Power Integration for a Smoother Hybrid Driving Experience

Hybrid cars provide an important stepping stone between the conventional combustion engine and full electric propulsion. Engine start-stop technology is a key component of the major hybrid powertrains in the market today, and will benefit from greater power electronic integration to improve performance and reliability. **David Jacquinod, Application and Marketing Manager, Automotive Business Unit, International Rectifier Corporation, USA**

As always, in the automotive marketplace, the greatest excitement surrounds the most futuristic concepts. Today's is a new low-carbon motoring lifestyle in which owners plug-in their electric vehicles (EVs) to charge at home or in public areas such as supermarket car parks, instead of filling them with increasingly expensive petrol or diesel. However, numerous changes are needed in electric power and information infrastructures before widespread use of plug-in EVs can become a practicable proposition. Hybrid vehicles that feature a relatively small internal combustion engine, which is combined with an electric motor, offer a more readily usable proposition to help reduce vehicle emissions in the immediate future.

Various forms of hybrid vehicle are already in the marketplace, and all use auto stop-start technology to maximize the savings in combustion engine emissions. Full hybrids, which have a large electric motor capable of propelling the vehicle while the combustion engine is turned off, are capable of starting and stopping the engine automatically (auto start-stop) to achieve seamless transitions between electric and conventional propulsion. An alternative is the mild hybrid, which uses a smaller electric motor/generator to provide assistance such as when extra power is needed for acceleration. In the mild hybrid, auto start-stop eliminates idling of the combustion engine. A mild hybrid powertrain can be produced at lower cost than a full hybrid system, making the environmental advantages of hybrid technology accessible to a broader range of markets.

An even more competitively priced configuration is the microhybrid, which combines a small combustion engine with auto start-stop to eliminate idling, and can be achieved without designing a completely new powertrain. Stop-start technology contributes to fuel savings of between 10% and 15 % for a microhybrid in a city or urban driving environment. This compares with 10-25 % in a mild hybrid and 25-40 % lower fuel consumption in a full hybrid. Market analyst Yole Developpement has predicted that microhybrid production will rise from around five million vehicles in 2012 to some 45 million in 2020; by far the most accessible and widely adopted hybrid format for the next few years.

Designing the start-stop system

Stop-start technology calls for some important changes to the vehicle's electrical systems. All types of hybrid vehicles are adopting improved battery technologies, for example, since conventional lead-acid batteries have significantly shorter lifetime when required to restart the vehicle repeatedly during each journey. Moreover, as the battery's voltage drops significantly when cranking the engine to restart, a power switch is needed to disconnect it from electrical systems such as the radio, climate control, GPS and interior or exterior lights to prevent this voltage drop interfering with correct operation. The battery voltage can fall to around 6V during cranking, whereas the electrical systems require a stable supply, or board net voltage, which is nominally 13V. An auxiliary battery or DC/DC converter provides this stable voltage while the main battery is disconnected, as shown in figures 1a and 1b.

The power switch is typically a power MOSFET of low on-resistance ($R_{DS(ON)}$), controlled by a gate driver that turns the switch off when necessary to protect electrical loads against fluctuations in the battery voltage. The key functional element of the gate driver is a boost converter capable of generating a gate drive voltage of around 15 V when operating from an input voltage in the range 4-36 V. Since the MOSFET power switch must remain turned on by default, even when the vehicle is parked, the driver must also have low current consumption, to minimize drain on the vehicle battery. However, designing a driver capable of meeting all these requirements using discrete components is challenging. Some designers have used an integrated gate driver IC as an alternative, but these are typically optimized for unrelated applications such as mobile phone handsets or PDAs.

A new gate controller optimized for start-stop applications enables designers to eliminate much of the complexity surrounding control of power switches for main battery disconnection. This driver, the AUIR3240S, has low quiescent current and is fabricated using a proven technology qualified at 175°C and used successfully in various automotive applications since 2006. Qualification at 175°C allows the start-stop driver and power switch to be deployed under the hood and thereby situated close to the main battery. The driver also integrates diagnostic circuitry for monitoring output current, and provides a thermal sensor interface supporting the design of robust and reliable systems.

The AUIR3240S is capable of driving several MOSFET power switches in parallel to achieve very low $R_{DS(ON)}$ with current consumption below 50 µA. Figure 2 shows a typical application circuit comprising the AUIR3240S, including the external components required for output current monitoring and thermal protection.

