g. from the top side, reducing the need for the cooling of the device through the PCB or even cooling from both sides using the ECU-housing or other available heat sinking elements in the ECU design is possible. Customers achieve proprietary system solutions and can differentiate products from those that use standard packaged parts and wire bonds. Examples of various schematic implementations are shown in Figure 3.

The company's newer IGBTs also feature the proprietary solderable front metal that allows complete bond wireless die

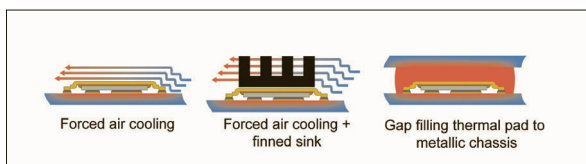


Figure 3: Switching alternatives are possible with the automotive-qualified technology.

attach and both sided cooling concepts for high voltage systems using IGBTs and diodes. The company believes it is the first to commercially release automotive-qualified IGBTs as bare die with solderable front metal, enabling customers with silicon handling capabilities to build and design their own dual-side, cooled bond, wireless power modules or power stages. The solderable front metal devices make available wireless automotive power management for system designers who normally do not have extensive access to proprietary Si.

## ⇒ IGBT carrier

A proprietary die carrier solution with the solderable-front-metal-IGBT attachment is available to support customers who do not have the capability to handle bare die in their assembly lines. The high performance IGBTs are made of very thin wafer material that can be as thin as 60µm. These silicon wafers are thin and flexible like a sheet of paper and handling requires a highly sophisticated process and expensive equipment. Many Tier 1 and Tier 2 system suppliers do not want to invest in such equipment or go through the learning process of thin die handling or very high yield losses during thin wafer handling.

Automotive power switches mounted to proprietary die carriers will later become part of the customer's power module and it will allow everybody to handle and use the most sophisticated IGBTs and thin dice without the need or capability of thin wafer equipment. Companies like IR will take care of the assembly

process of very thin dice to a substrate and the final testing of the switches which is also a huge problem on bare die or wafer level. Standard pick and place machines and solder equipment will be sufficient even for very advanced power module or ECU concepts.

Advantages include electrical performance improvements, better switching behaviour with less ringing and the optimised dual-sided cooling (at least 50% increase in overall heat exchange area, 35% reduction in RthJC and approximately 25% improved Si current density). Another interesting benefit will materialise in the layout and dimensioning of the application for the required lifetime of a car. While bond wire lift-off is even in relatively rugged DBC-based modules the first failure mode in power cycling stress, the bond wireless IGBT technology with proprietary solderable front metal has the potential to greatly extend the power cycling capability by (orders of magnitude).

To avoid a premature bond-wire lift-off failure in the field, typically expensive substrates and heat sinking methods, as well as over-sized power switches are used to reduce the Delta-T temperature swing of each power cycle. In a bond wireless system the die sizes can be much smaller and the system is able to operate under much harder cycling conditions for a much longer period of time. This means the system cost for inverters, DC/DC converters and other power management applications in a car can be reduced significantly using solderable front metal devices, improving performance, reliability and cost-efficiencies.

To help system designers with the task of developing a power stage with the right control IC, companies like IR offer automotive driver ICs that apply to a broad range of topologies and system requirements of state-of-the-art inverters, converters or power supplies. The company's proprietary automotive high- and low-voltage gate driver ICs feature superior ruggedness and latch immunity. In the voltage range up to 75V, drivers are used based on a proprietary smart power process allowing very high current switching. In the range of 100V to 1200V, the company offers a high-voltage, junction-isolated driver IC portfolio, with a high-performance NTSOA (negative transient voltage spike safe operating area).

The failure mode of ICs is often called latch-up due to large negative voltage spikes when switching half bridges with high currents and inductive loads. These ICs are rugged and latch-immune and can drive huge IGBTs with very high current density such as a solderable front metal devices. If the system designer needs more drive current, a buffer IC has up to 10A current capability.

A portfolio of devices can enable automotive power system designers to select an entire chipset for advanced wireless power management to support the energy efficiency of future cars.

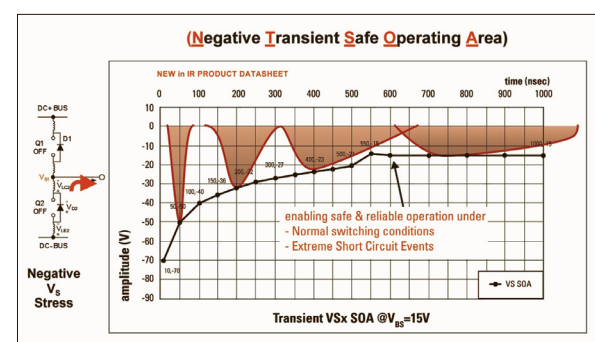


Figure 4: A proprietary process delivers NTSOA in a high-voltage, isolated driver IC.

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