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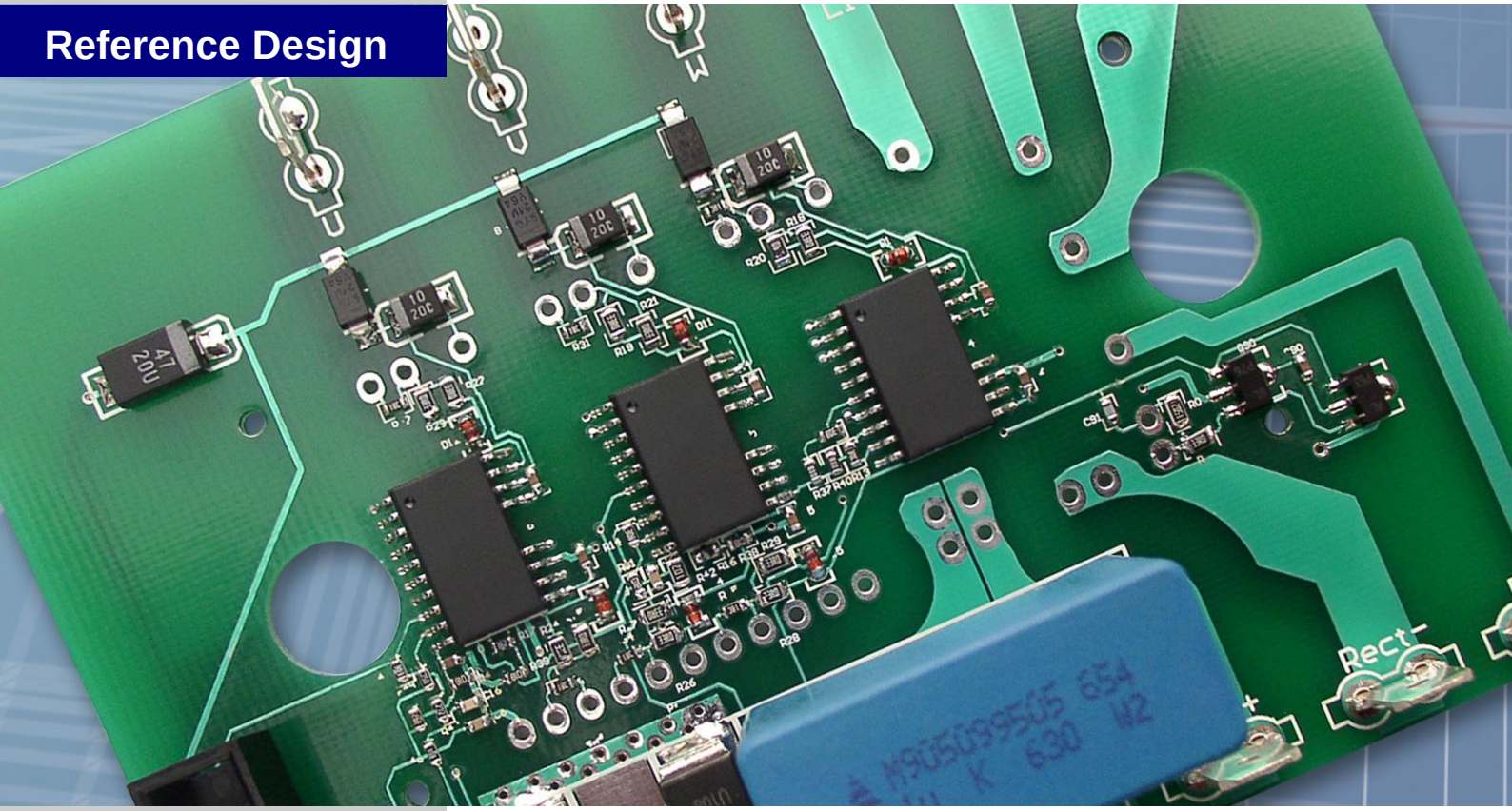
Reference Design



Evaluation Board for *flow*PIM 1 Power Modules

EVA_P58x for PIM / CIB Modules

Reference Design no.:
RD_2011-01_001-v04

Vincotech

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Revision history:

Date	Revision Level	Description	Page number(s)
Jan. 2011	1	First release	20
Mar. 2011	2	Change of pictures	20
Sep. 2011	3	Corrected pin assignment for J6	20
Jul. 2012	4	Updated and added several diagrams	20

1 Introduction

This application note describes the Evaluation Driver Board for the module family P58x or in other words the *flow*PIM 1 3rd generation. This board provides a plug and play solution identifying the switching behavior and efficiency of this module family.

The following picture shows the driver board without an IGBT module. This board can be used for the complete range of *flow*PIM 1 3rd generation modules by simply changing the components that are highlighted in table 4. The board will be delivered without these components and also without the power module. The components have to be added according to the selected module to each board and the module have to be ordered separately.

