

KIT8020-CRD-5FF0917P-2

Evaluation Board for Cree's SiC MOSFET in a TO-247-4 Package



Application Note

CPWR-AN20, Rev-

Cree Power Applications

This document is prepared as an application note to install and operate Cree evaluation hardware.

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CAUTION

PLEASE CAREFULLY REVIEW THE FOLLOWING PAGE, AS IT CONTAINS IMPORTANT INFORMATION REGARDING THE HAZARDS AND SAFE OPERATING REQUIREMENTS RELATED TO THE HANDLING AND USE OF THIS BOARD.

警告

请认真阅读以下内容，因为其中包含了处理和使用本板子有关的危险和安全操作要求方面的重要信息。

警告

ボードの使用、危険の対応、そして安全に操作する要求などの大切な情報を含むので、以下の内容をよく読んでください。



CAUTION

DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD. THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS EVALUATION BOARD WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS BOARD CAN REACH TEMPERATURES ABOVE 50° CELSIUS. FURTHER, THESE CONDITIONS WILL CONTINUE FOR A SHORT TIME AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED.

Please ensure that appropriate safety procedures are followed when operating this board, as any of the following can occur if you handle or use this board without following proper safety precautions:

- **Death**
- **Serious injury**
- **Electrocution**
- **Electrical shock**
- **Electrical burns**
- **Severe heat burns**

You must read this document in its entirety before operating this board. It is not necessary for you to touch the board while it is energized. All test and measurement probes or attachments must be attached before the board is energized. You must never leave this board unattended or handle it when energized, and you must always ensure that all bulk capacitors have completely discharged prior to handling the board. Do not change the devices to be tested until the board is disconnected from the electrical source and the bulk capacitors have fully discharged.

警告

请勿在通电情况下接触板子，在处理板子前应使大容量电容器完全释放电力。接通电源后，该评估板上可能存在非常高的电压，板子上一些组件的温度可能超过 50 摄氏度。此外，移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电量。

操作板子时应确保遵守正确的安全规程，否则可能会出现下列危险：

- 死亡
- 严重伤害
- 触电
- 电击
- 电灼伤
- 严重的热烧伤

请在操作本板子前完整阅读本文件。通电时不必接触板子。在为板子通电前必须连接所有测试与测量探针或附件。通电时，禁止使板子处于无人看护状态，或操作板子。必须确保在操作板子前，大容量电容器释放了所有电量。只有在切断板子电源，且大容量电容器完全放电后，才可更换待测试器件

警告

通電している時、ボードに接触するのは禁止です。ボードを処分する前に、大容量のコンデンサーで電力を完全に釈放すべきです。通電してから、ボードにひどく高い電圧が存在している可能性があります。ボードのモジュールの温度は 50 度以上になるかもしれません。また、電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。

ボードを操作するとき、正確な安全ルールを守るのを確保すべきです。さもないと、以下の危険がある可能性があります：

- 死亡
- 重症
- 感電
- 電撃
- 電気の火傷
- 厳しい火傷

当ボードを操作する前に、完全に当書類をよく読んでください。通電している時にボードに接触する必要がありません。通電する前に必ずすべての試験用のプローブあるいはアクセサリーをつないでください。通電している時に無人監視やボードを操作するのは禁止です。ボードを操作する前に、大容量のコンデンサーで電力を完全に釈放するのを必ず確保してください。ボードの電源を切った後、また大容量のコンデンサーで電力を完全に釈放した後、試験設備を取り換えることができます。

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1. Introduction

The purpose of Cree's KIT8020-CRD-5FF0917P-2 evaluation board is to demonstrate high-speed switching performance of Cree's 3rd Generation (C3M) silicon carbide (SiC) Metal Oxide Semiconductor Field-Effect Transistor (MOSFET) in a TO-247-4 package. Cree's new TO-247-4 package provides a separate Kelvin source pin for gate drive signal return which reduces gate ringing and provides clean gate signal. Cree's KIT8020-CRD-5FF0917P-2 evaluation board (as shown in Figure 1) comes in the configuration of a basic half bridge circuit with two Cree SiC MOSFETs (P/N: C3M0075120K). This evaluation board can be configured into synchronous boost, synchronous buck, inverter and other common power conversion topologies. Moreover, this evaluation board is designed to allow a user to:

- Analyze a printed circuit board (PCB) layout example for driving Cree's generation 3 SiC MOSFET in a newly developed TO-247-4 package.
- Evaluate the performance of a Cree generation 3 SiC MOSFET in a TO-247-4 package during switching events and steady state operation.
- Characterize Turn ON (E_{ON}) and Turn OFF (E_{OFF}) losses.
- Evaluate the effects of different gate resistor (R_g) values, uni-polar versus bipolar gate drives, various thermal interface materials and cooling methods.
- Measure double pulsed clamped inductive switching data.



Figure 1. Cree's KIT8020-CRD-5FF0917P-2 evaluation board

2. Comparison between Cree’s C3M and C2M SiC MOSFETs

The main difference between Cree’s generation 3 (C3M) and generation 2 (C2M) SiC MOSFET is the gate to source voltage (V_{GS}) requirements. As shown in Figure 2 and Figure 3, operational values of V_{GS} for C3M are -4V/+15V while operational values of V_{GS} for C2M are -5V/+20V. This reduction in V_{GS} requirements lowers the overall power losses in Cree’s C3M SiC MOSFET.

