CPWR-AN15, Rev -, 03-2016
Auxiliary Power Supply board for 7LD2PAK

CRD-060DD17P-2: Auxiliary Power Supply evaluation board for C2M1000170J SiC MOSFET

Board Summary

The CRD-060DD17P-2 is a demonstration board for a single-end Flyback converter design with a commercially available 1700V Silicon Carbide (SiC) MOSFET. The design utilizes Cree's 1700V SiC MOSFET in a new 7LD2PAK surface mount package which combines a small footprint with a wide creepage distance: 7mm between drain and source. By moving to the new surface mount package, design engineers can achieve economical thermal designs without the need for heat sink on the MOSFET. The demonstration board is not designed to be a product and is to be only used as a tool to evaluate the performance of Cree switching devices.

INTRODUCTION

Three-phase applications, such as motor drive, UPS and PV inverter, have a front end AC/DC or DC/DC converter to boost the DC link voltage up to 600Vdc to 800Vdc. Factoring in a design margin, the maximum DC link voltage is up to 1000V. To support such systems in practice, an auxiliary power supply is used to generate power for cooling fans, displays, control logic and system protection functions with the DC link voltage as its input. For such low power applications, Flyback topology is the most common type in the industry; however, the conventional single end Flyback topology has difficulty in meeting high input voltage. The first difficulty is caused by the high input voltage (1000Vdc); the single-end Flyback topology would require high blocking voltage switching devices. Currently, the Silicon MOSFET only has 1500V blocking voltage, which has low voltage stress design margin and thus affects the reliability of the power supply. The second challenge is that most of the 1500V Si MOSFETs have very large on-state resistance, and this will lead to higher losses, higher thermal and lower efficiency, especially when the whole three-phase system is operating at light output load and auxiliary power losses occupy most of total system losses. Lastly, to support a wide input voltage range, a pure resistance start up circuit is normally used. However, the start-up resistance will lead to losses at high input voltage. Larger start-up resistance will have less losses but lead to long start-up time at low input voltage.

In order to overcome these auxiliary power supply design challenges to supply high input voltage, two-switch Flyback converter was proposed to use high side and low side 800V Si MOSFETs as shown in Fig.1, but it has the additional isolation gate drive circuit which increases component counts and complicates the design. This application note proposes a single-end Flyback converter to replace complicated two-switch Flyback converter by using 1700V SiC MOSFET. An active start-up circuit is also introduced to achieve less start-up losses with faster start up time. The 60W experimental reference design demonstrates that the 1700V SiC MOSFET can reduce total cost and simplify the design of auxiliary power supply.

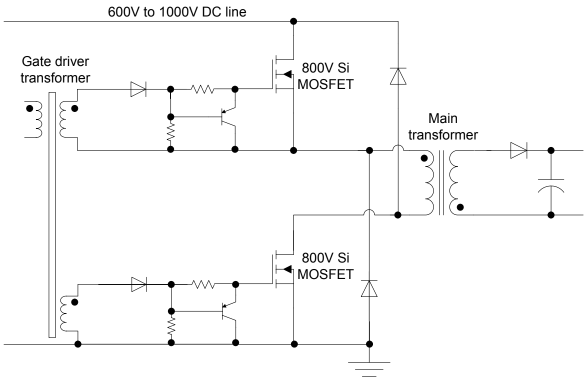


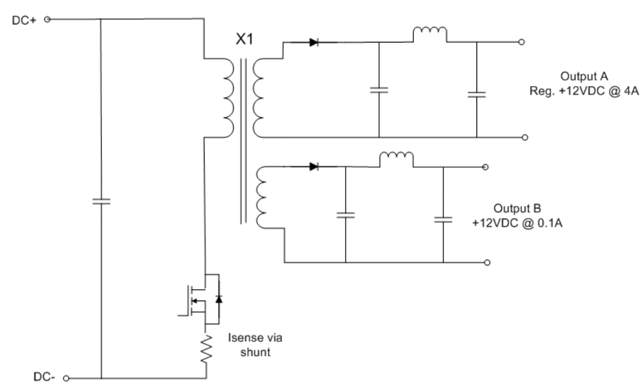
Figure 1: A conventional two-switch Flyback converter with 800V Si MOSFET

User Guide

Desription: A wide input, dual output, fly-back evaluation board designed to showcase the performance of a 1700V, 1 ohm SiC Wolfspeed MOSFET in a surface mount package (C2M1000170J).

