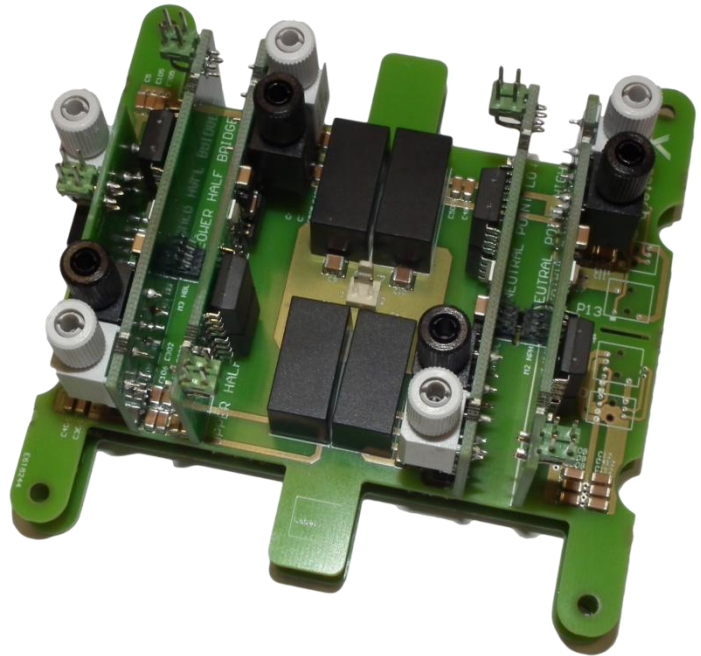




Vincotech

Reference Design



# Gate driver for *M20XP(E)* Power Modules

GD-M20x for MNPC Modules

Rev.6

Reference Design no.:  
RD\_2013-06\_001-v01



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## 1 Introduction

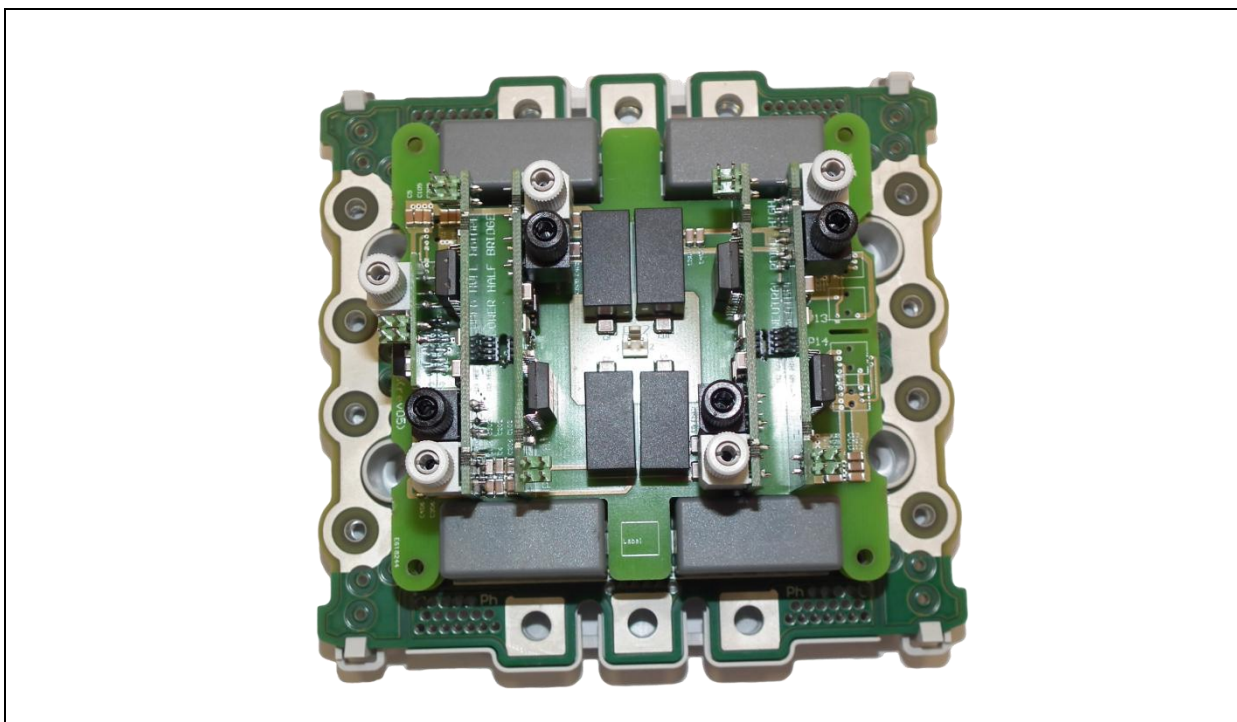
This application note describes the Evaluation Driver Kit for the module family M20x or in other words the *flow*MNPC 4w generation. The topology used in these modules is the Mixed voltage Neutral Point Clamped which has 1200 V components in the half bridge and 600 V components in the neutral path. The board provides a plug and play solution identifying the switching behavior and efficiency of this module family.

This module family is available as a single phase module as well as a three phase module. The single phase module types can be paralleled to achieve a higher output current. Detailed information is available in Vincotech's webpage [www.vincotech.com](http://www.vincotech.com).

This is the first module that carries a high power PCB with capacitors to achieve a low inductance design.

The following picture shows the driver boards with an IGBT module. It is a kit with four different subsystems. This kit can be used to drive the complete range of M20XP(E) modules.

- Current Boost PCB
- Power supply PCB
- Controller PCBs for input and output signals
- PCB for thermistor signal conditioning



*Figure 1: Evaluation driver board with a single phase module*

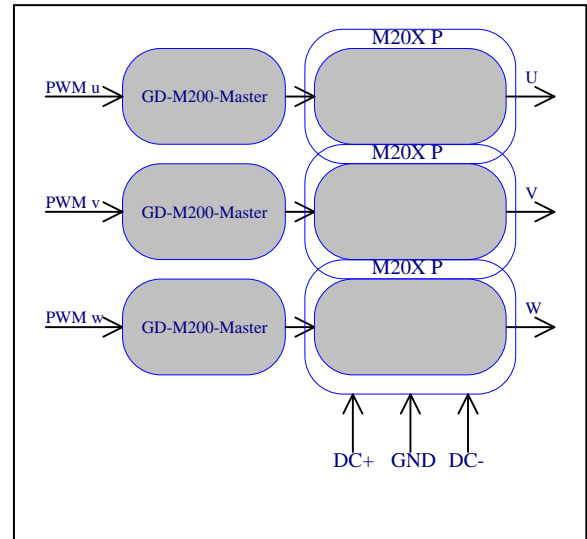
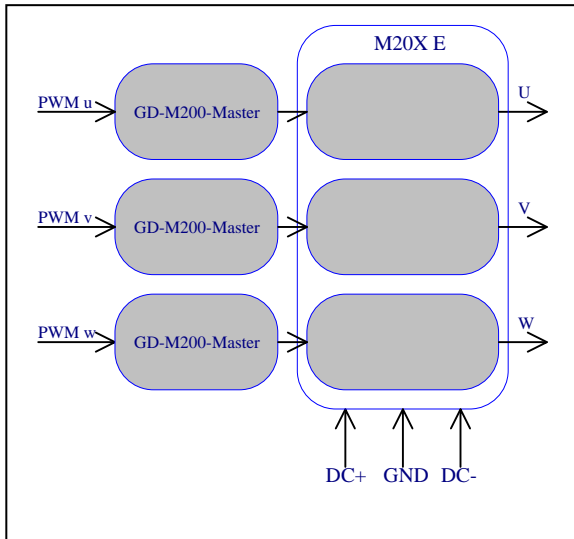
Ordering number is listed below.

