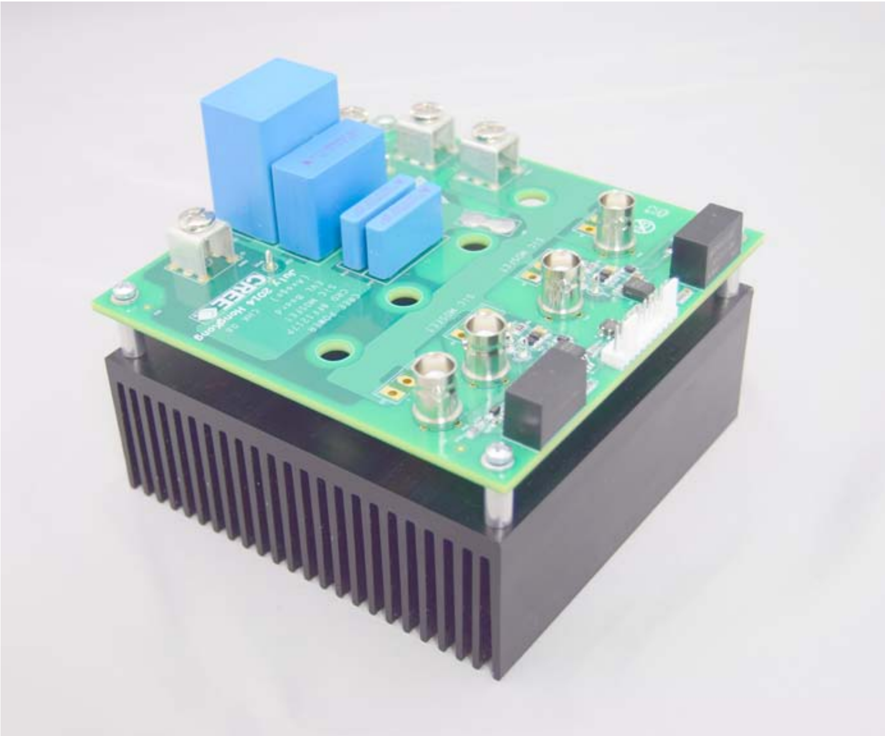
KIT8020-CRD-8FF1217-1
CREE MOSFET Evaluation Kit
User's Manual

REV A
CREE Power Applications
10/31/2014



This document is prepared as a user reference guide to install and operate CREE evaluation hardware.

Safety Note: Cree designed evaluation hardware is meant to be an evaluation tool in a lab setting for Cree components and to be handled and operated by highly qualified technicians or engineers. The hardware is not designed to meet any particular safety standards and the tool is not a production qualified assembly.

1. Introduction

This Evaluation (EVL) Board (model number **CRD8FF1217P-1/2**) is to demonstrate the high performance of CREE 1200V SiC MOSFET and SiC Schottky diodes (SBD) with standard TO-247 package. It can be easily configured for several topologies from the basic phase-leg configuration. This EVL board can be used for the following purposes:

- Evaluate the SiC MOSFET performance during switching events and steady state operation.
- Easily configure different topologies with SiC MOSFET and SiC diodes
- Functional testing with SiC MOSFET, for example, double pulse test to measure switching losses (E_{on} and E_{off}).
- PCB layout example for driving SiC MOSFET and SiC diode.
- Gate drive reference design for a TO-247 SiC MOSFET.

This user manual will include information on the EVL board architecture, hardware configuration, Cree SiC power devices and an example application when using this board.

Please note that JM1 as shown in Figure 1 is open circuit. It is necessary to short this with a wire or insert a shunt as shown in section 6.2 to complete the circuit before operation.

2. Board Overview

The EVL board's general block diagram is shown in Figure 1. There is a phase-leg which can include two SiC MOSFETs (Q1 and Q2) with half bridge phase-leg configuration and two anti-parallel SiC Schottky diodes (D1 and D3) with Q1 and Q2. The gate drive block with electrical isolation is designed on the board to drive SiC MOSFET Q1 and Q2. There are four power trace connectors (CON1, CON2, CON3 and CON5) and one 10 pin signal/supply voltage connector (CON4) on board.

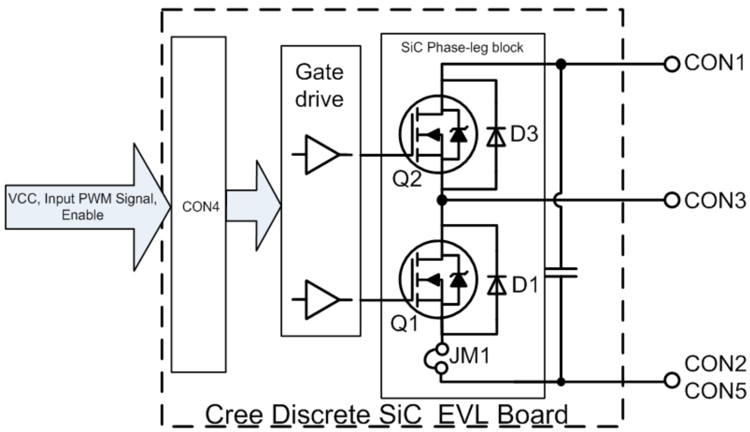


Figure 1: General block diagram of Cree Discrete SiC EVL board

There are two versions of this EVL board. The first version with model number CRD8FF1217P-1 includes two 2.5A gate driver integrating opto-coupler from Avago ACPL-W346 and two 2W isolation DC/DC converters from Mornsun G1212S-2W for both high side and low side individually. The 2W DC/DC converter with +12V Vcc input generates +24V Vcc_out output voltage with 6KVDC isolation that is supplying voltage to W346 on a push-pull gate drive of the secondary side as shown in Figure 2. In this circuit a 5V zener in parallel with 1uF capacitor is used to generate -5V Vgs voltage for the SiC MOSFET, where turn-off and turn-on Vgs voltage is equal to 24V-5V=19V. Note that a SiC MOSFET can be turned off with zero voltage, and the -5V turn-off voltage helps with faster turn-off and lower turn-off losses. It also improves dv/dt inducted self turn-on and noise immunity during transient periods with more headroom from Vgs turn-on threshold voltage. The first version can implement any PWM signal to drive the SiC phase leg block, if the board is operating in synchronous mode with a high side MOSFET and a low side MOSFET, the input signals must have additional dead time to avoid shoot through.

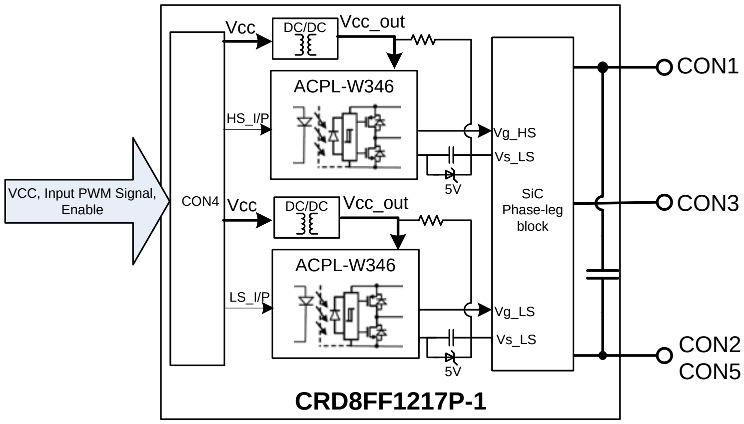


Figure 2. CRD8FF1217P-1 Block diagram with ACPL-W346

The second version with model number CRD8FF1217P-2 includes a single isolated high side and low side driver from Silicon Labs Si8233 to drive both high side and low side MOSFETs together as shown in Figure 3. The Vcc with 5V input to Si8233 is a supply voltage for logic on the primary side, and +22V_Vcc with +22V input is supply voltage for a push-pull driver on secondary side. The driver IC has two independent sink/sources with 5KVrms withstand voltage. The +22V voltage is to directly supply VDD to low side drive for Vg_LS, while for high side supply voltage, a bootstrap drive circuit is used to supply Vcc on the high side. Figure 4 shows the bootstrap drive circuit. When Q1 is turned on and SW is pulled down to the ground, the bootstrap capacitor, C7, charges through the bootstrap diode D5 from the VDD (+22V_Vcc) power supply as shown by the red dashed line. This is provided by VDDA when SW is pulled to a higher voltage by high side switch Q2, the VDDA supply floats and the bootstrap diode reverses bias and blocks the rail voltage and supply high side drive shown as blue dashed line. The bootstrap diode D5 must withstand high blocking voltage with low reverse recovery current to minimize noise. In this board, a Cree 1200V SiC Schottky diode C4D02120E is used. Also, a 5V zener with 1uF is in series with a Vg trace on both the high side and low side, which can generate -5V Vgs voltage for SiC MOSFET turn-off. The bootstrap circuit has the advantage of being simple and low cost, but has some limitations. Duty-cycle and on-time is limited by the need to refresh the charge in the bootstrap capacitor, which limits the topology application for this second version of the EVL board when duty cycle is variable. However, it can work well on most topologies with fixed duty cycle, such as phase shift full-bridge or LLC resonant converter. The Si8233 has an integrated dead time function with a resistor to ground used to set. So, the input signals do not need additional dead time on this version.

