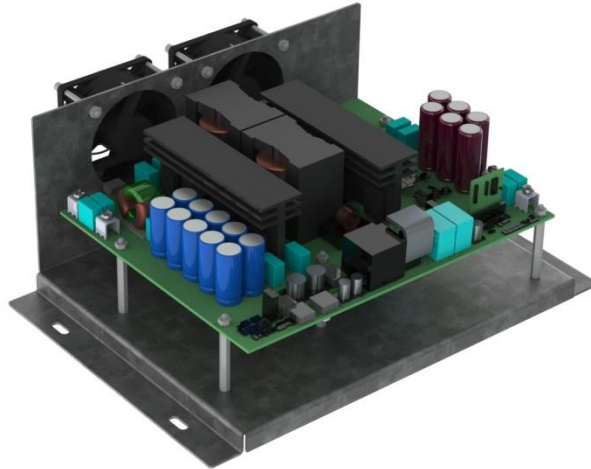


CRD-20DD09P-2

20kW Full Bridge Resonant LLC Converter

Enabling smaller, cooler and lower cost off-board electrical vehicle chargers



User's Manual

CPWR-AN18, Rev -

CREE Power Applications

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

All parts of this User's Manual are provided in English, and the Cautions are provided in English, Mandarin, and Japanese. If the end user of this product 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 evaluation 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。若本板子的终端用户不熟悉上述任何一种语言，则您应当确保该终端客户能够理解本文件中的条款与条件，包括且不限于本板子的危险以及安全操作条件。

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

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Note: This Cree-designed evaluation hardware for Cree components 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. The hardware is not designed to meet any particular safety standards and the tool is not a production qualified assembly.

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 assembling and 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

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

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。通电している時にボードに接触する必要がありません。通电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をつないでください。通电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。

Introduction

The purpose of this evaluation hardware is to demonstrate the system performance of Cree's 3rd Generation Silicon Carbide (SiC) Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs) in a full bridge LLC circuit that may be typically used for fast DC chargers for electrical vehicles. The new 1000V rated device in a 4L-TO247 package, specifically designed for SiC MOSFETs, has a Kelvin source connection to improve switching losses and reduce ringing in the gate circuit. It also features a notch between the drain and source pins to increase the creep distance to accommodate higher voltage SiC MOSFETs.

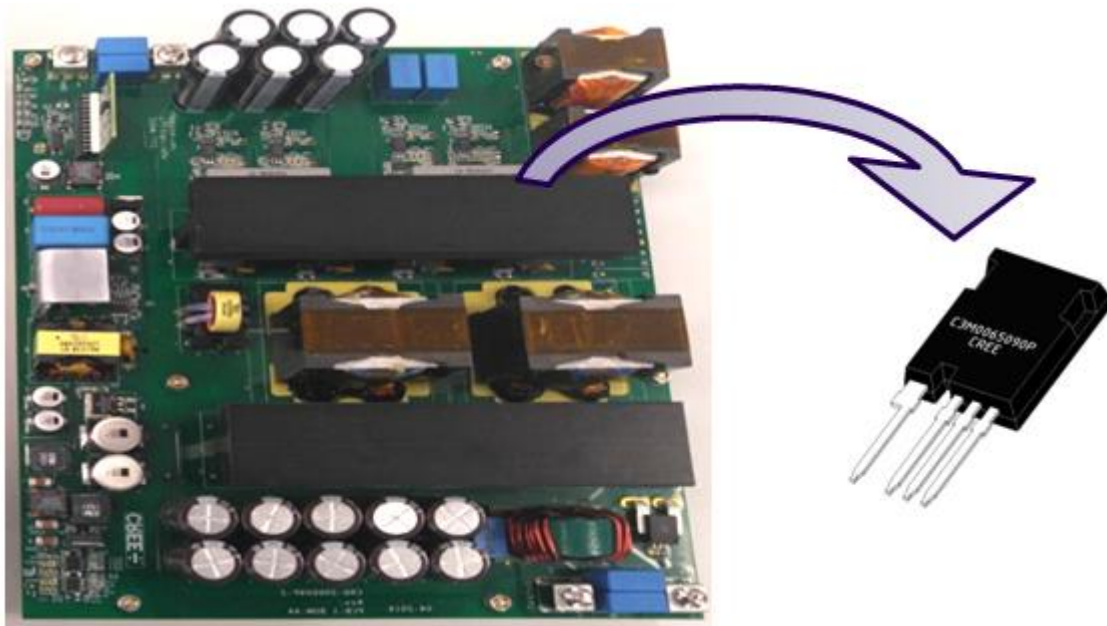


Figure 1. 20kW LLC hardware uses the latest Cree 1000V SiC MOSFETs in the 4L-TO247 package.

This board was designed to make it easy for the user to:

- Evaluate converter level efficiency and power density gains when using the new 1000V, 65 mΩ SiC MOSFETs in a 4L-TO247 package in a full bridge resonant LLC circuit.
- Check waveforms such as V_{gs} and V_{ds} and I_d for ringing.
- Evaluate thermal performance.
- Integrate a SiC based isolated DC/DC stage in a larger multi-stage prototype system for evaluation (a fast DC charger for electric vehicles, for example).
- Serve as a printed circuit board (PCB) layout example for driving Cree's Gen 3 SiC MOSFETs with a Kelvin source pin.
- Conduct parallel operations of Cree's Gen3 MOSFETs in an LLC circuit.

