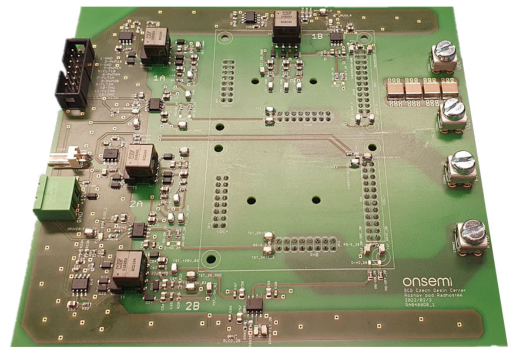
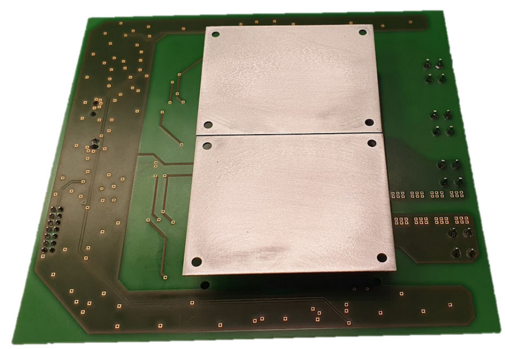
Evaluation Board for 1200 V SiC MOSFET M3S in D2PAK-7LD showing Benefit of IMS PCB User's Manual

EVBUM2838/D



Top View



Bottom View

Figure 1. Evaluation Board Photo

Evaluation Board Description

This evaluation board supports evaluation of **onsemi**'s NTBG022N120M3S 22 mΩ 1200 V SiC MOSFET in D2PAK−7LD working together with NCD57084 isolated gate drivers using a printed circuit board using IMS. These products are used in energy infrastructure applications, such as PV inverters, UPS or EV chargers to improve efficiency and power density compared with IGBT or superjunction MOSFET solutions. This manual describes the board function, board layout and comparison of the IMS PCB thermal properties with the thermal properties of a standard FR4 board. It includes details of layout, schematics, and bill of materials.

The evaluation board contains four SiC MOSFETs soldered onto an IMS PCB in a full−bridge topology. The gate driver stage consists of four NCD57084 high current galvanically isolated gate drivers. The driver provides 3 kV insulation between primary and secondary side. The gate drive voltage is supplied through an isolated DC/DC voltage source using the NCV3064.

The evaluation board can be connected to an external controller providing PWM inputs and handling fault signals. Use of an external sensor for over current and over voltage protection is recommended.

Evaluation Board Operation

The board is designed as ROHS compliant. Design of the board was not qualified for manufacturing. No tests were made on whole operating temperature range. No lifetime tests were performed. The board must be used in lab environment only and must be operated by skilled personal trained on all safety standards. Further details of used components are in their respective datasheets.

Features

- Low Thermal Resistance IMS PCB
- 4 Isolated Gate Drivers with 3 kV Insulation
- On Board NTC for IMS Temperature Sensing
- Low Inductance PCB Layout
- Modular Pinout allows Evaluation of Multiple Topologies

APPLICATIONS INFORMATION

Evaluation Board Block Diagram

The evaluation board consists of 3 PCBs as shown in Figure 2. The main PCB contains the gate driver stage, power terminals and PWM terminals. Each of the other two PCBs contains a half−bridge circuit made of 2 D2PAK−7L transistors and a decoupling capacitor soldered on an isolated metal printed circuit board. Half−bridge boards are soldered to the main board.

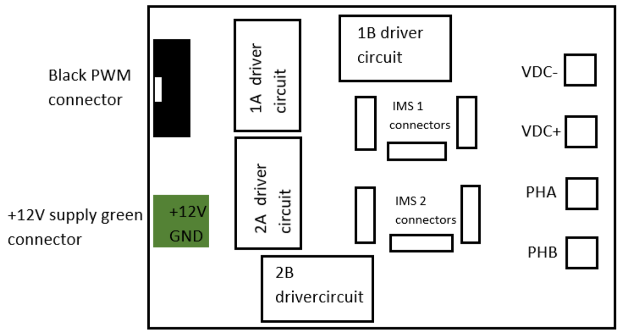


Figure 2. Simplified Block Diagram

Mechanical Dimensions

Main board outline dimensions are 138 mm x 150 mm. The board outline is shown in Figure 3. Thickness of the main board is 1.5 mm.

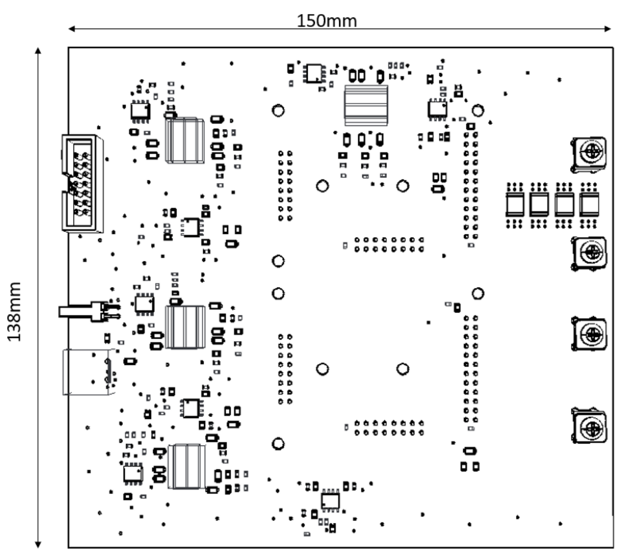


Figure 3. Main Board Dimensions

Single IMS board dimensions are 62.8 x 49.5mm. Thickness of the IMS PCB is 1 mm.

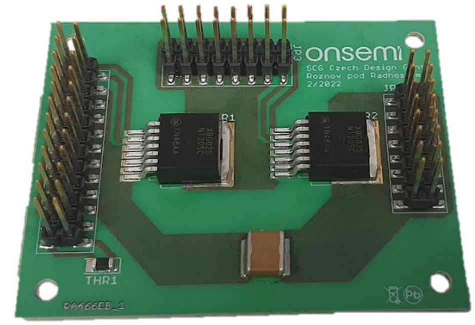


Figure 4. IMS Board Picture

PCB Stack

Driver board is a standard 4−layer FR4 PCB with 70 μm copper thickness. Halfbridge boards are IMS substrate boards to achieve low Rth_{J-H}. IMS board stack is depicted in Figure 5. Dielectric layer is 50 μm thick and allowing 4kV AC withstand voltage.