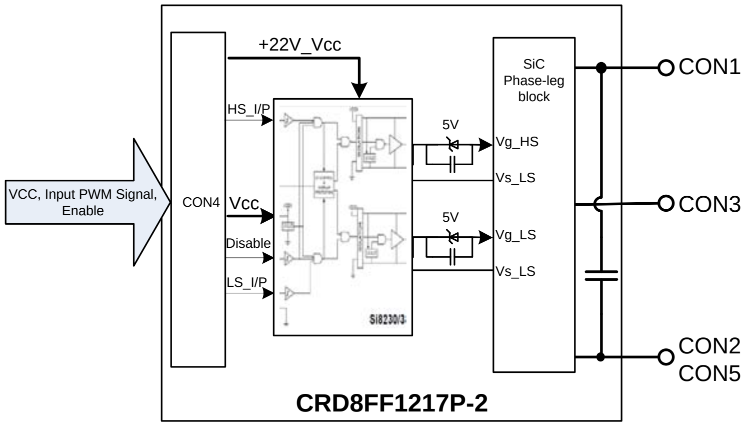


Figure 3. CRD8FF1217P-2 Block diagram with Si8233

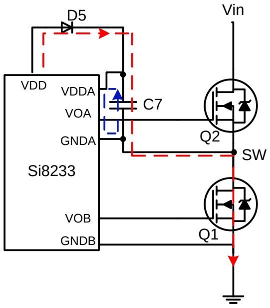


Figure 4. Simplified bootstrap drive circuit on CRD8FF1217P-2 version

The EVL board size is 124mmx120mmx40mm (not including heatsink). Different types of heatsinks can be assembled depending on your cooling requirements. Figure 5A shows the board attached with a 120mmx120mmx45mm heatsink on the bottom of PCB board as an example. SiC devices are horizontal with the PCB board, however, users can choose any type of heatsink that works with the standard TO-247 package. Figure 5b gives another example for a vertical heatsink attachment with PCB board and SiC power devices.

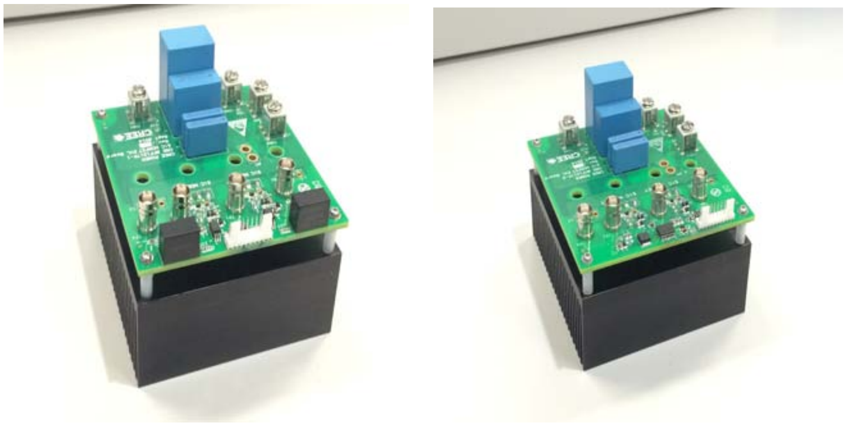


Figure 5a. Cree EVL board assembly (-1 is shown on left). See Appendix for assembly parts information.

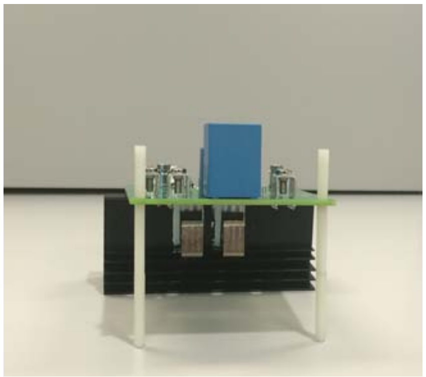


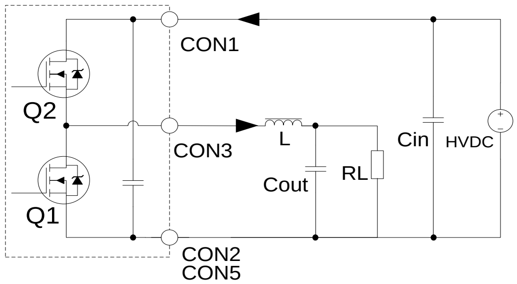
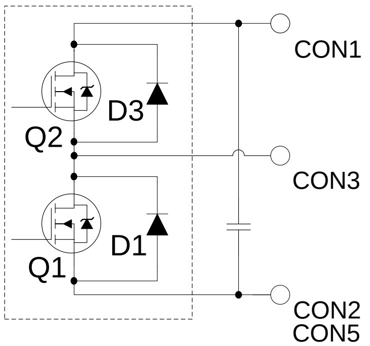
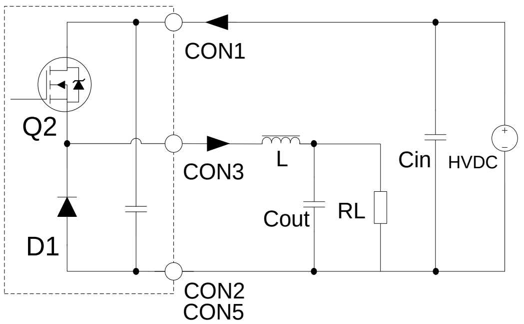
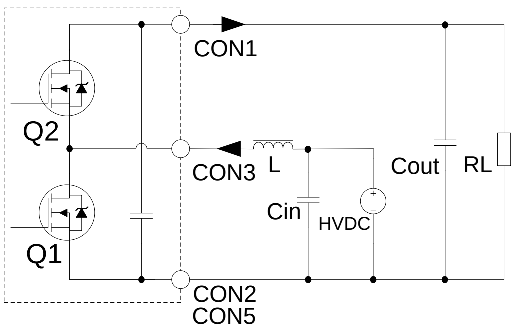
Figure 5b. Cree EVL board picture with a vertical heatsink for TO-247 package

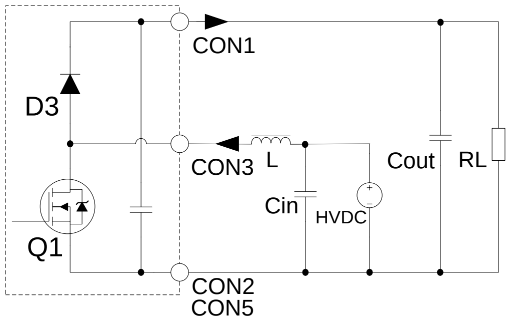
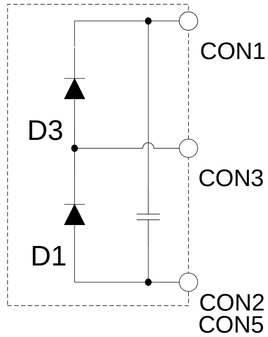
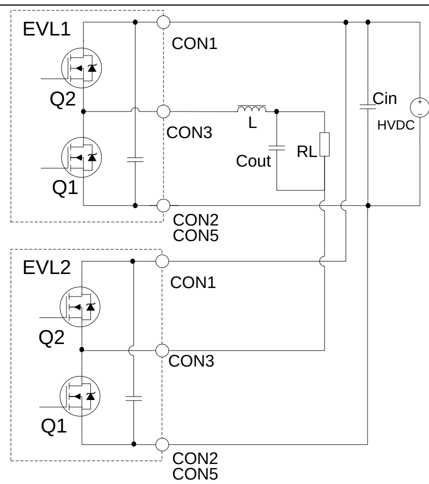
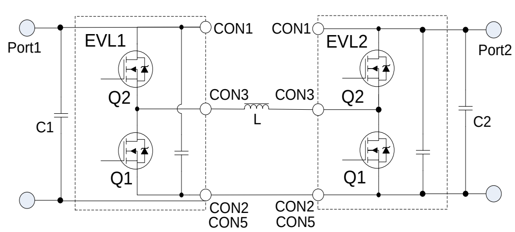
3. Configurations

