Evaluation Board for 1200 V M3S 4-PACK SiC MOSFET Module User's Manual

EVBUM2878G-EVB

Evaluation Boards Description

Evaluation board is designed for evaluations **onsemi** 1200 V M3S (Full bridge) 4PACK modules in F2 package.

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 super junction MOSFET solutions. This manual describes the board function, board layout and application test description. It includes details of layout, schematics, and bill of materials.

Purpose of the evaluation board is double pulse switching test and open loop power test of **onsemi** full bridge modules.

Evaluation board supports **onsemi** modules:

- NXH011F120M3F2PTHG
- NXH007F120M3F2PTHG
  (module is not included in BOM)

4 PACK module is controlled by isolated single gate drivers.

The driver provides 2.5 kV RMS insulation between primary and secondary side. The gate drive voltage is supplied through an isolated DC/DC Source. The board includes an integrated DC−link with the option of assembling different types of film capacitors.

The evaluation board can be connected to an external controller providing PWM inputs and handling fault signals.

Figure 1. Evaluation Board for 4PACK Modules

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

- 4 Layer FR4 PCB with 70 μm Copper Thickness
- High Thermal Emissivity − Black PCB Color
- 4 Isolated Single Gate Drivers with 2.5 kV Insulation
- Connector Base for Input and Output Signals
- Integrated Film DC−link
- Mounting Holes for Connection Rogowski Coil and Measurement Probes
- Low Inductance PCB Layout

APPLICATIONS INFORMATION

Evaluation Board

The evaluation board contains the 4x single gate driver stage with NCD57084. Secondary side of gate drivers is supplied through an isolated 2 W DC/DC Source. Primary side +5 V, secondary side +18 V/−3 V (recommended for M3S option to replace with another voltage see BOM).

The power terminals AC1 and AC2 are center of the 4PACK for connecting the load. VDC+ and VDC− are used for external High Voltage Power source. The recommended capacity for the DC link is 180 μF (see BOM below).

For filtering high frequency, it is possible assembling snubber capacitors C1−C4 for filtering high frequency oscillations.

For AC double pulse test (DPT) is connect to inductor terminals COIL1A and COIL1B. The temperature inside the module is measured using the NTC1 and NTC2 pins. Multimeter with resistance measurement is suitable.

PCB Mechanical Dimension

PCB board outline dimensions are 275 mm x 141 mm, thickness PCB is 2mm. The board outline is shown in Figure 2. Thickness of the main board is 2.0 mm.

Holes for mechanical mounting of the heatsink are 6 x 4.2 mm. The PCB mask is black due to high thermal emissivity for measurement with thermal camera.

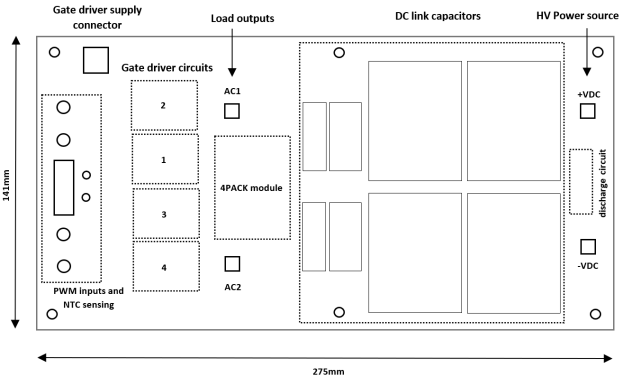


Figure 2. Simplify PCB Block Diagram

Gate Drivers – 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.

Link to datasheet: NCD57084/D

Input PWM Signals

Input signals are connected to SMA connectors IN1− IN4 or to relevant PIN heather marked INPUTS.

Pin layout is on Figure 3.

For input signals can be used external signal generator or microprocessor development board.

Input voltage level PWM according to datasheet:
V_{IL} Low Input Voltage 0–1.5 V
V_{IH} High Input Voltage 3.5–5 V
(V_{CC} voltage is +5 V)

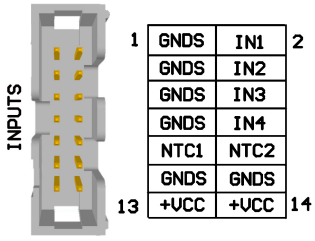


Figure 3. Connector INPUT Pin Layout

Electrical Rating

The board is rated to DC voltage input 800 Vdc. Maximum voltage in the DC link is 1000 V. There is no protection for exceeding maximum.

DC link voltage or for reverse polarity. No inrush current limitation is present on the board.

Be especially careful when working under high voltage during measurement. The DC link remains under Voltage several minutes after disconnecting the HV source. Discharge is provided by resistors R1−R24.

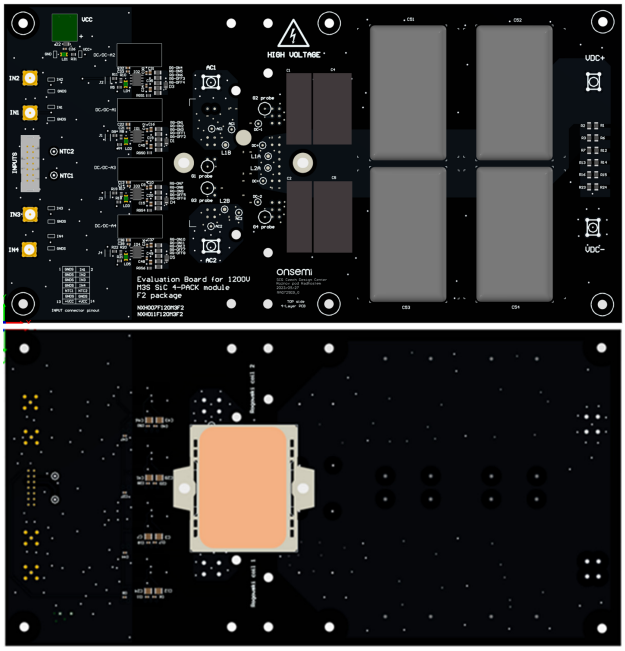


Figure 4. TOP and BOTTOM View Eval. Board

NTC Thermistor Sensing

The built−in NTC resistor monitors temperature inside module. Eval. board marked connectors NTC1 and NTC2.

The resistance value corresponds 5 kΩ at 25°C.