The hardware is NOT designed to be a production ready design or work in harsh operating environments. The control loop is NOT tested for step load changes and it does NOT have a pre-charge

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circuit or any means to limit inrush current. There are NO electrical fuses or disconnect mechanisms included in the hardware. It is meant to be used by trained and qualified personnel to evaluate Cree's MOSFET and diode products in a LLC resonant converter.

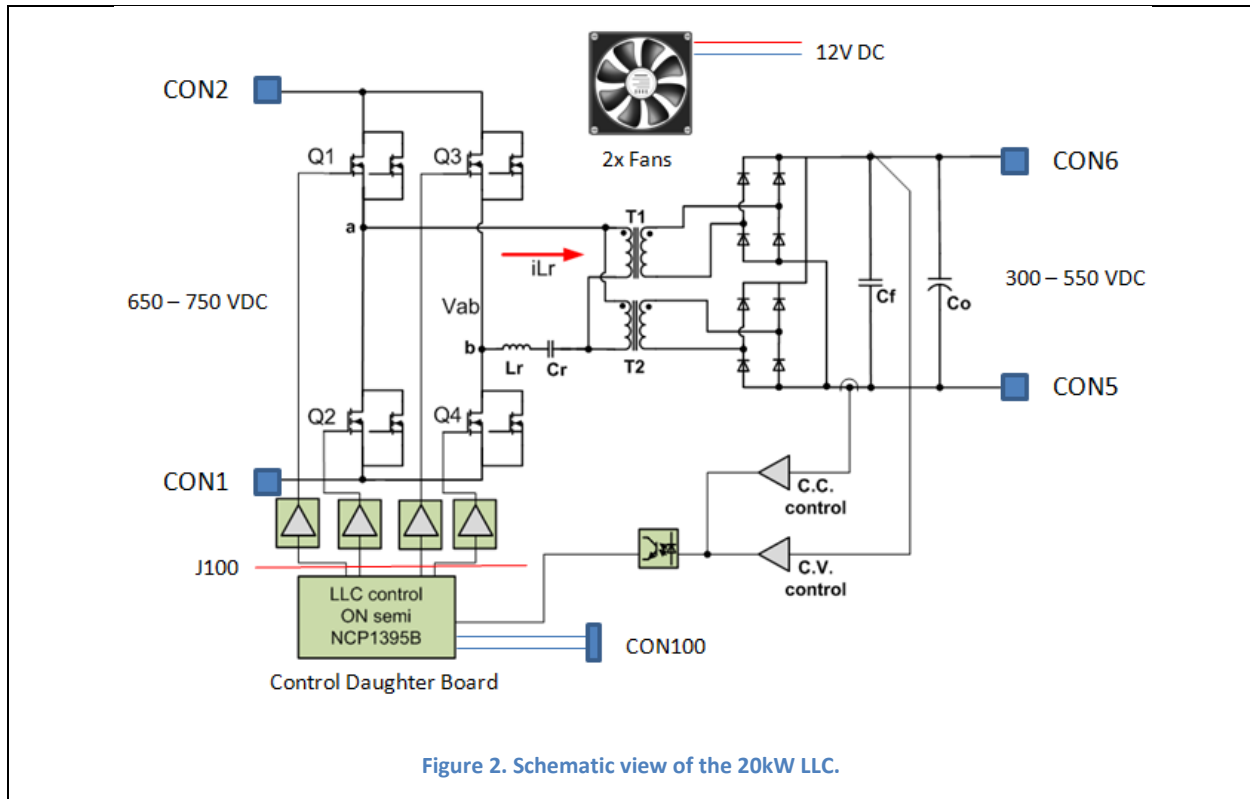
Hardware Overview

The LLC evaluation board is designed to be a plug and play demo board. It only requires a suitable input DC supply, an output DC load, external 12VDC supply for the cooling fans and an ON/OFF switch. The complete PCB assembly is mounted on a metal plate with mounting holes and includes two cooling fans. The PCB also includes an on-board wide-input auxiliary power supply to power on-board systems.

Download additional documentation for this design at www.wolfspeed.com/power/tools-and-support.

1. Electrical Overview

Input voltage:	DC 700V (Nominal), DC 650V to 750V
Output voltage:	DC 500V (Nominal), DC 300V to 550V
Output current:	35A (Maximum)
Power:	20kW (Maximum)



The full bridge LLC uses 2x C3M00650100K (65mΩ, 1000V SiC MOSFETs) in parallel per switch position on the primary side of the transformer. The tank circuit is designed for switching frequency range from 110 – 350 kHz which represents input voltage range from 650 – 750 VDC.