The EVL board can be adaptable to implement difference topologies when using the different configurations of SiC MOSFETs and SiC diodes. It is possible to test several topologies with this board: synchronous Buck, non-synchronous Buck (or high-side Buck), synchronous Boost, non-synchronous Boost, half phase-leg bridge converter, H bridge converter (2x EVL boards) and bi-directional buck-boost converters. Table 1 summarizes the possible topologies that can be implemented using this EVL board. For the phase-leg configuration, it can either use discrete anti-parallel SiC SBD or body diode of SiC MOSFET, thus the body diode of SiC MOSFET can be evaluated without anti-parallel diode with option one in the below table.

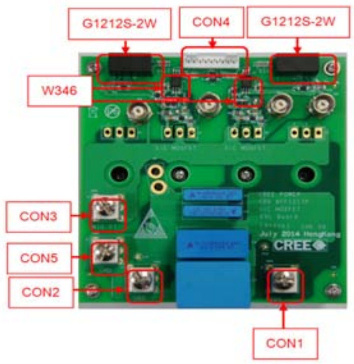
With double EVL boards, H-bridge converter and bi-directional DC/DC converter can be configured. For H-bridge with different control architecture, the phase shift full bridge, resonant LLC ZVS converter and single phase DC/ AC converter can all be achieved. For bi-directional DC/DC converter, it can achieve either Buck from port 1 to port 2 or Boost from port2 to port 1. Furthermore, with three EVL boards, it can even be set up as a three-phase DC/AC inverter for some motor drive or inverter applications.

Table. 1 The EVL board topology configuration

Option One: Syn. Buck converter or Phase-leg bridge topology without anti-parallel diodes		• Step down voltage or phase leg topology w/o anti-parallel diodes • SiC Body diode used • Connect inductor L with CON3 as output • CON1: INPUT • CON3: OUTPUT • CON2, CON5: GND
Option Two: Phase-leg bridge topology with anti-parallel SiC SBD		• Phase-leg, switching with external anti-parallel diode • SiC SBD used • CON1, CON3: Input/ output depends on which topology apply to board • CON2, CON5: GND
Option Three: Non-syn Buck converter		• Step down voltage • Connect inductor L with CON3 as output • CON1: INPUT • CON3: OUTPUT • CON2, CON5: GND
Option Four: Syn. Boost converter		• Step up voltage • Connect inductor L with CON3 as input • CON1: OUTPUT • CON3: INPUT • CON2, CON5: GND

Option Five: Non-syn Boost converter		• Step up voltage • Connect inductor L with CON3 as input • CON1: OUTPUT • CON3: INPUT • CON2, CcON5: GND
Option Six: Diode bridge		• Bridge diode with SiC SBD • CON1: OUTPUT (Positive) • CON3: INPUT • CON2, CON5: OUTPUT (Negative)
Option Seven: H bridge topology configuration using two EVL boards		• Full bridge converter with Phase shift or resonant • single phase DC/AC inverter
Option Eight: Bi-directional DC/DC converter		• Port 1 is input and port 2 is output with Buck converter, Q2 of EVL2 is constantly turn-on, and Q1 of EVL2 is constantly turn-off • Port 1 is output and port 2 is input with Boost converter, Q2 of EVL1 is constantly turn-on and Q1 of EVL2 is constantly turn-off

4. Hardware Description



The above figures give top view of the EVL board, the top right is CRD8FF1217P-1 and the top left is CRD8FF1217P-2. The picture highlights key test points and connectors on the boards.

4.1 Test points

To make testing more effective and easy, the BNC connectors are added on the board to measure both Vgs and Vds waveforms for the SiC MOSFET Q1 and Q2. A current test point with two unpopulated through-hole contacts is available to measure the drain current through the low side switch. A jumper (JM1) can be inserted to the test point and measure current using current probe. In addition, coaxial shunts (http://www.tandmresearch.com/) are recommended for accurate current measurements with less delay time; this can minimize the stray inductance on the switching loops and achieve accurate switching loss measurement. Also, some test points are added between gate resistors for measuring the voltage across the gate resistors. Thus it can estimate the gate current Ig to the SiC MOSFET.

4.2 Connectors

For the connectors, CON1, CON2, CON3 and CON5 are power trace connectors, and their definitions are depending on the different topology as described in Table 1. CON4 is for the signal/logic inputs and supply voltage for ICs. The definition of CON4 for each pin is shown in Table 2.

Table. 2 Pin definitions for connector CON4

Connector CON4 Pin	CRD8FF1217P-1	CRD8FF1217P-2
Pin1	N/A	+22V_VCC: +22Vdc
Pin2	N/A	+22V_VCC_RTN:GND for +22V
Pin3	N/A	NA
Pin4	N/A	NA
Pin5	VCC: +12Vdc	5V_VCC: +5Vdc
Pin6	VCC_RTN: GND for +12Vdc	VCC_RTN: GND for +5Vdc
Pin7	Input_HS: signal input for Q2	Input_HS: signal input for Q2
Pin8	Input_HS_RTN: signal ground for Q2	Disable: 5V = disable (output pull low), 0V = Enable (output = input state)
Pin9	Input_LS: signal input for Q1	Input_LS: signal input for Q1
Pin10	Input_LS_RTN: signal ground for Q1	VCC_RTN: GND for +5V

4.3 Board design

A SiC device is a fast switching device, and it is important to maximize SiC's high performance and minimize ringing with fast switching. The EVL board introduces some design approaches to minimize the ringing on the board:

- The gate drive and logic signal are put on top of the PCB board, while the main power trace and switching devices are put on the bottom layer. There is no crossover or overlap between gate signal and switching power trace, which can minimize high dv/dt and di/dt noise influence from the switching node to gate signal.

- Four de-coupling film capacitors with valued 10nF, 10nF, 0.1uF and 5uFare placed close to the SiC devices; it can reduce high frequency switching loop and bypass noise within switching loop.
- The layout of gate drive circuitry is designed with symmetric trace distance, which can introduce balance impendence on the gate drive. Also, the gate drive is placed as close as possible to the SiC MOSFETs.
- The power trace layout is optimized to reduce the switching loops.

5. SiC Devices

SiC devices including SiC MOSFET and SiC Schottky diodes are recognized as next generation wide bandgap devices. It can provide fast switching with less loss compared to conventional Si devices. Cree (www.cree.com/power) is the world's leading manufacturer of silicon-carbide Schottky diodes and MOSFETs for efficient power conversion. The standard TO-247 package 1200V SiC MOSFETs and SiC SBDs are available to order or apply for free samples at Cree website in order to evaluate SiC power devices with this EVL board. The different on-state resistor Rds(on) MOSFETs are available from Cree with standard drain to source on-state resistor 25mohm, 40mohm, 80mohm, 160mohm and 280mohm.