Ordering Number: **EVA_P58x**

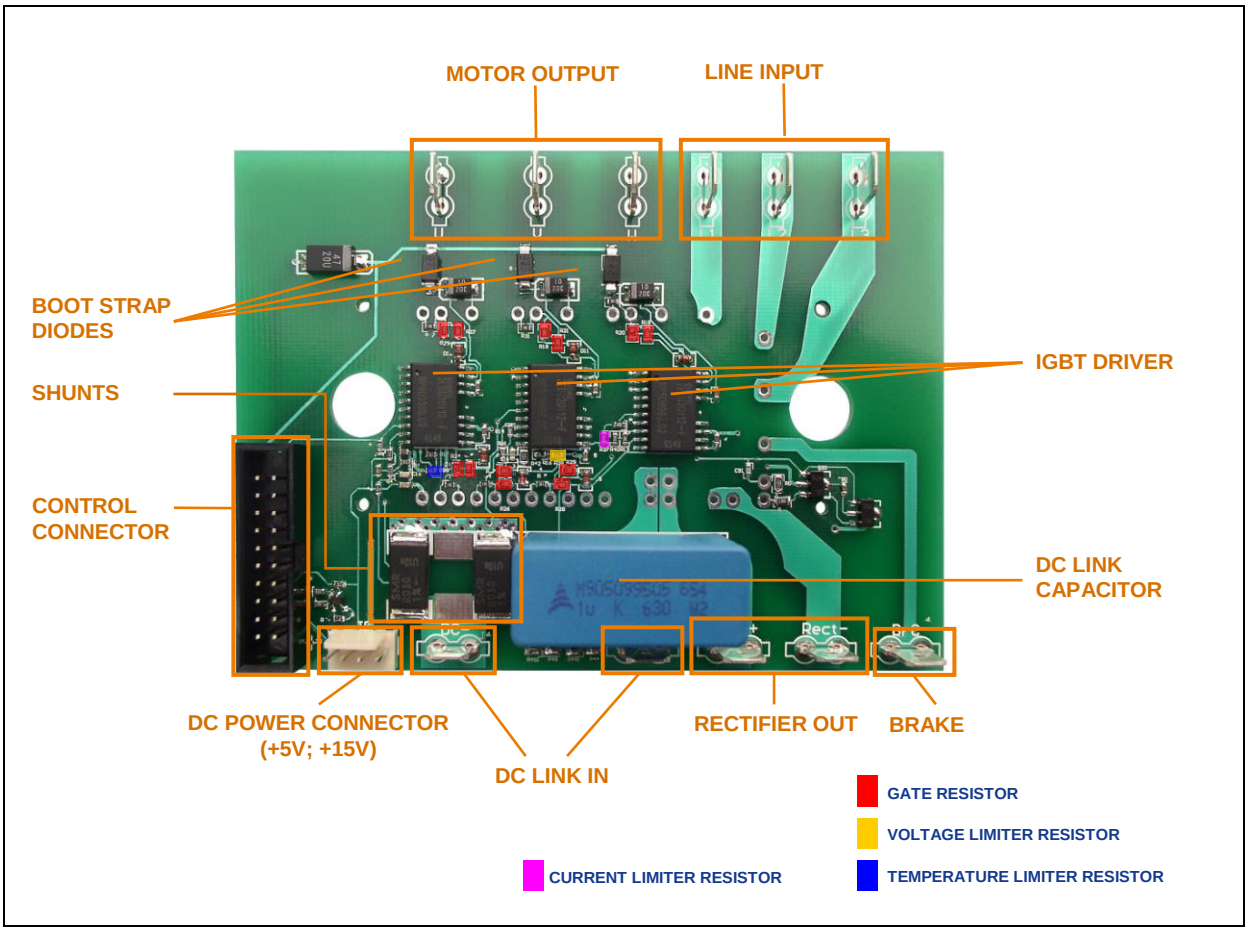


Figure 1: Evaluation driver board without a module

2 Features of driver board

The next chapter describes the main features, basic electrical parameters as well as pin assignments and mechanical dimensions.

2.1 Main features

- Two channel drivers for each leg
- Supply for upper IGBT drivers through bootstrap circuit
- Ground potential of drivers related to DC-
- Under voltage lockout
- 3.3V and 5 V TTL compatible inputs
- Non-inverting inputs
- Dedicated SD shutdown input (active high)
- One FAULT_NEG fault output signal (active low)
- Over voltage, over-current and over-temperature limitation by onboard comparator
- DCV DC-link voltage, DCI DC-link current amplified analog outputs
- Heatsink temperature sense with thermistor
- +15 V power supply for the drivers
- +5 V power for amplifier and references
- Gate drive currents of +1 A / –2 A
- Suitable for up to 600 V / 50 A and 1200 V / 35 A modules
- PCB designed to fulfill the requirements of IEC61800-5-1, pollution degree 2, over voltage category III

2.2 *Electrical parameters*

The electrical characteristics involve the guaranteed value spread for the supply voltages, load and junction temperature given below. Typical values represent the median values, which are related to production processes. Unless otherwise noted all voltages are given with respect to ground (GND). VSL = 15 V, VSH – GNDH = 14 V (15V - (bootstrap diode voltage and low-side IGBT forward drop) = 14 V).

CL = 1 nF, T_a = 25 °C. Positive currents are assumed to be flowing into pins.

	min.	typ.	max.	Unit	Remarks
U_{CE} – max for 600 V modules			600	V	
U_{CE} – max for 1200 V modules			1200	V	
I_C – RMS current through PCB			30	A	@ T_h = 80 °C
U_{DC} – supply voltage for drivers	14	15	16	V	
U_{CC} – supply voltage for logic and analog	4.9	5	5.3	V	
Voltage for logic inputs U_{InH}, U_{InL}, SD	0	5	5.3	V	
DCI current analog output gain		4.34		V/V	reference to shunt voltage
DCV voltage analog output gain 1200/600		3/5		V/480V	
Over Current protection		1/(2*shunt)		A	1) set by shunt
Over Voltage protection 1200/600		735/440		V	1) set by R14
Over Temperature protection		80		°C	
f_{sw} – switching frequency	2	8	16	kHz	1) set by PWM controller
$R_{th(j-a)}$ – driver IC			90	K/W	
T_{VJmax} – Junction temperature	-40		150	°C	
T_{ST} – Storage temperature	-40		85	°C	
[1)] Refer to the next table					
For additional information refer to the datasheet of 2ED020I12-FI from Infineon					

Table 1: Electric parameters

The following table shows the different modules available in the P58x series. Here information about the recommended switching frequency and the recommended passive components are mentioned.

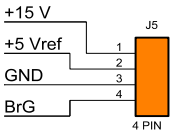
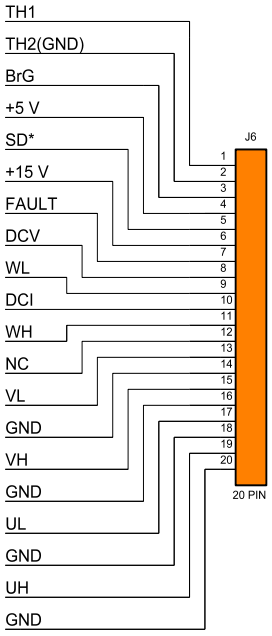
Module	P580 -A41	P589	P580	P589 -A41	P589 -A31	P588 -A41	P588	P585	P586
Current [A]	35	25	35	25	25	15	15	30	50
Voltage [V]	1200	1200	1200	1200	1200	1200	1200	600	600
Frequency*[kHz]	4	4	4	4	8	4	4	8	8
Shunt Rsw4 … Rsw6 [Ω]	0.015	0.015	0.015	0.015	0.015	0.03	0.03	0.015	0.01
R14 [kΩ]	2	2	2	2	2	2	2	4	4
Gate resistors [Ω]	16	32	16	32	32	32	32	16	16
C14 [µF]	0.47	0.47	0.47	0.47	0.47	0.47	0.47	1	1
*: optimum									

Table 2: Members of P58x family

Note: Other modules with the same pinning can be driven as well as long as the maximum RMS current is not exceeded.

2.3 Pin assignments

The driver board has connectors to provide the power to the PCB and to support signals to e.g. the driver circuit.

	J5		J6	
1	+15 V		TH1	
2	+5 Vref		TH2(GND)	
3	GND		BrG	
4	BrG		+5 V	
5			SD*	
6			+15 V	
7			FAULT	
8			DCV	
9			WL	
10			DCI	
11			WH	
12			NC	
13			VL	
14			GND	
15			VH	
16			GND	
17			UL	
18			GND	
19			UH	
20			GND	

*: active high

Table 3: Pin assignment for connector J5 and J6

2.4 Mechanical dimensions

Mechanical dimensions for width, length and height (without module): **111** mm x **81** mm x **23** mm

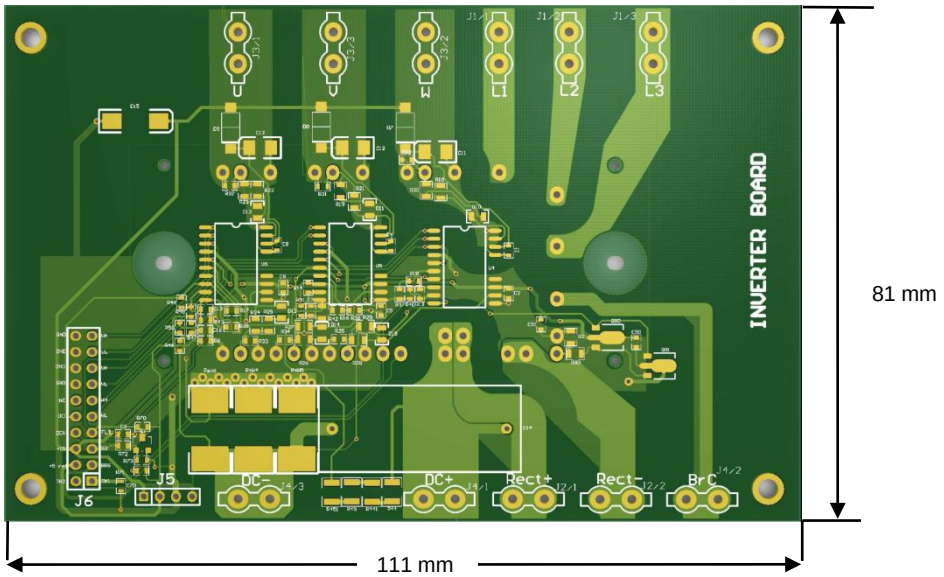


Figure 2: PCB of Evaluation Driver Board

3 Description of electrical parts

This chapter describes the different electrical parts like the input signals, output signals and driver circuit for better understanding of how the board works. Also shown in this chapter are some hints to adjust switching speed and performance of the used IGBT module.

