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AN-5073
Active Miller Clamp Technology

Summary

For IGBT drive design, especially for low- and medium-power IGBT drive applications, engineers tend to adopt a simple board-level layout and a straight-forward solution. Removing the driving negative power supply becomes an attractive solution, while it also poses certain challenges.

As shown in Figure 1, both the high-side and low-side IGBTs are powered by a single power source. Normally, these two IGBTs do not switch on simultaneously and their gate voltage is not high simultaneously (as in the black waveform shows in Figure 2). A voltage glitch can occur after IGBT turn-off due to the existence of dv/dt (as the red waveform shows in Figure 2).

As shown in Figure 3, Q1 turns on after Q2 turns off and the CE voltage across Q2 increases. Due to the very high dv/dt, current is able to pass through C_{gc} of Q2 and flow through the current-limiting resistance R_g and the drive output resistance. This current is called the Miller current. It can be calculated by the following formula:

$$I_{gc} = C_{gc} \times \frac{dv}{dt} \quad (1)$$

When the switching speed increases, dv/dt increases accordingly, and the Miller current causes VGE2 to rise to the threshold voltage of Q2, then causes Q1 and Q2 to switch on simultaneously. This is very dangerous for both Q1 and Q2, and it can certainly lead to power wastage.

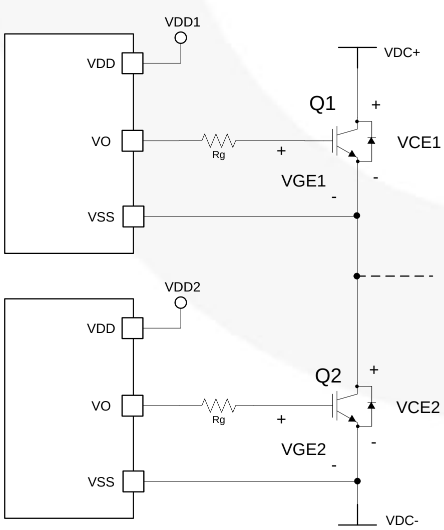

Figure 1. Application Circuit without Negative Power Supply in a Bridge Arm

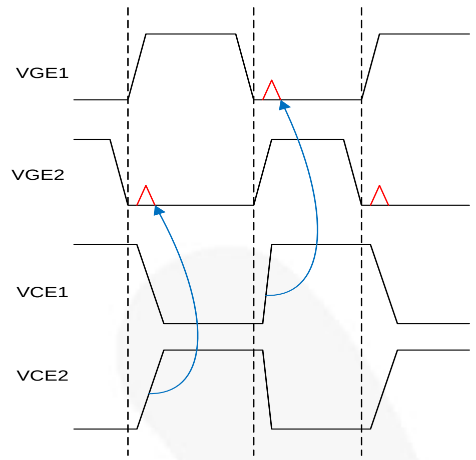

Figure 2. VGE and VCE Waveforms for Q1 and Q2

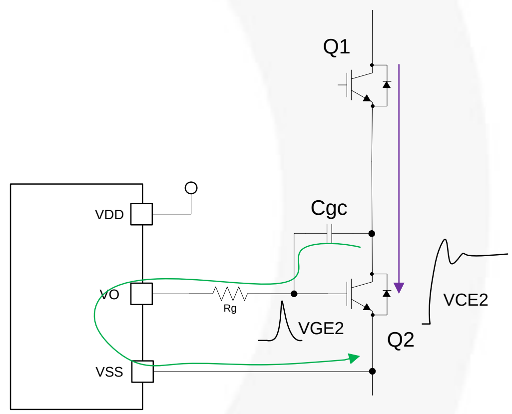

Figure 3. Schematics for Generation of Q2 Miller Current and Flow-through Current

To avoid this issue, the IGBT gate voltage should be controlled effectively after the IGBT switches off to limit the influence of the Miller current. Some of the common solutions are illustrated in Figure 4 and Figure 5, where the green line represents the turn-off current and the red line represents the turn-on current. In Figure 4, a different resistance is used for IGBT turn-on and turn-off, which ensures that the resistance, when the Miller current is flowing through, is smaller. This limits any voltage glitch at the gate. However, the turn-off resistance should not be too small. If it is too small, it causes the IGBT to turn off too quickly, resulting in too high a di/dt. The method shown in Figure 5 uses a PNP transistor. The PNP transistor turns on and more Miller current is bypassed by the PNP during IGBT turn-off.