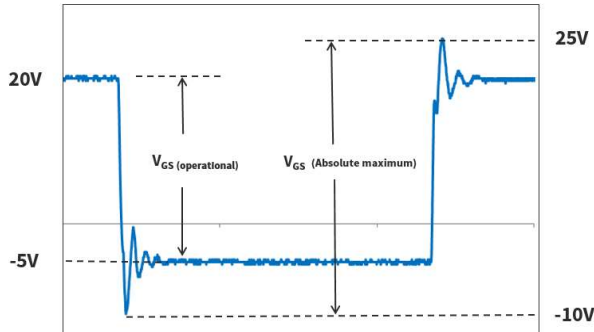


Figure 2. VGS requirements of Cree’s C2M MOSFET

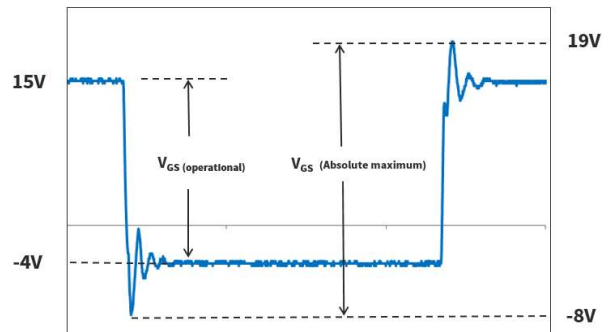


Figure 3. VGS requirements of Cree’s C3M MOSFET

V_{GS} REQUIREMENTS	C2M MOSFET	C3M MOSFET
Operational V_{GS}	-5V/+20V	-4V/+15V
Maximum V_{GS}	-10V/+25V	-8V/19V
Safe Operating V_{GS}	0V/+18V	0V/+15V

Table 1. Comparison of Cree’s C2M MOSFET and Cree’s C3M MOSFET on the basis of VGS Requirements

3. Package Contents of Cree’s KIT8020-CRD-5FF0917P-2 Evaluation Board

ITEM #	QTY	DESCRIPTION	MANUFACTURER	Part Number
1	1	CRD-5FF0917P TO247-4L Eval Board Assembly		CRD-5FF0917P
2	2	High force clip	Aavid Thermalloy	MAX03-HNG
3	1	Heat sink extrusion, custom length (70mm)	Aavid Thermalloy	78060
4	2	MOSFET, 1200V, 75mohm	Cree	C3M0075120K
5	2	Kapton Thermal Interface 22mm x 29mm	Fisher Elektronik	KAP 1 P
6	4	Standoff, ¼" Hex Size, 2" Length, 6-32 Thread	McMaster-Carr	92745A349
7	2	Spacer, ¼" OD, 5/32", un-threaded Al #6 screw	McMaster-Carr	92510A031
8	4	Nylon Hex Nut, 6-32 Thread Size	McMaster-Carr	94812A300
9	2	Phillips Screw, M3x0.5mm Thread, 10mm Long	McMaster-Carr	92005A120
10	1	Shorting strip (1/4" length)	McMaster-Carr	9053K21
11	2	Steel split washer Lock Washer for M3 Screw Size, 3.4mm ID, 6.2mm OD	McMaster-Carr	91202A222

Table 2. Package Contents of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board

4. Overview of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board

The physical dimensions of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board when fully assembled are 133mm x 88mm x 101mm (as shown in Figure 4). Cree’s KIT8020-CRD-5FF0917P-2 evaluation board package includes the PCB, two Cree SiC 1200V MOSFETs (P/N: C3M0075120K), a heatsink (including mounting clips), a thermal pad and various hardware components.

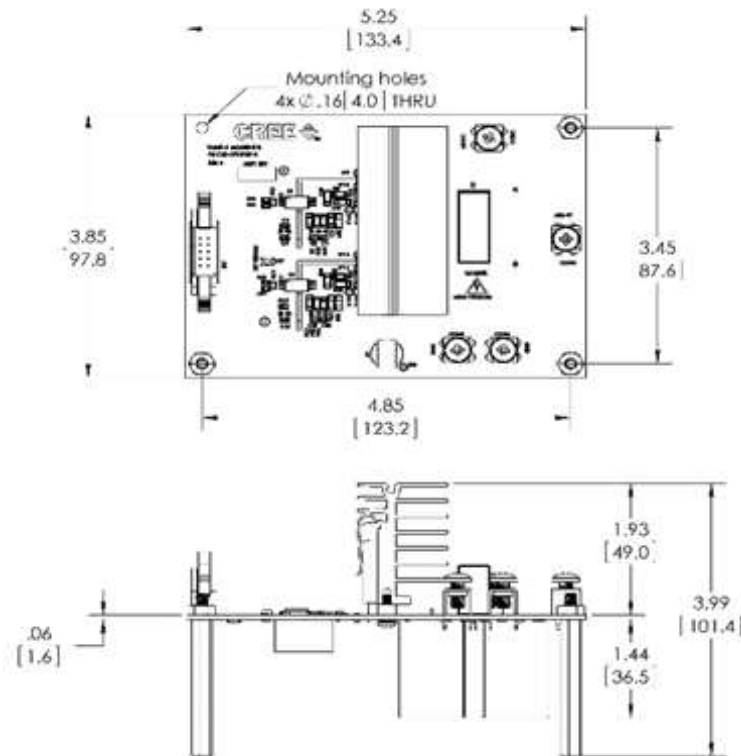


Figure 4. Physical dimensions of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board

A general block diagram of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board is shown in Figure 5. Besides the two Cree’s C3M0075120K SiC MOSFETs (Q1 and Q2) in a half bridge configuration, there are two onboard isolated gate driver circuits which are used to drive both Q1 and Q2, there are four power connectors (CON1, CON2, CON3, and CON4) for connecting to the +DC link, -DC link, and the midpoint, and there is also a 10-pin ribbon cable connector (J10) onboard that carries the logic power and gate drive control signals.

