Evaluation Board for Transfer-Molded Power Modules NXH35C120L2C2SG and NXH50C120L2C2ESG with NCD57000 Gate Drivers

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EVAL BOARD USER'S MANUAL

EVBUM2669/D

Evaluation Board Description

The TMPIM evaluation board supports the evaluation of transfer molded power modules NXH35C120L2C2SG and NXH50C120L2C2ESG working together with NCD57000 gate drivers when designing a motor control application. This manual describes the board function, schematics, bill of material, board layout and operation.

The evaluation board contains a transfer−molded power integrated module in CIB (converter – inverter – brake) topology. This module contains a B6 diode rectifier, six IGBTs for inverter and a brake chopper. The gate driver stage consists of seven NCD57000 high current galvanically isolated gate drivers. The driver provides 5 kV insulation between primary and secondary side.

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 familiar with all safety standards. Further details of used components are located in respective datasheets.

Features

- Transfer Molded Power Module in CIB Configuration
- 7 Isolated Gate Drivers with 5 kV Insulation
- Short Circuit Protection
- On Board NTC for Rectifier Protection
- Selectable PWM Polarity
- Fault Output with Automatic Reset Function
- Low Inductance PCB Layout

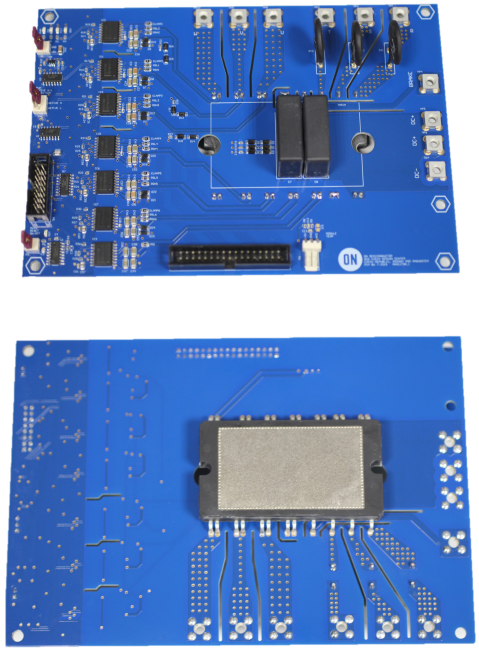

Figure 1. Evaluation Board Top and Bottom View

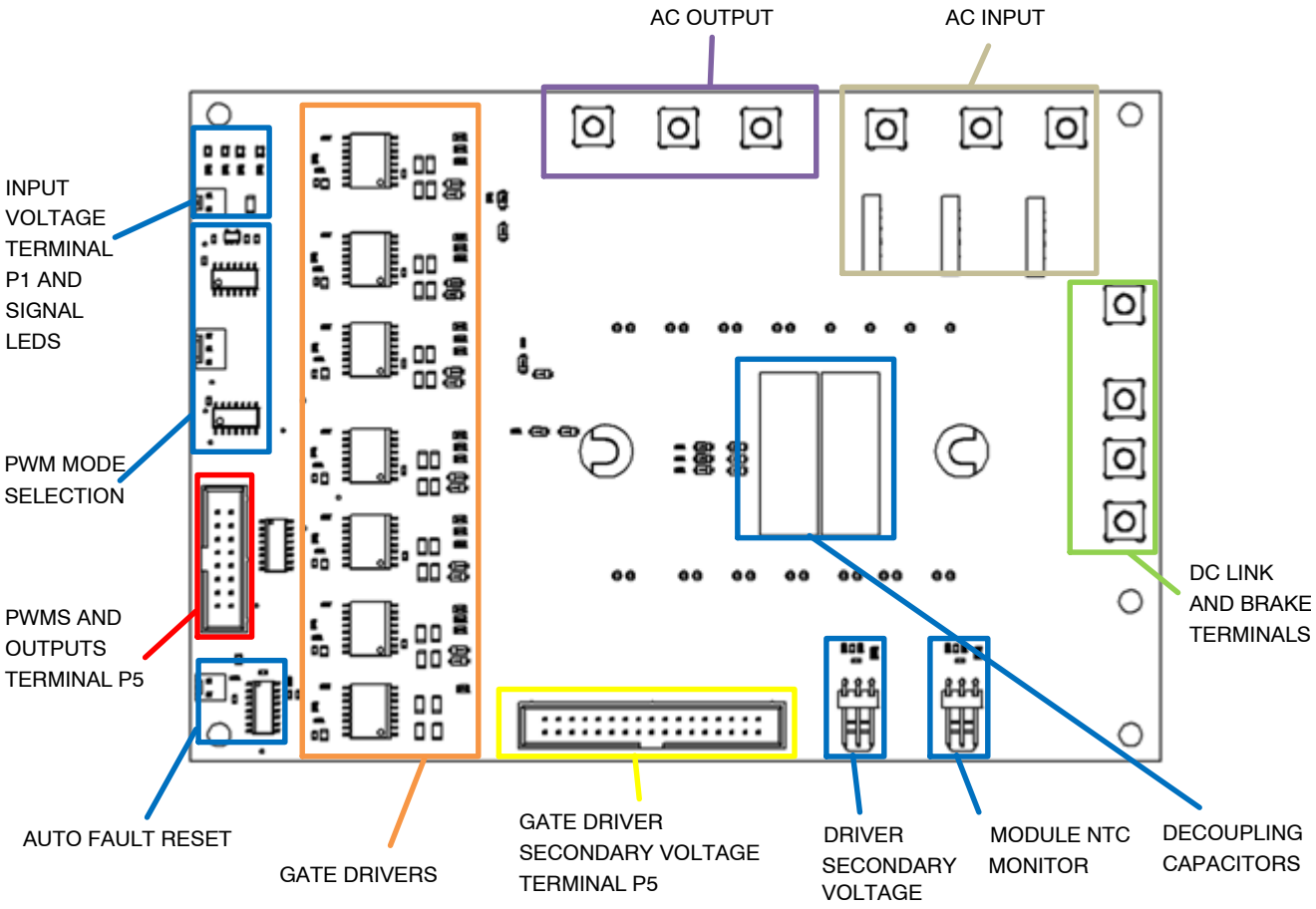

Figure 2. Simplified Block Diagram

APPLICATION INFORMATION

Mechanical Dimensions

Board outline dimensions are 185 mm x 127.25 mm. The board outline is shown in Figure 3.

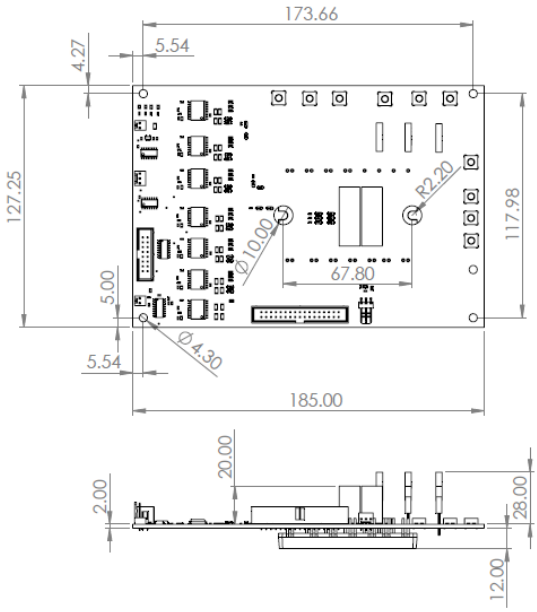

Figure 3. Board Mechanical Dimensions

Electrical Rating

The board is rated to AC voltage input 3 x 400 V/231 V AC 50 Hz. Nominal voltage in the DC link is 600 V. Maximum voltage in the DC link is 800 V. There is no protection for exceeding maximum DC link voltage. While using external NTC for inrush current limit, current has to be limited to 10 A rms. For higher current, the user of the evaluation board must replace the inrush current limit NTC by higher current version; or must use an AC power source having a current limit circuit.