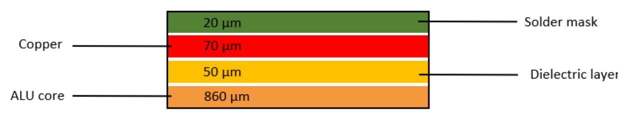


Figure 5. IMS Board Stack

Electrical Rating

The board is rated to DC voltage input 800 VDC. Nominal voltage in the DC link is 600 V. Maximum voltage in the DC link is 900 V. There is no protection for exceeding maximum DC link voltage or for reverse polarity. No inrush current limitation is present on the board.

Power Supply Connection

For the primary side of the gate drivers, the user must connect an external regulated voltage of 12 V / 1 A to connector JP1. Secondary side of gate driver is supplied through flyback DC/DC source 12 V / +18 V, −3.5 V realized with NCV3064 controller.

Connector Pinout

For connection of PWM signals into the board the connector X1 must be used. Driver UVLO faults (active low) are conencted to connector X1. Pins thermistor 1 and 2 provide singnals from the NTCs which are soldered on the IMS PCB. Connector X1 pinout is depicted in Figure 6.

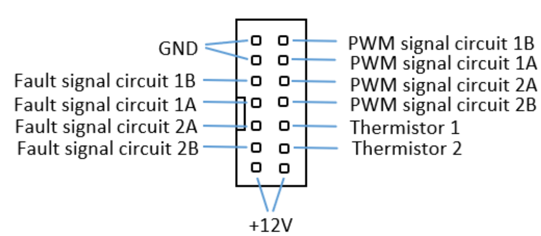


Figure 6. Connector X1 Pinout

Fault Outputs

The NCD57084 gate driver has two protection functions, READY function “RDY” and DESAT. The RDY fault is triggered by UVLO at the secondary side of the driver. RDY is active LOW. RDY fault is cleared with rising edge of input PWM signal is high and secondary UVLO condition is not present. At the first power up of the evaluation board the drivers will be in fault condition. Fault signal will be cleared with first PWM pulse. The second protection function of the gate driver desaturation protection “DESAT” is not used on this board.

NTC Temperature Sensing

The built−in NTC monitors the IMS PCB temperature of the half−bridge. The NTC is connected to terminal X1. Signal is set to correspond TTL active low at 100°C NTC temperature

Switching Losses and Double Pulse Test

The switching was tested on the board with a double pulse test. Tested was B leg, bottom MOSFET commuting with high side diode. Current was captured by Rogowski coil attached around the D2PAK legs.

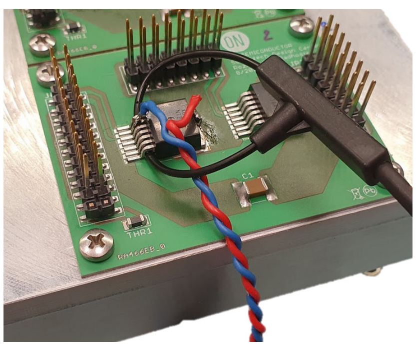


Figure 7. Double Pulse Measurement

The waveform shows no oscillation during switching. Voltage overshoot during turn−off for ~50 A switching is 109 V.

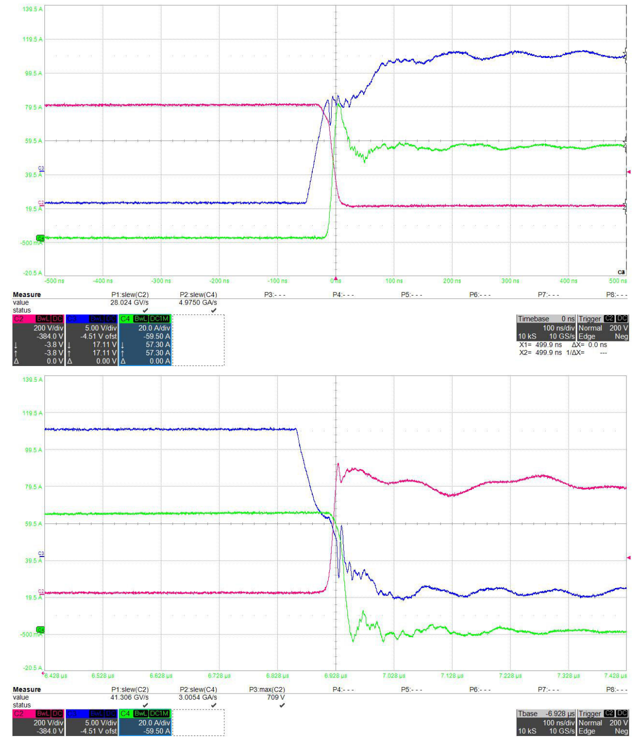


Figure 8. Switching Waveforms − Green Id, Red Vds, Blue Vgs

From the measurements switching loss was calculated at both Tj = 25°C and Tj = 125°C, measured values align well with the MOSFET datasheet. User can calculate application board power losses from Figure 9.

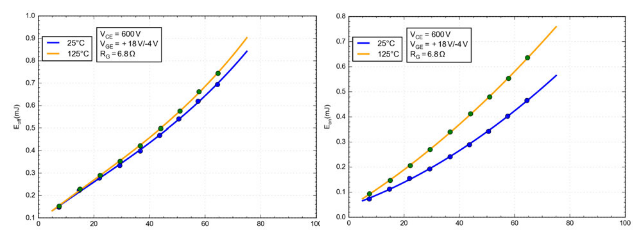


Figure 9. E_{ON} and E_{OFF} Power Losses

Board Usage

The following equipment is needed to use the board: 12 V / 1 A laboratory source, HV power supply, PWM generator, DC link. Connect 12 V to terminal XJ1 power board. Plug power source to terminal P2. Connect the load inductor to terminals PHA and PHB. Connect DC link to terminals DC+ and DC−. Connect PWM generator to the terminal XJ1. Turn on the 12 V power source. Turn on the HV power source. Start PWM operation.

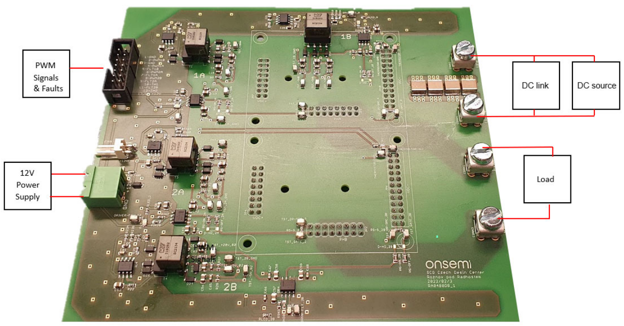


Figure 10. Board Connection

Rth Test

Temperature test was performed on two different half–bridge PCBs. First board was “standard” FR4 PCB with thermal vias underneath the D2PAK package. Second board was IMS PCB which comes with the demo board. Details of each PCB is given in Figure 11. PCB layout of FR4 board is in the Figure 12.

