Application Brief

External vs. Internal Bootstrap Diode – Tradeoffs and Considerations

Introduction

Half-bridge gate drivers often use a diode to generate the high-side bias required to drive the floating switch in a half-bridge configured system. This diode is called a bootstrap diode, and is a critical part of the half-bridge gate driver operation. Because the bootstrap diode is so important, many half-bridge gate driver ICs integrate the bootstrap diode within the IC to save board space and the cost of the diode on the Bill of Materials(BOM) . However, many half-bridge gate driver ICs do not include the bootstrap diode and require the user to place an external bootstrap diode. This document covers the tradeoffs between both options to consider to implement the best option for different systems.

Bootstrap diode function

The bootstrap circuit consists of three main components- the bootstrap diode (Dboot), capacitor(Cboot), and resistor(Rboot).

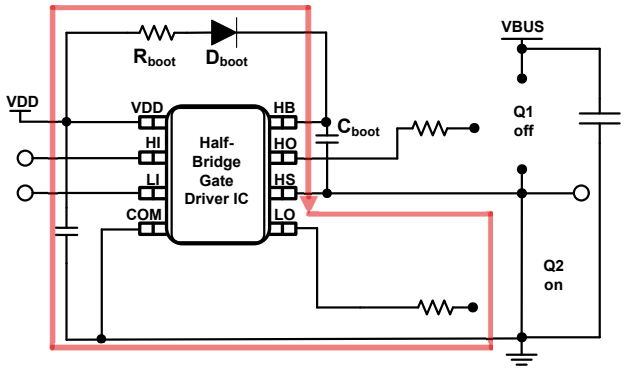

Figure 1. Bootstrap diode charging path labeled

For an explanation of the operation and component selection in the bootstrap circuit, please see "Bootstrap Circuitry Selection for Half-Bridge Configurations".

Advantages of Integrated Bootstrap Diode

Half-bridge gate driver ICs such as UCC27301A have a bootstrap diode integrated into the device. The integrated diode eliminates the need for an external bootstrap diode. Eliminating the external bootstrap diode saves the space of the external diode on the board (multiplied by the number of drivers on the board). Additionally, the integration saves the cost and BOM complexity of the external diode. Finally, the integrated bootstrap diode is designed to work in general purpose applications and therefore saves the circuit designer time and effort of designing the bootstrap diode circuit.

The exact amount of size and cost savings offered by integration depends on the diode being replaced. The bootstrap diode is selected based on the system max voltage, startup time, and the acceptable voltage drop during operation. For example, a bootstrap diodes designed for >600V operation which meet the high voltage spacing requirements (such as creepage), are in larger packages than a diode designed for 48V systems. So, while all systems receive the size and cost benefits to integration, the magnitude of those savings depend on the system, as well as the available options for integrated diode gate driver ICs.

Advantages of External Bootstrap Diode

The main advantage of the external bootstrap diode is the increased design flexibility. With an external bootstrap diode, the designer can size the Dboot and Rboot components to fit the exact specifications required for the application. With an external diode, Rboot can be placed in series with Dboot and adjusted as needed. For an integrated diode, there is no way to place a series resistor without also placing the resistance in series with the VDD, HB, or HS pins. Therefore, the external bootstrap diode gives more flexibility to adjust the bootstrap circuit parameters without affecting the gate drive loop.

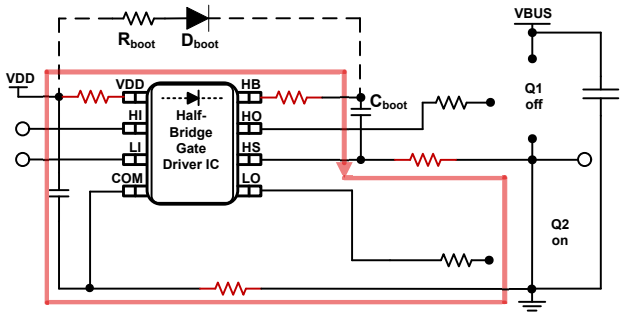

Figure 2. Bootstrap diode charging path Rboot options with integrated diode

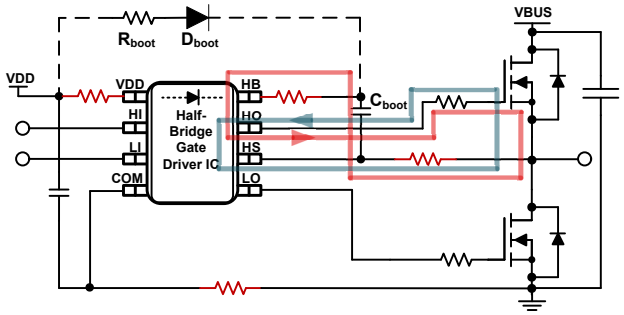

Figure 3. Gate turn-on and turn-off loops showing influence of Rboot placement

Another aspect of the design flexibility is the different types of diodes available. Using an external diode enables the use of Schottky or SiC Schottky diodes which are normally not be available in an integrated gate driver IC. Schottky diodes can offer lower forward voltage and reverse recovery losses than what is typically available in internal bootstrap diodes, making them a good option for certain systems like those using GaN at high switching frequency. Additionally, many high-voltage (>600V) half-bridge drivers have bootstrap diode dynamic resistances (Rd) in the 10's or 100's of Ohms, while discrete diodes tend to have Rd in the 1's of Ohms or lower. Lower Rd enables higher switching frequency and duty cycle of the system, and external bootstrap diodes can therefore enable systems with higher switching frequency requirements.

One more advantage of an external bootstrap diode is the multisourcing flexibility. To use gate drive IC's with integrated bootstrap diodes, every multisource option must have a diode with similar enough performance to work in the system. However, for external diodes, there are industry standard diodes such as the 1N4148, MURS160, and ES1D diodes which are offered by many different manufacturers. Because the specifications of these standard diodes are similar, they are easier to multisource.

Conclusion

Integrated bootstrap diodes help save board space and cost and are used in many systems. These savings are easy to see and understand, but there are some advantages to external bootstrap diodes also. Primarily, external bootstrap diodes offer more flexibility for specs, multisource, and adjustability via Rboot.

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