

Achieving Reverse Battery Protection Using TI High Side Switch Controllers



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ABSTRACT

With evolving zonal architectures in automotive power distribution system, there is an increase in demand for High side switch controllers to drive most of the primary and secondary high current loads with external MOSFETs. These system designs include power distribution box and loads such as PTC heaters, body motors, and so on.

One of the key system requirement from car OEMs in 12-V automotive systems is to protect the DUT against the reverse battery connection. During maintenance of car battery or jump start of the vehicle, the battery can be connected in reverse polarity during reinstallation and this can cause damage to the connected subsystems, circuits, and components. Appropriate protection circuits need to be designed to make sure the DUT is protected and withstand the reverse battery condition. Based on the load type, the reverse battery protection can be implemented either with a back to back power switch or with a forward load switch topology.

This application note highlights how the TPS1211-Q1 high side switch controller can be used to achieve reverse battery protection for various high current body loads with various circuit configurations.

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1 TPS1211-Q1 High Side Switch Controller Overview

The TPS1211-Q1 family is a 45-V smart high-side drivers with protection and diagnostics. With wide operating voltage range of 3.5 V – 40 V, the device is suitable for 12-V system designs. The device has a strong 3.7-A peak source (PU) and 4-A peak sink (PD) gate driver that enables power switching using parallel FETs in high current system designs. Use INP as the gate driver control input. MOSFET slew rate control (ON and OFF) is possible by placing external R-C components.

The device has accurate current sensing ($\pm 2\%$ at 30 mV) output (IMON) enabling system designs for energy management. The device has integrated two-level, overcurrent protection with FLT_I output with complete adjustability of thresholds and response time. Auto-retry and latch-off fault behavior can be configured. The device features remote overtemperature protection with FLT_T output enabling robust system protection. TPS12110-Q1 has an accurate overvoltage protection ($< \pm 2\%$), providing robust load protection. The TPS12111-Q1 integrates a precharge driver (G) with control input (INP_G).

This feature enables system designs that must drive large capacitive loads by precharging first and then turning ON the main power FETs. TPS1211-Q1 has an accurate undervoltage protection ($< \pm 2\%$) using the EN/UVLO pin. Pull EN/UVLO low (< 0.3 V) to turn OFF the device and enter into shutdown mode. In shutdown mode, the controller draws a total shutdown current of 0.9 μ A (typical) at 12-V supply input. Figure 1-1 shows the TPS1211-Q1 functional block diagram.

