User Guide PRD-08388

KIT-CRD-3DD065P & KIT-CRD-3DD12P

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Evaluation Kit User Guide

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。

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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

1. Introduction

The purpose of Wolfspeed's KIT-CRD-3DD065P and KIT-CRD-3DD12P, Buck-Boost Evaluation Kit (as shown in Figure 1) is to demonstrate the high-speed switching performance of Wolfspeed's 3rd Generation (C3M™) Silicon Carbide (SiC) Metal Oxide Semiconductor Field-Effect Transistor (MOSFET). This evaluation kit supports the TO-247-4L package. The TO-247-4L package comes with an added Kelvin source pin that reduces the effects of L*di/dt in the gate circuit. The reduced L*di/dt in the gate circuit allows more voltage to be applied at the gate and source which results in faster dynamic switching.

Wolfspeed's KIT-CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation Kit also accepts the traditional TO-247-3L package without the need of any additional adapters. This provides the end user with the ability to test and compare the performance of Wolfspeed's 3rd Generation (C3M™) MOSFETs in various packages.

The evaluation kit comes in a half-bridge configuration with the provision of adding a MOSFET or diode in the upper and lower positions. This allows the evaluation board to be configured in common power conversion topologies such as synchronous buck or synchronous boost converter topologies. There is also a provision of adding diodes in either the top or the bottom positions. This provision allows users to run the evaluation kit in an asynchronous buck converter topology or in an asynchronous boost converter topology. To reduce power loss, Wolfspeed's KIT-CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation Kit comes with a low-loss inductor made up of "Sendust" material.

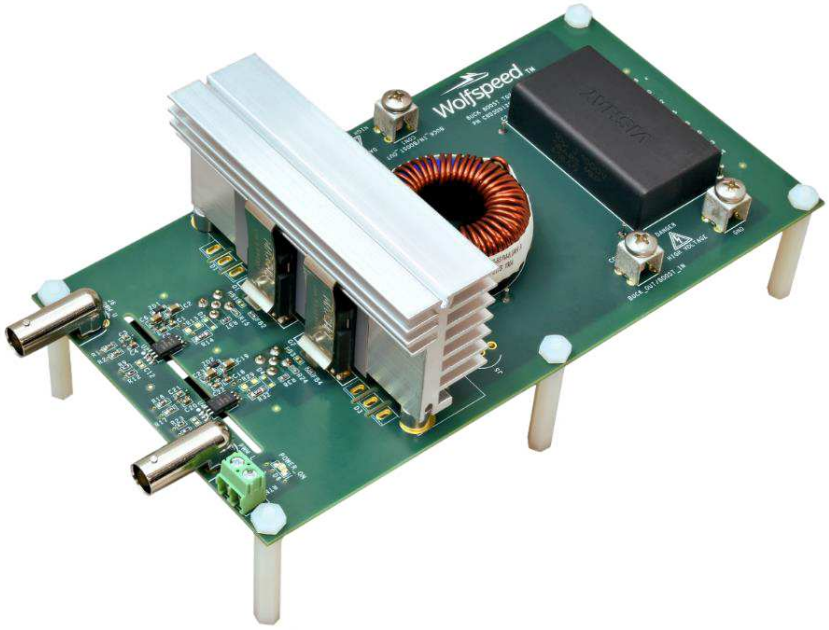


Figure 1: KIT-CRD-3DD065P/CRD-3DD12P, buck-boost evaluation kit

2. Package Contents

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

Table 1: Package Contents of Kit- CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation Kit

Item No.	QTY 1200V	QTY 650V	Description	Manufacturer	P/N
1	1	-	CRD-3DD12P Buck Boost Eval Board Assy.	Make	CRD-3DD12P-1
	-	1			CRD-3DD12P-2
2	4	4	High force clip	Aavid Thermalloy	MAX03-HNG
3	1	1	Heat sink extrusion, custom length 4 in.	Aavid Thermalloy	780603U04000G
4	2	-	MOSFET, 1200V, 75 mohm	Wolfspeed	C3M0075120K
	-	2	MOSFET, 650V, 60 mohm	Wolfspeed	C3M0060065K
5	4	4	Thermal Pad (Cut to 22mm x 29mm rectangle)	Bergquist	
6	1	1	Foam insert top	Make	See drawing
7	1	1	Conductive foam strip	Make	See drawing
8	1	1	S/N Label	Make	n/a
9	1	-	Cover graphic Label	Make	
	-	1		Make	
10	1	1	Foam insert	Make	See drawing
11	6	6	Male-Female Threaded Hex Standoff Nylon 6/6, 1/4" Hex Size, 1-1/2" Long, 6-32 to 6-32	McMaster-Carr	92745A348
12	2	2	Spacer, 1/4" OD, 5/32" Length, un-threaded Al, #6 screw	McMaster-Carr	92510A031
13	6	6	Nylon Hex Nut, 6-32 Thread Size	McMaster-Carr	94812A300
14	2	2	Phillips Round Head Screw, M3 x 0.5 mm Thread, 10 mm Long	McMaster-Carr	92005A120
15	2	2	Steel Split Lock Washer for M3 Screw Size, 3.4 mm ID, 6.2 mm, OD	McMaster-Carr	91202A222
16	1	1	Package Box	Uline	S-16677
17	3	3	2”x3” 4mil recloseable poly bag	Uline	S-12269
18	1	1	ESD Label on box	Uline	S-2246
19	2	2	CONN ADAPT SMA PLUG TO BNC JACK	Amphenol	242102

3. Board Overview

The physical dimensions of the Buck-Boost Evaluation Kit are 222 mm X 97 mm X 49 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: C3M0060065K) or Wolfspeed’s (C3M™) 1200V 75 mΩ MOSFETs (P/N: C3M0075120K), heatsink (including mounting clips), thermal pad and hardware accessories.

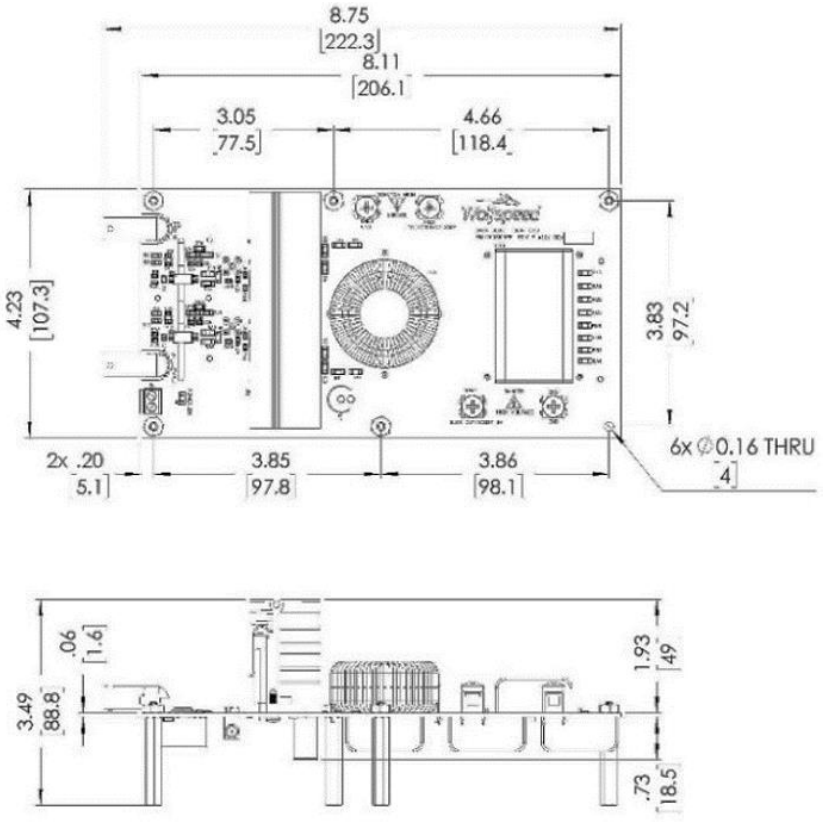


Figure 2: Physical dimensions of KIT-CRD-3DD065P/CRD-3DD12P

4. Electrical Performance

The electrical specifications of the evaluation kit are shown in Table 2. Please refer to the table for the maximum voltage. The maximum power capability of the evaluation kit is 2500 W. A single 15 VDC power source (VCC, Logic Power) is added to the evaluation kit to provide power to the logic circuit. The amount of current that the VCC source will require depends on the switching frequency and the type of devices that are populated on the PCB Board of the evaluation kit. The VCC Input Current is the standby current that the evaluation kit will draw when nothing is being switched.

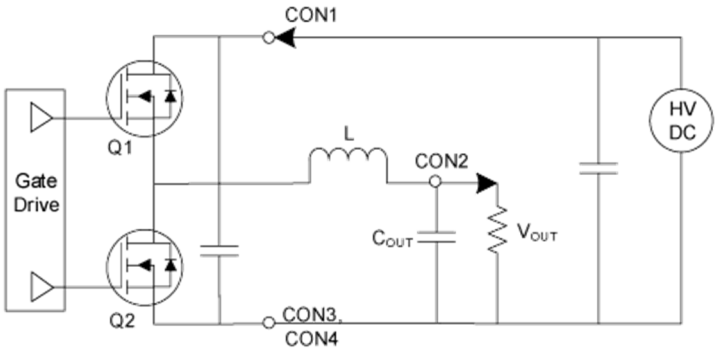
Table 2: Electrical Specifications

Items	Values	
Kit version	CRD-3DD065P (650V)	CRD-3DD12P (1200V)
Max input voltage	450	800V
Max output voltage	450	800V
Max output power	2500W*	
VCC (logic power)	15VDC	
VCC input current (standby)	40mA* (typical)	
Frequency	100khz*	

(*Power and frequency limits are based on the inductor. Different output power and switching frequency can be achieved with a different inductor.)