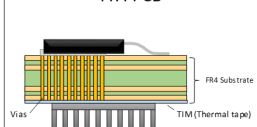
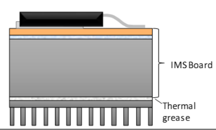
	FR4 PCB	IMS PCB
		
Thickness	1mm	1mm
Plating	70 um CU + 25 um	70 um CU + 25 um
Insulation	None – given by TIM	2kV DC
Relative price	100%	124.5%
Assembly	Difficult – soldering void	Easy
Challenge	High thermal resistance	1 layer design, coupling capacitance
Thickness	1mm	1mm

Figure 11. Rth Test PCBs

Material composition of each board is different resulting in different thermal resistance. From material parameters the thermal resistance junction to heatsink was calculated.

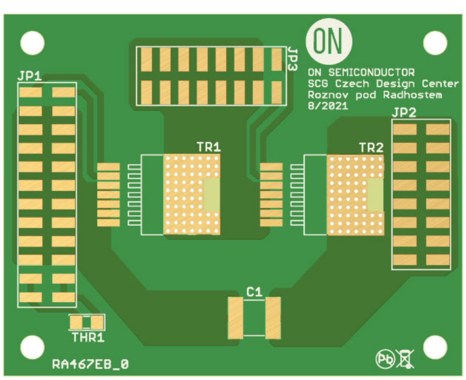


Figure 12. Layout of FR4 PCB with Thermal Vias

From Figure 13 it can be observed that the Rth_{J-H} of the IMS board is superior to that of standard FR4 PCB. The main contributor to the high Rth value is the insulation pad between the heatsink and the PCB which is needed to electrically insulate the drains of the MOSFETs.

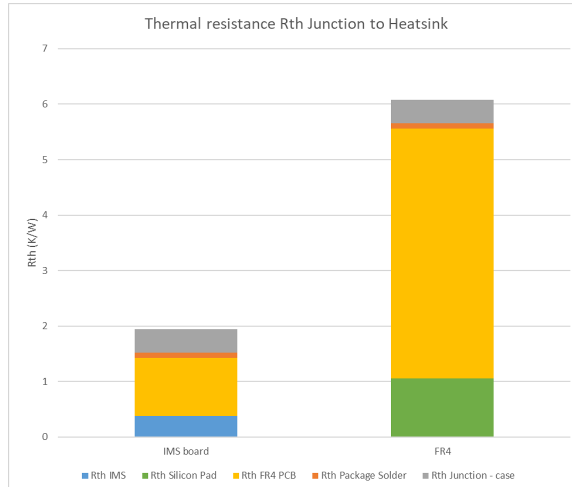


Figure 13. Calculated Rth_{J-H} for FR4 Board and IMS Board

For the test transistor an observation hole was used to measure directly junction temperature with an IR camera. The whole setup was painted black so that the measured temperatures are as close to reality as possible. Air cooled heatsink with low Rth_{H-A} was used. The half–bridge circuit on the PCB was loaded with DC current, transistors were supplied with lower Vgs than nominal in order to increase the device losses.

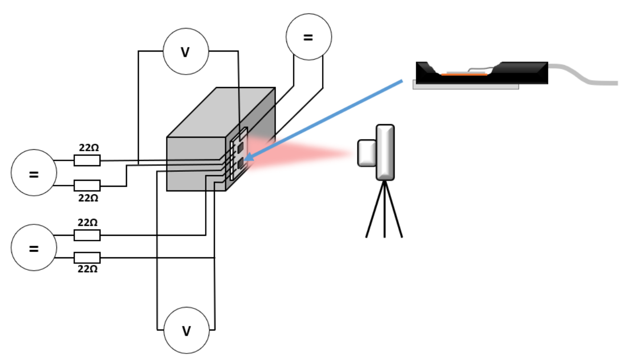


Figure 14. Measurement Setup

The thermocouple was buried inside the heatsink 1 mm under the die, so that heatsink temperature could be accurately observed. Whole system was observed with IR camera.

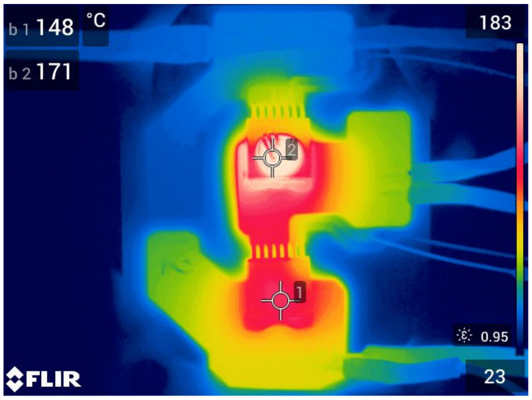


Figure 15. FR4 Board Measurement

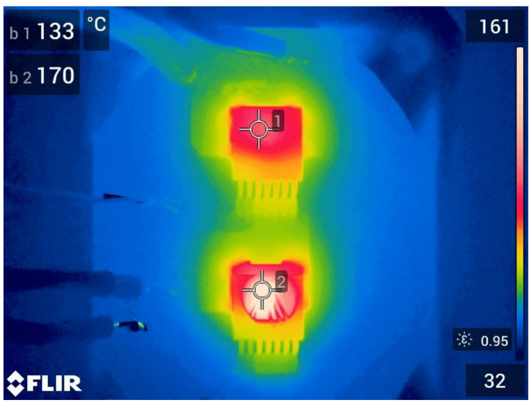


Figure 16. IMS Board Measurement (board rotated)

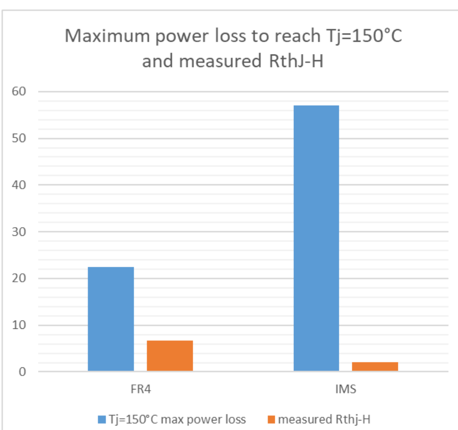


Figure 17. Power Loss to reach Tj = 150°C

By the test it was observed that maximum power loss on the device to reach 150°C junction temperature is 57 W for IMS PCB and 23 W for FR4 PCB. Measured Rthj−h for FR4 was 6.5 W/K and 2.0 W/K for IMS PCB.

