Application Report
SNVA083A–May 2004–Revised May 2013

AN-1317 Selection of External Bootstrap Diode for LM510X Devices

ABSTRACT

This application report discusses the selection of an external bootstrap diode for LM510X devices.

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1 Introduction

The gate drive requirements for a power MOSFET utilized as a high side switch, in applications like half-bridge converters or synchronous buck converters can be summarized as follows:

- Gate voltage must be 6 to12V higher than the source voltage. To fully enhance a high side switch, the gate to source voltage would have to be higher than the threshold voltage plus the minimum necessary voltage to fully enhance the MOSFET.
- The gate voltage must be controllable from the logic level, which are normally referenced to ground. Thus, the control signals need to be level shifted to the source terminal of high side MOSFET (HS node), which in most applications, swings between ground and the high voltage rail.
- The power dissipation of the gate driver must remain within the package thermal limitations.

Highly integrated gate driver IC's integrate following blocks.

- Low side gate driver
- High side level shifter
- High side gate driver
- Under-voltage lockout protection for both high and low side drive
- Bootstrap diode

The bootstrap circuit requires a high voltage and high speed diode along with low ESR/ESL capacitor as shown in Figure 1.

The internal bootstrap diode charges the bootstrap capacitor ($C_{BOOTSTRAP}$) every cycle when low side MOSFET turns on. The charging of the capacitor involves high peak currents, and therefore transient power dissipation in the internal bootstrap diode may be significant and dependent on the forward voltage drop of the internal diode. The reverse recovery time of the bootstrap diode must be very small, in order to achieve reduction in reverse recovery losses. Both the diode conduction losses and reverse recovery losses contribute to the total losses in the gate driver and need to be considered in calculating the gate driver IC power dissipation.

For high frequency and high capacitive loads, it may be necessary to consider using an external bootstrap diode placed in parallel with internal bootstrap diode to reduce power dissipation. The location of the external bootstrap diode should be very close to the gate driver chip. This application note quantifies the losses in the internal bootstrap diode at various external capacitive loads and supply rail voltages, and the remedies to overcome it.

