Efficient SiC MOSFET Gate Protection Using SMFA Series Asymmetric TVS Diodes

Introduction

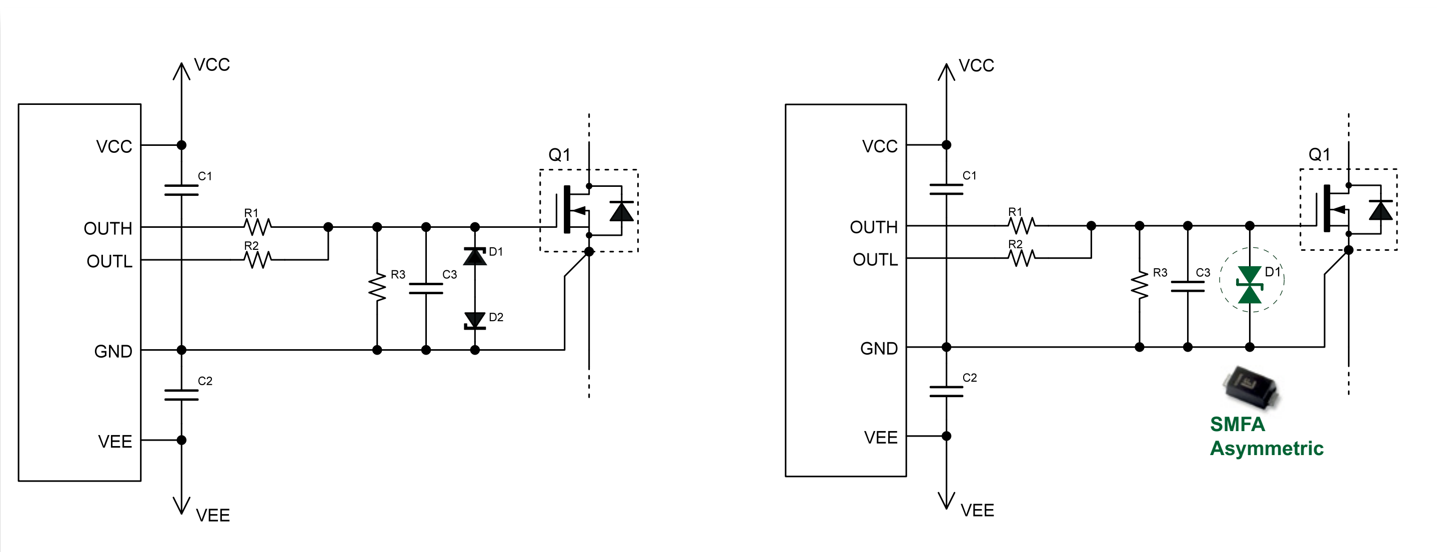
Silicon Carbide (SiC) MOSFETs are used for an increasingly large number of applications in the field of power supplies and power electronics. As development in the field of power semiconductors progresses, switching losses are being minimized. With the increasing switching speeds, designers should pay more attention to the MOSFET's gate-driver circuit, ensuring safe control of the MOSFET to prevent parasitic turn-on and avoid damage to the power semiconductor. The sensitive MOSFET gate structures must be protected from excessive high voltages. Littelfuse offers efficient protection solutions that help to maximize the service life, reliability, and robustness of power supplies.

Gate driver design measures

Several topics are worth consideration regarding the robustness of a SiC-MOSFET driver circuit. In addition to the driver's primary task of switching the semiconductor safely, various drivers also offer a short-circuit protection function. Furthermore, it is essential to prevent parasitic switching with suitable design measures, such as applying a negative gate voltage during the turn-off state. The negative gate voltage ensures an increased offset to the MOSFET's gate-threshold voltage and increases the immunity to voltage slopes within the switching cell. A further mandatory measure is the protection of the MOSFET's gate against overvoltage surges caused by electrostatic discharge (ESD) events or parasitic effects in the circuit.

Silicon-based power semiconductors like Si-IGBTs and Si-MOSFETs usually have a symmetric gate voltage rating. This rating would allow symmetric TVS diodes for gate protection, which is unnecessary since the maximum Si gate voltage ratings are sufficiently higher than the applied driving voltages. Unlike Si devices, SiC-MOSFETs typically have significantly lower negative gate voltage ratings than positive gate voltage. Consequently, asymmetrical protection using two separate TVS diodes, as shown in Figure 1, is common. Littelfuse now offers SMFA-type integrated asymmetrical, bidirectional TVS diodes. This solution helps to effectively reduce parasitic effects and PCB area, especially in fast-switching SiC applications.

Figure 1. Standard gate protection with two separate TVS diodes vs. one integrated asymmetric SMFA-type TVS Diode



Product selection

The Littelfuse SMFA Asymmetric Series TVS Diode protects the SiC-MOSFET gate against positive and negative overvoltage surges. Depending on the required maximum gate voltage ratings of the SiC-MOSFET, the SMFA types are chosen from positive breakdown voltages between 17.6 and 23.4 V. The negative breakdown is set to 7.15 V. Further details of the components can be found in Table 1. The SMFA asymmetric TVS are tested according to IEC 61000-4-2 and come in a SOD-123FL low-profile package.

