User Guide PRD-06987

KIT-CRD-8FF65P (650V) KIT-CRD-8FF90P (900V) Evaluation Kit User Guide

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Contents

This document is prepared as a user guide to install and operate Wolfspeed® evaluation hardware. All parts of this user guide are provided in English, and the cautions are provided in English, Mandarin, and Japanese. If the end user of this board is not fluent in any of these languages, it is your responsibility to ensure that they understand the terms and conditions described in this document, including without limitation the hazards of and safe operating conditions for this board.

本文件中的所有内容均以英文书写，“注意”部分的内容以英文、中文和日语书写。作为本板子的终端用户，即使您不熟悉上述任何一种语言，您也应当确保正确理解本文件中的条款与条件，包括且不限于本板子的危险隐患以及安全操作条款。

当書類のすべての内容は英語で書きます。「注意点」の内容は英語、中国語、また日本語で書きます。当ボードの端末使用者は上記の言語が一つでもわからないなら、当端末使用者は当書類の条約と条件が理解できるのを確保すべきです。そして、当ボードの危険や安全に使用する条件を含み、また限りません。

Note: This Wolfspeed-designed evaluation hardware for Wolfspeed® components is a fragile, high voltage, high-temperature power electronics system that is meant to be used as an evaluation tool in a lab setting and to be handled and operated by highly qualified technicians or engineers. When this hardware is not in use, it should be stored in an area that has a storage temperature ranging from -40° Celsius to 105° Celsius. If this hardware is transported, special care should be taken during transportation to avoid damaging the board or its fragile components and the board should be transported carefully in an electrostatic discharge (ESD) bag, or with ESD or shorting protection that is the same as, or similar to, the protection that is or would be used by Wolfspeed when shipping this hardware, to avoid any damage to electronic components. Please contact Wolfspeed at *forum.wolfspeed.com* if you have any questions about the protection of this hardware during transportation. The hardware does not contain any hazardous substances, is not designed to meet any industrial, technical, or safety standards or classifications, and is not a production-qualified assembly.

本样机（易碎、高压、高温电力电子系统）由科锐为评估其功率半导体产品而设计，用以作为在实验室环境下由专业的技术人员或工程师处理和使用的评估工具。本样机不使用时，应存储在-40°C~105°C温度范围的区域内；如需运输样机，运输过程中应该特别小心，避免损坏电路板等易碎组件。如果您对此硬件在运输之中的保护有任何疑问，请联系forum.wolfspeed.com。 样机应放置在防静电包装袋内谨慎运输，避免损坏电子组件。本样机不含任何有害物质，但其设计不符合任何工业、技术或安全标准或分类，也不是可用于生产的组件。

このクリーのコンポーネント用評価ハードウェアは壊れやすい高電圧の高温パワーエレクトロニクスシステムであり、ラボ環境での評価ツールとして使用され、優秀な技術者やエンジニアによって処理され、操作されることを意図している。ハードウェアが使用されていない場合、保管温度が-40℃から105℃の範囲に保管してください。このハードウェアを輸送する場合は、輸送中にボードまたはその壊れやすいコンポーネントに損傷を与えないよう特別な注意を払う必要がある。また電子部品の損傷を避けるためにボードを静電気放電（ESD）袋に静置して慎重に輸送するべき。ハードウエアの輸送中の保護について質問があれば https://forum.wolfspeed.com/ に連絡してください。ハードウェアには危険物質が含まれていないが、工業的、技術的、安全性の基準または分類に適合するように設計されておらず、生産適格組立品でもない。

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。

1. Introduction

The purpose of this evaluation board is to demonstrate the high performance of Wolfspeed® SiC MOSFETs in a 7-pin D2PAK package. This evaluation board (Fig. 1) comes configured as a half bridge, but it can be configured into other common topologies such as a synchronous boost or synchronous buck topology. This board was designed to make it easy for the user to:

- Evaluate SiC MOSFET switching performance and characterize E_{ON} and E_{OFF} losses in SiC MOSFETs.
- Evaluate SiC MOSFET steady state performance. The heatsinks are predrilled with wells for thermocouples so the heatsink temperature just underneath the MOSFET's case can be measured.
- Use as a printed circuit board (PCB) board layout example for driving SiC MOSFETs.
- Use as a gate drive reference design for a D2PAK package MOSFET.

Figure 1: Wolfspeed's KIT-CRD-8FF65P/CRD-8FF90P evaluation kit

2. Package Contents

The package contents of the evaluation kit are listed in Table 1.

Table 1: Package Contents of KIT-CRD-8FF65P/CRD-8FF90P Evaluation Kit

Item	Kit Version 650V	Kit Version 900V	Description	Manufacturer	Part Number
1	1	-	CRD-8FF6590P-X PCB Assy.	CM	CRD-8FF6590P-1
	-	1		CM	CRD-8FF6590P-2
2	1	1	Heat sink, custom length 3 in.	Aavid Thermalloy	
3	1	1	Foam insert top	Make	See drawing
4	1	1	S/N Label	Make	n/a
5	1	-	Cover graphic Label	Make	
	-	1		Make	
6	1	1	Foam insert	Make	See drawing

Item	Kit Version 650V	Kit Version 900V	Description	Manufacturer	Part Number
7	4	4	Male-Female Threaded Hex Standoff Nylon-6/6, 1/4" Hex Size, 1-1/2" Long, 6-32 to 6-32	McMaster-Carr	92745A348
8	4	4	Nylon Hex Nut, 6-32 Thread Size	McMaster-Carr	94812A300
9	2	2	Steel Pan Head Screw, Internal-Tooth Lock, Washer, 4-40, 5/8"	McMaster-Carr	90403A112
10	1	1	Package Box 9 x 6.5 x 4in.	Uline	S-9842
11	1	1	2”x3” 4mil recloseable poly bag	Uline	S-12269
12	1	1	ESD Label on box	Uline	S-2245
13	1	1	Safety note	Make	See drawing
14	1	1	FAN AXIAL 30X10MM 12VDC WIRE	Mechatronics	MR3010E12B-RSR
15	1	1	FINGER GUARD 30MM METAL	Qualtek	8346
16	5	5	M5x6 Reny screw	SolidSpot	RENYLC506(L)
17	1	1	Serial number label	CM	make
18	2	2	Thermal Interface	Bergquist	QII-0.006-AC-1212

3. Board Overview

The physical dimensions of Wolfspeed’s KIT-CRD-8FF65P/CRD-8FF90P evaluation kit are 119 mm X 98 mm X 54 mm (as shown in Figure 2). The evaluation kit comes with a Printed Circuit Board (PCB), Wolfspeed’s (C3M™) 650 V 60 mΩ MOSFETs (P/N: C3M0060065J) or Wolfspeed’s (C3M™) 900 V 65 mΩ MOSFETs (P/N: C3M0065090J), a heatsink, nonconductive hardware screws, a thermal pad and hardware accessories.

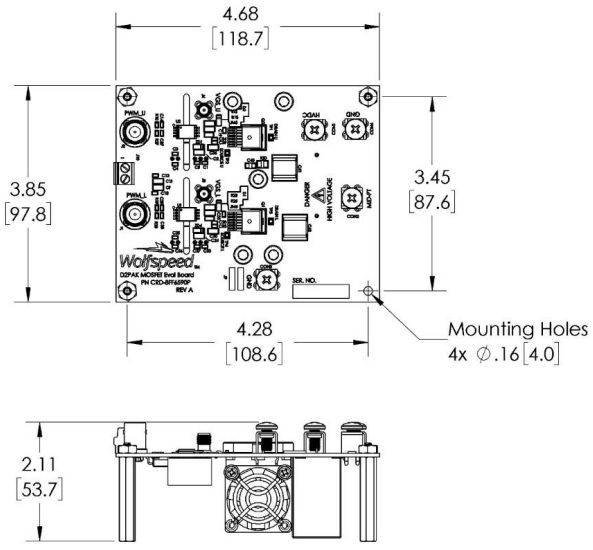


Figure 2: Physical dimensions of the evaluation board

4. Electrical Performance

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

通電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。通電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。

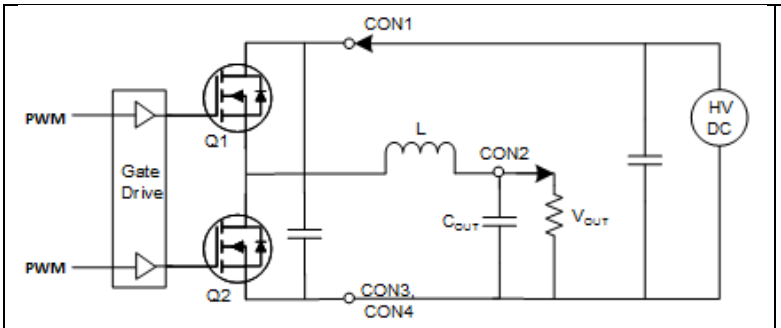
The electrical specifications of Wolfspeed's KIT-CRD-8FF65P/CRD-8FF90P Evaluation Kit are shown in Table 2. Please refer to the table for the maximum DC bus voltage. A single 15 VDC benchtop power supply must be supplied to the evaluation kit to provide power to the logic (VCC) and gate driver circuits. The amount of current that the 15 VDC source must supply depends on the switching frequency and the type of devices that are populated on the PCB of the evaluation kit. The listed 15 VDC (VCC input current) is the standby current that the evaluation kit will draw, when nothing is being switched.