Warning! 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.

Specifications:

Vin: 300 – 1000 VDC **Vout A:** 12V @ 4A **Vout B:** 12V @ 0.1A **Controller:** TI UCC2844D **Cooling:** Using two sided non-isolated copper pads **Pout Max.:** 48W **Size:** 120(l)x70(w)x35(h) mm **Weight:** 125 g	 **Figure 1 Basic circuit diagram.**

Input Connector: TE Connectivity 63849-1 **Output A connector:** 6 pos, Molex 22-27-2061 **Output B connector:** 4 pos, Molex 22-27-2041	 **Figure 2 Evaluation board connectors.**

The evaluation board is in a ready to use form. Please use nylon standoffs (not included) in the corner 4x Φ3.5 mm mounting holes to raise the board off the surface to avoid unintended shorts. Example stand-offs and nuts available on DigiKey P/N 36-25506-ND and P/N 36-4688-ND maybe used. A DC input source should be connected between DC+ and DC- and voltage (Vin) set within the limits of the specifications. When the DC source is turned ON the board generates 12Vdc at outputs A and B.

CAUTION

DO NOT TOUCH THE PRODUCT WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE PRODUCT. THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS EVALUATION PRODUCT WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS PRODUCT 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 product, as any of the following can occur if you handle or use this product 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 product. It is not necessary for you to touch the product while it is energized. All test and measurement probes or attachments must be attached before the product is energized. You must never leave this product unattended or handle it when energized, and you must always ensure that all bulk capacitors have completely discharged prior to handling the product.

Performance:

Basic performance and switching characteristics are shown below in Figures 3, 4 and 5. Please note that the measured data shown in the figures below are taken at the worst operating conditions when Vin = 1kV.

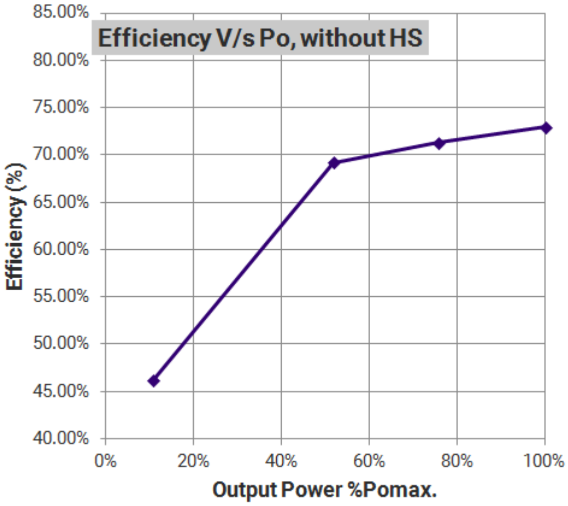


Figure 3 Efficiency versus % Pomax = 48.13W @ Vin=1kV.

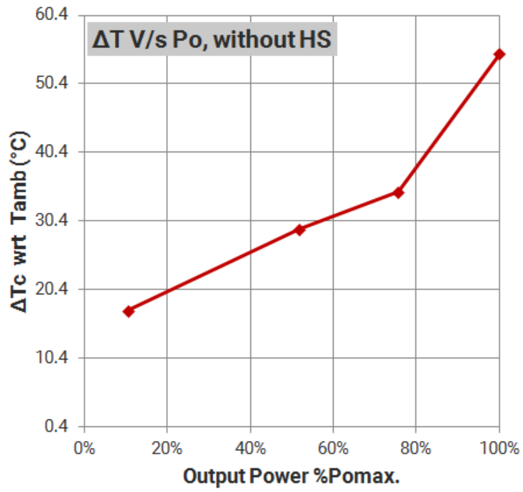


Figure 4 Temperature rise of case wrt ambient versus %Pomax=48.13W @ Vin=1kV.

