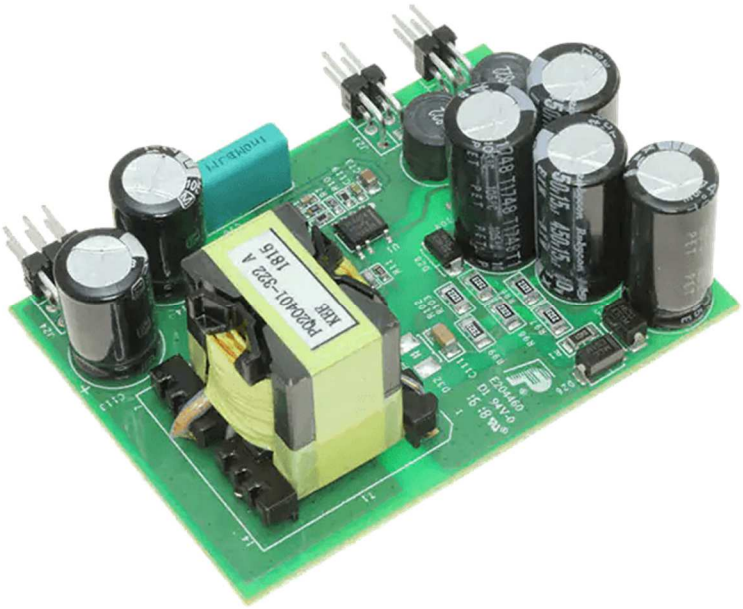
User Guide PRD-06980

CRD-15DD17P

15 W Flyback Auxiliary Power Supply User Guide



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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.

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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

For high-power and high-voltage applications including solar inverters, energy storage systems, traction/locomotive industry and lighting applications, the DC input can be as high as 1200 VDC and AC input can be in between the range of 480 VAC to 530 VAC. To support low-power subsystems (i.e. cooling fans, displays, controller biasing etc..) of these high-power and high-voltage systems, a low-power auxiliary (AUX) power supply that can take high voltage input (AC or DC) and can generate low DC voltage at the output is required.

For such low-power applications, the topology that is most commonly used in the industry is the flyback topology. In the present market, silicon-based MOSFETs are widely used power switching devices for flyback converters. However, silicon MOSFETs do have some limitations, including 1500V blocking voltage with low design margin of voltage stress which has a significant impact on the reliability of the power supply. In addition to that, most of the 1500V silicon MOSFETs have very large (R_{dson}) on-state resistance, which will lead to higher power loss, lower efficiency and high thermal stress.

In this application note, Wolfspeed, Inc. has introduced a wide input range (300V-1200V), 15 W flyback auxiliary power supply board (P/N: CRD15DD17P) based on Wolfspeed's C2M1000170J, 1700V, 1000 mΩ, (TO-263-7) SiC MOSFET. The designed flyback converter can accept 480VAC - 530VAC or 300 VDC - 1200 VDC input to provide 12 VDC at the output. The designers have designed the flyback converter board in a simplified way by keeping in mind the cost and size parameters.

Figure 1: Wolfspeed's CRD15DD17P, 15 W flyback auxiliary power supply board

2. Design Specifications

The design specifications of Wolfspeed's CRD15DD17P, 15 W flyback auxiliary power supply board are listed in Table. 1

Table 1: Design Specifications

Parameters	Values
Input voltage range, 50-60Hz	480 VAC – 530VAC or 300 VDC - 1200 VDC
Output voltage	12 VDC
Output current	1.3 A
Output power	15 W
Switching frequency	100 kHz (max)
Efficiency	85%
Max ambient operating temperature	50 ^{0}C
Topology	Single-end flyback
Power devices package	TO-263-7

3. Physical Dimensions

The physical dimensions of the flyback auxiliary power supply board are 64 mm (L) X 45 mm (W) X 25 mm (H) as shown in Figure 2.

Figure 2: Physical dimensions and connections

4. Electrical Operation

The CRD15DD17P, 15 W flyback auxiliary power supply board is based on Wolfspeed's C2M1000170J, 1700V, 1000 mΩ, TO-263-7 SiC MOSFET (as shown in Figure 4). The C2M1000170J has a fast-intrinsic diode with low Qrr and a very low output capacitance. It also comes in a compact surface-mount package with extended leads for higher voltage capability and low source inductance.

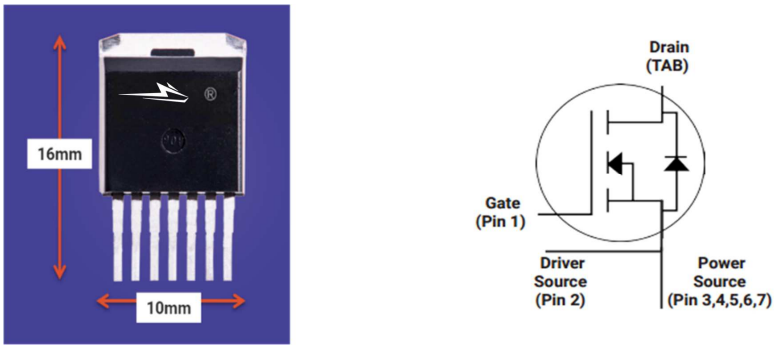

Figure 3: C2M1000170J SiC MOSFET in a TO-263-7 package

A Texas Instruments Inc. based flyback controller (P/N: UCC28740) (as shown in Fig. 4) has been utilized in this design. This controller has several benefits which include: less than 10 mW no load power capability, optocoupled feedback for constant voltage (CV) mode and primary side regulation for constant current (CC) mode, enable +/- 1% voltage regulation across line and load, 700 V startup switch, valley switching operation for highest overall efficiency, frequency dithering to ease EMI compliance, clamped gate drive output for MOSFET and overvoltage, low line and overcurrent protection function.