5. Example Topologies

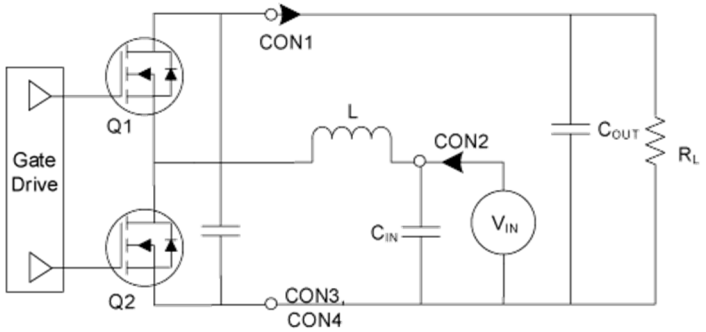
5.1 Synchronous Buck Converter



- Step down voltage
- MOSFET body diode is used instead of flyback diode
- CON1 is input
- CON2 is output
- CON3, CON4 is ground

Figure 3: Synchronous buck converter configuration

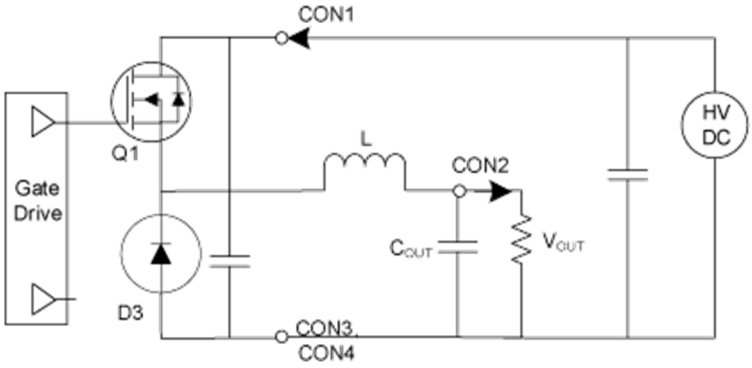
5.2 Synchronous Boost Converter



- Step up voltage
- MOSFET body diode is used instead of flyback diode
- CON1 is output
- CON2 is input
- CON3, CON4 is ground

Figure 4: Synchronous boost converter configuration

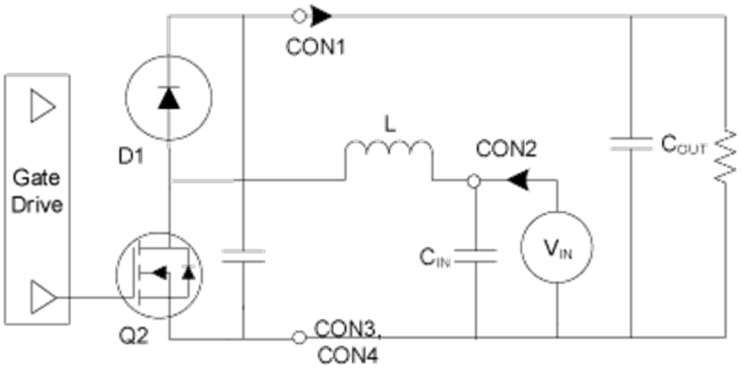
5.3 Asynchronous Buck Converter



- Step down voltage
- SiC diode is used in lower position in place of MOSFET
- CON1 is input
- CON2 is output
- CON3, CON4 is ground

Figure 5: Asynchronous buck converter configuration

5.4 Asynchronous Boost Converter



- Step down voltage
- SiC diode is used in lower position in place of MOSFET
- CON1 is input
- CON2 is output
- CON3, CON4 is ground

Figure 6: Asynchronous boost converter configuration

6. Mechanical Assembly

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 Buck-Boost Evaluation Kit must be assembled prior to testing. The heatsink, standoffs, thermal insulator, and semiconductor devices must be installed according to the arrangement mentioned in Figure 7. The two screws and washers must be installed from the bottom side of the PCB. Please note that the spacers should be placed between the heatsink and the PCB and the two heatsink mounting screws should not be overtightened.

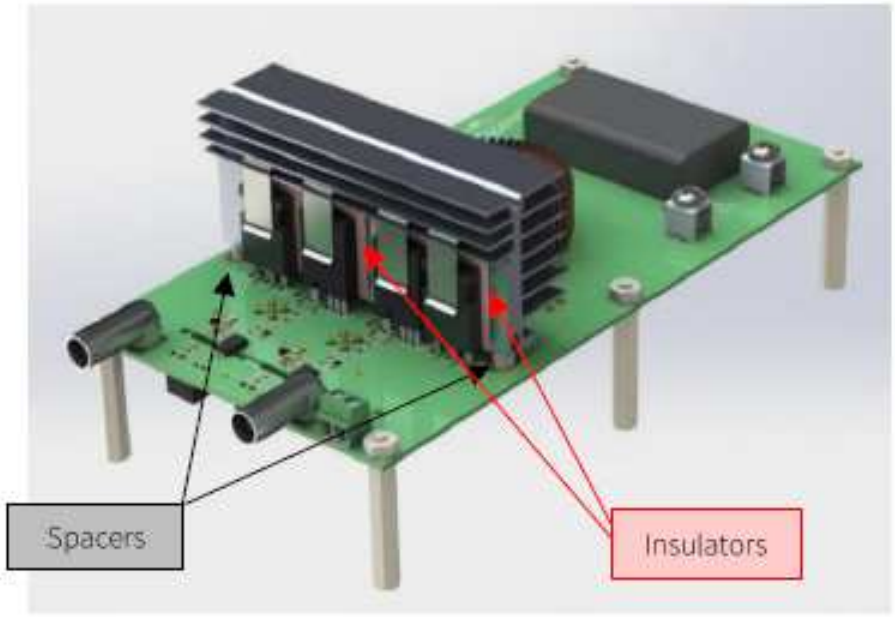


Figure 7: Mechanical assembly

Cooling:

The heatsink must have a cooling fan to dissipate the heat generated from the losses of MOSFETs or diodes. The amount of appropriate airflow is dependent on the losses, which can vary widely depending on voltage, current, frequency, and other factors. Wolfspeed suggests to use a 12 V, 80 mm fan rated for 133 CFM (@2.03 inches H20), such as P/N: PFB0812DHE from Delta Inc., which when functioning correctly should provide sufficient airflow to cool down the heatsink and the inductor at full load.

Inductor:

The inductor is a toroidal design, based on a high-temperature-rated powdered core (as shown in Figure 8). The maximum rated DC current of the inductor is 8A. The inductor is designed to support Pulse Width Modulation

(PWM) frequencies up to 100kHz (Test Conditions: P_{OUT}=2500 W, V_{IN} =400 V/ V_{OUT}=800V (OR) P_{OUT}=2500 W, V_{IN} =800 V/V_{OUT} =400 V). The inductor requires airflow to keep the temperatures within the 180 °C maximum. The evaluation kit can operate at higher frequencies (>100 kHz); however, the current may need to be reduced. The complete inductor specification can be found in the Appendix.

Figure 8: Inductor used for buck and boost converter

7. Terminals and Connections

An illustration of the terminals and the connections of KIT-CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation Kit has been provided in Figure 9.

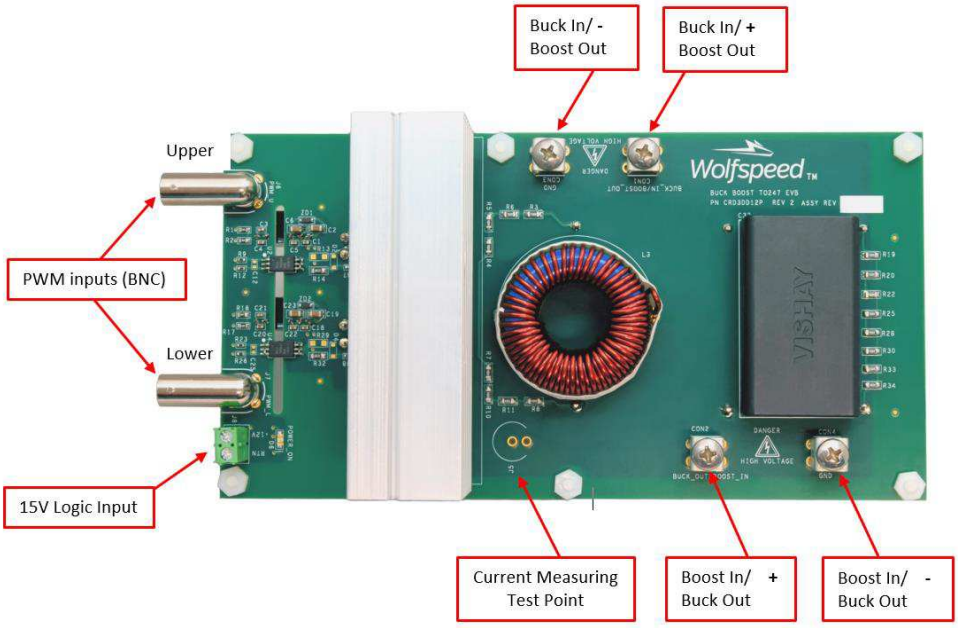


Figure 9: Top view of the buck-boost evaluation kit

Power Terminals:

Terminals CON1, CON2, CON3 and CON4 are the power terminals (as shown in Figure 10), and their definitions vary based on the topology.