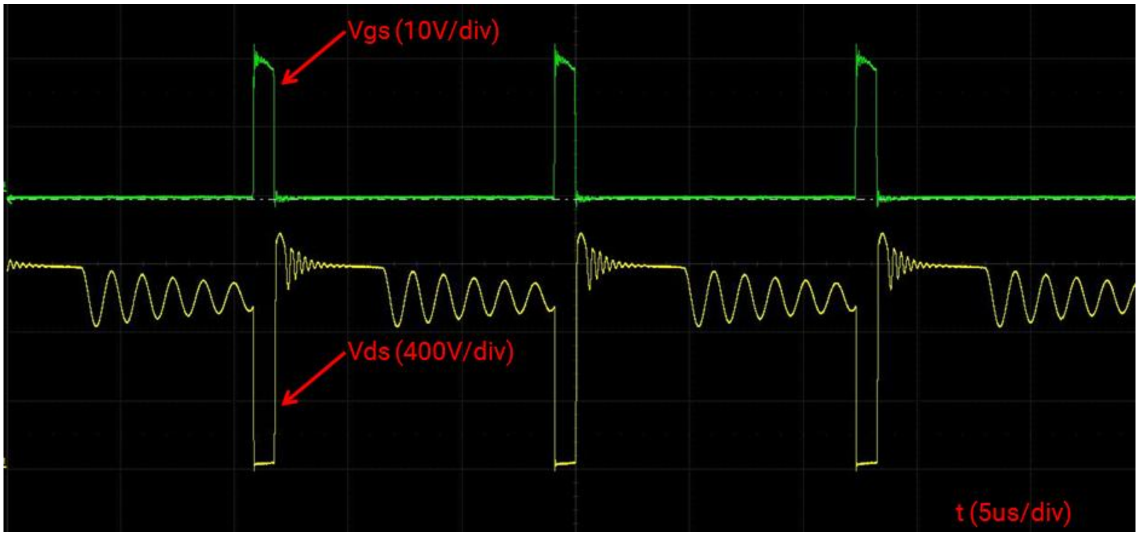


Figure 5 Switching waveforms Vgs and Vds of the SiC MOSFET.

Cooling:

Standard cooling for the primary side SiC MOSFET is using copper pads on both sides of the board interconnected using vias. Please refer to the layout files and diagram in the later sections on exact geometry and dimensions. The board uses heavier 2oz copper to improve cooling. The copper pads are not isolated from the drain tab on the MOSFET, hence is electrically hot.

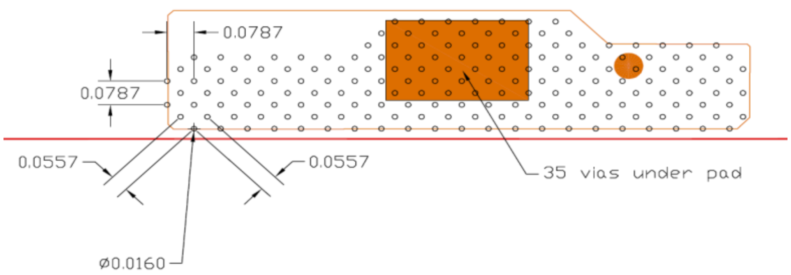


Figure 6 Basic layout of the cooling pad under the surface mount SiC MOSFET [inches].

Optionally, it is possible to increase output power with the addition of a small surface mount heat sink, like the one from AAViD P/N 573300D00010G, available via online distributors. Please note that the heat sink is not included and when mounted will be electrically hot and represents a shock hazard if handled when operating.

Figure 7 Example surface mount heat sink from AAVID.

The system is evaluated under different operating conditions with and without the optional heat sink to illustrate the difference in performance.

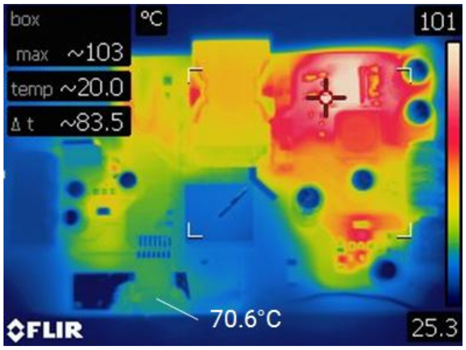


Figure 8 Vin=300V, Full load, no heat sink.