Figure 4: Flyback controller IC (P/N: UCC28740) from Texas Instruments Inc.

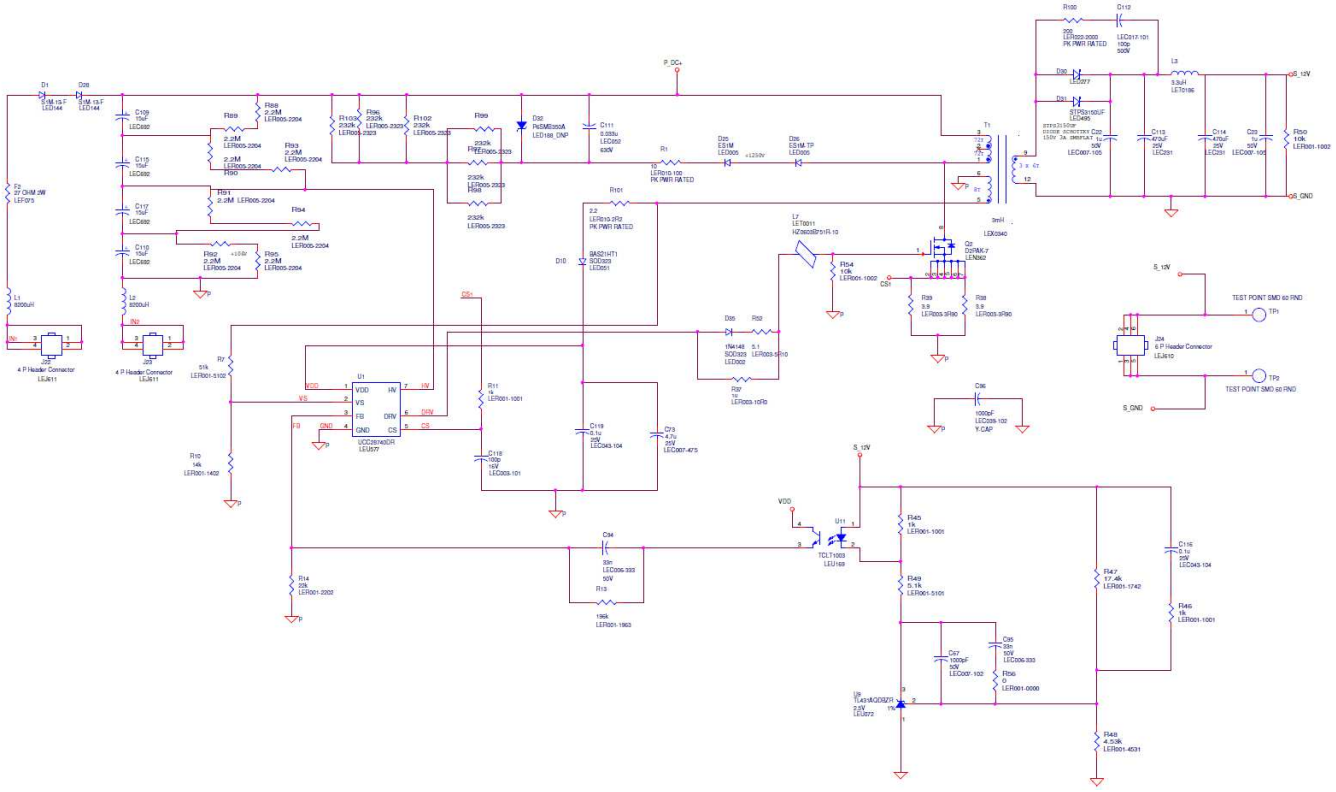

Figure 5: Schematic of CRD15DD17P, 15 W flyback auxiliary power supply board

The 15 W flyback auxiliary power supply board accepts both AC and DC input, referring to Figure 5. If the type of input is AC, diodes D1 and D28 serve as an input voltage rectifiers and DC voltage is established across the four aluminum capacitors C109, C110, C115 and C117. The inductors L1 and L2 are used for electromagnetic interference (EMI) suppression. A fusible resistor F2 is used to reduce the charging current to reduce the EMI and will open when there is over current condition due to malfunction in the circuit. The midpoint between capacitors C115 and C117 has half the rectified DC input voltage, so the maximum voltage that controller (U1) will see at its HV pin would be 600 VDC for 1200 VDC input, which is below the 700 V rating. The voltage at this midpoint provides an initial charging current via controller's (U1) built-in high-voltage start-up switch until VDD reaches the turn-on voltage of the controller (U1). Once the controller starts switching the primary side's main switch, voltage VDD will be maintained via auxiliary winding (5-6) of the flyback transformer, and the internal switch that provides start-up current in the controller (U1) will be turned off to reduce power loss.