Module	M200P	M208P	M209P	M200E	M208E	M209E
1 Phase system	1 X GD-M200-Master			1 X GD-M200-Master + 2 X GD-M200-SLAVE		
3 Phase system				3 X GD-M200-Master		

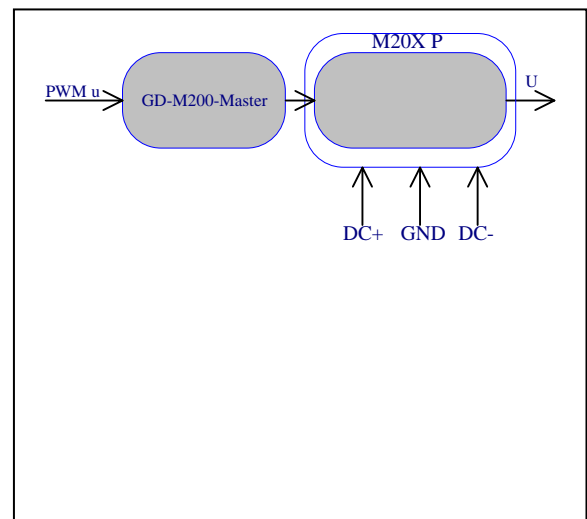
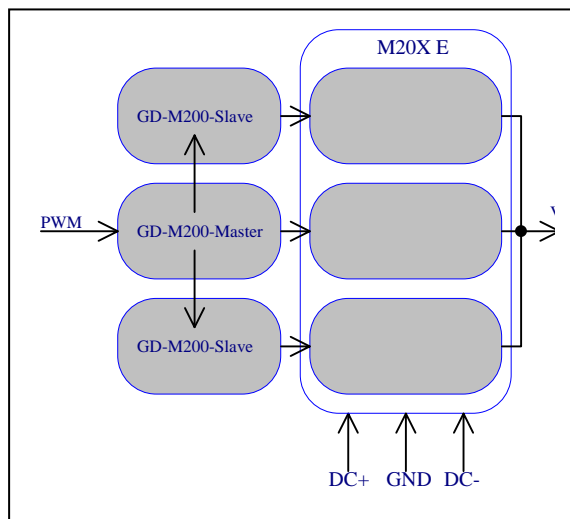
*Table 1: Ordering number*

This ordering number will include all necessary boards to drive a complete phase. To drive the three-phase modules, indicated with an E at the end, three kits are necessary, one Master and two Slaves for parallel operation, and for a 3 Phase system three Master drives are needed.

Three phase connection:



Single phase connection:



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

## 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

- Four drivers for each switch
- Single 15 V power supply with 3000VAC isolation
- Gate voltage of -8 V / +16 V
- Voltage for each switch is generated by a DC/DC converter
- Non-inverting PWM inputs
- Input and output signals 0 V / +5 V
- Alternative input and output signals by fiber optics
- Desaturation protection
- Two steps turn-off with 10 V intermediate level
- Active miller clamp
- Under voltage lockout
- Fault output signal (active high) for each switch
- Heatsink temperature sense with thermistor
- Gate drive current of  $\pm 20$  A peak
- 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 voltage, load and processes. Unless otherwise noted all voltages are given with respect to ground (GND).

Positive currents are assumed to be flowing into pins.

	min.	typ.	max.	Unit	Remarks
$U_{CE}$ – max for 600 V switches			600	V	
$U_{CE}$ – max for 1200 V switches			1200	V	
$P_{max}$ – max output power supply			2	W	
$U_S$ – supply voltage for drivers	14,5	15	15,5	V	See note 1
$I_S$ – Input current no load / full load		30/250		mA	For 1 dc/dc converter
$U_{CC}$ – supply voltage for logic	4.5	5	5.5	V	
$U_{ge\_x}$ – On voltage for logic inputs	4.5	5	5.5	V	
$U_{ge\_x}$ – Off voltage for logic inputs	-3	0	0.8	V	
Under voltage lockout	14	14,5	15	V	UVLO top threshold
Under voltage lockout	13	14	14,5	V	UVLO bottom threshold
Desaturation protection		7		V	
$f_{sw}$ – switching frequency		8	16	kHz	See note 2
$T_a$ – Ambient temperature	-25		70	°C	
$T_{ST}$ – Storage temperature	-40		85	°C	
For additional information refer to the datasheet of TD350 from ST and the datasheet of the HCNW2611 from Avago Technologies					
Note 1: The secondary voltage for the gate drive will change with the same ratio.					
Note 2: Limitation by IGBT losses					

Table 2: Electric parameters

The following table shows different modules available in the M20xy series. Here information about the recommended switching frequency and the assembled passive components are mentioned.

The last letter P indicates a single phase module whereas the E indicated a three phase module.

Module	M208P	M209P	M200P	M208E	M209E	M200E
Nominal chip current [A]	300	400	600	300	400	600
Frequency <sup>1</sup> [kHz]	40	30	20	40	30	20
Gate resistors $R_{G\_ext\_on}$ [ $\Omega$ ]	1.25	1.25	1.25	1.25	1.25	1.25
Gate resistors $R_{G\_ext\_off}$ [ $\Omega$ ]	1.25	1.25	1.25	1.25	1.25	1.25
Gate emitter resistor $R_{GE}$ [ $\Omega$ ]	15K	15K	15K	15K	15K	15K
Gate emitter capacitor $C_{GE}$ <sup>2</sup> [ $\mu$ F]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
<sup>1</sup> : Limit given by the output power of power supply						
<sup>2</sup> : not assembled						

Table 3: Members of M20x family

## 2.3 Channel Assignment

The evaluation driver kit consists of four channels for the IGBTs and an additional channel for the thermistor.