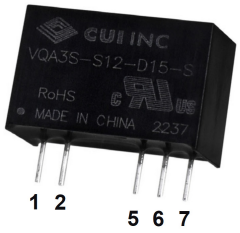
Table 1. VALUE OF RESISTANCES AT DIFFERENT TEMPERATURE

Temp (°C)	Typ. Resistance (kΩ)	Temp (°C)	Typ. Resistance (kΩ)
−40	99.09	75	0.968
−25	44.44	100	0.493
0	13.72	125	0.271
25	5	150	0.159
50	2.083	175	0.099

Isolated DC−DC Driver Converter

Eval. board contains four separate DC−DC converters for supply secondary side of the drivers.

For driving **onsemi** 4PACK M3S modules is recommended gate driving −3 V/18 V.



PIN CONNECTIONS	
1	V_{IN+}
2	V_{IN-}
5	V_{OUT-}
6	0V
7	V_{OUT+}

Figure 5. Pin Out DC−DC Converter CUI VQA3S−S5−D18−S

Gate Resistance − R_G

The choice of optimal value gate resistor is compromise between switching losses and VDS overshoot.

Low R_G value − high switching speed, low losses, higher VDS overshoot

High R_G value − low switching speed, higher losses, lower VDS overshoot

Recommended value:

NXH007F120M3F2PTHG − RG_{ON} = 2R2

NXH011F120M3F2PTHG − RG_{ON} = 3R9

(Assembled with RG_{ON} = 3R9, RG_{OFF} − not populate)

Resistor type is for pulse withstanding in SMD 1206 package. Eval. board allows assembled more pieces in parallel for better heat distribution.

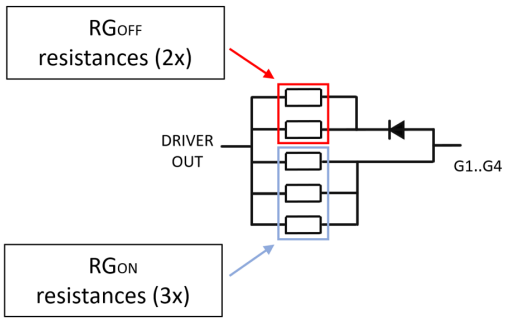


Figure 6. Gate Resistances Schematic

1200 V M3S 4PACK SIC MOSFET Module

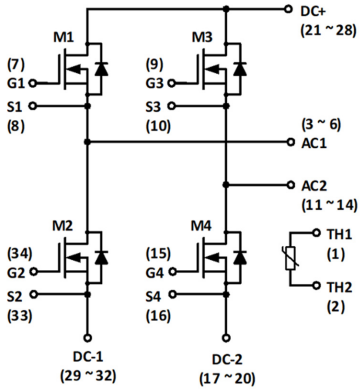
Full bridge power modules containing 1200 V SiC MOSFET and NTC thermistor with HPS DBC.

onsemi offers in F2 package two R_{DS-ON} variants with same pinout.

1200 V 7 mΩ variant: NXH007F120M3F2PTHG

1200 V 11 mΩ variant: NXH011F120M3F2PTHG

Link to datasheets: datasheets



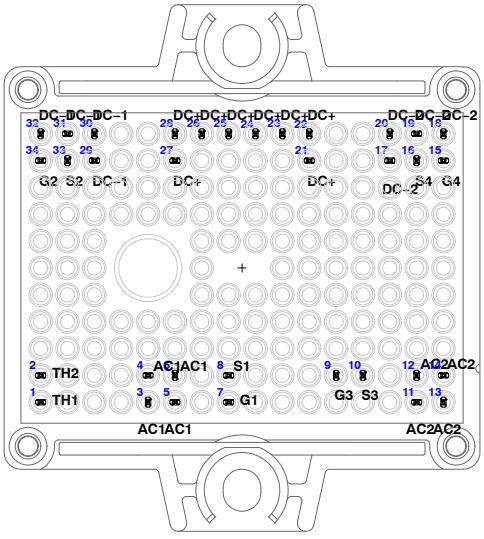


Figure 7. 4PACK Module Schematic and Pinout

EVALUATION TESTING

1) AC − Double Pulse Test

Switching AC test was performed with module NXH011F120M3F2PTHG.

Tested was half bridge LEG1 with M1, M2 switch. LEG2 half bridge is closed.

LOW side M2 MOSFET commuting with M1 high side body diode. Input pulse signal is connected to connector IN2 for LOW side switch M2. The IN1 connector for HIGH side switch is not connected (Gate Voltage M1 switch is −3 V). For better oscillation immunity is recommended short jumper J3 and J4.

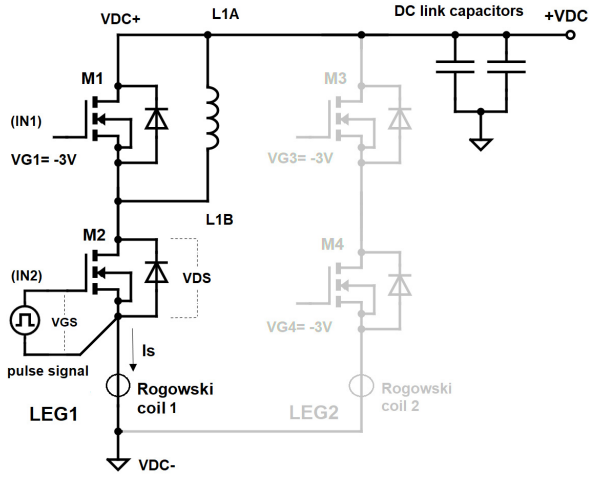


Figure 8. Double Pulse Test Schematic

Current was captured by Rogowski coil attached through the DC−1 pins. Mounting details of fixing the Rogowski coil to PCB, see Figure 11. probe type CWT MINI HF3R − picture on the left, iwatsu SS−685 − on the right. For high measurement accuracy is recommended probe with a high bandwidth.

Measurement Process

Connect the V_{GS}, V_{DS} probes and the Rogowski coil according to the picture. In the next step, connect the Load inductor to terminals L1A and L1B. Signal pulse generator to connector IN2. Plug +5V to terminal VCC and HV source to terminal VDC+ and VDC−.

Turn on the 5V power supply and start PWM operation. Increase the voltage of the HV source and monitor the V_{GS}, V_{DS} and I_D waveforms on the Oscilloscope.

For measurement in temperature >25°C is used hotplate. Temperature inside the module is monitored on the pins NTC1 and NTC2.

