ACPL-P349/C87A/C79A

Wolfspeed(CREE) SiC MOSFET C2M0025120D and Diode C4D40120D

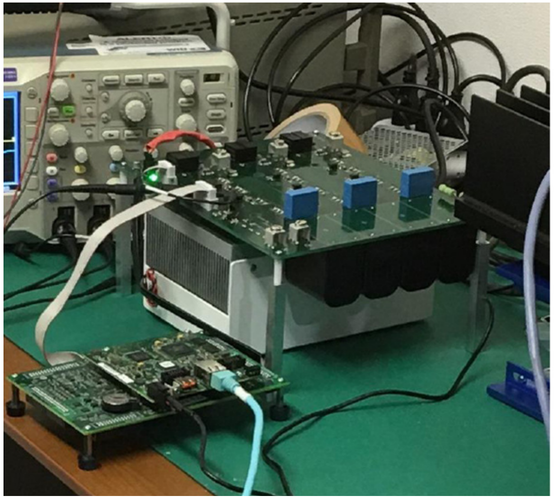
Reference Design

Description

SiC devices including SiC MOSFET and SiC Schottky diodes are recognized as next-generation wide-bandgap devices. They can provide fast switching with minimized loss compared to conventional Si devices and improve overall system efficiency. Higher current switching and higher frequency switching reduce the overall system size and costs. The technical benefits coupled with lower costs have increased the fast adoption of SiC power semiconductors in applications like industrial motor control, induction heating and industrial power supplies, and renewable energy.

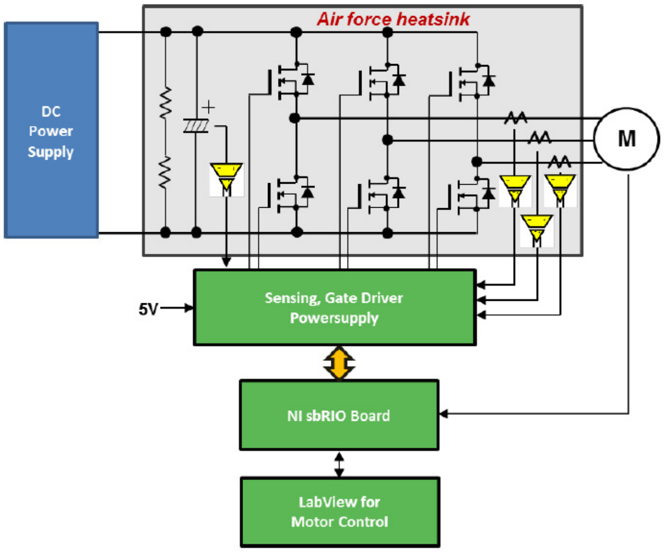
Broadcom gate-drive optocouplers are used extensively with Silicon-based semiconductors IGBT and Power MOSFETs can also be used for SiC operations. Optocouplers are used to provide reinforced galvanic insulation between the control circuits from the high voltages and the power semiconductors. The ability to reject high common mode noise (CMR) prevents erroneous driving of the SiC power semiconductors during high-frequency switching.

Figure 1 Three-Phase 15 kW SiC Inverter by NSOLUTION



The three-phase 15 kW SiC Inverter designed by NSOLUTION is meant to demonstrate the high performance of Wolfspeed (CREE) 1200V/90A SiC MOSFET (C2M0025120D) and SiC Schottky diodes (C4D40120D). The inverter also includes gate optocouplers ACPL-P349 for driving the SiC MOSFET, ACPL-C87A for DC voltage detection, and ACPL-C79A for three-phase AC-current measurements. The basic block diagram is shown in Figure 2.

Figure 2 SiC Inverter Block Diagram



The reference design shown in Figure 2 describes the functions and basic operation of optocouplers, ACPL-P349, C87A, and C79A used in the three-phase SiC inverter. For ordering info, detailed operation, board configuration, schematic, and other information, contact NSOLUTION by e-mail (contact@nsolution) or by web (http://nsolution.co.jp/).

SiC Inverter Features and Operations

As shown in Figure 3, the inverter uses a six-gate drive optocoupler ACPL-P349 to drive the SiC MOSFET directly in the three-phase full bridge topology. The ACPL-P349 is a basic gate driver optocoupler used to isolate and drive the SiC MOSFET operating at high DC bus voltage. It has a rail-to-rail output with 2.5A maximum output current to provide fast switching with high voltage and high driving current to efficiently and reliably turn on and off the SiC MOSFET. The ACPL-P349 is one of the industry's fastest with the maximum propagation delay less than 110 ns and typical rise and fall times around 8 ns. A very high CMR of 70 kV/µs is required to isolate high transient noise and prevent erroneous outputs during high-frequency operation. It can provide isolation certified by UL1577 for up to V_{ISO} 3750 V_{RMS}/min and IEC 60747-5-5 for working voltage, V_{IORM} up to 891V_{PEAK}.