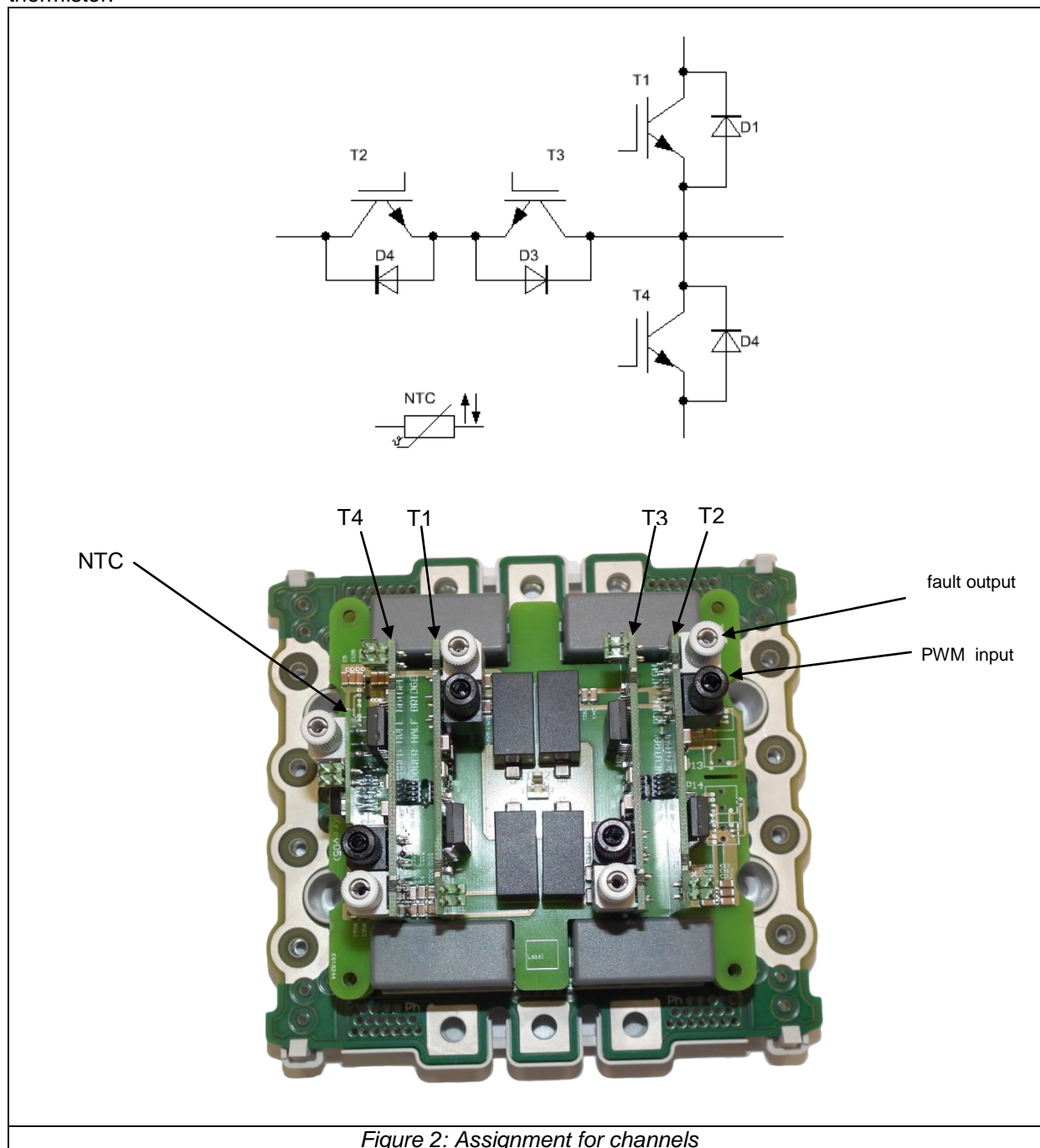


Figure 2: Assignment for channels

## 2.4 Pin assignments and connectors for operation

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

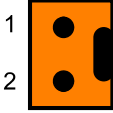
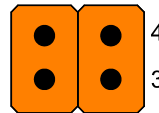
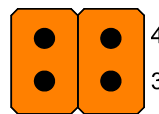
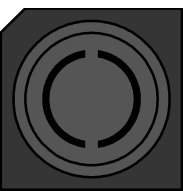
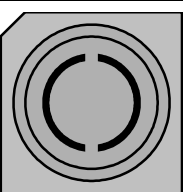
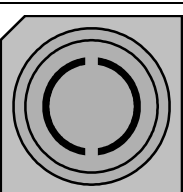
	<b>P17 – Power Supply</b>	<b>P17</b> 	<b>P200 – Signal</b>	<b>P200</b> 
1	+15 V		VCC	
2	GND		Fault - Output	
3			GND	
4			PWM - Input	
			<b>P300 – Thermistor</b>	<b>P300</b> 
1			VCC	
2			Temp - Output	
3			D_GND	
4			nc	
-for each channel			<b>U200 – Input signal</b>	
			-SFH551/1-1V digital receiver for optical data transmission -optical fiber: unconnectorized 2.2mm polymer 650nm	
-for each channel			<b>U201 – Output signal</b>	
			-SFH756V transmitter for optical data transmission with polymer optical fiber 2,2 mm 650nm	
-one per module			<b>U5 – Output thermistor</b>	
			-SFH756V transmitter for optical data transmission with polymer optical fiber 2,2 mm 650nm	

Table 4: Pin assignment for connectors



## 2.5 Mechanical Dimensions

Mechanical dimensions for width, length and height (without module): **98 mm x 95 mm x 46 mm**