3.1 Power module

In this module family a 3~ rectifier is used to convert the voltage from AC to DC. P58x modules are available with and without a brake chopper. Six IGBTs with freewheeling diodes are implemented for the conversion from DC to AC. The IGBTs and the freewheeling diodes have the same current rating. Therefore the modules can be used for 100 % braking operation.

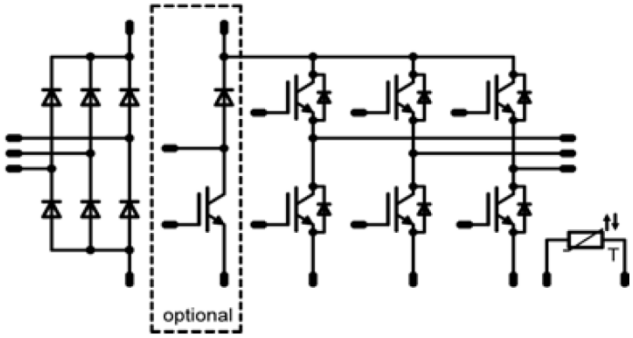


Figure 3: Topology of P58x module family

For temperature measurement a NTC is equipped. Note that this NTC has only a functional isolation.

3.2 Required power supply

To ensure a correct operation of the evaluation board a 15V power supply for the gate drivers and 5V for the logic and analog signals have to be connected.

3.3 Input / output signals

The switching of the IGBT inverter needs to be controlled by 6 PWM channel and the PWM voltage level is 3.3 - 5.3 V.

For measuring the DC link voltage and current DCV, DCI analog output signals are provided. These are generated by universal operational amplifiers of the gate driver ICs. The TH1 thermistor output is available without amplification to measure the heatsink temperature from the power module.

The reference point TH2 of the thermistor needs to be connected to GND in order to activate the over-temperature protection on the driver board.

3.4 Fault output and SD input

All fault outputs are connected together to get one collective fault. The fault output is activated for over-voltage or over-current on the DC link or over-temperature on the heatsink.

The fault signal is not latched, which means that the fault signal is active only for the duration of overload condition.

By nature, the fault caused by the over-current signal can be of short duration so the signal must be latched or the software must react within the allowed t_{sc} short-circuit time of the IGBTs.

A SD shutdown input is provided to keep all drive signals off for fast reaction.

The entire driver ICs contain one amplifier and one comparator (Figure 4, Figure 4, Figure 6). These are responsible for the threshold voltage for over current, over voltage and over temperature. If one of the three paths exceeds the threshold voltage the SD will be activated, as every comparator's output is in connection. The output of comparators needs to be inverted.

The reference voltages of the comparators are set to 490 mV according to the following equation:

$$V_{ref} = 5V_{ref}\frac{R43}{R43 + R50} = 5V_{ref}\frac{1.3k}{1.3k + 12k} = 490mV$$

For additional information please refer to the driver's datasheet of the 2ED020I12-F from Infineon.

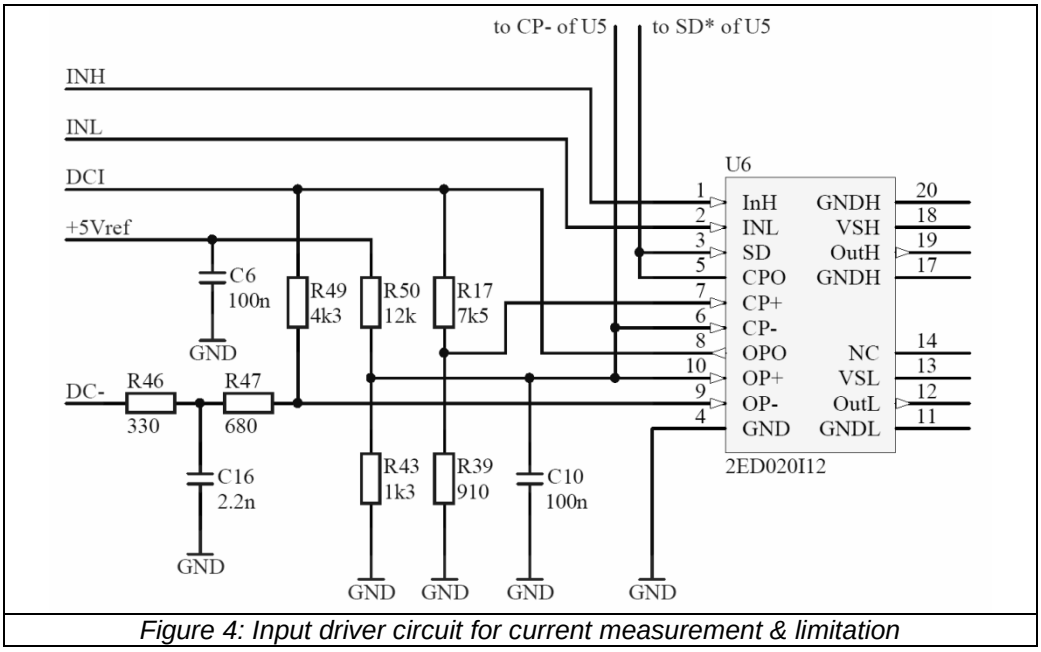


Figure 4: Input driver circuit for current measurement & limitation

The operation amplifier of the driver IC is used to handle the measured current in the emitter shunts RsW4 to RsW6.

Resistor R39 sets the threshold voltage for the over current detection. The next equation shows how the current detection can be changed: $V_{DCI} * \frac{R39}{R39+R17} = V_{ref}$

If the resistor R39 is reduced it will result in an increase of current limitation.