For IMS PCB correlation between transistor case temperature and junction temperature was captured. So user can determine the actual Tj value based on temperature reading of the transistor mold compound.

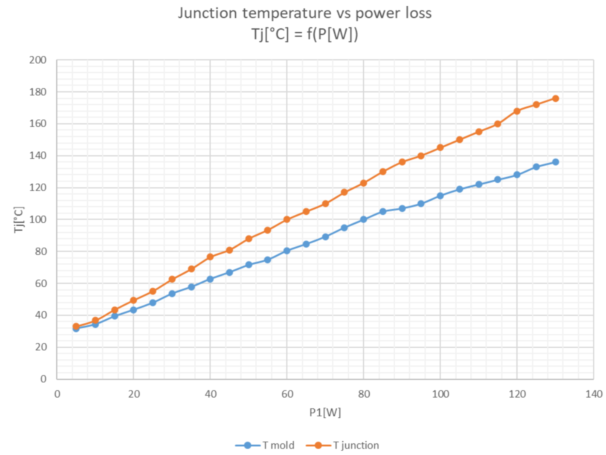


Figure 18. Power Loss to reach Tj = 150°C

Application Testing

The evaluation board was placed on a heatsink and connected to DC link and output LCL filter. PWM signals were generated from a MCU board. Test was performed in emulated application condition in a synchronous boost/buck configuration with 50 kHz switching frequency.

Power board delivered 10 A at 600 V VDC condition. Reaching case temperature of mosfet 65 degress.

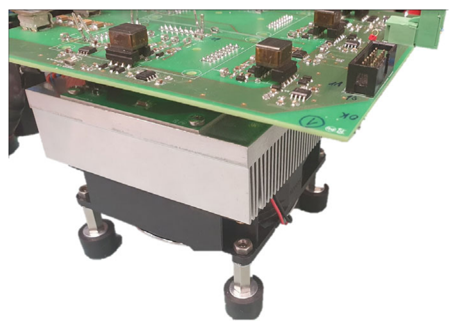


Figure 19. Application Board placed on a Heatsink

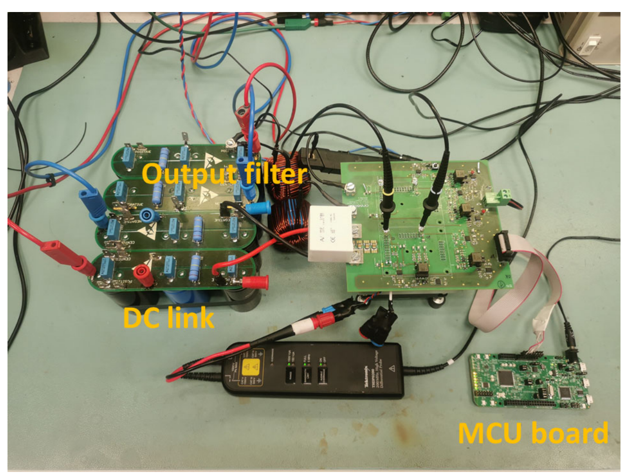


Figure 20. Application Test Setup

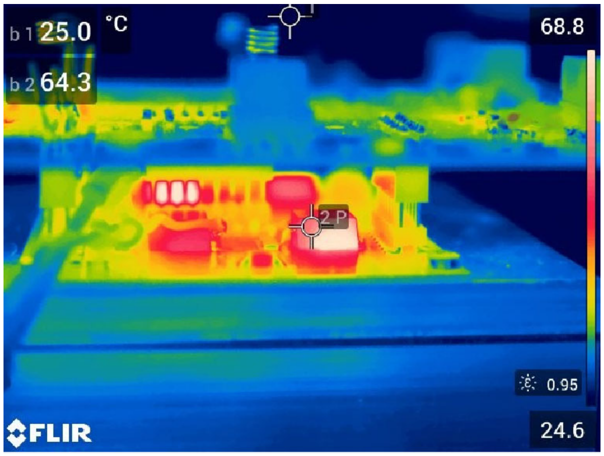


Figure 21. Temperature during Operation

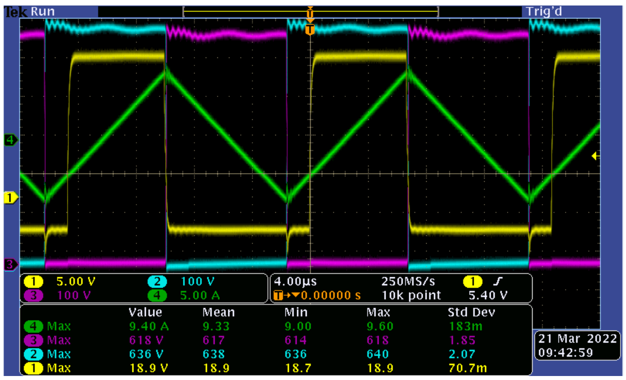


Figure 22. Application Waveform (Yellow– Vgs, Red – Vds1, Blue – Vds2, Green – Coil current)