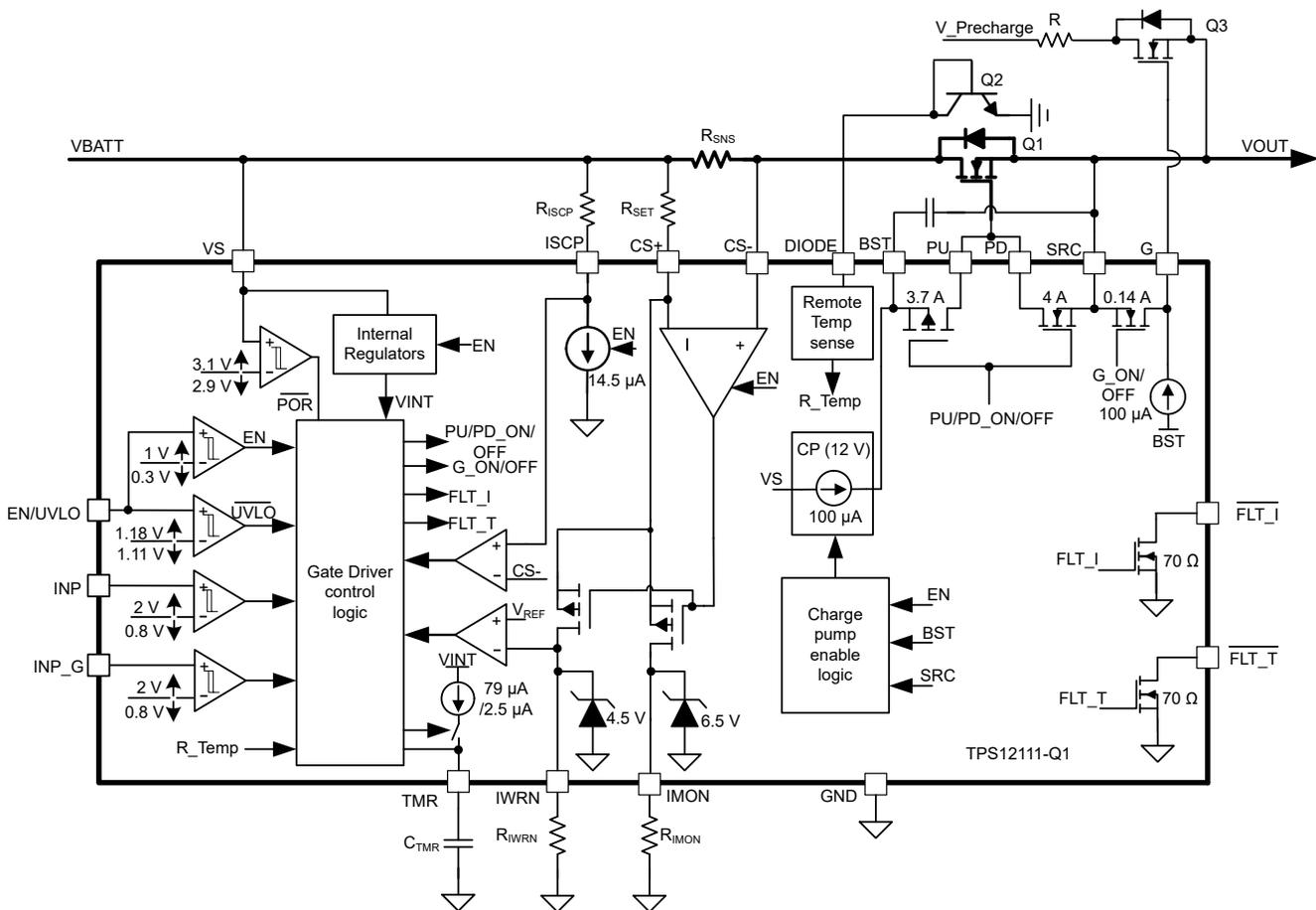


Figure 1-1. TPS1211-Q1 Functional Block Diagram

2 System Design Examples with Reverse Battery Protection

2.1 Design 1: Power Distribution Box

Figure 2-1 shows an example of power distribution box with two-channel outputs VOUT1 and VOUT2. Input power source can be from a battery or a DC-DC. A grouped input reverse battery protection scheme is implemented using LM74500-Q1 reverse polarity protection controller and an external MOSFET Q1.

The output of the LM74500-Q1 reverse battery protection stage is connected to the TPS12110-Q1 high side switch controllers. The TPS12110-Q1 ICs and the loads connected to the outputs gets protected from the input reverse battery condition by the LM74500-Q1 circuit. During input reverse battery condition the LM74500-Q1 controller pulls GATE to SOURCE and the MOSFET Q1 gets turned OFF disconnecting the input battery connection to the downstream TPS12110-Q1 ICs and the loads.

TPS12110-Q1 does not see reverse voltages and therefore does not need any special reverse protection techniques for this section of the system design.