Table 2: Electrical Specifications

Items	Values	
Kit Version	CRD-8FF65P (650 V)	CRD-8FF90P (900 V)
Included MOSFETs	C3M0060065J	C3M0065090J
MOSFET Specs	650 V, 60 mohm	900 V, 65 mohm
Max DC Bus Voltage	450 V	600 V
VCC (Logic Power)	15 VDC	
VCC Input Current (Standby)	40 mA (typical)	

5. Example Topologies

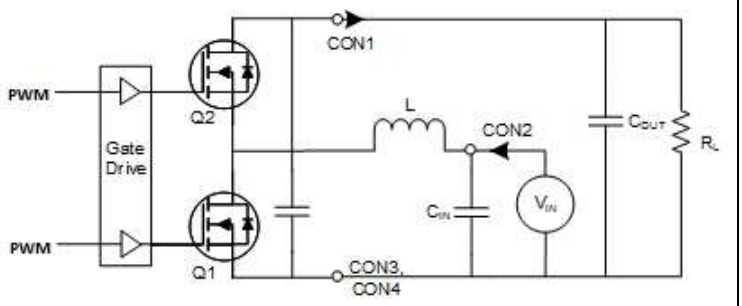
5.1 Synchronous Buck Converter



- Step down voltage
- MOSFET channel is used instead of antiparallel diode
- MOSFET body diode conducts during deadtime
- CON1 is input
- CON2 is output
- CON3, CON4 is ground

Figure 3: Synchronous buck converter configuration

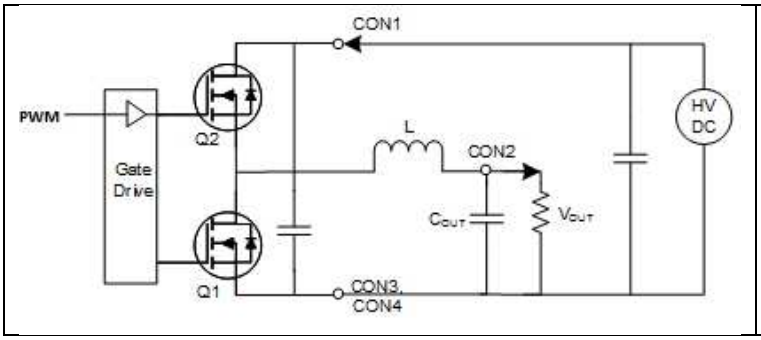
5.2 Synchronous Boost Converter



- Step up voltage
- MOSFET channel is used instead of antiparallel diode
- MOSFET body diode conducts during deadtime
- CON1 is output
- CON2 is input
- CON3, CON4 is ground

Figure 4: Synchronous boost converter configuration

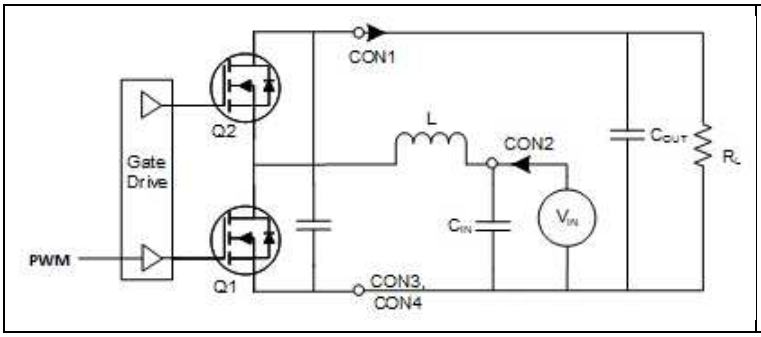
5.3 Asynchronous Buck Converter



- Step down voltage
- MOSFET body diode is used during current freewheel
- CON1 is input
- CON2 is output
- CON3, CON4 is ground

Figure 5: Asynchronous buck converter configuration

5.4 Asynchronous Boost Converter

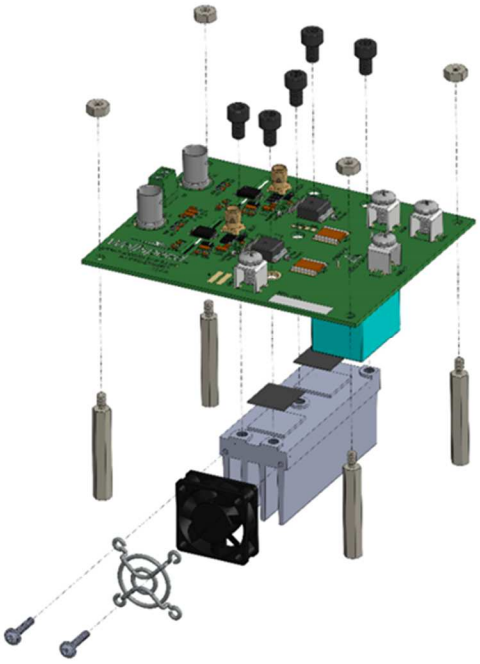


- Step up voltage
- MOSFET body diode conducts during current freewheel
- CON1 is output
- CON2 is input
- CON3, CON4 is ground

Figure 6: Asynchronous boost converter configuration

6. Mechanical Assembly

Wolfspeed's KIT-CRD-8FF65P/CRD-8FF90P evaluation kit must be assembled prior to testing. The heatsink, cooling fan, fan guard, standoffs, and thermal gap filler pad must be installed according to the arrangement shown in figure 7 (a).



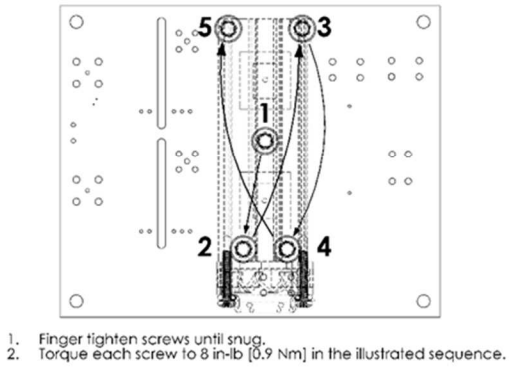


Figure 7 (a) *Figure 8 (b)*

Figure 9 (a): Exploded mechanical assembly,
Figure 7 (b): Heatsink screw torquing sequence

Install the cooling fan with the two provided 4-40 screws, but only tighten until snug and do not over tighten. Peel the backing off the included thermal gap pad and apply the pad to the two raised embossments on the heatsink. Carefully align the PCB's mounting holes with the holes on the heatsink. Secure the PCB to the heatsink with the 5 included Remy screws. The five screws must be torqued to 8 in-lb (0.9 Nm) in the order shown in Figure 7 (b). Last, install the 4 standoffs. **YOU MUST INSTALL THE THERMAL PAD!** (Fig. 8).