SCHEMATICS, LAYOUT AND BILL OF MATERIAL

Schematics

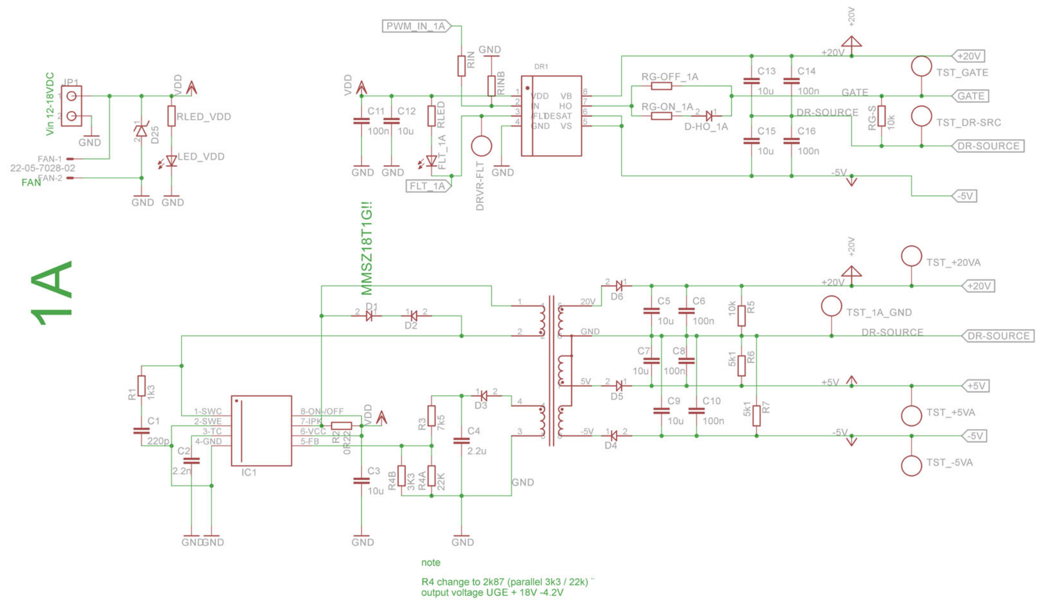


Figure 23. (1 A) Gate Driver and Flyback DC−DC Source Schematics

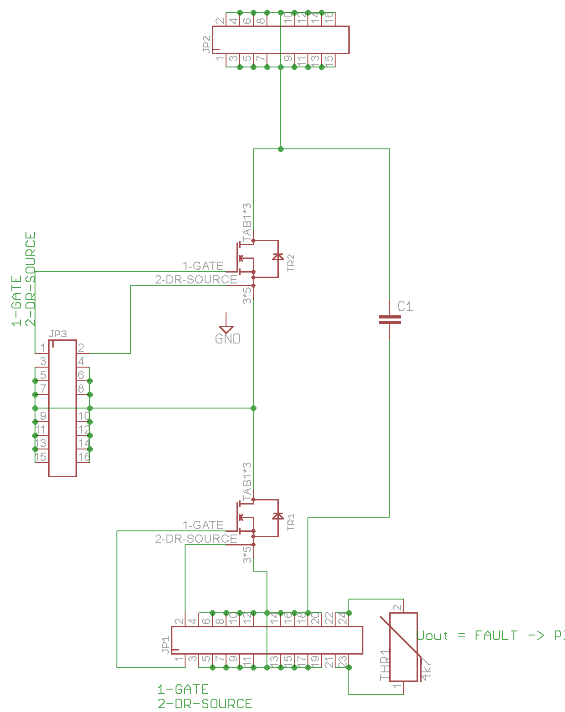


Figure 24. Power Board Schematics

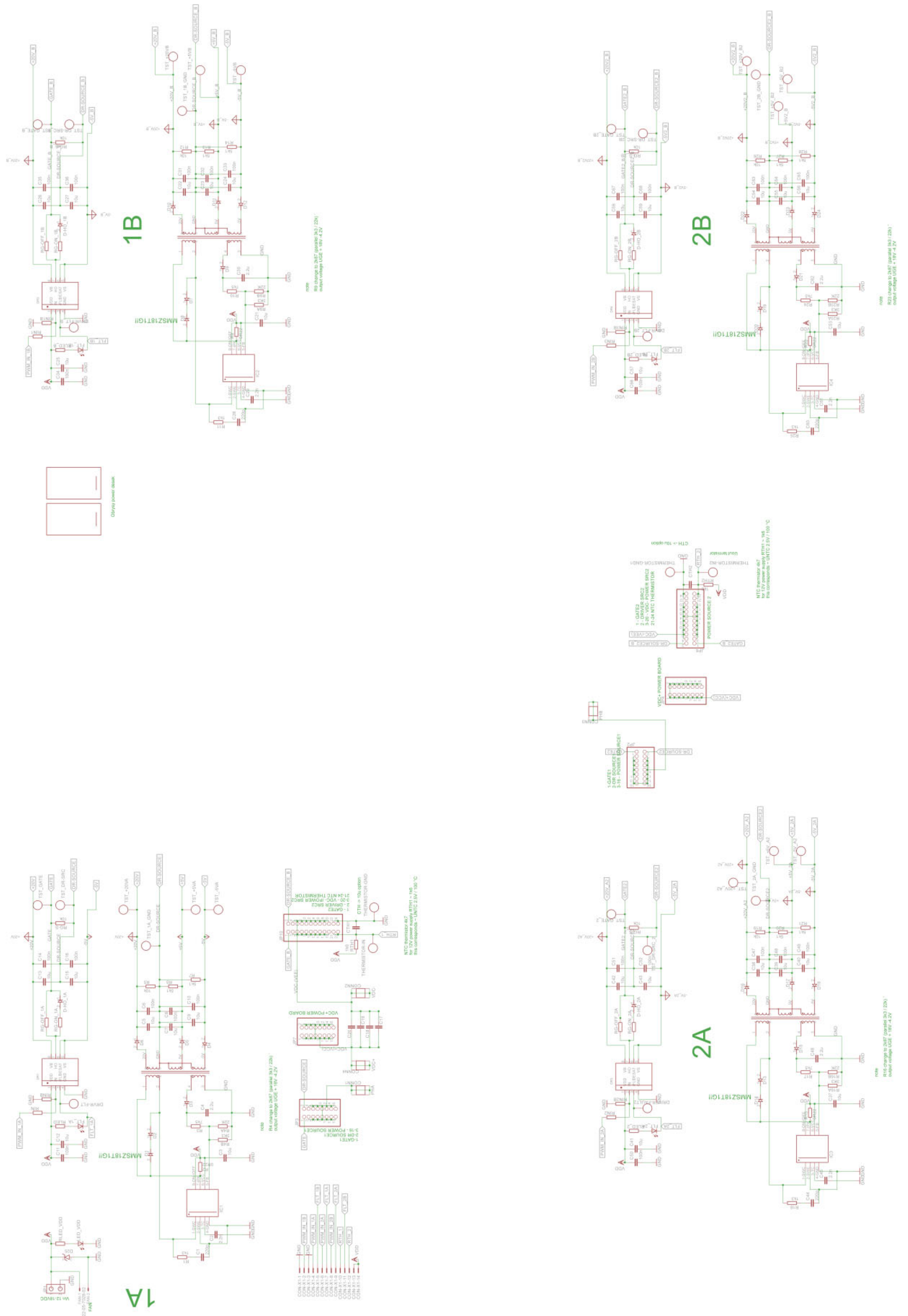


Figure 25. Complete Schematics

Layout of Driver Board

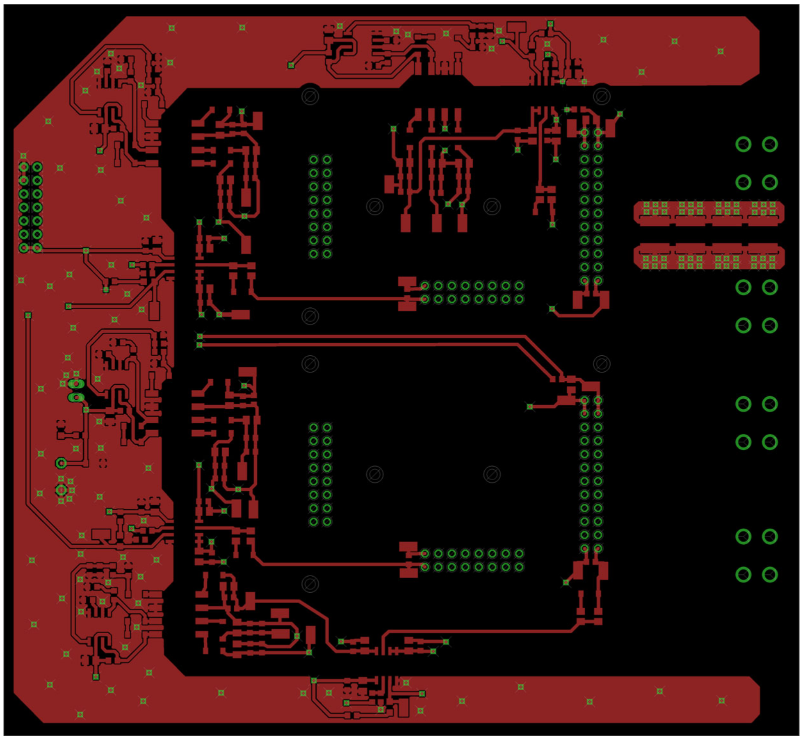


Figure 26. Top Layer

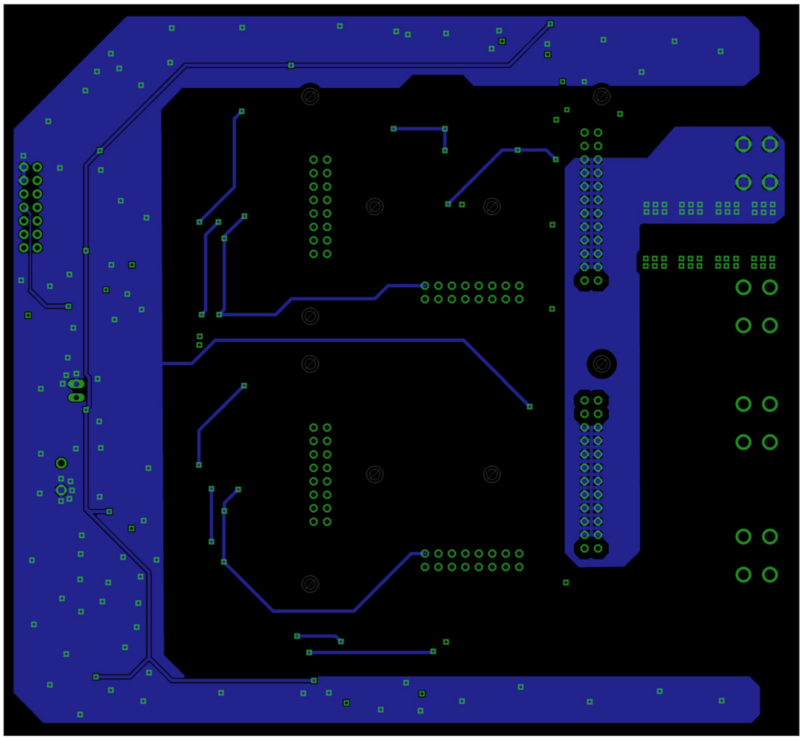


Figure 27. Bottom Layer

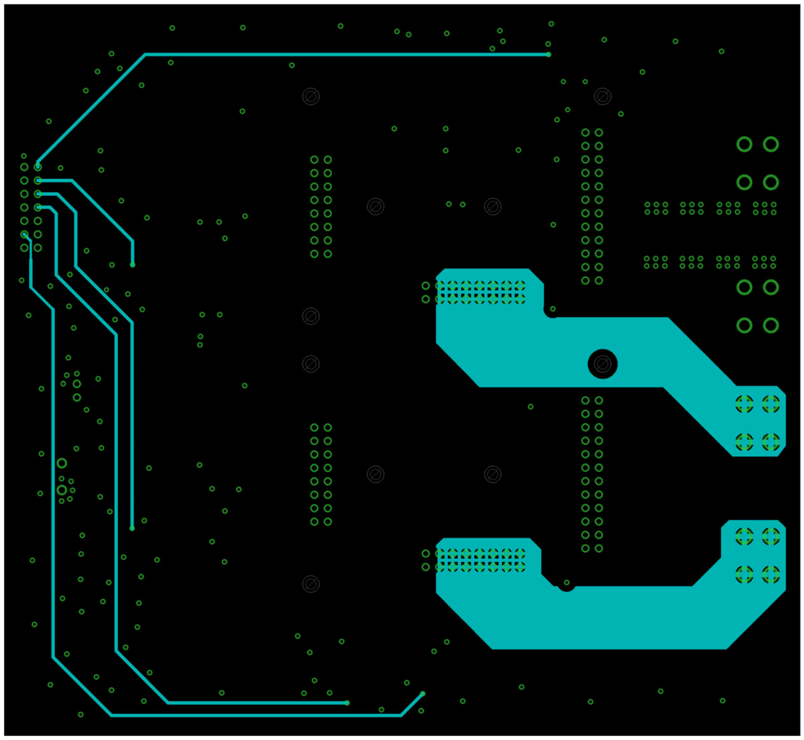


Figure 28. Signal Layer 1

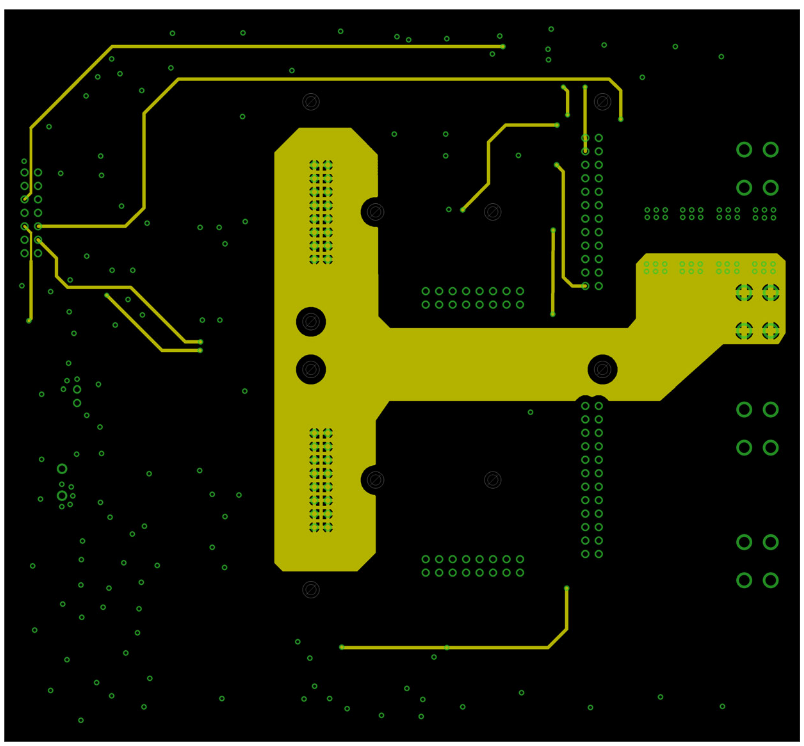


Figure 29. Signal Layer 2

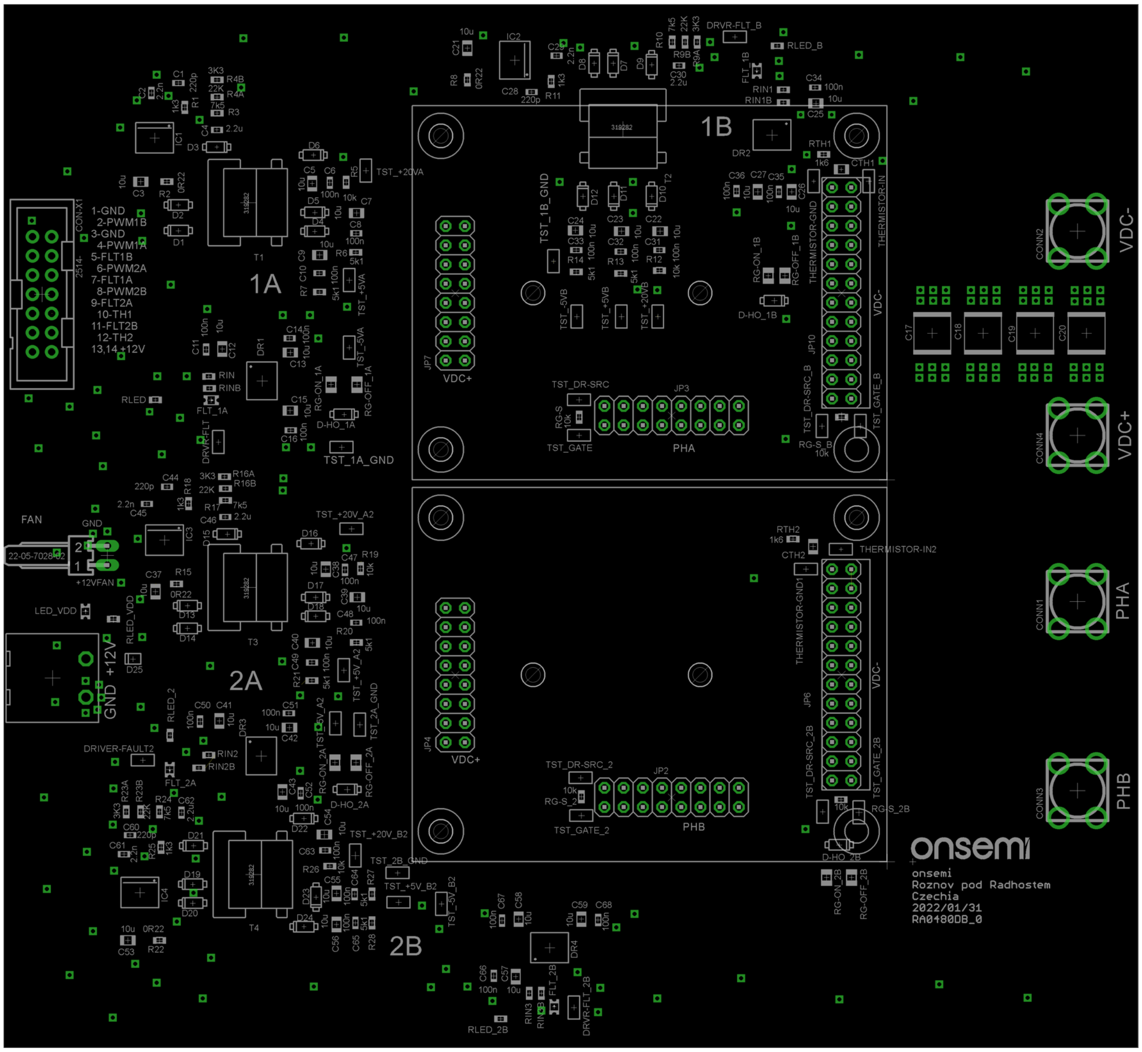


Figure 30. Assembly TOP

Layout of Power Board

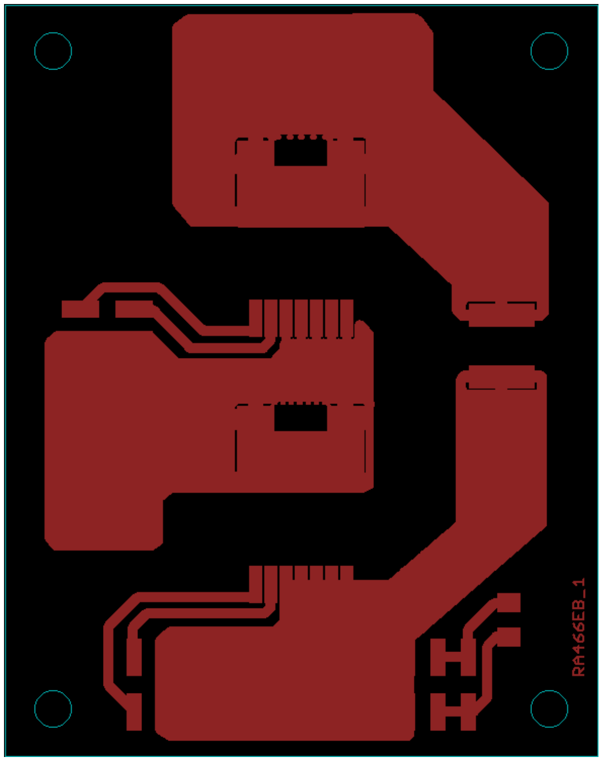


Figure 31. Top Layer

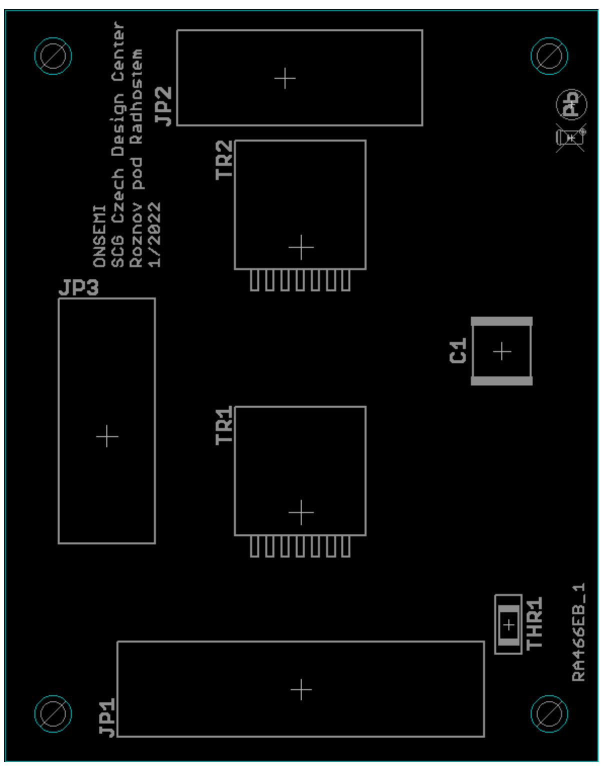


Figure 32. Assembly TOP

Table 1. BILL OF MATERIAL 2X POWER BOARD

#	Value/Name	Designator	Package	Manufacturer
2	0.1uF/ 1kV	C1	C1812X104KDRACTU	KEMET