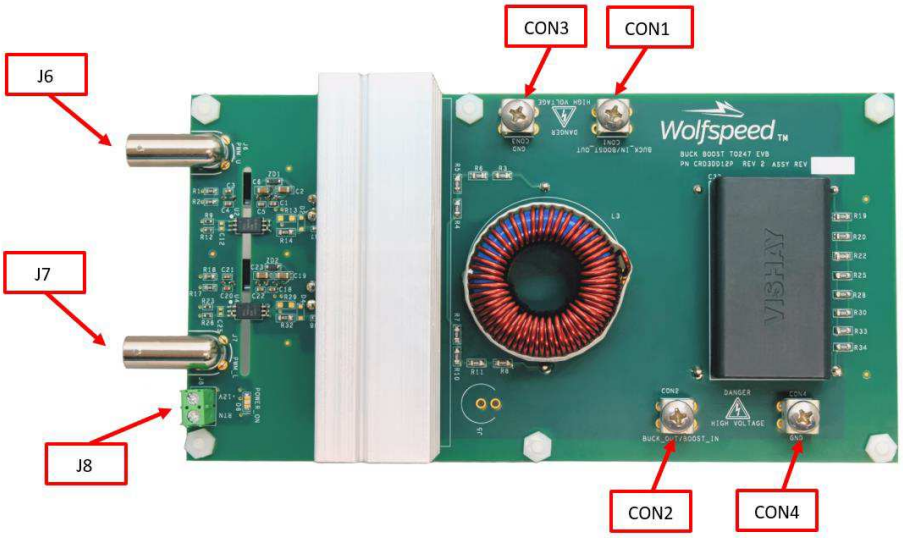


Figure 10: Terminals and connections

Logic Power And PWM Input Signals:

The 15 VDC logic power supply is connected to J8 (as shown in Figure 10). The pin definition of J8 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 gate drivers designed for the lower and the upper PWM Input channels (J7 & J6) (as shown in Figure 10). The pin 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 J6 and J7

Terminal	Signal	Reference
J6	PWM Input Upper Channel	PWM_U
J7	PWM Input Lower Channel	PWM_L

8. Test Point Locations

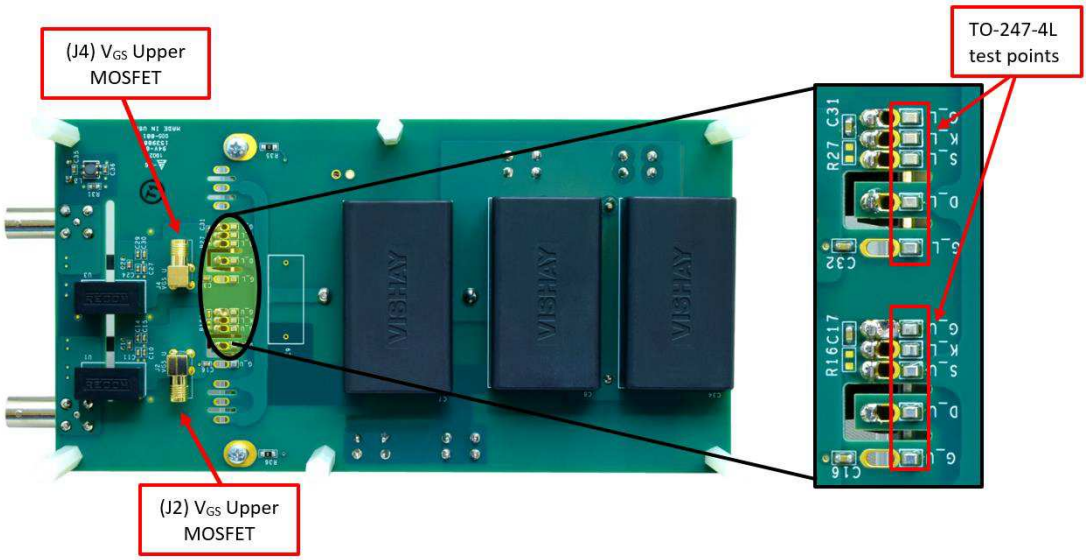


Figure 11 (a) *Figure 11 (b)*

Figure 11. a: Bottom view of the evaluation kit
Figure 11. b: TO-247-4L test loops

The Buck-Boost Evaluation Kit comes with many test points (as shown in Figure 11 (a) and Figure 11(b)) to make it convenient for users to capture critical waveforms such as drain to source voltage (VDS), gate to source voltage (VGS), and drain current (ID). It is critical to take these measurements as close as possible to the device pins. On the bottom side of the evaluation kit's PCB board, there is a test loop placed right next to the device pins for both TO-247-3 or TO-247-4 footprints (as shown in Figure 12). The test loop makes it convenient for the users to attach the clip-on probes to the PCB board.

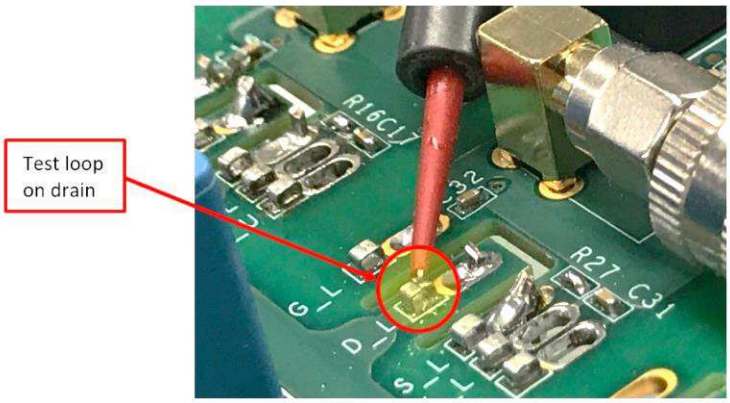


Figure 11: Test point on the drain (TO-247-4 footprint)

There is also a Sub Miniature A (SMA) connector located on the bottom 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 (as shown in Figure 13 (a)). A standard 10X passive (compensated) probe can be connected to the BNC adapter (as shown in Figure 13 (b)), but first it must be fitted with a BNC male adapter. Wolfspeed recommends using a compensated probe with an SMA connector while taking gate signal measurements. By

using a simple 50 Ω SMA to BNC cable between the PCB board and the oscilloscope, users can experience impedance mismatch. Users can also obtain gate waveforms by using the SMA connectors with a compensated passive probe plugged into the oscilloscope in the high-impedance setting.

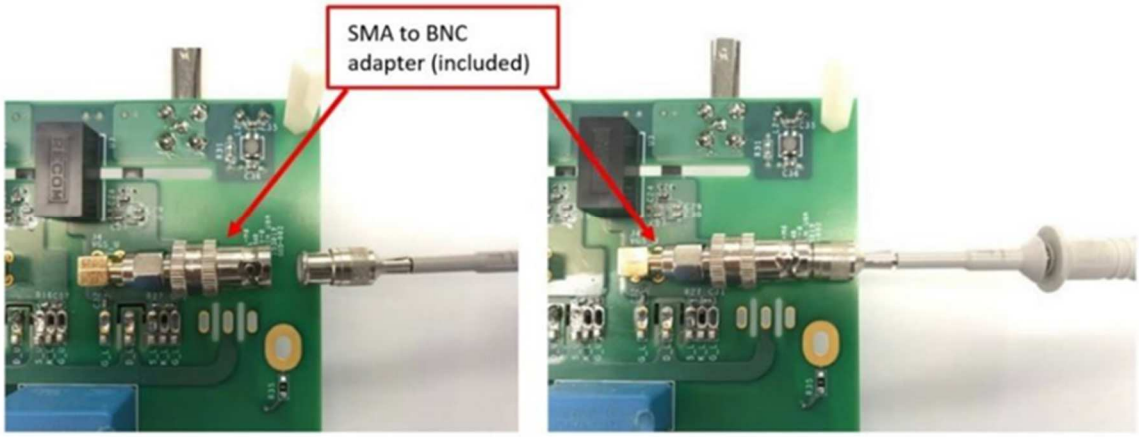


Figure 13 (a) *Figure 13 (b)*

Figure 13. a: Lower MOSFET (J4) SMA connector shown with BNC adapter (included),
Figure 13. b: 10X passive probe fitted with BNC adapter

9. Configuring the Evaluation Kit for TO-247-3L Devices

While a standard KIT-CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation kit is configured to evaluate C3M™ MOSFETs in a TO-247-4L package, the evaluation kit also supports C3M™ MOSFETs in a traditional TO-247-3L package. To convert either the upper or the lower MOSFET (Table 6) position into a TO-247-3L configuration, a 0Ω 0603 type resistor must be populated in each position (R16, R27) on the bottom side of the PCB (as shown in Figure 14). The main purpose of 0Ω resistor is to tie the Kelvin source and the power source together, which makes it convenient for a user to accommodate the TO-247-3L package on the PCB. Also, if converting the lower MOSFET from 4L to 3L, the 0Ω jumper at FB4 (top side of board) must be desoldered and resoldered at FB3 (Figure 15). If converting the upper MOSFET from 4L to 3L, the 0Ω jumper at FB2 (top side of board) must be desoldered and resoldered at FB1 (Figure 15).