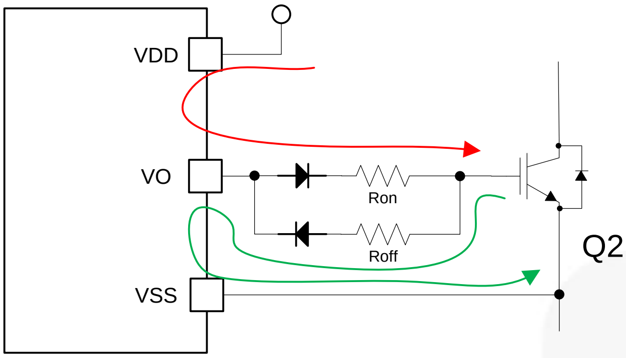

Figure 4. Method 1 for Lowering Effects of Miller Current: Reduce IGBT Turn-off Resistance

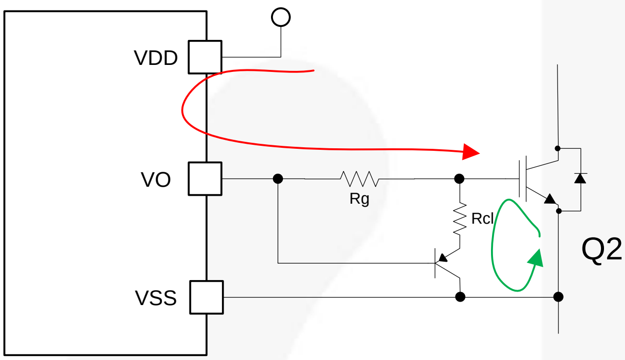

Figure 5. Method 2 for Lowering the Effects of Miller Current: Use a PNP as Current Bypass

To ease this integration, Fairchild Semiconductor has introduced smart gate drive optocoupler products with an active Miller clamp function, such as the FOD8318 and FOD8332*, for devices in high-voltage applications. As shown in Figure 6, these products integrate a MOSFET switch to bypass the Miller current. When the gate voltage is reduced to 2 V, V_{gcl} rises to enable the active Miller clamp switch to turn on during IGBT turn-off. The typical clamp current is 1.1 A when the clamp voltage is 2.5 V; thus the IGBT gate voltage is clamped below the IGBT turn-on voltage. During IGBT turn-on, V_{gcl} drops, and this turns off the active Miller clamp switch and disables the active Miller clamp function. The Miller clamp function is only effective during IGBT turn-off and does not affect IGBT turn-on.

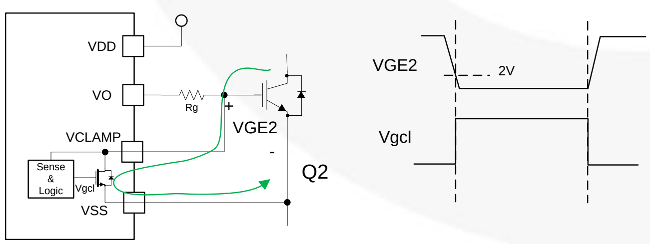

Figure 6. Active Miller Clamp Technology

The allowable dv/dt for an IGBT is relative to its switching characteristics and to those of the drive circuit, including the drive impedance. The following discusses an evaluation result in which an IGBT- FGH60B60SMD (600 V/60 A) was driven by Fairchild Semiconductor's FOD8318. The drive resistance was 20 Ω and the IGBT gate voltage increased to as much as 5.12 V when dv/dt was 2.3 kV/µs, as shown in Figure 7. After utilizing the active Miller clamp function, the gate voltage on the IGBT was just 1.68 V, at the same dv/dt and under the same test conditions, as shown in Figure 8. This shows that the active Miller clamp function is capable of effectively reducing dv/dt effects.