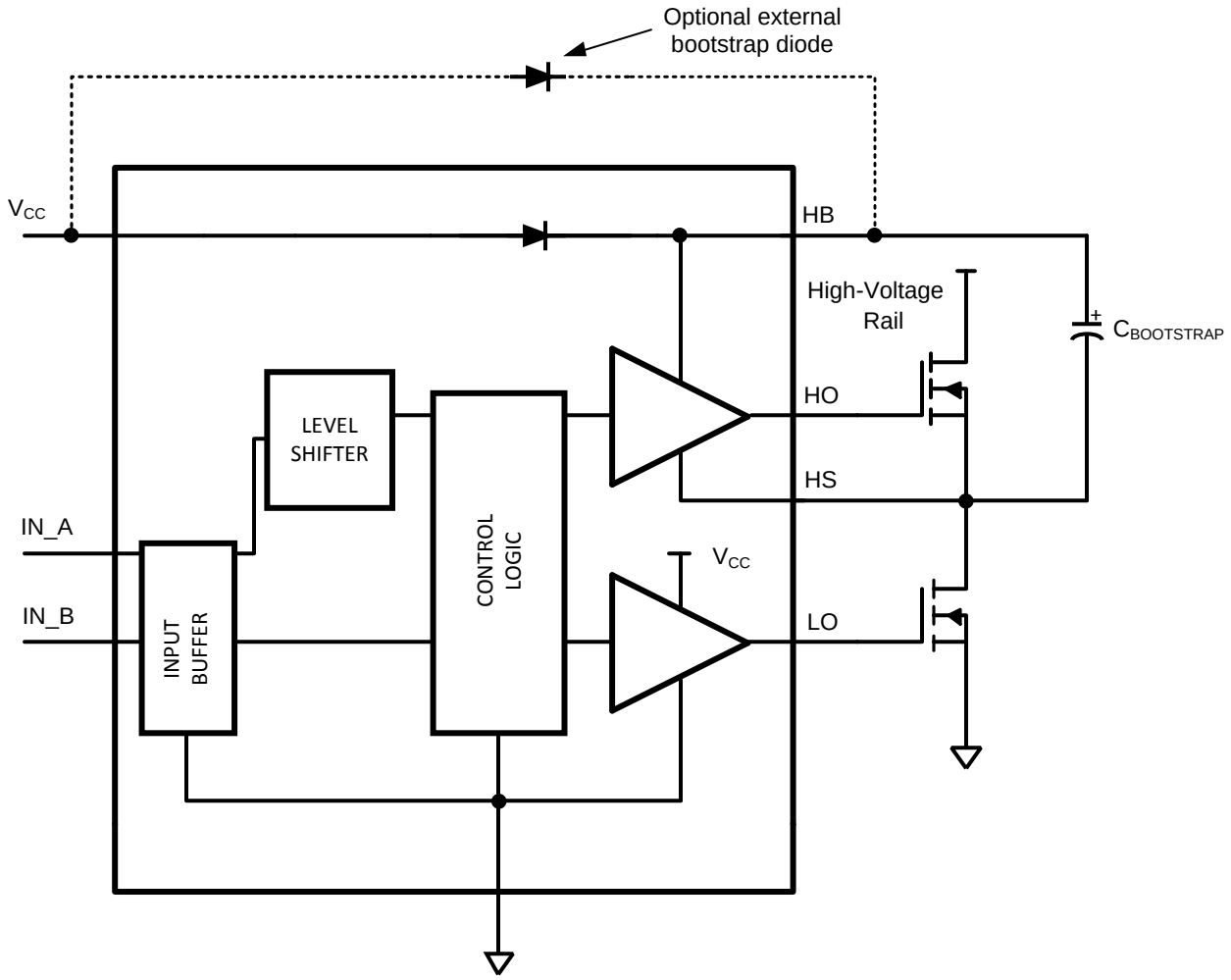

Figure 1. Simplified Schematic of High and Low Side Driver

2 Theory of Operation

2.1 Power Dissipation

The total IC power dissipation is the sum of the gate driver losses and the bootstrap diode losses. The gate driver losses are related to the switching frequency (f), output load capacitance on LO and HO (C_L), and supply voltage (V_{DD}) and can be roughly calculated as:

$$P_{DGATES} = 2 \times f \times C_L \times V_{DD}^2 = 2 \times f \times Qg \times V_{DD} \quad (1)$$

Where Qg is the total gate charge of the external MOSFET in coulombs.

There are some additional losses in the gate drivers due to the internal CMOS stages used to buffer the LO and HO outputs. Figure 2 shows the measured gate driver power dissipation verses frequency and total gate charge of external MOSFET in coulombs. At higher frequencies and load capacitance values, the power dissipation is dominated by the power losses driving the output loads and agrees with Equation 1. Figure 2 can be used to approximate the power losses due to the LM510X gate drivers. This data was taken by connecting external capacitive loads on both outputs of LM510X driver.

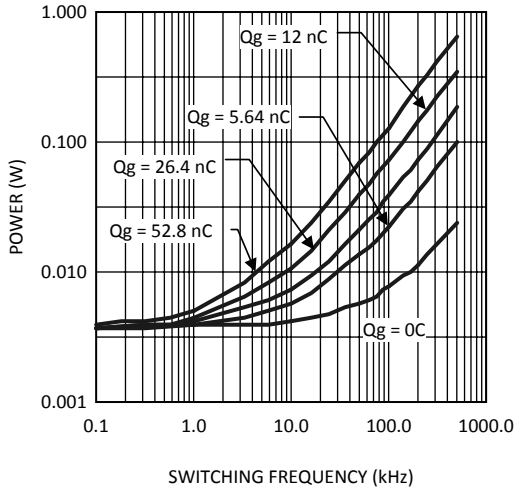

Figure 2. Gate Driver Power Dissipation (LO + HO)
V_{CC} = 12V, Neglecting Diode Losses