WARNING: Inrush current NTC will get very hot during operation, special caution has to be made to avoid injuries. When inrush current NTC is hot its resistance drops to very low values, turning on the board with heated inrush current NTC can cause rectifier diode damage!

Power Supply Connection

For the primary side of the gate drivers, the user must connect an external regulated voltage of 5 V/1 A to connector P1.

For the secondary side voltage of the gate driver, there are three options. The first option is that the user connects external voltage to the connector P7. This connector supplies the low side gate drivers, high side gate drivers are supplied through bootstrap diodes. The second option is that the user connects an external regulated voltage on 34 pin flat cable P2. In order to use external supply voltage solder jumpers SJ2 – SJ6 has to be open (not connected). The solder jumpers SJ2, SJ3 and SJ4 are located on the bottom side of the pcb.

The third option is to use the DC−DC board. The DCDC board is not provided with the application board. But the schematics and gerber files are located on the ON Semiconductor webpage. On the DC/DC board the user must connect an external regulated voltage of 5 V/1 A to connector P1DCDC.

The DC−DC board consists of four isolated Murata voltage sources and output capacitors. The board provides isolated voltage for all gate drivers. DC−DC source insolation voltage is 5 kV.

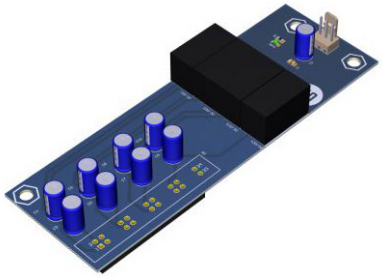

Figure 4. DC−DC Voltage Source

Table 1. CONNECTOR P1DCDC – DC−DC SOURCE POWER CONNECTOR

Pin Name	Pin Function	Comment
1	GND	DC−DC primary ground
2	N.C.	Not connected
3	+5 V	Input voltage for DC−DC sources

Output connector of the DC−DC source P2DCDC follows the pinout of the connector P2 on the main board, not connected pins are removed.

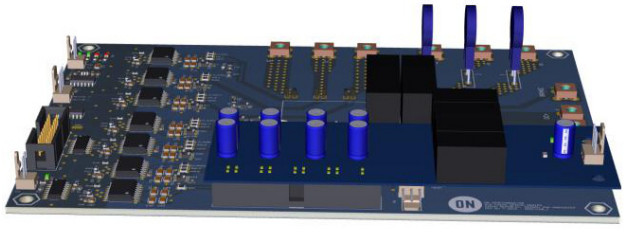

Figure 5. Board with Connected DC−DC Source

PWM Active High/Low Setting and Enable

The board can accommodate PWM with active H or active L, TTL logic levels. Enable pin is needed to run PWM through the driver, enable pin can also work as active low or active high. The selection of logic is realized with two XOR ICs and user selected jumper on connector P4. Table 2 shows the jumper position and PWM input polarity respectively.

Table 2. PWM ACTIVE H/L SETTINGS

Pin Con. P5	Pin Name Con. P5	Jumper Position on Connector P4	Polarity
3	PWM TOP U	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
4	PWM TOP V	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
5	PWM TOP W	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
6	PWM BOTTOM U	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
7	PWM BOTTOM V	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
8	PWM BOTTOM W	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
12	BRAKE	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW
13	ENABLE	Pin 1−2	ACTIVE HIGH
		Pin 2−3	ACTIVE LOW

Fault and Ready Outputs

The NCD57000 gate driver is equipped with two protective functions. READY function “RDY”. This fault is triggered by UVLO at the secondary side of the driver. RDY is active LOW. RDY fault is cleared when the secondary voltage becomes >12 V. When operating with the bootstrap circuit (see power supply connection) the RDY fault is active high during whole operation. The second protective function is generated by desaturation protection “DESAT” and is triggered in case of short circuit/over current. DESAT is active low. When triggered the signal stays low until reset pulse is provided to the reset pin of the driver. DESAT and RDY outputs can be tied together.

Blanking time of DESAT protection t_{BLANK} and voltage threshold can be set by an external capacitor C_{BLANK} and series resistance R_S according to equations (eq.1) and (eq.2)

$$t_{BLANK} = C_{BLANK} \cdot \frac{V_{DESAT\_TH}}{I_{DESAT}} \quad \text{(eq. 1)}$$

$$V_{DESAT\_TH} > R_S \cdot I_{DESAT} + V_{Fdiode} + V_{CESAT\_IGBT} \quad \text{(eq. 2)}$$

Where V_{DESAT_TH} is threshold voltage of DESAT protection, I_{DESAT} is charging current, V_{Fdiode} is forward drop voltage of DESAT diodes and V_{CESAT_IGBT} represents the Vce saturation voltage during overcurrent. Protection circuit is depicted in Figure 6.

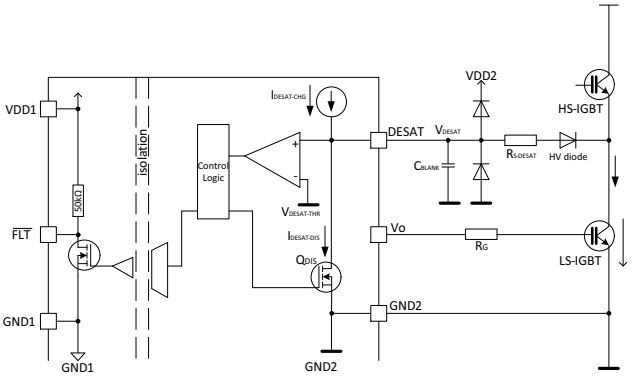

Figure 6. DESAT Circuit Schematic

The on−chip blanking capacitor is 47 pF giving a blanking time of ~1.3 μs. The desat function is triggered when the Ic > 275 A. After DESAT is triggered NCD57000 toggles “soft turn−off” limiting the collector current di/dt so the power module is not damaged by excessive collector voltage overshoot.

Short Circuit Behavior

The power integrated module is capable of surviving short circuit of duration 10 μs. Repeated short circuit conditions could result in thermal overload and destruction of the module. The on−board desat system can detect and turn off the short in 4 μs. Testing was performed during phase – ground short circuit at phase U at output connector. DC link voltage 600 V, 125°C module case temperature. Waveform is captured in Figure 8.

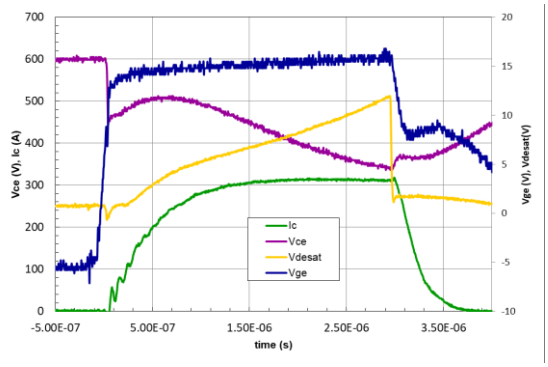

Figure 7. Behavior during Short Circuit Event

Auto Fault Resetting Circuit

When there is a fault condition detected by the gate driver IC, the fault pin is switched to logic 0. Gate driver stays in the fault condition until there is a falling edge on the reset pin. To automatically reset the fault pin the board is equipped with 74VHC123 – Dual Retriggerable Monostable Multivibrator. 74VHC123 monitors the voltage on the Fault pin. When there is a logic 0 condition, 74VHC123 generates a delayed reset pulse. The delay between the fault and the reset pulse is set by the capacitors C1 and C2. By default the time is set to 10 ms. Automatic fault reset can be disabled by disconnecting jumper from terminal P3, but it is recommended to solder out the 74VHC123 IC. Reset pulse then must be generated from micro controller.