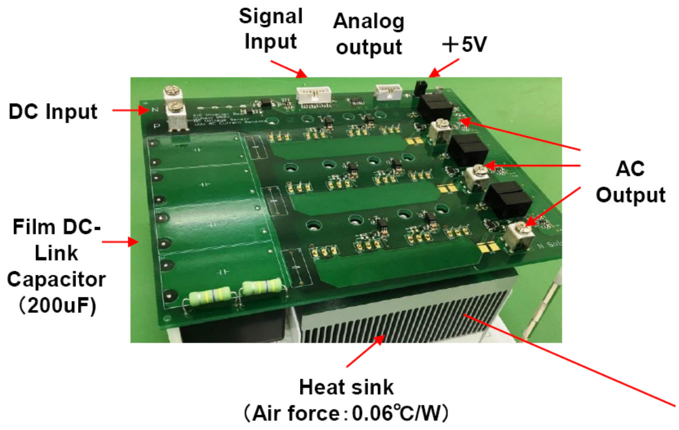
Three isolation amplifiers, ACPL-C79As, are used to sense the current of U, V, and W phases. The ACPL-C79A implements a sigma-delta analog-to-digital converter, chopper-stabilized amplifiers, and a fully differential circuit topology to provide low offset and high gain accuracy of ±1%. It operates from a single 5V supply and provides excellent linearity and dynamic performance of 60 dB SNR. With 200 kHz bandwidth and 1.6 µs fast response time, the current sensor captures transients in short circuit and overload conditions. It has high common-mode transient (15 kV/µs) and EMI immunity to provide precision and stability in motor control applications.

A shunt resistor is used to sense the current and measure the voltage applied to the ACPL-C79A through an RC anti-aliasing filter. Finally, the differential output of the isolation amplifier is converted to a ground-referenced single-ended output voltage with a simple differential amplifier circuit.

The ACPL-C87A is optical isolation amplifiers with 2V input range and high 1 GΩ input impedance designed for voltage sensing. A resistive voltage divider is used to scale the high-voltage DC input to suit the input range of the voltage sensor. A differential output voltage that is proportional to the input voltage is created on the other side of the optical isolation barrier.

The ACPL-C87A has ±1% gain tolerance and operates from a single 5V supply. It provides excellent linearity and has high common-mode transient immunity of 15 kV/µs.

Figure 3 SiC Inverter PCB and Connection



A high-voltage DC input of 800V is applied across four film DC-link 200 µF capacitors. The control circuit is powered by a single 5V (1A) power supply. The inverter can operate at 15 kW, $I_{OUT} \leq 30A_{RMS}$ and a carrier frequency of ≤200 kHz, depending on the heat sink and ambient temperature.

