The purpose of this paper is to demonstrate a systematic approach to design high−performance bootstrap gate drive

Figure 6 shows the waveforms of the high−side, N−channel MOSFET during turn−off.

The bootstrap capacitor (C_{BOOT}) is charged every time the low−side driver is on and the output pin is below the supply voltage (V_{DD}) of the gate driver. The bootstrap capacitor is discharged only when the high−side switch is turned on. This bootstrap capacitor is the supply voltage (V_{BS}) for the high circuit section. The first parameter to take into account is the maximum voltage drop that we have to guarantee when the high−side switch is in on state. The maximum allowable voltage drop (V_{BOOT}) depends on the minimum gate drive voltage (for the high−side switch) to maintain. If V_{GSMIN} is the minimum gate−source voltage, the capacitor drop must be:

$$V_{BOOT} = V_{DD} - V_F - V_{GSMIN} \qquad \text{(eq. 2)}$$

where:

V_{DD} = Supply voltage of gate driver [V]; and
V_F = Bootstrap diode forward voltage drop [V]

The value of bootstrap capacitor is calculated by:

$$C_{BOOT} = \frac{Q_{TOTAL}}{\Delta V_{BOOT}} \qquad \text{(eq. 3)}$$

where Q_{TOTAL} is the total amount of the charge supplied by the capacitor.

The total charge supplied by the bootstrap capacitor is calculated by equation 4:

$$Q_{TOTAL} = Q_{GATE} + (I_{LKCAP} + I_{LKGS} + I_{QBS} + I_{LK} + I_{LKDIODE}) \times t_{ON} + Q_{LS} \qquad \text{(eq. 4)}$$

where:

Q_{GATE} = Total gate charge;
I_{LKGS} = Switch gate−source leakage current;
I_{LKCAP} = Bootstrap capacitor leakage current;
I_{QBS} = Bootstrap circuit quiescent current;
I_{LK} = Bootstrap circuit leakage current;
Q_{LS} = Charge required by the internal level shifter, which is set to 3 nC for all HV gate drivers;
t_{ON} = High−side switch on time; and
$I_{LKDIODED}$ = Bootstrap diode leakage current.

The capacitor leakage current is important only if an electrolytic capacitor is used; otherwise, this can be neglected.

For example: Evaluate the bootstrap capacitor value when the external bootstrap diode used.

- Gate Drive IC = FAN7382 (ON Semiconductor)
- Switching Device = FCP20N60 (ON Semiconductor)
- Bootstrap Diode = UF4007
- V_{DD} = 15 V
- Q_{GATE} = 98 nC (Maximum)
- I_{LKGS} = 100 nA (Maximum)
- I_{LKCAP} = 0 (Ceramic Capacitor)
- I_{QBS} = 120 μA (Maximum)
- I_{LK} = 50 μA (Maximum)
- Q_{LS} = 3 nC
- T_{ON} = 25 μs (Duty = 50% at f_s μ

The approximate maximum gate charge Q_G that can be switched in the indicated time for each driver current rating is calculated in Table 1:

–

2 A	133 nC	67 nC
4 A	267 nC	133 nC
9 A	600 nC	300 nC

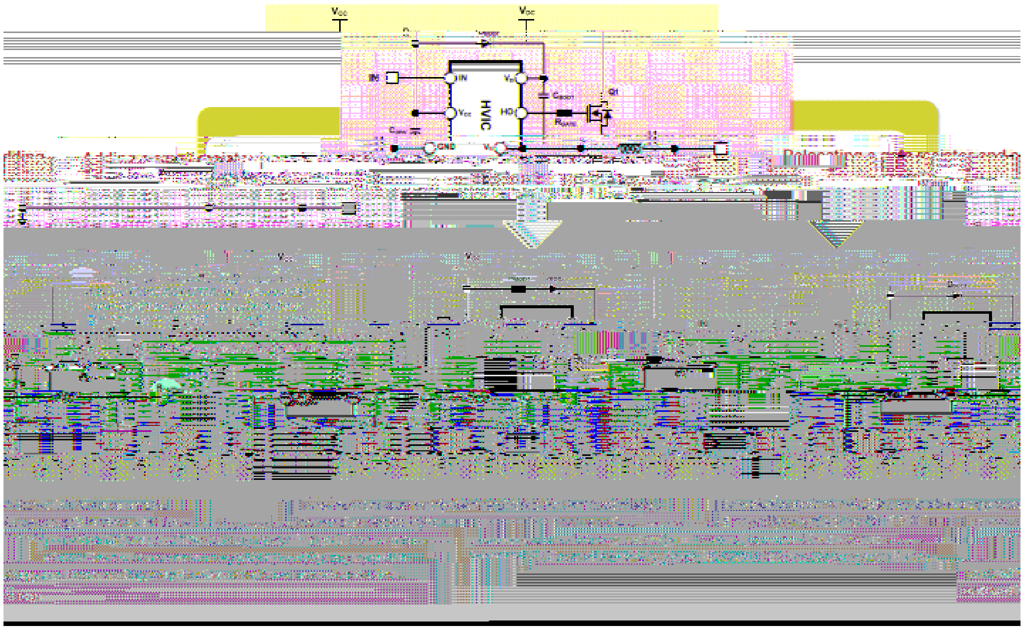
1. For a single 4 A, parallel the two channels of a dual 2 A!

For example, a switching time of 100 ns is:
1 % of the converter switching period at 100 kHz;
3 % of the converter switching period at 300 kHz; etc.

1. Needed gate driver current ratings depend on what gate charge Q_G must be moved in switching time $t_{SW-ON/OFF}$ (because average gate current during switching is I_G):

$$I_{G.AV.SW} = \frac{Q_G}{T_{sw\_on}} \qquad \text{(eq. 16)}$$

$$R_{DRV(ON)} = \frac{V_{DD}}{I_{SOURCE}} = \quad 15\ V \qquad \text{(eq. 30)}$$


HVIC
IN
HO
GND
Q1