Brake Chopper

Board is equipped with gate driver controlling module brake chopper. Braking resistor can be connected to power terminals MP6 and MP7.

NTC Module Temperature Sensing

Module built−in NTC is monitoring the case temperature of the module. NTC is connected to terminal P6. When applying 5 V to PIN1−P6 and GND to PIN2−P6, PIN3−P6 will be triggered active H (3.3 V) when the NTC inside the module reaches 100°C. The voltage divider circuit can be bypassed by solder jumper SJ1 for direct NTC sensing

Switching Losses

The switching was tested on the board with double pulse test. Tested was U phase leg, bottom igbt commuting with high side diode. The waveform shows no oscillation during switching and the measured values align with datasheet.

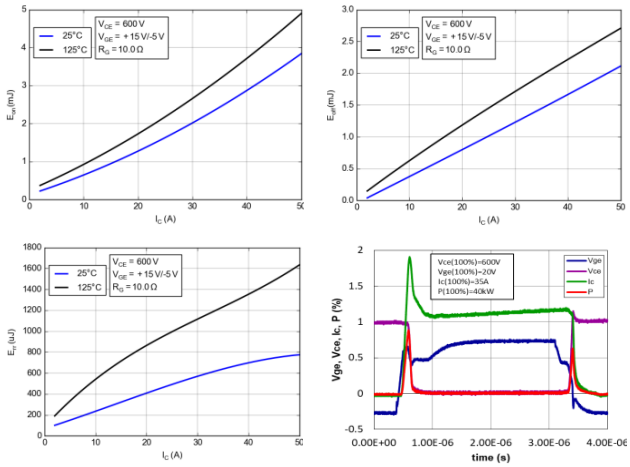

Figure 8. a) Turn−on Losses, b) Turn−off Losses, c) Reverse Recovery Losses, d) Switching Waveform for XH35C120L2C2SG

Board Usage

For using the board needed equipmnet is 5 V/1 A laboratory source, 15 V/1 A laboratory voltage source, 3phase mains power supply, PWM generator, DC link, heatsink and load motor. Connect 5 V to terminal P1 and connect 15 V to terminal P7. Connect 3 phase mains supply to terminals MP1, MP2, MP3 (R, S, T), connect the load motor to terminals MP8, MP9, MP10 (U, V, W). Connect DC link to terminals MP6 and MP7. Connect PWM generator to the terminal P5. Select PWM polarity on terminal P4. Turn on the 5 V power source.Turn on the 15 V power source. Turn on the mains power source. Start PWM operation.

PIN FUNCTION DESCRIPTION

Table 3. CONNECTOR P1 – VCC +5 V POWER CONNECTOR

Pin name	Pin Function	Comment
1	GND	
2	+5 V	

Table 4. CONNECTOR P2 – DRIVER SECONDARY VOLTAGE

1	VEE_LS	18	Neutral_V
2	Neutral_LS	19	VEE_V
3	VEE_LS	20	VDD_V
4	VDD_LS	21	N.C.
5	N.C.	22	N.C.
6	N.C.	23	N.C.
7	N.C.	24	N.C.
8	N.C.	25	VEE_W
9	VEE_U	26	Neutral_W
10	Neutral_U	27	VEE_W
11	VEE_U	28	VDD_W
12	VDD_U	29	N.C.
13	N.C.	30	N.C.
14	N.C.	31	N.C.
15	N.C.	32	N.C.
16	N.C.	33	N.C.
17	VEE_V	34	N.C.

Table 5. CONNECTOR P3 – AUTO FAULT RESET

Pin name	Pin Function	Comment
1	+5 V	Voltage for auto fault reset IC
2	5 V	

Table 6. CONNECTOR P4 – PWM MODE SELECTION

Pin name	Pin Function	Comment
1	GND	Jumper position 1 & 2 PWM ACTIVE HIGH
2	SELECT	
3	+5 V	Jumper position 2 & 3 PWM ACTIVE LOW

Table 7. CONNECTOR P5 – INPUT PWM CONNECTOR

Pin name	Pin Function	Comment
1	+5 V	
2	GND	
3	PWM TOP U	
4	PWM TOP V	
5	PWM TOP W	
6	PWM BOTTOM U	
7	PWM BOTTOM V	
8	PWM BOTTOM W	
9	FAULT	ACTIVE LOW, DESAT TRIGGERED
10	RDY	ACTIVE LOW, UVLO DRIVER SECONDARY TRIGGERED
11	RESET	ACTIVE LOW
12	BRAKE	
13	ENABLE	
14	N.C.	
15	N.C.	
16	N.C.	

Table 8. CONNECTOR P6 – MODULE NTC CONNECTOR

Pin name	Pin Function	Comment
1	VNTC	Voltage input for NTC
2	GND_NTC	Ground input for NTC
3	NTC	NTC measurement

Table 9. CONNECTOR P7 – DRIVER SECONDARY VOLATGE

Pin name	Pin Function	Comment
1	GND	Voltage for gate driver secondary side
2	N.C.	Not connected
3	+15 V	Voltage for gate driver secondary side