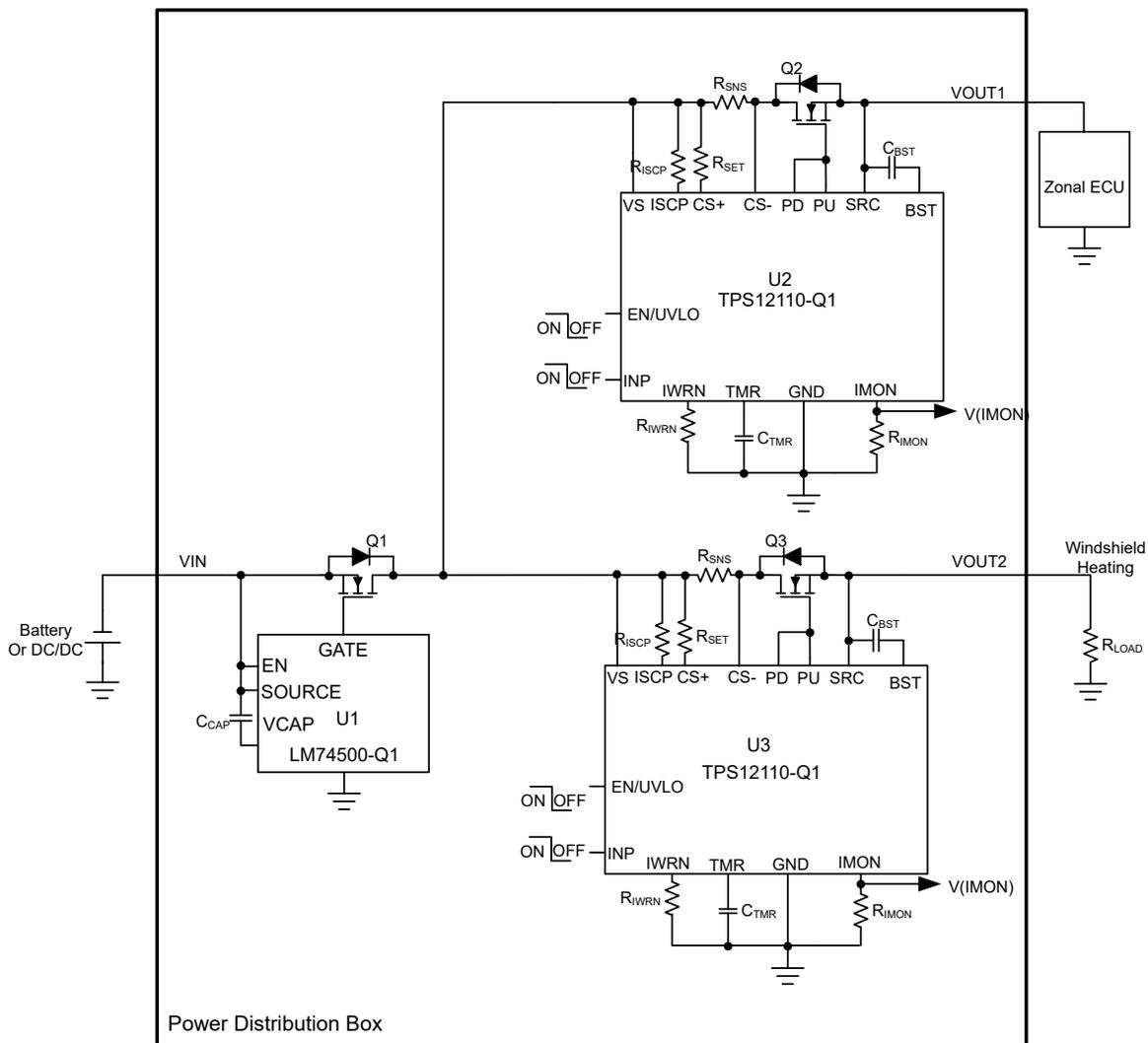


Figure 2-1. Power Distribution Box with Grouped Reverse Battery Protection Using LM74500-Q1 Controller