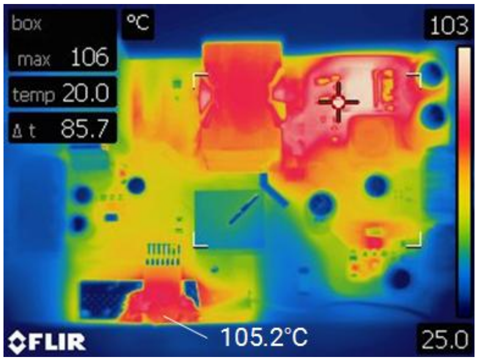


Figure 9 Vin=1kV, Full load, with heat sink.

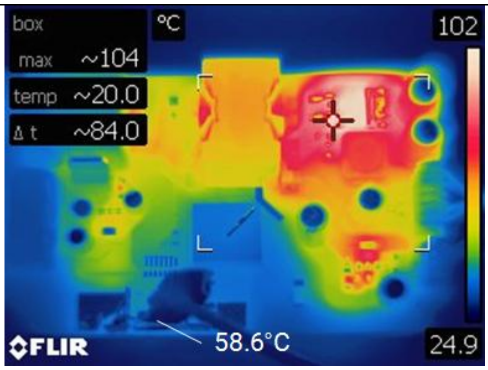


Figure 10 Vin=300V, Full load, with heat sink.

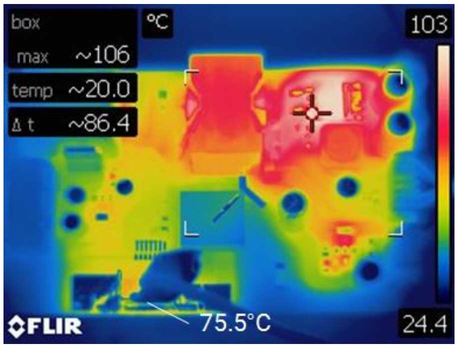


Figure 11 Vin=1kV, Full load, with heat sink.

In Figures 8-11, one can see the differences in case temperature, which is measured using a thermocouple, at low and high input voltage and at full load with and without the Aavid heat sink attached. The thermocouple used is isolated and attached to the metal tab on the 7L-D2pak of the SiC MOSFET to measure the case temperature. Also, note that the hottest component on the board is the diode on the secondary side of the transformer. It is possible to get higher output power with an up rated diode on the secondary side of the transformer.

Output power performance improves with the surface mount heat sink. Figures 12-15 show the improved performance and also compares the efficiency of the system as function of input voltage, with and without the heat sink.

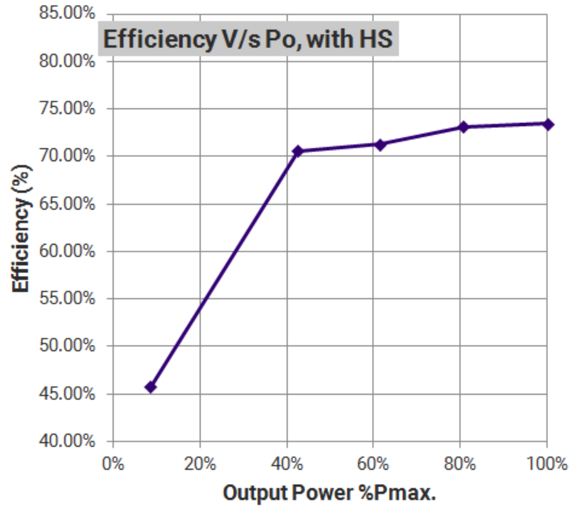


Figure 12 Efficiency Vs %Pomax=58W with heat sink.