Before powering up Wolfspeed's CRD15DD17P, 15 W flyback auxiliary power supply board, place a sheet of insulation material (not included) underneath the board to avoid any unintended electrical short conditions. After the power is applied to the board, the output could be measured by using a 12 VDC digital multimeter (DMM) or by using an oscilloscope.

For applications with < 1000 VDC input, two snubber resistors R96 and R97 (as shown in Figure 5) can be used to improve efficiency. For the reliable startup of the board with 300 VDC – 1000 VDC input, replace R90, R91, R93 and R94 (as shown in Figure. 5) with 0Ω resistors to short capacitors C115 and C117 (as shown in Figure 5).

5. Performance Data

5.1 Voltage Regulation

The CRD15DD17P, 15 W flyback auxiliary power supply board was tested under various load conditions and at various input voltage levels. Under all those conditions, the voltage regulation was well within 0.25 % (as shown in Figure. 6).

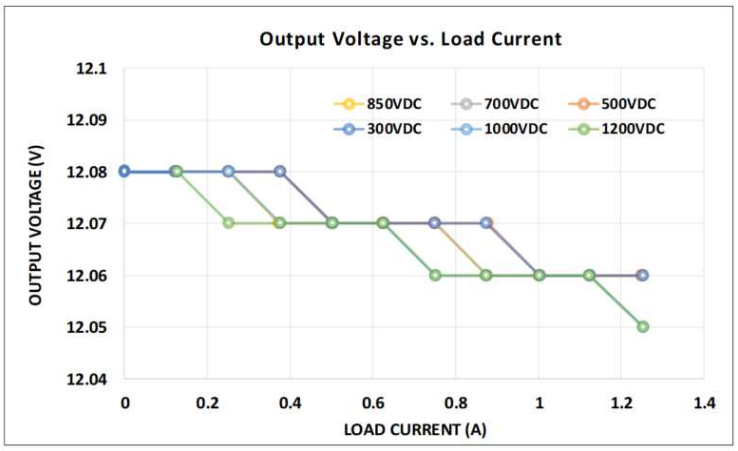

Figure 6: Voltage regulation data

5.2 EMI

The conducted EMI of the power supply board was measured at full load with the input voltage set at 277 VAC (as shown in Figure 7). Under these conditions, the power supply board passes the FCC part 15 Class A standard for commercial applications with enough margin.

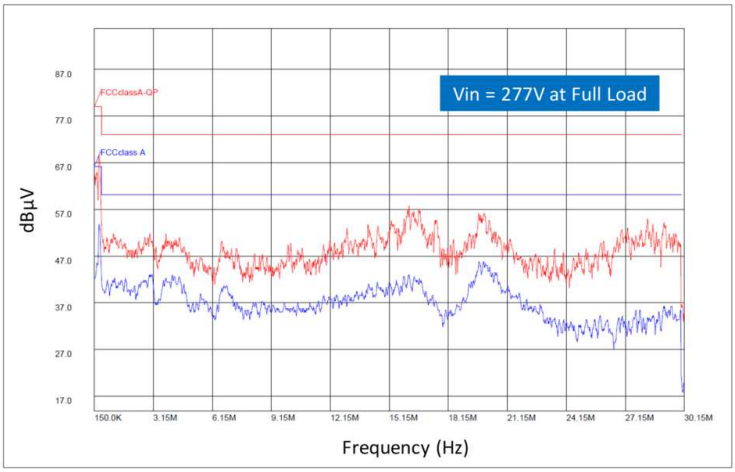

Figure 7: Conducted EMI measurement at full load with 277 VAC input

5.3 Efficiency

The efficiency of the power supply board was tested under various operating conditions (as shown in Figure 8 and Figure 9). These measurements were taken at 300 V, 500 V, 850 V, 1100 V and 1200 V DC input voltage levels and the peak efficiency achieved at each input voltage was 85% (@300 VDC), 84% (@500 VDC), 80% (@850 VDC), 70.8 % (@1100 VDC) and 70% (@1200 VDC).