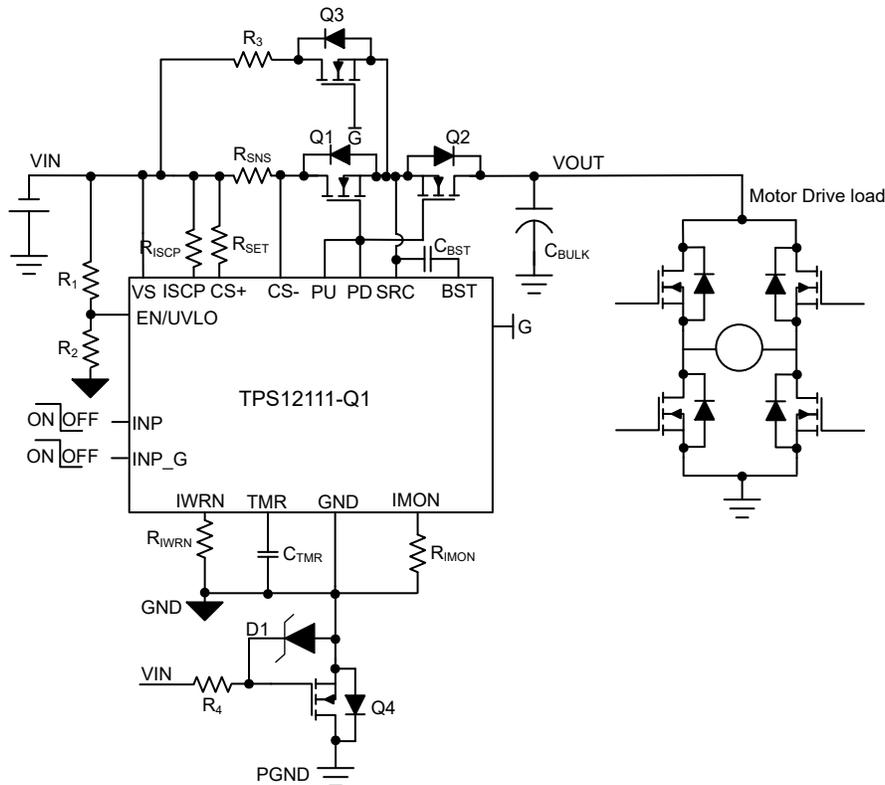


Figure 2-3. TPS12111-Q1 Application Schematic with MOSFET Based Ground Side Disconnect Switch

2.3 Design 3: Heater Load Driving

Resistive loads such as PTC heaters used for seat heating and windshield heating do not generate reverse currents unlike in the case of body motors and then there is no technical need to have back-to-back MOSFETs in the power switching path.

The following section describes the reverse battery protection techniques in the case of such loads.

2.3.1 Reverse Battery Protection with MOSFET OFF

Figure 2-4 shows TPS12110-Q1 application circuit to drive heater loads. PWM signal can be applied to the INP pin for controlling the ON or OFF duration of the load.

Since there is no reverse blocking MOSFET in the power path, during the reverse battery condition there is reverse current flow from PGND, load, MOSFET Q1 body diode and to the battery as shown in the Figure 2-4.

In this condition, the MOSFET Q1 can see high-power dissipation and can damage due to excess heat and current stress on the body diode. Adding a reverse blocking MOSFET can be one technical design to avoid this stress and protect the MOSFET Q1. However, the blocking MOSFET characteristics like $R_{DS(on)}$, current rating must be the same as a MOSFET Q1. This design results in double the cost of the power stage and increases the design size which is not acceptable in high-current system designs.