2. Mechanical Overview

Overall Dimensions:	291 x 357 x 144 mm (including fans and metal mounting base)
Net Weight:	4.7 kg (including fans and metal mounting base)

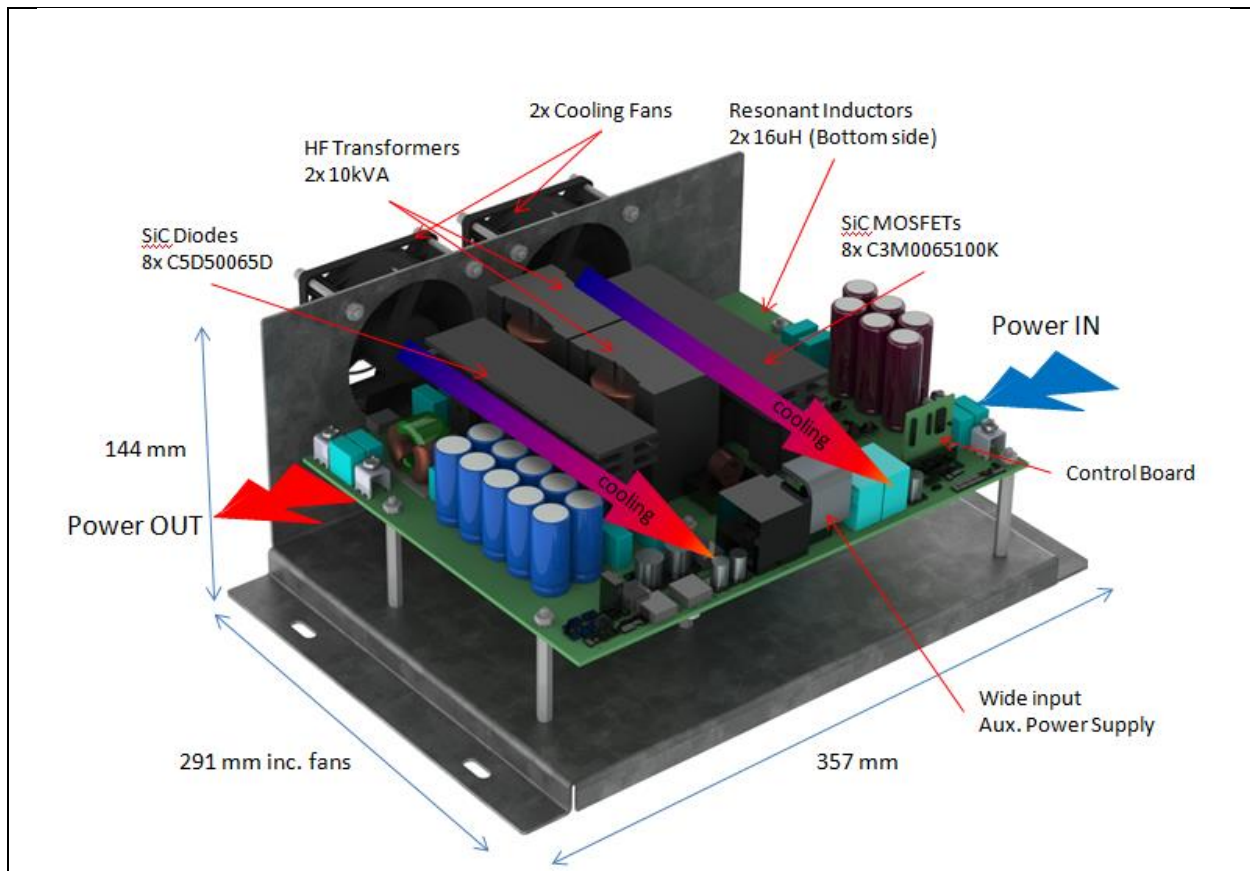


Figure 3. Overview of the 20kW LLC highlighting the major components.

The evaluation unit includes the necessary cooling fans and a metal base plate for easy mounting on a lab bench. The cooling should be turned ON prior to conducting power testing over 500W. The PCB assembly only weighs 3.2 kg without the fans and metal base. Ducting the forced air over the magnetics and heat sinks can improve the thermal performance of the system.

The two cooling fans illustrated above feature finger guards on the intake side, but there are no finger guards on the opposing side and care should be taken to protect your fingers from the rotating fan blades by not handling the system when in operation.

3. Connectors



CAUTION

*****HIGH VOLTAGE RISK*****

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

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

警告

*****高压危险*****

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

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

警告
高圧危険

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。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、ボードに接触しないでください。

ボードのコネクターは充電中また充電した後、ひどく高い電圧が存在しているので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。ボードを操作している時、正確な安全ルールを守っているのを確保してください。さもなければ、感電、電撃、厳しい火傷などの死傷が出る可能性があります。設備をつないで試験する時、必ずボードの電源を切ってください。また、大容量のコンデンサーで電力を完全に釈放してください。使用后、すぐにボードの電源を切ってください。電源を切った後、大容量のコンデンサーに貯蓄している電量はコネクターに持続的に入るので、ボードを操作する前に、必ず大容量のコンデンサーの電力を完全に釈放するのを確保してください。

CON1	Input -NEG DC Terminal for M5 cable lug and screw. Rated to 800V, 40A. Recommend using electrical grease for improved contact.	CON5	Output -NEG DC Terminal for M5 cable lug and screw. Rated to 800V, 40A. Recommend using electrical grease for improved contact.	CON100	2 Pos plate through hole on PCB to solder cables to the ON/OFF switch. 5A max.
CON2	Input -POS DC Terminal for M5 cable lug and screw. Rated to 800V, 40A. Recommend using electrical grease for improved contact.	CON6	Output -POS DC Terminal for M5 cable lug and screw. Rated to 800V, 40A. Recommend using electrical grease for improved contact.	J100	12 Pos header for controller board. 20V, 1A max.