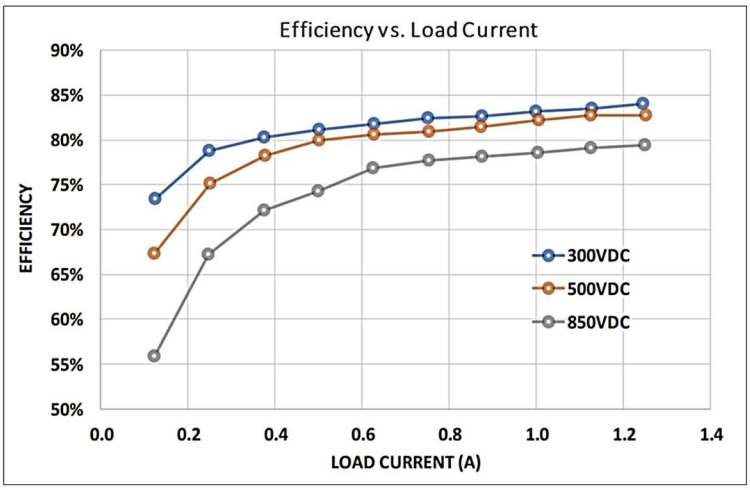

Figure 8: Efficiency measurements at 300 VDC, 500 VDC and 850 VDC input

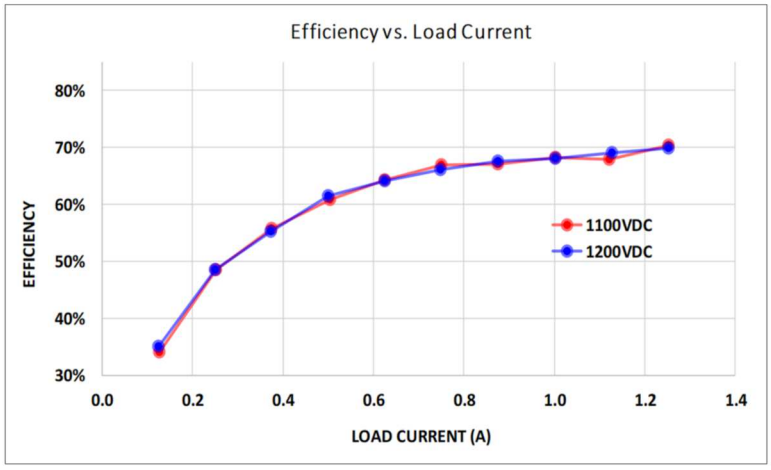

Figure 9: Efficiency measurements at 1100 VDC and 1200 VDC input

5.4 Waveforms at Various Operating Conditions

The performance of CRD15DD17P can be evaluated by using startup waveforms of output voltage at 300 VDC and 1200 VDC taken at full-load and open load conditions (as shown in Figure 10 (a), 10(b) and Figure 11 (a), 11 (b)). The waveforms of output voltage both at full load and open load conditions show very low overshoot and ripple.

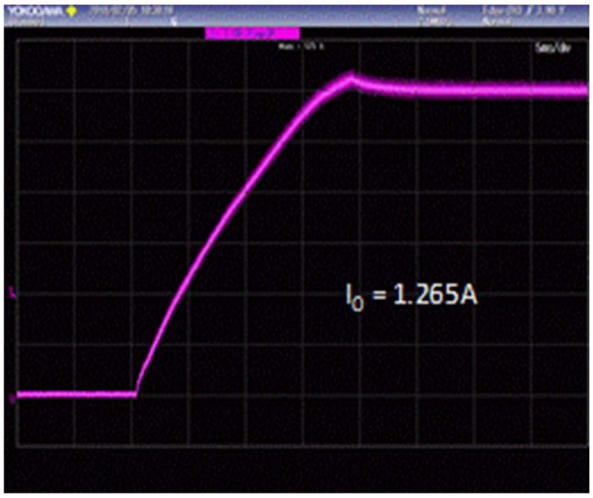

Figure 10 (a)

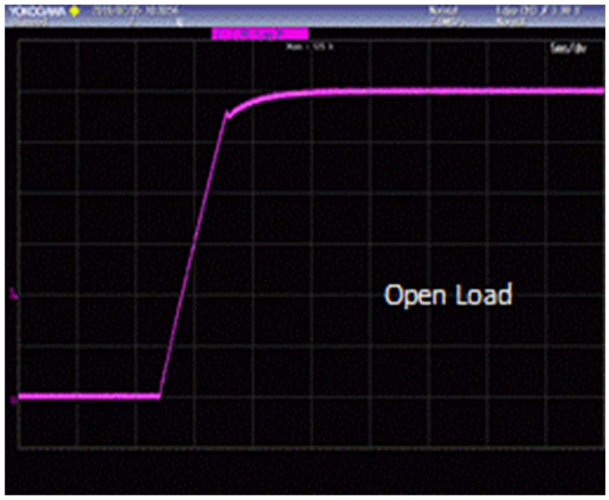

Figure 10 (b)

Figure 10 (a): Startup waveform of output voltage at 300 VDC input and full load,
Figure 11 (b): Startup waveform of output voltage at 300 VDC input at open load

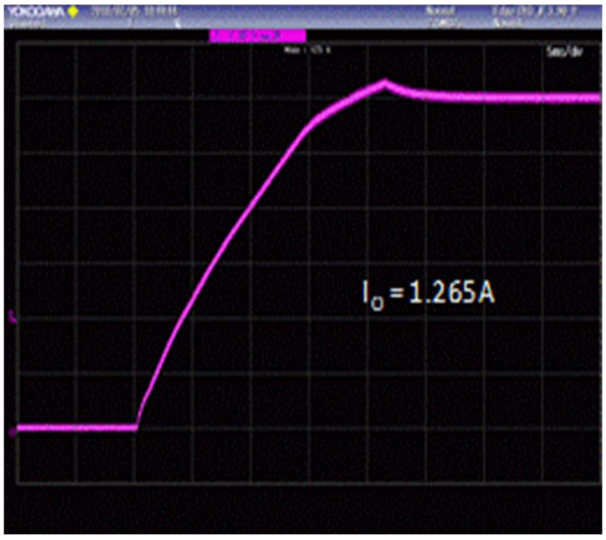

Figure 11 (a)