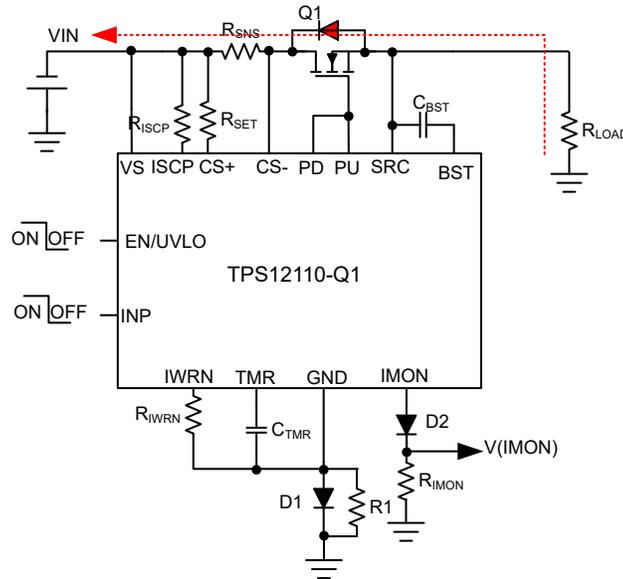


Figure 2-4. TPS12110-Q1 Application Schematic for Driving PTC Heater Load with MOSFET OFF During Reverse Battery Condition

2.3.2 Reverse Battery Protection with MOSFET ON

Turning the MOSFET Q1 ON during input, the reverse-battery condition address the challenges mentioned in [Section 2.3.1](#). [Figure 2-5](#) shows the TPS12110-Q1 application circuit to turn ON the MOSFET Q1 during reverse battery condition.

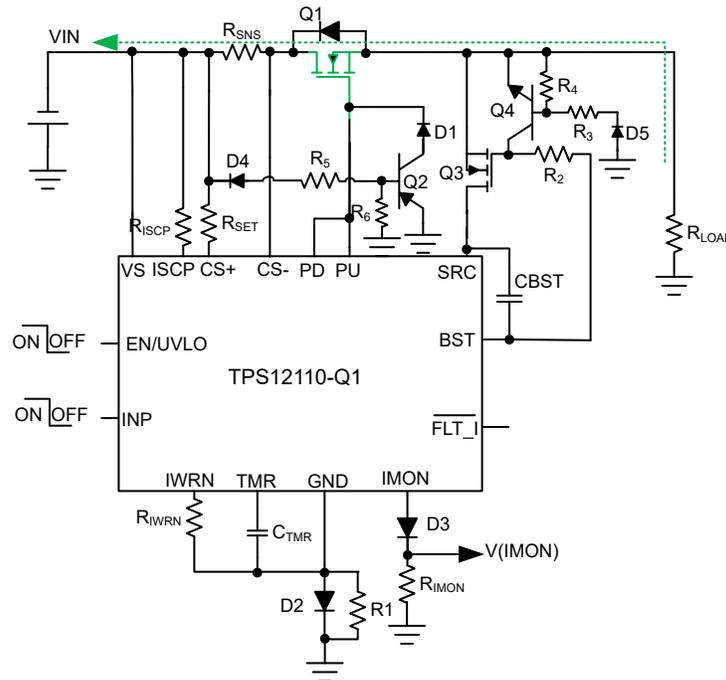


Figure 2-5. TPS12110-Q1 Application Schematic for Driving PTC Heater Load with MOSFET ON During Reverse Battery Condition

With the application circuit shown in [Figure 2-5](#) the MOSFET Q1 can be turned ON during input reverse battery condition. During input reverse battery condition the source of the MOSFET Q1 follows the input reverse voltage. D5, R3, R4 path conducts during this condition and turns ON Q4. This then turns OFF Q3. Q3 is a signal N-FET to disconnect the Q1's source to device SRC pin during input reverse battery condition. R6, R5, D4 path conducts and turns ON Q2. D1's anode gets connected to GND through Q2. GATE voltage of Q1 gets pulled

to VF of D1 (-1V) and SOURCE terminal to negative VIN minus body diode drop of Q1 (-14V+1V = -13V). This results in VGS drive of -1V-(-13V) = 12 V turning ON the MOSFET Q1 and load current conducts through the MOSFET Q1's RDSON.

The TPS1211-Q1 gets protected by disconnecting the GND with the help of D2. D3 is placed on the top side of the IMON resistor. With this placement, the IMON signal does not include the D3 voltage drop.

