



## Introduction (Continued)

tion 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.

## Theory Of Operation

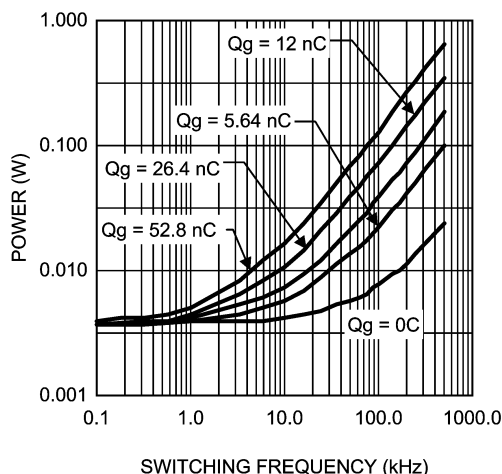
### POWER DISSIPATION

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:

$$P_{DGATES} = 2 \times f \times C_L \times V_{DD}^2 = 2 \times f \times Q_g \times V_{DD}$$

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

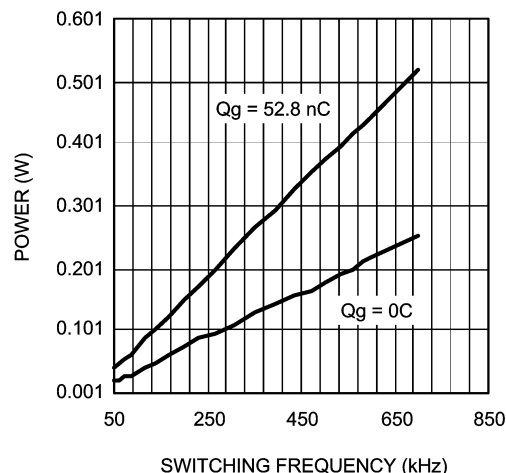
There are some additional losses in the gate drivers due to the internal CMOS stages used to buffer the LO and HO outputs. The following plot *Figure 2* shows the measured gate driver power dissipation versus frequency and total gate charge of external MOSFET in coulombs. At higher frequencies and load capacitance values, the power dissipation is dominated by the power losses driving the output loads and agrees well with the above equation. This plot 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.



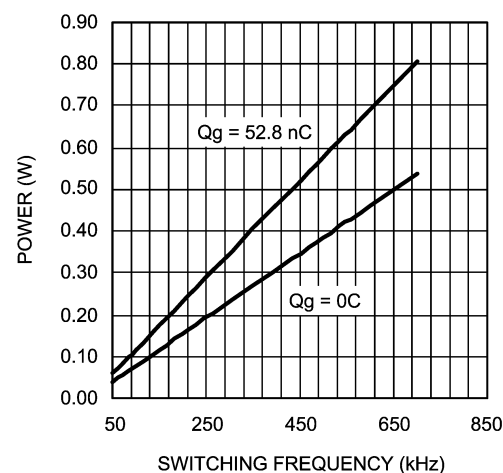
**FIGURE 2. Gate Driver Power Dissipation (LO + HO)**  
 $V_{CC} = 12V$ , Neglecting Diode Losses

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 ( $V_{IN}$ ) to the half bridge result in higher reverse recovery losses. The following plots (FIG 3 & 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.



**FIGURE 3. Diode Power Dissipation**  
 $V_{IN} = 40V$



**FIGURE 4. Diode Power Dissipation**  
 $V_{IN} = 80V$

The total IC power dissipation can be estimated from the above plots 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 LM510X datasheet).

## 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)	

## Conclusion

This application note 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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