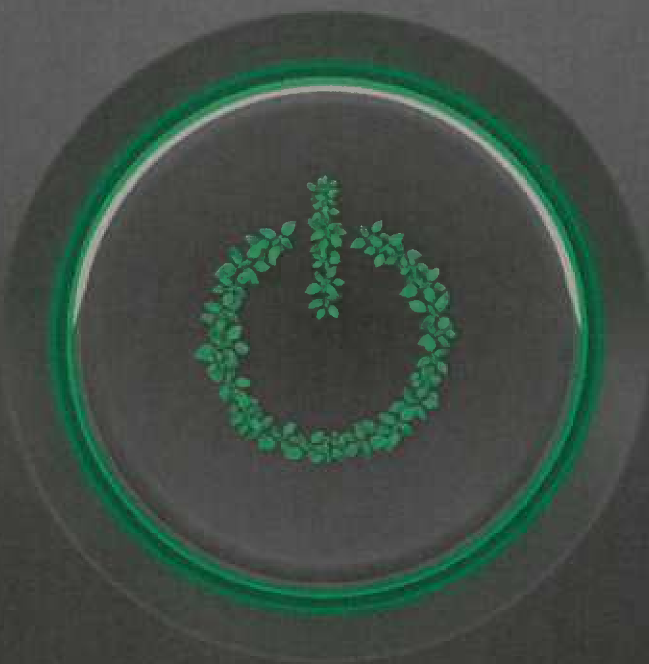

ADVANCED POWER SWITCHES BOOST MICROHYBRID EMISSIONS GAINS

PACKAGING AND CIRCUIT INTEGRATION DELIVER IMPROVED PERFORMANCE FOR START-STOP AUTOMOTIVE APPLICATIONS.

BY MASASHI SEKINE AND JIFENG QIN • INTERNATIONAL RECTIFIER CORP

Automotive start-stop operation, which reduces idling by shutting down a car's engine when the car momentarily stops, is a simple concept that can go a long way toward improving fuel economy and cutting emissions. The ICE (internal-combustion engine) system remained the predominant technology for vehicle propulsion among the roughly 80 million cars produced worldwide in 2011. Global trends, however, are conspiring to shift the balance toward alternatives. On one hand, the price of petroleum has skyrocketed; on the other, legislation governing emission standards is becoming more stringent worldwide.

IMAGE: ISTOCK AND SHUTTERSTOCK

In Europe, vehicle carbon-dioxide emissions are subject to a voluntary agreement between the European Union and automakers, but legislation has been pushed because overall performance remains way off the voluntary goal. Meanwhile, the Euro 6 standard, which requires substantial reductions in oxides of nitrogen emissions, will be phased in over the next few years. These developments ratchet up the challenges confronting automakers as they work to conform to evolving standards.

Clearly, reducing fuel consumption is one key to meeting the stringent new requirements. Toward that end, the market will boom in the next 10 years for HEVs (hybrid-electric vehicles) of all configurations—micro, mild, full, and plug-in—as well as for full EVs. Adoption of HEVs and EVs will be critical for meeting carbon-dioxide emissions targets for 2020.

Research firm Yole Développement predicts that combined HEV/EV demand will increase this decade at a compound annual rate of 31% to reach 50 million cars in 2020, or about 50% of all cars produced that year (**Figure 1**). Analysts expect microhybrid vehicles to account for most of that volume.

AT A GLANCE

- Stopping the internal-combustion engine when a vehicle is not moving is a cost-effective method of cutting fuel use and emissions.
- Start-stop can be accomplished with dual batteries or with a battery and boost converter that stores energy in an inductor.
- Specialized battery power switches are available that disconnect the starter and main battery from the auxiliary electrical systems during engine start.