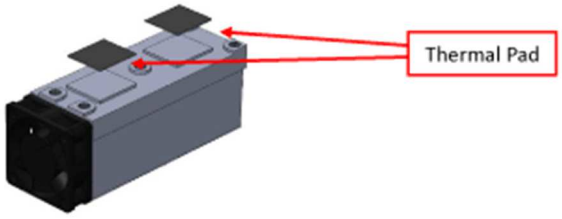


Figure 10: Thermal gap filler pad

7. Board Diagram

7.1 MOSFET and Gate Driver Locations

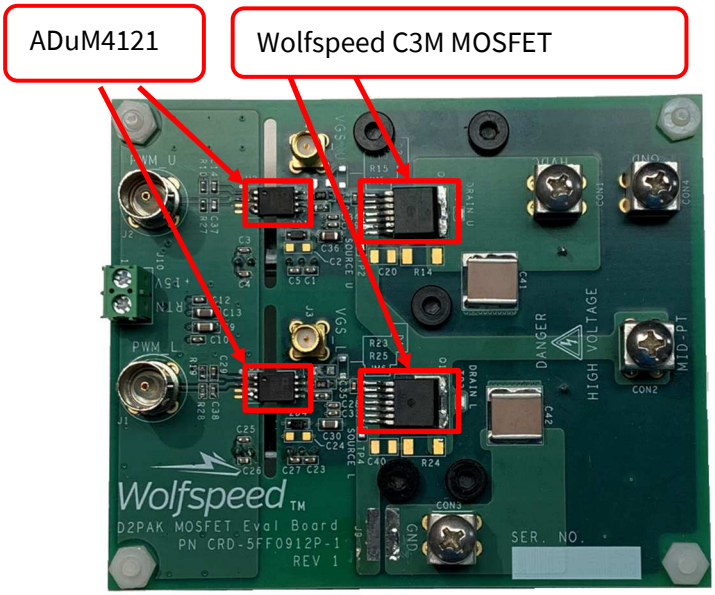


Figure 11: Gate driver and MOSFET locations

7.2 Power Terminals

Terminals CON1, CON2, CON3 and CON4 are the power terminals. Their definitions vary based on the topology.

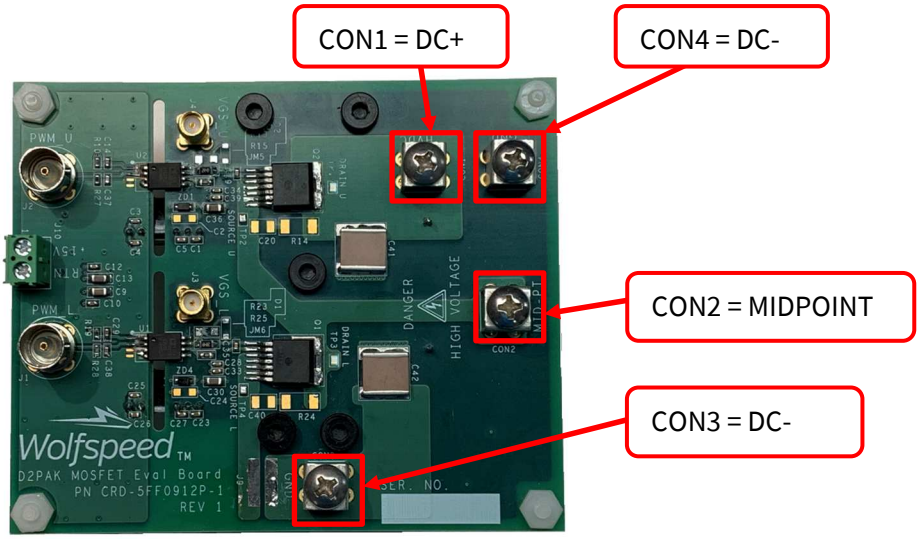


Figure 12: Main power terminals

7.3 Test Point Locations

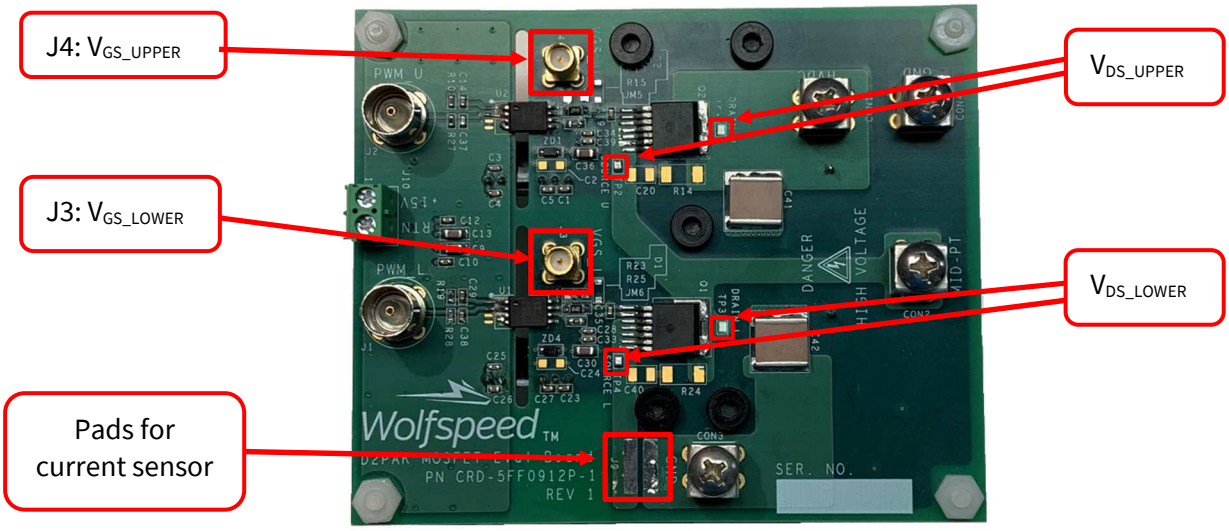


Figure 13: Test point locations

7.4 Logic Power and PWM Input Signals

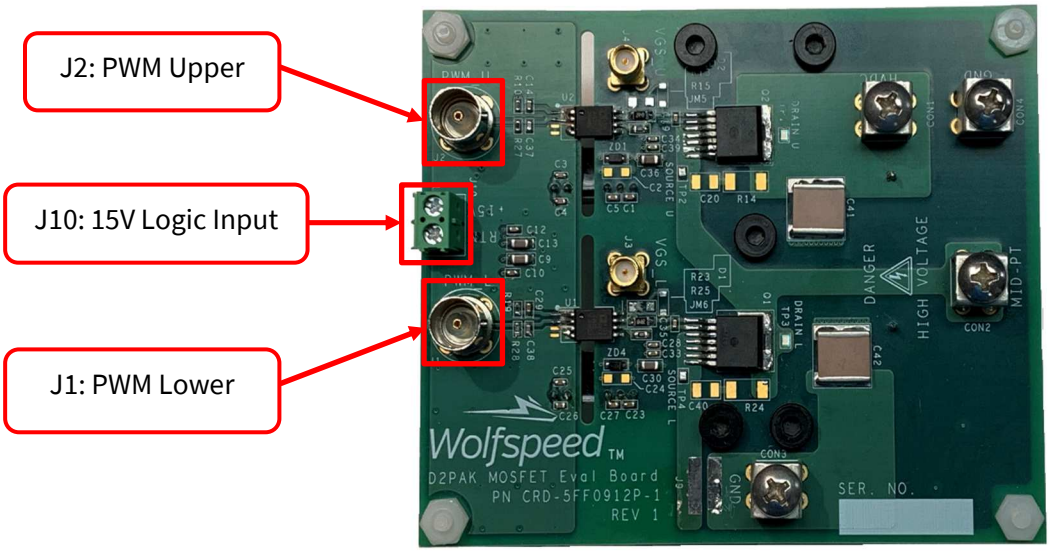


Figure 14: Low-voltage input connectors

The 15 VDC logic power supply is connected to J10 according to the polarity shown on the board silkscreen and in Figure 12. The pin definition of J10 is shown in Table 3. The total amount of current drawn from the 15 VDC supply depends on the circuit topology, devices installed and the PWM frequency. The standby current drawn from the 15 VDC supply without any switching condition is listed in Table 4. The 15 VDC supply mainly powers the isolated DC/DC power supplies which power the gate drivers for the lower and the upper channels. The definition of each PWM channel is shown in Table 5.

Table 3: Pin Definitions of Connector J8

J8	
1	15V+(VCC)
2	COMMON

Table 4: Input Requirements

Parameter	Typical
Input Current(standby)	40mA
PWM Input Signal	5V

Table 5: Pin Definitions of Connectors J1 and J2

Terminal	Signal	Reference
J2	PWM Input Upper Channel	PWM_U
J1	PWM Input Lower Channel	PWM_L

8. Test Point Locations

The evaluation kit comes with many test points (Fig. 11) so that users may capture critical waveforms such as drain to source voltage (V_{DS}), gate to source voltage (V_{GS}), and drain current (ID). It is critical to take these measurements as close as possible to the device pins. On the top side of the evaluation kit's PCB board, there are test loops placed right next to the drain tab and source (power) pins for each MOSFET. The test loop makes it convenient for the users to attach the clip-on probes to the PCB board (Fig. 13).