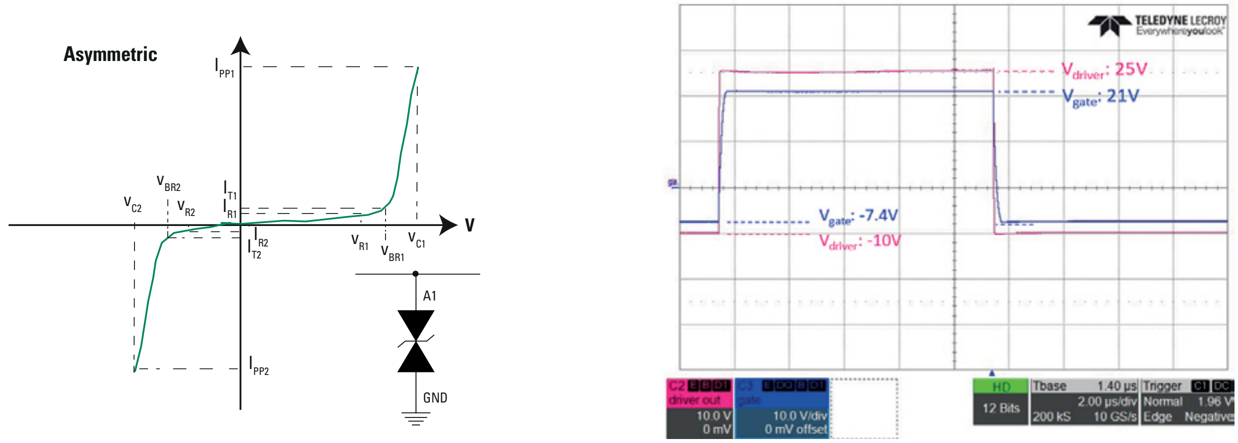
Table 1. SMFA-series product portfolio

Part Number	Marking	A1 → A2										
		Maximum Reverse Leakage I_{R1} @ V_{R1} (µA)	Stand-off Voltage V_{R1} (V)	Breakdown Voltage V_{BR} (Volts) @ I_{T1}			Typical Clamping Voltage V_{C3}@I_{PP3} (V)	Typical Peak Pulse Current I_{PP3} (A)	Maximum Clamping Voltage V_{C1}@ I_{PP1} (V)	Maximum Peak Pulse Current I_{PP1} (A)	Test Current I_{T1} (mA)	Junction Capacitance Typ@ 1 MHz, 0 V Bias (pF)
				Min.	Nom.	Max.						
SMFA1505CA	FM	1	15	16.7	17.6	18.5	18.57	2	24.05	16.63	1	565
SMFA1805CA	FT	1	18	20.0	21.1	22.1	24.47	2	28.73	13.92	1	515
SMFA1905CA	FU	1	19	21.1	22.2	23.3	25.55	2	30.29	13.21	1	485
SMFA2005CA	FV	1	20	22.2	23.4	24.5	26.40	2	31.85	12.56	1	440

Part Number	Marking	A1 ← A2										
		Maximum Reverse Leakage I_{R2} @ V_{R2} (µA)	Stand-off Voltage V_{R2} (V)	Breakdown Voltage V_{BR} (Volts) @ I_{T2}			Typical Clamping Voltage V_{C4}@I_{PP4} (V)	Typical Peak Pulse Current I_{PP4} (A)	Maximum Clamping Voltage V_{C2}@ I_{PP2} (V)	Maximum Peak Pulse Current I_{PP2} (A)	Test Current I_{T2} (mA)	Junction Capacitance Typ@1 MHz, 0 V Bias (pF)
				Min.	Nom.	Max.						
SMFA1505CA	FM	400	5.5	6.82	7.15	7.48	7.85	2	10.5	33.0	10	565
SMFA1805CA	FT	400	5.5	6.82	7.15	7.48	7.85	2	10.5	33.0	10	515
SMFA1905CA	FU	400	5.5	6.82	7.15	7.48	7.85	2	10.5	33.0	10	485
SMFA2005CA	FV	400	5.5	6.82	7.15	7.48	7.85	2	10.5	33.0	10	440

Figure 2 shows the static and dynamic clamping performance of the SMFA-type asymmetrical TVS diodes. For test purposes, the driver voltage was increased to show the TVS diode's dynamic clamping. The SMFA TVS diodes are not suitable for permanently limiting an excessively high driver voltage.

Figure 2. Clamping characteristics of SMFA-type integrated asymmetric TVS Diode



Static characteristics   Dynamic clamping

Conclusion

With the new integrated asymmetric TVS SMFA-series, Littelfuse provides an innovative solution to maximize robustness of SiC MOSFET gate-driver circuits, while enabling designs, that are cost effective, require less PCB-space, and minimize parasitic effects.

Reference

For more information about Littelfuse SMFA Asymmetric Series, please use the following links on Littelfuse website
Product series page: https://www.littelfuse.com/products/tvs-diodes/surface-mount/smfa-asymmetric.aspx