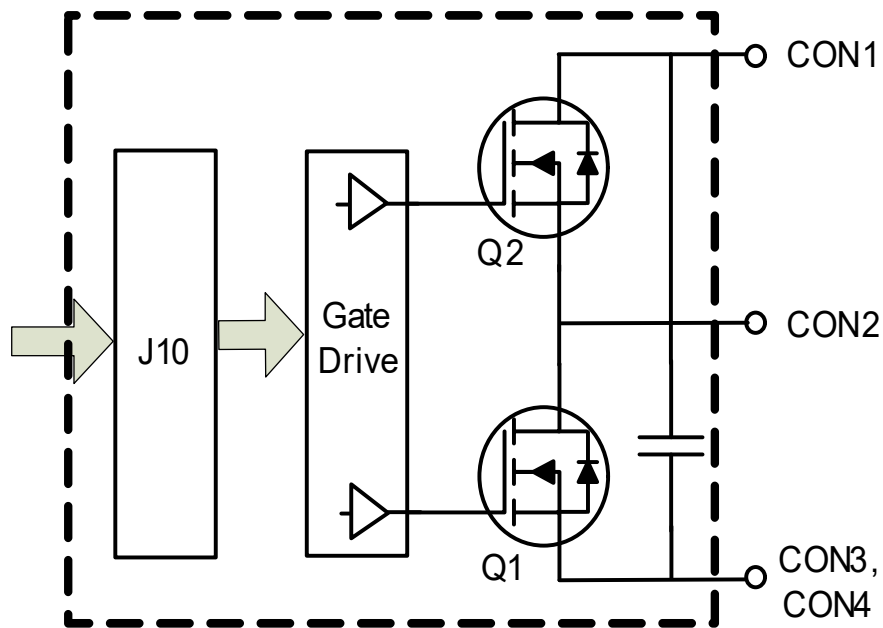


Figure 5. Block Diagram of Cree KIT8020-CRD-5FF0917P-2 evaluation board

Each gate drive circuit consists of an opto-coupler based isolated gate driver chip from Silicon Laboratories Inc. (P/N: SI8261BCD) and a 2W isolated DC/DC converter from Murata Manufacturing Co. Ltd. (P/N: MEJ2D1209SC). The Silicon Laboratories chip provides 5000V of isolation between the low voltage control side and the high voltage drive side. Each DC/DC converter is sourced with a +12V input. Through a series of jumpers, JM1-JM4, (as shown in Figure 6), each gate driver can be configured as a low cost uni-polar (+15V/0V) gate driver or as a high performance bi-polar gate driver (+15V/-3V). The DC/DC converter provides 5.2 KV maximum isolation for 60 seconds.

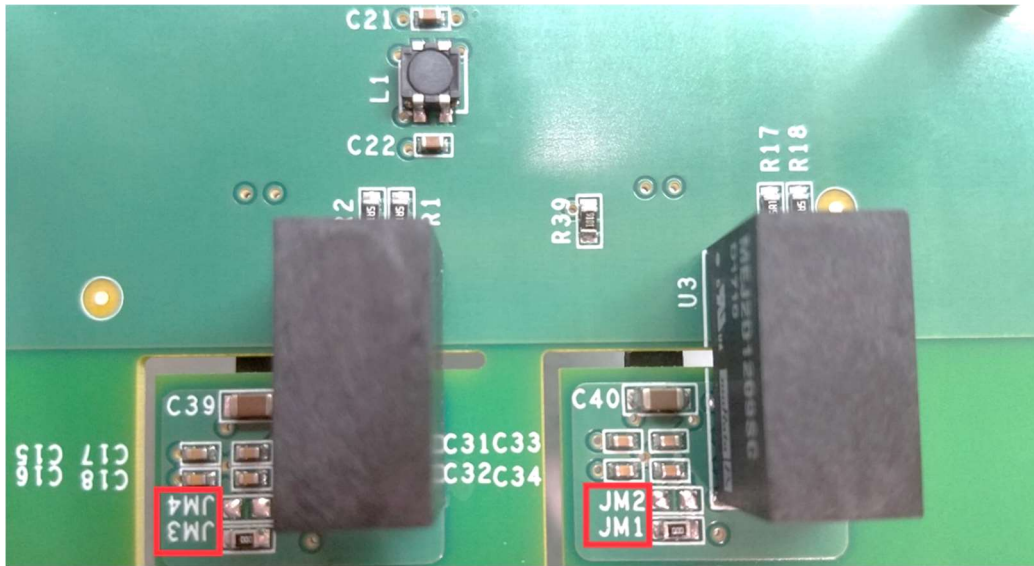


Figure 6. Jumpers (JM1-JM4) to configure gate drivers of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board

Table 3 shows the configuration of jumpers (JM1-JM4) based on desired gate drive output levels identified in the table.

Gate Drive Output		
	+15V/-3V	+15V/0V
JM1, JM3	SHORT	OPEN
JM2, JM4	OPEN	SHORT

Table 3. Configuration of Jumpers (JM1-JM4) based on gate drive output levels

5. Example Topologies

The reason for choosing a half bridge circuit for Cree’s KIT8020-CRD-5FF0917P-2 evaluation board is because of its ability to be a constituent portion of various power conversion topologies. Two example configurations are listed below, with the components shown outside of the dotted box. Cree’s KIT8020-CRD-5FF0917P-2 evaluation board can also be configured in various other topologies (such as a non-synchronous buck topology) with modifications, and with the addition of multiple evaluation boards one can prototype a H-bridge or a 6-pak based power conversion topology.

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A. Synchronous Buck Converter

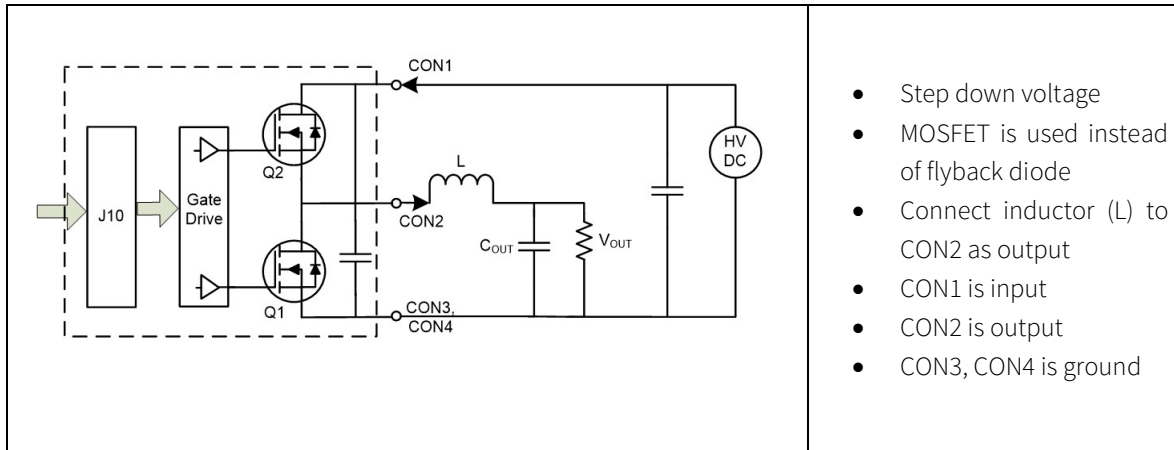


Figure 7. Cree's KIT8020-CRD-5FF0917P-2 evaluation board configured as synchronous buck converter