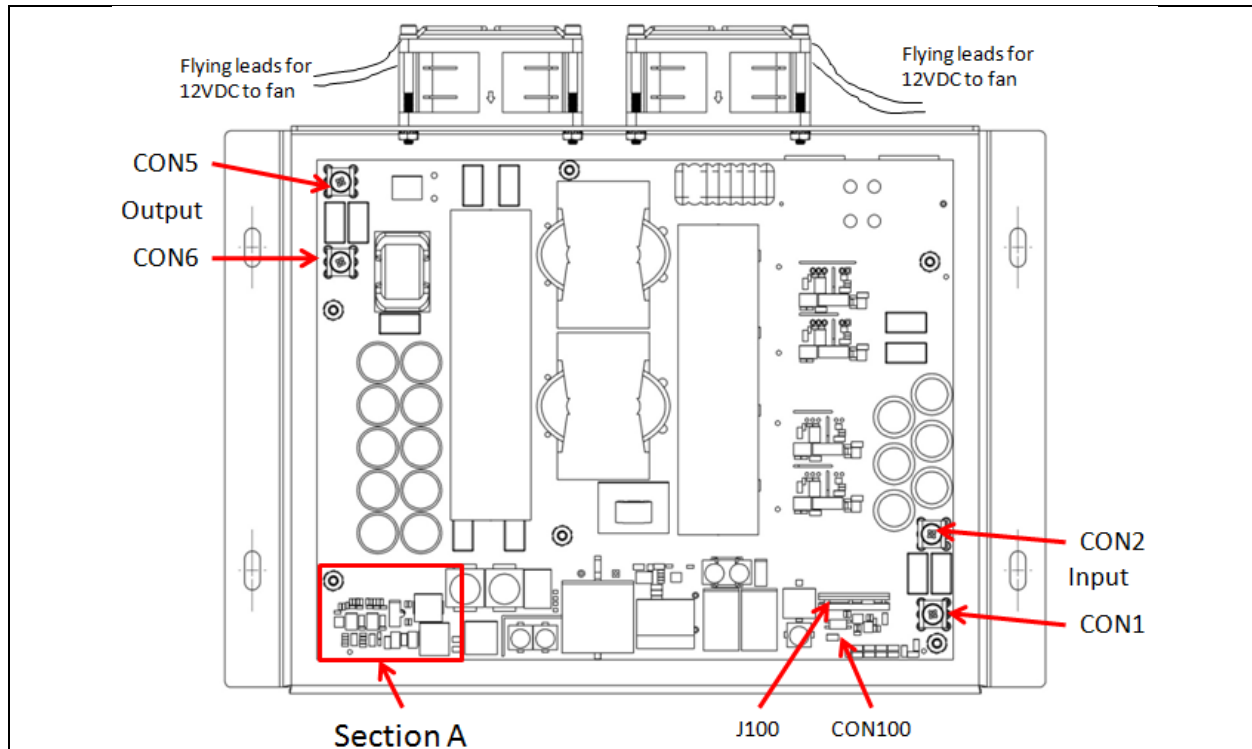


Figure 4. Connector locations. Also, note Section A on the PCB is an area that contains components that need to be modified when operating in variable output voltage mode.

All necessary connector locations are identified for normal operation. For the specific case of variable output operation (see Section 7 on variable output voltage setting), it is necessary to locate CON101. It is located in the area of the PCB labeled Section A.

4. Control Board

The control board is a small 1.25" x 1.25" daughter board connected to J100 and oriented as shown in the image in Figure 5. The control chip is a high performance resonant mode controller, NCP1395B, from ON Semiconductor.

No power should be applied to the main board without the control board connected and oriented correctly.



Figure 5. Orientation of control board.

5. Installing the ON/OFF switch and normal power up/down procedure

In order to operate the hardware correctly, it is necessary to connect a 48V, 500mA rated toggle switch at connector C100 (see Figure 4) between pins 1 and 2.

Power up procedure:

- 1) Make sure all parts and wires are connected properly and all terminals are connected to right polarity.
- 2) Set loading to min. value (for E-load, it is C.C. mode at 5A or loading power to 2500W).
- 3) Turn on HVDC power source and increase supply HVDC voltage to 700V (input voltage).
- 4) Turn on the converter by switch at CON100.
- 5) Increase the loading to get full output power.

Power down procedure:

- 1) Decrease the loading to minimum.
- 2) Turn off the converter by switch at CON100.
- 3) Turn off HVDC power source.

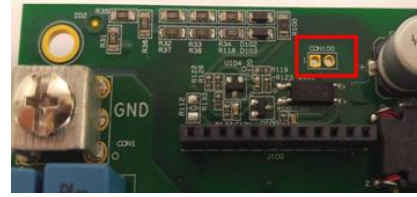


Figure 6. Location of the plated holes for connecting the ON/OFF switch near the INPUT terminals.

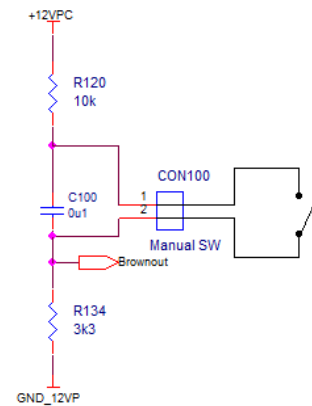


Figure 7. Schematic wiring for the ON/OFF switch.



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.