SCHEMATICS

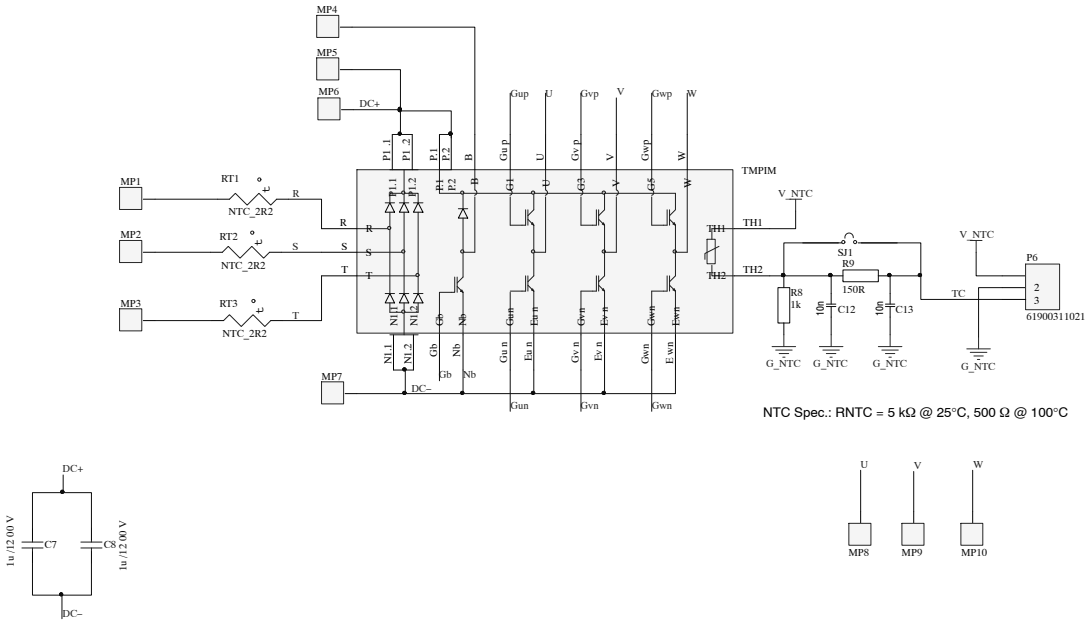

Figure 9. Power Module Schematics

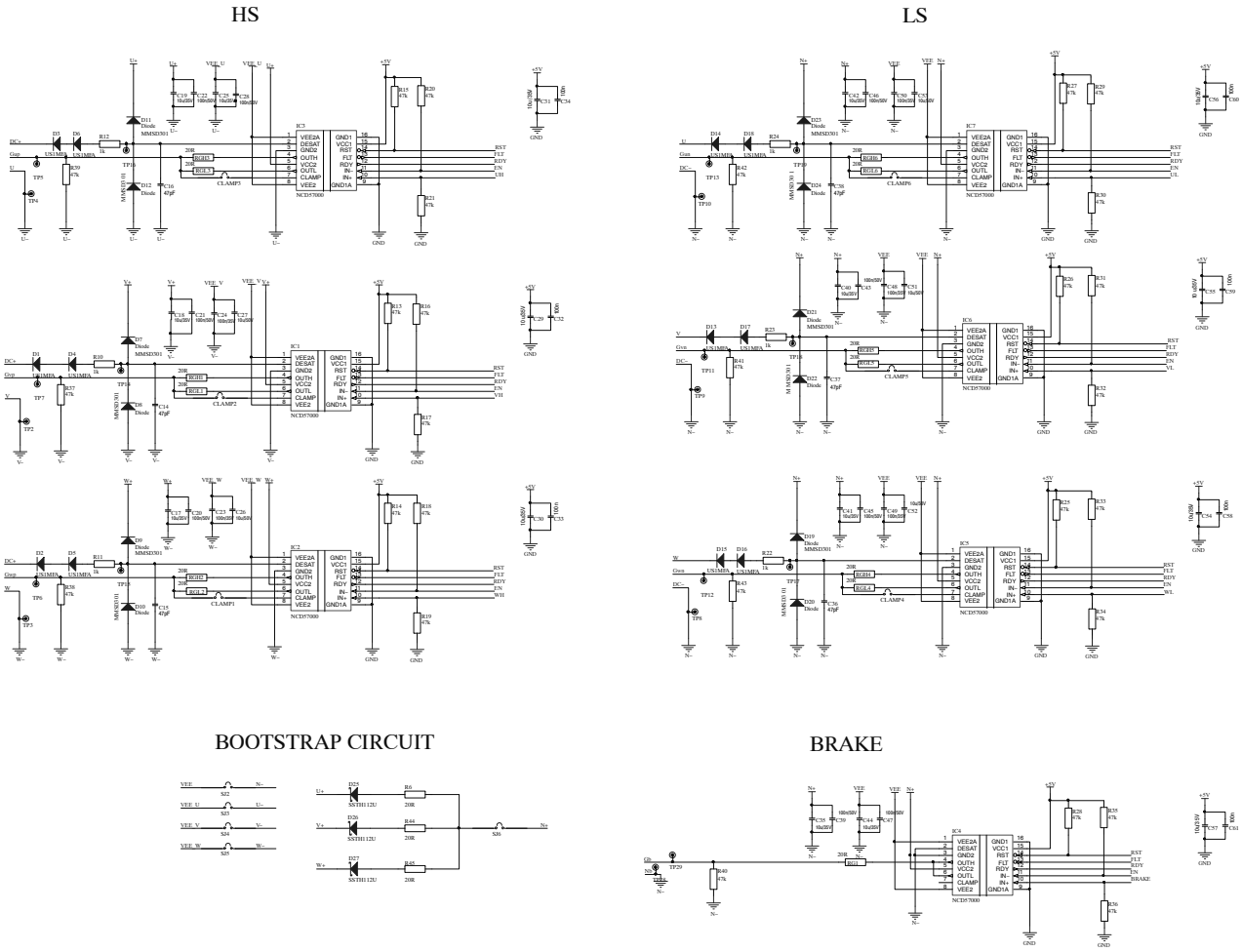

Figure 10. Gate Driver Schematics

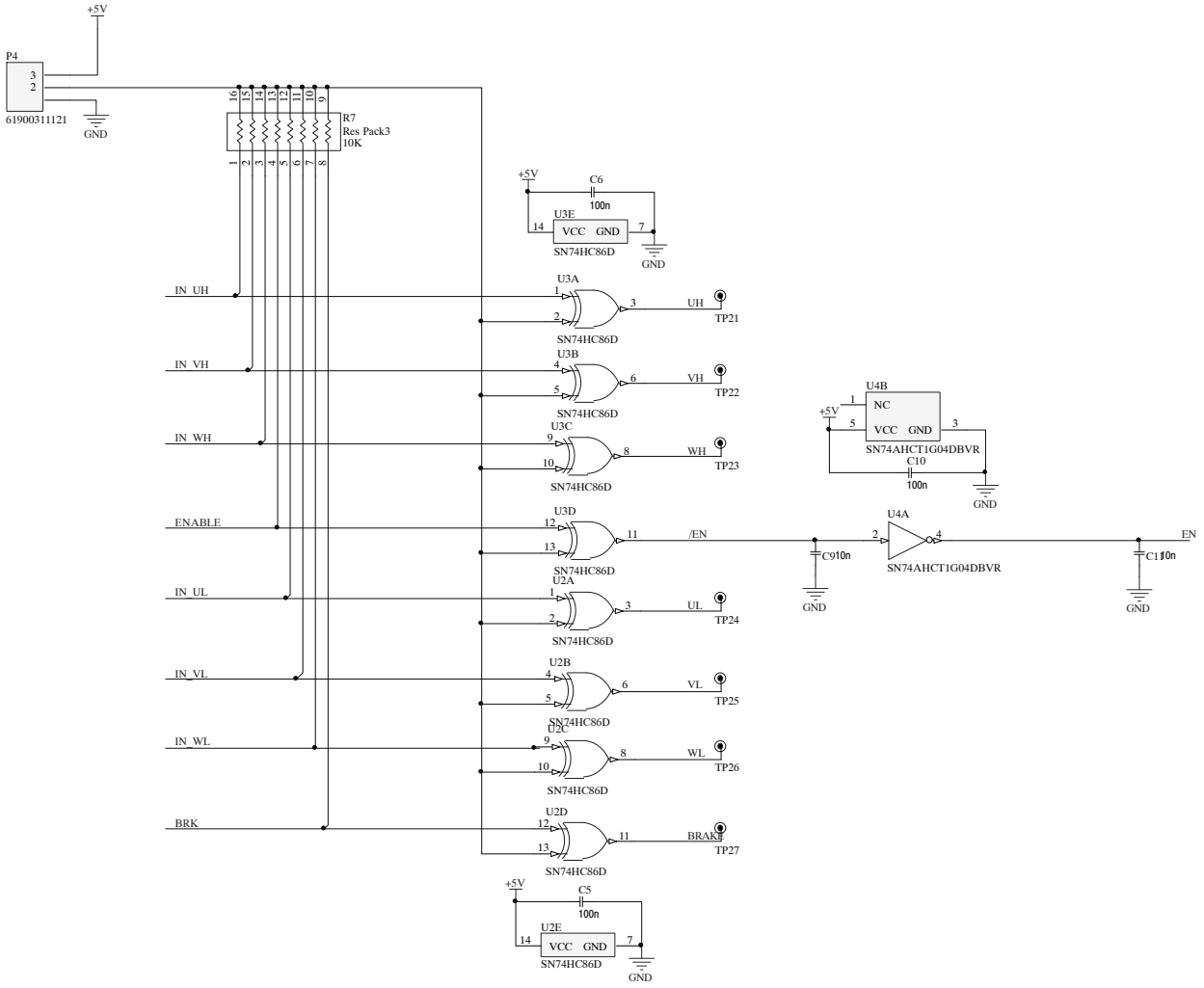

Figure 11. PWM Selection Schematics

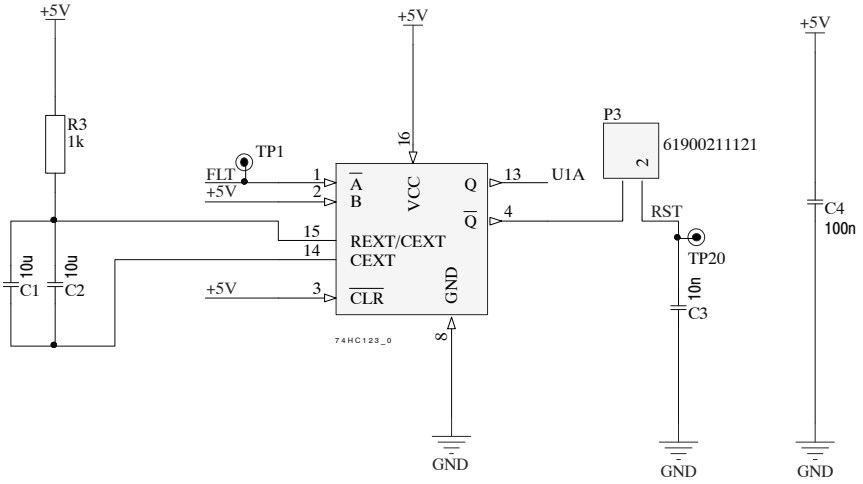

Figure 12. Automatic Fault Reset Schematics

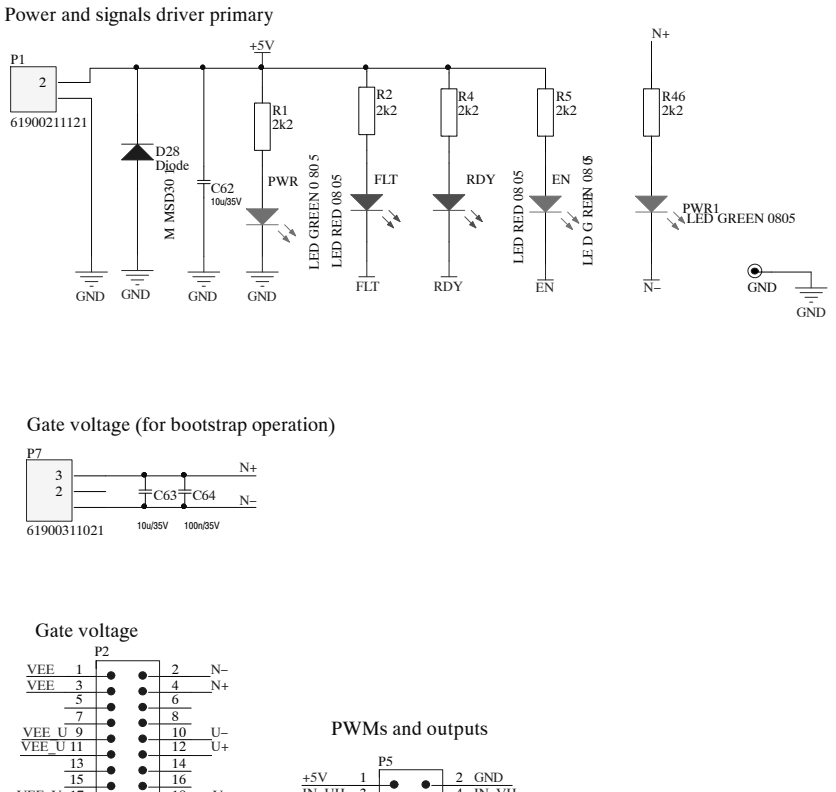

Figure 13. Power and Signal Connectors

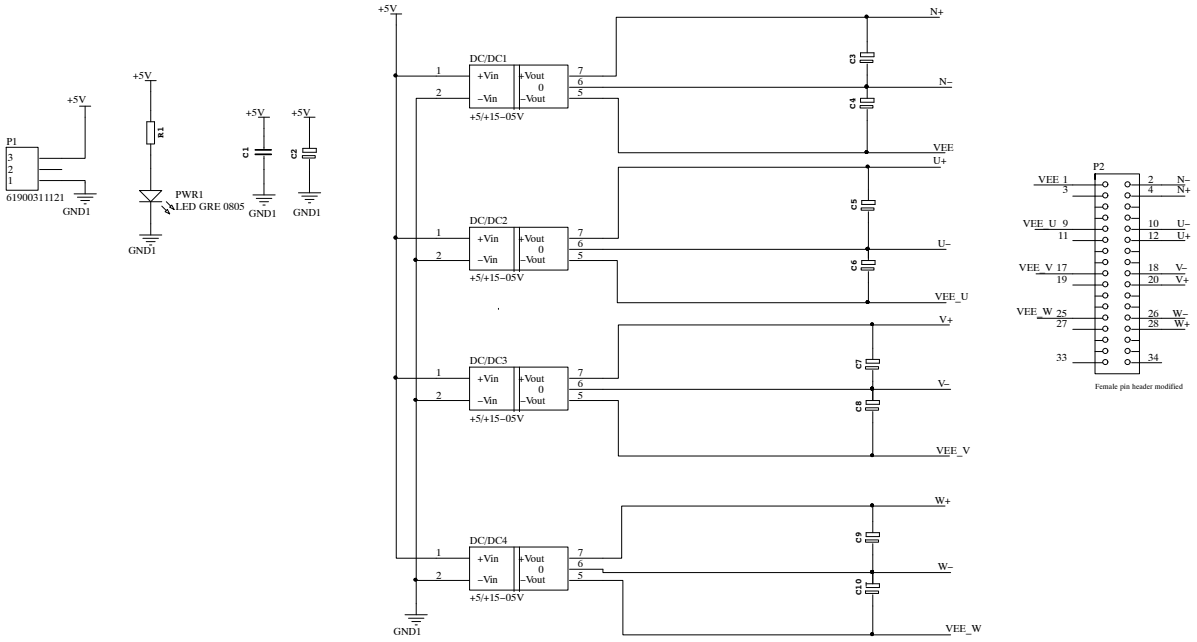

Figure 14. DC−DC Source Schematics

LAYOUT

Layout of Main Board

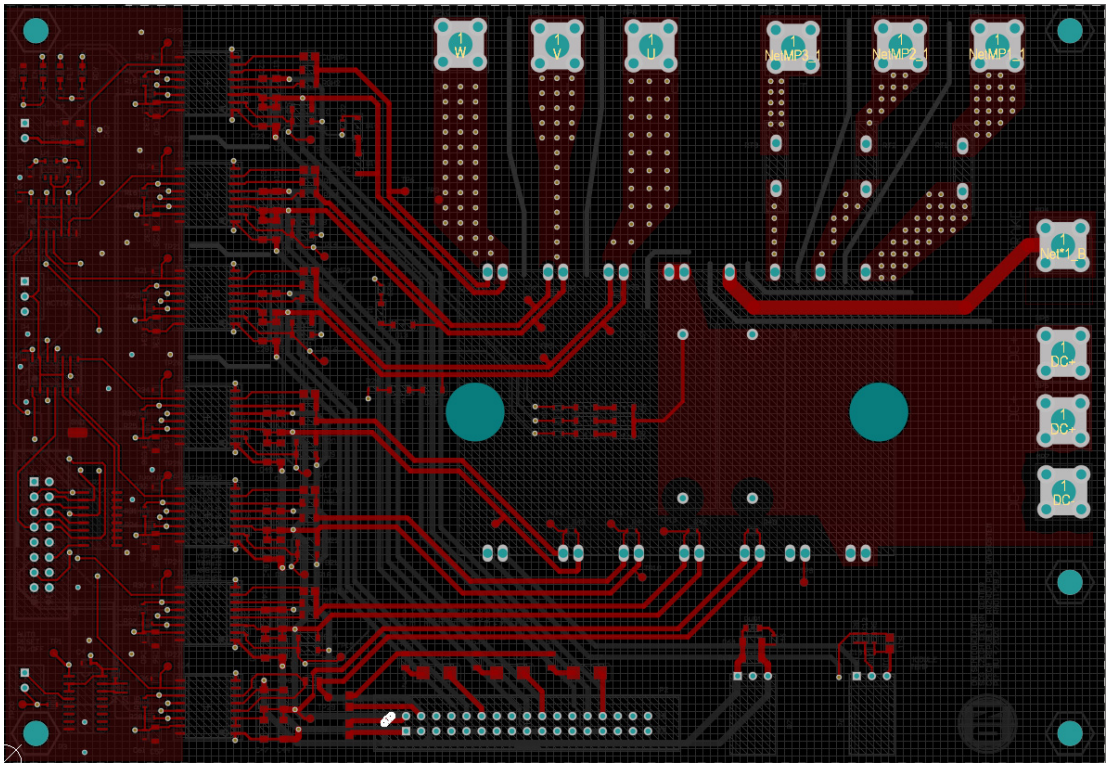

Figure 15. Top Layer

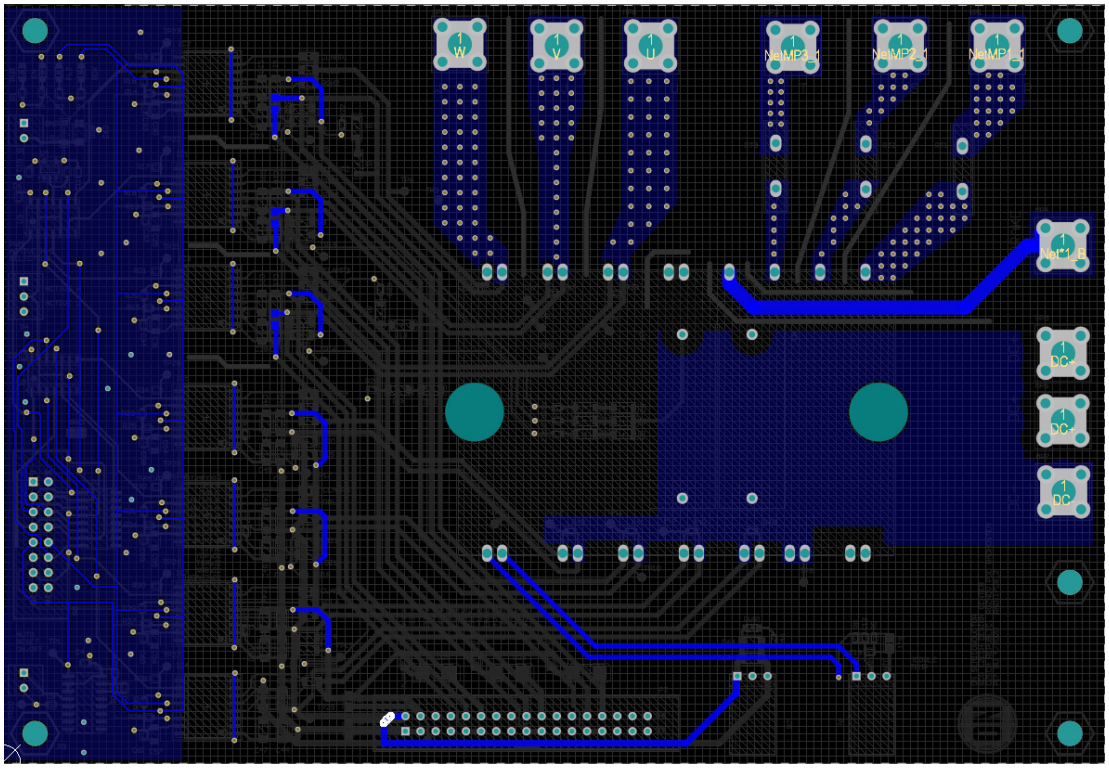

Figure 16. Bottom Layer

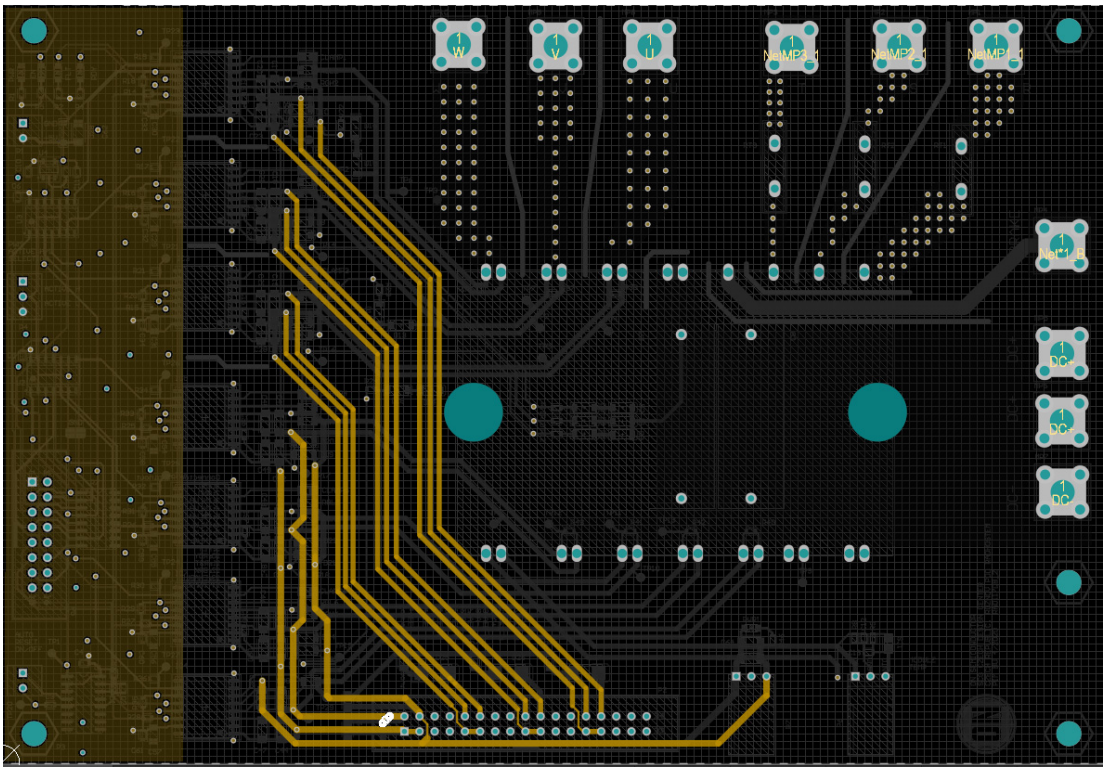

Figure 17. Signal Layer 1

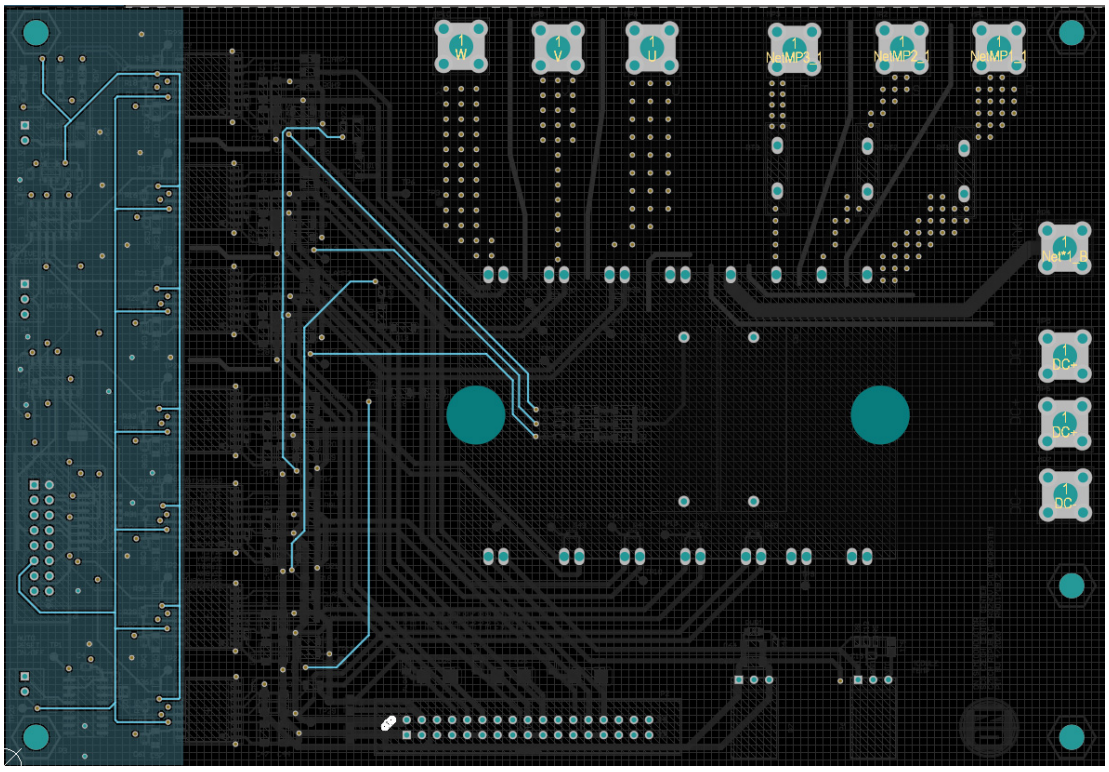