B. Synchronous Boost Converter

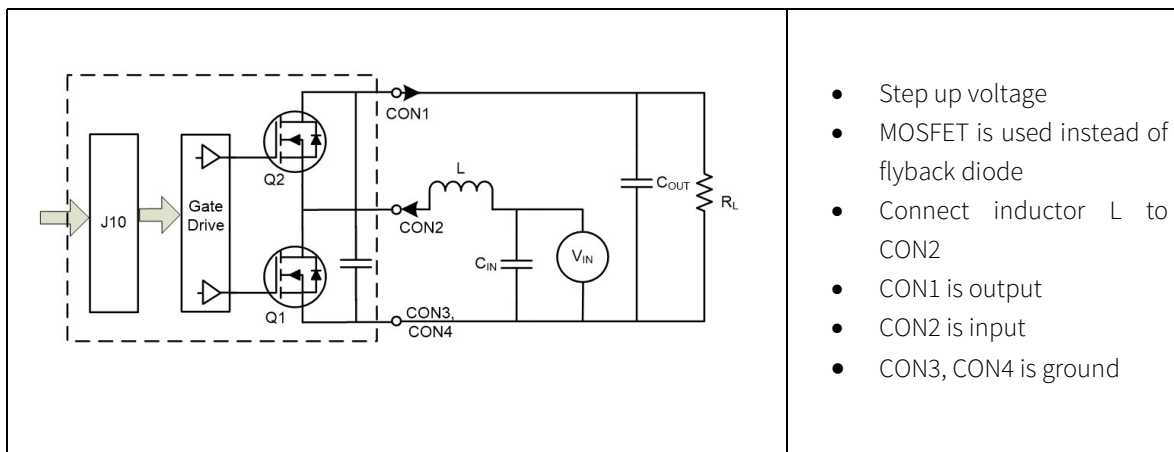


Figure 8. Cree's KIT8020-CRD-5FF0917P-2 evaluation board configured as synchronous boost converter

6. Terminals and Connectors



CAUTION
HIGH VOLTAGE RISK

THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS BOARD WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS BOARD CAN REACH TEMPERATURES ABOVE 50° CELSIUS. FURTHER, THESE CONDITIONS WILL CONTINUE AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED. DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD.

The connectors on the board have very high voltage levels present when the board is connected to an electrical source, and thereafter until the bulk capacitors are fully discharged. Please ensure that appropriate safety procedures are followed when working with these connectors as serious injury, including death by electrocution or serious injury by electrical shock or electrical burns, can occur if you do not follow proper safety precautions. When devices are being attached for testing, the board must be disconnected from the electrical source and all bulk capacitors must be fully discharged. After use the board should immediately be disconnected from the electrical source. After disconnection any stored up charge in the bulk capacitors will continue to charge the connectors. Therefore, you must always ensure that all bulk capacitors have completely discharged prior to handling the board.

警告

高压危险

接通电源后，该评估板上可能存在非常高的电压，板子上一些组件的温度可能超过 50 摄氏度。此外，移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电量。通电时禁止触摸板子，应在大容量电容器完全释放电量后，再触摸板子。

板子上的连接器在充电时以及充电后都具有非常高的电压，直至大容量电容器完全释放电量。请确保在操作板子时已经遵守了正确的安全流程，否则可能会造成严重伤害，包括触电死亡、电击伤害或电灼伤。连接器件进行测试时，必须切断板子电源，且大容量电容器必须释放了所有电量。使用后应立即切断板子电源。切断电源后，大容量电容器中存储的电量会继续输入至连接器中。因此，必须始终在操作板子前，确保大容量电容器已完全释放电量。

警告

高压危险

通电してから、ボードにひどく高い電圧が存在している可能性があります。ボードのモジュールの温度は50度以上になるかもしれません。また、電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。通电している時にボードに接触するのは禁止で

す。大容量のコンデンサーで電力をまだ完全に釈放していない時、ボードに接触しないでください。ボードのコネクタは充電中また充電した後、ひどく高い電圧が存在しているので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。ボードを操作している時、正確な安全ルールを守っているのを確保してください。さもないければ、感電、電撃、厳しい火傷などの死傷が出る可能性があります。設備をつないで

試験する時、必ずボードの電源を切ってください。また、大容量のコンデンサーで電力を完全に釈放してください。使用后、すぐにボードの電源を切ってください。電源を切った後、大容量のコンデンサーに貯蓄している電量はコネクタに持続的に入るので、ボードを操作する前に、必ず大容量のコンデンサーの電力を完全に釈放するのを確保してください。

Terminals CON1, CON2, CON3 and CON4 of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board are the power terminals (as shown in Figure 9) and their definitions vary based on topology. An Amphenol FCI connector (J10) (P/N # 71918-110LF) carries all of the control and logic signals. The definition of J10 for each pin is shown in Table 4.

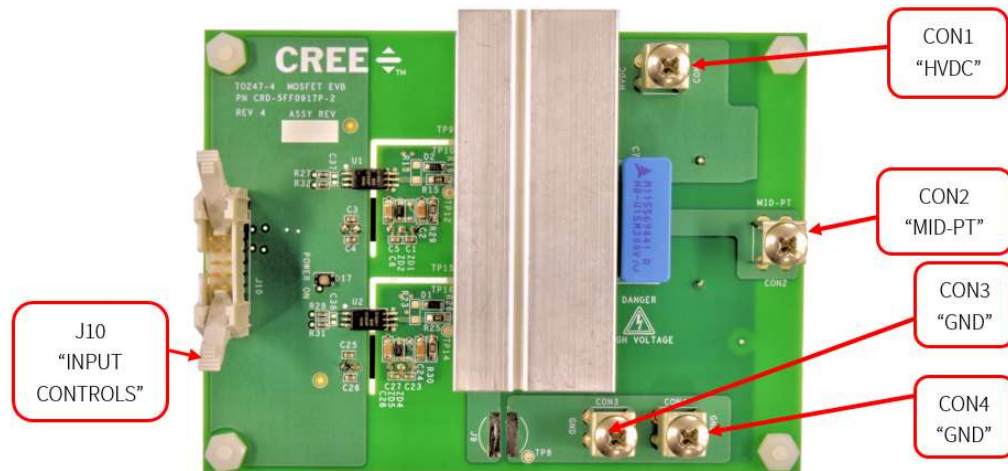


Figure 9. Top view of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board showing locations of various connectors