HYBRID TYPES

The major difference between microhybrid systems and full- or plug-in-hybrid systems is that microhybrids lack an electric powertrain to propel the vehicle. Rather, the microhybrid's start-stop system shuts down and restarts the ICE to reduce the amount of time the engine spends idling, such as when a car is sitting at a traffic light or in a traffic jam. The mild hybrid has a regenerative braking system in addition to the start-stop feature. Fuel-economy gains from these technologies are typically in the range of 5% to 10% compared with conventional vehicles' fuel-economy numbers (**Table 1**).

Various start-stop systems are available. One is the super starter, which uses a rugged dc starter plus a battery-management system. With a low, $80 average cost to the end user, super starters hold an estimated two-thirds of the total market for start-stop systems. Car manufacturers adopting the technology include BMW.

Another start-stop system is the BAS (belt-driven alternator starter), featuring a dc-ac inverter with average power typically in the 1.5- to 3-kW range. Such systems are virtually silent and offer an engine-restart time as low as 400 msec. With an estimated end-user price of approximately $300, BAS systems are found in many midpriced vehicles.

Finally, for conditions of extreme cold that can compromise the operation of conventional start-stop systems, a dual-battery solution or a dc-dc boost solution can be used to maintain the bus voltage.

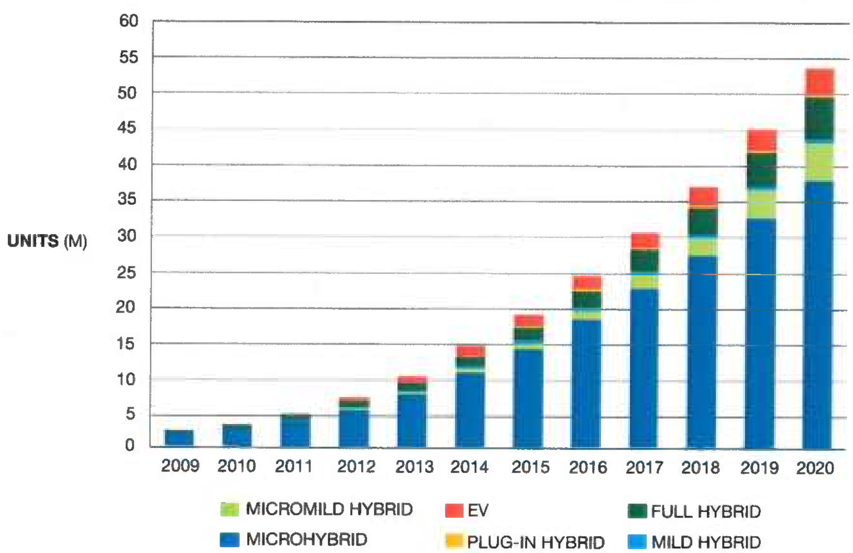

Figure 1 HEV/EV demand is forecast to increase 31% annually through 2020 (courtesy Yole Développement, August 2011).

TABLE 1 HEV TYPES BY FUNCTION

Function	Microhybrid/ micromild hybrid	Full hybrid	Plug-in hybrid
Start-stop	Yes	Yes	Yes
Regenerative braking	Yes (micromild only)	Yes	Yes
Electric drive	No	Yes	Yes
Recharge on grid	No	No	Yes
Fuel savings (%)	5 to 10	25 to 40	50 to 100

TWO BATTERIES

In a typical dual-battery technology, when the ICE is running, power switch Q_1 remains on so that the load is fully supplied by the main battery as well as an alternator (**Figure 2**). When the vehicle stops, the ICE turns off, and the main battery becomes the only source of power supply to the load. At engine restart, the main-battery voltage must supply a transient current as high as 1000A to the starter motor, resulting in a transient-voltage drop at the main-battery terminal to as low as 6V.

To prevent the power-electronics circuit from shutting down due to the battery-cranking transient event, a controller sends a turnoff signal to Q_1 to disconnect the main battery from the load. The auxiliary battery then supplies power to the load and maintains the battery voltage.

After the engine restarts successfully and the alternator resumes operation, Q_1 is turned on and the system reenters vehicle running mode.