6. Example Application and Measurements

6.1 Board Setup

In order to demonstrate the EVL with SiC devices, a synchronous phase-leg Buck converter configuration is used as an example to evaluate the performance of the SiC EVL board. This is option one configuration on table 1. The table below gives the electrical parameters. Please note the switching frequency is at 40KHZ in this case due to the design limitation of the available inductor, but it does not mean the switching frequency is limited to 40KHZ. Because of low switching losses of SiC MOSFET, the switching frequency can increase to higher without sacrificing much switching losses when using SiC MOSFET. The purpose of 40KHZ setting is competing with 1200V Si IGBT for inverter application with this phase-leg configuration, which frequency is normally ranged from 15KHZ to 20KHZ.
In the testing, two 25mohm SiC MOSFETs are assembled on the PCB board with heatsink for both high side Q2 and low side Q1. The figure gives the test setup with EVL boards. The signal generators are used to generate high side and low side PWM signals with Input_HS and Input_LS. Note that the dead time period must be applied to the input signal between Input_HS and Input_LS for CRD8FF1217P-1. For CRD8FF1217P-2, the dead time function is integrated into the drive ICs; at this example, a 450ns dead time is set and there is no need for additional dead time between Input_HS and Input_LS in CRD8FF1217P-2.
For CRD8FF1217P-2, the disable pin 4.8 of CON4 should connect to ground of input +5V DC supply to enable gate signal to outputs. This disable pin can control the on/off of the board after the input is power up.

Table. 3 Electrical parameters

Items	Parameters
Input Voltage	600Vdc
Output Voltage	300Vdc
Output RMS Current	30A
Output Power	9KW
Peak MOS current	40A
Switching Frequency	40KHZ
Duty Cycle	50%
Dead time	~450ns
Inductor	400uH
Output Capacitors	300uF

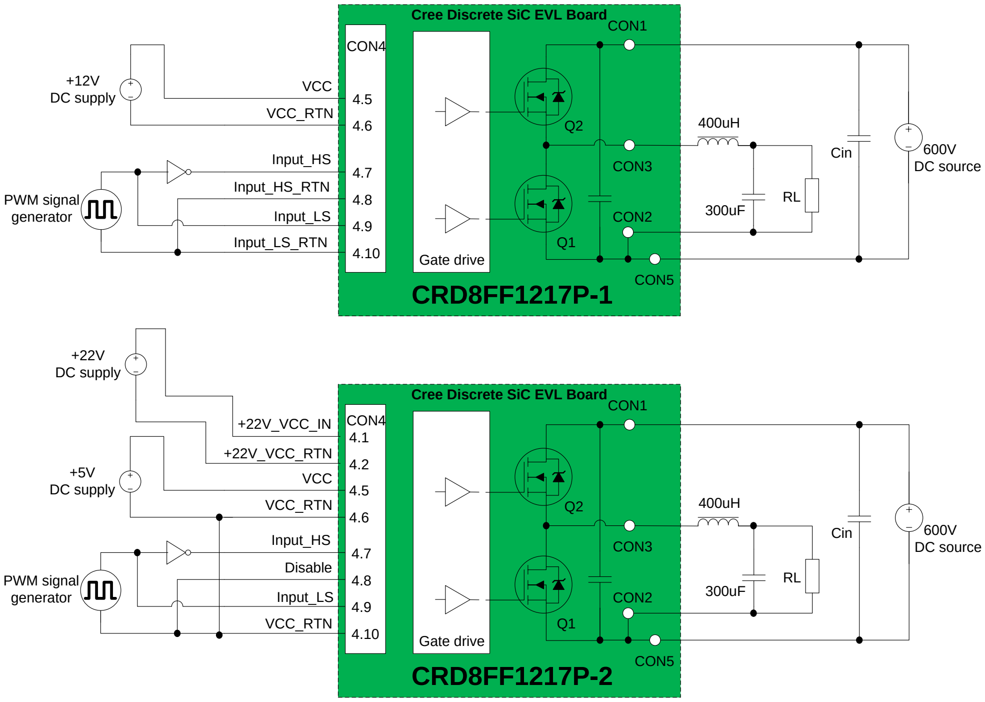


Figure 7. Test setup for the EVL boards with CRD8FF1217P-1 and CRD8FF1217P-2

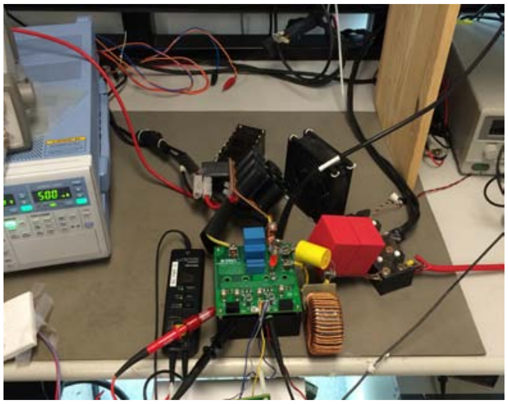


Figure 8. Bench test setup of the EVL boards

6.2 Measurements

To maximize the accuracy of the measurements when using the EVL board, some suggestions are listed below:

- Use a highly accurate 0.0131ohm shunt (recommend SDN series shunt resistors from T&M Research), to measure the low side current waveform as shown below in Figure 9. This can help to shorten the current sense loop.

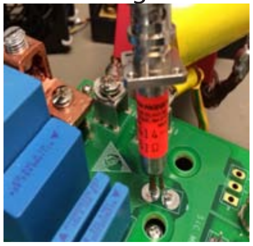


Figure 9. Low side current measurement

- A BNC probe is connected to measure low-side Vgs waveform, a x100 HV probe is used to measure low side Vds waveform, and a differential probe is used to measure high-side Vgs waveform. All probes must be placed as close as possible to reduce incorrect ringing due to probe placement.

- Place the power inductor as close as possible to connect at CON3 to reduce the switching node loop area, and a 1uF 1200V film capacitors is connected between the output of inductor and ground connector CON5.
- A 12W AC fan is used to cool the heatsink and inductor when measuring waveforms and taking thermal measurements.
- A RC snubber is added on the drain to source to damp high dv/dt ringing on the switching node and slow the high dv/dt.
- A capacitance (1nF) is added between gate to source terminal to shunt the miller current from drain to gate. This external capacitor will introduce low impedance path for Cdv/dt from miller capacitance effect and reduce the ringing on the gate pins.
- Use of a ferrite bead (FB) on the gate pin of TO-247 MOSFETs will introduce high impedance on the gate path for MHz high frequency and reduce the Vgs ringing.
- Reduce the stray capacitance of inductor with single layer structure.

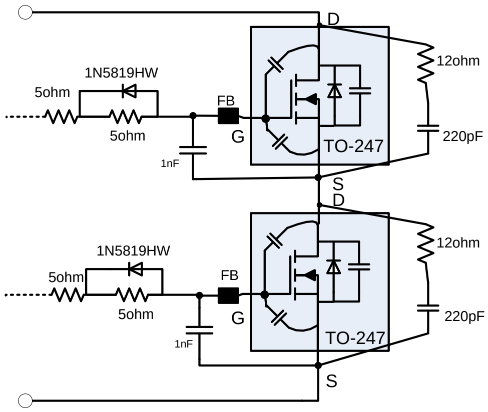


Figure 10. Gate drive and RC snubber configuration

6.3 Test data

The switching waveforms are shown in the below figures. In the operation of the synchronous Buck converter, the low-side body diode conducts before low-side MOSFET is turned on, thus this low-side MOSFET operates in Zero Voltage Switching (ZVS) mode and high-side MOSFET operates in hard-switching mode. However, high dv/dt during fast transient of high-side MOSFET will affect the operational behavior of the low-side MOSFET, and the charge stored in miller capacitance will be transferred via its gate loop, inducing some spurious gate voltage in this topology. The above methods mentioned in section 6.2 will help to damp this noise and reduce the ringing on the gate and drain to source. Note that the incorrect test method itself may also introduce some noises from oscilloscope measurement, but it is sometimes not a true representation of the actual transient events on the switching devices.