1	COMMON
2	POWER IN (+VCC)
3	HIGH SIDE Pulse Width Modulation (PWM) RETURN
4	HIGH SIDE PWM INPUT, 5V=SWITCH ON, 0V=SWITCH OFF
5	COMMON
6	COMMON
7	LOW SIDE PWM RETURN
8	LOW SIDE PWM INPUT, 5V=SWITCH ON, 0V=SWITCH OFF
9	COMMON
10	COMMON

Table 4. Pin definitions for input controls connector J10

7. Cooling



CAUTION

IT IS NOT NECESSARY FOR YOU TO TOUCH THE BOARD WHILE IT IS ENERGIZED. WHEN DEVICES ARE BEING ATTACHED FOR TESTING, THE BOARD MUST BE DISCONNECTED FROM THE ELECTRICAL SOURCE AND ALL BULK CAPACITORS MUST BE FULLY DISCHARGED.

SOME COMPONENTS ON THE BOARD REACH TEMPERATURES ABOVE 50° CELSIUS. THESE CONDITIONS WILL CONTINUE AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED. DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD.

PLEASE ENSURE THAT APPROPRIATE SAFETY PROCEDURES ARE FOLLOWED WHEN OPERATING THIS BOARD AS SERIOUS INJURY, INCLUDING DEATH BY ELECTROCUTION OR SERIOUS INJURY BY ELECTRICAL SHOCK OR ELECTRICAL BURNS, CAN OCCUR IF YOU DO NOT FOLLOW PROPER SAFETY PRECAUTIONS.

警告

通电时不必接触板子。连接器件进行测试时，必须切断板子电源，且大容量电容器必须释放完所有电量。

板子上一些组件的温度可能超过 50 摄氏度。移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电量。通电时禁止触摸板子，应在大容量电容器完全释放电量后，再操作板子。

请确保在操作板子时已经遵守了正确的安全规程，否则可能会造成严重伤害，包括触电死亡、电击伤害、或电灼伤。

警告

通电している時にボードに接触する必要がありません。設備をつないで試験する時、必ずボードの電源を切ってください。また、大容量のコンデンサーで電力を完全に釈放してください。

ボードのモジュールの温度は 50 度以上になるかもしれません。電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。通电している時にボードに接触するのは禁止です。大容量のコンデンサーで電力をまだ完全に釈放していない時、ボードを操作しないでください。

ボードを操作している時、正確な安全ルールを守っているのを確保してください。さもなければ、感電、電撃、厳しい火傷などの死傷が出る可能性があります。

Cree's KIT8020-CRD-5FF0917P-2 evaluation board has several integrated features designed for effective thermal management. Since the heatsink is common to both MOSFETs, it needs to be isolated from each MOSFET tab. This isolation is achieved with the help of a high performance Kapton thermal interface pad manufactured by Fisher Elektronik (P/N: KAP1P). A rendering of the assembly is shown below in Figure 10.

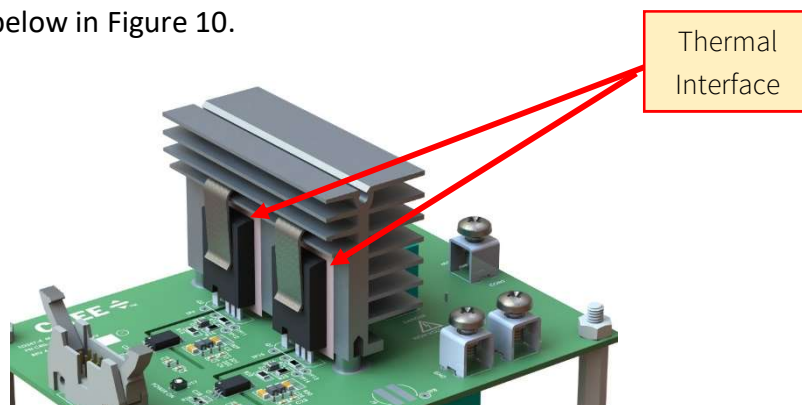


Figure 10. Cree's KIT8020-CRD-5FF0917P-2 evaluation board assembly rendering

8. Test Point Locations

The test points of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board are highlighted in Figure 11. A standard .100” pin header should be soldered on all the major nodes in order to connect oscilloscope probes properly.

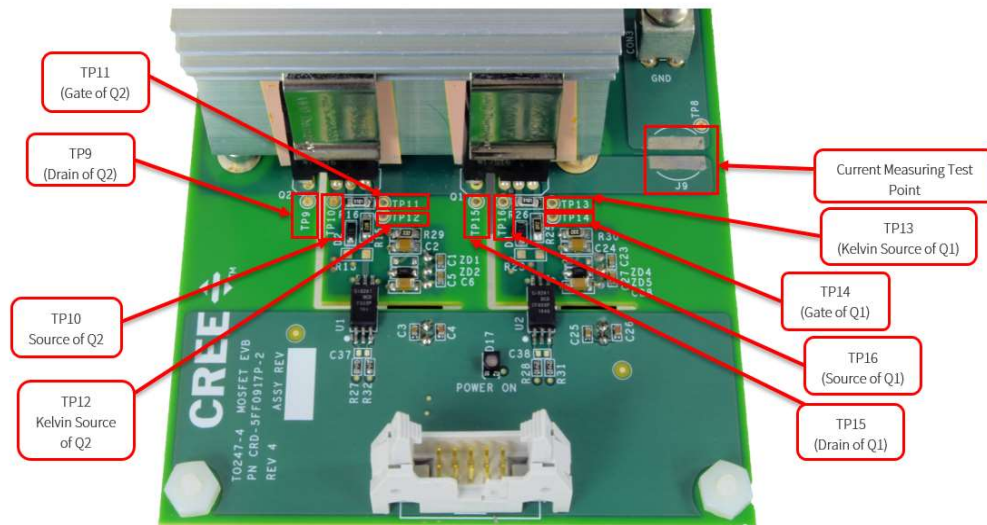


Figure 11. Test Point Locations of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board



Figure 12. 0.100” pin headers installed



Figure 13. Oscilloscope probe attached

Figure 12 shows an example in which a pair of 0.100” pin headers are soldered on the test points 13 & 14 of Cree’s KIT8020-CRD-5FF0917P-2 evaluation board. With the help of these headers, an oscilloscope probe can monitor gate to source voltage (VGS) of the lower MOSFET (as shown in Figure 13).