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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。

6. Changing the preset output voltage

By default, the output voltage of the evaluation hardware is preset to 500 VDC. However, it is possible to change the output voltage setting by changing the values of resistors R115 and R116. Figure 8 shows the corresponding output voltage setting for different values of R115 and R116.

Vin	Vout	Io(Max)	R115	R116
700Vdc	500Vdc	35A	10k	39k
750Vdc	550Vdc	35A	16k	13k
650Vdc	300Vdc	35A	27k	27k

Figure 8. R115 and R116 values for setting output voltage. Row 1 shows the default values and settings for the hardware.

Resistors R115 and R116 are located in Section A illustrated in Figure 4 above. R115 is located on the top side while R116 is located on the bottom side of the PCB.

Follow power up and down procedures as described in Section 5.

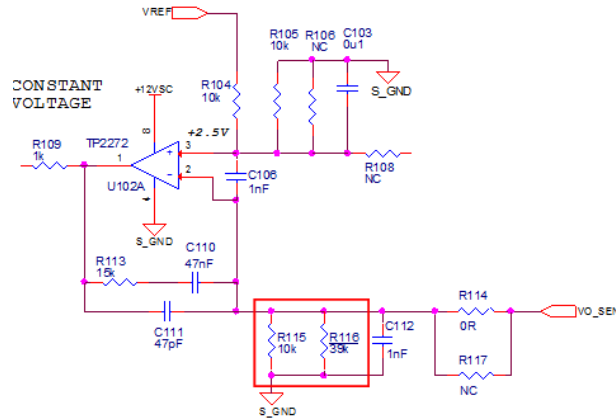


Figure 9. Schematic view of R115 and R116. They are located in Section A (see Figure 4) top side (R115) and bottom side (R116).

7. Variable output voltage setting

To use the feature of variable output voltage, it is necessary to make the following component changes (see Figures 10, 11, and 12):

- 1) R108 change to 10kΩ.
- 2) R106 change to 10kΩ.
- 3) R115 change to 10kΩ, R116 change to 39kΩ.
- 4) Apply the control voltage (range 0.93V to 6V) at CON101.2 to S_GND (C50: "S_GND" Pin or U102.P4).

Turn on procedure when using control voltage:

- 1) Make sure all parts and wires are connected properly, and all terminals are connected to right polarity.
- 2) Set loading to min. value (for E-load, it is C.C. mode at 5A or loading power to 2500W).
- 3) Apply 4.9V to CON101.2 to S_GND to set the output voltage to 500V, or follow the Figure 12 list to set control voltage for wanted output voltage value.
- 4) Turn on HVDC power source and

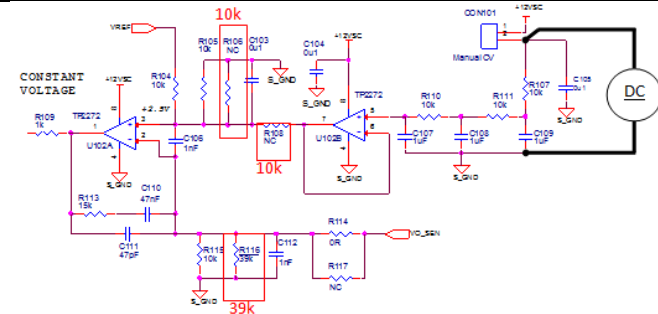


Figure 10. Portion of the schematic highlights where to add DC source to control output voltage and other components that need to be changed.

Input voltage:	DC 650 to 750V
Output voltage:	DC 500V(Nominal), DC 300V to DC 550V
Output current:	20A (Max. at any voltage rating), 35A (Max. at specified voltage rating)
Control voltage at CON101.2 to S_GND:	0V to 6V, Max.: 10V, Min.: 0V

Figure 11. Electrical specification for the hardware when operating in the variable output voltage setting.

HVDC output	Control voltage	Iout:
500V (Nominal)	4.90V	20A
300V (Min.)	0.93V	20A
400V	2.90V	20A
550V	5.84V	20A

Figure 12. Control voltage values corresponding to the desired output voltage.

increase supply HVDC voltage to 650V ~ 750V (input voltage). 5) Turn on the converter by switch at CON100. 6) Increase the loading to 20A (Max). <u>Turn off procedure:</u> 1) Decrease the loading to 5A. 2) Turn off the converter by switch at CON100. 3) Turn off HVDC power source.	
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8. Cooling Requirements

The two cooling fans included with the hardware are Delta Model No. PFB0812DHE. They are standard 12VDC, 80 x 80 x 38 mm fans and can be replaced with fans from other suppliers, provided that the replacement fans meet the air-flow requirements of the fans included with the hardware. The fans must be connected to an external power source and running prior to performing any power testing > 500W. Temperature measurements are provided in Section 9, the 'Testing and Performance' section, below.

9. Testing and Performance

For reference, the 20kW LLC evaluation hardware is wired as shown in Figure 13 to make measurements. Test data is provided in Figures 14-18 on efficiency, waveforms, and temperatures and should be used as reference to verify that the hardware is in working order.

