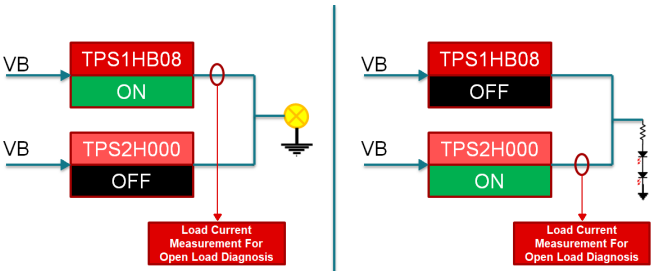
Open Load Detection and Limp Home Function in BCM

Open Load Detection is a crucial and important function of the body control module (BCM). By using this function, the body control module can perform open-circuit diagnosis on loads, such as lamps and wiper motors, when the car is running or stopped. Open load diagnosis is an important function of the high-side switch (HSS). This function is mainly realized by measuring the current flowing through the power switch. Usually, the HSS has an inherent function of load current diagnosis. Open load diagnosis can be performed when the load is enabled or disabled. It is conducive not only to safe driving but also to maintenance and repair.

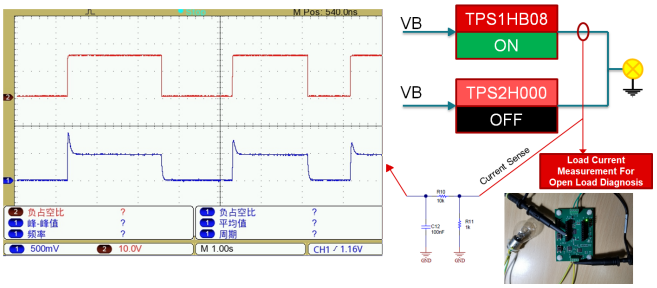
Power switches from different manufacturers in the market also have this function. However, with the popularity of LED lamps, OEMs require a lamp driver to be compatible with both high-current diagnosis of lamp bulbs and low-current diagnosis of LED lamps. Conventional high-side switches in the market are difficult to be compatible with the two. Most HSSs cannot detect current accurately below 300 mA. The solution introduced here can detect not only the large current of conventional bulbs, such as current greater than 10 A, but also the small current of LED lamps, such as current greater than 5 mA. It is realized by connecting an HSS with high $R_{DS(on)}$ and an HSS with low $R_{DS(on)}$ in parallel, as Figure 1 shows.

Figure 1. Open Load Detection Block Diagram



When the load to be driven is a large current load such as a bulb, use software to turn off the HSS TPS2H000 with high $R_{DS(on)}$. Then, functions such as driving and diagnosis are completed by the HSS TPS1HB08 with low $R_{DS(on)}$. Figure 2 shows the test results.

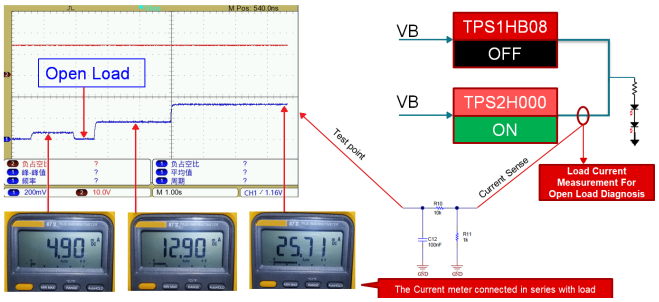
Figure 2. Bulb Current Measurement



The load is a 21-W bulb, and the blue waveform on the oscilloscope indicates the voltage of the current feedback pin CS of the HSS TPS1HB08. When the load bulb is turned on, the voltage of the CS pin is 500 mV, and when the load bulb is turned off, the voltage of the CS pin is approximately 0 mV. Based on the voltage measurement results, you can easily judge whether a load open circuit has occurred by using a 10-bit or 12-bit single-chip analog-to-digital converter (ADC).

When the load to be driven is a small current load such as an LED lamp of which the power is less than 3 W or the current is less than 300 mA, turn off the HSS TPS1HB08 with low $R_{DS(on)}$ with software. Then, functions such as driving and diagnosis are completed by the HSS TPS2H000 with high $R_{DS(on)}$. Figure 3 shows the test results.