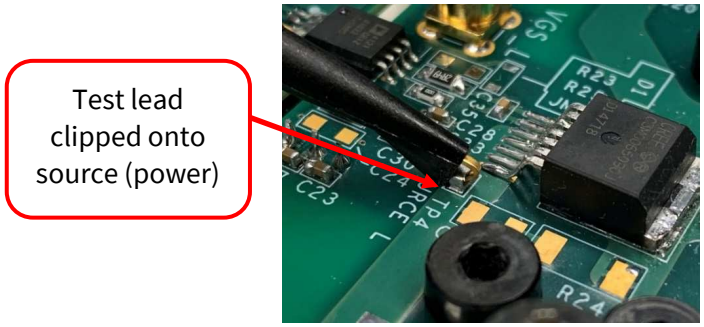


Figure 15: Test lead clipped on the source (power)

There are also two Sub Miniature A (SMA) connectors located on the top side of the board for monitoring the VGS on both the upper and the lower devices. The evaluation kit comes with two SMA to Bayonet Neill–Concelman (BNC) adapters. A standard 10X passive (compensated) probe can be connected to the BNC adapter (Fig. 14).

A user should use a compensated probe fitted with one of the included SMA to BNC adapters to take gate signal measurements via the SMA connectors (J3 & J4). A user should not use a simple SMA to BNC cable to go directly between the PCB board and the oscilloscope, as the user will experience impedance mismatch which will degrade the waveforms. Users should obtain clean gate waveforms by using the SMA connectors with a compensated passive probe (with included SMA to BNC adapter) plugged into the oscilloscope in the high-impedance setting.

If taking measurements on the upper gate (J4), it will require an isolated probe or an oscilloscope with isolated channels or damage could occur to the board and/or oscilloscope!

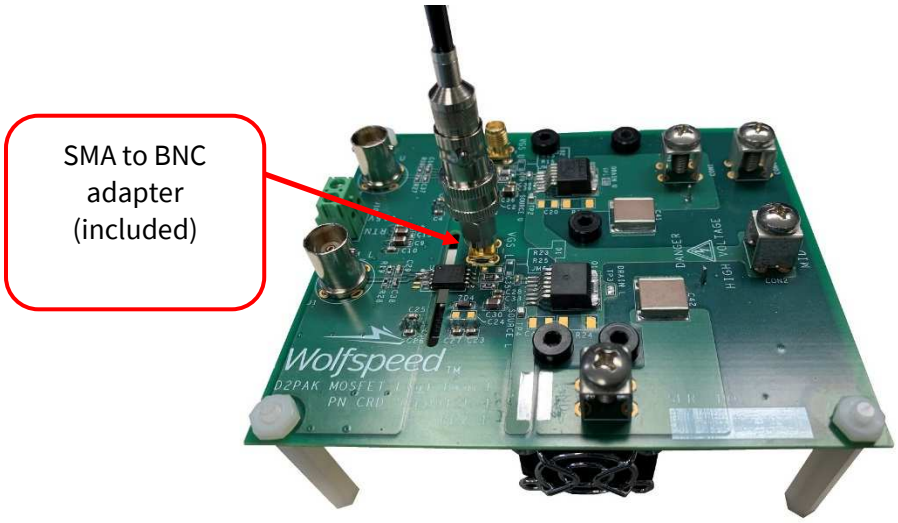


Figure 16: SMA to BNC adapter and X10 passive probe

9. Current Sensing

The evaluation kit comes with a placeholder (J9) (as shown in Figure 15(a)) for adding a current viewing device, such as the current viewing resistor from T&M Research (P/N: SDN-414-01) (as shown in Figure 15(b)). The current viewing resistor from T&M Research has a resistance of 10 mΩ; therefore, it should be compatible with most oscilloscopes that have a probe attenuation set to 100X (50 Ω input). If a different resistor is chosen, it should have a minimal insertion inductance.

Figure 15 (a)

Figure 15 (b)

Figure 17 (a): Placeholder for current sensor,
Figure 15 (b): Current viewing resistor installed

10. Cooling

This evaluation board contains multiple features to aid in heat dissipation. First, the top and bottom layers of the pc board are 2oz copper with large planes connected to the drain tab of each MOSFET which help dissipate heat. Second, there is an 11mm x 7mm aluminum nitride insert embedded in the pc board underneath the MOSFETs that transfers heat from the top side of the pc board to the bottom side. Not only is the aluminum nitride a thermal conductor, it is also an electrical insulator which is needed as the heatsink is common to both MOSFETs . The board is mechanically attached via 5 nonconductive screws to an extruded aluminum heatsink with an integrated 30 mm fan. A small thermal gap filler pad from The Berquist Company (P/N: QII-0.006-AC-1212) is used between the heatsink and the pc board to ensure good physical contact and hence good thermal conductivity. Figure 16 shows a cross sectional view of the thermal management stackup.

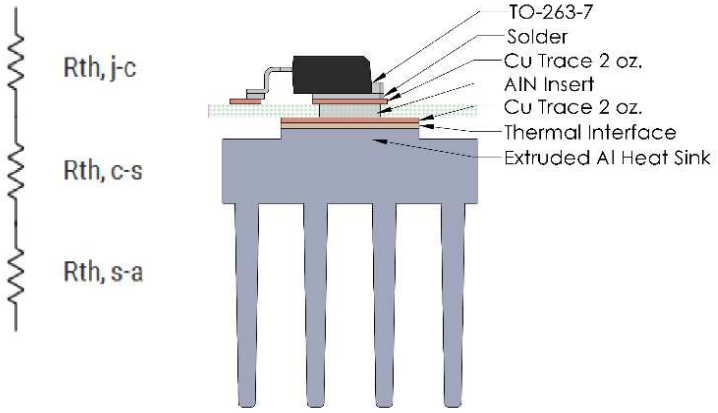


Figure 18: Thermal management stack up

Table 6: Measured Thermal Resistance Values

Parameter	Value	Note
R^{th}, j-c (˚C/W)	1.2 (650 V kit) 1.1 (900 V kit)	From datasheet
R^{th}, c-s (˚C/W)	1.28	Note (1)
R^{th}, s-a (˚C/W)	2.60	

Note (1) *The supplied thermal gap filler was included due to its solid performance and ease of use. There are other thermal gap fillers and even thermal pastes that can be substituted to reduce the case-to-sink impedance, provided they are applied properly. The included gap filler has an adhesive on one side to secure it to the raised embossments on the heatsink and keep it in place while assembling the pc board onto the heatsink.*

11. Example Application 1 (Synchronous Boost Converter)

This section shows how to run Wolfspeed's KIT-CRD-8FF65P/CRD-8FF90P evaluation kit in a Synchronous Boost Converter topology (Fig. 17). The electrical parameters for the test setup are shown in table 7.

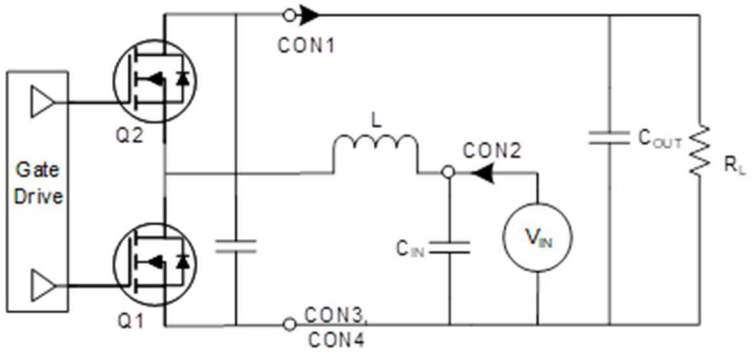


Figure 19: Synchronous boost converter schematic

Table 7: Synchronous Boost Electrical Parameters

Items	Parameters
Input Voltage	200 V
Output Voltage	≈385 V
Output Current	11 A
Output Power	4200 W
Switching Frequency	100 kHz
Duty Cycle	48.5%
Deadtime	200 ns
Inductor	400 uF
Output Capacitor	40 uF
Input Capacitor	40 uF

An SMA to BNC adapter should be connected to J3 (VGS lower MOSFET). A 10X compensated passive oscilloscope probe with a BNC connector is then attached with J3 to monitor the VGS on the lower MOSFET (Fig. 18). A 10 mΩ current viewing resistor from T&M Research (P/N: SDN-414-01) is populated at J9 to get current measurements through the lower MOSFET. Since the lower MOSFET is referenced to the -DC link along with the VGS probe, a 100X high-voltage passive probe is attached to the drain and power source of the lower MOSFET to capture VDS. The current shunt is installed backwards so that its common is connected to the same node as VDS and VGS (all three probes are referenced to the same point or the MOSFET source). The IDS signal is simply inverted by the scope. An inductor was added along with some film capacitors to the input and output (Fig. 19). The switching waveforms are shown in Figure 20.