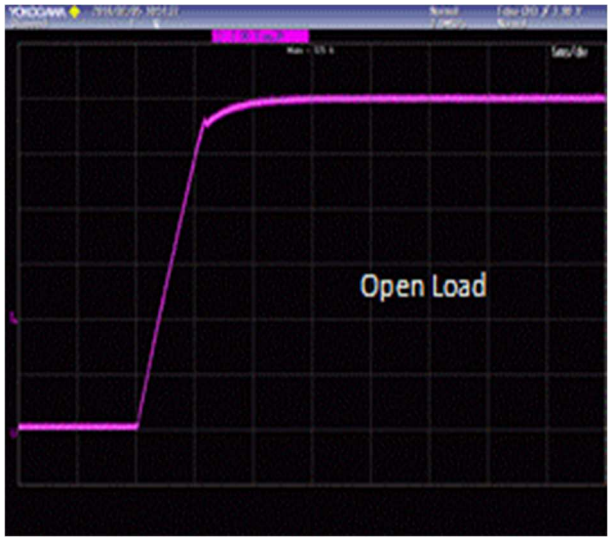

Figure 11 (b)

Figure 12 (a): Startup waveform of output voltage at 1200 VDC input and full load
Figure 13 (b): Startup waveform of output voltage at 1200 VDC input at open load

In addition to startup waveforms of output voltage, drain-source voltage (V_{DS}) and gate-source voltage (V_{GS}) waveforms as shown in Figure 12 (a) and 12 (b) can also be used to evaluate the overshoot of these signals and ensure they remain in the SOA of the device. Referring to Figures 12(a) and 12(b), V_{GS} waveform is free from gate ringing while V_{DS} waveform has peak voltage of 1600 V which is less than the rated voltage of Wolfspeed's C2M1000170J, 1700V, 1000 mΩ, TO-263-7 SiC MOSFET.

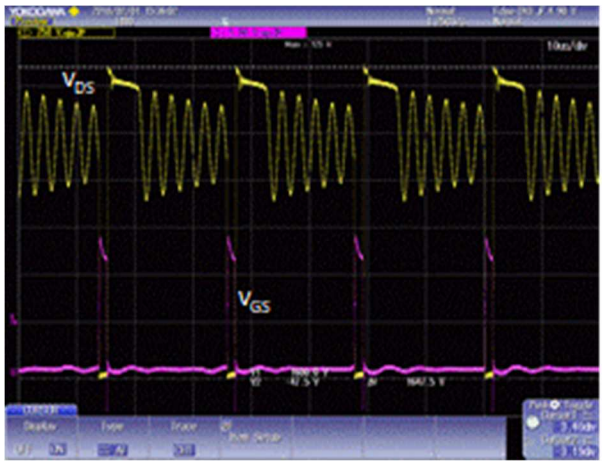

Figure 12 (a)

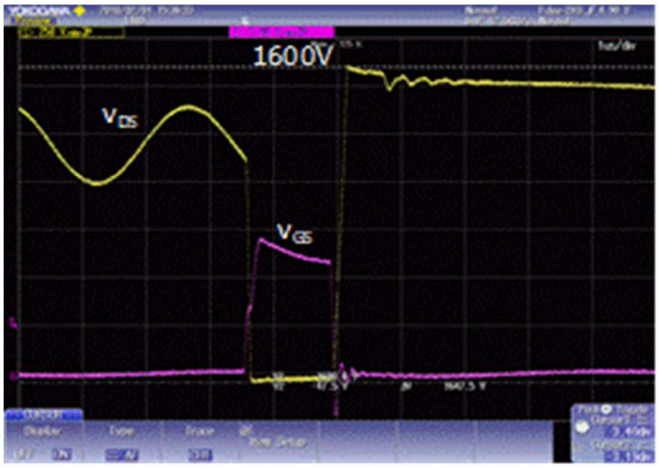

Figure 12 (b)

Figure 14 (a): Gate-source (V_{GS}) and drain-source voltage (V_{DS}) waveforms at 1200 VDC input,
Figure 15 (b): Single pulse view of gate-source (V_{GS}) and drain-source voltage (V_{DS}) waveforms at 1200 VDC input

5.5 Thermal Measurements

Thermal measurements of the power supply board were taken at various line voltages and load conditions. These measurements were well below the rated temperature range as shown in Figures 13-18.