During the normal operation at positive VIN levels, Q2 and Q4 gets turned OFF. Q3 is turned ON by the BST drive from TPS1211-Q1 connecting the MOSFET Q1's SOURCE to TPS1211-Q1's SRC terminal. Diode D1 gets disconnected from the GND.

Figure 2-6 shows the waveform of the above application circuit during the -14 V automotive reverse battery test. As shown, the MOSFET Q1 turns ON as the gate to source is at approximately 12 V level during this test. The following bill of material components were used.

- D1, D2, D3, D4, D5 = BAS40H,115
- Q2 = MMBT3906WT1G
- Q3 = PMV60ENEAR
- Q4 = MMBT3904WT1G
- R1, R4, R6 = 10 kΩ
- R2 = 100 kΩ
- R3, R5 = 1 kΩ

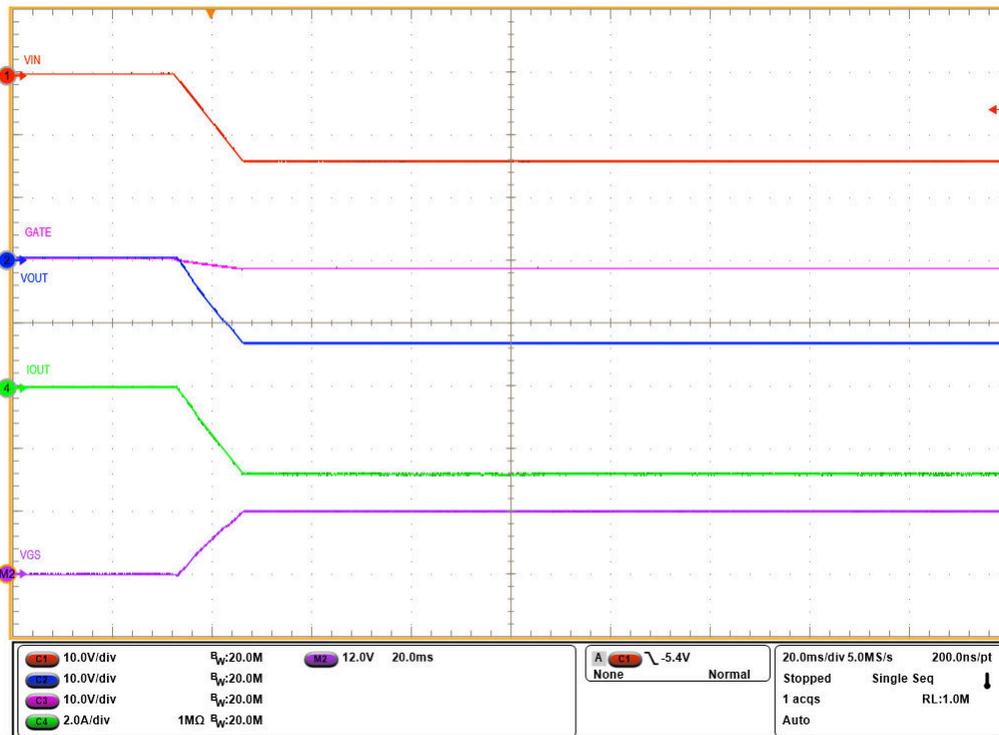


Figure 2-6. Performance Graph Showing Reverse Battery Protection with MOSFET ON

3 Summary

Based on the load type, the reverse battery protection can be implemented either with a back-to-back power switch or with a forward load switch topology. Various reverse battery protection system design examples are based on TPS1211-Q1 High side switch controller, as described in this application note, can be adopted based on the load type.

4 References

- Texas Instruments, [TPS1211-Q1 45-V, Automotive, Smart High-Side Driver With Protection and Diagnostics](#), data sheet.
- Texas Instruments, [LM74500-Q1 Reverse Polarity Protection Controller](#), data sheet.

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