Figure 18. Signal Layer 2

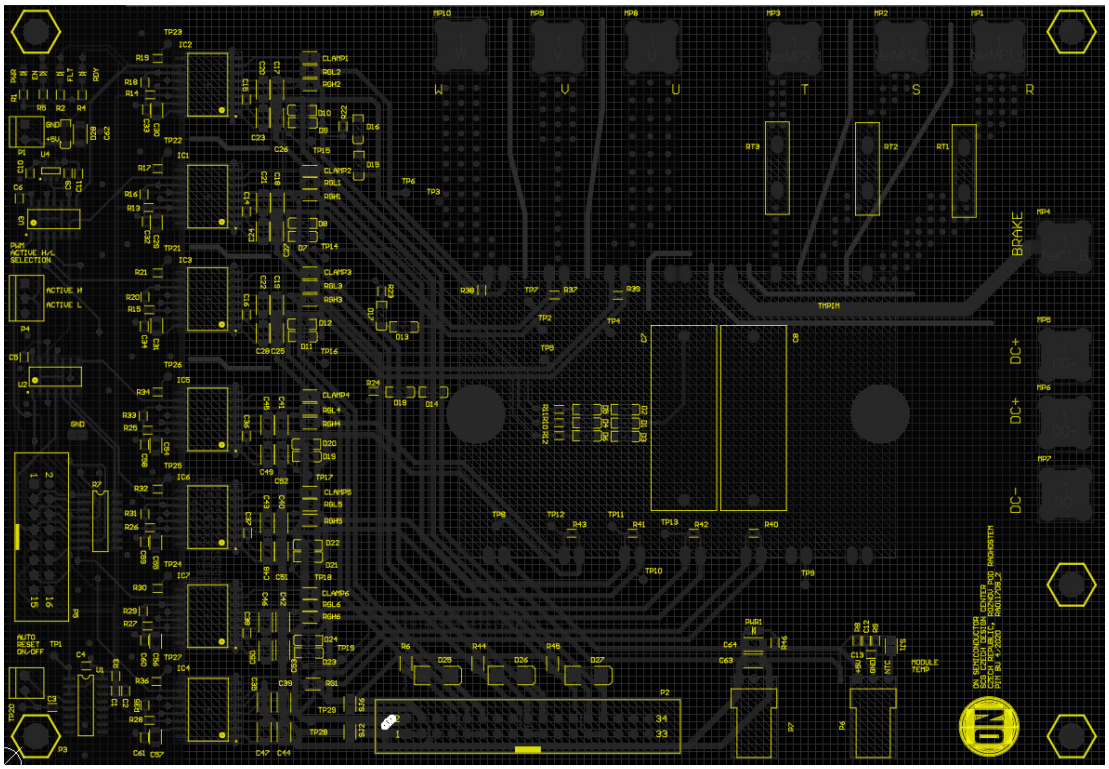

Figure 19. Top Overlay

Layout of DC−DC Source

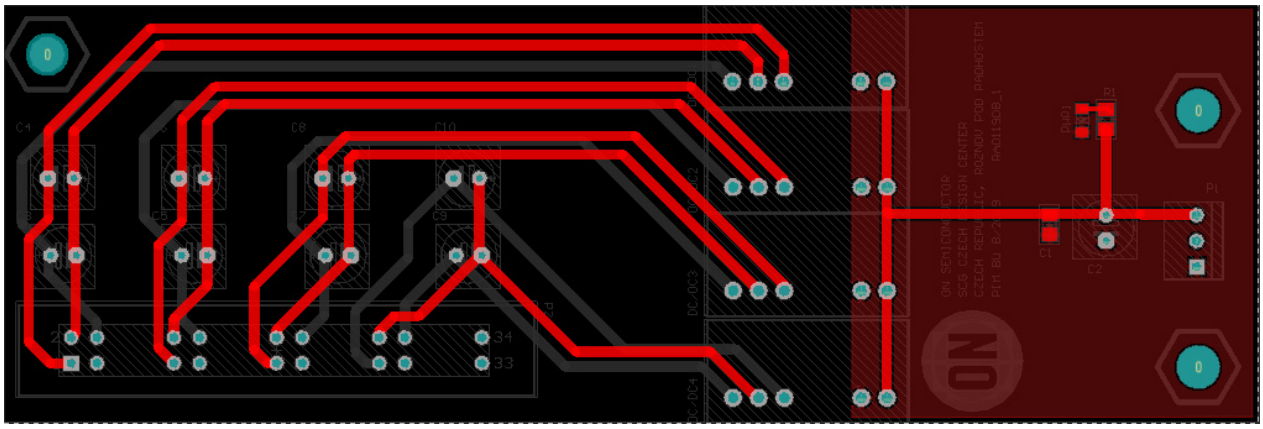

Figure 20. Top Layer

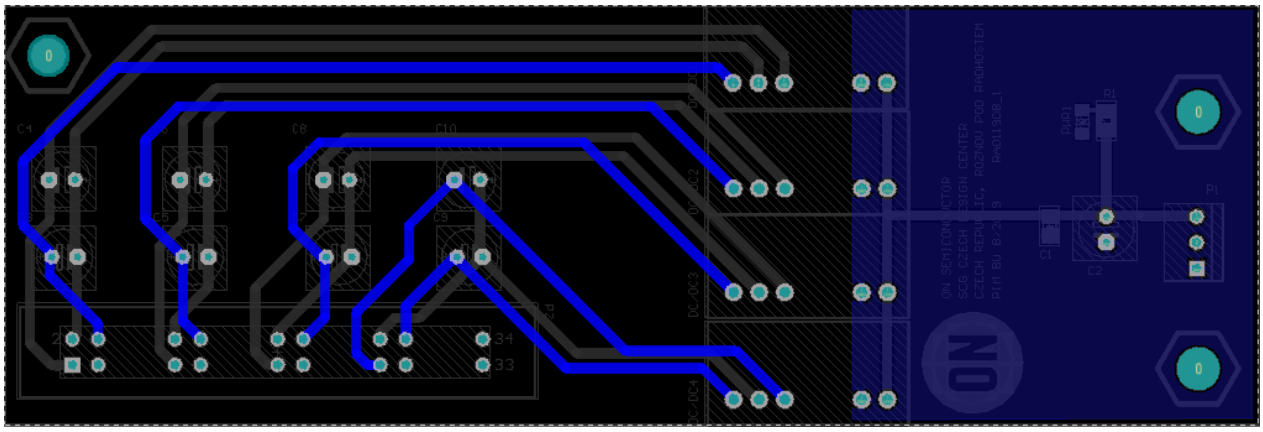

Figure 21. Bottom Layer

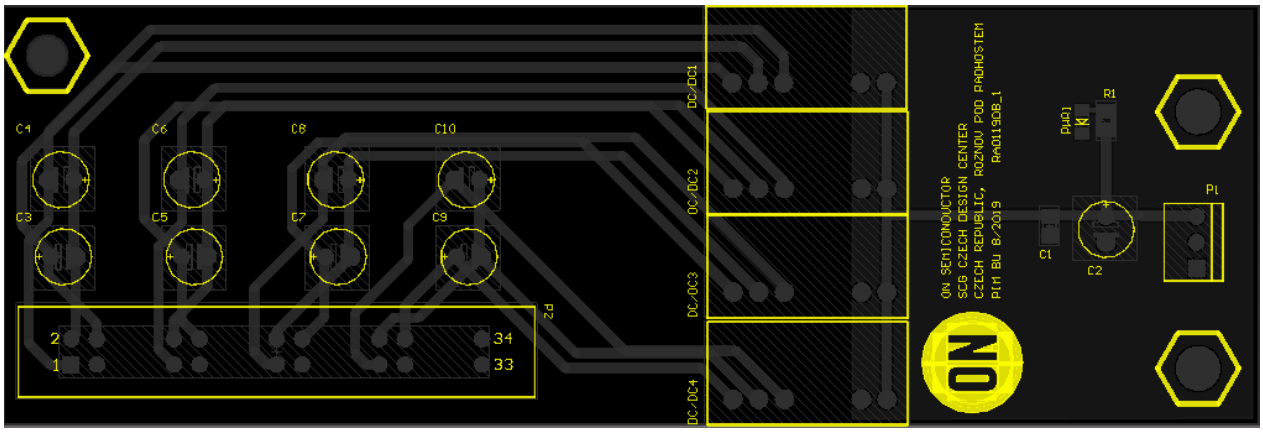

Figure 22. Top Overlay

BILL OF MATERIAL

Table 10. BILL OF MATERIAL MAIN BOARD

#	Value/Name	Designator	Package	Manufacturer
2	LED RED 0805	FLT, RDY	0805	DIALIGHT
13	MMSD301	D7, D8, D9, D10, D11, D12, D19, D20, D21, D22, D23, D24, D28	SOD−123	ON Semiconductor
3	LED GREEN 0805	EN, PWR, PWR1	0805	DIALIGHT
1	150 Ω	R9	0603	Vishay
9	100 nF/25 V	C20, C21, C22, C28, C39, C43, C45, C46, C47	1206	Kemet
6	100 nF/25 V	C23, C24, C48, C49, C50, C64	1206	Kemet