They key criteria determining the chosen MOSFET's performance in a start-stop application is its $R_{DS(ON)}$ and current rating, which must be adequate to carry the peak

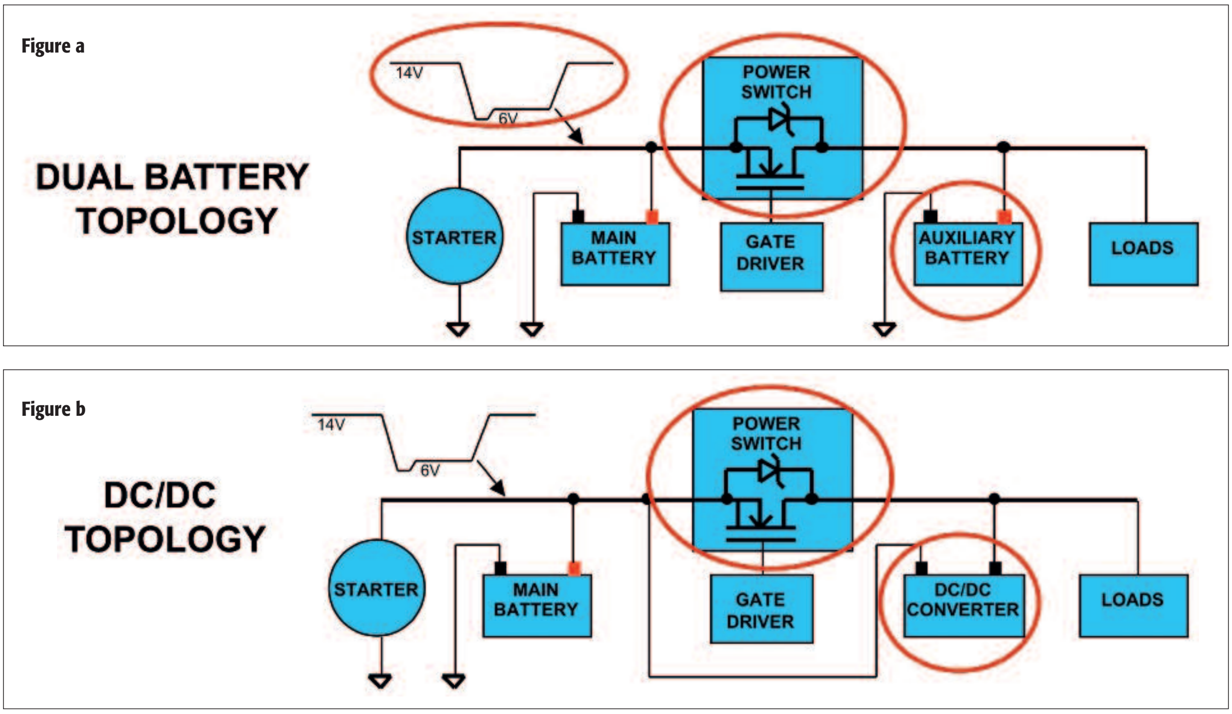

Figure 1: Start-stop power switch with auxiliary battery supply (a) and start-stop power switch with DC/DC converter (b)

load current calculated for the vehicle. Suitable MOSFETs that can be used with this device include the AUIRF1324S-7L or the AUIRF3004-7L, which are rated for 24V and 40 V breakdown voltage respectively. The AUIRF3004-7L provides a higher safety margin allowing the device to withstand voltage fluctuations above the nominal voltage. Both devices have low $R_{DS(ON)}$, which helps to minimize energy losses in vehicle modes when the power switch is turned on.

Conclusion

Influenced by factors such as environmental awareness and steadily rising petrol and diesel prices, car owners are increasingly sympathetic to new vehicle technologies that are effective in reducing emissions and improving fuel economy. Consumers are being encouraged to imagine charging small city cars overnight from an AC supply fed substantially from renewable energy sources such as wind or solar. In the short term, hybrid vehicles using smaller combustion engines that never waste fuel by idling can deliver valuable savings as a stepping stone into that future. Full, mild and microhybrid powertrain types are established. Among these, the microhybrid currently offers the lowest-cost, most accessible option.

In a typical hybrid application, automatic engine start-stop operation is essential to deliver an acceptable user experience by ensuring seamless transitions between modes in which the engine is running and those where it is turned off. Suitable power switching is an important part of the start-stop system, and is needed to ensure correct operation of all vehicle electrical systems as engine cranking can take place automatically on multiple occasions during any journey.

A number of suitable power MOSFET switches are already available, but driver design has typically challenged engineers to build a low-power boost converter using discrete components or to choose from ICs originally conceived for non-automotive applications. The advent of IR's automotive-qualified dedicated start-stop controller IC, using proven technology qualified at 175°C, simplifies the design of more integrated, reliable and higher performing start-stop systems for all types of hybrid vehicles.

Figure 2: Integrated MOSFET gate driver with current monitoring and thermal protection