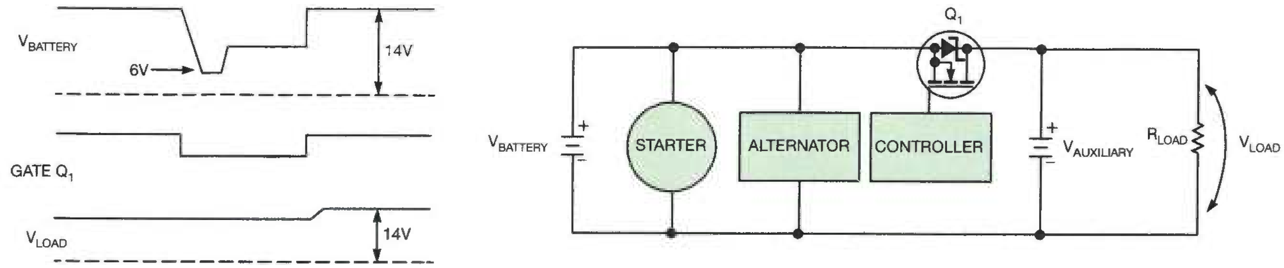

Figure 2 Dual-battery switch technology in the microhybrid system uses an auxiliary battery to provide high starting currents for start-stop operations. During start, Q_1 disconnects the main battery from the power-electronics circuit, to which the auxiliary battery then supplies the correct voltage.

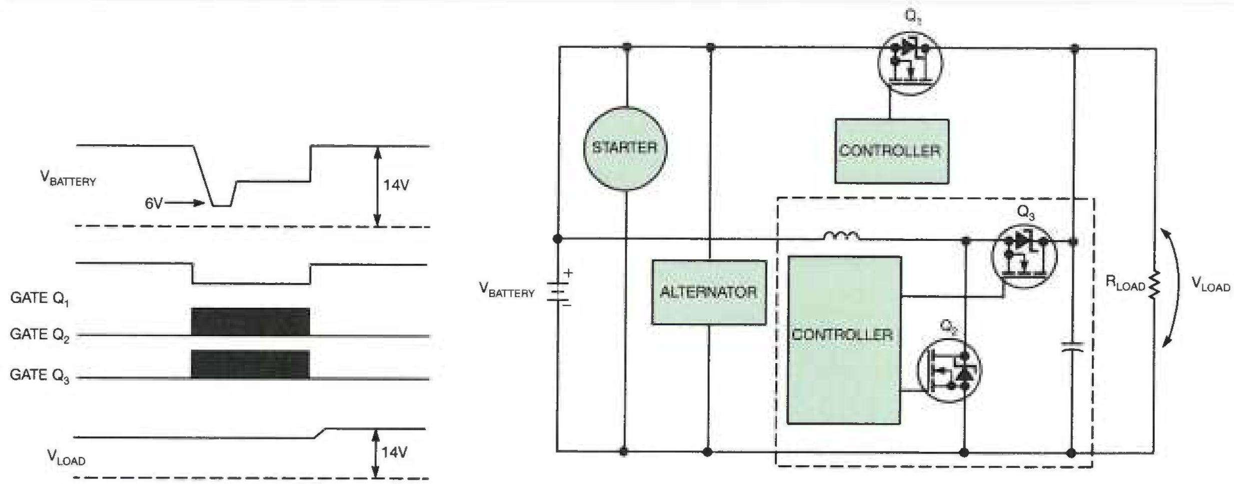

Figure 3 The dc-dc boost converter topology in a microhybrid system stores energy in the converter inductor. Here the boost converter (dotted box) functions as the auxiliary battery in the dual-battery system.

Power switch Q_1 and the controller are also used as a part of a reverse battery-protection circuit. If the main battery is connected in reverse polarity, Q_1 stays off because no signal is coming from the controller. It protects circuitry on the load by terminating the reverse-current-flow path.