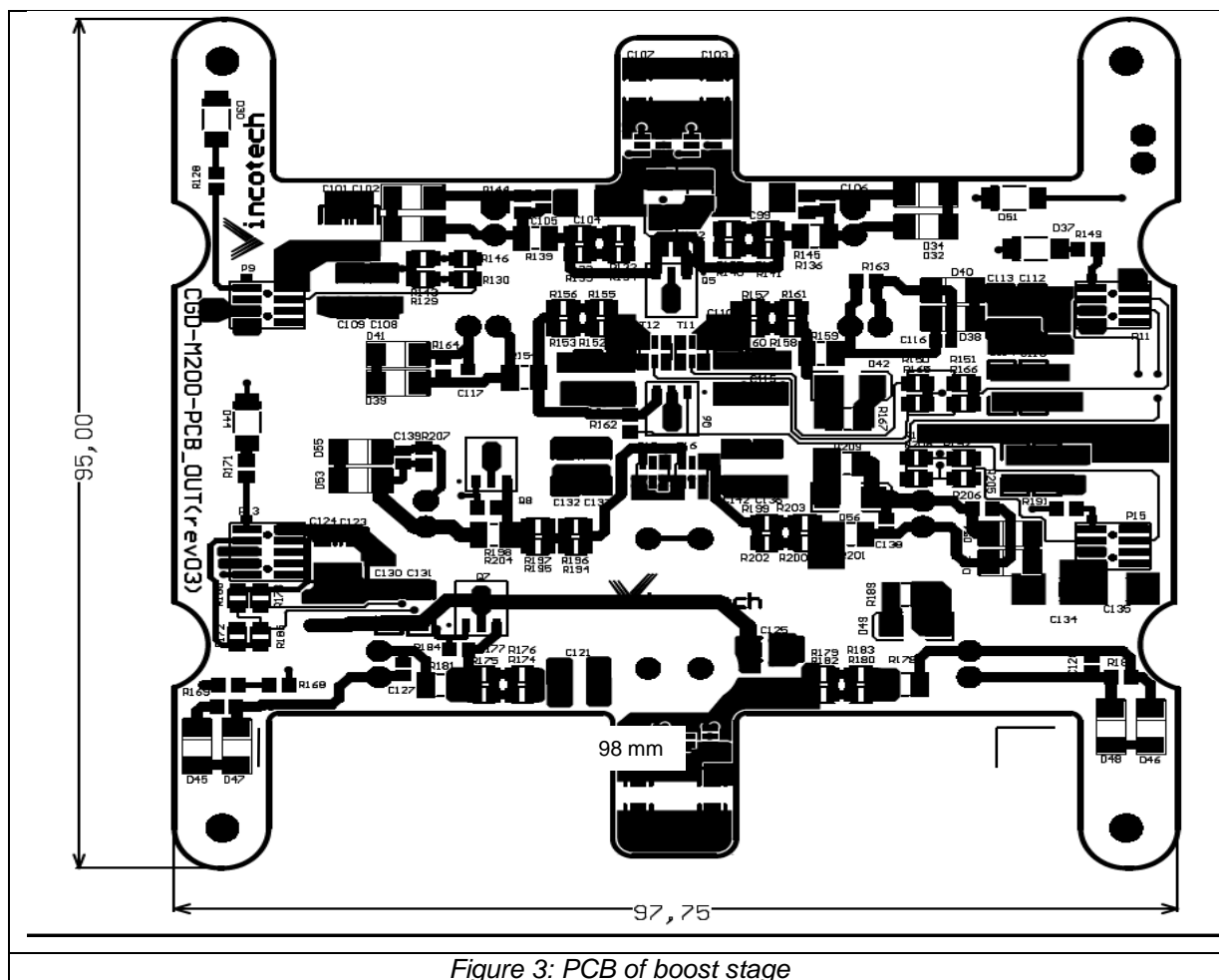


Figure 3: PCB of boost stage

## 3 Description of Electrical Parts

This chapter describes the different electrical parts like the input signals, output signals and driver circuit for a better understanding how the board works.

### 3.1 Power Module

This power module family is suitable for PV applications and for UPS applications. M20xE(P) modules are available in single phase and in three phase configuration based on a mixed voltage neutral point clamped topology which is also known as NPC2 topology. Two 1200V IGBTs with freewheeling diodes are implemented for the half bridge. Two 600V IGBTs with freewheeling diodes are placed between the neutral point and the output. The IGBTs and the freewheeling diodes have the same current rating. For temperature measurement a NTC is equipped. Note that this NTC has only a functional isolation.

### 3.2 Required power supplies

To ensure a correct operation of the evaluation kit one single 15 V power supply for all gate drivers of a single phase module is enough. The 15 V has to be supported through the connector P17. A 5 V power supply ensures the input and output signals for the logic. This has to be applied on each channel as well as on the PCB with the thermistor measurement.

### 3.3 Input / output signals

As mentioned each channel needs a 5 V power supply. The voltage can be supplied with one single power supply. No isolation between the channels is needed.

The switching of the IGBT inverter needs to be controlled by 4 channels for each phase. The dedicated connector for input signals is the connector P200. Each switch has its own fault output activated by under voltage lockout or by desaturation supported through the same connector.

The output of the thermistor is a PWM signal. All inputs U200 and outputs U201 are available as optical signals through fibre optic connectors.

### 3.4 Thermistor output

The thermistor output is generated with a voltage-controlled pulse width modulator. It is supported to the connector P300 and the fiber optic connector U5. This PCB needs a 5 V power supply as well. The attached diagram gives the duty cycle and input modulation voltage as a function of the NTC temperature which is build in the power module.