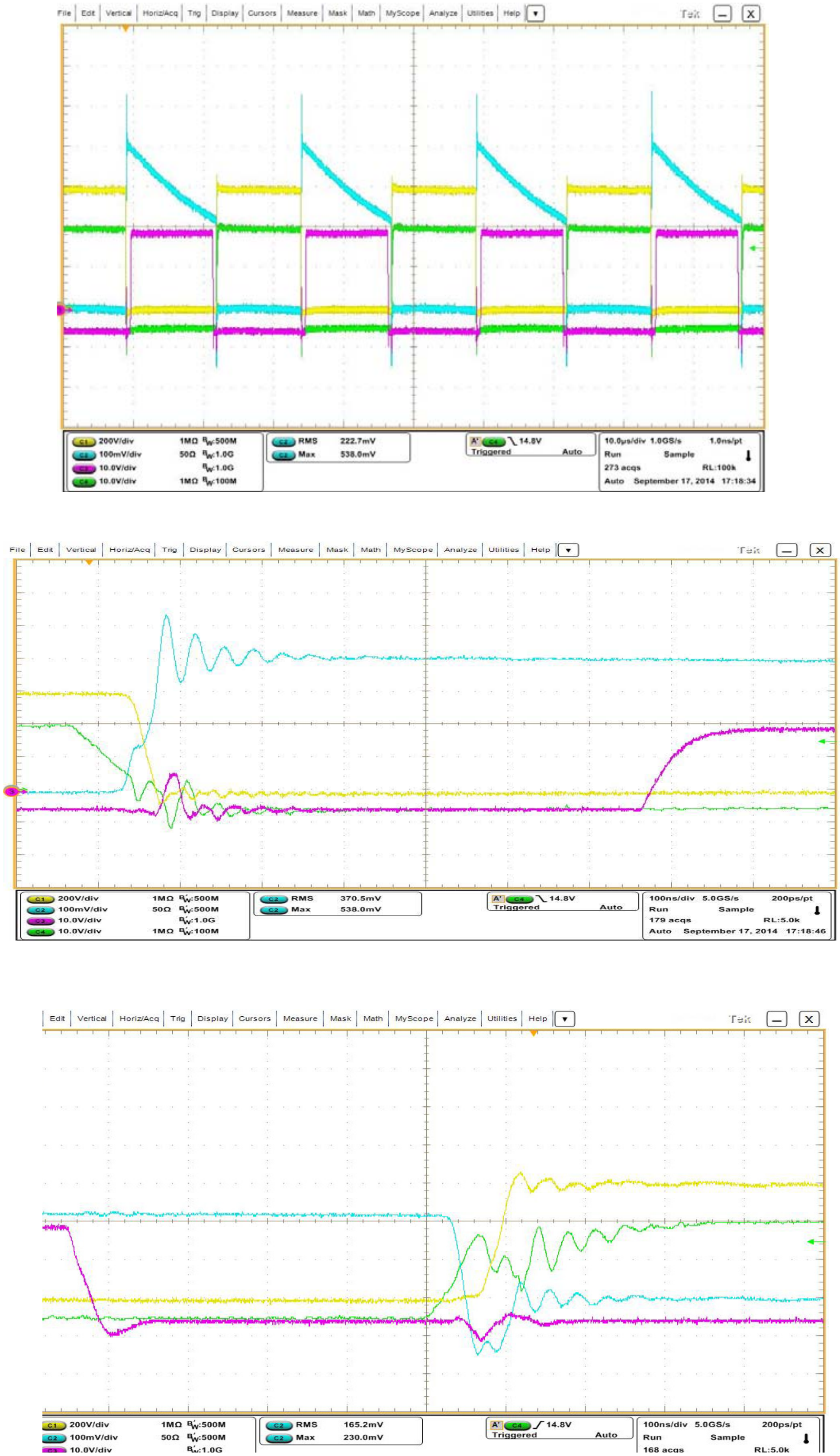


Figure 11. Vgs, Id and Vds waveforms at 9KW loading
(Ch1: low-side Vds yellow 200v/div); (Ch2: low-side Id blue 100mv/0.0131ohm/div);
(Ch3: low-side Vgs pink 10v/div); (Ch4: high-side Vgs green 10v/div)

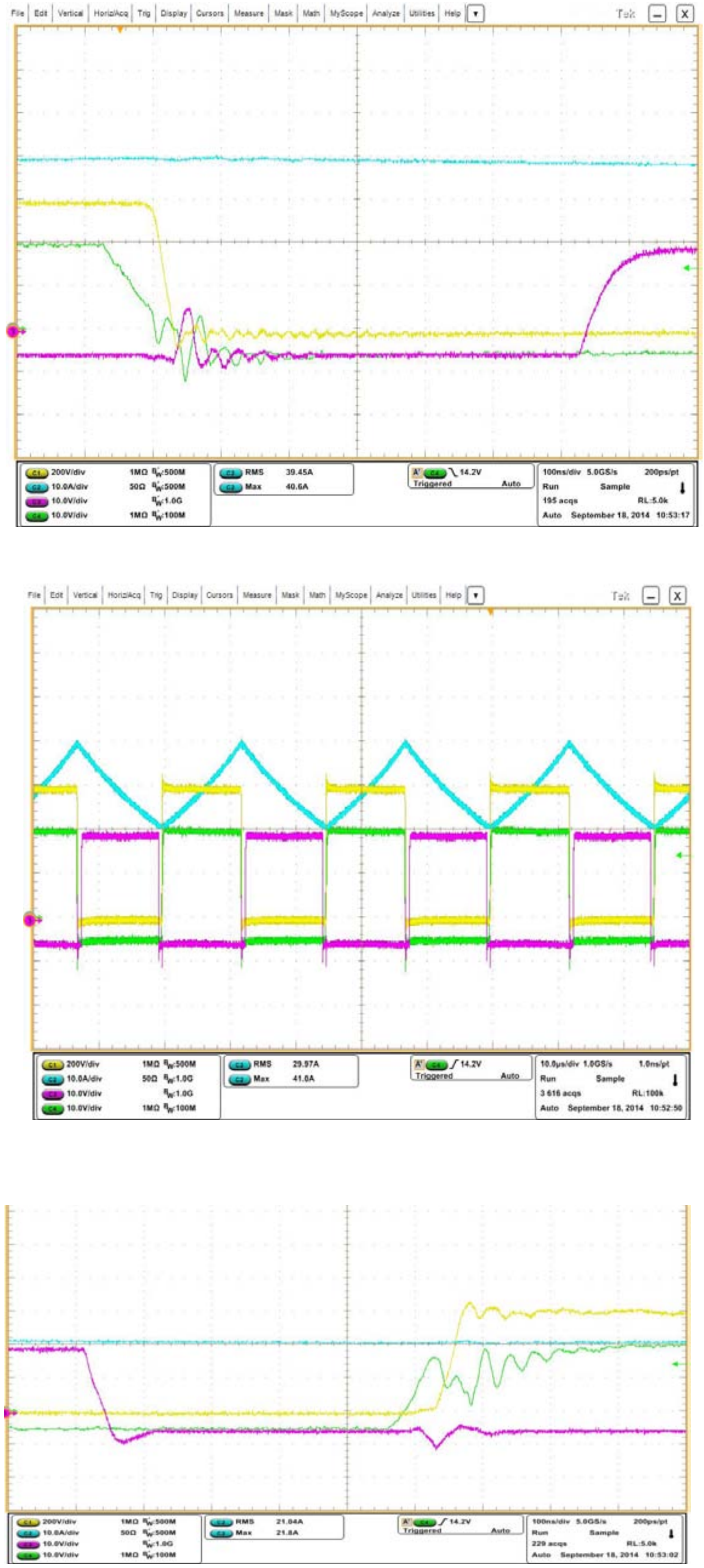


Figure 12. Vgs, Inductor current IL and Vds waveforms at 9KW loading
(Ch1: low-side Vds yellow 200v/div); (Ch2: inductor current IL 10A/div);
(Ch3: low-side Vgs pink 10v/div); (Ch4: high-side Vgs green 10v/div)

The EVL board's maximum efficiency in this configuration is around 98.9% at 4KW half load using the Yokogawa WT3000 to measure it. It includes losses from the inductor, switching devices, and capacitors. Considering the high switching frequency (40kHz) and high duty cycle (50%), the efficiency is high compared to conventional Si IGBT solutions.

Figure 13. Efficiency data for this EVL board

Figure 14 shows the thermal performance for this EVL board at full load 9KW after 30 minutes of continuous operation. The test condition is at room temperature with open frame and 12W fan cooling the heatsink and inductor. It demonstrates high performance of SiC MOSFET with low temperature, low losses and high switching frequency.