11	100 nF/16 V	C4, C5, C6, C10, C32, C33, C34, C58, C59, C60, C61	0603	Kemet
6	47 pF	C14, C15, C16, C36, C37, C38	0603	Kemet
28	47 kΩ	R13, R14, R15, R16, R17, R18, R19, R20, R21, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43	0603	Vishay
16	20 Ω	R6, R44, R45, RG1, RGH1, RGH2, RGH3, RGH4, RGH5, RGH6, RGL1, RGL2, RGL3, RGL4, RGL5, RGL6	0805	Vishay
5	10 μF/25 V	C26, C27, C51, C52, C53	1206	Kemet
11	10 μF/25 V	C17, C18, C19, C25, C35, C40, C41, C42, C44, C62, C63	1206	Kemet
7	10 μ/F25 V	C29, C30, C31, C54, C55, C56, C57	0805	Kemet
2	10 μF/16 V	C1, C2	0603	Kemet
5	10 nF/16 V	C3, C9, C11, C12, C13	0603	Kemet
1	10 kΩ	R7	SOIC16	Bourns
5	2.2 kΩ	R1, R2, R4, R5, R46	0603	Vishay
8	1 kΩ	R3, R8, R10, R11, R12, R22, R23, R24	0603	Vishay
1	NXH35C120L2C2SG	M1	DIP26	ON Semiconductor