2	PINHEADER 12x2	JP1	FTS−104−01−F−DV−P−TR	SAMTEC
4	PINHEADER 8X2	JP2, JP3	8X2−2.54MM−SMD	SAMTEC
2	NTC/4k7	THR1	NTC −1206−B57621C5	EPCOS
4	NTBG022N120M3S	TR1, TR2	D2PAK−7L−CASE−48BJ	**onsemi**

Table 2. BILL OF MATERIAL DRIVER BOARD

#	Value/Name	Designator	Package	Manufacturer
4	220p/50V	C1, C28, C44, C60	X7R 0603K	Wurth Elektronik
4	2n2/50V	C2, C29, C45, C61	X7R 0603K	AVX
28	10u/25V	C3, C5, C7, C9, C12, C13, C15, C21, C22, C23, C24, C25, C26, C27, C37, C38, C39, C40, C41, C42, C43, C53, C54, C55, C56, C57, C58, C59	X7S 0805K	TDK
24	0.1uF/25V	C6, C8, C10, C11, C14, C16, C31, C32, C33, C34, C35, C36, C47, C48, C49, C50, C51, C52, C63, C64, C65, C66, C67, C68	X7R 0603	AVX
4	100n/1000V	C17,18,19,20	C1812X104KDRACTU	KEMET
4	2.2uF/25V	C4, C30, C46, C62	X6S 0603K	Murata Electronics
2	10u/25V	CTH1, CTH2	DO NOT POPULATE	
4	1k3/1%	R1, R11, R18, R25	0603K	Panasonic
4	7k5/1%	R3, R10, R17, R24	0603K	Panasonic
4	0R22/1%	R2, R8, R15, R22	0603K	Panasonic