The CRD15DD17P board has large copper pads available on both sides of the board interconnected through vias (as shown in Figure 19-20). These vias have been used for Wolfspeed's C2M1000170J, 1700V, 1000 mΩ, TO-263-7 SiC MOSFET and snubber resistors on the primary side of the board. The copper pads are not isolated from the drain tab of the MOSFET, hence are electrically hot. At 1.2 kVDC input voltage, the snubber resistors can get hot. To maintain their temperature below the limit, more copper has been added into the copper pads to mount snubber resistors further apart from each other. The worst-case temperature of C2M1000170J at 1.2 kVDC input and full load is 103 °C.

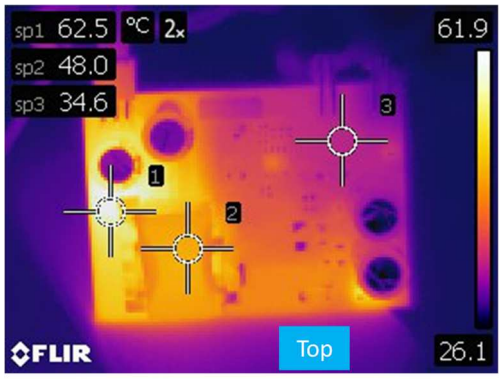

Figure 16: Thermal image of top layer at 300VDC input and full load

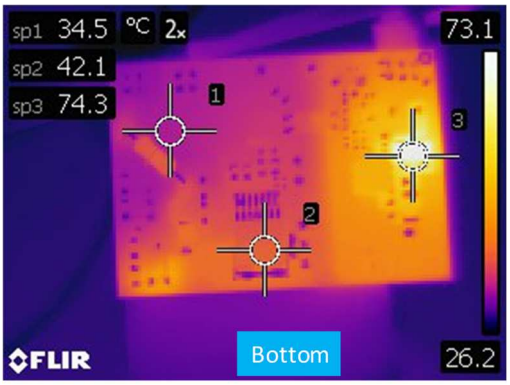