For current measurement the V_{DCI} voltage is given by the following equation:

$$V_{DCI} = 2.5V - (V_{DC-to\,GND} * 4.34)$$

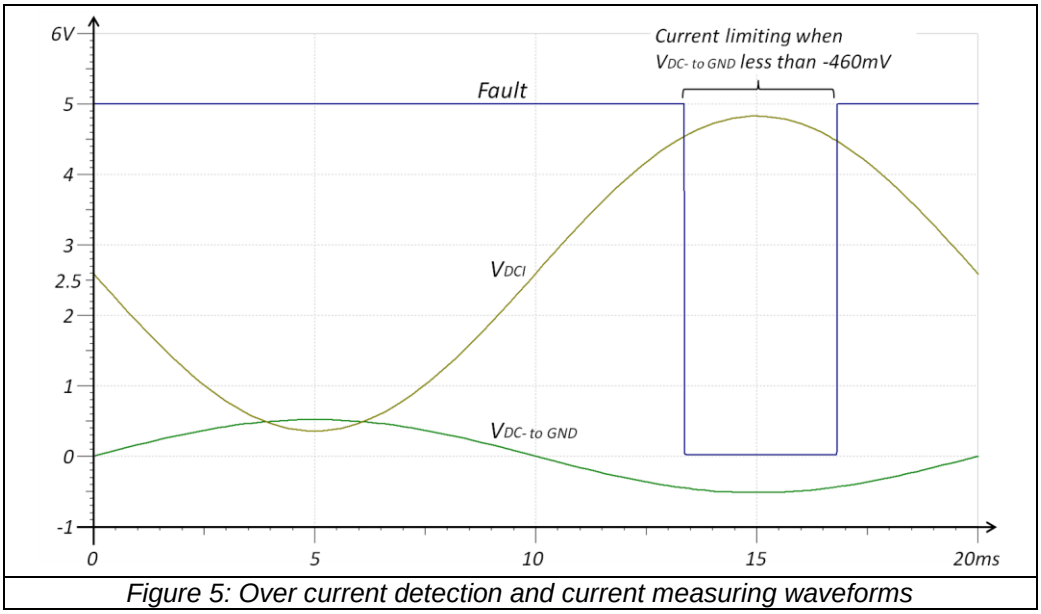


Figure 5: Over current detection and current measuring waveforms

The driver IC U5 handles the measured DC-Link voltage (DCV) through the operation amplifier. The over voltage threshold can be adjusted with R38. The next equation shows how the current detection can be changed: $V_{DCV} * \frac{R38}{R38+R16} = V_{ref}$

The voltage limit can be decreased with increasing R38. For 600 V modules R14 has to be 4 kΩ, and for 1200 V modules R14 has to be 2 kΩ.

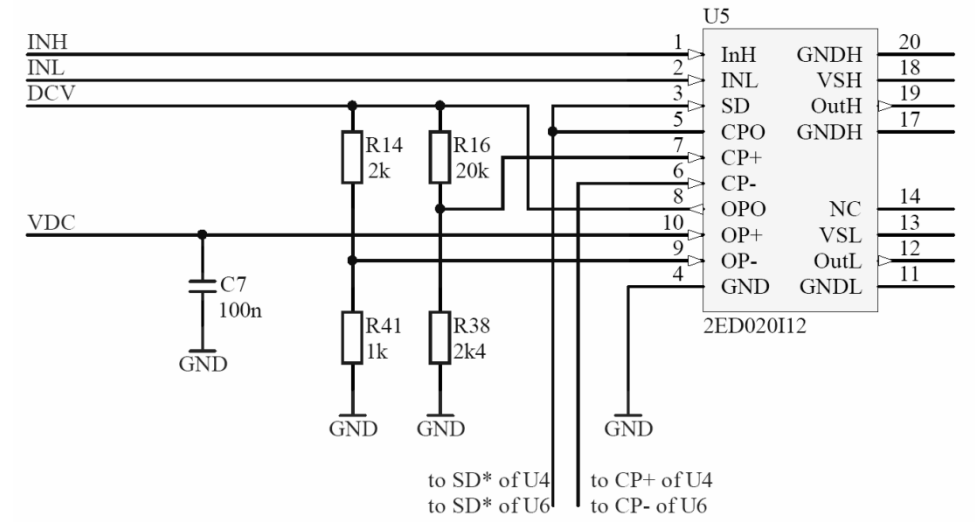


Figure 6: Input driver circuit for voltage limit and measurement for 1200 V modules

For DC+ voltage (high voltage DC link) measurement the V_{DCV} voltage is given by the following equation:

$$V_{DCV} = \frac{V_{DC\ Link}}{481} * \left(1 + \frac{R14}{R41}\right)$$

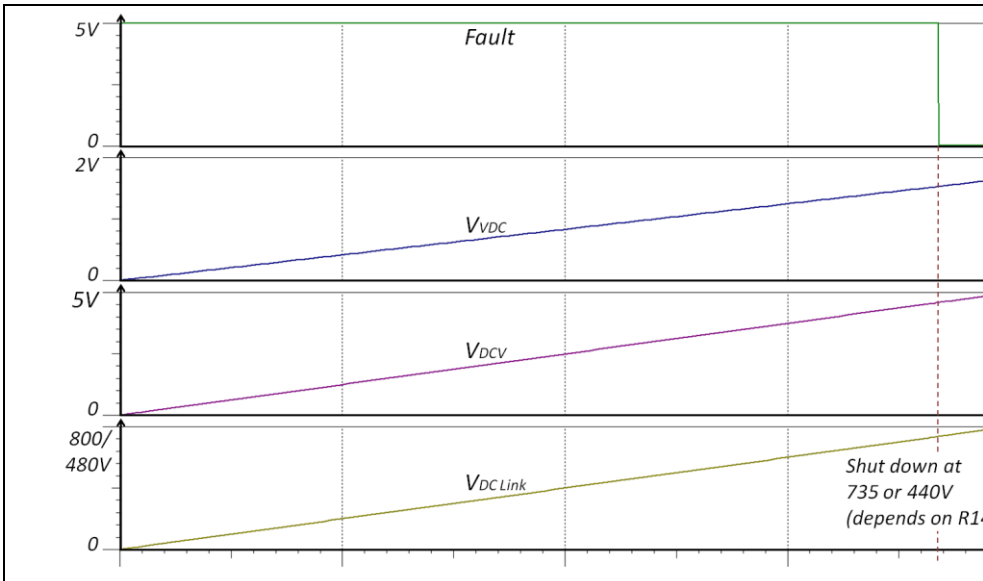


Figure 7: Over voltage detection and voltage measuring waveforms

The driver IC U4 handles the resistance of the build in NTC through the operation amplifier.

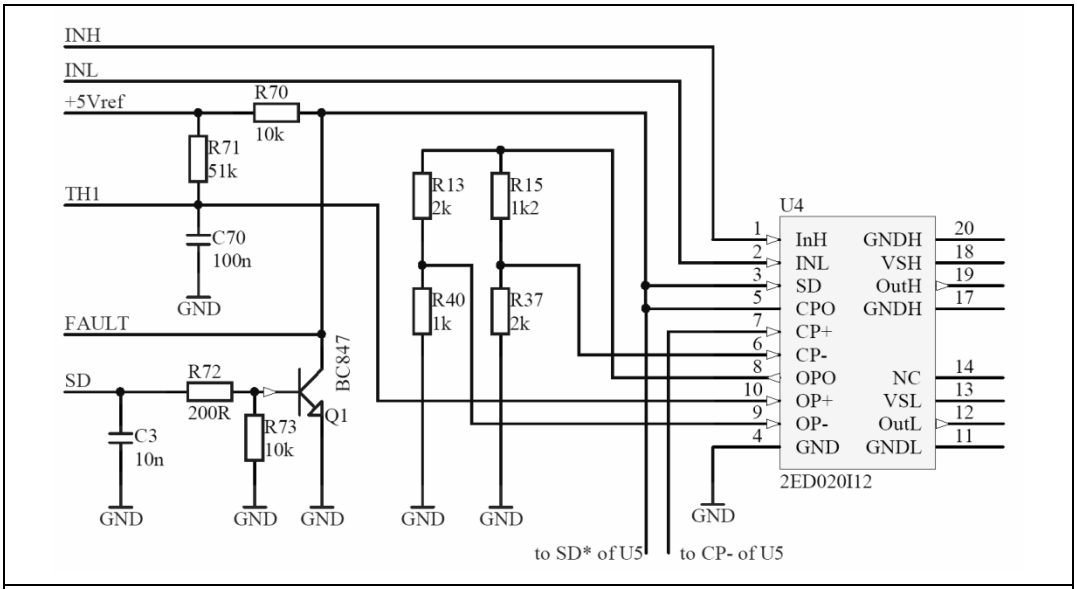


Figure 8: Input driver circuit for temperature limit

Working of the temperature limit is the same as previous shown in. Here resistor R37 can be changed to adjust the temperature trip.