4	22k/1%	R4A, R9B, R16B, R23B	0603K	Panasonic
4	3k3/1%	R4B, R9A, R16A, R23A	0603K	Panasonic
16	10k/1%	R5, R12, R19, R26, RG−S, RG−S2, RG−S2B, RG−SB, RLED, RLED_2, RLED_2B, RLED_B, RIN1B, RIN2B, RIN3B, RINB, RLED_VDD	0603K	Panasonic
8	5k1/1%	R6, R7, R13, R14, R20, R21, R27, R28	0603K	Panasonic
4	100R/1%	RIN, RIN1, RIN2, RIN3,	0603K	Panasonic
8	6R8/1%	RG−OFF_1A,1B,2A,2B, RG−ON 1A,1B,2A,2B	0805/125mW	MULTICOMP PRO
2	1K6/1%	RTH1, RTH2	0603K	Panasonic
4	LED RED	FLT_1A, FLT_1B, FLT_2A, FLT_2B	LED SMD 0805 20mA, 1.9V	KINGBRIGHT
1	LED GREEN	LED_VDD	LED SMD 0805 GREEN	KINGBRIGHT
4	475uH SMD transformer	TR1, TR2, TR3, TR4	flyback converter; Uin = 15V, $Uout_1$=20V, $Uout_2$=−5V, $Uout_3$ = 5V, $Uout_4$_aux = 5V	Wurth Elektronik
4	DIODE 18V/500mW	D1, D8, D14, D20	Zener diode− MMSZ18T1G	**onsemi**
1	DIODE 15V/500mW	D25	Zener diode− MMSZ15T1G	**onsemi**
20	DIODE 60V/2A	D2, D3, D4, D5, D6, D7, D9, D10, D11, D12, D13, D15, D16, D17, D18, D19, D21, D22, D23, D24	Schottky diode − SS26FL	**onsemi**