Figure 17*: Thermal image of bottom layer at 300VDC input and full load*

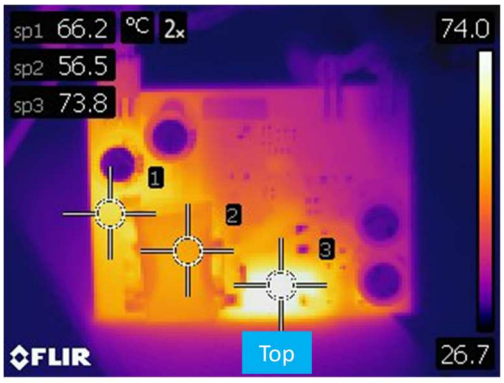

Figure 18: Thermal image of top layer at 850VDC Input and Full Load

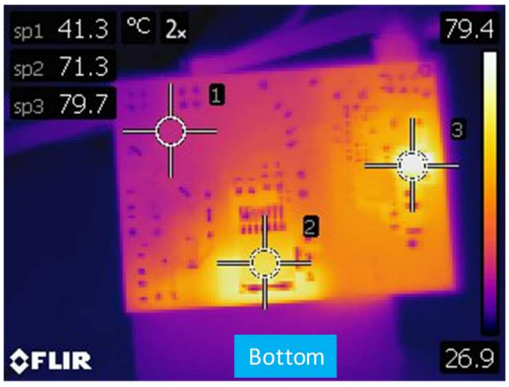

Figure 19: Thermal image of bottom layer at 850VDC Input and Full Load

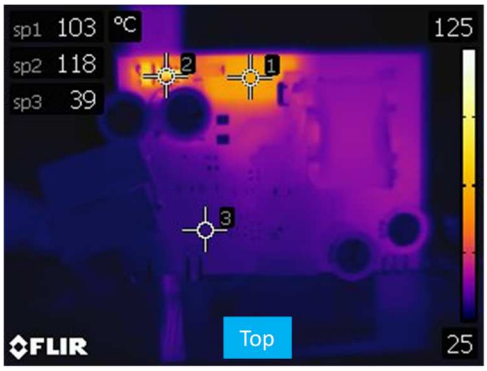

Figure 20: Thermal image of top layer at 1.2kVDC input and full load

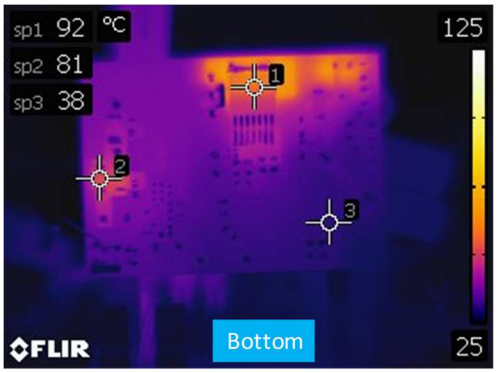

Figure 21: Thermal image of bottom layer at 1.2kVDC input and full load

6. PCB Layout and Bill of Materials (BOM)

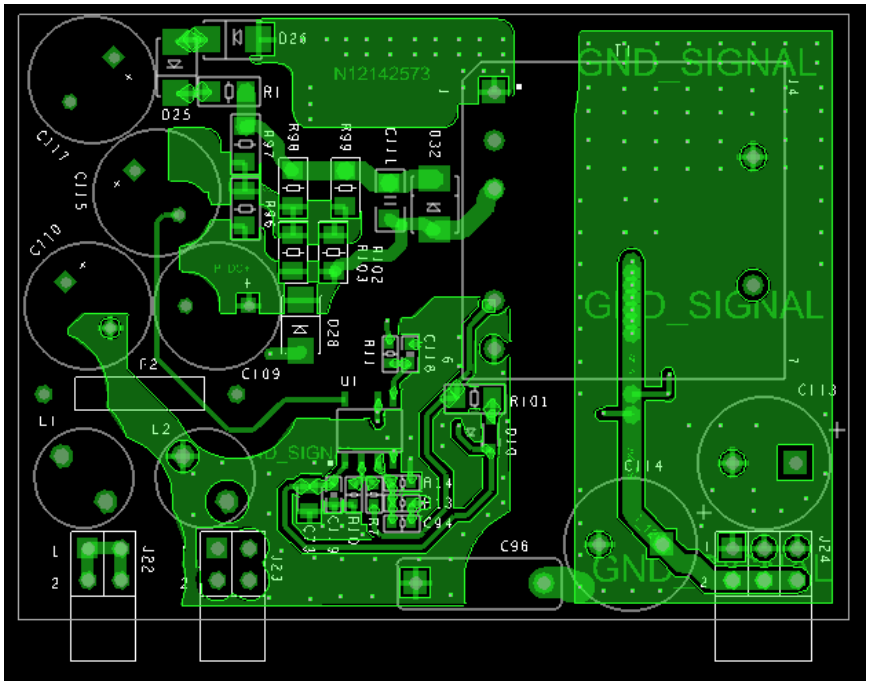

Figure 22: Top layer of the PCB

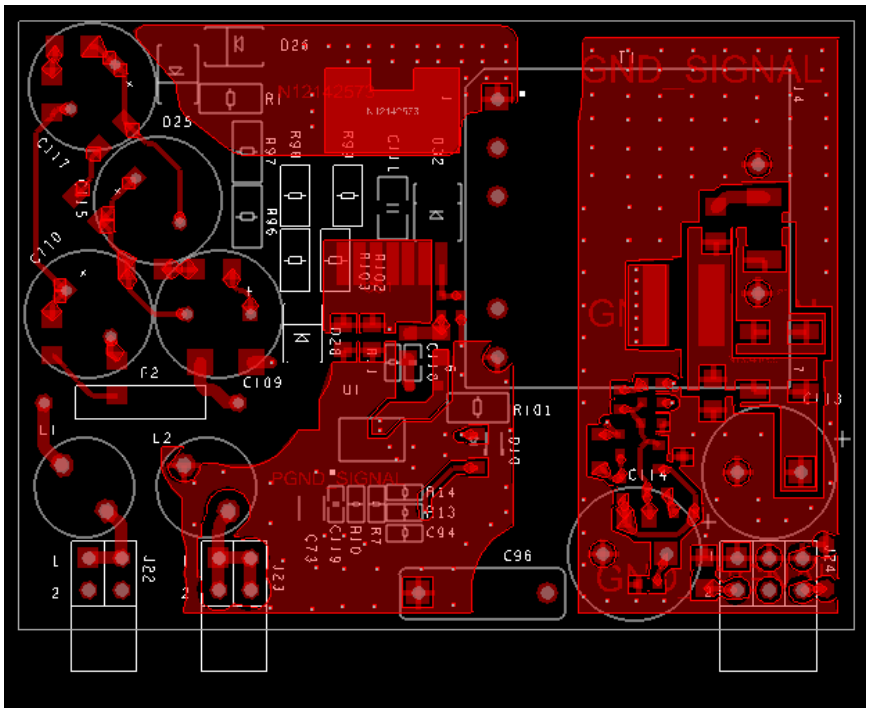

Figure 23: Bottom layer of the PCB

Table 2: Bill of Materials (BOM) of Wolfspeed's CRD15DD17P, 15 W Flyback Auxiliary Power Supply Board