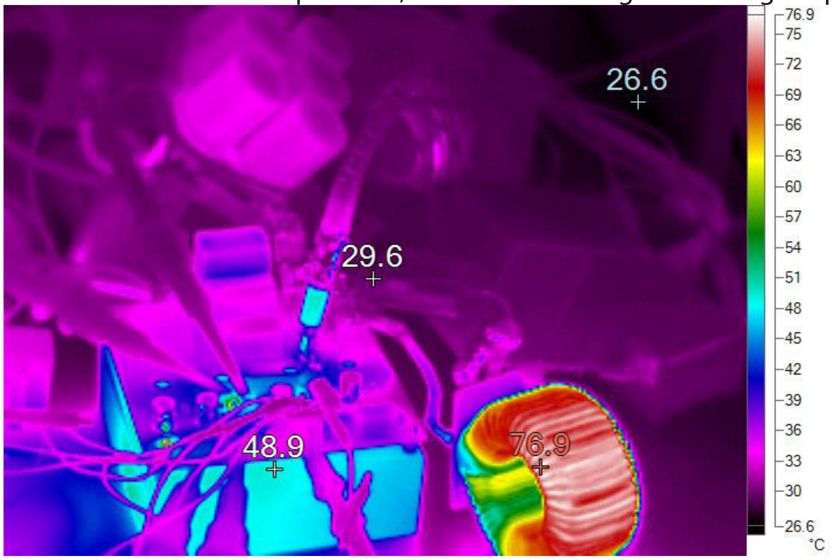


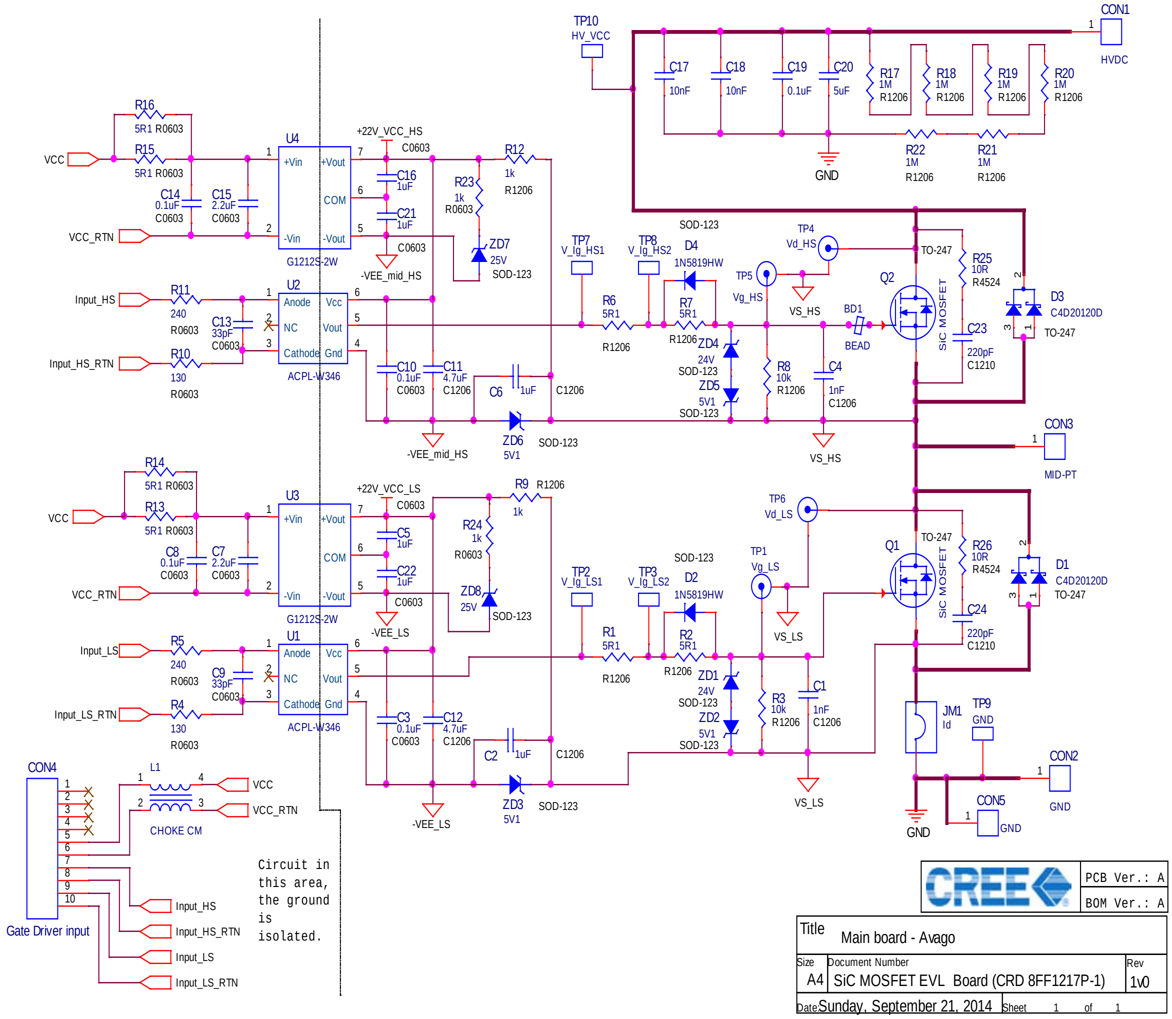
Figure 14. Thermal photo for this EVL board

7. Reference

1. C2M0025120D datasheet, Cree Inc
2. C4D20120D datasheet, Cree Inc
3. 'Performance Evaluations of Hard-Switching Interleaved DC/DC Boost Converter with New Generation Silicon Carbide MOSFETs' Available in Cree website: http://www.cree.com/Power/Document-Library
4. 'Design Considerations for Designing with Cree SiC Modules Part 1. Understanding the Effects of Parasitic Inductance' Available in Cree website: http://www.cree.com/Power/Document-Library
5. 'Design Considerations for Designing with Cree SiC Modules Part 2. Understanding the Effects of Parasitic Inductance' Available in Cree website: http://www.cree.com/Power/Document-Library