Figure 4 SiC Inverter Schematic

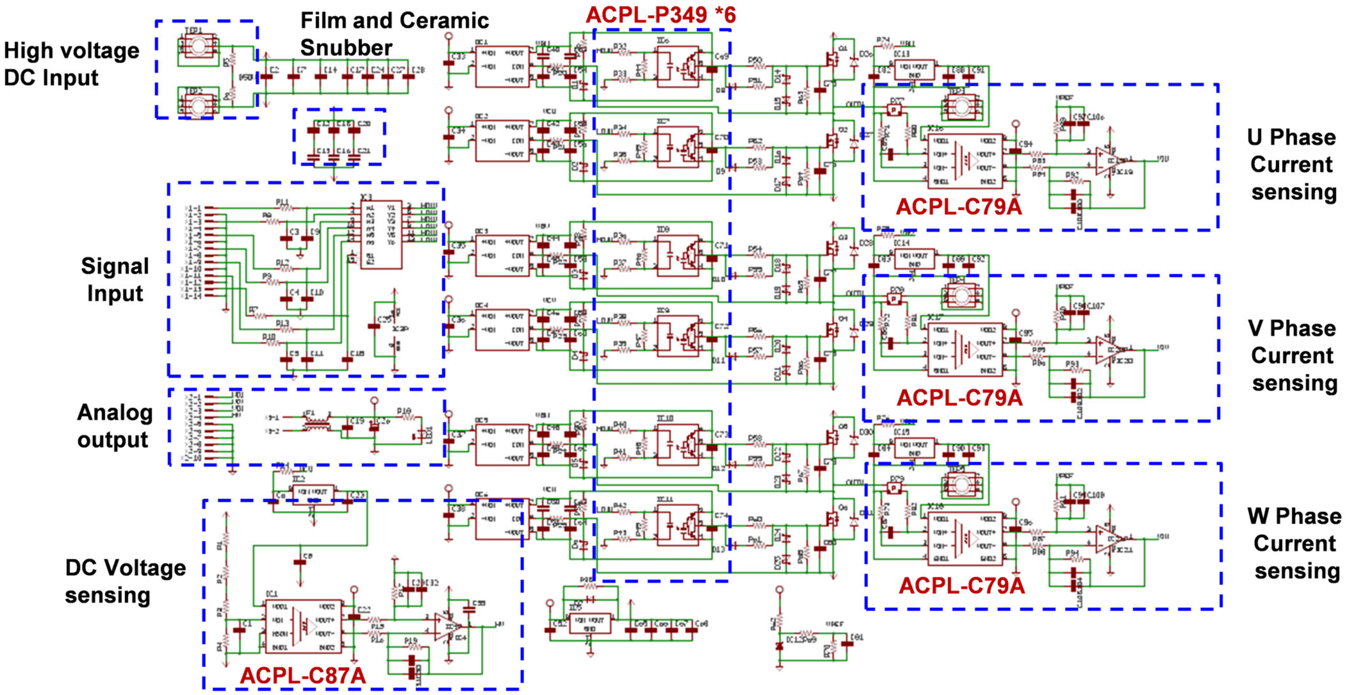
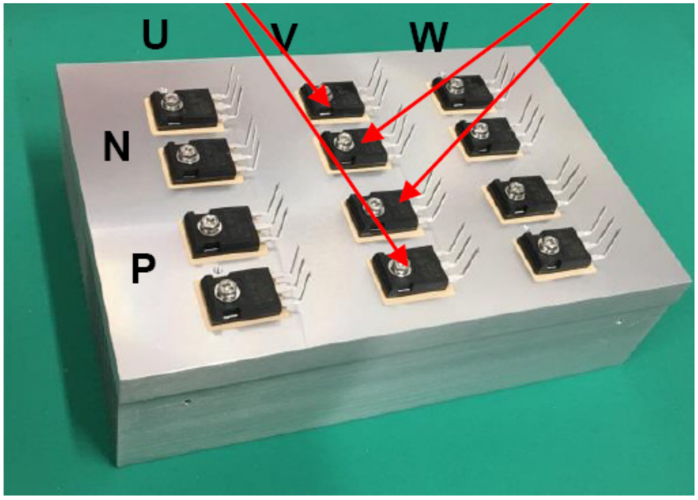
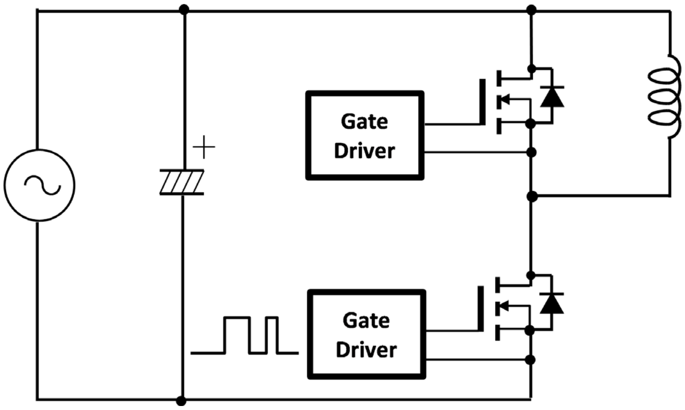


