Electronic Design

By RICK NELSON, Contributing Editor

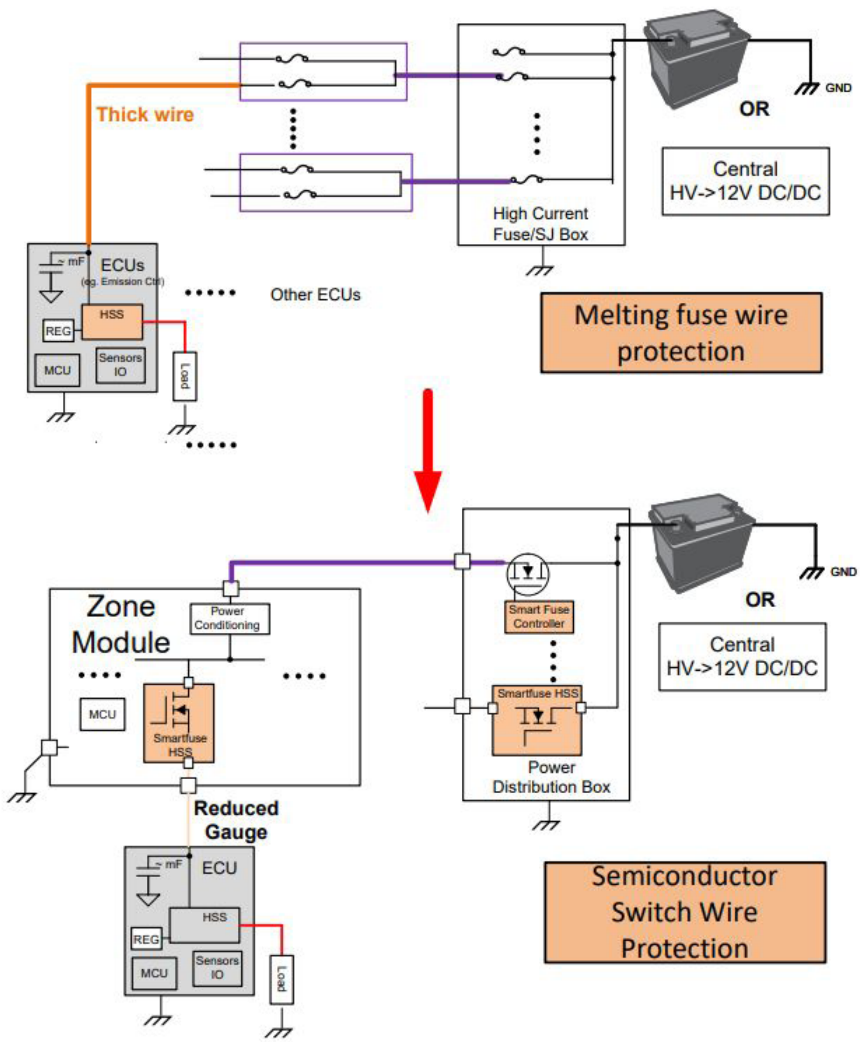
High-Side Switch Smooths Transition to Zonal Automotive Architectures

Sponsored by Texas Instruments: Automakers are replacing classic melting-wire fuses with semiconductor eFuses, which offer programmable functionality and don't require replacement after a fault.

Although essential to safe operation, fuses have inconvenienced drivers for decades. When a fault occurred, the driver would have to search clumsily for the fuse box, usually somewhere under the dashboard, and hope the right replacement fuse was readily available. The melting-wire fuses presented problems for automotive engineers as well, who had to route long thick wires from the battery to the fuse box and on to the taillight or wherever else the power was required.

The eFuse Alternative

Today, however, as automakers transition to software-defined vehicles with zonal architectures, automotive engineers are replacing the melting-wire fuses with semiconductor switches called eFuses—also known as smart fuses. These fuses can reset after a fault clears, and because drivers and service technicians don't require access, automotive en-



1. Melting-wire fuse configurations (top) are giving way to smart fuses, which can be distributed among zones throughout the vehicle.

gineers can locate the eFuses in zone modules throughout the vehicle *(Fig. 1)*.

eFuses offer other advantages as well for the software-defined vehicle. For example, eFuses equipped with a communications link such as the Serial Peripheral Interface (SPI) enable a connected car to monitor each eFuse's status and perform remote diagnostics.