Item	Qty Per	Reference Designator	Description	Manufacturer Name	Manufacturer P/N
1	2	C22, C23	CAP CER 1µF 50V X7R 0805	Murata Electronics North America	GRM21BR71H105KA12L
2	1	C67	CAP CER 1000pF 50V 10% 0805 X7R	KEMET	C0805C102K5RACTU
3	1	C73	CAP CER 4.7µF 25V X7R 0805	Taiyo Yuden	TMK212AB7475KG-T
4	2	C94, C95	CAP CER 0.033µF 50V X7R 0603	AVX CORP.	06035C333KAT2A
5	1	C96	CAP FILM 1000pF 20% 1.25kVDC RAD	KEMET	PHE850EA4100MA01R17
6	4	C115, C117, C109, C110	CAP ALUM 15µF 20% 450V RADIAL	Rubycon	450BXW15MEFC10X20
7	1	C111	CAP CER 0.033µF 630V X7R 1206	TDK Corporation	C3216X7R2J333K160AA
8	1	C112	CAP CER 100pF 500V X7R 1206	KEMET	C1206C101KCRACTU
9	2	C113, C114	CAP ALUM 470µF 20% 25V RADIAL	Panasonic Electronic Components	EEU-EB1E471
10	1	C118	CAP CER 100PF 16V X7R 0603	AVX Corporation	0603YC101KAT2A
11	2	C116, C119	CAP CER 0.1µF 25V X7R 0603	Murata Electronics North America	GRM188R71E104KA01D
12	1	D10	DIODE GEN PURP 250V 200mA SOD323	ON Semiconductor	BAS21HT1G
13	2	D25, D26	DIODE GEN PURP 1kV 1A DO214AC	MICRO COMMERCIAL COMPONENT	ES1M-TP
14	2	D1, D28	DIODE GEN PURP 1KV 1A SMA	Diodes Incorporated	S1M-13-F
15	1	D30, D31	DIODE SCHOTTKY 150V 3A SMBFLAT	STMicroelectronics	STPS3150UF
16	1	D35	DIODE GEN PURP 75V 150mA SOD323	MICRO COMMERCIAL COMPONENT	1N4148WXTPMSTR
17	1	F2	Metal Film Resistor Through Hole 2W 27 ohm 10% FUSIBLE	TT ELECTRONICS	EMC2-27RKI
18	2	J22, J23	4 Positions Header Connector, 0.100" (2.54mm), Through Hole, Right Angle, Tin	SAMTEC INC USA	TSW-102-09-T-D-RA

Item	Qty Per	Reference Designator	Description	Manufacturer Name	Manufacturer P/N
19	1	J24	6 Positions Header Connector, 0.100" (2.54mm), Through Hole, Right Angle, Tin	SAMTEC INC USA	TSW-103-09-T-D-RA
20	2	L1, L2	FIXED IND 8.2mH 100mA 16Ω TH	Wurth Electronics Inc.	744731822
21	1	L3	FIXED IND 3.3µH 4.5A 20 mΩ SMD	Bourns Inc.	SDR0805-3R3ML
22	1	L7	FERRITE BEAD 750Ω 0603 1LN	Laird-Signal Integrity Products	HZ0603B751R-10
23	1	Q2	MOSFET N-CH 1700V 5.3A Surface Mount D2PAK (7-Lead)	Wolfspeed	C2M1000170J
24	1	R1	RES SMD 10Ω 5% 2/3W 1206	Panasonic Electronic Components	ERJ-P08J100V
25	1	R7	RES SMD 51kΩ 1% 1/10W 0603	Yageo	RC0603FR-0751KL
26	1	R10	RES SMD 14kΩ 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF1402V
27	3	R11, R45, R46	RES SMD 1kΩ 1% 1/4W 0603	Vishay Dale	CRCW06031K00FKEA
28	1	R13	RES SMD 196kΩ 1% 1/10W 0603	Vishay Dale	CRCW0603196KFKEA
29	1	R14	RES SMD 22kΩ 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF2202V
30	1	R37	RES SMD 10Ω 1% 1/8W 0805	Panasonic Electronic Components	ERJ6ENF10R0V
31	2	R38, R39	RES SMD 3.9Ω 1% 1/8W 0805	Vishay Dale	CRCW08053R90FKEA
32	1	R47	RES SMD 17.4kΩ 1% 1/10W 0603	Yageo	RC0603FR-0717K4L
33	1	R48	RES SMD 4.53kΩ 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF4531V
34	1	R49	RES SMD 5.1kΩ 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF5101V
35	2	R50, R54	RES SMD 10kΩ 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF1002V
36	1	R56	RES SMD 0Ω JUMPER 1/4W 0603	Vishay Dale	CRCW06030000Z0EA
37	1	R52	RES SMD 5.1Ω 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6RQF5R1V

Item	Qty Per	Reference Designator	Description	Manufacturer Name	Manufacturer P/N
38	8	R88, R89, R90, R91, R92, R93, R94, R95	RES SMD 2.2MΩ 1% 1/4W 1206	Vishay Dale	CRCW12062M20FKEA
39	6	R96, R97, R98, R99, R102, R103	RES SMD 232kΩ 1% 1/4W 1206	Panasonic Electronic Components	ERJ-8ENF2323V
40	1	R100	RES SMD 200Ω 1% 3/4W 2010	Vishay Dale	CRCW2010200RFKEF
41	1	R101	RES SMD 2.2Ω 5% 1/3W 1206	Stackpole Electronics Inc.	RPC1206JT2R20
42	1	T1	Flyback Transformer 3.2mH	Kunshan Eagerness Electronics Co., Ltd	PQ20401-802 A
43	1	U1	IC REG CTRLR FLYBK ISO 7SOIC	Texas Instruments	UCC28740D
44	1	U9	IC VREF SHUNT ADJ SOT23-3	Nexperia USA Inc.	TL431AQDBZR,215
45	1	U11	OPTOISOLATR 5kV TRANSISTOR 4-SOP	Vishay Semiconductor Opto Division	TCLT1003

7. Revision History

Date	Revision	Changes
March 2018	-	1st Issue
January 2024	2	Branding and formatting updates

8. 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 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.