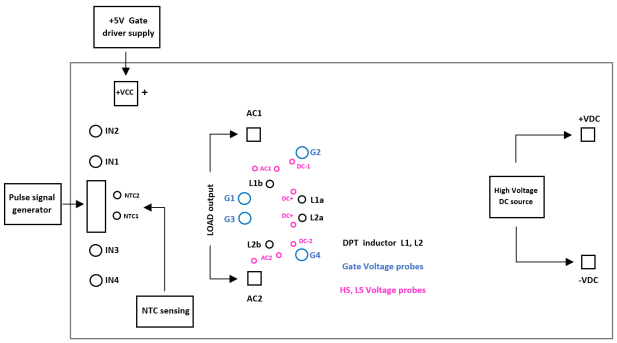


Figure 9. Board Connection

Table 2. DOUBLE PULSE TEST CONDITION

Voltage Supply V_{DC}	800 V
Drain Current I_D	> 180 A
Hotplate Temperature	T_j = 25°C, 125°C, 150°C
Gate Voltage	V_{GS} = 18/−3 V
Signal Generator	10 pulse, 30 kHz, PW = 4 μs
DPT − Load Inductor	105 μH @ 30 kHz
Gate Resistor	R_G = 3.9 Ω

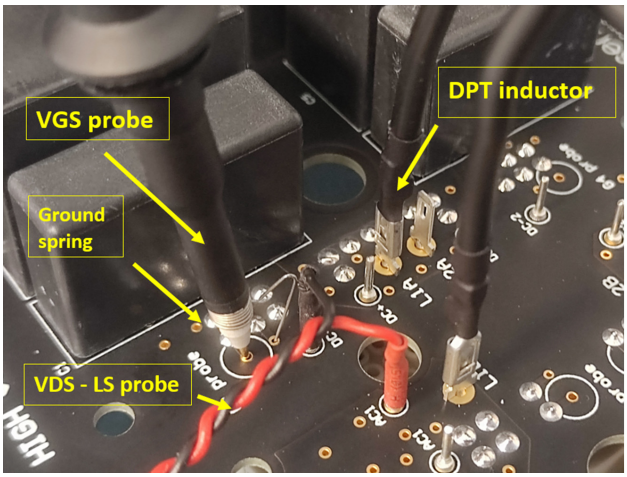


Figure 10. Double Pulse Test Probes

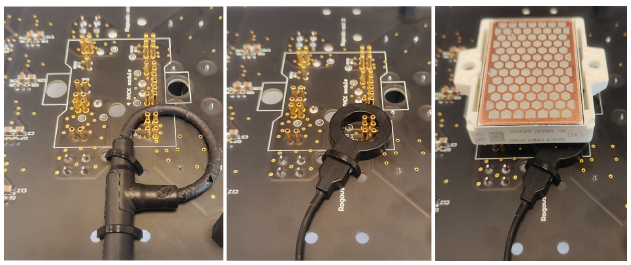


Figure 11. Mounting Detail Rogowski Coil to PCB

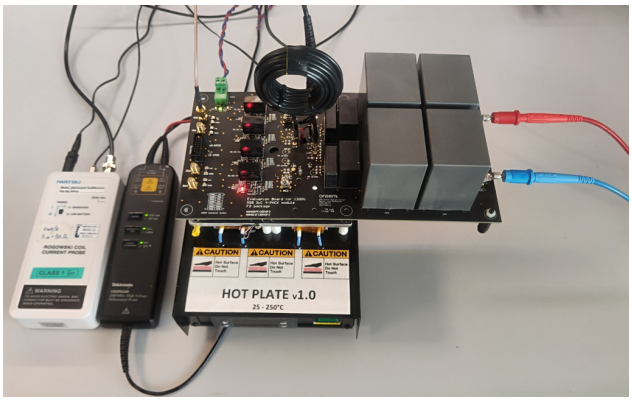


Figure 12. Double Pulse Test SETUP

Switching Waveforms, Losses

DPT test was performed with R_G = 3R9. The waveform does not show any large oscillations during switching. Voltage overshoot during turn is ≈ 177 V, current is ≈ 185 A.

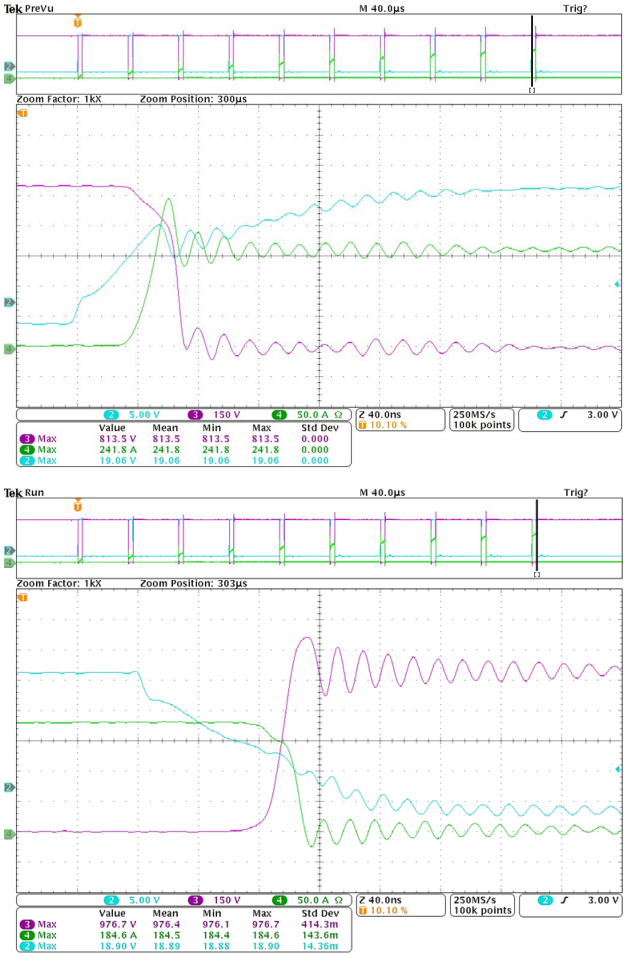
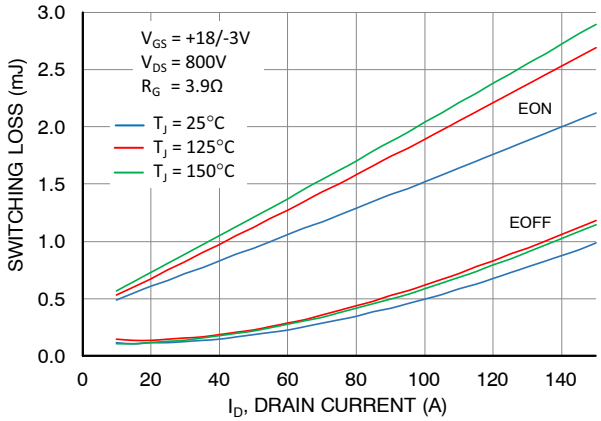