2	CAP_Snub_1200V	C7, C8		
12	0 Ω	CLAMP1, CLAMP2, CLAMP3, CLAMP4, CLAMP5, CLAMP6, SJ1, SJ2, SJ3, SJ4, SJ5, SJ6	0805	Vishay
12	US1MFA	D1, D2, D3, D4, D5, D6, D13, D14, D15, D16, D17, D18	SOD−123	ON Semiconductor
3	SSTH112U	D25, D26, D27	SMB	Vishay
1	SMD Test Point	GND	S1751−46R	HARWIN
7	NCD57000DWR2G	IC1, IC2, IC3, IC4, IC5, IC6, IC7	SOIC16W	ON Semiconductor
10	WP−THRBU, 50 A, M4x2.5 mm	MP1, MP2, MP3, MP4, MP5, MP6, MP7, MP8, MP9, MP10	74650074	Wurth
2	WR−WTB 2.54 mm Male Locking Header, 2p	P1, P3	61900211121	Wurth
1	Male Box Header 34 pins	P2	612034235121	Wurth
1	Male Locking Header, 3p	P4	61900311121	Wurth
1	Male Box Header 16 pins	P5	61201621621	Wurth
2	Male Left Angled Header, 3p	P6, P7	61900311021	Wurth

Table 10. BILL OF MATERIAL MAIN BOARD (continued)

#	Value/Name	Designator	Package	Manufacturer
3	NTC_2R2	RT1, RT2, RT3	15mm	EPCOS
5	Plastic stand M4	SP1, SP2, SP3, SP4, SP5	702942500	Wurth
1	74HC123_0	U1	SOIC16	ON Semiconductor
2	SN74HC86D	U2, U3	SOIC16	ON Semiconductor
1	SN74AHCT1G04DBVR	U4	SOT−23−5	ON Semiconductor

Table 11. BILL OF MATERIAL DC−DC SOURCE

#	Value/Name	Designator	Package	Manufacturer
1	100 nF/16 V	C1	0805	Kemet
9	20 μF/25 V	C2, C3, C4, C5, C6, C7, C8, C9, C10	CPOL−EUE2,5−6E	Kemet
4	DC−DC MGJ2D051505SC	DC−DC1, DC−DC2, DC−DC3, DC−DC4	MGJ2D051505SC	Murata
1	Male Locking Header 3p	P1	61900311121	Wurth
1	Female Box Header 34 pins	P2		Wurth
1	LED GREEN 0805	PWR1	0805	Dialight
1	2.2 Ω	R1	0805	Vishay
3	Plastic spacer	SP1, SP2, SP3	M4	Duratool

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