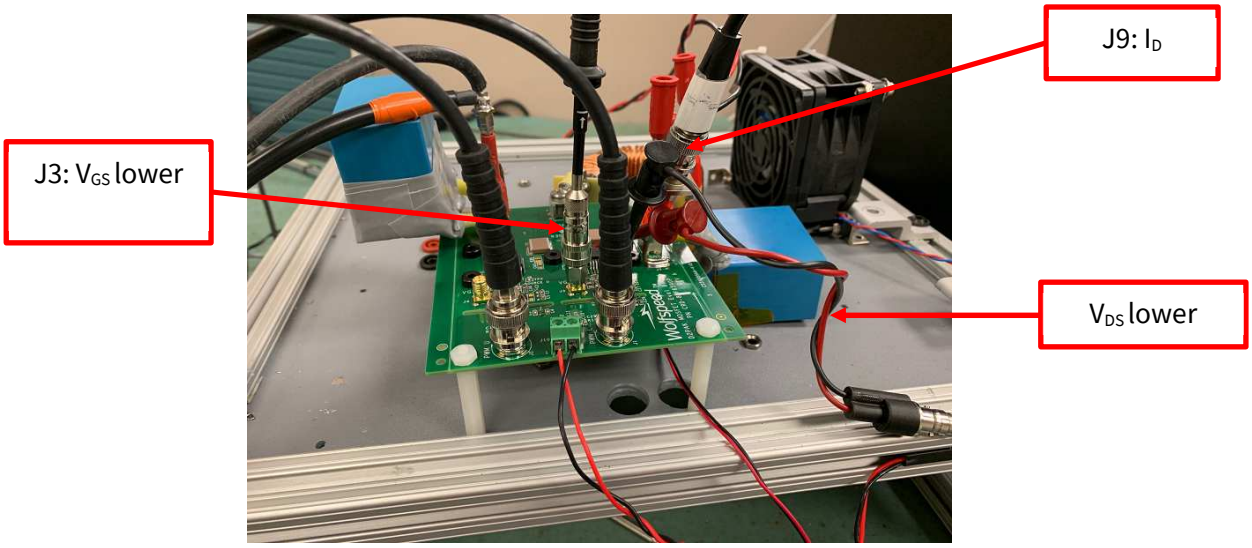


Figure 20: Probe locations

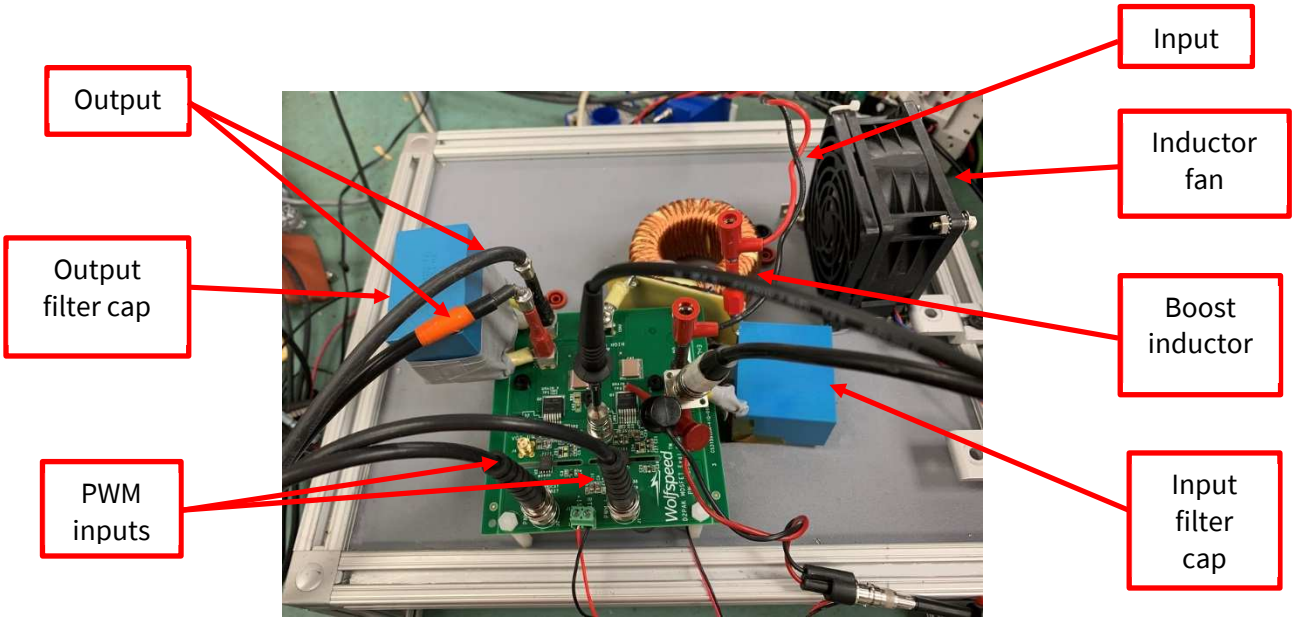


Figure 21: Synchronous boost converter setup

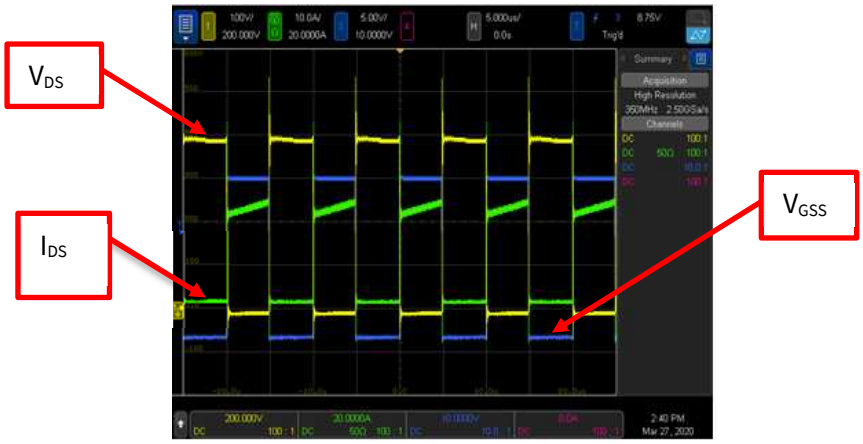


Figure 22: Switching waveforms of boost converter

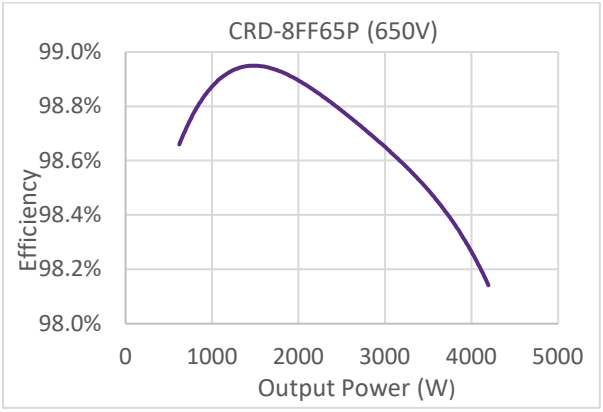


Figure 21 (a)

Figure 21 (b)

Figure 23 (a): Synchronous boost converter efficiency,
Figure 21 (b): Synchronous boost converter thermal scan at 4200 W

Specifications for the inductor (Fig. 22) used for the synchronous boost converter test can be seen in table 8.

Figure 24: Synchronous boost inductor

Table 8: Inductor Specifications

Nominal Inductance	≈ 400uH
Core	KAM290060A
Turns	44

12. Example Application 2 (Switching Energy Measurements)

This board is useful for making double-pulsed clamped inductive switching measurements. Figure 23 shows how the board should be connected to make the switching measurements.