Figure 13. Turn ON, Turn OFF Typical Waveforms.
T_j = 25°C (Green I_D, Red V_{DS}, Blue V_{GS})



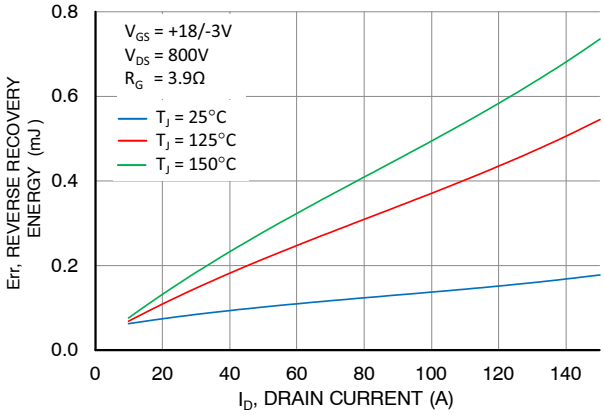


Figure 14. E_{ON}, E_{OFF}, E_{RR} SWITCHING LOSS for NXH011F120M3F2PTHG

2) Load Continuous Test

Load test was performed with module NXH011F120M3F2PTHG.

The module is mounted on the aluminum heatsink 25 x 20 x 5 cm, R_{TH} = 0.2 K/W with active cooling.

Load inductor is connected to output terminals AC1 and AC2. PWM signals were generated from a MCU board. Output was a rippled current generated by a hard switching using 30 kHz switching frequency. Evaluation Board delivered 52 A at 600 V condition, reaching NTC condition 121°C in Power Integrated Module.

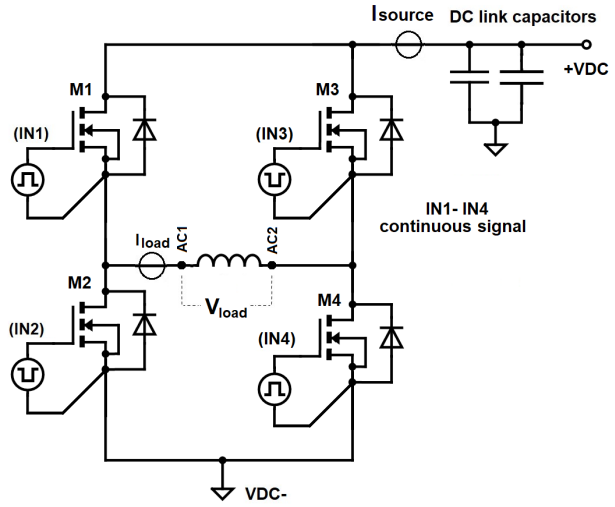


Figure 15. Load Test Schematic

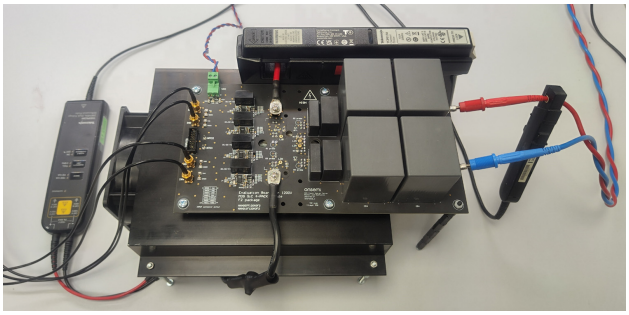


Figure 16. Load Test SETUP

Table 3. OPERATION CONDITION FOR 4PACK TEST

V_{DC} Link	600 V
I_S Current Source	685 mA
Load Current	52.3 A
POWER	31.3 kW
NTC Temperature	≈ 121°C (Steady State)

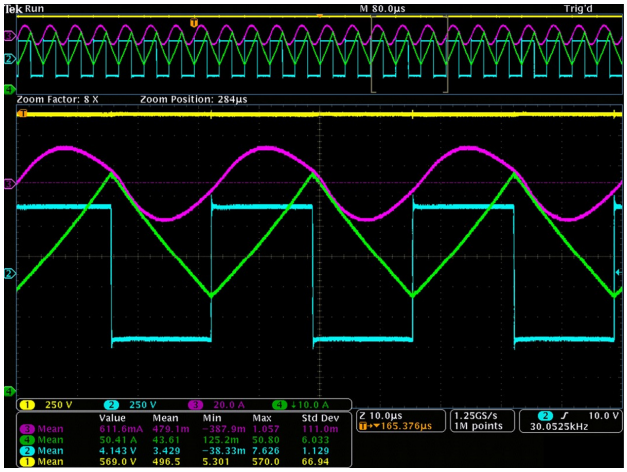


Figure 17. Oscilloscope Waveforms
(Yellow V_{DC} link, Red I_C current source, Green I_{Load}, blue V_{Load})

