



Is Now Part of



ON Semiconductor®

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

ON Semiconductor and the ON Semiconductor logo are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

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 V_{GE2} 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.

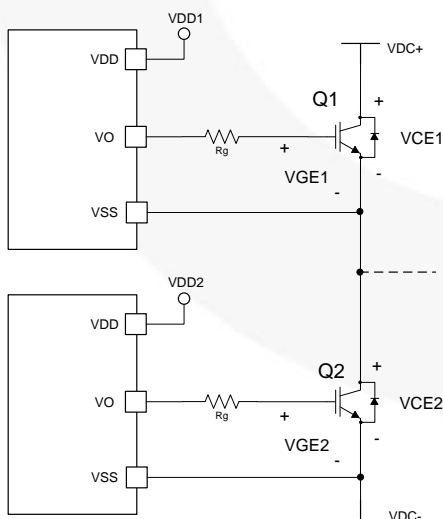


Figure 1. Application Circuit without Negative Power Supply in a Bridge Arm

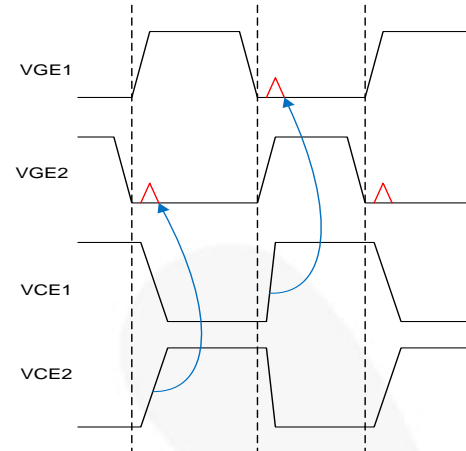


Figure 2. VGE and VCE Waveforms for Q1 and Q2

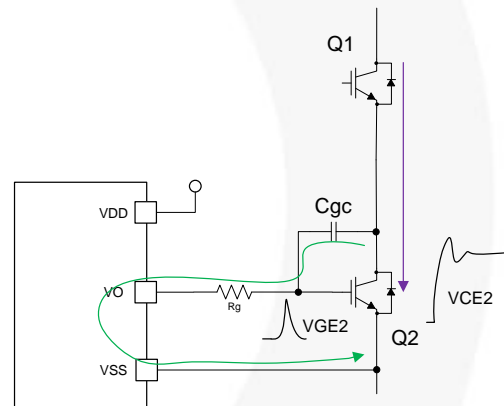


Figure 3. Schematics for Generation of Q2 Miller Current and Flow-through Current

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.

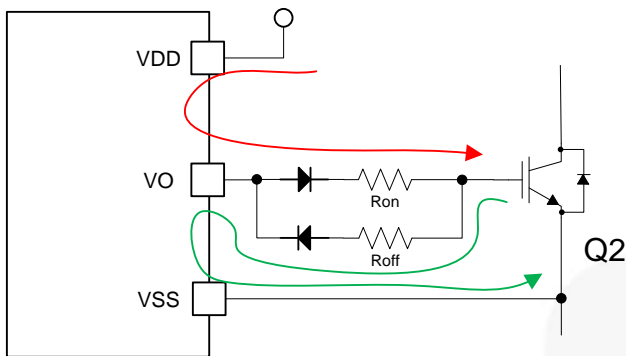


Figure 4. Method 1 for Lowering Effects of Miller Current: Reduce IGBT Turn-off Resistance

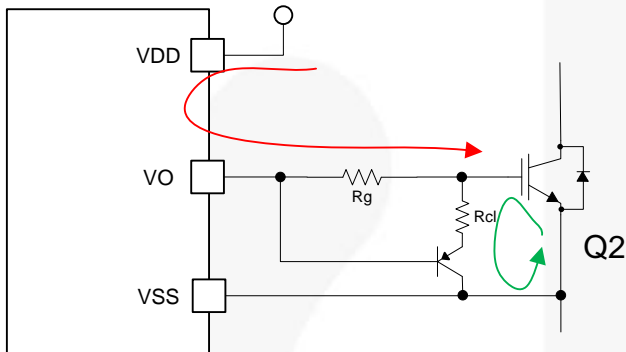


Figure 5. Method 2 for Lowering the Effects of Miller Current: Use a PNP as Current Bypass

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.

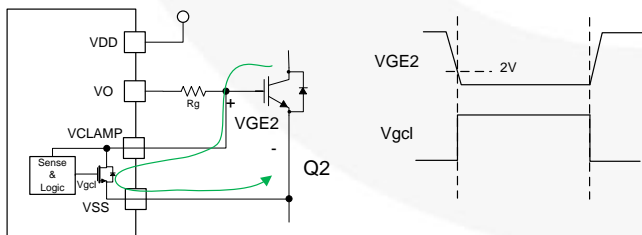


Figure 6. Active Miller Clamp Technology

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/ μ s, 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.

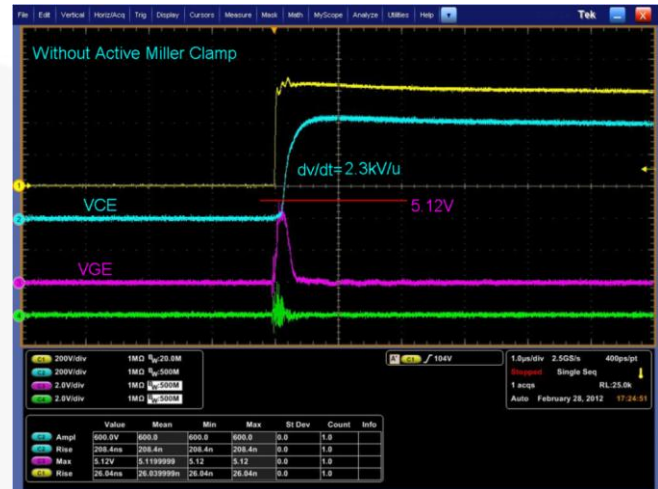


Figure 7. VGE and VCE Waveforms without Active Miller Clamp Function



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

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

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.

$$I_{gc} < \frac{V_{GE(th)max}}{R_g + R_{drv}} = \frac{6V}{20 + 1} = 0.29A \quad (2)$$

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*](#)

DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION, OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free
USA/Canada

Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910

Japan Customer Focus Center
Phone: 81-3-5817-1050

ON Semiconductor Website: www.onsemi.com

Order Literature: <http://www.onsemi.com/orderlit>

For additional information, please contact your local
Sales Representative