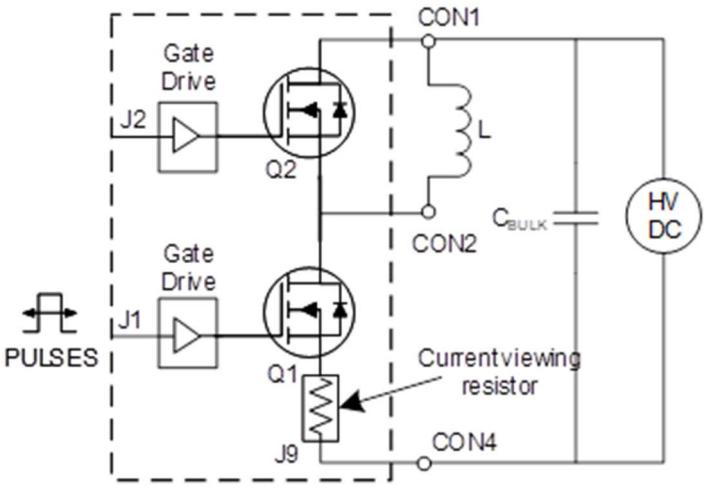


Figure 25: Clamped inductive switching measurement circuit

A precision current viewing resistor will be needed so that the current though Q1 can be measured. There are provisions (J9) on the board for installing a through-hole current viewing resistor. The board comes with a placeholder (jumper) in place. This jumper must be removed when adding a current viewing resistor. The T&M Research resistor (P/N: SDN-414-01) (Fig. 15b) may be used in this application. It has a resistance of 10 Ω; therefore, it should be compatible with any oscilloscopes that have a probe attenuation set to x100. If a different resistor is chosen, it should have a minimal insertion inductance. The IDS probe is installed backwards so that its common is tied to the MOSFET source along with the VDS and VGS probes. The IDS waveform is simply inverted on the scope.

Due to the fast switch speeds associated with Wolfspeed SiC MOSFETs, the following steps must be followed closely to yield accurate results:

- Scope probes measuring V_{DS} and V_{GS} must have minimal loop between signal and ground.
- The oscilloscope scope probes measuring V_{DS} and I_{DS} must be deskewed.
- Bulk capacitance may need to be added to the board to minimize DC link droop during two-pulse measurements. The amount will vary based on desired current level and pulse width.
- Figures 24a & 24b show a two-pulse setup.
- Figure 25 shows the measured switching waveforms.

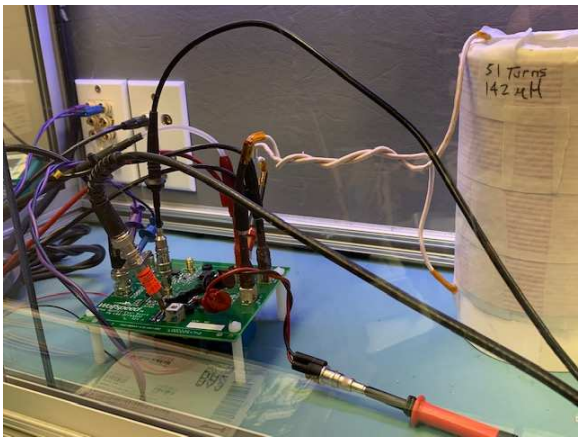


Figure 24 (a)

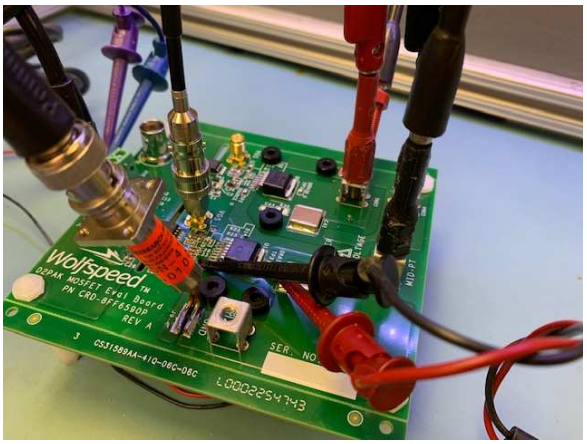


Figure 24 (b)

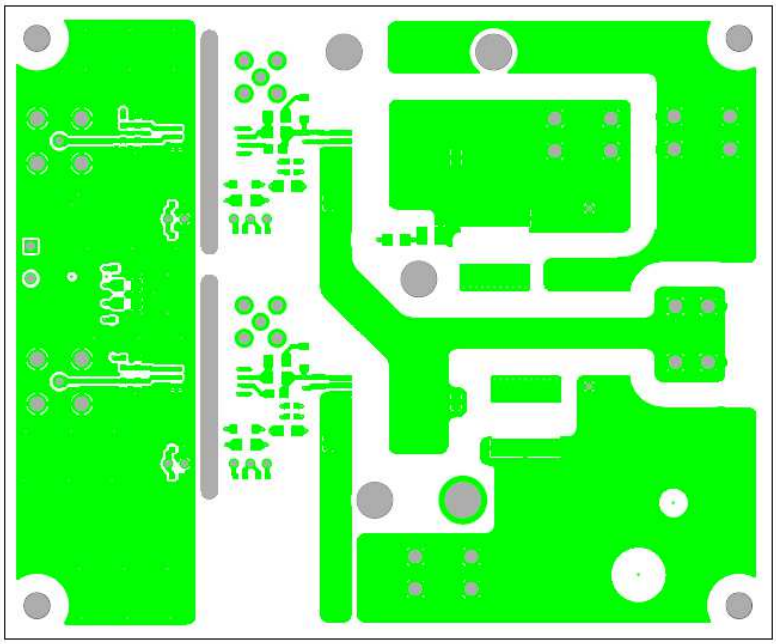
Figure 26a & 24b: KIT-CRD-8FF65P/CRD-8FF90P configured for double-pulse measurements

Figure 27: Double pulse waveform

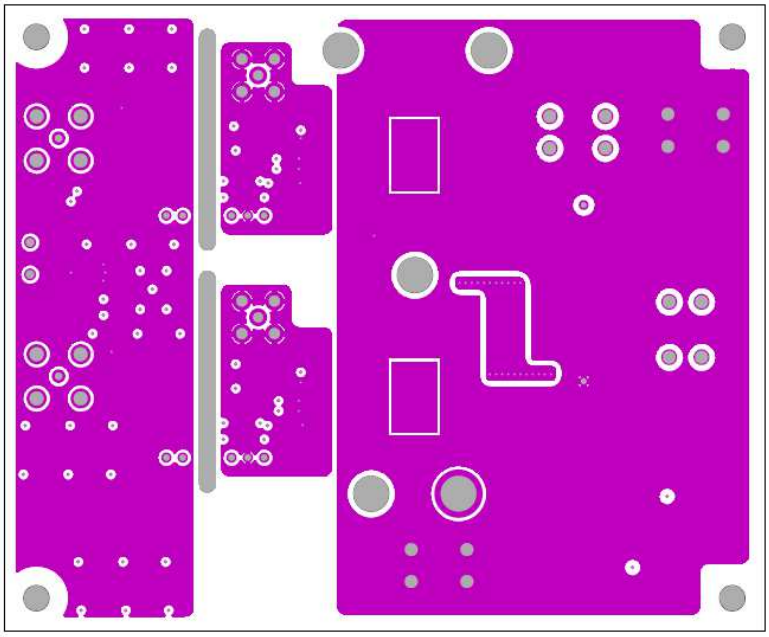
13. PCB Layout

Note: A larger copy of the PCB layout may be obtained at https://www.wolfspeed.com/products/power/evaluation-kits/, or upon request by contacting Wolfspeed at forum.wolfspeed.com/