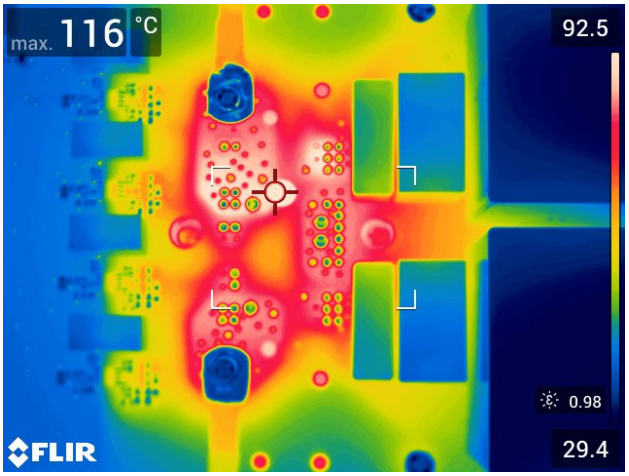


Figure 18. PCB Temperature during Operation

SCHEMATIC

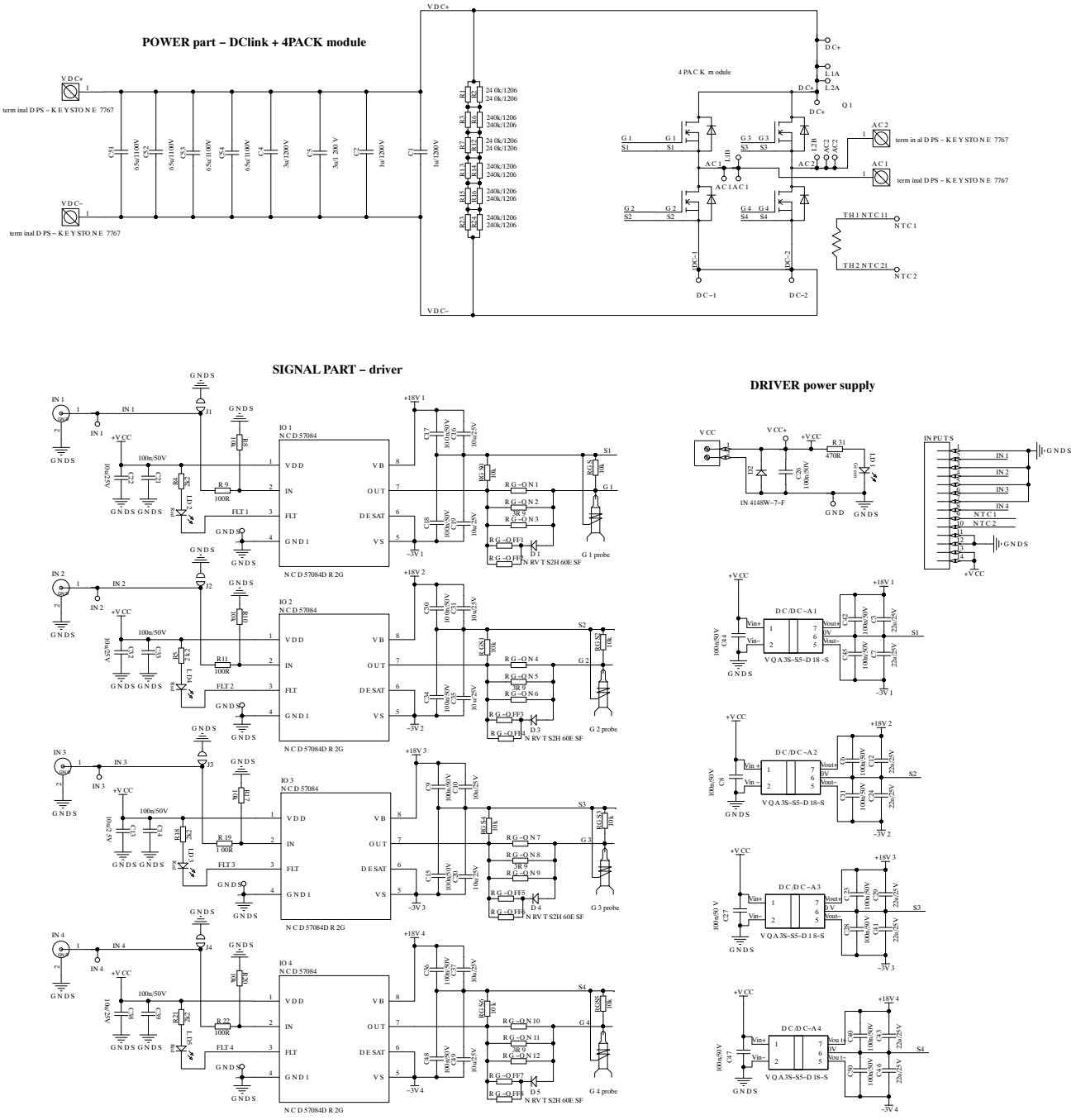


Figure 19. Complete Schematics