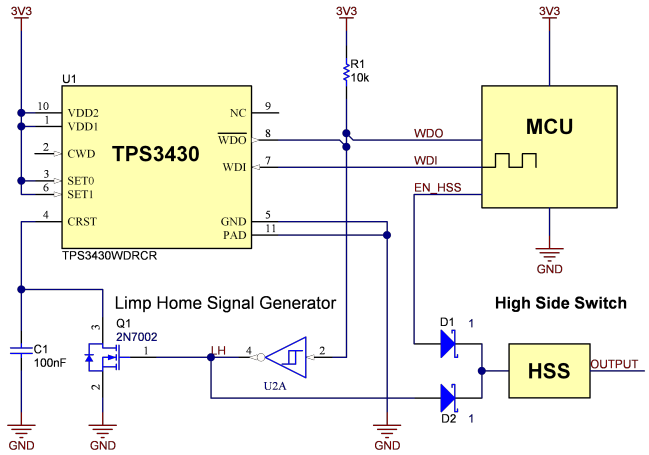
Figure 3. LED Current Measurement



The ammeter is connected in series in the load circuit. The blue waveform on the oscilloscope indicates the voltage of the current feedback pin CS of the HSS TPS2H000. When different LED lamps are switched over, the load current is 4.9 mA, 12.9 mA, and 25.7 mA, respectively. The voltage measured from the current feedback pin CS of the power switch TPS2H000 by the oscilloscope is at the following approximate values: 65 mV, 160 mV, and 330 mV, respectively. This accuracy allows you to use a 12-bit or 10-bit single-chip ADC to easily judge whether a load open circuit has occurred.

Limp Home Function is a crucial and important function of the body control module. When an automobile system cannot work normally due to a failure of the microcontroller in BCM while driving, this function can be used to generate a hardware signal (limp home signal) that can directly control the hardware without the participation of the microprocessor, so that key modules such as lamps, doors, and wipers can work normally and the driver can safely drive the car home or to a nearby maintenance point.

Figure 4. Limp-Home Function Schematic

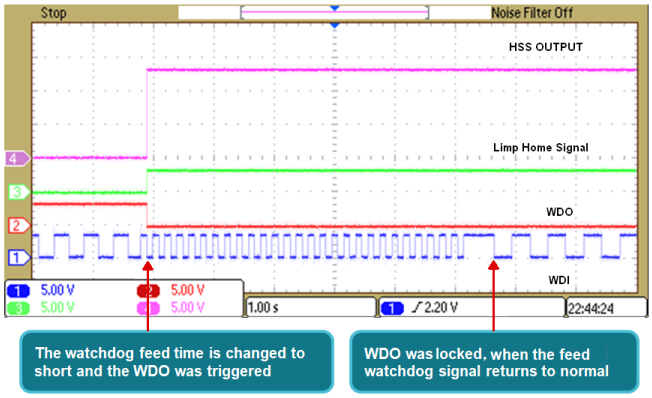


The working principle of the limp home function is as follows: it detects the software running state of the body control module according to the hardware scheme. When the software is found to be running incorrectly, the limp home function generates a high-level signal. By using TI's watchdog device, TPS3430-Q1, a circuit for generating effective and stable limp home signals can be designed, as Figure 4 shows. The TPS3430 device is a window watchdog. An effective watchdog signal must be generated within a given time frame; otherwise, a low-level watchdog output (WDO) is triggered. WDO is usually connected to the RESET pin of the microcontroller. Low-level WDO may result in system reboot or lockout. U2 is a phase inverter. It is used to convert low-level signals of the WDO into high-level signals for driving the high-side switch. D1 and D2 are used to turn on the HSS as long as either the LH and EN_HSS signals are in high level. The working principle in Figure 4 is as follows:

When the system software runs normally, the WDI pin receives a watchdog signal of the normal cycle, such as a square wave signal of 300 ms. WDO always outputs high-level signals and is not reset. Once the system has an error, the cycle of the watchdog signal changes, such as more than 300 ms or less than 300 ms, or even no watchdog signal. Then, the signal level at the WDO pin changes from high to low, indicating that the system software has failed.

According to the testing waveform, once the cycle of the watchdog signal is wrong, a high-level signal (see the green line in Figure 5) is generated at LH immediately. That is, the signal level changes from low (which is normal) to high and the status is permanently locked by Q1. This high-level signal can be used to enable the car lamps and wipers without the participation of the microprocessor in BCM. Q1 is used to lock the signal level at the CRST pin of TPS3430-Q1 to low and thus prevent the TPS3430-Q1 device from resetting.

Figure 5. Limp-Home Signal Testing Waveform



To unlock the LH signal, the entire system must be powered on again or the TPS3430 device must power on separately. This design is flexible. A counter circuit can be connected to the WDO signal in series to make it enter the limp home mode after 3 to 5 faults. You can also add a switch to the power input of the TPS3430 device to control the power supply of the TPS3430 to power it on again, so that the system can automatically exit the limp home mode.

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