Designing High-Side and 3-Phase Isolator MOSFET Circuits in Motor Applications

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TEXAS INSTRUMENTS

Introduction

Automotive motor systems, like those in electric power steering (EPS) systems, often utilize isolation switches to disable various parts of the power stage in response to system faults. These isolation switches are most commonly used to isolate the power stage from the battery voltage, or isolate individual motor phases to allow for fail-operational functionality.

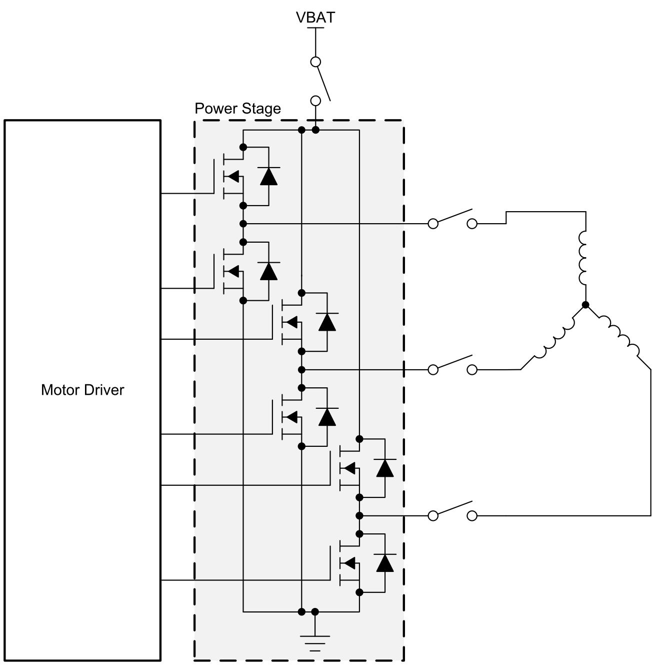

Figure 1. High-Side and Phase Isolation Switches

These switches can be implemented with a variety of components, but NMOS power FETs are usually the preferred option due to their low power dissipation. However, to turn on the NMOSFETs, the system must apply a gate voltage higher than the battery voltage. In motor drivers that utilize a bootstrap architecture, this means that an external voltage source must be provided to supply the overdrive voltage.

However, with TI motor drivers that incorporate an integrated boost converter (like the DRV3205-Q1) or charge pump (like the DRV3245Q-Q1 and DRV8305-Q1), this voltage supply is already available, and can be used to drive the isolation switch FETs with a few external components. While these motor drivers are designed to support these external loads, care must be taken to avoid exceeding the total current limit of the overdrive supply.

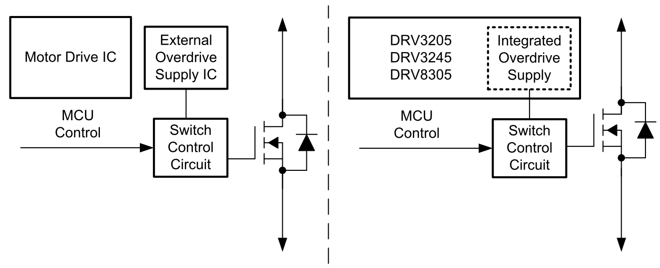

Figure 2. Overdrive Supply Comparison

There are several methods for controlling the isolation switches, with various advantages and drawbacks depending on the circuit topology. The following circuits demonstrate a few different possible control methods.

Topology 1:

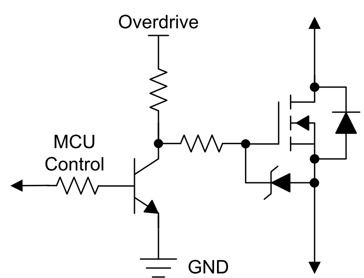

Figure 3. Single Transistor Control Circuit

This simple control method uses a single transistor connected to GND, with a current limiting resistor on the overdrive voltage supply and the gate of the FET. While this topology *does* minimize component count, the turn on and turn off times for the switch will be very slow. This is because the resistor must be sized appropriately to avoid overloading the overdrive supply when the FET is turned off.

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Toplogy 2:

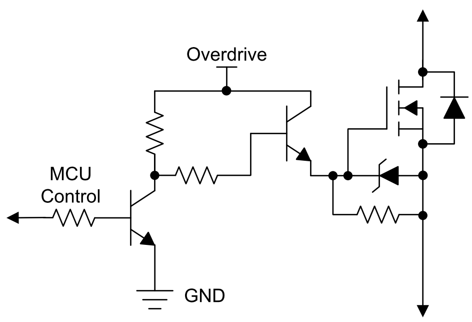

Figure 4. Active Pull-Up Control Circuit

This second circuit uses an additional transistor to provide a faster turn-on for the FET, but the passive pull-down means that the turn-off time will still be relatively long. Additionally, the passive pulldown will cause a constant current load on the overdrive supply when the FET is on.

Topology 3:

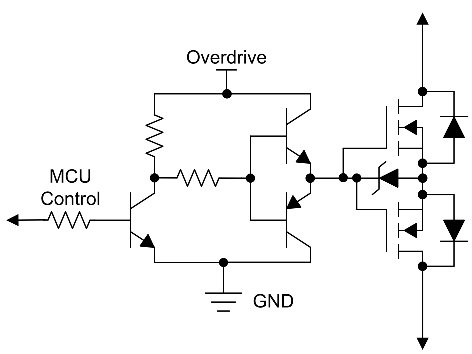

Figure 5. Push/Pull Control Circuit with Bidirectional Switch

This third circuit uses a PNP/NPN BJT stack in order to provide an active pullup and pulldown to the switch, providing a much faster turn-on/turn-off. This architecture will minimize the current load on the overdrive voltage supply in both the on and off states, as the only continuous load on the overdrive supply is through the low-current control transistor. Additionally, this circuit demonstrates the use of two NMOSFETs placed back-to-back to provide a bi-directional cutoff.

Conclusion

Isolation switches allow designers to dynamically control the power stage in response to a variety of system faults, and TI motor drivers with integrated overdrive supplies allow these switches to be implemented in a simple and cost-effective manner. Ultimately, the optimal control circuit for any system will be determined by a combination of speed, cost, and layout space. The above topologies are not an extensive list of every possible architecture, but should serve as a starting point for designing isolation switches in motor drive systems. For more information on the relevant TI motor drivers, check the links in the following table. For any additional questions, please visit the Motor Drivers Forum on TI's E2E™ online community.

Table 1. Device Recommendations

Device	Integrated Overdrive Supply:
DRV3205-Q1	Boost Converter
DRV3245Q-Q1	Charge Pump
DRV8305-Q1	Charge Pump

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