If a user converts the board to evaluate a TO-247-3L device and thereafter wants to test a TO-247-4L device, then the 0Ω resistor must be removed from each position before testing.

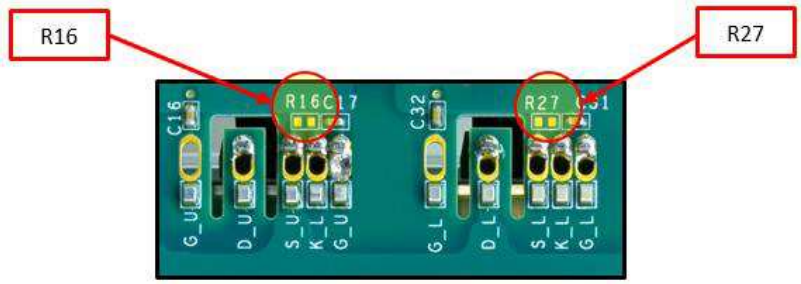


Figure 12: Location of resistors on the bottom side of PCB

Table 6: Definition of Resistors

Device	Resistor
Upper MOSFET (Q1)	R16
Lower MOSFET (Q2)	R27

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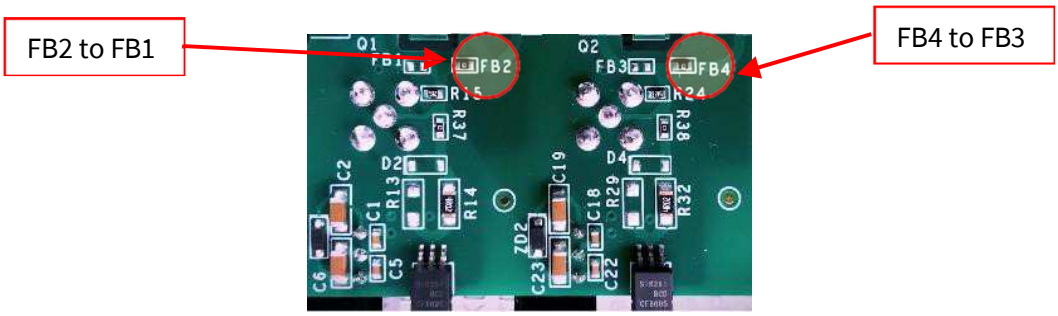


Figure 13: Location of resistors on the top side of PCB

10. Current Sensing

Please note that Wolfspeed's KIT-CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation Kit will not work without a current sensing device or without populating a jumper at J5.

The evaluation kit comes with a placeholder (J5) (as shown in Figure 10) 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 16), among many others. The current viewing resistor from T & M Research has a resistance of 10mΩ; therefore, it is compatible with most oscilloscopes that have a probe attenuation set to 100X (50Ω input). If a different resistor is chosen, it should have as low inductance as possible.

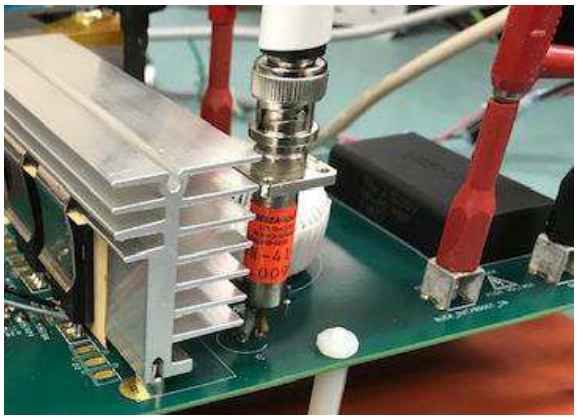
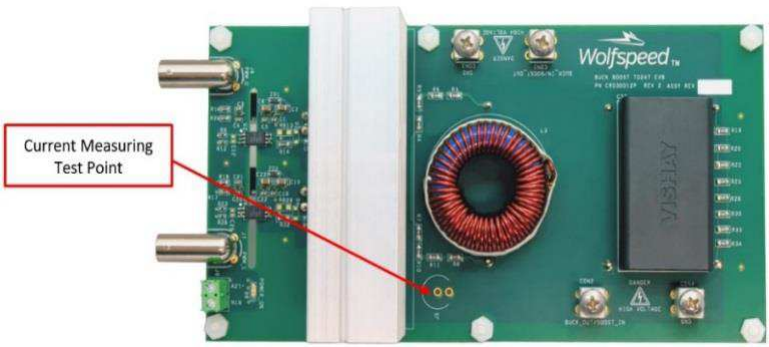


Figure 14: Evaluation kit with current viewing resistor installed

If the user does not use a current viewing resistor to sense current, then a short jumper must be populated at J5. This jumper should be soldered into J5 with a minimal length, to minimize the insertion inductance.



Wolfspeed's KIT-CRD-3DD065P, Buck-Boost evaluation kit will not work without a current sensing resistor device or without populating a jumper at J5

Figure 15: Current measuring test point

11. Example Application 1 (Boost Converter)

To run KIT-CRD-3DD065P/CRD-3DD12P in an Asynchronous Boost Converter topology (as shown in Figure 18 (a)), the SMA to BNC adapter should be connected to J4 (VGS lower MOSFET) which is located at the bottom of the PCB Board. A 10X passive oscilloscope probe with a BNC connector is then attached with J4 to monitor the VGS on the lower MOSFET (as shown in Figure 18 (b). A 10mΩ current viewing resistor from T&M Research (P/N: SDN-414-01) is populated at J5 (as shown in Figure 18 (b)) to get current measurements through the lower MOSFET. To get VDS voltage waveform, a 50X high voltage differential probe is attached to the drain and power source of the lower MOSFET. The switching waveforms are shown in Figure 19.

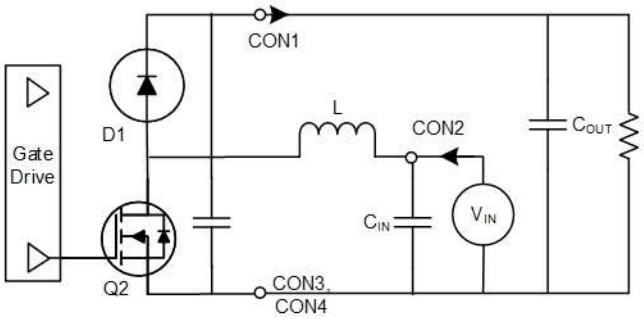


Figure 18 (a)

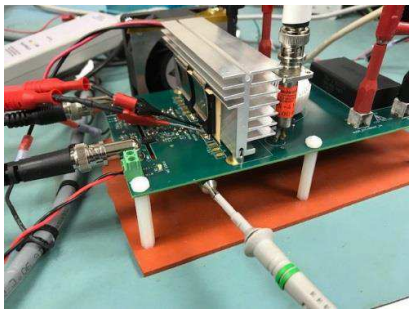


Figure 18 (b)

Figure 18. a: Asynchronous boost converter topology
Figure 18. b: Asynchronous boost converter hardware setup

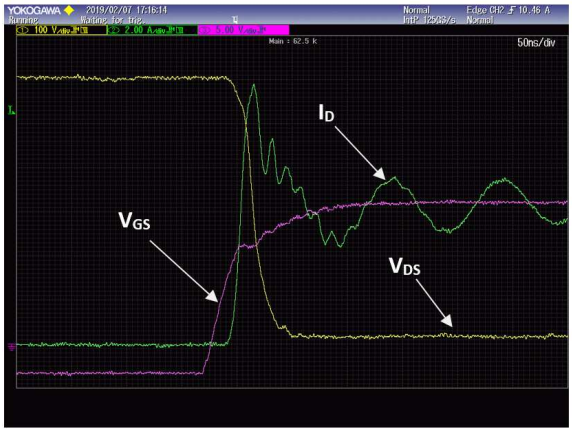


Figure 16: Switching waveforms of boost converter

12. Example Application 2 (Buck Converter)

The evaluation kit can be arranged in the form of a buck converter in both the synchronous mode (turning on lower MOSFET channel for current freewheel) (as shown in Figure 20 (a) and in the asynchronous mode (current freewheels through lower MOSFET's body diode only with the lower MOSFET channel turned off) (as shown in Figure 20 (b).