LAYOUT OF EVALUATION BOARD

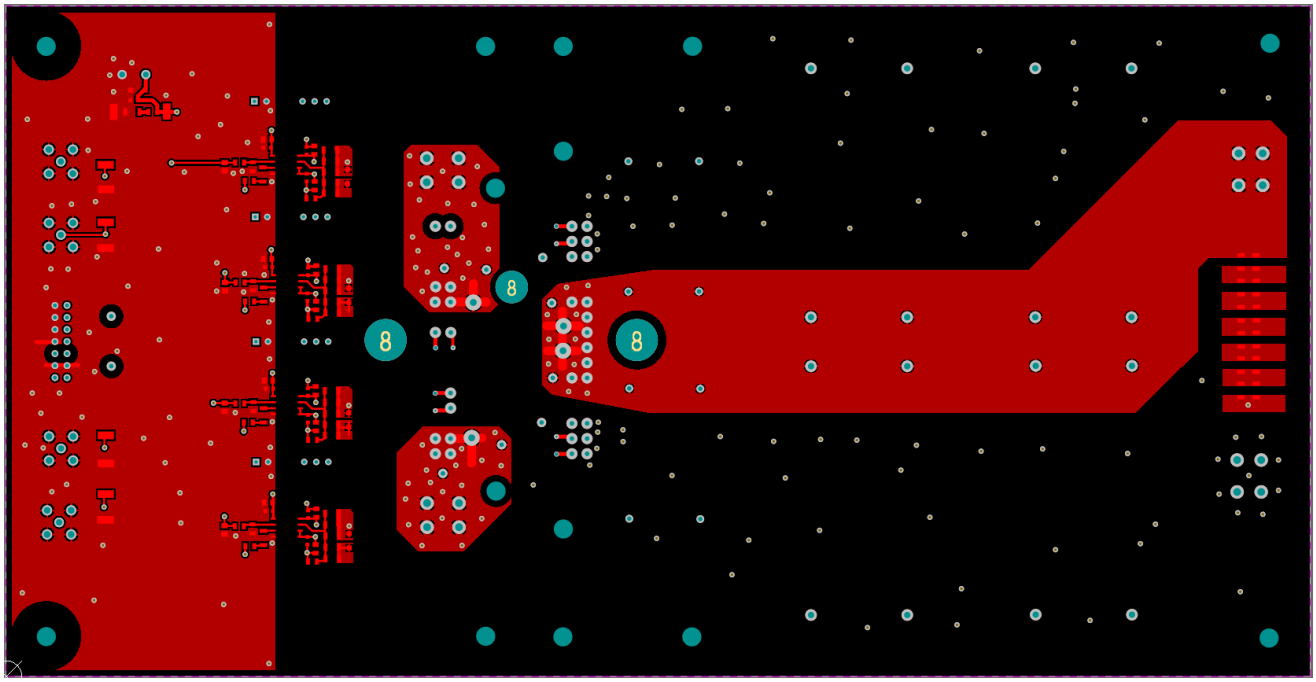


Figure 20. TOP Layer

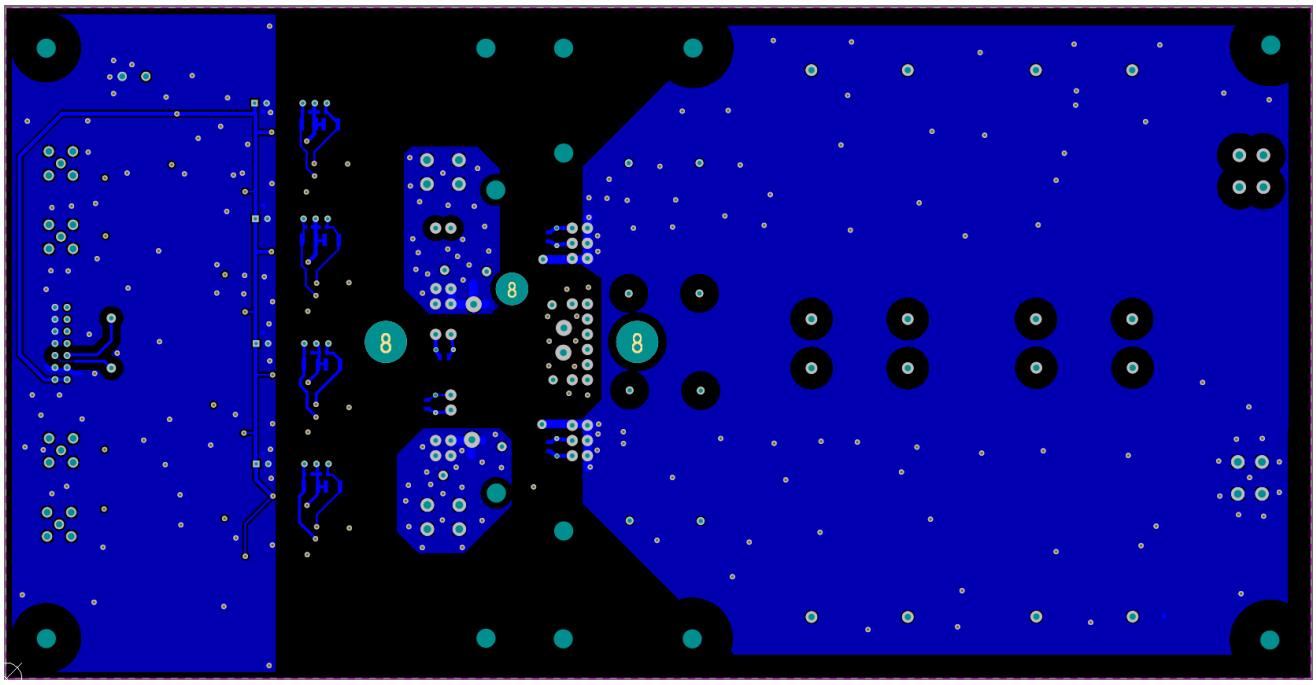


Figure 21. BOTTOM Layer

LAYOUT OF EVALUATION BOARD (CONTINUED)