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9. Example Application: Double Pulse Measurements

Cree’s KIT8020-CRD-5FF0917P-2 evaluation board will allow the user to make double pulsed clamped inductive switching measurements. Figure 14 is showing an arrangement in which Cree’s KIT8020-CRD-5FF0917P-2 evaluation board should be connected in order to make the switching measurements.

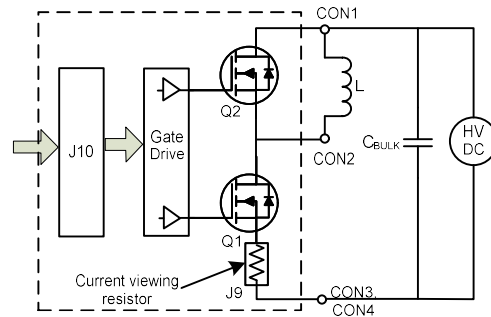


Figure 14. Clamped Inductive Switching Measurement Circuit

A precision current measuring device will be required in order to measure current through Q1. There is a connection point (J9) on the board that can be used to view current on an oscilloscope. T&M Research Products Inc. makes a viewing resistor (P/N # SDN-414-01) (as shown in Figure 15) that has a resistance of 10 mΩ (which typically works well with most of the oscilloscopes with probe attenuation set to x100), that is sold separately, and that may be used with Cree’s KIT8020-CRD-5FF0917P-2 evaluation board. If a different value of resistor is chosen, then the user should make sure that the resistor has minimal insertion inductance. If current does not need to be viewed, then the ¼” shorting strip (which comes with Cree’s KIT8020-CRD-5FF0917P-2 evaluation board) should be soldered into J9.

Note: Either a current measuring device or the shorting strip must be soldered into place (J9) before operating this board.



Figure 15. SDN-414-01 current viewing resistor (sold separately)

Due to the fast switching speeds associated with Cree SiC MOSFETs, the following steps must be followed closely to yield the most accurate results possible.

- Scope probes measuring drain to source voltage (VDS) and gate to source voltage (VGS) must have minimal loop area between the signal and the ground.
- The oscilloscope probes measuring VDS and drain to source current (IDS) must be de-skewed.
- Bulk capacitance may need to be added to the board to minimize DC link voltage sag during two-pulse measurements. The amount will vary based on desired current level and the pulse width.

Figure 16 shows a two-pulse experimental setup. Figure 17 shows the measured waveforms. Green waveform shows the output current, pink waveform shows the gate signal and yellow waveform shows the output voltage.

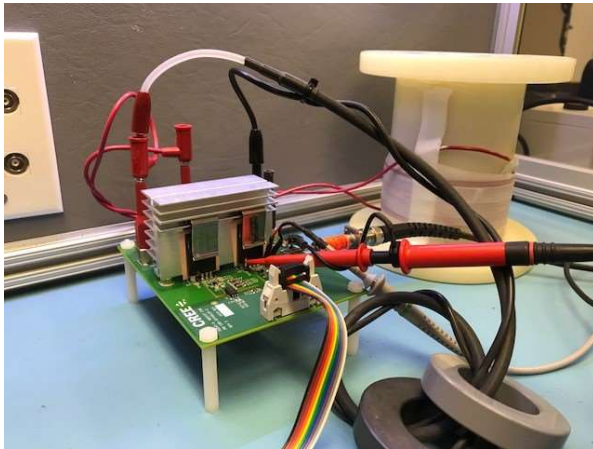


Figure 16. Two-pulse setup



Figure 17. Waveforms measured

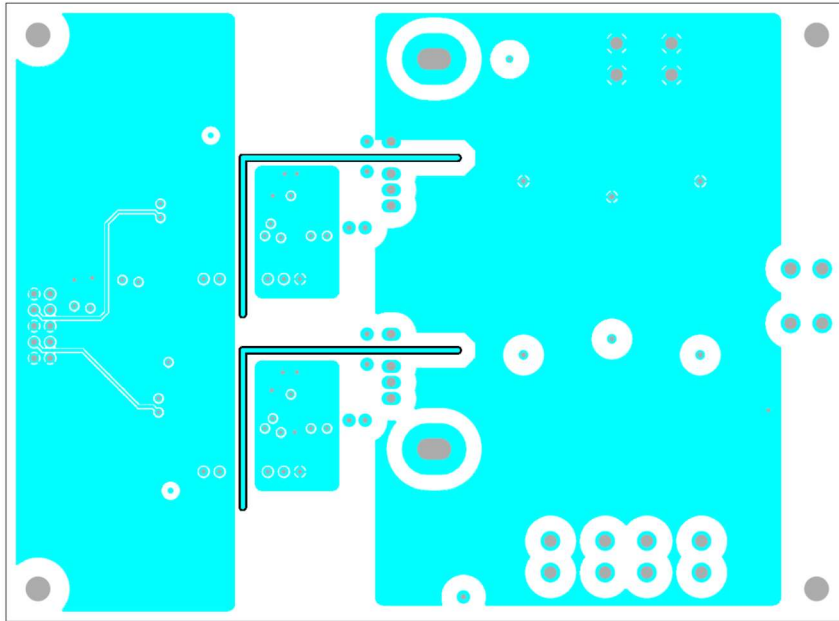


Figure 20. Inner Copper Layer 1 of Cree's KIT8020-CRD-5FF0917P-2 evaluation board PCB