In addition, a controller can dynamically reconfigure each eFuse based on load requirements. The eFuse's programmability enables one device type to be used across multiple vehicle-model variants, thereby simplifying bills of materials and streamlining software development.

Moreover, you can choose eFuses that offer configurable time-current profiles that overcome the drawbacks of a flat current limit. These eFuses can accommodate short-duration high-current events (such as inrush currents) but turn off during sustained overload conditions.

Many eFuses include a low-power mode in which they draw minimal quiescent currents. This mode minimizes battery drain when a vehicle is parked, but its electronic control units (ECUs) remain active. These eFuses can even monitor load conditions to determine when to switch between active and low-power modes, offloading this task from an external microcontroller unit (MCU).

eFuses are also available with a configurable capacitive load-drive mode, which enables them to effectively power the many zonal-architecture loads that are capacitive in nature. You can find versions with programmable current and voltage thresholds that enable the efficient driving of both large and small capacitive loads.

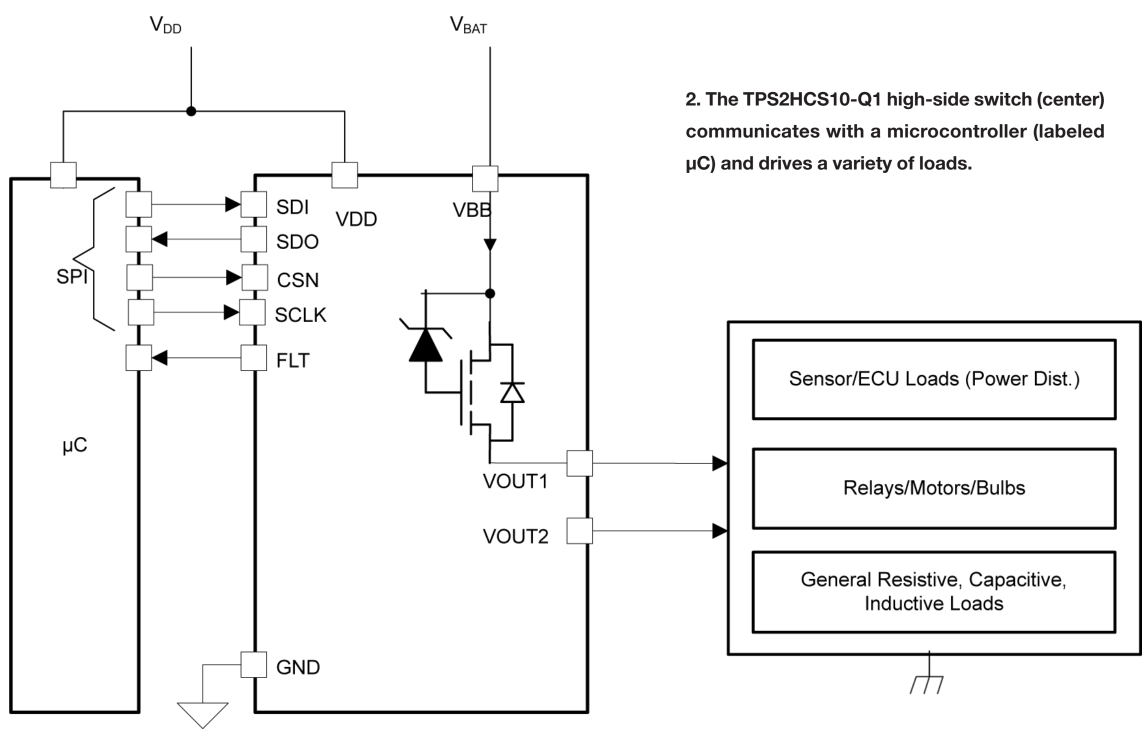
Smart High-Side Switch

An example of an eFuse that offers such features is Texas Instruments' TPS2HCS10-Q1 automotive-qualified smart high-side switch *(Fig. 2)*. The device includes two channels, and its internal field-effect transistors (FETs) offer an on-resistance ($R_{DS(on)}$) of 11 mΩ (typical). The device's operating voltage range is 6 to 18 V, and it can withstand load-dump events to 35 V. The current rating is 12 A.