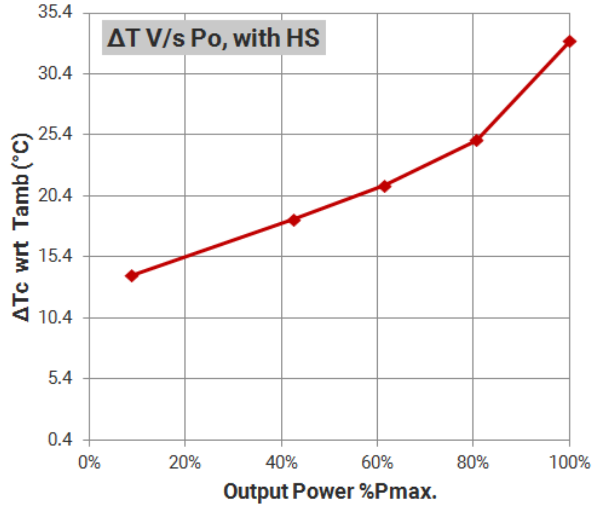


Figure 13 Temperature rise of case wrt ambient Vs %Pomax=58W with heat sink.

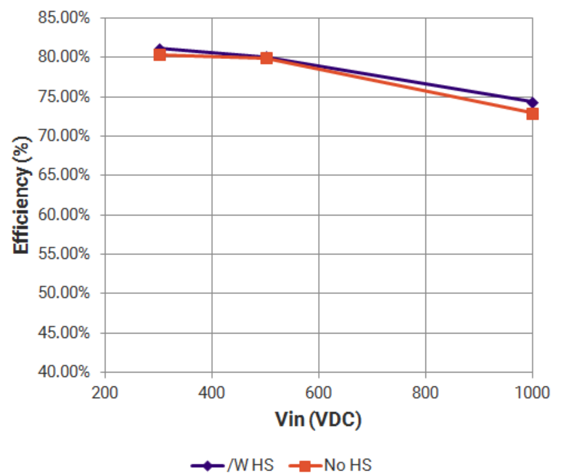


Figure 14 Efficiency Vs Vin with and without heat sink.

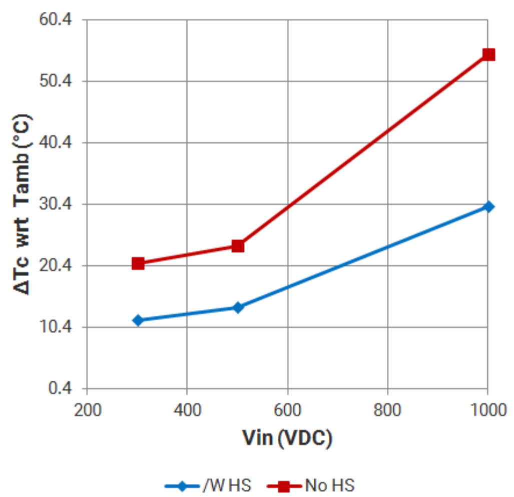


Figure 15 Case temperature rise Vs Vin with and without heat sink.

CREE

Bill of Materials:

P/N: CRD-060DD17P-2			REV: AA	Date: 12/28/15	
Iter	Qt	Locations (optional)	Description (optional)	Manufacturer Na	Manuf P/N
1	2	C201 C202	CAP FILM 1.8UF 5% 630VDC RADIAL	Panasonic	ECW-FA2J185J
2	1	C203	CAP FILM 0.22UF 5% 1.6KVDC RAD	Kemet	PHE450RD6220JR06L2
3	1	C204	CAP FILM 1200PF 5% 1.6KVDC RAD	Panasonic	ECW-H16122JV
4	5	C205 C212 C228 C233 C236	CAP CER 1UF 50V 10% X7R 0603		
5	8	C206 C217 C218 C219 C225 C226 C230 C231	CAP CER 0.1UF 50V 10% X5R 0603		
6	2	C207 C208	CAP ALUM 22UF 20% 35V RADIAL	Panasonic	EEA-GA1V220
7	1	C209	CAP ALUM 10UF 20% 50V RADIAL	Panasonic	ECEA1HKS100
8	1	C213	CAP CER 0.022UF 50V 10% X7R 0603		
9	1	C214	CAP CER 1000PF 50V 10% X7R 0603		
10	2	C215 C216	CAP CER 100PF 50V 5% C0G 0603		
11	0	C220	NC		
12	2	C221 C222	CAP CER 10000PF 50V 10% X7R 0603		
13	2	C223 C224	CAP ALUM 680UF 20% 35V RADIAL	Panasonic	EEU-HD1V681
14	1	C227	CAP ALUM 100UF 20% 35V RADIAL	Nichicon	UPB1V101MPD
15	1	C229	CAP ALUM 220UF 20% 35V RADIAL	Panasonic	EEU-EB1V221
16	1	C232	CAP ALUM 47UF 20% 35V RADIAL	Panasonic	EEA-GA1V470
17	1	C234	CAP CER 100PF 100V 5% NP0 1206		
18	1	C235	CAP CER 33PF 100V 5% NP0 1206		
19	1	C237	NC		
20	1	C238	CAP CER 0.1UF 50V X7R 1206		
21	2	CON201 CON202	Connector	TE Connectivit	63849-1
22	1	CON207	CONN HEADER 6POS .100 VERT TIN	Molex	22-27-2061
23	1	CON208	CONN HEADER 4POS .100 VERT TIN	Molex	22-27-2041
24	2	D201 D202	DIODE FAST RECOVERY 1KV 1A SMA	Diodes	RS1M-13-F
25	5	D203 D205 D206 D207	DIODE GEN PURP 100V 300MA SOD123	Diodes	1N4148W-7-F
26	1	D204	DIODE GEN PURP 200V 1.5A SMA	STM	STTH1R02A
27	1	D208	DIODE SCHOTTKY 100V 30A TO263AB	Vishay	VB30100S-E3/8W
28	1	D209	DIODE SCHOTTKY 100V 3A SMB	STM	STPS3H100U
29	1	D210	NC		
30	1	L201	3.5uH 9.25A .008Ohm	Wurth	744771003
31	1	L203	2.2 uH 20 % 2 A	Coilcraft	PFL4517-222ME
32	1	Q202	TRANS NPN DARL 1200V 0.1A TO220	STM	STP03D200
33	1	Q203	TRANS NPN 40V 0.6A SOT23		MMBT2222A
34	2	Q204 Q206	TRANS NPN 100V 5.1A	NXP	PBSS306NZ
35	1	Q207		CREE	C2M1000170J
36	6	R201 R202 R203 R204 R205 R206	RES SMD 1.5M OHM 1% 1/4W 1206		
37	8	R207 R208 R209 R210 R211 R212 R213 R214	RES SMD 51K OHM 1% 1/4W 1206		
38	3	R215 R216 R217	RES SMD 220K OHM 1% 1W 2512		
39	3	R219 R248 R249	RES SMD 100 OHM 1% 1W 2512		
40	2	R220 R221	RES SMD 1.3 OHM 1% 1W 2512		
41	1	R222	RES SMD 10 OHM 1% 1/4W 1206		
42	1	R223	RES SMD 0.0 OHM 1/4W 1206		
43	3	R224 R245 R246	RES SMD 10K OHM 1% 1/4W 1206		
44	1	R225	RES SMD 1 OHM 1% 1/4W 1206		
45	1	R226	RES SMD 51 OHM 1% 1/4W 1206		
46	3	R228 R232 R239	RES SMD 10K OHM 1% 1/8W 0603		
47	1	R229	RES SMD 11K OHM 1% 1/8W 0603		
48	2	R230 R233	RES SMD 0.0 OHM 1/8W 0603		
49	1	R231	RES SMD 2.2K OHM 1% 1/8W 0603		
50	0	R234 R218	NC		
51	1	R235	RES SMD 2.4K OHM 1% 1/8W 0603		
52	1	R236	RES SMD 5.6K OHM 1% 1/8W 0603		
53	1	R237	RES SMD 1K OHM 1% 1/8W 0603		
54	1	R238	RES SMD 39K OHM 1% 1/8W 0603		
55	1	R240	RES SMD 33K OHM 1% 1/8W 0603		
56	1	R241	RES SMD 36 OHM 1% 1/4W 1206		
57	1	R242	RES SMD 510K OHM 1% 1/10W 0603		
58	1	R243	RES SMD 4.7K OHM 1% 1/8W 0603		
59	1	R244	RES SMD 1K OHM 1% 1/4W 1206		
60	1	T201		wurth	750342480 NP1538 01
61	1	U201	IC PWM BOOST FLYBACK CM 8SOIC	TI	UC2844D8TR
62	1	U202	OPTOISOLATOR 5KV TRANSISTOR 4SM	Fairchild	FOD817ASD
63	1	U203	IC VREF SHUNT ADJ SOT23-3	TI	TL431AIDBZR
64	1	YC200	CAP CER 1000PF 760VAC Y5U RADIAL	Vishay	VY1102M35Y5UQ63V0
65	1	ZD202	DIODE ZENER 20V 500MW SOD123	Diodes	BZT52C20-7-F
66	1	ZD203	DIODE ZENER 13V 500MW SOD123	Diodes	BZT52C13-7-F
67	1	ZD204	DIODE ZENER 2V 500MW SOD123	Diodes	BZT52C2V0-7-F