4	DIODE 30V/2A	D−HO_1A, D−HO_1B, D−HO_2A, D−HO_2B	Schottky Barrier Rectifiers NRVBSS23FA	**onsemi**

Table 2. BILL OF MATERIAL DRIVER BOARD (continued)

#	Value/Name	Designator	Package	Manufacturer
4	NCD57084	DR1, DR2, DR3, DR4	Isolated Compact IGBT Gate Driver – SOIC−8	**onsemi**
4	NCP3064BDR2G	IC1, IC2, IC3, IC4	Boost/Buck/Inverting Converter, Switching Regulator– SOIC−8	**onsemi**
1	Connector 5.08mm/2pin	JP1	Terminal Block MSTBA 2,5/ 2-G-5,08	PHOENIX CONTACT
1	MOLEX 2.54mm/2pin	FAN	MOLEX 22−05−7028−02, Right Angle	MOLEX
4	HEADER 2x8	JP1, JP2, JP3, JP7	FEMALE HEADER 16PIN(2x8) ZL5,5−2X08 SG	HSU
2	HEADER 2x12	JP6, JP10	FEMALE HEADER 24PIN(2x12)	HSU
1	PIN HEADER 2x14	CON−X1	WR−BHD Male Box Header 2x14pin 2,54mm – 61201421621	WURTH ELEKTRONIK
4	Screw terminal	CONN1, CONN2, CONN3, CONN4	Screw terminal 3,5mm – K14−00A	DEGSON
32	Testerpad	TST…	SMD testpad S1751−46R	Harwin

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