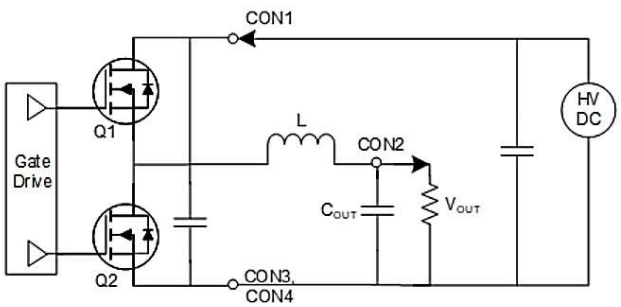


Figure 20 (a)

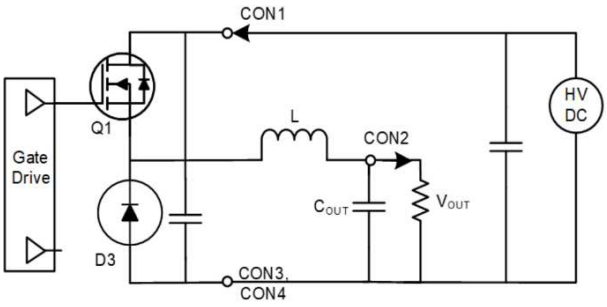


Figure 20 (b)

Figure 20. a: Synchronous buck converter topology
Figure 20. b: Asynchronous buck converter topology

In the synchronous mode, the current will freewheel through the lower MOSFET's body diode during the deadtime (≈200ns) between switch transitions. The efficiency curves of synchronous and asynchronous topologies implemented on KIT-CRD-3DD12P are shown in Figure 21.

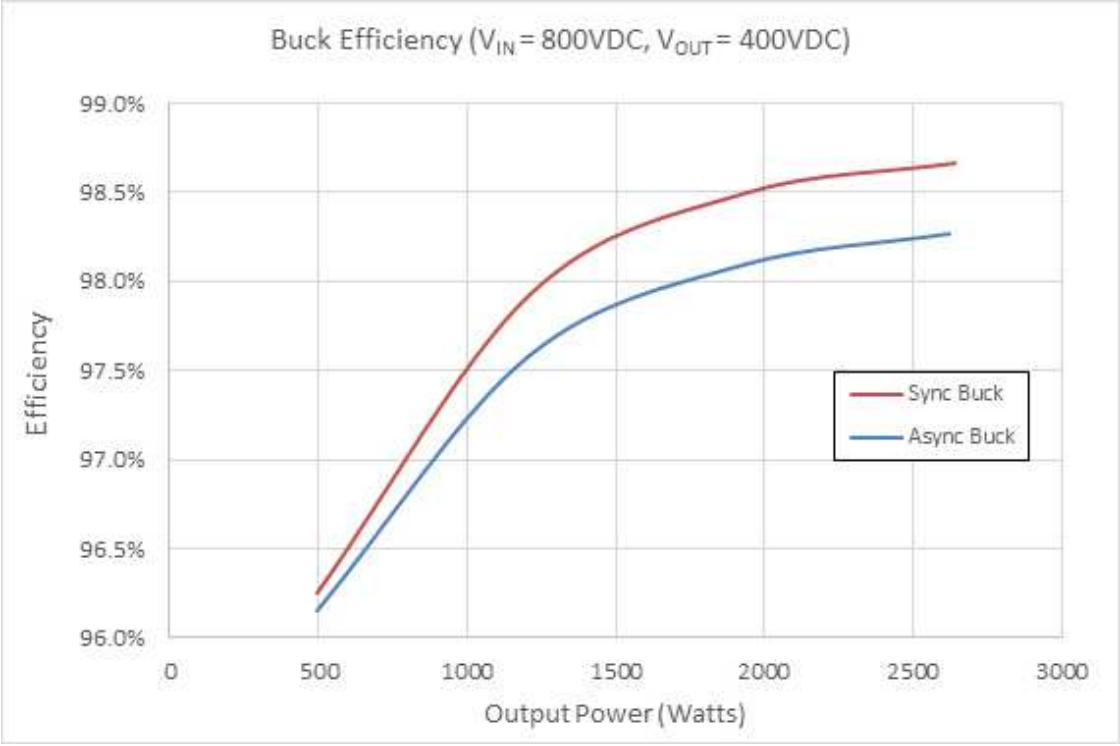


Figure 17: Efficiency curves of synchronous and asynchronous buck converter topologies (KIT-CRD-3DD12P)

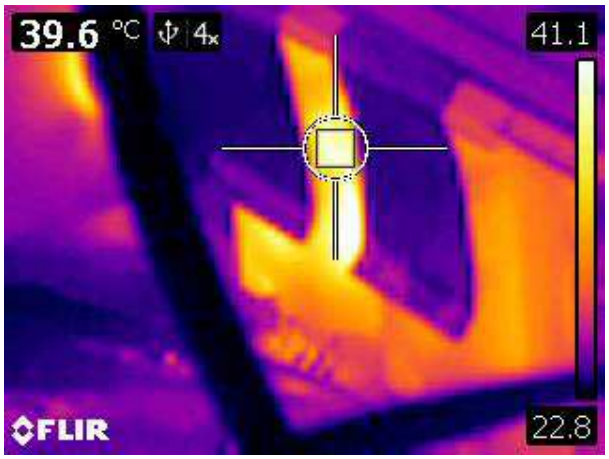


Figure 18: Thermal scan of MOSFET (1200V)

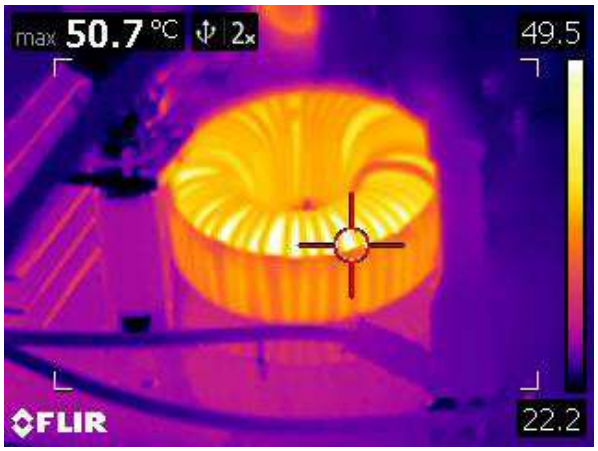


Figure 19: Thermal scan of Inductor (1200V)

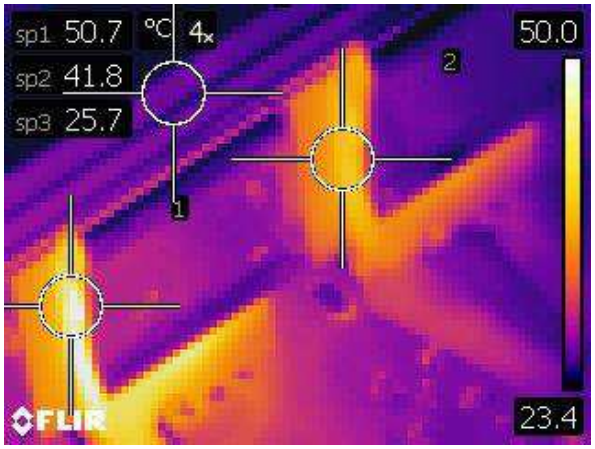


Figure 20: Thermal scan of MOSFET (650V)