Full Schematic:

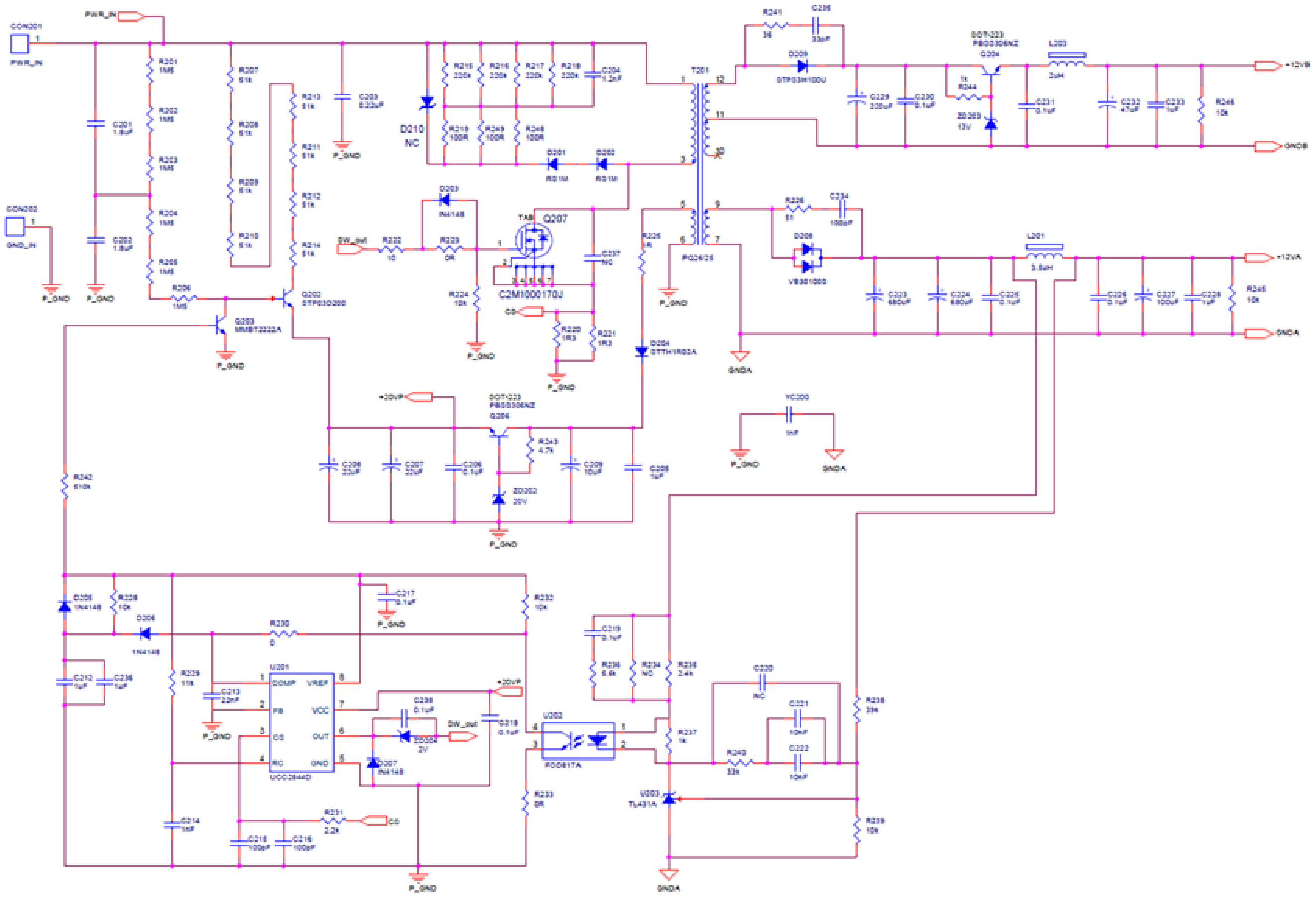


Figure 16 Complete fly-back evaluation board schematic.

Board Layout:

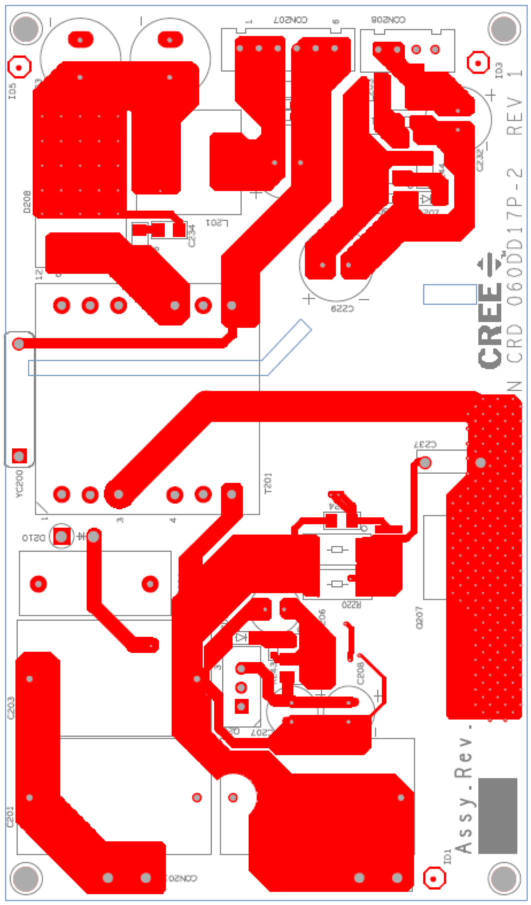