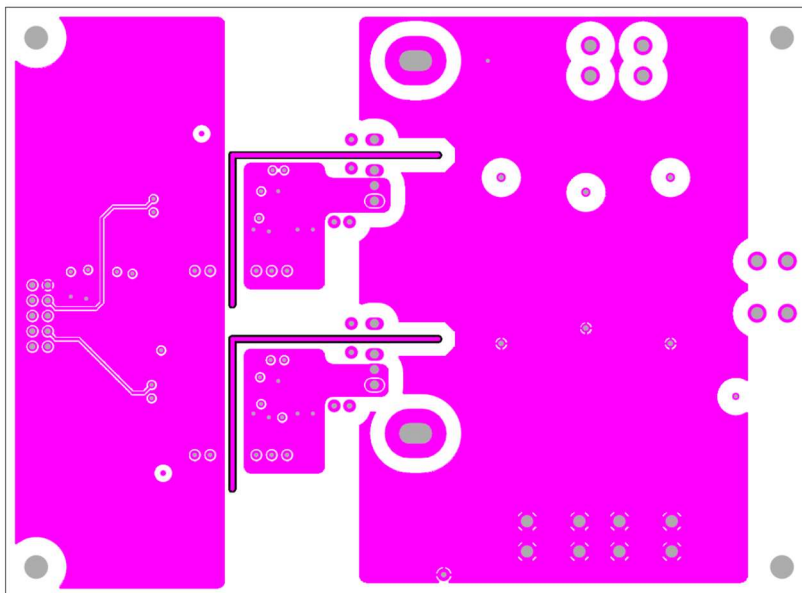


Figure 21. Inner Copper Layer 2 of Cree's KIT8020-CRD-5FF0917P-2 evaluation board PCB

12. Bill of Materials

Item	Qty Per	Reference Designator	Description	Manufacturer Name	Manufacturer's P/N
1	4	CON1-4	TERM PC SNAPIN VRT 10-32 W/SCREW	Keystone	8174
2	6	C1,C3,C5,C23,C25 C27	1 μ F \pm 10% 50V Ceramic Capacitor X7R	Taiyo Yuden	UMK107AB7105KA-T
3	4	C2,C6,C24,C28	10 μ F \pm 10% 35V Ceramic Capacitor X7R	Taiyo Yuden	GMK316AB7106KL-TR
4	4	C4,C21,C22,C26	4.7 μ F \pm 10% 35V Ceramic Capacitor X5R	Murata	GRM188R6YA475KE15D
5	1	C7	0.15 μ F \pm 20% Film Capacitor 300V 1500V	Epcos	B32023A3154M
6	2	C8,C41	CAP FILM 0.47UF 5% 1.6KVDC RAD	Kemet	R76TR34704030J
7	4	C15,C17,C31,C33	0.10 μ F \pm 10% 50V Ceramic Capacitor X7R	Samsung	CL10B104KB85FNC
8	4	C16,C18,C32,C34	10000pF \pm 10% 50V Ceramic Capacitor X7R	Kemet	C0603C103K5RACTU
9	2	C19,C35	1000pF \pm 10% 50V Ceramic Capacitor X7R	Samsung	CL31B102KBCNUNC
10	2	C20,C36	100pF \pm 10% 2000V Ceramic Capacitor X7R	Kemet	C1210C101KGRACU
11	2	C39,C40	4.7 μ F \pm 10% 50V Ceramic Capacitor X7R	Taiyo Yuden	UMK316AB7475KL-T
12	2	D1,D2	Diode Schottky 40V 1A Surface Mount SOD-123	Diodes Inc.	1N5819HW-7-F
13	1	D17	LED RGB DIFFUSED 4PLCC SMD	Cree	CLVBA-FKA-CAEDH8BBB7A363
14	2	JM1, JM3	RES SMD 0.0 OHM JUMPER 1/8W 0805	Panasonic	ERJ-6GEY0R00V
15	1	J10	10 Positions Header, Shrouded Connector 0.100"	Amphenol FCI	71918-110LF
16	1	L1	common mode choke	TDK	ACM4520-142-2P-T000
17	4	R1,R2,R17,R18	RES SMD 5.1 OHM 5% 1/8W 0805	Yageo	RC0805JR-075R1L
18	8	R3,R4,R5,R6,R7 R9,R42,R43	RES SMD 1M OHM 1% 1/4W 1206	Panasonic	ERJ-8ENF1004V
19	2	R15,R25	RES SMD 8.2 OHM 5% 1/3W 1206	Rhom	ESR18EZPJ8R2
20	2	R14,R24	RES SMD 10 OHM 1% 2W 2512	Bourns	CRM2512-FX-10R0ELF
21	2	R16,R26	RES SMD 5.1K OHM 1% 1/4W 1206	Panasonic	ERJ-8ENF5101V
22	4	R27,R28,R31,R32	RES SMD 91 OHM 1% 1/10W 0603	Yageo	RC0603FR-0791RL
23	2	R29,R30,	RES SMD 2K OHM 1% 1/4W 1206	Panasonic	ERJ-8ENF2001V
24	2	R40,R41	RES SMD 0.0 OHM JUMPER	Panasonic	ERJ-8GEY0R00V
25	1	R39	RES SMD 9.1K OHM 1% 1/8W 0805	Rhom	MCR10ERTF9101
27	2	U1,U2	DGTL ISO 5KV GATE DRIVER 6SDIP	Silicon Labs	SI8261BCD-C-ISR
28	2	U3,U4	Isolated Module DC DC Converter 2 O/P 9V - 9V 111mA, 111mA 10.8V - 13.2V Input	Murata	MEJ2D1209SC
29	2	ZD1,ZD4	DIODE ZENER 20V 500MW SOD123	ON Semi	MMSZ20T1G
30	2	ZD2,ZD5	DIODE ZENER 3.3V 500MW SOD123	ON Semi	MMSZ5226BT1G
31	1		Bare Board		CRD-5FF0917P

Table 5. Bill of Materials of Cree's KIT8020-CRD-5FF0917P-2 evaluation board

CPWR-AN20, Rev -, 02-2018

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13. Revision History

Date	Revision	Changes
02/09/2018	Rev -	1 st Issue

IMPORTANT NOTES

Purposes and Use

Cree, Inc. (on behalf of itself and its affiliates, “Cree”) reserves the right in its sole discretion to make corrections, enhancements, improvements, or other changes to the board or to discontinue the board.