3.5 Gate resistor

The P58x family consists of several power ratings. Therefore the gate resistor has to be adjusted to guarantee best switching performance like shown in Table 2. On the other hand the switching speed and there the gate resistor as well influence the EMI behavior.

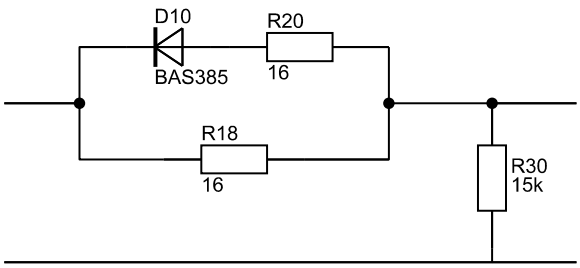


Figure 9: Gate resistors. Here bottom IGBT phase W with 16 Ω

The driver board has two gate resistors for each IGBT and a diode as can be seen in Figure 9. In this configuration the turn-on and the turn-off can be adjusted independently. For the switch-on of the IGBT the bottom resistor is active only. If the IGBT gets the turn-off signal, the upper path is active. In case that the IGBT gets an undefined signal from the driver, the 15 kΩ resistor between gate and emitter short-circuits.
The gate resistors are: R18, R19; R20, R21; R22, R23; R24, R25; R26, R27; R28, R29
Table 2 shows which value of gate resistor should be implemented.

3.6 Switching frequency

The switching frequency is limited by the maximum heat dissipation or in other words the maximum junction temperature of the driver IC.
With the following equation the needed power for driving an IGBT at a given frequency can be calculated.

$$P = f_{sw} \cdot \Delta U_{GE} \cdot Q_{ge}$$

f_{sw} stands for the applied switching frequency for the switch. The difference of the turn-on voltage and turn-off voltage is expressed with ΔU_{GE} and the gate charge Q_{ge} is given in the module datasheet.

The gate charge voltage diagram is given in the modules datasheet.

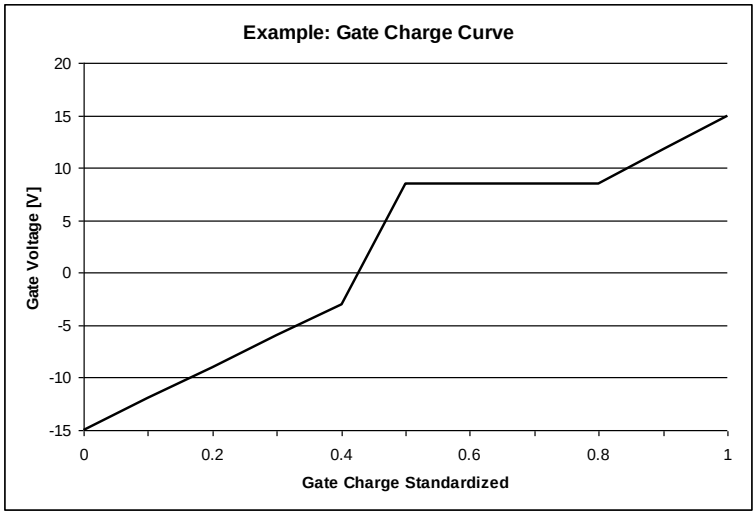


Figure 10: Nominated Gate charge curve

The evaluation driver board works with a gate emitter voltage ΔU_{GE} of 15 V.

With a given power loss P the rise of the junction temperature of the driver can be calculated:

$$\Delta T_{(j-a)} = P \cdot R_{th(j-a)}$$

In this case $R_{th(j-a)}$ is the thermal resistance given in the datasheet of the driver IC.

Finally the ambient temperature and the maximum operation temperature of the PCB have to be defined. The used PCB material in case of the driver board is FR4, which allows an operation temperature of 105 °C.

4 Definition of layers

The driver board is based on a 2-Layer PCB. The used material is FR4. Figure 11 depicts a cross section for the layer thickness and for pre-packs.