8. Appendix

Schematic of CRD 8FF1217P-1

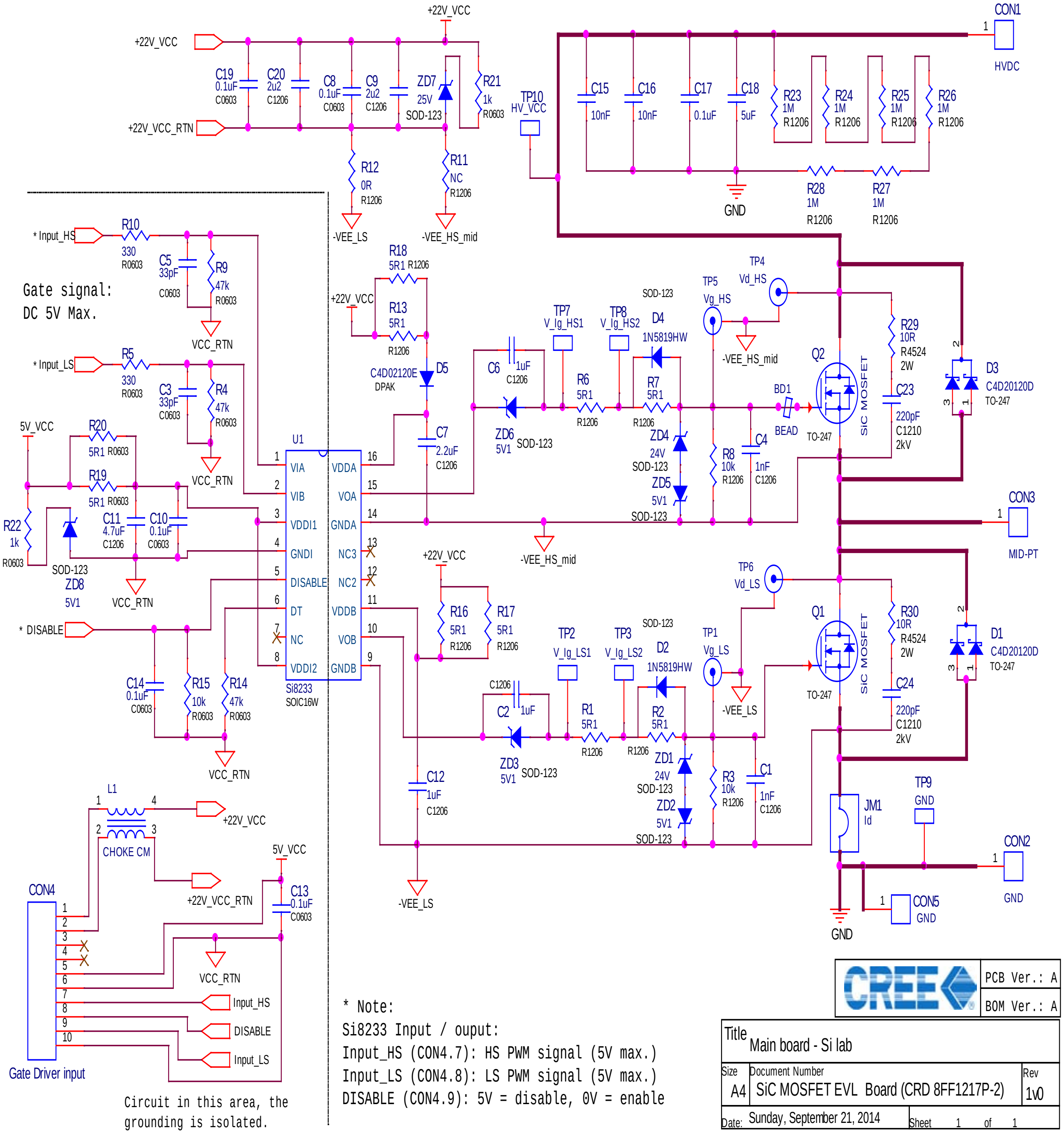


Component list of CRD 8FF1217P-1

	Part Ref.	Value	Part number	Brand	Description	Type	PCB
1	BD1	Bead	74270011	Wurth	ferrite bead	THR	
2	C1	1nF			Ceramic, C0G, 10%	SMD	C1206
3	C2	1uF			Ceramic, X7R, 10%	SMD	C1206
4	C3	0.1uF			Ceramic, X7R, 10%	SMD	C0603
5	C4	1nF			Ceramic, C0G, 10%	SMD	C1206
6	C5	1uF			Ceramic, C0G, 10%	SMD	C0603
7	C6	1uF			Ceramic, X7R, 10%	SMD	C1206
8	C7	2.2uF			Ceramic, X7R, 10%	SMD	C0603
9	C8	0.1uF			Ceramic, X7R, 10%	SMD	C0603
10	C9	33pF			Ceramic, C0G, 10%	SMD	C0603
11	C10	0.1uF			Ceramic, X7R, 10%	SMD	C0603
12	C11	4.7uF			Ceramic, X7R, 10%	SMD	C1206
13	C12	4.7uF			Ceramic, X7R, 10%	SMD	C1206
14	C13	33pF			Ceramic, C0G, 10%	SMD	C0603
15	C14	0.1uF			Ceramic, X7R, 10%	SMD	C0603
16	C15	2.2uF			Ceramic, X7R, 10%	SMD	C0603
17	C16	1uF			Ceramic, X7R, 10%	SMD	C0603
18	C17	10nF	B32653A1103K	EPCOS	CAP FILM 10nF 1.6KVDC RADIAL, PP	THR	
19	C18	10nF	B32653A1103K	EPCOS	CAP FILM 10nF 1.6KVDC RADIAL, PP	THR	
20	C19	0.1uF	B32654A1104K	EPCOS	CAP FILM 0.1UF 1.6KVDC RADIAL, PP	THR	
21	C20	5uF	B32774D1505K	EPCOS	CAP FILM 5UF 1.3KVDC RADIAL, PP	THR	
22	C21	1uF			Ceramic, X7R, 10%	SMD	C0603
23	C22	1uF			Ceramic, X7R, 10%	SMD	C0603
24	C23	220pF		Kemet	CAP CER 220PF 2KV 5% NP0 1210	SMD	C1210
25	C24	220pF		Kemet	CAP CER 220PF 2KV 5% NP0 1210	SMD	C1210
26	CON1	HVDC	7808	Skystone	female, M5, 30A, 6P		
27	CON2	GND	7808	Skystone	female, M5, 30A, 6P		
28	CON3	MID-PT	7808	Skystone	female, M5, 30A, 6P		
29	CON4	Gate Driver input	22-27-2101	Molex	10pin, 2.54mm, male		
30	CON5	GND	7808	Skystone	female, M5, 30A, 6P		
31	D1		C4D20120D	CREE	1200V, 20A	THR	TO-247
32	D2		1N5819HW-7-F	Diodes	DIODE SCHOTTKY 40V 1A SOD123	SMD	SOD-123
33	D3		C4D20120D	CREE	1200V, 20A	THR	TO-247
34	D4		1N5819HW-7-F	Diodes	DIODE SCHOTTKY 40V 1A SOD123	SMD	SOD-123
35	JM1	Id			dim. 1.75mm jumper wire x2 for Id connect to GND		
36	L1	CM CHOKE	ACM4520-142-2P-T000	TDK	CM choke	SMD	
37	Q1	SiC MOSFET	C2M0025120D	CREE	25-mΩ, 1200-V, SiC MOSFET	THR	TO-247
38	Q2	SiC MOSFET	C2M0025120D	CREE	25-mΩ, 1200-V, SiC MOSFET	THR	TO-247
39	R1	5R1			Res, 1%	SMD	R1206
40	R2	5R1			Res, 1%	SMD	R1206
41	R3	10k			Res, 1%	SMD	R1206
42	R4	130			Res, 1%	SMD	R0603
43	R5	240			Res, 1%	SMD	R0603
44	R6	5R1			Res, 1%	SMD	R1206
45	R7	5R1			Res, 1%	SMD	R1206
46	R8	10k			Res, 1%	SMD	R1206
47	R9	1k			Res, 1%	SMD	R1206
48	R10	130			Res, 1%	SMD	R0603
49	R11	240			Res, 1%	SMD	R0603
50	R12	1k			Res, 1%	SMD	R1206
51	R13	5R1			Res, 1%	SMD	R0603

52	R14	5R1			Res, 1%	SMD	R0603
53	R15	5R1			Res, 1%	SMD	R0603
54	R16	5R1			Res, 1%	SMD	R0603
55	R17	1M			Res, 1%	SMD	R1206
56	R18	1M			Res, 1%	SMD	R1206
57	R19	1M			Res, 1%	SMD	R1206
58	R20	1M			Res, 1%	SMD	R1206
59	R21	1M			Res, 1%	SMD	R1206
60	R22	1M			Res, 1%	SMD	R1206
61	R23	1k			Res, 1%	SMD	R0603
62	R24	1k			Res, 1%	SMD	R0603
63	R25	10R	S4-10RF1	Riedon	RES 10 OHM 2W 1% WW SMD	SMD	R4524
64	R26	10R	S4-10RF1	Riedon	RES 10 OHM 2W 1% WW SMD	SMD	R4524
65	TP1	Vg_LS	546-4027	RS	BNC socket, female		
66	TP2	V_Ig_LS1	5020	keystone	round, 1pin, test point		
67	TP3	V_Ig_LS2	5020	keystone	round, 1pin, test point		
68	TP4	Vd_HS	546-4027	RS	BNC socket, female		
69	TP5	Vg_HS	546-4027	RS	BNC socket, female		
70	TP6	Vd_LS	546-4027	RS	BNC socket, female		
71	TP7	V_Ig_HS1	5020	keystone	round, 1pin, test point	MECH	
72	TP8	V_Ig_HS2	5020	keystone	round, 1pin, test point	MECH	
73	TP9	GND	5020	keystone	round, 1pin, test point	MECH	
74	TP10	HV_VCC	5020	keystone	round, 1pin, test point	MECH	
75	U1		ACPL-W346-060E	Avago		SMD	
76	U2		ACPL-W346-060E	Avago		SMD	
77	U3	G1212S-2W	G1212S-2W	Mornsun		THR	
78	U4	G1212S-2W	G1212S-2W	Mornsun		THR	
79	ZD1	24V			24V, 350mW, 1%	SMD	SOD-123
80	ZD2	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
81	ZD3	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
82	ZD4	24V			24V, 350mW, 1%	SMD	SOD-123
83	ZD5	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
84	ZD6	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
85	ZD7	25V			25V, 350mW, 2%	SMD	SOD-123
86	ZD8	25V			25V, 350mW, 2%	SMD	SOD-123