THE BOARD DESCRIBED IS AN ENGINEERING TOOL INTENDED SOLELY FOR LABORATORY USE BY HIGHLY QUALIFIED AND EXPERIENCED ELECTRICAL ENGINEERS TO EVALUATE THE PERFORMANCE OF CREE POWER SWITCHING DEVICES. THE BOARD SHOULD NOT BE USED AS ALL OR PART OF A FINISHED PRODUCT. THIS BOARD IS NOT SUITABLE FOR SALE TO OR USE BY CONSUMERS AND CAN BE HIGHLY DANGEROUS IF NOT USED PROPERLY. THIS BOARD IS NOT DESIGNED OR INTENDED TO BE INCORPORATED INTO ANY OTHER PRODUCT FOR RESALE. THE USER SHOULD CAREFULLY REVIEW THE DOCUMENT TO WHICH THESE NOTIFICATIONS ARE ATTACHED AND OTHER WRITTEN USER DOCUMENTATION THAT MAY BE PROVIDED BY CREE (TOGETHER, THE “DOCUMENTATION”) PRIOR TO USE. USE OF THIS BOARD IS AT THE USER’S SOLE RISK.

Operation of Board

It is important to operate the board within Cree’s recommended specifications and environmental considerations as described in the Documentation. Exceeding specified ratings (such as input and output voltage, current, power, or environmental ranges) may cause property damage. If you have questions about these ratings, please contact Cree at sic_power@cree.com prior to connecting interface electronics (including input power and intended loads). Any loads applied outside of a specified output range may result in adverse consequences, including unintended or inaccurate evaluations or possible permanent damage to the board or its interfaced electronics. Please consult the Documentation prior to connecting any load to the board. If you have any questions about load specifications for the board, please contact Cree at sic_power@cree.com for assistance.

Users should ensure that appropriate safety procedures are followed when working with the board as serious injury, including death by electrocution or serious injury by electrical shock or electrical burns can occur if you do not follow proper safety precautions. It is not necessary in proper operation for the user to touch the board while it is energized. When devices are being attached to the board for testing, the board must be disconnected from the electrical source and

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any bulk capacitors must be fully discharged. When the board is connected to an electrical source and for a short time thereafter until board components are fully discharged, some board components will be electrically charged and/or have temperatures greater than 50° Celsius. These components may include bulk capacitors, connectors, linear regulators, switching transistors, heatsinks, resistors and SiC diodes that can be identified using board schematic. Users should contact Cree at sic_power@cree.com for assistance if a board schematic is not included in the Documentation or if users have questions about a board's components. When operating the board, users should be aware that these components will be hot and could electrocute or electrically shock the user. As with all electronic evaluation tools, only qualified personnel knowledgeable in handling electronic performance evaluation, measurement, and diagnostic tools should use the board.

User Responsibility for Safe Handling and Compliance with Laws

Users should read the Documentation and, specifically, the various hazard descriptions and warnings contained in the Documentation, prior to handling the board. The Documentation contains important safety information about voltages and temperatures.

Users assume all responsibility and liability for the proper and safe handling of the board. Users are responsible for complying with all safety laws, rules, and regulations related to the use of the board. Users are responsible for (1) establishing protections and safeguards to ensure that a user's use of the board will not result in any property damage, injury, or death, even if the board should fail to perform as described, intended, or expected, and (2) ensuring the safety of any activities to be conducted by the user or the user's employees, affiliates, contractors, representatives, agents, or designees in the use of the board. User questions regarding the safe usage of the board should be directed to Cree at sic_power@cree.com.

In addition, users are responsible for:

- compliance with all international, national, state, and local laws, rules, and regulations that apply to the handling or use of the board by a user or the user's employees, affiliates, contractors, representatives, agents, or designees.
- taking necessary measures, at the user's expense, to correct radio interference if operation of the board causes interference with radio communications. The board may generate, use, and/or radiate radio frequency energy, but it has not been tested for compliance within the limits of

computing devices pursuant to Federal Communications Commission or Industry Canada rules, which are designed to provide protection against radio frequency interference.

- compliance with applicable regulatory or safety compliance or certification standards that may normally be associated with other products, such as those established by EU Directive 2011/65/EU of the European Parliament and of the Council on 8 June 2011 about the Restriction of Use of Hazardous Substances (or the RoHS 2 Directive) and EU Directive 2002/96/EC on Waste Electrical and Electronic Equipment (or WEEE). The board is not a finished product and therefore may not meet such standards. Users are also responsible for properly disposing of a board's components and materials.

No Warranty

THE BOARD IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, INCLUDING BUT NOT LIMITED TO ANY WARRANTY OF NON-INFRINGEMENT, MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE, WHETHER EXPRESS OR IMPLIED. THERE IS NO REPRESENTATION THAT OPERATION OF THIS BOARD WILL BE UNINTERRUPTED OR ERROR FREE.

Limitation of Liability

IN NO EVENT SHALL CREE BE LIABLE FOR ANY DAMAGES OF ANY KIND ARISING FROM USE OF THE BOARD. CREE'S AGGREGATE LIABILITY IN DAMAGES OR OTHERWISE SHALL IN NO EVENT EXCEED THE AMOUNT, IF ANY, RECEIVED BY CREE IN EXCHANGE FOR THE BOARD. IN NO EVENT SHALL CREE BE LIABLE FOR INCIDENTAL, CONSEQUENTIAL, OR SPECIAL LOSS OR DAMAGES OF ANY KIND, HOWEVER CAUSED, OR ANY PUNITIVE, EXEMPLARY, OR OTHER DAMAGES. NO ACTION, REGARDLESS OF FORM, ARISING OUT OF OR IN ANY WAY CONNECTED WITH ANY BOARD FURNISHED BY CREE MAY BE BROUGHT AGAINST CREE MORE THAN ONE (1) YEAR AFTER THE CAUSE OF ACTION ACCRUED.

Indemnification

The board is not a standard consumer or commercial product. As a result, any indemnification obligations imposed upon Cree by contract with respect to product safety, product liability, or intellectual property infringement do not apply to the board.