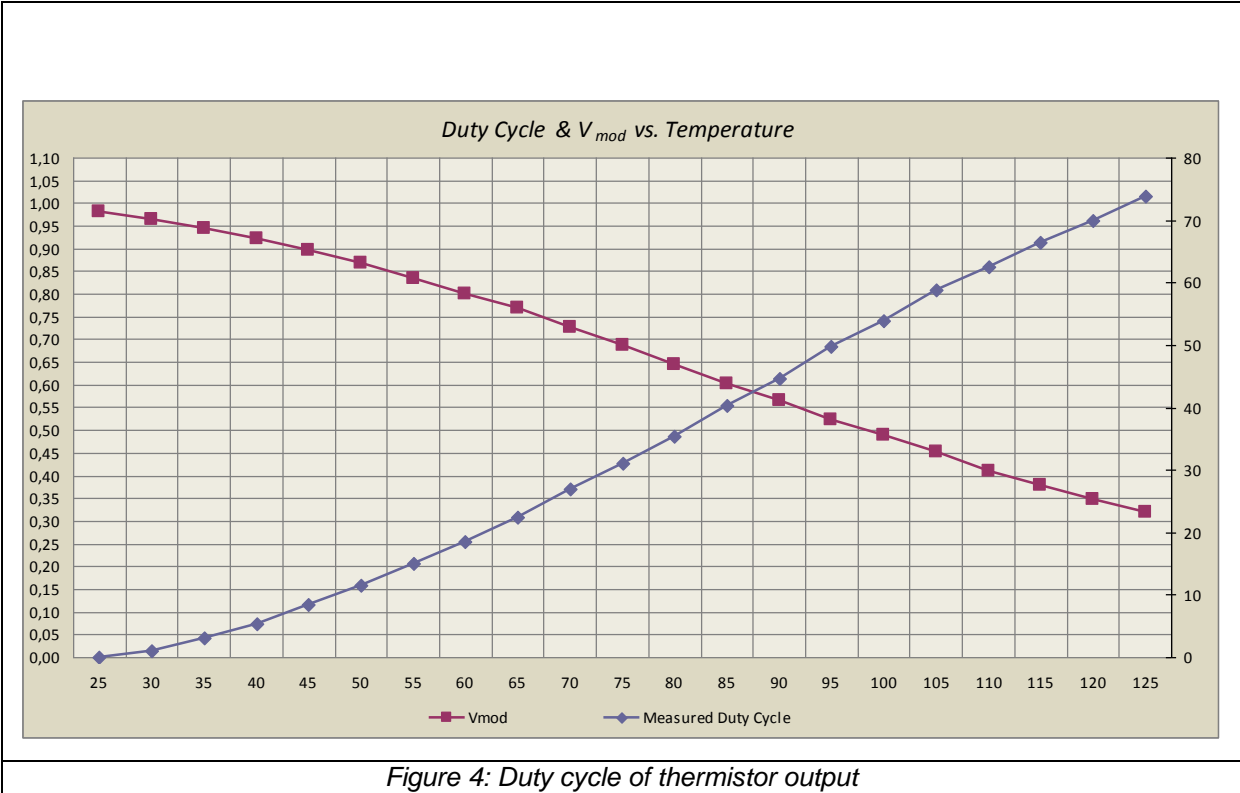


Figure 4: Duty cycle of thermistor output

### 3.5 PCB – Power Supply

The power supply board supports all four channels of the M20x evaluation kit. A 15 V power supply has to be used to support the 2-pin connector in the middle of the PCB (P17). Four independent DC/DC converters are used on this board to generate +16 V / -8 V for each IGBT.

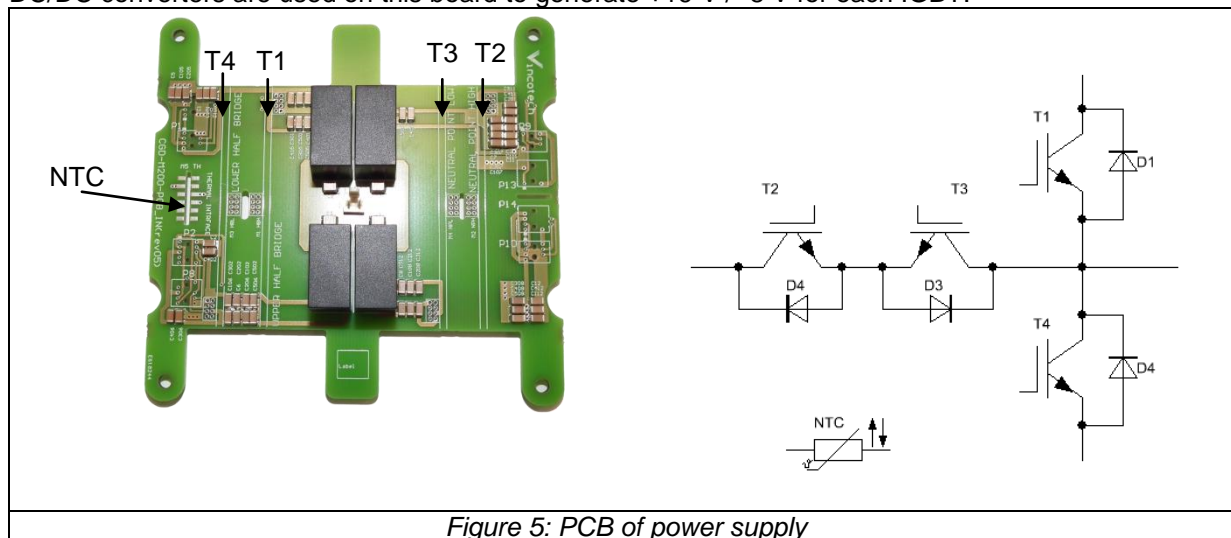


Figure 5: PCB of power supply

The asymmetric bipolar voltage for the IGBTs is generated by a DC/DC converter IG136-15

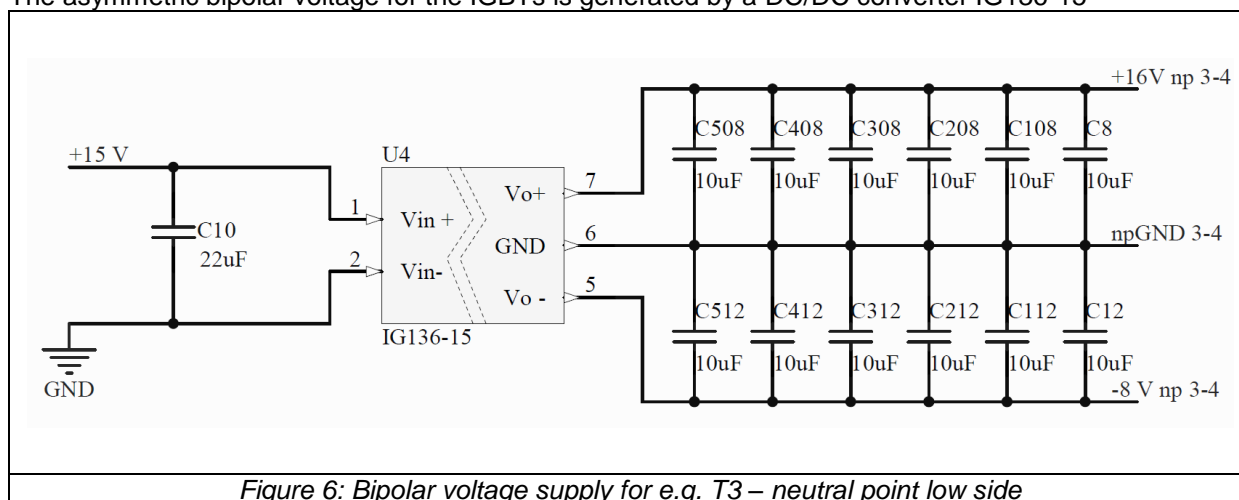
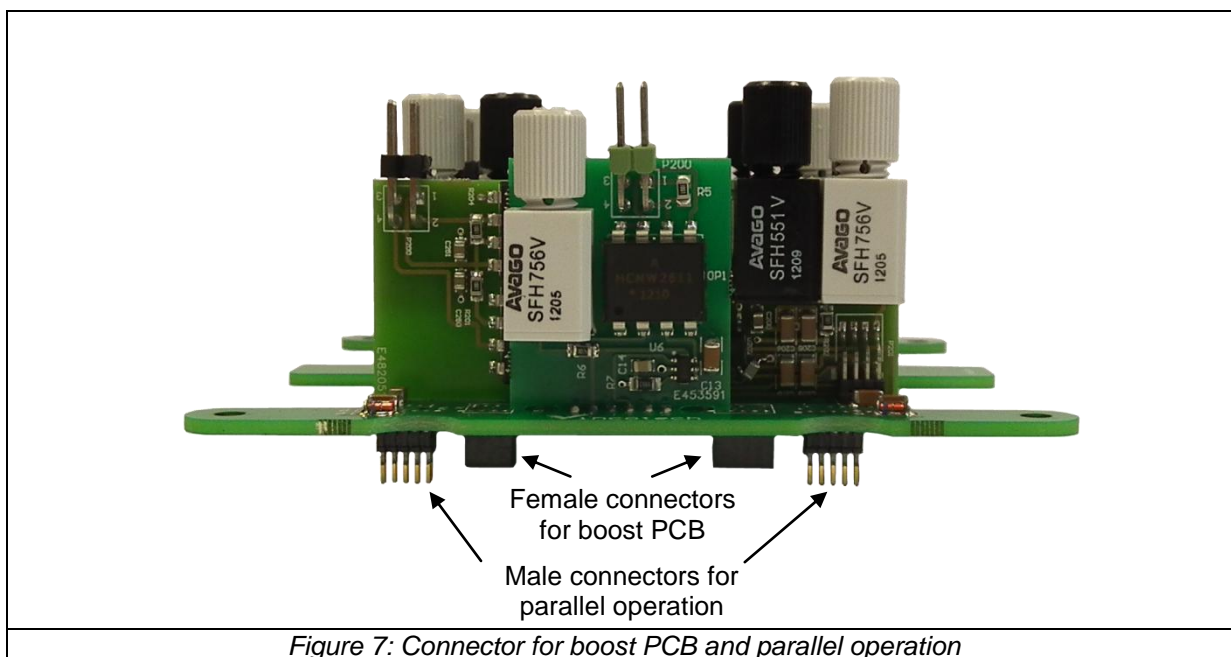