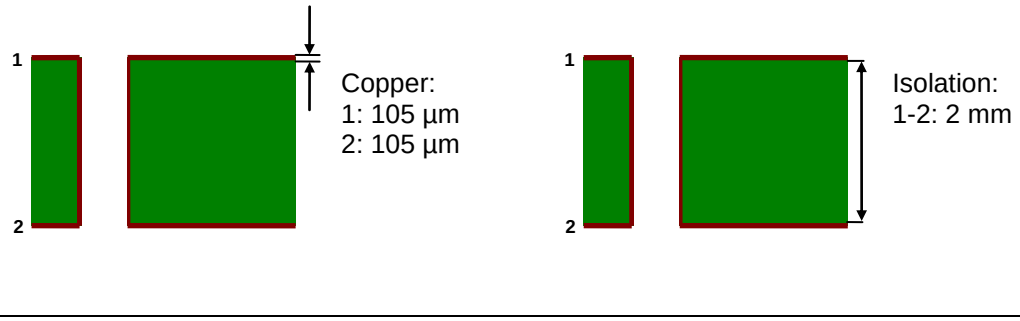


Figure 11: Copper thicknesses and isolation for layers

5 Schematics

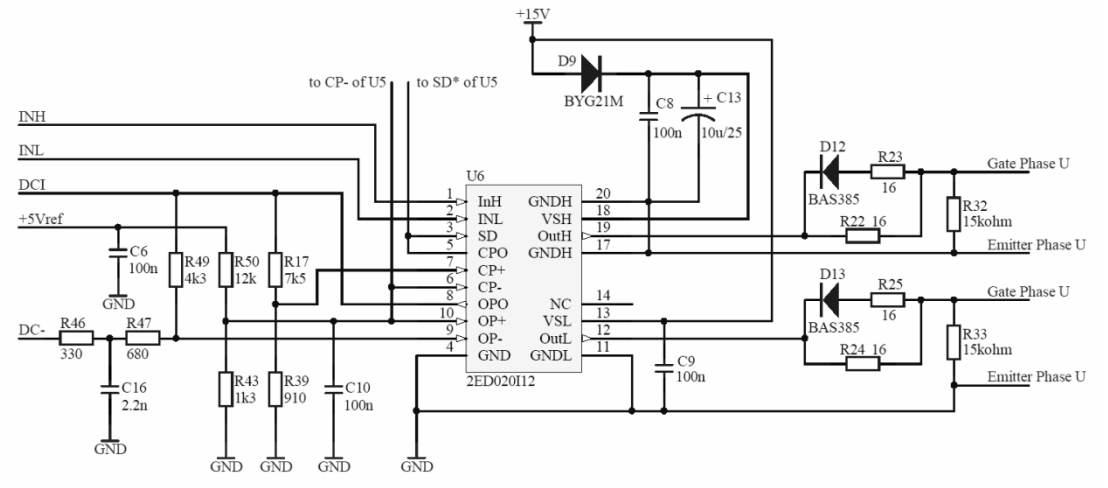


Figure 12: Driver Circuit Phase U

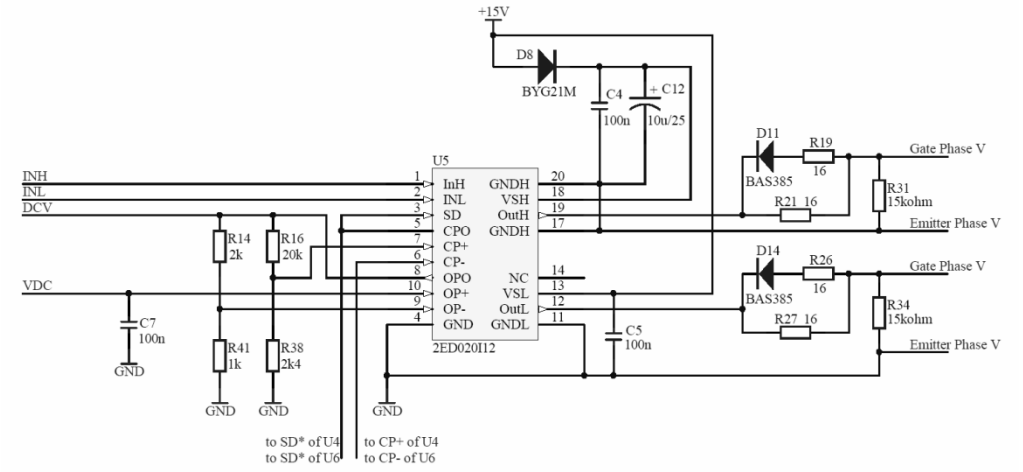


Figure 13: Driver Circuit Phase V

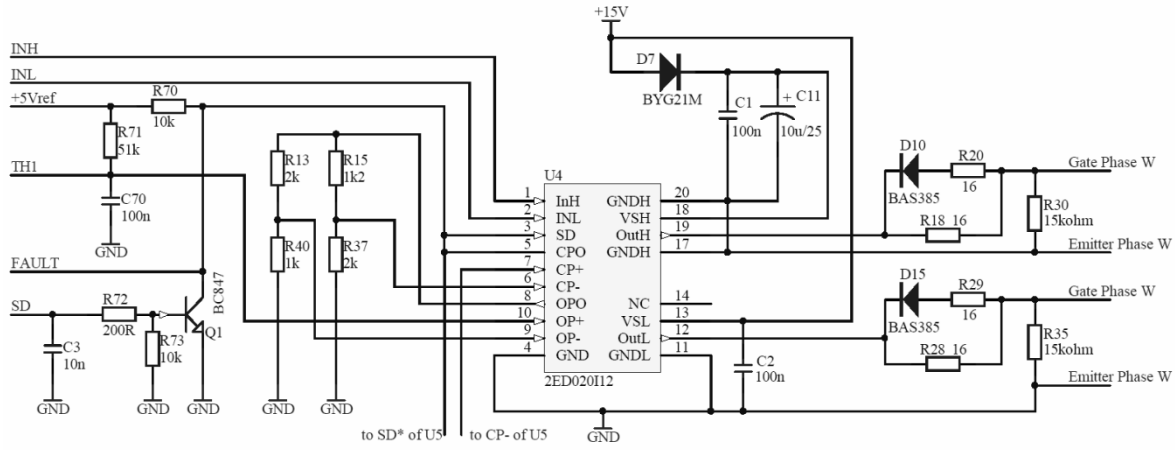


Figure 14: Driver Circuit Phase W

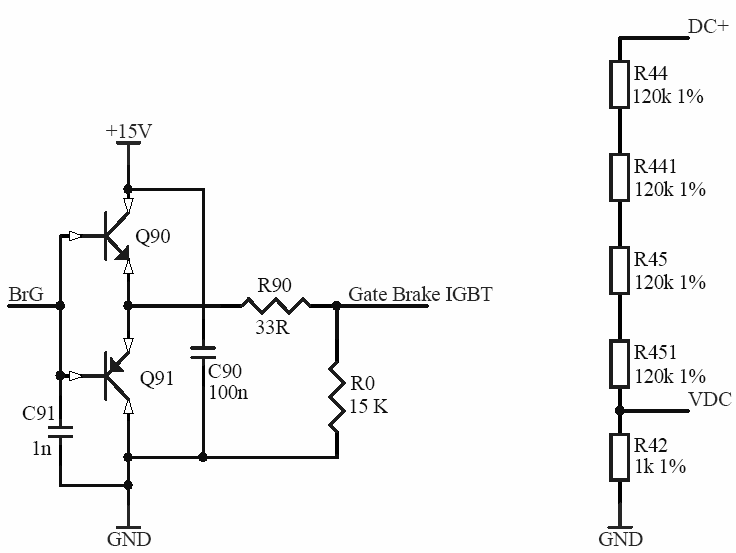


Figure 15: Brake circuit and voltage divider

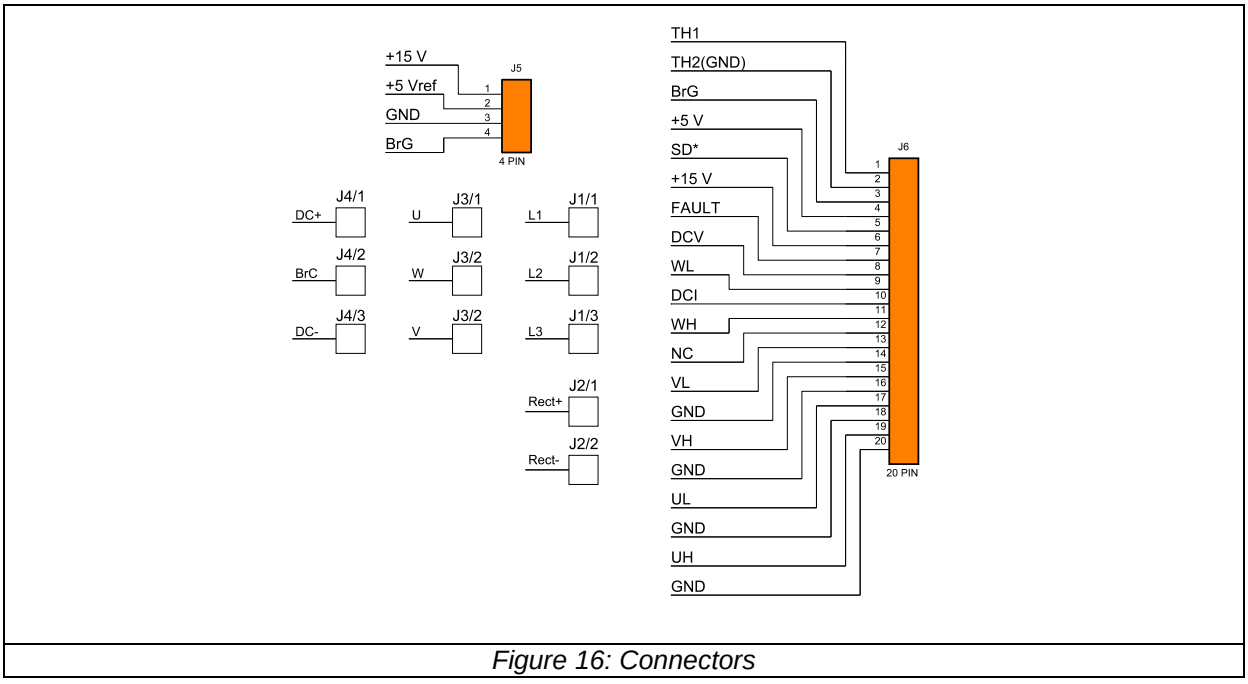


Figure 16: Connectors

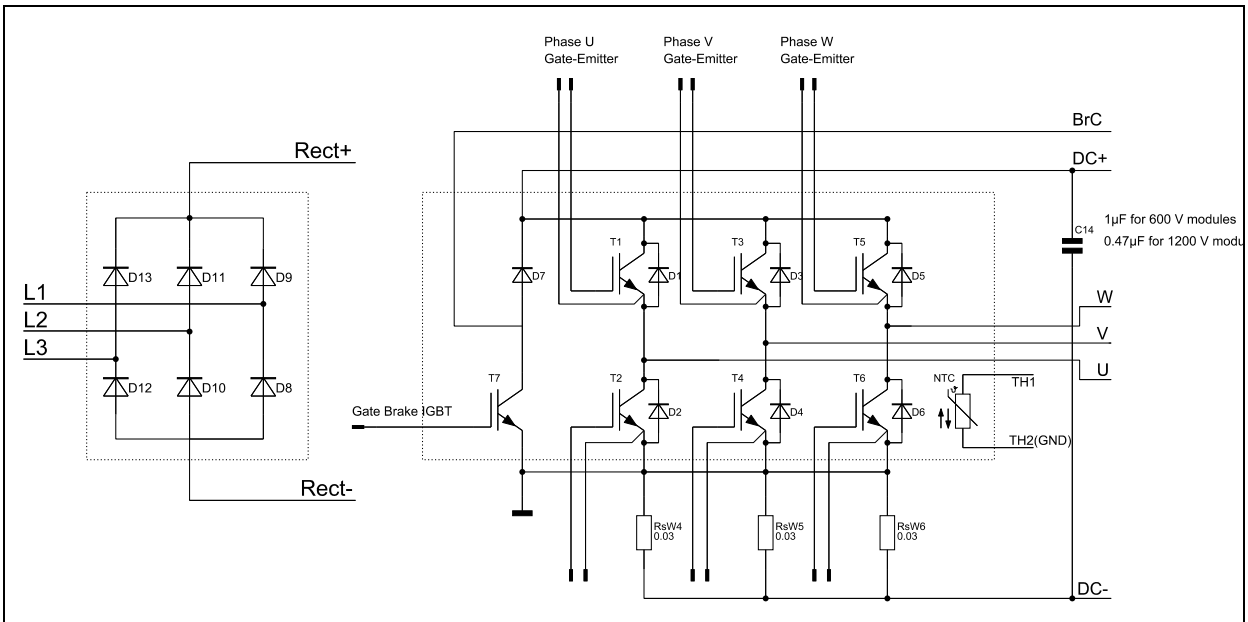


Figure 17: P58x Power Module

6 Layout

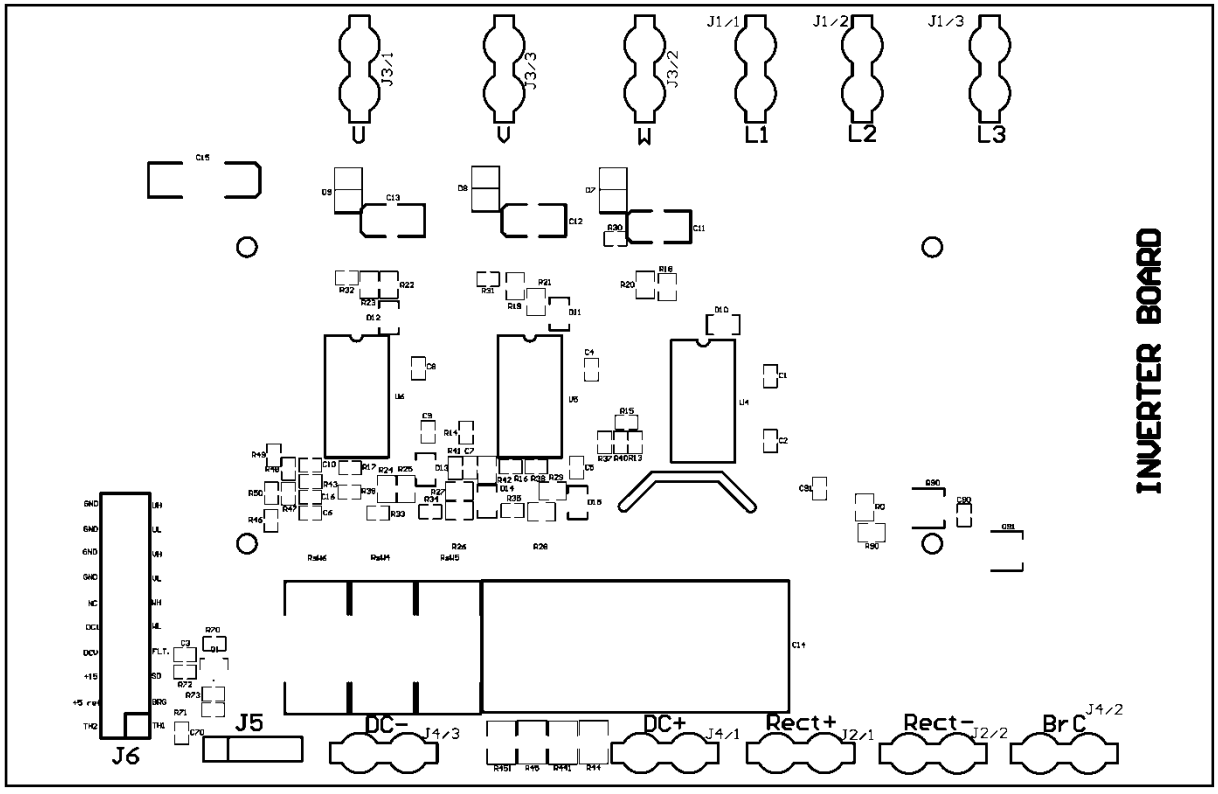


Figure 18: Assembly drawing

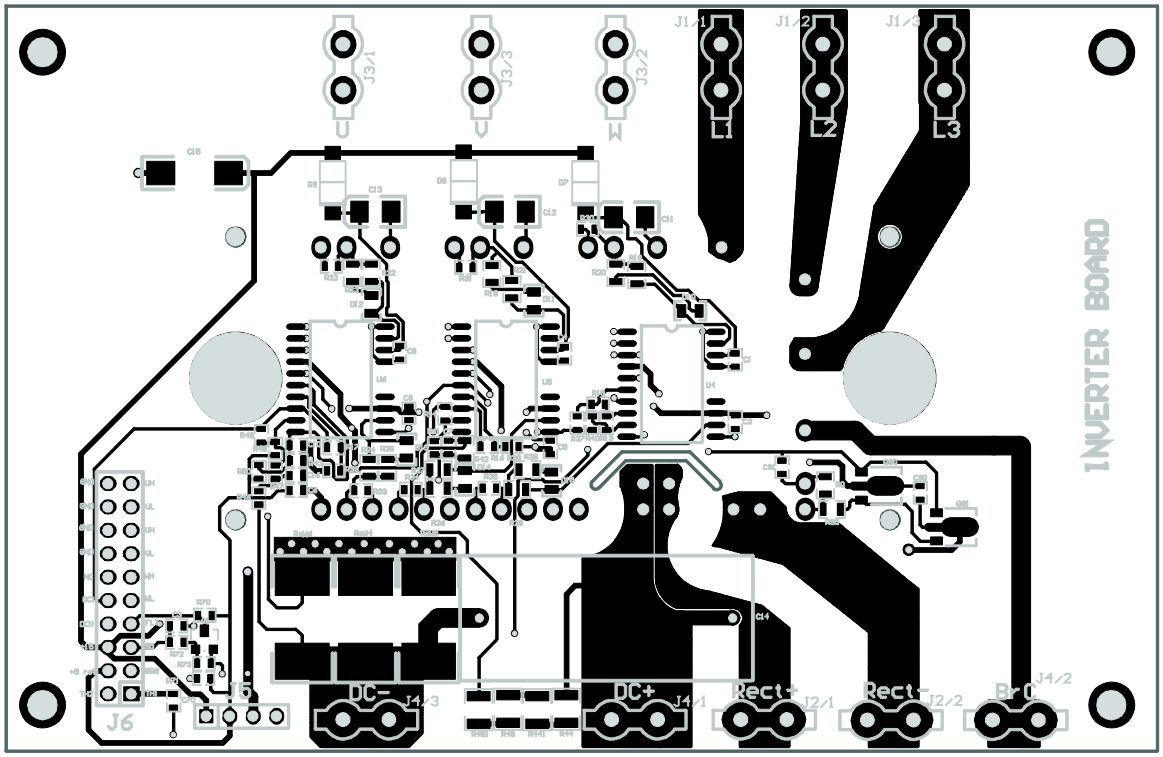


Figure 19: TOP layer

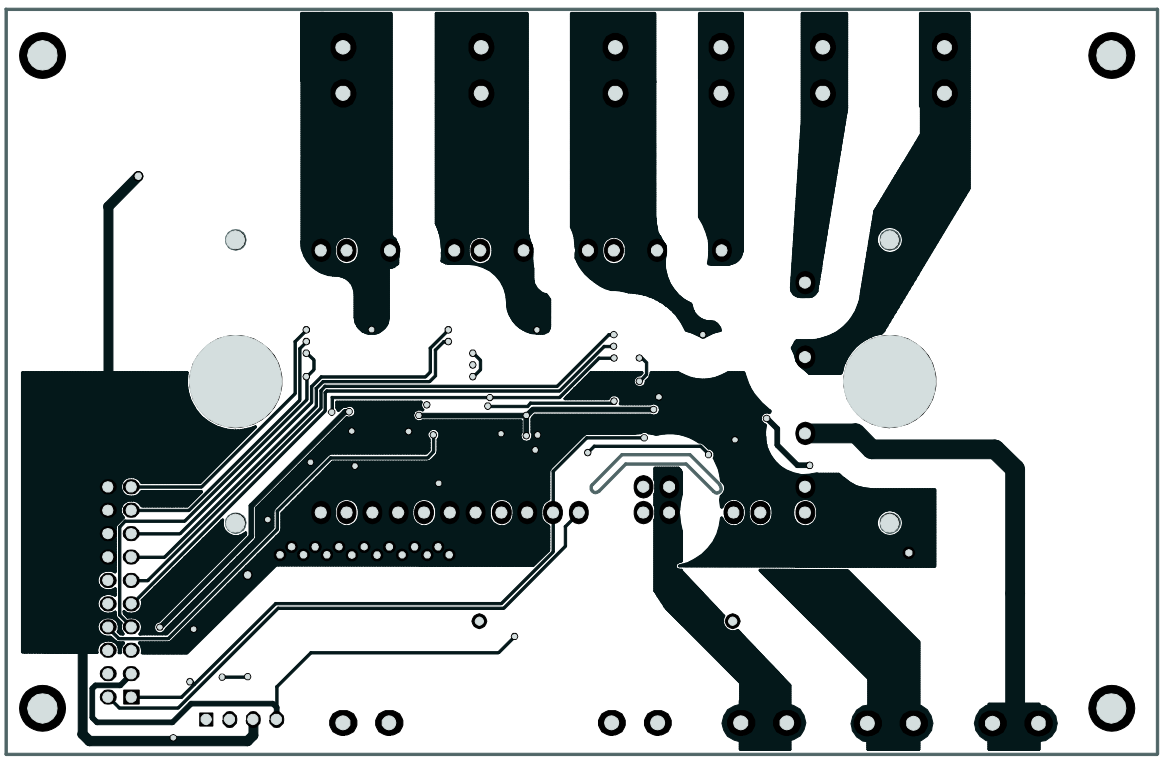


Figure 20: BOTTOM layer

7 Bill of material

	Qty	Value Device	Designator	Part name(s)	Preferred supplier	Comment