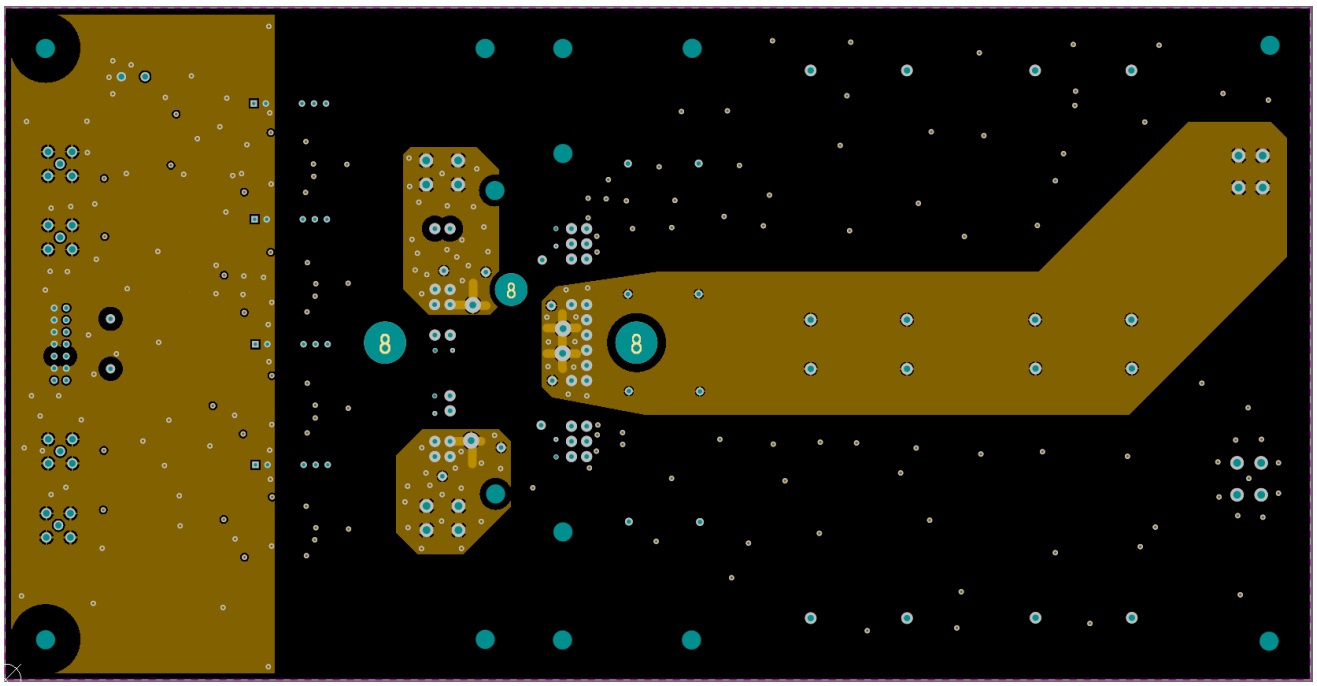


Figure 22. Signal Layer 1

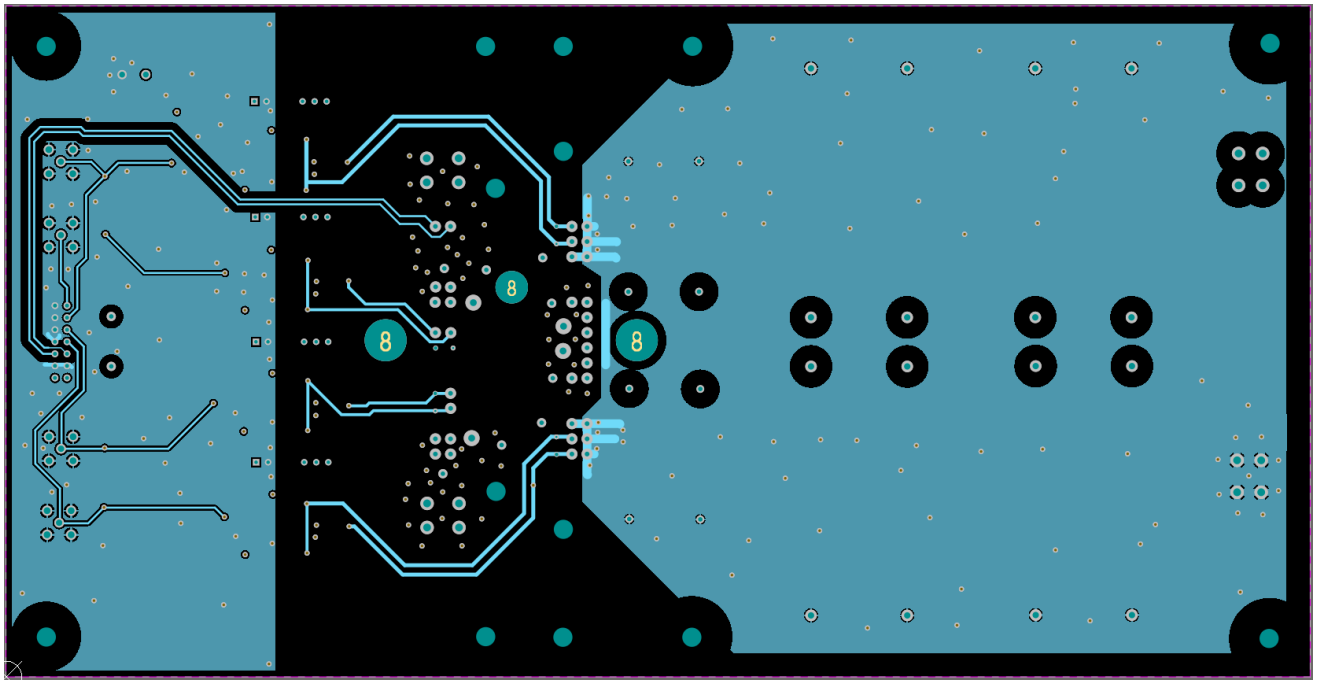


Figure 23. Signal Layer 2

LAYOUT OF EVALUATION BOARD (CONTINUED)