Figure 6: Bipolar voltage supply for e.g. T3 – neutral point low side

The DC /DC converter (IG136-15) is a 2 W 15V input, +17V/-8,7V output with 3000VACrms I/O isolation.

Different connectors are used on the bottom side of the power supply PCB to supply the signals from the input, output and thermistor PCB to the boost PCB.

Additional connectors on the bottom side of the power supply PCB are used for Master-Slave operation. This configuration can be used to parallel e.g. three M200P modules.



*Figure 7: Connector for boost PCB and parallel operation*

The pin assignment for the bottom connectors is like the following:

Connectors for boost PCB			Connectors for parallel operation		
Pin	Signal	Comment	Pin	Signal	Comment
1	desat np H	Desaturation protection	1	desat np H	Desaturation protection
2	+16V np 1-2	Positive supply voltage	2	+16V np 1-2	Positive supply voltage
3	out H np H	Output for high signal	3	out H np H	Output for high signal
4	out L np H	Output for low signal	4	out L np H	Output for low signal
5	-8V np 1-2	Negative supply voltage	5	-8V np 1-2	Negative supply voltage
6	clamp np H	Clamp	6	clamp np H	Clamp
7	npGND 1-2	Ground	7	npGND 1-2	Ground
8	nc	not connected	8	nc	
			9	nc	
			10	nc	

*Table 5: Pin assignment for connectors, e.g. T2 – neutral point high side*

### 3.6 PCB – CTR Input and Output

Four additional vertical mounted PCBs provide the PWM input signals for the IGBTs as well as fault signals coming from the IGBTs.

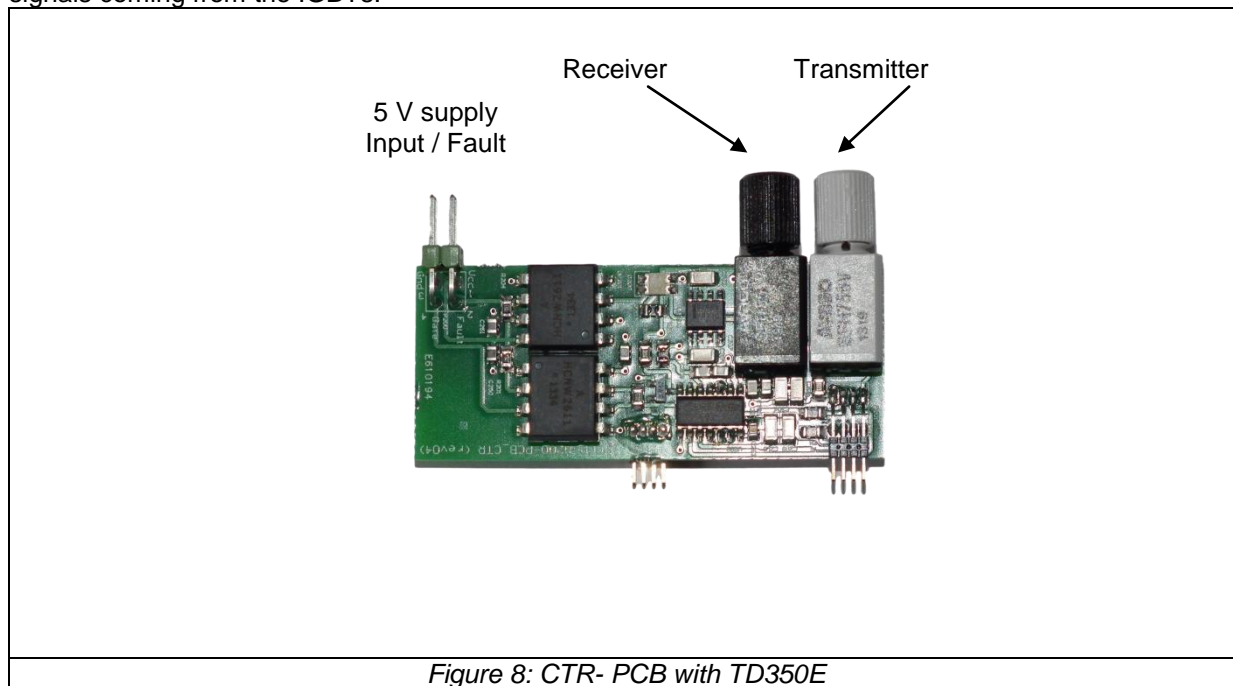
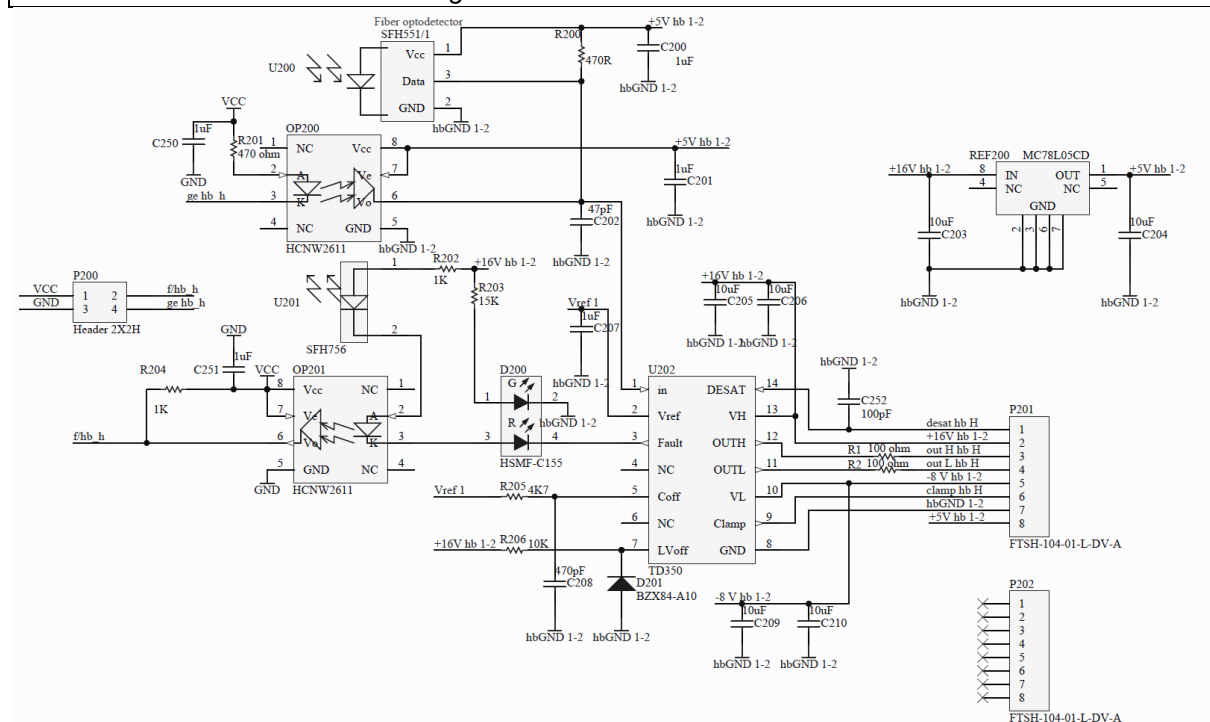