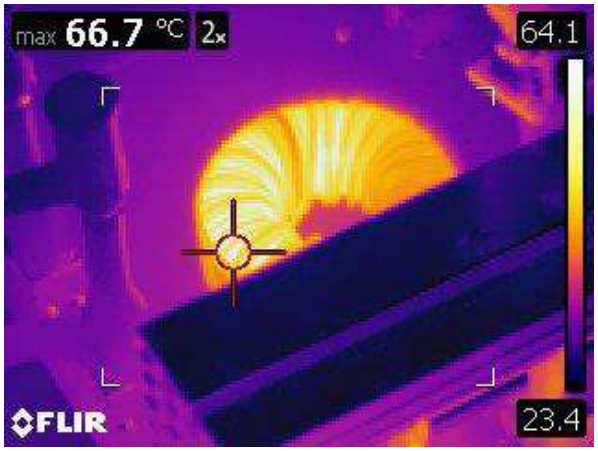


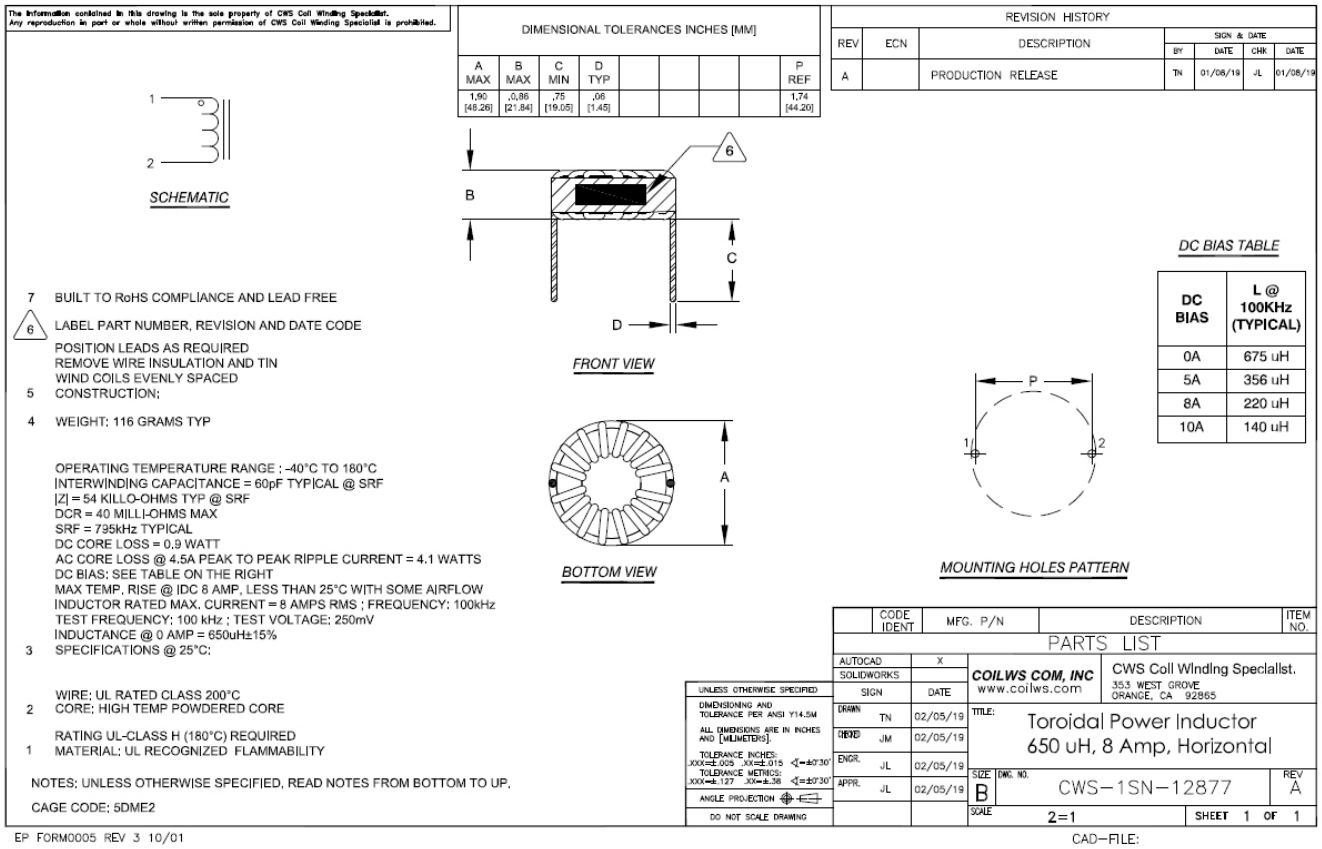
Figure 21: Thermal scan of Inductor (650V)

Figures 22-25 show the thermal scans of a MOSFET and the inductor while running at full load condition (2.5kW). These thermal scans illustrate that higher power levels can be achieved with Wolfspeed's KIT-CRD-3DD065P/CRD-3DD12P, Buck-Boost Evaluation Kit. However, an inductor capable of more DC current would be needed to achieve these higher power levels, as the inductor included in the standard evaluation kit would saturate if the user exceeded the specified maximum power (2.5 kW).

13. Appendix

13.1 Inductor Specification

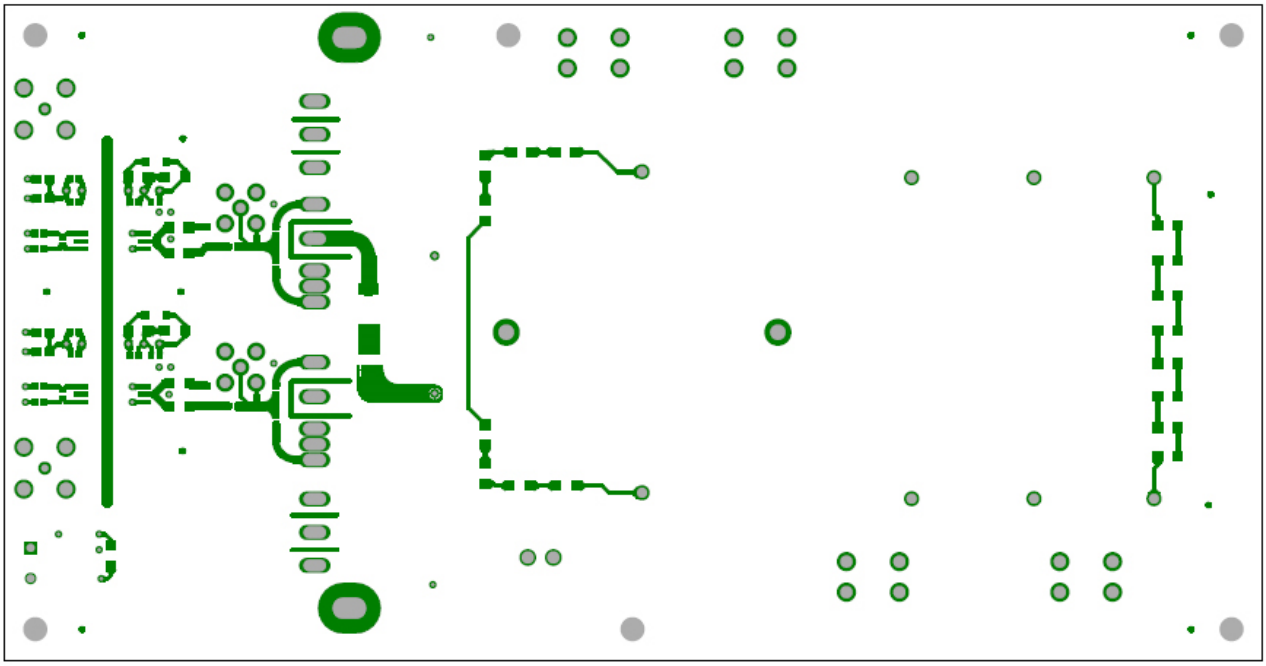
Note: a larger copy of the inductor specification may be obtained upon request by contacting Wolfspeed at forum.wolfspeed.com