Schematic of CRD 8FF1217P-2



Component list of CRD 8FF1217P-2

	Part Ref.	Value	Part number	Brand	Description	Type	PCB Footprint
1	BD1	Bead	74270011	Wurth	Ferrite bead	THR	
2	C1	1nF			Ceramic, C0G, 10%	SMD	C1206
3	C2	1uF			Ceramic, X7R, 10%	SMD	C1206
4	C3	33pF			Ceramic, C0G, 10%	SMD	C0603
5	C4	1nF			Ceramic, C0G, 10%	SMD	C1206
6	C5	33pF			Ceramic, C0G, 10%	SMD	C0603
7	C6	1uF			Ceramic, X7R, 10%	SMD	C1206
8	C7	2.2uF			Ceramic, X7R, 10%	SMD	C1206
9	C8	0.1uF			Ceramic, X7R, 10%	SMD	C0603
10	C9	2.2uF			Ceramic, X7R, 10%	SMD	C1206
11	C10	0.1uF			Ceramic, X7R, 10%	SMD	C0603
12	C11	4.7uF			Ceramic, X7R, 10%	SMD	C1206
13	C12	1uF			Ceramic, X7R, 10%	SMD	C1206
14	C13	0.1uF			Ceramic, X7R, 10%	SMD	C0603
15	C14	0.1uF			Ceramic, X7R, 10%	SMD	C0603
16	C15	10nF	B32653A1103K	EPCOS	CAP FILM 10nF 1.6KVDC RADIAL, PP	THR	
17	C16	10nF	B32653A1103K	EPCOS	CAP FILM 10nF 1.6KVDC RADIAL, PP	THR	
18	C17	0.1uF	B32654A1104K	EPCOS	CAP FILM 0.1UF 1.6KVDC RADIAL, PP	THR	
19	C18	5uF	B32774D1505K	EPCOS	CAP FILM 5UF 1.3KVDC RADIAL, PP	THR	
20	C19	0.1uF			Ceramic, X7R, 10%	SMD	C0603
21	C20	2.2uF			Ceramic, X7R, 10%	SMD	C1206
22	C23	220pF	C1210C221JGGACTU	Kemet	CAP CER 220PF 2KV 5% NP0 1210	SMD	C1210
23	C24	220pF	C1210C221JGGACTU	Kemet	CAP CER 220PF 2KV 5% NP0 1210	SMD	C1210
24	CON1	HVDC	7808	Skystone	female, M5, 30A, 6P	MECH	
25	CON2	GND	7808	Skystone	female, M5, 30A, 6P	MECH	
26	CON3	MID-PT	7808	Skystone	female, M5, 30A, 6P	MECH	
27	CON4	Gate Driver input	22-27-2101	Molex	10pin, 2.54mm, male	MECH	
28	CON5	GND	7808	Skystone	female, M5, 30A, 6P	MECH	
29	D1	C4D20120D	C4D20120D	CREE	1200V, 20A	THR	TO-247
30	D2	1N5819HW	1N5819HW-7-F	Diodes	DIODE SCHOTTKY 40V 1A SOD123	SMD	SOD-123
31	D3	C4D20120D	C4D20120D	CREE	1200V, 20A	THR	TO-247
32	D4	1N5819HW	1N5819HW-7-F	Diodes	DIODE SCHOTTKY 40V 1A SOD123	SMD	SOD-123
33	D5	C4D02120E	C4D02120E	CREE	1200V, 2A	SMD	DPAK
34	JM1	Id			dim. 1.75mm jumper wire x2 for Id connect to GND	MECH	
35	L1	CM CHOKE	ACM4520-142-2P-T000	TDK	CM choke	SMD	
36	Q1	SiC MOSFET	C2M0025120D	CREE	25-mΩ, 1200-V, SiC MOSFET	THR	TO-247
37	Q2	SiC MOSFET	C2M0025120D	CREE	25-mΩ, 1200-V, SiC MOSFET	THR	TO-247
38	R1	5R1			Res, 1%	SMD	R1206
39	R2	5R1			Res, 1%	SMD	R1206
40	R3	10k			Res, 1%	SMD	R1206
41	R4	47k			Res, 1%	SMD	R0603
42	R5	330			Res, 1%	SMD	R0603
43	R6	5R1			Res, 1%	SMD	R1206
44	R7	5R1			Res, 1%	SMD	R1206
45	R8	10k			Res, 1%	SMD	R1206
46	R9	47k			Res, 1%	SMD	R0603
47	R10	330			Res, 1%	SMD	R0603

48	R11	NC				SMD	R1206
49	R12	0R			Res, 1%	SMD	R1206
50	R13	5R1			Res, 1%	SMD	R1206
51	R14	47k			Res, 1%	SMD	R0603
52	R15	10k			Res, 1%	SMD	R0603
53	R16	5R1			Res, 1%	SMD	R1206
54	R17	5R1			Res, 1%	SMD	R1206
55	R18	5R1			Res, 1%	SMD	R1206
56	R19	5R1			Res, 1%	SMD	
57	R20	5R1			Res, 1%	SMD	R0603
58	R21	1k			Res, 1%	SMD	R0603
59	R22	1k			Res, 1%	SMD	R0603
60	R23	1M			Res, 1%	SMD	R1206
61	R24	1M			Res, 1%	SMD	R1206
62	R25	1M			Res, 1%	SMD	R1206
63	R26	1M			Res, 1%	SMD	R1206
64	R27	1M			Res, 1%	SMD	R1206
65	R28	1M			Res, 1%	SMD	R1206
66	R29	10R	S4-10RF1	Riedon	RES 10 OHM 2W 1% WW SMD	SMD	R4524
67	R30	10R	S4-10RF1	Riedon	RES 10 OHM 2W 1% WW SMD	SMD	R4524
68	TP1	Vd_HS	546-4027	RS	BNC socket, female	MECH	
69	TP2	V_Ig_LS2	5020	keystone	round, 1pin, test point	MECH	
70	TP3	V_Ig_LS1	5020	keystone	round, 1pin, test point	MECH	
71	TP4	Vd_HS	546-4027	RS	BNC socket, female	MECH	
72	TP5	Vg_HS	546-4027	RS	BNC socket, female	MECH	
73	TP6	Vd_LS	546-4027	RS	BNC socket, female	MECH	
74	TP7	V_Ig_HS1	5020	keystone	round, 1pin, test point	MECH	
75	TP8	V_Ig_HS2	5020	keystone	round, 1pin, test point	MECH	
76	TP9	GND	5020	keystone	round, 1pin, test point	MECH	
77	TP10	HV_VCC	5020	keystone	round, 1pin, test point	MECH	
78	U1	Si8233	Si8233BD-C-IS	SiLabs		SMD	SOIC16W
79	ZD1	24V			24V, 350mW, 1%	SMD	SOD-123
80	ZD2	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
81	ZD3	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
82	ZD4	24V			24V, 350mW, 1%	SMD	SOD-123
83	ZD5	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
84	ZD6	5.1V			5.1V, 350mW, 1%	SMD	SOD-123
85	ZD7	25V			25V, 350mW, 2%	SMD	SOD-123
86	ZD8	5.1V			5.1V, 350mW, 1%	SMD	SOD-123

Additional component list for the example testing in section 6

QTY	Part number	Brand	Description	Comments
1	820303B04724G	Aavid	heat sink, 120mm x 123mm (Need drill hole for mounting)	Heat sink for whole PCB board
4			Nylon tube, M4, 15mm, for PCB board stand at 4 corner	
4			Screw, Phillips head, M3x21mm, for PCB board stand at 4 corner	
4			M3 washer	
4			Screw, Phillips head, M3x10mm, for TO-247 mounting	For SiC device assembly
4	AOS 218 247 1	Fischer elektronik	Aluminum oxide insulator pad with screw hole, TO 247, 25 x 21 x 1.5 mm	
4			Insulating Shoulder Washers, M3, Nylon66, for TO-247 mounting	
1	SDN-414-01	T&M Research	0.01ohm current viewing resistor	Shunt resistor for current Id measurement

Heat sink hole drilling diagram for the example testing in Section 6