Figure 8: CTR- PCB with TD350E



A 5 V power supply is required for each input and output PCB. A common power supply can be used. Two different options are available to drive the IGBT. One is through a usual connector on the left side. The other is with fiber optics.

One pin / fiber supports the PWM switching signal for the IGBT and the other supports a fault signal back.

The pin assignment is shown in Table 4.

An opto coupler in widebody package provides the isolation between the user side and the power side for each signal direction.

The green LED indicates that a voltage is applied on the secondary side. In this case the supply voltage comes from the power supply PCB.

The red LED starts lighting when a fault is detected.

A voltage regulator generates the 5 V secondary supply voltage for the input opto coupler and the receiver fiber out of the 16 V coming from the power supply PCB.

The IGBT driver IC is the TD350E

Features of the IGBT gate driver IC

- Active Miller clamp feature
- Two-level turn-off with adjustable level and delay
- Desaturation detection
- Fault status output
- Negative gate drive capability
- UVLO protection
- 2 kV ESD protection (HBM)

**Activ Miller clamp:** During turn-off, the gate voltage is monitored and the clamp output is activated when gate voltage goes below 2 V (relative to GND). The clamp voltage is  $V_L + 3$  V max. for a Miller current up to 500 mA. The clamp is disabled when the IN input is triggered again. The current capability of the clamp output is increased by an external PNP bipolar transistor placed on the current booster PCB (bottom PCB).

**Two-level turn-off:** The two-level turn-off is used to increase the reliability of the application. During turn-off, gate voltage can be reduced to a programmable level (set by D201 to a 10 V) in order to reduce the IGBT current (in the event of overcurrent). This action prevents both dangerous overvoltage across the IGBT and RBSOA problems, especially at short-circuit turn-off. The two-level turn-off ( $T_a$ ) delay is programmable through an external resistor (R205) and capacitor (C208) for accurate timing use the following equation :

$$T_a [\mu s] = 0.7 \cdot R_{205} [k\Omega] \cdot C_{208} [nF] \quad T_a \text{ is set to } 1,5 \mu s$$

Turn-off delay ( $T_a$ ) is also used to delay the input signal to prevent distortion of input pulse width.

**Desaturation detection:** When the **desat** voltage goes higher than 7 V, the output is driven low (with 2-level turn-off). The FAULT output is activated. The FAULT state is exited at the next falling edge of IN input. A programmable blanking time is used to allow enough time for IGBT saturation. The blanking time is made of an internal 250 $\mu$ A current source and an external capacitor (C252). The high voltage diode blocks the high voltage during IGBT off state (a standard 1kV); the 1k $\Omega$  resistor filters parasitic spikes and also protects the DESAT input.

During operation, the DESAT capacitor is discharged when TD350 output is low (IGBT off). When the IGBT is turned on, the DESAT capacitor starts charging and desaturation protection is effective after the blanking time ( $t_b$ )

$$t_b = 7.2[V] \cdot C_{252} / 250[\mu A]$$

When a desaturation event occurs, the fault output is pulled down and TD350 outputs are low (IGBT off) until the IN input signal is released (high level), then activated again (low level).

$$C_{252} = 100 pF$$

**Fault status output:** the dedicated output pin of the IC is used to signal a fault event (desaturation, UVLO) to a controller. The fault pin drives direct the OP 201 optocoupler via a red colored LED. When a fault event is detected the red LED will light up.

**Minimum ON time:** In order to ensure the proper operation of the 2-level turn-off function, the input ON time ( $T_{win}$ ) must be greater than the  $T_{winmin}$  value:

$$T_{winmin} = T_a + 2 \cdot R_{del} \cdot C_{208} = 1,5 + 2 \cdot 0,5 \cdot 0,47 = 2\mu s$$

$R_{del}$  is the internal discharge resistor of TD350E 0,5 k $\Omega$  (from the datasheet of TD350E)

Input signals smaller than  $T_a$  are ignored. Input signals larger than  $T_{winmin}$  are transmitted to the output stage after the  $T_a$  delay with minimum width distortion ( $\Delta T_w = T_{wout} - T_{win}$ ).

For an input signal width  $T_{win}$  between  $T_a$  and  $T_{winmin}$ , the output width  $T_{wout}$  is reduced below  $T_{win}$  (pulse distortion) and the IGBT could be partially turned on. These input signals should be avoided during normal operation.