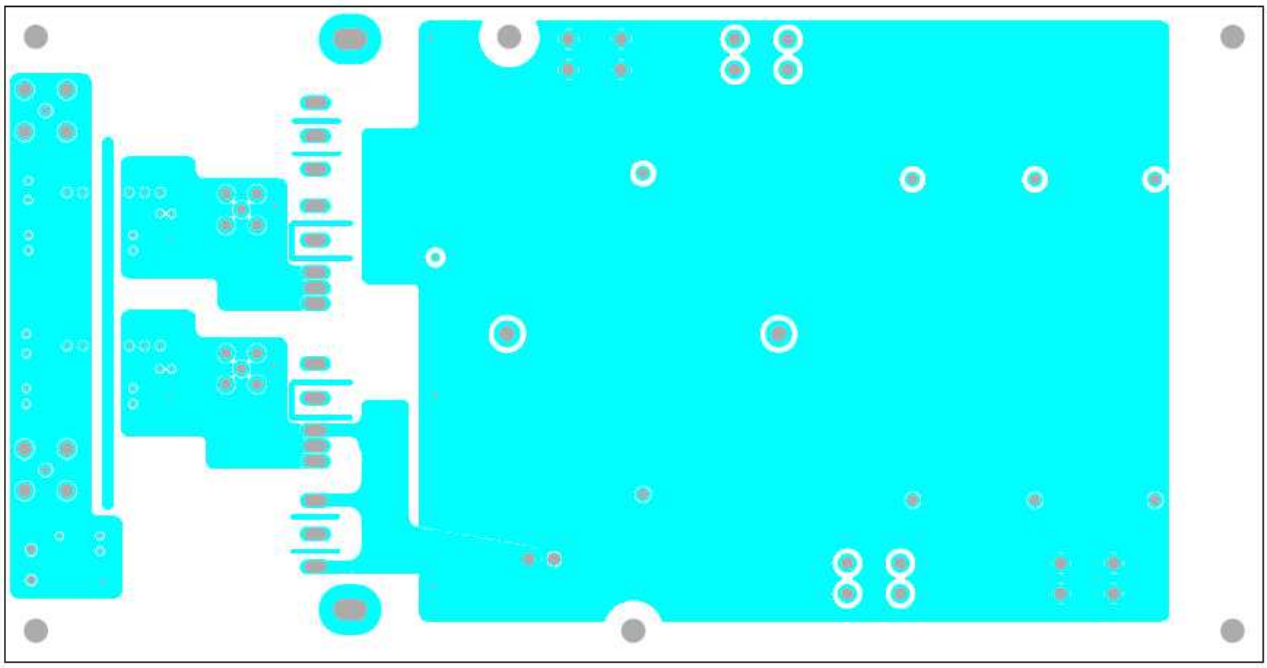
13.2 PBC Layout

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

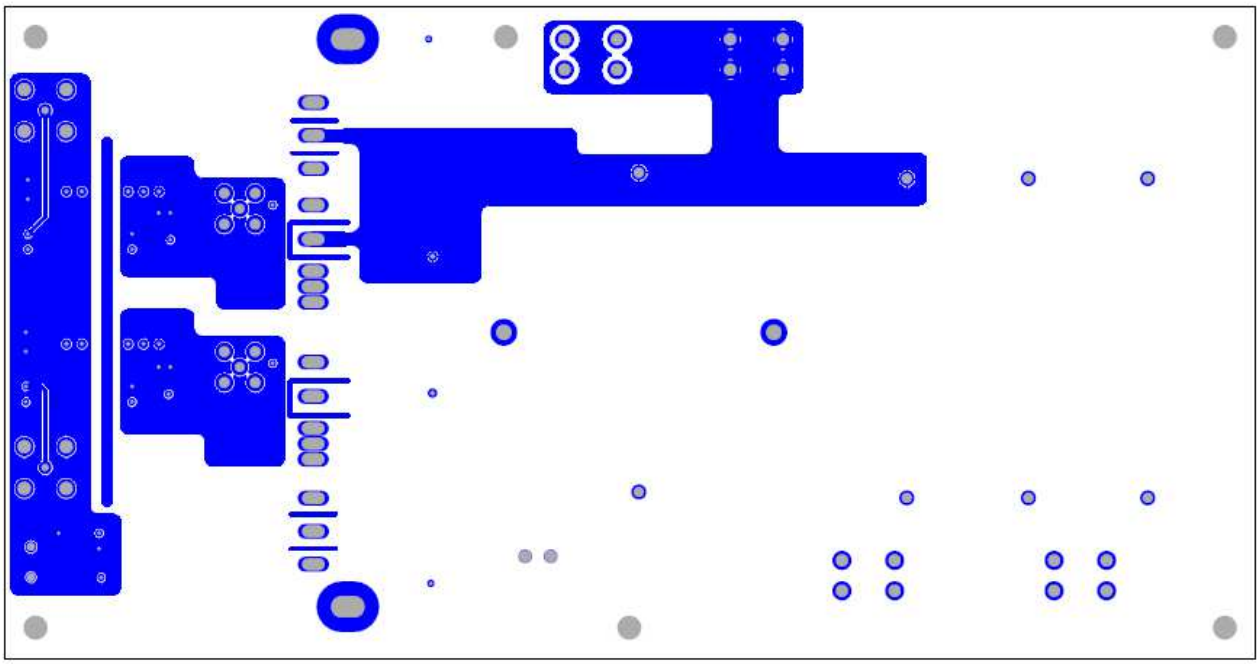
Power Board Top Copper Layer



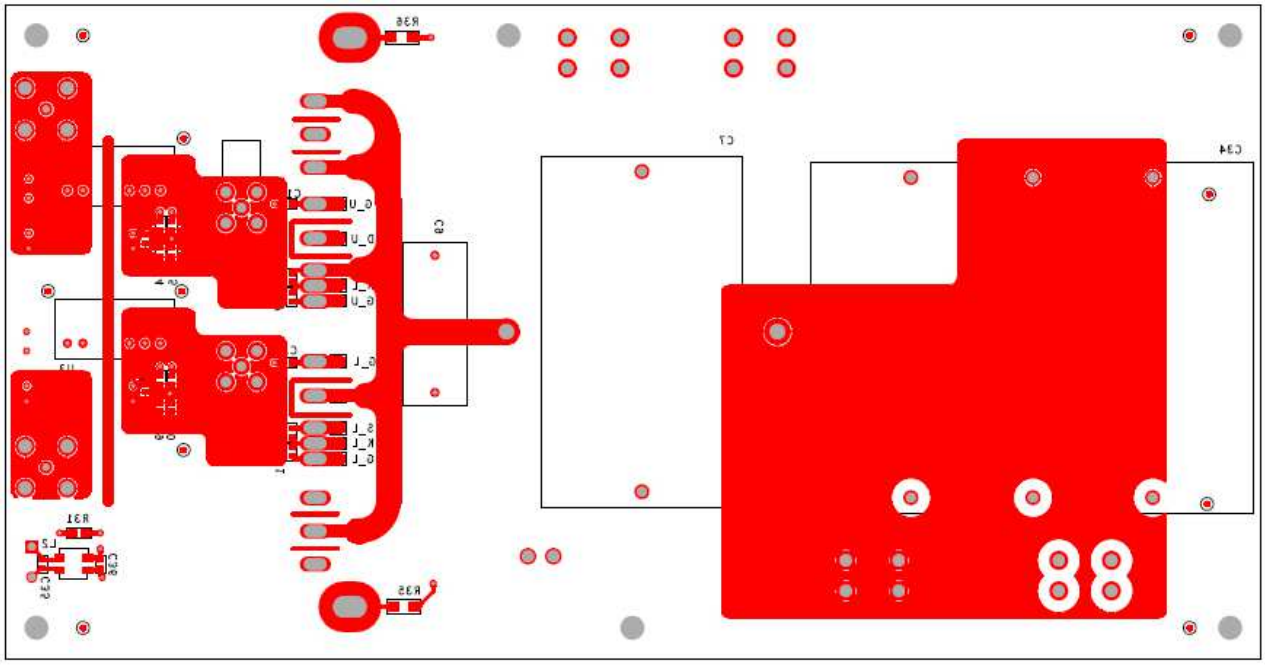
Power Board Inner Copper Layer 2



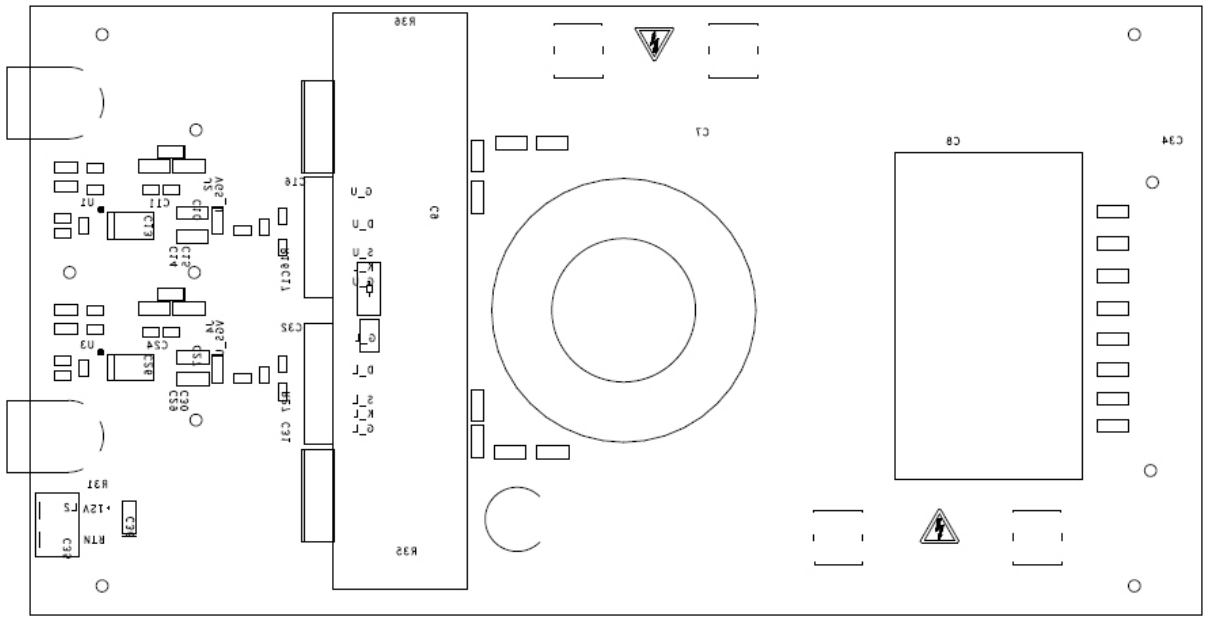
Power Board Inner Copper Layer 3



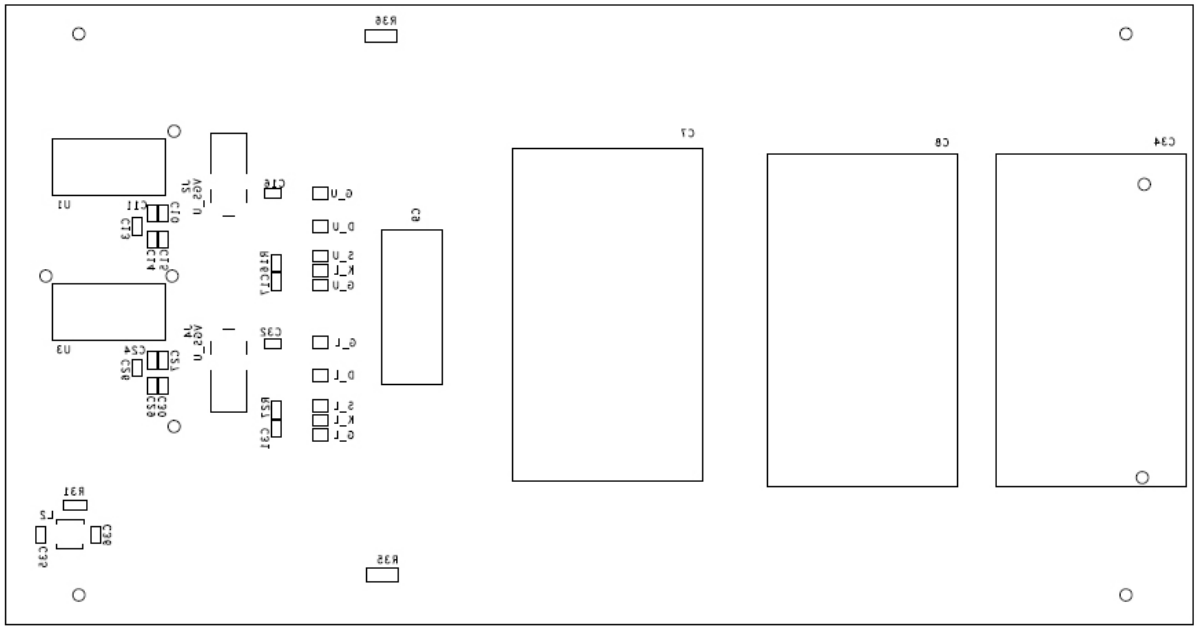
Power Board Bottom Copper Layer



Power Board Top Layer Silkscreen

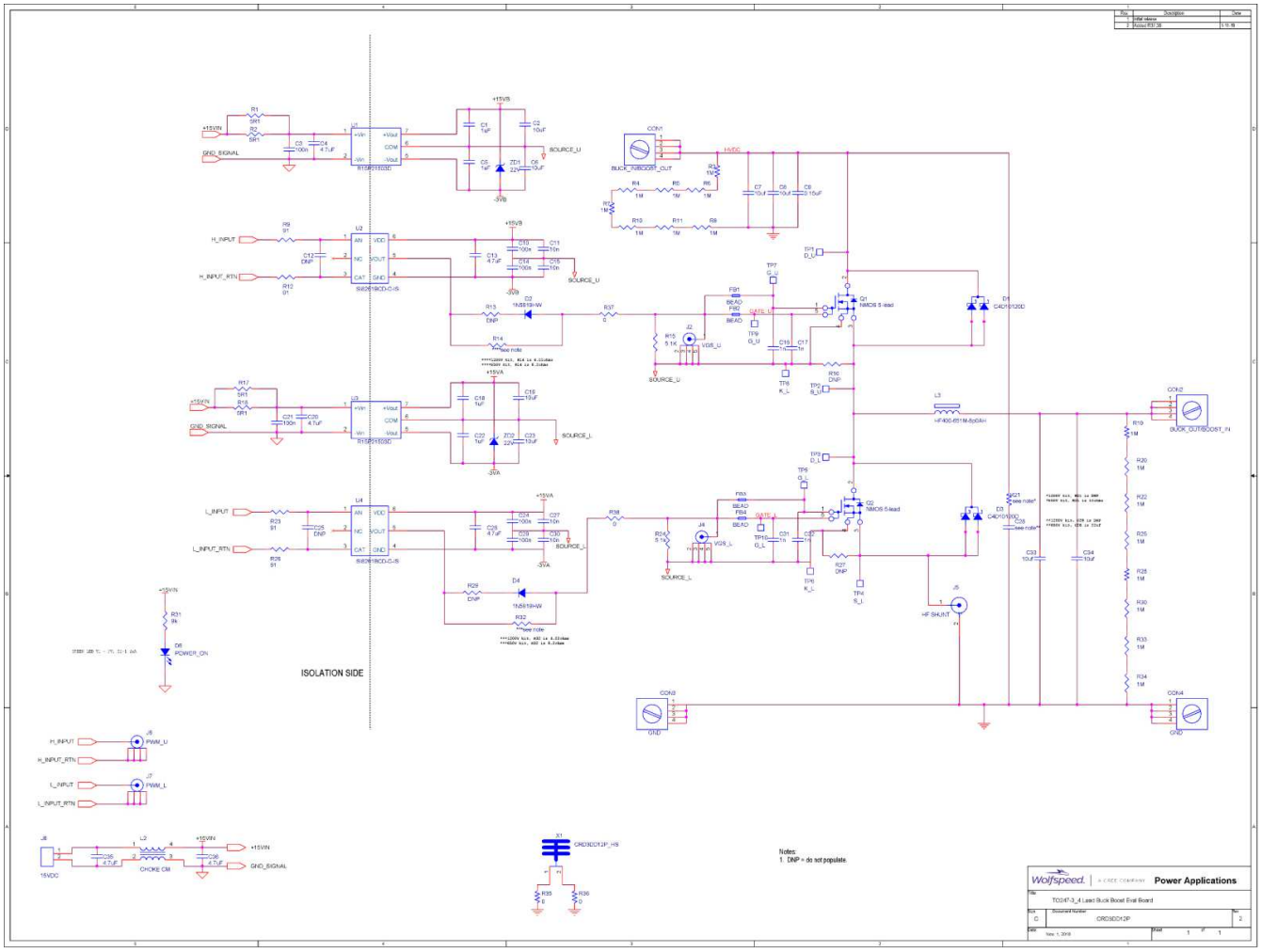


Power Board Bottom Layer Silkscreen



13.3 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



13.4 Bill of Materials

Item	1200V	650V	Reference Designator	Description	Manufacturer	Manufacturer P/N
1	4	4	CON1, CON2, CON3, CON4		KEYSTONE	8174
2	4	4	C1, C5, C18, C22	CAP CER 1UF 50V 10% X7R 0603	Taiyo Yuden	UMK107AB7105KA-T
3	4	4	C2, C6, C19, C23	CAP CER 10UF 35V X7R 1206	TDK or Taiyo Yuden	CGA5L1X7R1V106K160AE GMK316AB7106KL-TR
4	4	4	C7, C8, C33, C34	Film Capacitors 10uF 1000volt 5% 2pin 52.5mm LS	VISHAY	MKP1848S61010JY2B
5	6	6	C3, C10, C14, C21, C24, C29	CAP CER 0.1UF 50V 10% X7R 0603	AVX or Samsung	MM035C104KCZ2A or CL10B104KB8SFNC
6	6	6	C4, C13, C20, C26, C35, C36	CAP CER 4.7UF 35V 10% X5R 0603	MURATA or TDK	ZRB18AR6YA475KE05L or C1608X5R1V475M080AC
7	1	1	C9	CAP FILM 0.15UF 20% 1.5KVDC RAD	EPCOS	B32023A3154M
8	4	4	C11, C15, C27, C30	CAP 10000pF ±10% 50V Ceramic X7R 0603	KEMET	C0603C103K5RACTU
9	0	0	C12, R13, R16, C25, R27, R29			DNP
10	4	4	C16, C17, C31, C32	CAP CER 1000PF 50V 10% X7R 0603	KEMET	C0603C102K5RECTU
11	0	-	C28	CAP CER 0.022uf 1kV X7R 1210		DNP
	-	1			KEMET	C1210C223KDRAC7800
12	0	0	D1, D3			DNP
13	0	0	D2, D4			DNP
14	1	1	D6	LED GREEN CLEAR CHIP SMD	LITE-ON INC	LTST-C150KGKT

Item	1200V	650V	Reference Designator	Description	Manufacturer	Manufacturer P/N