Figure 17 Top side copper.

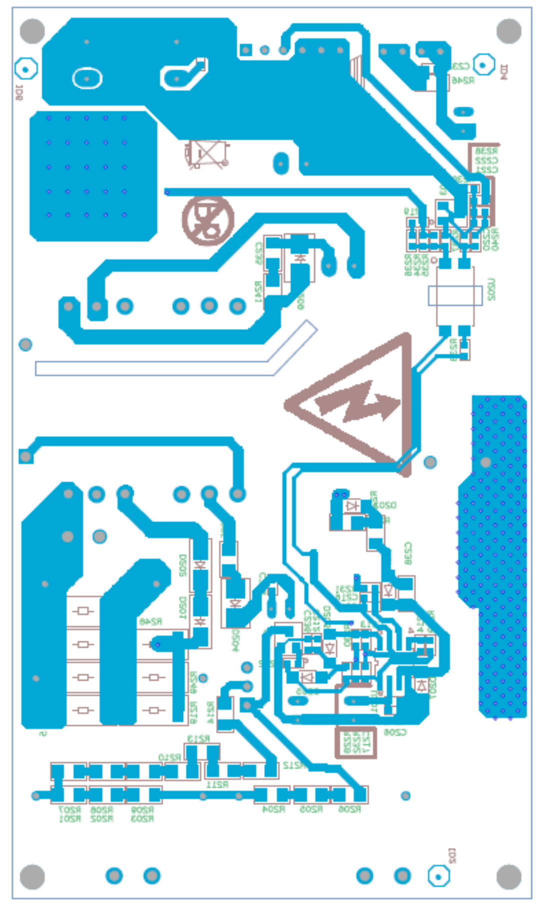


Figure 18 Bottom side copper.

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