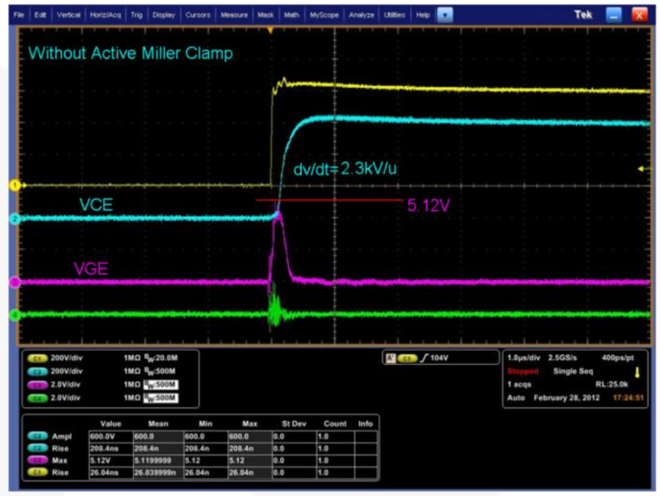

Figure 7. VGE and VCE Waveforms without Active Miller Clamp Function

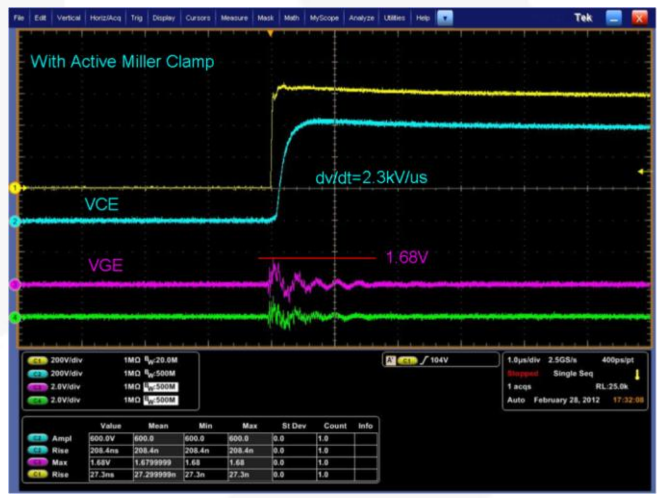

Figure 8. VGE and VCE Waveforms with Active Miller Clamp Function

The question then arises, how to determine whether Fairchild's product is suitable for driving the applied IGBT? This requires comparing the I_{CLAMP} data with the Miller current I_{gc} in the applied IGBT. Consider the C_{res} parameter to be equivalent to the IGBT C_{gc}. In this case, C_{res} is rated at 85 pF according to the FGH60N60SMD specification.

Using formula (1), calculate

$$I_{gc} = C_{GC} \text{ x } dv/dt = 85 \text{ pF x } 2.3 \text{ kV/µs} = 0.20 \text{ A}.$$

The minimum I_{CLAMP} is 0.35 A, according to Fairchild's specification, and this is higher than 0.2 A. Therefore, the Fairchild FOD8318 can be used in the single-source drive IGBT FGH60N60SMD.

$$Igc < \frac{VGE(th)max}{Rg + Rdrv} = \frac{6V}{20 + 1} = 0.29A \qquad (2)$$

In addition, an IGBT turns on when a glitch voltage reaches its threshold voltage. Therefore, calculate the I_{gc} from the threshold voltage ($V_{GE(th)max}$).

A simpler method is to compare the maximum I_{gc}, calculated using formula (2) and I_{CLAMP}, especially when the dv/dt condition is unknown.

If the drive resistance is 10 Ω, the I_{gc} increases to 0.55 A, based on formula (2). In this case, the clamp current is bypassed, at the least at 0.35 A. The residual 0.2 A current is able to flow through 11 Ω and then generate 2.2 V of V_{GE}. This does not turn on the IGBT.

Of course, I_{CLAMP} is also limited. The absolute maximum rating of the function is 1.7 A.

Conclusion

With the application of the active Miller clamp function, the Fairchild gate driver optocoupler products, FOD8318 and FOD8332, can help engineers to effectively shut off the IGBT during a high dv/dt situation, without the need to use a negative power supply voltage. This reduces the complexity of board-level routing while improving drive reliability. For more product information, please visit www.fairchildsemi.com.

Related Resources

FOD8318 − 2.5 A Output Current, IGBT Drive Optocoupler With Active Miller Clamp, Desaturation Detection and Isolated Fault Sensing

FOD8332 − 2.5 A Output Current, IGBT Drive Optocoupler With Active Miller Clamp, Desaturation Detection and Isolated Fault Sensing

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