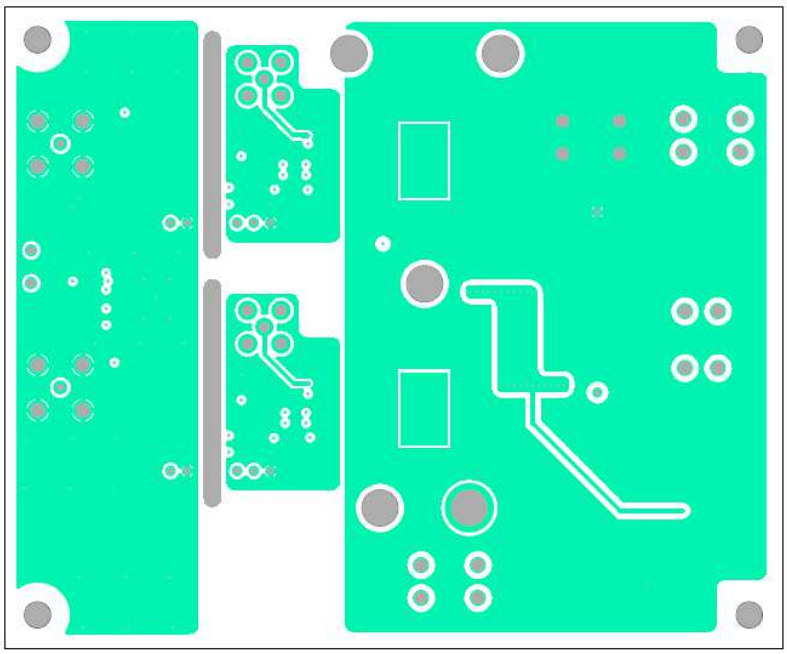
Power Board Top Copper Layer



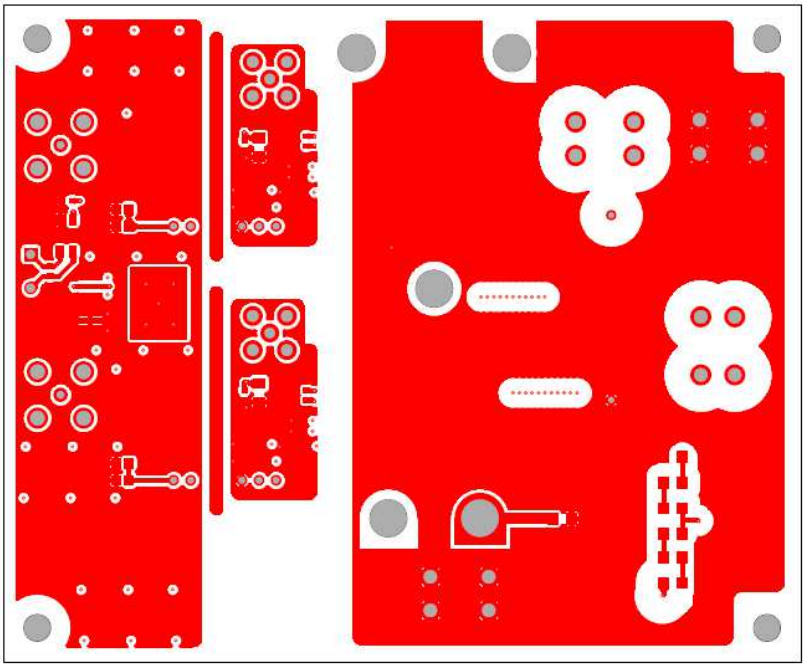
Power Board Inner Copper Layer 2



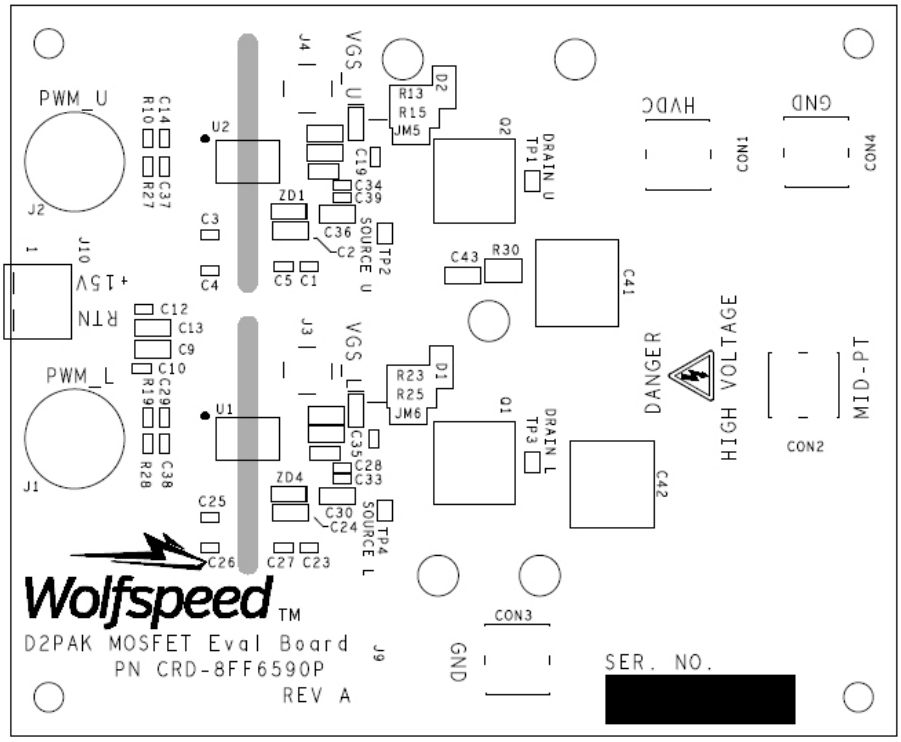
Power Board Inner Copper Layer 3



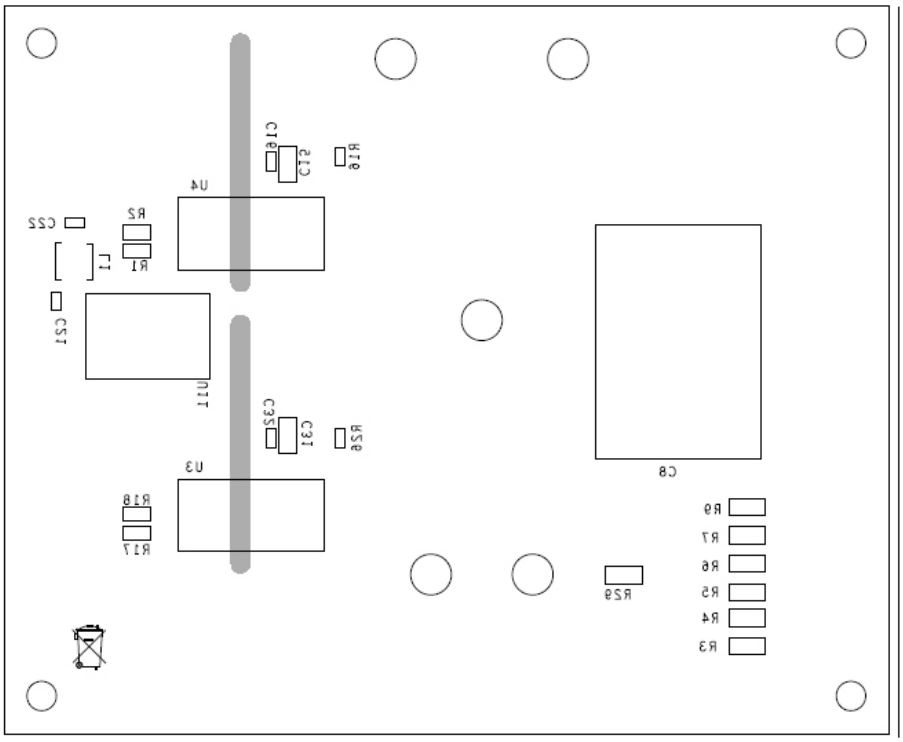
Power Board Bottom Copper Layer



Power Board Top Layer Silkscreen

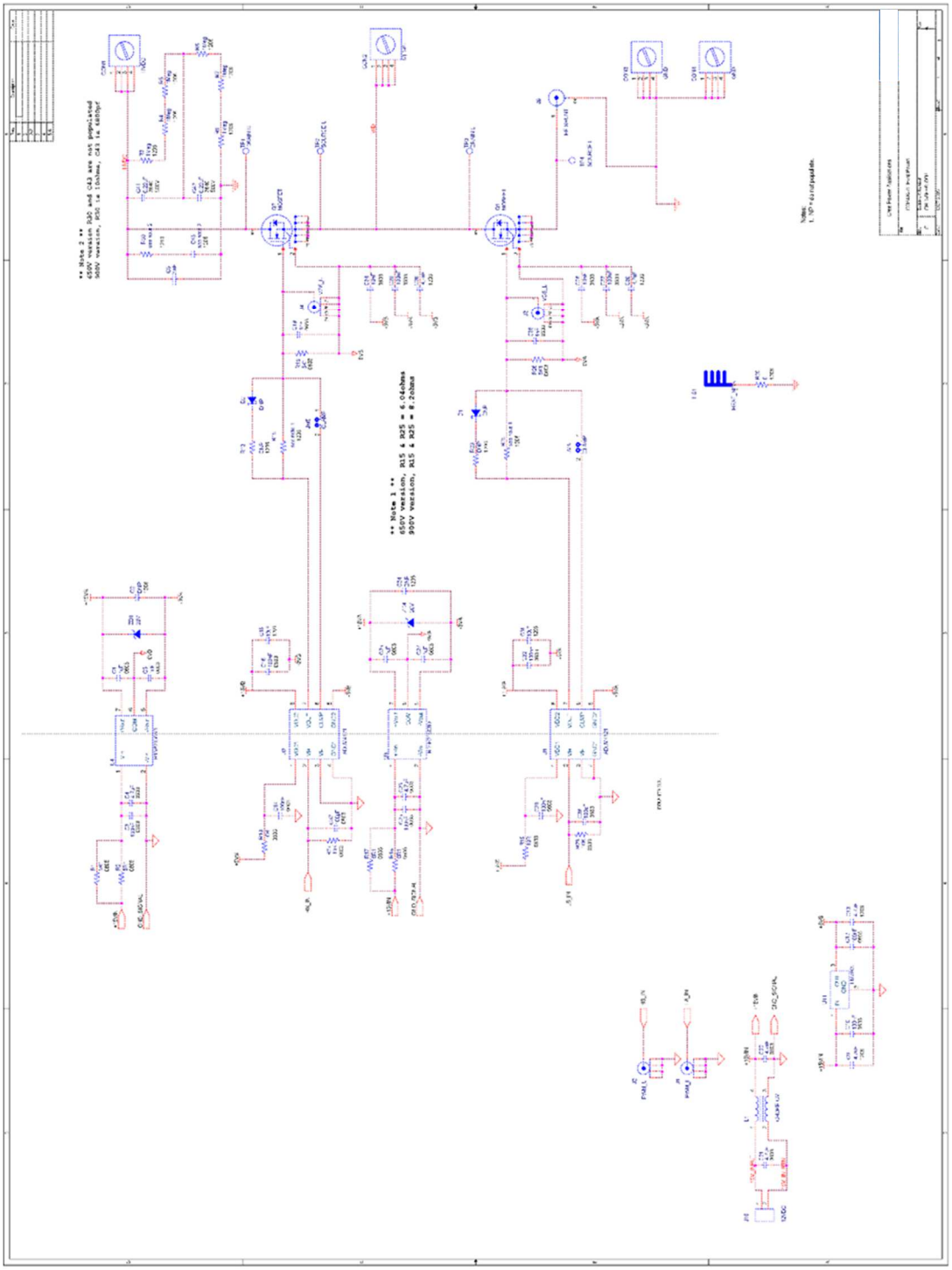


Power Board Bottom Layer Silkscreen



14. Schematic

Note: A larger copy of the schematic may be obtained at https://www.wolfspeed.com/products/power/evaluation-kits/, or upon request by contacting Wolfspeed at forum.wolfspeed.com/



15. Bill of Materials

Table 9: Bill of Materials (BOM) of Wolfspeed's KIT-CRD-8FF65P (650 V) and KIT-CRD-8FF65P (900 V)

Item	650 V	900 V	Locations (optional)	Value	Description (optional)	Manufacturer Name	Manuf P/N
1	4	4	CON1-4		TERM SCREW 10-32 4 PIN PCB	Keystone Electronics	8174
2	4	4	C1, C5, C23, C27	1uF	CAP CER 1UF 50V 10% X7R 0603	Taiyo Yuden	UMK107AB7105 KA-T
3	2	2	C2, C24	DNP	Capacitor,		
4	10	10	C3, C10, C12, C14, C16, C25, C29, C32, C33	100nF	CAP CER 0.1UF 50V X7R 0603	Samsung	CL10B104KB8S FNC
5	4	4	C4, C21, C22, C26	4.7uF	CAP CER 4.7UF 25 V X5R 0603	Samsung	CL10A475KA8N QNC
6	1	1	C8	5uF	CAP FILM 5UF 10% 1.3KVDC RADIAL	TDK	B32774D1505K
7	4	4	C9, C13, C30, C36	4.7uF	CAP CER 4.7UF 50 V 10% X7R 1206	Taiyo Yuden	UMK316AB7475 KL-T
8	2	2	C15, C31	10uF	CAP CER 10UF 35 V X7R 1206	Taiyo Yuden	GMK316AB7106 KL-TR
9	2	2	C19, C35	1nF	CAP CER 1nF 50 V X7R 0603	Samsung	CL10B102KC8N NNC
10	1	1	C43	DNP			
11	2	2	C28, C34	10nF	CAP CER 10000PF 100 V X7R 0603	Murata	GCM188R72A10 3KA37D
12	2	2	C37, C38	100pF	CAP CER 100pF 50 V 10% X7R 0603	Samsung	CL10B101KB8N NNC
13	2	2	C41, C42	0.22uF	CAP CER 0.22UF 500 V C0G/NP0 3640	KEMET	CKC33C224KC GACAUTO
14	2	2	D1, D2	DNP			
15	2	2	JM5, JM6	CLAMP	RES 0 OHM jumper 1/8W 1% 0805 SMD	Panasonic	ERJ-6GEY0R00V
16	2	2	J1, J2		CONN BNC JACK STR 50 OHM PCB	TE Connectivity	5-1634503-1
17	2	2	J3, J4		CONN SMA JACK STR 50 OHM PCB	TE Connectivity	5-1814832-1
18	1	1	J9	HF SHUNT	PC TEST POINT COMPACT SMT	Keystone	5016
19	1	1	J10	12	TERM BLK 2POS	Phoenix Contact	1935161

Item	650 V	900 V	Locations (optional)	Value	Description (optional)	Manufacturer Name	Manuf P/N
				VDC	SIDE ENTRY 5MM PCB		
20	1	1	L1	CHOKE CM	ACM4520-142-2P-T000	TDK	ACM4520-142-2P T000
21	2	2	Q1, Q2		650 V, 60 mohm MOSFET	Wolfspeed	C3M0060065J
22	4	4	R1, R2, R17, R18	5R1	RES SMD 5.1 OHM 5% 1/8W 0805	Yageo	RC0805JR-075R1L
23	6	6	R3, R4, R5, R6, R7, R9	1Meg	RES SMD 1M OHM 1% 1/4W 1206	Panasonic	ERJ-8ENF1004V