DC-DC BOOST

A similar configuration uses a dc-dc boost converter instead of an auxiliary battery (**Figure 3**). At engine restart, bypass switch Q_1 disconnects the main battery from the load, and a dc-dc converter supplies a boosted voltage to the load during the cranking period.

The dc-dc boost converter comprises one inductor, two power switches (Q_2 and Q_3), and one output capacitor. All energy is stored at the inductor when Q_2 turns on. Q_3 would be off at that time. The inductor then transfers the energy to the load through Q_3 when Q_2 is off. The voltage on the main battery and the

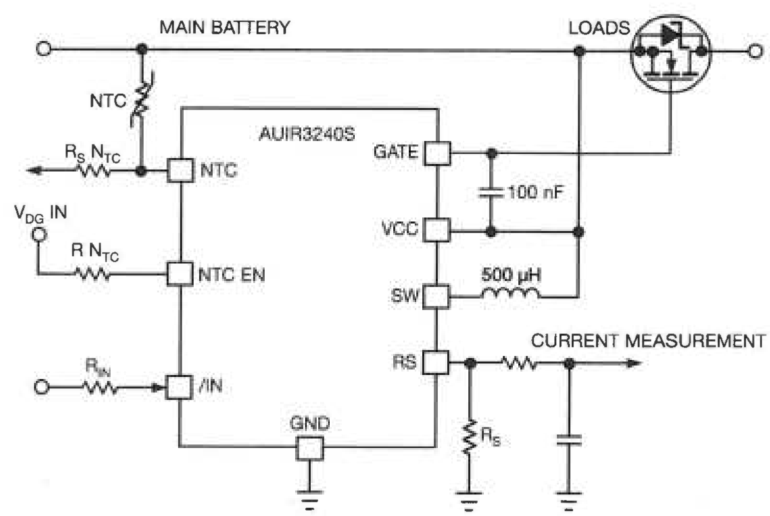

Figure 4 The dual-battery system can use the board-net stabilizer in the highly integrated AUIR3240S power-switch high-side MOSFET driver. The power switch disconnects the starter and battery from auxiliary systems when the engine is started.

voltage on the load terminal determine the duty cycle of Q_2. A PWM controller operates this type of synchronous dc-dc boost converter in continuous-conduction mode to maintain the voltage on the load terminal.

MICROHYBRID EXAMPLE

For the battery switch, International Rectifier's AUIRF1324S-7P surface-mount MOSFET delivers a maximum on-state resistance as low as 1 mΩ and an output current up to 240A. For through-hole packaging requirements, the company offers the AUIRF1324L in a conventional TO-262 with a maximum on-state resistance of 1.65 mΩ.

The wide-lead, TO-262-packaged AUIRF1324WL power MOSFET can reduce the maximum on-state resistance by roughly 20%. Wider-lead packages mean more areas fit the internal wirebonds at the MOSFET's source terminal. The lower on-state resistance and the improved wirebonding inside the package collectively yield an approximately 30% increase in the maximum-drain-current rating.

All MOSFETs in the 24V 1324 family are suitable candidates for battery-switch applications. IR also offers 40V automotive-grade MOSFETs with an on-state resistance as low as 1.25 mΩ. These products are suited for dc-dc-converter applications.

The AUIR3240S, an automotive-grade high-side MOSFET driver, drives the battery power switch for start-stop applications **(Figure 4)**. The highly integrated boost converter was designed specifically for start-stop systems, which require a board-net stabilizer that uses a power switch to disconnect the starter and main battery from the auxiliary electrical systems during engine start. The AUIR3240S can drive several MOSFETs in parallel to achieve very low on-state resistance, with current consumption of less than 50 μA. The device provides 15V on the output, with a wide input voltage of 4 to 36V. The AUIR3240S also features diagnostics on the output current and a thermal sensor interface for a robust design.

Continued development of microhybrid start-stop systems requires solutions for reducing the cranking voltage drop, integrating more electronics into the starter and furthering the evolution of battery technologies. Power-electronics vendors and automakers are putting the components in place to make the necessary advancements. EDN

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