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Capacitive Discharge Circuit for Surge Current Evaluation of SiC

by Mark R. Morgenstern

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14. ABSTRACT

The power components branch has constructed an apparatus used for surge current testing of prototype semiconductor switch devices. The test apparatus is small-scale. It provides a 1 J pulse at a 5-25μS pulse width. Shoot-through is a concern in many of the power conversion applications and the pulse provided by this apparatus can provide a very useful model of what device behavior to expect when shoot-through currents occur. Other device characteristics that can also be measured with this apparatus are: maximum current rise rate, forward transconductance, high voltage blocking, required gate charge, and safe operating area.

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Surge, current, evaluation, silicon carbide, switches

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In recent years there has been widespread interest in developing SiC semiconductor technology for power electronics applications. This interest is due to wide band gap and other superior characteristics such as high temperature operation and the ability to handle large current densities. The purpose of the apparatus described in this report is to measure the response of SiC semiconductor devices to current surges in the on state and high blocking voltages in the off state. These measurements allow us to evaluate certain device characteristics critical to understanding how a prototype SiC semiconductor switch will operate in real power electronics applications. One example of this might be using a surge current pulse to represent an expected "shoot-through" current in a half bridge inverter. There are other device characteristics that can be evaluated using the circuit in figure 1 and by varying the time, current and voltage parameters of the figure 3 waveform, as well as gate bias. These indicate maximum current rise rate, forward transconductance, high voltage blocking, required gate charge, and safe operating area.

In the circuit of figure 1, the capacitor (C1) trickle charges through Rc and D1. During discharge, Rc and D1 prevent oscillations from occurring between C1 and line inductance between Vdc and Rc. Rl provides a reasonably low resistance, while L1 (intrinsic in the connections ~100 nH) spreads the discharge to occur in the 5–25 μS time range.

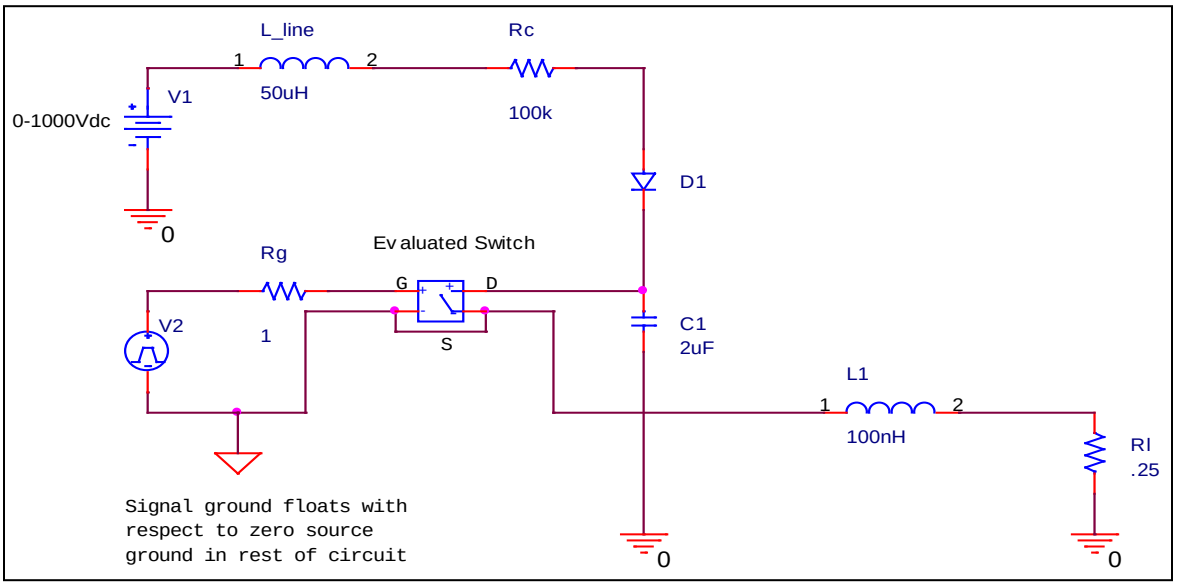

Figure 1. Schematic of the capacitive discharge circuit. See figure 6 for circuit of V2.

During the process of trouble shooting and refining this apparatus, 5 A 4 HSiC SiC MOSFETS provided by Cree (figure 2 – right), were evaluated at a surge current of 180A (36 times the continuous current rating of the parts as seen in figure 3) at a gate bias of 30V. However, at a gate bias of 15 V, a maximum surge current of only 70 A was achieved. Fast switching at high currents requires aggressive gate drive (figure 6). The capacitive discharge circuit (figures 1, 4, and 5) will be used to evaluate 20 A parts (figure 2 – left) similar to the parts mentioned above,

as well as evaluate and compare different types of SiC switches for best suitability in high power conversion applications.

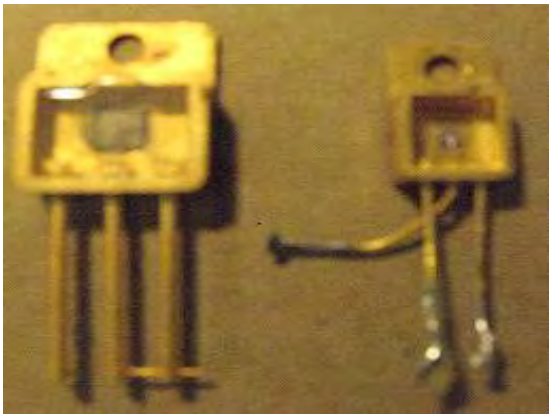

Figure 2. Sample test subjects – 4 HSiC MOSFETS provided by Cree Inc. 20A MOSFET on left, 5A MOSFET on right.