24	2	2	R10, R19	10R	RES 10 OHM 1/16W 1% 0603 SMD	Panasonic	ERJ-3EKF10R0V
25	2	-	R15, R25	6.04	RES SMD 6.04 OHM 5% 1/3W 1206	Vishay Dale	CRCW12066R04FKEA
	-	2		8.2	RES SMD 8.2 OHM 1% 1/4W 1206	Yageo	RC1206FR-078R2L
26	3	3	R13, R23, R30	DNP			
27	2	2	R16, R26	5K1	RES SMD 5.1K OHM 1% 1/10W 0603	Yageo	RC0603FR-075K1L
28	2	2	R27, R28	10K	RES 10K OHM 1/16W 1% 0603 SMD	Panasonic	ERJ-3EKF1002V
29	1	1	R29	0	RES SMD 0R OHM 1% 1/4W 1206	Yageo	RC1206JR-070RL
30	4	4	TP1-4	DRAIN U	PC TEST POINT NATURAL	Harwin	S2751-46R
31	2	2	U1, U2		DGTL ISO 5 KV 1CH GATE DRVR 8SOIC	Analog Devices	ADuM4121CRIZ
32	2	2	U3, U4		DC-DC CONVERTER 15 V - 3V	Recom	R15P21503D
33	1	1	U11	LM7805	5 V, 1 A regulator	On Semiconductor	MC7805CD2TR4G
34	2	2	ZD1, ZD4	20V	DIODE ZENER 20 V 500 MW SOD123	On Semiconductor	MMSZ20T1G
35	0	-	R30		DNP		
	-	1			RES SMD 10 OHM 1% 3/4W 1210	Yageo	CRCW121010R0FKEAHP

Item	650 V	900 V	Locations (optional)	Value	Description (optional)	Manufacturer Name	Manuf P/N
36	0	-	C43		DNP		
	-	1			CAP CER SMD 1210 6800PF 20% 2 kV	Kemet	C1210C682MGR AC7800
37	1	1			ESD BAG		
38	1	1			S/N Label		
39	1	1			PCB, CRD-8FF6590P_REVA		

16. Revision History

Date	Revision	Changes
June 2020	Rev. A	1st Issue
October 2020	Rev. A	Filled in missing 900 V version components in BOM
January 2024	2	Branding and formatting updates

17. Important Notes

Purposes and Use

Wolfspeed, Inc. (on behalf of itself and its affiliates, "Wolfspeed") 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 WOLFSPEED 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 WOLFSPEED (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 Wolfspeed'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 Wolfspeed at forum.wolfspeed.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 Wolfspeed at forum.wolfspeed.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 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 Wolfspeed at forum.wolfspeed.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 Wolfspeed at forum.wolfspeed.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 WOLFSPEED BE LIABLE FOR ANY DAMAGES OF ANY KIND ARISING FROM USE OF THE BOARD. WOLFSPEED'S AGGREGATE LIABILITY IN DAMAGES OR OTHERWISE SHALL IN NO EVENT EXCEED THE AMOUNT, IF ANY, RECEIVED BY WOLFSPEED IN EXCHANGE FOR THE BOARD. IN NO EVENT SHALL WOLFSPEED 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 WOLFSPEED MAY BE BROUGHT AGAINST WOLFSPEED 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 Wolfspeed by contract with respect to product safety, product liability, or intellectual property infringement do not apply to the board.