Great care should be taken when capturing switching forms, and industry standard good practices should be followed when making measurements to minimize the effects of parasitics in measurements. The following equipment was used in taking the measurements in Figures 14-18:

- Yokowaga WT3000 power analyzer.
- LeCroy Digital Oscilloscope
- 1kV, 20kW E-load bank from FaithTech Model FT68020D
- 50kW Variable DC source with a 70A, 1000VDC solar fuse for safety
- FLIR thermal imager

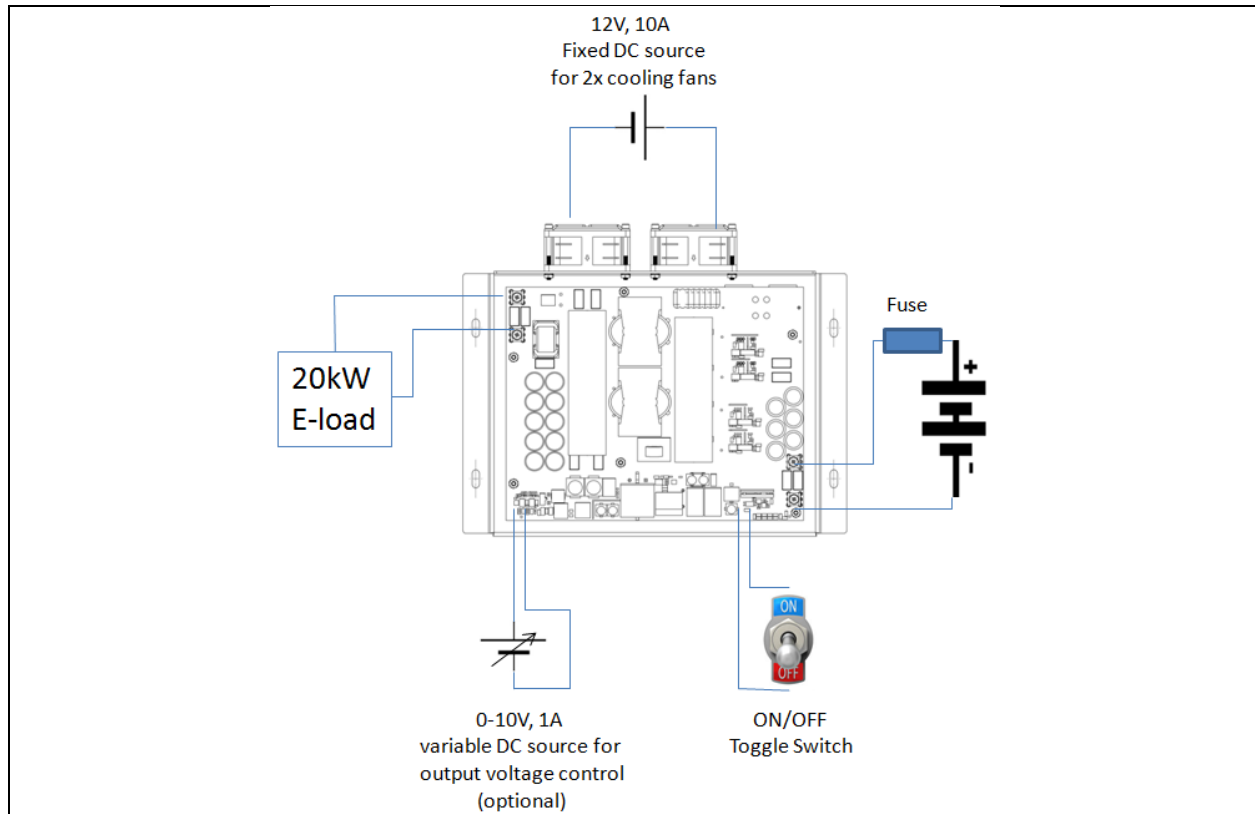


Figure 13. Test circuit used to take the measurements in this section.