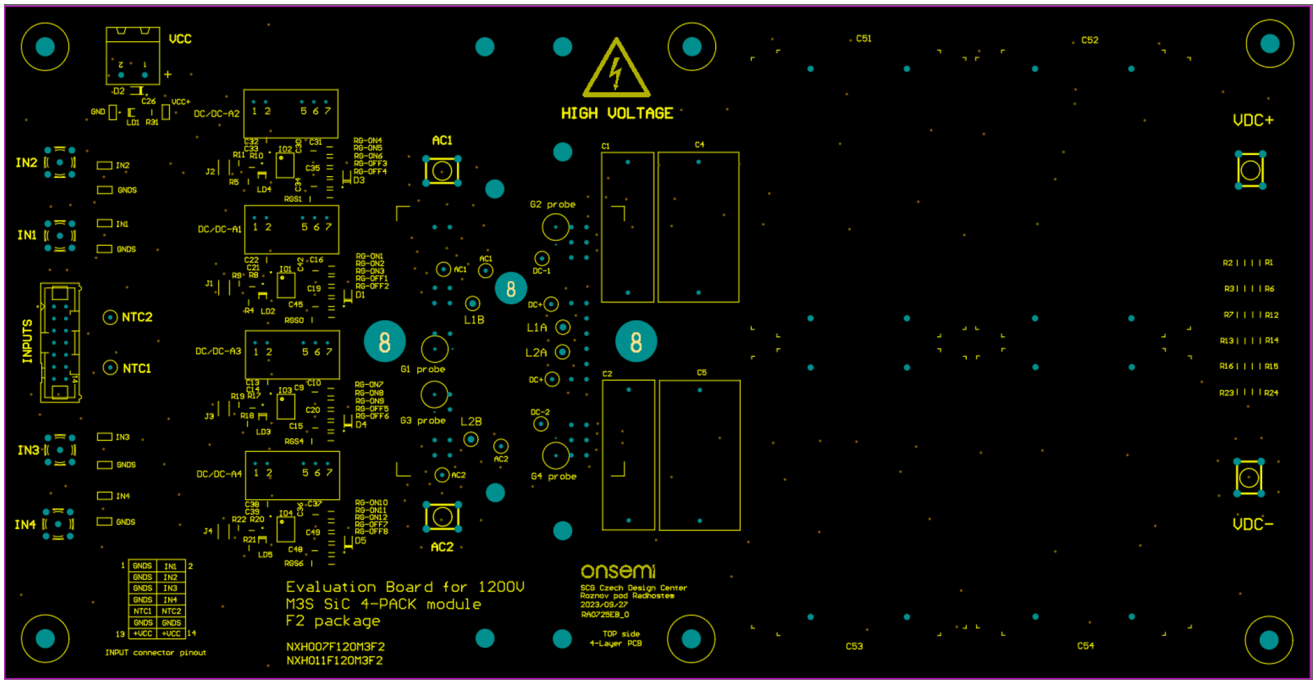


Figure 24. Assembly TOP

BILL OF MATERIALS

Table 4. BILL OF MATERIALS

Designator	#	Description	Value	Manufacturer Part Number
R1, R2, R3, R6, R7, R12, R13, R14, R15, R16, R23, R24	12	SMD Chip Resistor, Thick Film, AEC−Q200 WCR Series, 240 kΩ, 200 V, 250 mW	240 kΩ	TT ELECTRONICS / WELWYN WCR1206−240KFI
R4, R5, R18, R21	4	SMD Chip Resistor, 2.2 kΩ, ±5%, 125 mW, Thick Film	2.2 kΩ	TE CONNECTIVITY CRGCQ0805J2K2
R8, R10, R17, R20, RGS, RGS0, RGS1, RGS2, RGS3, RGS4, RGS5, RGS6	12	SMD Chip Resistor, 10 kΩ, ±5%, 125 mW, Thick Film	10 kΩ	MULTICOMP PRO MCHVR05JTEW1002
R9, R11, R19, R22	4	SMD Chip Resistor, 100 Ω, ±5%, 125 mW, Thick Film	100 Ω	MULTICOMP PRO MCSR08X101 JTL
R31	1	SMD Chip Resistor, 470 Ω, ±5%, 125 mW, Thick Film	470 Ω	MULTICOMP PRO MCSR08X471 JTL
RG−OFF1, RG−OFF2, RG−OFF3, RG−OFF4, RG−OFF5, RG−OFF6, RG−OFF7, RG−OFF8, RG−ON1, RG−ON3, RG−ON4, RG−ON6, RG−ON7, RG−ON9, RG−ON10, RG−ON12	16	SMD Chip Resistor with Pulse Withstanding		NOT POPULATE
RG−ON2, RG−ON5, RG−ON8, RG−ON11	4	SMD Chip Resistor, 3.9 Ω, ±5%, 333.3 mW, Thick Film, Pulse Withstanding	3.9 Ω	PANASONIC ERJT08J3R9V
C1, C2	2	Power Film Capacitor, Metallized PP, Radial Box − 2 Pin Through Hole	1 μF/1200 V	VISHAY MKP1848C51012JK2
C3, C7, C12, C24, C24, C29, C41, C43, C46	8	SMD Multilayer Ceramic Capacitor, 22 μF, 25 V, ±20%, X7R	22 μF/25 V	KEMET C1210C226M3RACTU
C4, C5	2	Power Film Capacitor, Metallized PP, Radial Box − 2 Pin, Through Hole	3 μF/1200 V	VISHAY MKP1848C53012JK2
C6, C8, C9, C11, C14, C15, C17, C18, C21, C23, C26, C27, C28, C30, C33, C34, C36, C39, C40, C42, C44, C45, C47, C48, C50	25	SMD Multilayer Ceramic Capacitor, 0.1 μF, 50 V, ±10%, X7R	100 nF/50 V	WURTH ELEKTRONIK 885012206095
C10, C13, C16, C19, C20, C22, C31, C32, C35, C37, C38, C49	12	SMD Multilayer Ceramic Capacitor, 10 μF, 25 V, ±10%, X7S	10 μF/25 V	TDK C2012X7S1E106K125AC
C51, C52, C53, C54	4	Power Film Capacitor, Metallized PP, Radial Box − 4 Pin, Through Hole	45 μF/1200 V	C4AQPEW5450M3BJ
D1, D3, D4, D5	4	Trench Schottky Rectifier, Very Low Leakage 2 A, 60 V	−	**onsemi** NRVTS2H60ESF
D2	1	Small Signal Diode, Single, 100 V, 300 mA, 1.25 V, 4 ns, 2 A	−	DIODES INC. 1N4148W−7−F
DC/DC−A1, DC/DC−A2, DC/DC−A3, DC/DC−A4	4	Isolated Through Hole DC/DC Converter, ITE, 1:1, 2 Output, 18 V, 80 mA	−	CUI VQA3S−S5−D18−S
IO1, IO2, IO3, IO4	4	Isolated Compact IGBT/SiC Gate Driver	−	**onsemi** NCD57084DR2G
LD2, LD3, LD4, LD5	4	LED, Red, SMD 1206, 20 mA, 2.1 V, 633 nm	−	DIALIGHT 599−0210−007F
LD1	1	LED, Yellow Green, SMD 1206, 20 mA, 2.1 V, 569 nm	−	DIALIGHT 599−0260−007F

Table 4. BILL OF MATERIALS (continued)

Designator	#	Description	Value	Manufacturer Part Number
VCC CON	1	Terminal Block, Header, Plug, 5 mm, 2 Ways, 20 A, 320 V, Through Hole Right Angle	−	CAMDENBOSS CTB9350/2A
IN1, IN2, IN3, IN4	4	RF / Coaxial Connector, SMA Coaxial, Straight Jack, Solder, 50 Ω, RG174	−	LPRS SMA CONNECTOR
INPUTS CON	1	Pin Header, Board−to−Board, 2.54 mm, 2 Rows, 14 Contacts, Through Hole Straight	−	3M 30314−6002HB
AC1, AC2, DC+, NTC1, NTC2, DC−1, DC−2	10	Terminal PIN 1mm 13.14.119	−	ETTINGER 013.14.119
L1A, L1B, L2A, L2B	4	PCB Terminal, 2.8mm x 0.51mm, 0.11” x 0.02”, Brass, 1.4 mm, Tin	−	AMP TE CONNECTIVITY 0−0735187−2
AC1, AC2, VDC−, VDC+	4	Screw terminal PCB, M3.5, Sn, 69843	−	DEGSON K14−00A
GND, GNDS, IN1, IN2, IN3, IN4, VCC+	10	PCB Test Point, S1751 Series, Surface Mount, Brass, Tin Plated Contacts	−	HARWIN S1751−46
4−PACK module	1	Full SiC **onsemi** 4PACK module	−	NXH007F120M3F2 NXH011F120M3F2
Socket pin − DC/DC Converter	20	PCB spring Socket, dimension 1.27 mm, Gold Plated Contacts	−	AMP TE CONNECTIVITY 5050462−2
Socket pin − **onsemi** Module	34	2 mm socket, solder connection, to 1 mm pressfit	−	Stäubli 41.0001
PCB	1	FR4 Tg 135°C (ISOLA De104), thickness 2 mm, Copper 70/70/70/70 μm, TOP/BOT mask BLACK, TOP/BOT labels WHITE, Final Surface HAL PbSn	−	RA0725EB_0
Plastic fasteners	6	Plastic Fasteners − Standoff, Nylon 6.6 (Polyamide 6.6), M4, Hex Male−Female, 25 mm, 33 mm	−	WURTH ELEKTRONIK 971250485
Plastic nuts	6	Plastic nuts − Nylon 6.6, M4 Thread Size, 7 mm Width, 2.40 mm Thickness, WA−SNTE Series	−	WURTH ELEKTRONIK 709940400

ADDITIONAL INFORMATION

TECHNICAL PUBLICATIONS:
Technical Library: www.onsemi.com/design/resources/technical−documentation
onsemi Website: www.onsemi.com

ONLINE SUPPORT: www.onsemi.com/support
For additional information, please contact your local Sales Representative at www.onsemi.com/support/sales