15	4	4	R37, R38, FB4, FB2	RES SMD 0 OHM 1% JUMPER 1/10W 0603	YAGE0	RC0603JR-070RL
16	2	2	J2, J4	CONN SMA JACK R/A 50 OHM PCB	TE Connectivity	5-1814400-1
17	0	0	J5			DNP
18	2	2	J6, J7	BNC CONN JACK, FEMALE SOCKET 50OHM THROUGH HOLE, RIGHT ANGLE SOLDER	TE Connectivity	5-1634513-1
19	1	1	J8	TERM BLK 2POS SIDE ENTRY 5MM PCB	Phoenix Contact	1935161
20	1	1	L2	Common Mode Chokes / Filters 50V 1.2A 0.06ohms	TDK	ACM4520V-901-2P-T00
21	1	1	L3	Toroidal Power Inductor 650uH, 8 Amp	CWS	CWS-1SN-12877
22	0	0	FB1, FB3			DNP
23	4	4	R1, R2, R17, R18	RES SMD 5.1 OHM 5% 1/8W 0805	YAGE0	RC0805JR-075R1L
24	16	16	R3, R4, R5, R6, R7, R8, R10, R11, R19, R20, R22, R25, R28, R30, R33, R34	RES SMD 1M OHM 1% 1/4W 1206	YAGE0	ERJ-8ENF1004V
25	4	4	R9, R12, R23, R26	RES SMD 91 OHM 1% 1/10W 0603	YAGE0	RC0603FR-0791RL
26	0	0	R13, R29			DNP
27	2	-	R14, R32	RES SMD 4.02 OHM 1% 1206	RMCF1206FT4R02	STACKPOLE ELECTRONICS

Item	1200V	650V	Reference Designator	Description	Manufacturer	Manufacturer P/N
	-	2		RES SMD 8.2 OHM 1% 1/4W 1206	YAGE0	RC1206FR-078R2L
28	2	2	R15, R24	RES SMD 5.1K OHM 5% 1/10W 0603	YAGE0	RC0603JR-075K1L
29	0	-	R21	RES 10 OHM 1% 2W 2512		DNP
	-	1			Stackpole	RHC2512FT10R0
30	1	1	R31	RES SMD 9.1K OHM 1% 1/8W 0805	YAGE0	RC0805FR-079K1L
31	2	2	R35, R36	RES SMD 0R OHM 1% 1/4W 1206	YAGE0	RC1206JR-070RL
32	10	10	TP1-TP10	PC TEST POINT TIN SMD	Harwin	S2751-46R
33	2	2	U1, U3	Isolated DC/DC Converter 2W 15Vin 15/-3Vout	RECOM	R15P21503D
34	2	2	U2, U4	DGTL ISO 5KV GATE DRIVER 6SDIP	Silicon Labs	SI8261BCD-C-IS
35	2	2	ZD1, ZD2	Zener Diode 22V 500mW ±5% Surface Mount SOD-123	Diodes Incorporated	MMSZ5251B-7-F

14. Revision History

Date	Revision	Changes
April 2019	Rev. A	1st Issue
March 2020	Rev. B	Added newly launched 650V kit info
June 2020	Rev. C	Update schematic
January 2024	4	Branding and formatting updates

15. 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.