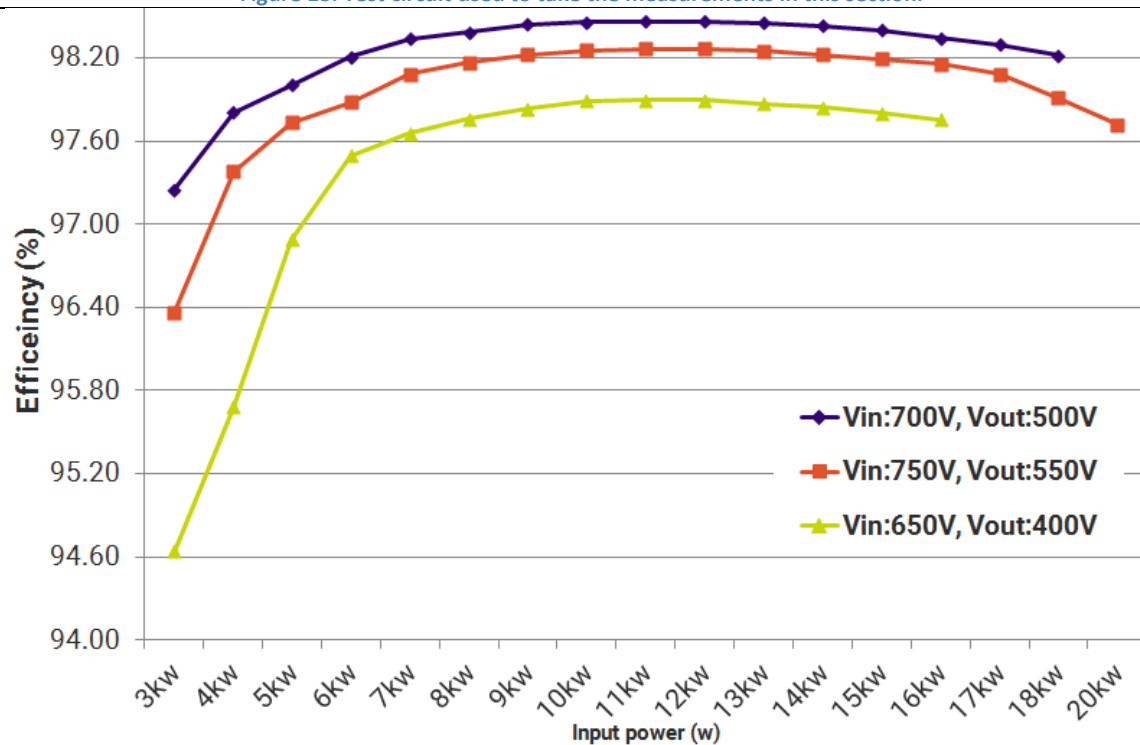


Figure 14. Measured efficiency as a function of output power.

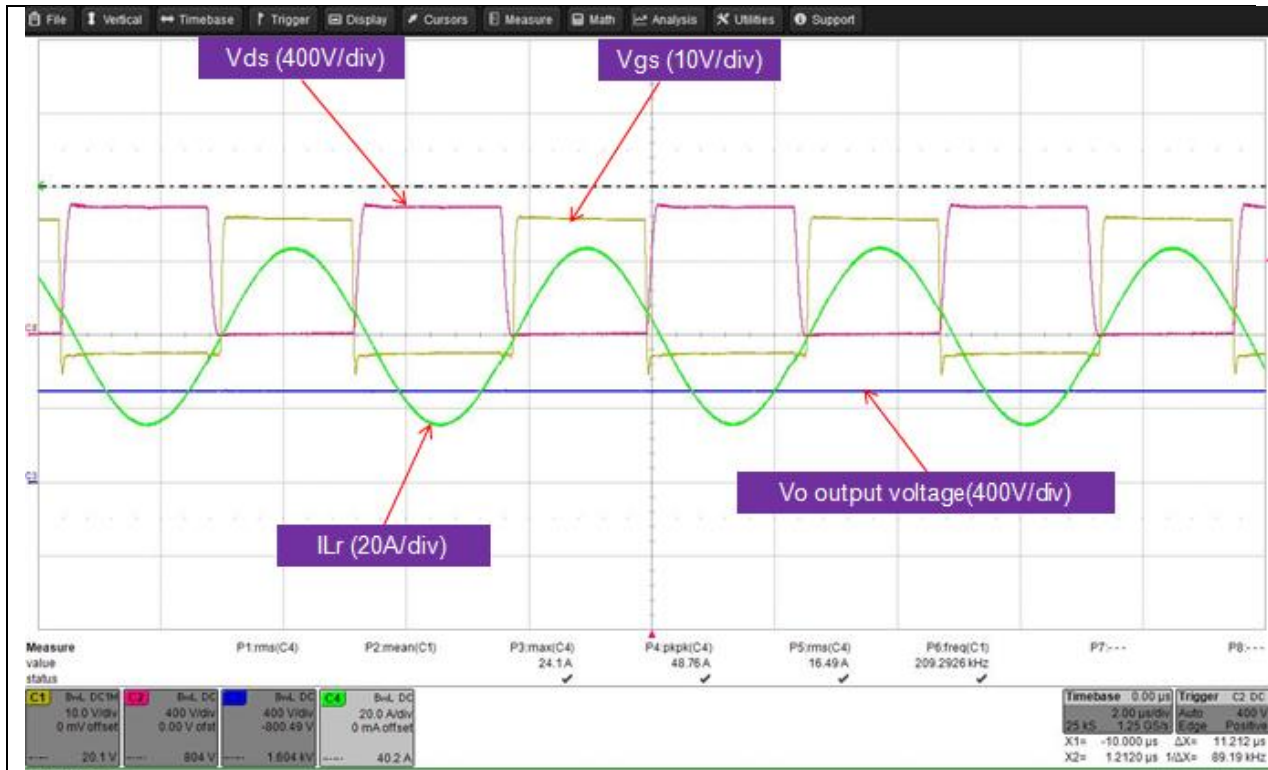


Figure 15. Switching waveforms under 50% load conditions.

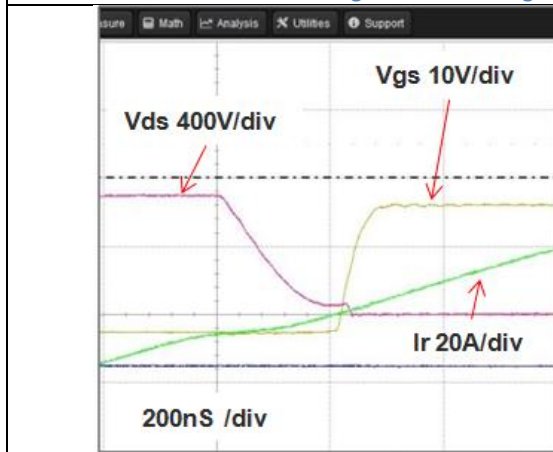


Figure 16. Detailed Turn-ON at full load.