The switch communicates with a host controller over an SPI bus, which includes clock, chip-select, data-in, and data-out pins. The device supports simple daisy-chain SPI operation in a primary-secondary configuration, with the controller acting as the primary device that issues commands to, and receives responses from, the TPS2HCS10-Q1, which acts as the secondary device.

The two devices' SPI communication involves data stored in the TPS2HCS10-Q1's on-chip memory-mapped registers. The controller can write commands and configuration information to a portion of these registers, and it can read back data from other registers.

For example, one register enables the controller to configure an overcurrent protection function with an adjustable threshold. Another can store a programmable current-time fuse profile, analogous to i^2t curves on melting-wire-fuse datasheets.



2. The TPS2HCS10-Q1 high-side switch (center) communicates with a microcontroller (labeled µC) and drives a variety of loads.

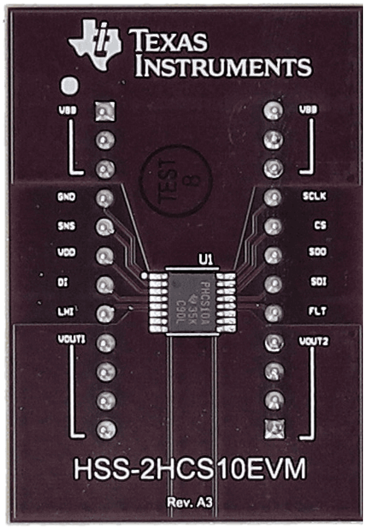
To enable the controller to read back data, the high-side switch includes a configurable sensing capability coupled with an integrated analog-to-digital converter (ADC). The controller can access ADC output values representing parameters such as load current, output voltage, battery voltage (V_{BAT}), and FET temperature via TPS2HCS10-Q1 data-feedback registers.

The TPS2HCS10-Q1 can operate in several states, or modes, which the controller can enable by writing commands to state registers. These states include SLEEP state, enabled when a vehicle is parked or in key-off mode. In addition, the device includes a low-power mode (LPM)—a state that supports 800 mA of peak current while consuming about 10 µA of quiescent current.

Then there's a CONFIG state that allows TPS2HCS10-Q1 registers to be configured over the SPI link, while an ACTIVE state enables normal operation, during which configuration can't be changed. Finally, a LIMP HOME state places the device in a safe mode in the event of a fault, such as an SPI communication failure.

Evaluating High-Side Switches

To help you evaluate high-side switches like the TPS2HCS10-Q1, [TI offers the HSS-HCMOTHERBRDEVM motherboard and a family of daughtercards for its high-side smart-switch portfolio](). To get started with the device, order both the motherboard and HSS-2HCS10EVM daughtercard *(Fig. 3)* and plug the daughtercard into the motherboard to form a complete evaluation module (EVM). Then, connect your computer to the EVM via a USB cable and download the TI Smart Fuse Configurator software.



3. This daughtercard works with a motherboard and configuration software to help you get started with TPS2HCS10-Q1 designs.

Next, connect a voltage representing V_{BAT}. The EVM includes a buck converter that will convert V_{BAT} to the 3.3 V required for the TPS2HCS10-Q1 and other components on the EVM. However, keep in mind that while the switch is an automotive-grade part, the motherboard is not. If you plan to use a battery simulator for V_{BAT} and simulate transients including shorts to ground and overvoltage surges, you may want to bypass the onboard buck converter and substitute an external automotive-grade 3.3-V supply.

Finally, connect your test loads to the EVM and open the Smart Fuse Configurator software. The software automatically detects the TPS2HCS10-Q1, and you can begin exploring its many functions and states.

Conclusion

eFuses in the form of smart high-side switches offer performance and functional advantages compared with melting-wire fuses as automakers move to zonal architectures. TI offers a complete line of high-side switches as well as evaluation modules and software that can assist you in making the transition.