The bootstrap diode power loss is the sum of the forward bias power loss that occurs while charging the bootstrap capacitor and the reverse bias power loss that occurs during reverse recovery. Since each of these events happens once per cycle, the diode power loss is proportional to frequency. Larger capacitive loads require more current to recharge the boot capacitor resulting in more losses. Higher input voltages (VIN) to the half bridge result in higher reverse recovery losses. Figure 3 and Figure 4 were generated based on calculations and lab measurements of the diode recovery time and current under several operating conditions. This can be useful for approximating the diode power dissipation.

The total IC power dissipation can be estimated from the plots shown in Figure 2, Figure 3, Figure 4 by summing the gate drive losses with the bootstrap diode losses for the intended application. Because the diode losses can be significant, an external diode placed in parallel with the internal bootstrap diode can be helpful in removing power from the IC. For this to be effective, the external diode must be placed close to the IC to minimize series inductance and have a significantly lower forward voltage drop than the internal diode. (please refer to the LM510X data sheet).

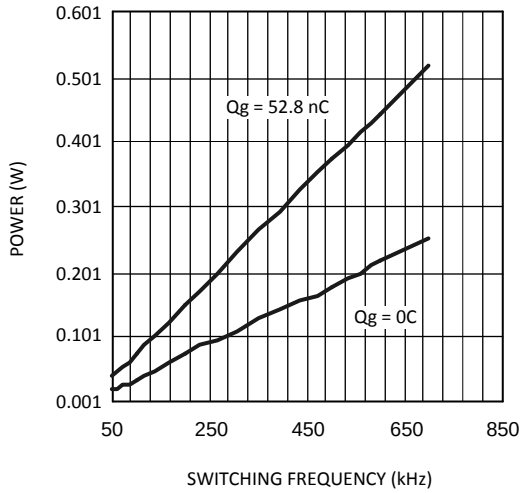

Figure 3. Diode Power Dissipation
V_{IN} = 40V

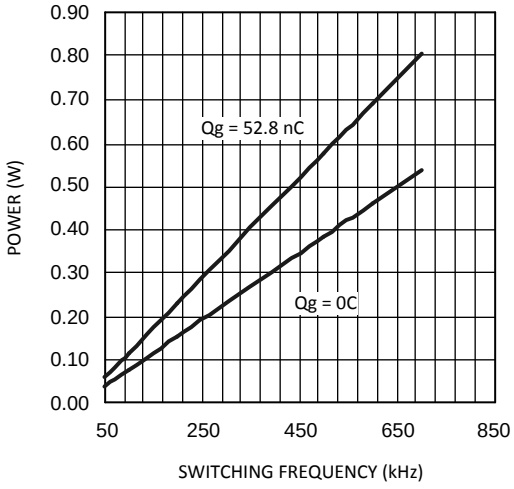

Figure 4. Diode Power Dissipation
V_{IN} = 80V

3 Recommended External Bootstrap Diodes

Table 1. Recommended External Bootstrap Diodes

Item	Diode Part Number	Manufacturer	Remarks	Approximate Cost/unit
1	CRH01	Toshiba	S-FLATTM PACKAGE	$0.15
			(3.5mm x 1.6mm)	
2	MURA110T3	ONSEMI	SMA PACKAGE	$0.11
			(5.5mm x 2.9mm)	
3	BYV40E	PHILIPS SEMI	SOT223 PACKAGE.	---------
			(6.7mm x 6.7mm)	
4	MA2YD1700L	PANASONIC	Schottky diode. High leakage current at high temperatures. Mini2-F1 package.	$0.18
			(3.5mm x 1.6mm)	

4 Conclusion

This application report quantifies the losses in the internal bootstrap diode of LM510X high and low side gate driver. In high frequency and high capacitive load applications, it is sometimes beneficial to use an external bootstrap diode to reduce power dissipated within the IC.

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265