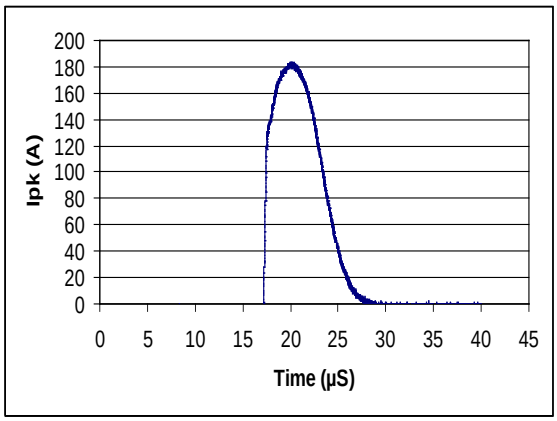

Figure 5: I_{pk} of 5A DMOSFET with gate bias of 30 V

Figure 3. Peak surge current of 5A 4 HSiC MOSFET shown in figure 2.

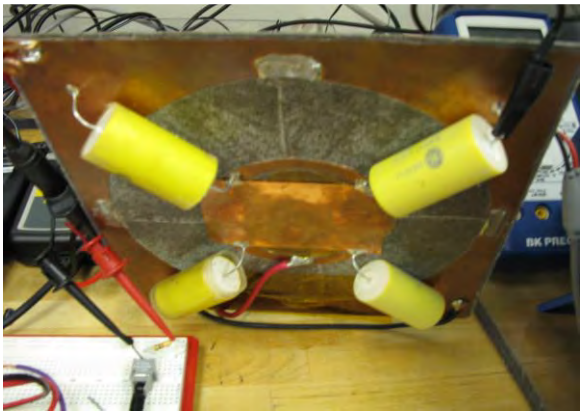

Figure 4. Parallel discharge capacitors on bottom of test board.

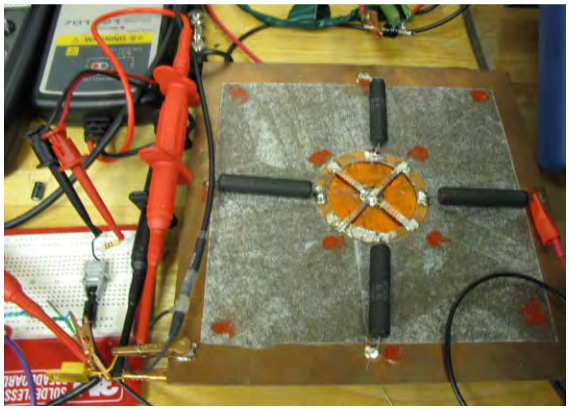

Figure 5. Parallel load resistors on top of test board. Test subject is clipped to test board on lower left.

Note: As can be seen in figures 4 and 5, the test board is arranged so that inductance is minimal and the current rise times from each capacitor are as close to overlapping as practical.

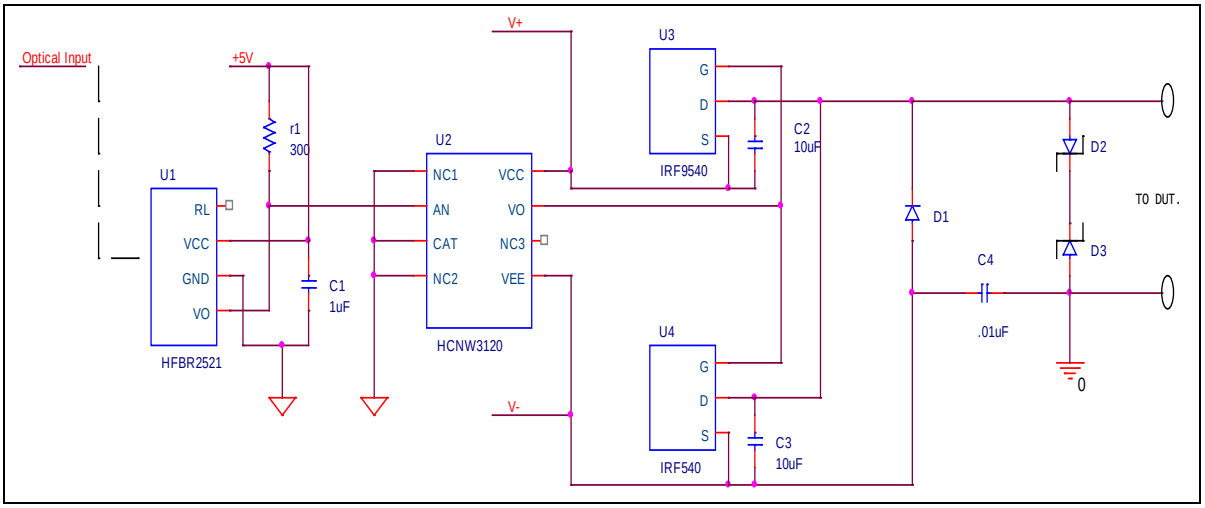

Figure 6. Gate drive circuit used in ring down circuit of figure 1.

Note: This circuit is V2 of figure 1. U1 provides the optical isolation necessary to float the entire gate drive while U2 provides level shifting needed for variable positive and negative gate rails, and U3 and U4 provide the fast current rise times necessary for surge current testing. Series gate resistor is external and is not shown in figure 6.

The capacitive discharge circuit, although it is very simple, can provide valuable information about the likely behavior of SiC MOSFET switches in power electronics applications. That information gives demonstrations of power electronics applications where SiC MOSFET switches are used (or any MOSFET switch with limited published data) a higher likelihood of success.

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