Figure 5 SiC Inverter Heat Sink, SiC MOSFETs, and Diodes



Test Measurements

Figure 6 Double Pulse Test Circuit

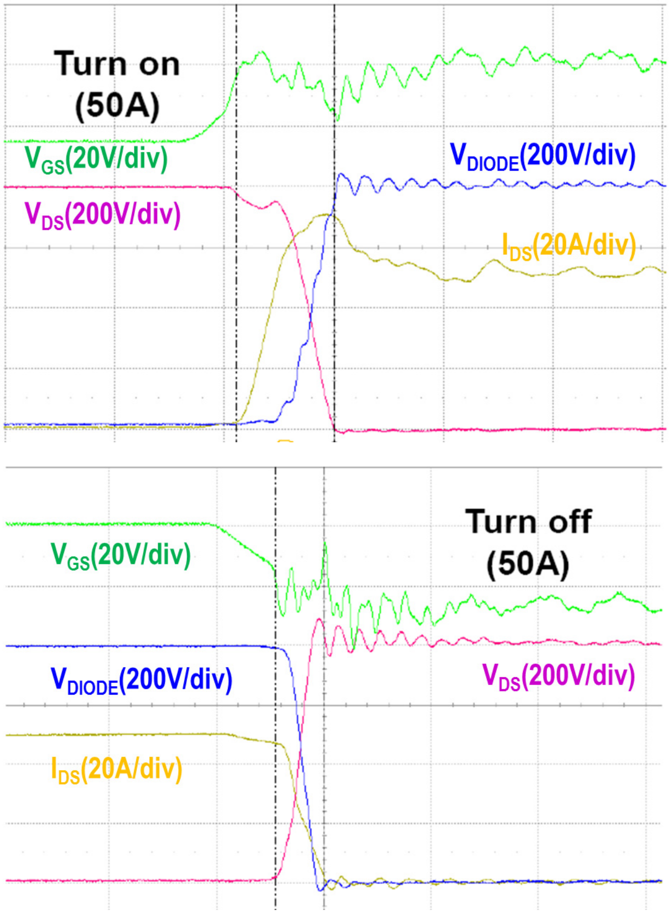


The double pulse test to confirm the Eon, Eoff, and Erec is done with the circuit in Figure 6. Test conditions:

- DC-link voltage = 800V
- Gate Drive Supply = +20V/–5V
- RGON = 5Ω
- RGOFF = 2.2Ω
- Inductor Load = 200 µH

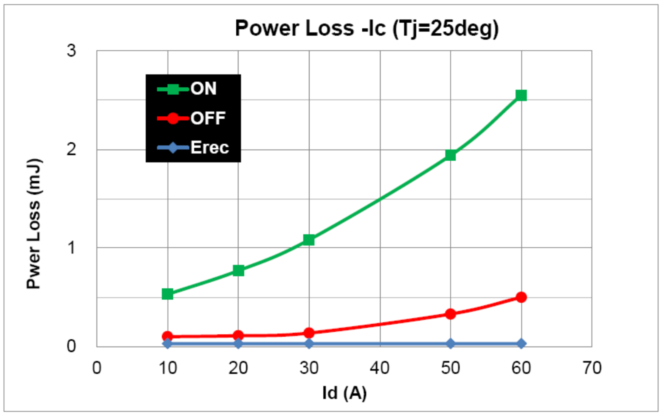
Figure 7 shows the switching of the SiC MOSFET at 50A (note the time division is 100 ns/div).

Figure 7 Double Pulse Test Switching Waveforms



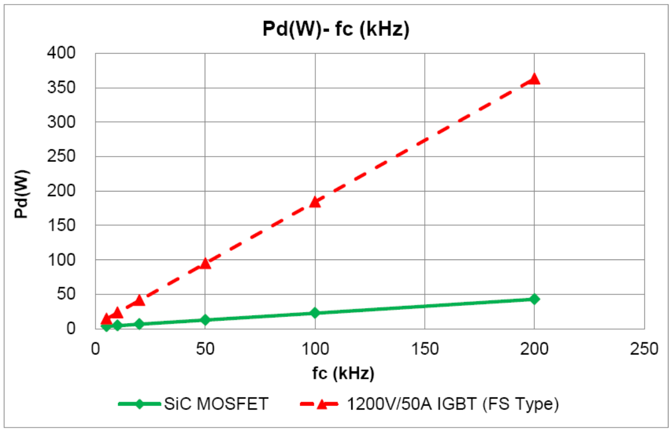
Using the same testing conditions, the power loss of drain current dependency is shown in Figure 8.

Figure 8 Power Loss vs. I_D of SiC MOSFET



The power loss simulation result is shown in Figure 9 with $10A_{RMS}$ output current for both the SiC MOSFET and equivalent IGBT. The simulation data depends on the result of the double pulse test for Eon, Eoff, and Erec as well as the DC characteristics for MOSFET Vds(ON), diode Vf, and IGBT Vce(sat). Due to the faster switching of the SiC MOSFET, the device has lower loss compared to IGBT at a high carrier frequency. This is useful in high frequency applications including motor control, battery charging, and power supply switching (reducing the system size and costs).

Figure 9 Power Loss Comparison of SiC MOSFET and IGBT as Carrier Frequency Dependency



For product information and a complete list of distributors, please go to our web site: www.broadcom.com.

ACPL-P349-CxxA-RM100 – April 27, 2017

Lead (Pb) Free
RoHS 6 fully compliant

RoHS 6 fully compliant options available;
-xxxE denotes a lead-free product