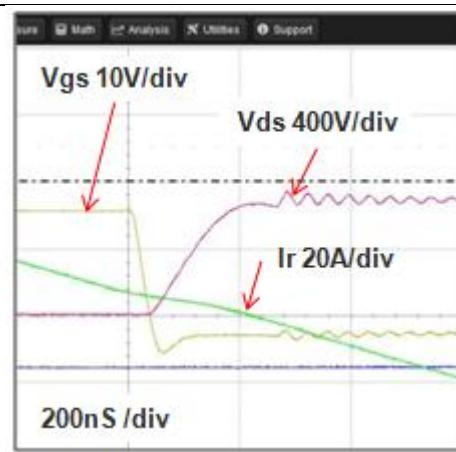
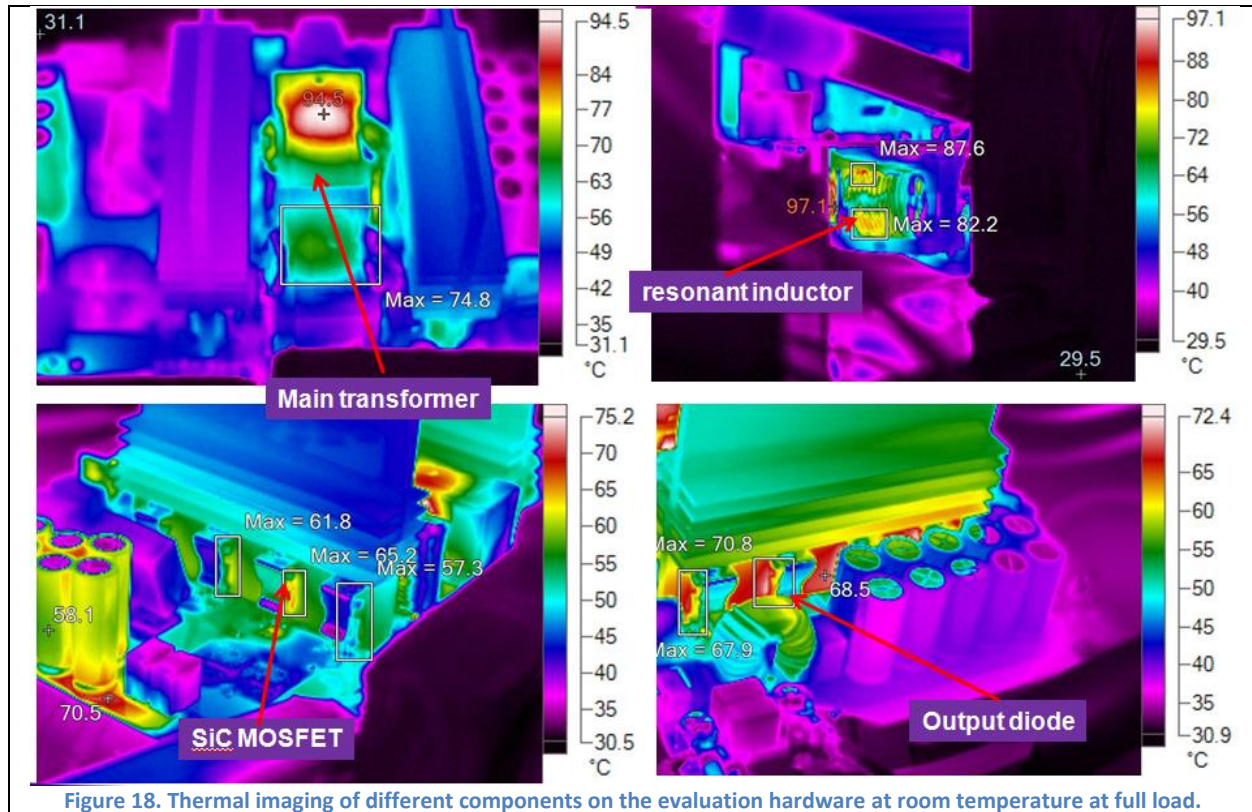


Figure 17. Detailed Turn-Off at full load.



COMPLETE DOCUMENTATION FOR THIS DESIGN, INCLUDING SCHEMATICS, THE BILL OF MATERIALS, AND GERBER FILES, ARE AVAILABLE FOR DOWNLOAD AT WWW.WOLFSPEED.COM

IMPORTANT NOTES

Purposes and Use

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

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

Operation of Board

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

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

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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 a board schematic. Users should contact Cree at sic_power@cree.com for assistance if a board schematic is not included in the Documentation or if users have questions about a board's components. When operating the board, users should be aware that these components will be hot and could electrocute or electrically shock the user. As with all electronic evaluation tools, only qualified personnel knowledgeable in handling electronic performance evaluation, measurement, and diagnostic tools should use the board.

User Responsibility for Safe Handling and Compliance with Laws

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

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

In addition, users are responsible for:

- compliance with all international, national, state, and local laws, rules, and regulations that apply to the handling or use of the board by a user or the user's employees, affiliates, contractors, representatives, agents, or designees.
- taking necessary measures, at the user's expense, to correct radio interference in the event that 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

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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 end 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, WHETHER EXPRESS OR IMPLIED. THERE IS NO REPRESENTATION THAT OPERATION OF THIS BOARD WILL BE UNINTERRUPTED OR ERROR FREE.

Limitation of Liability

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

Indemnification

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