Capacitor	1	1n	0603	C91		
Capacitor	1		MKP1840	C14		DC-Link; refer to Table 2
Capacitor	1	2n2	0603	C16		
Capacitor	1	10n	0603	C3		
Capacitor	3	10u / 25V	3528	C11, C12, C13		Boot-Strap
Capacitor	1	47u	7343	C15		Capacitor
Capacitor	11	100n	0603	C1, C2, C4, C5, C6, C7, C8, C9, C10, C70, C90		
Connector	1	20PIN	IDC20	J6		
Connector	1	CON4	SIP4	J5		
Diode	6	BAS385	MICROMELF	D10, D11, D12, D13, D14, D15		Switch-off driver path
Diode	3	BYG21M	DO-214AC-HV	D7, D8, D9		Boot-Strap Diode
IC	3	2ED020I12	P-DSO-18	U4, U5, U6	Infineon	Driver for IGBT modules
Resistor	3		4527	RsW4, RsW5, RsW6		refer to Table 2
Resistor	1		0603	R37		Refer to Chapter 3.4
Resistor	2		0603	R38, R39		Refer to Chapter 3.4
Resistor	4	1k	0603	R40, R41, R42, R43		
Resistor	1	3k	0603	R47		
Resistor	1		0603	R14		refer to Table 2
Resistor	1	20k	0603	R13		
Resistor	1	51k	0603	R71		
Resistor	2	2k7	0603	R16, R17		
Resistor	2	10k	0603	R70, R73		
Resistor	1	3k9	0603	R50		
Resistor	1	2k	0603	R15		
Resistor	1	15k	0805	R0		
Resistor	7	15k	0603	R30, R31, R32, R33, R34, R35		Gate-emitter pull down
Resistor	1	18k	0603	R49		
Resistor	1	11k	0603	R48		
Resistor	6		0805	R19, R20, R23, R25, R26, R29		Rg_off; refer to Table 2
Resistor	6		0805	R18, R21, R22, R24, R27, R28		Rg_on; refer to Table 2
Resistor	1	33	0805	R90		
Resistor	4	120k	1210	R44, R45, R441, R451		Voltage divider
Resistor	1	200	0603	R72		
Resistor	1	330	0603	R46		
Transistor	1	BC847	SOT-23	Q1		
Transistor	1	BCX53	SOT-89	Q91		PNP Bipolar Transistor
Transistor	1	BCX56	SOT-89	Q90		NPN Bipolar Transistor
Module	1	P58x	flow1	U7	Vincotech	PIM module; refer to Table 2

Table 4: Bill of material

Highlighted positions have to be assembled