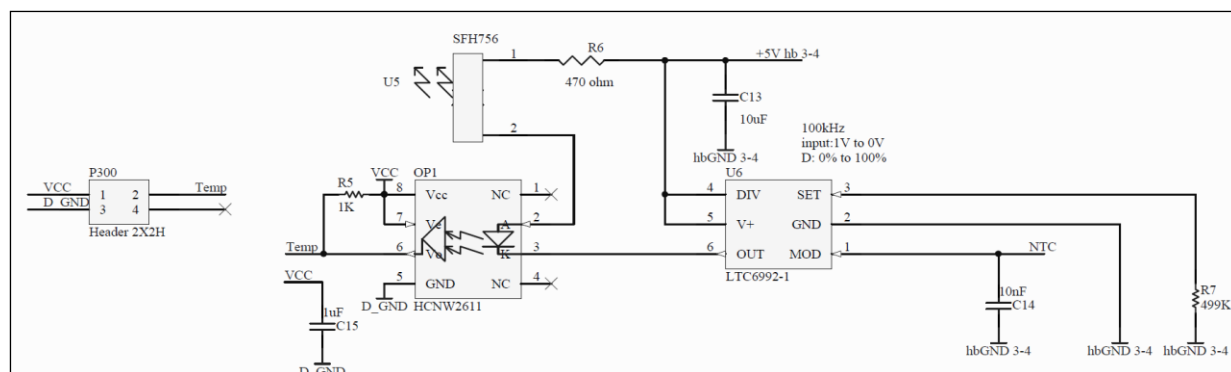
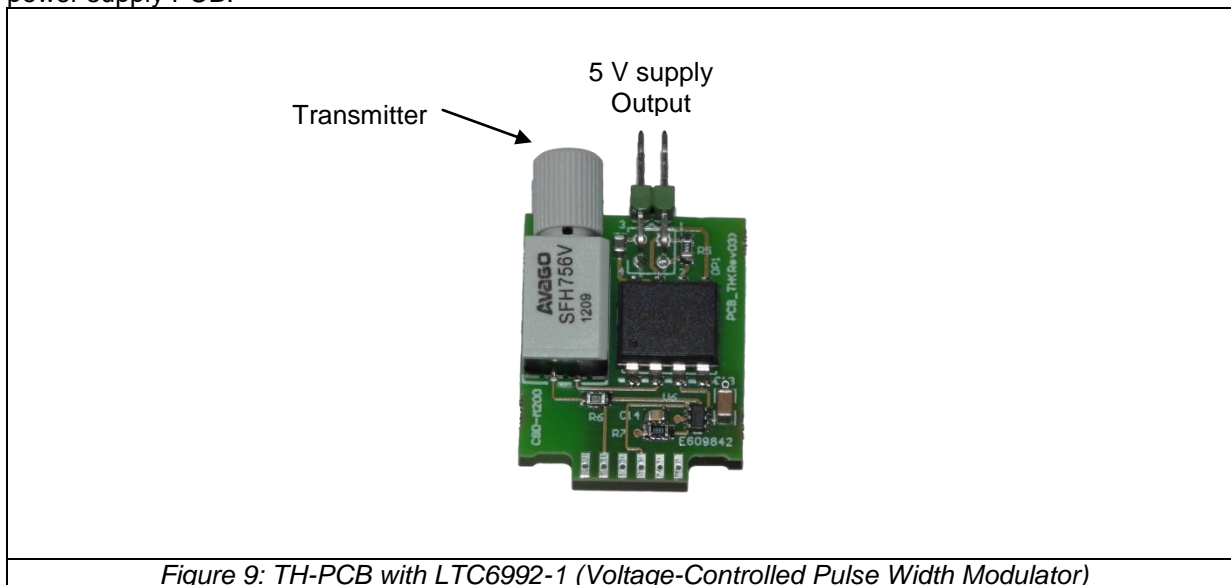
For more details see :

<http://www.st.com/web/en/resource/technical/document/datasheet/DM00023850.pdf>



### 3.7 PCB – Thermistor

One vertical mounted PCB measures the NTC and provides electrical and optical information. These PCBs are not equipped with a connector in newer driver kit versions but soldered direct into the power supply PCB.



A 5 V supply is required to power this PCB. The same power supply as for the Input and Output PCB can be used.

Two different options are available. One is through a usual connector on the left side. The other is with fiber optics.

An opto coupler in widebody package provides the isolation between the user side and the power side.

A voltage regulator generates the 5 V secondary supply voltage for the opto coupler out of the 16 V coming from the power supply PCB

### 3.8 PCB – Booster

The boost PCB provides the needed gate current to drive the IGBTs. Four independent driver channels are assembled.

It is supplied by the power supply PCB with +16 V and -8 V.

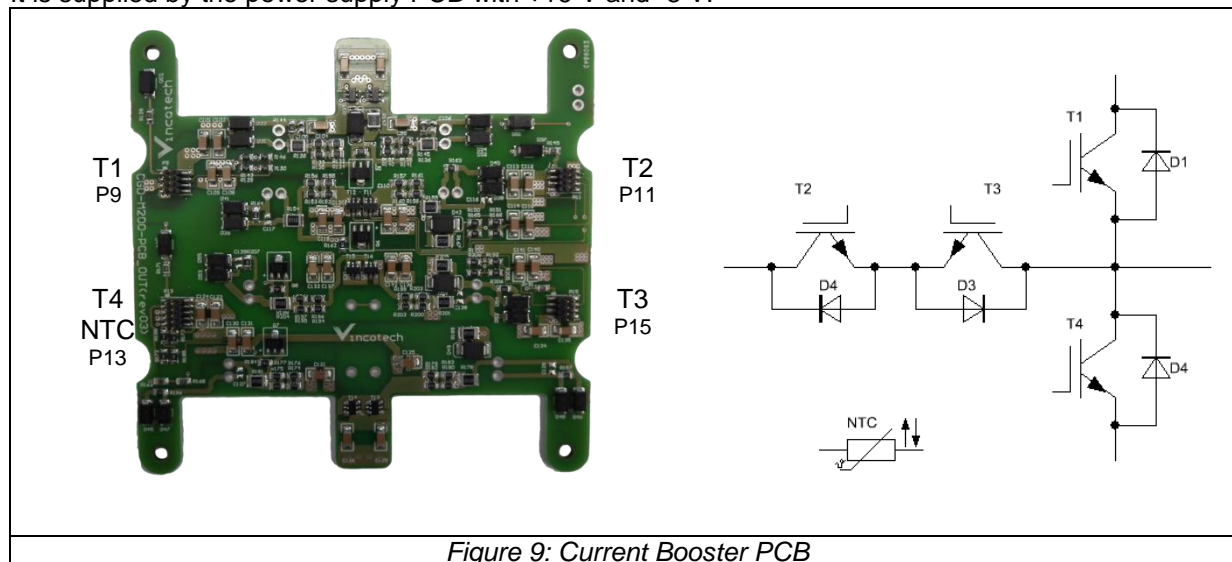


Figure 9: Current Booster PCB

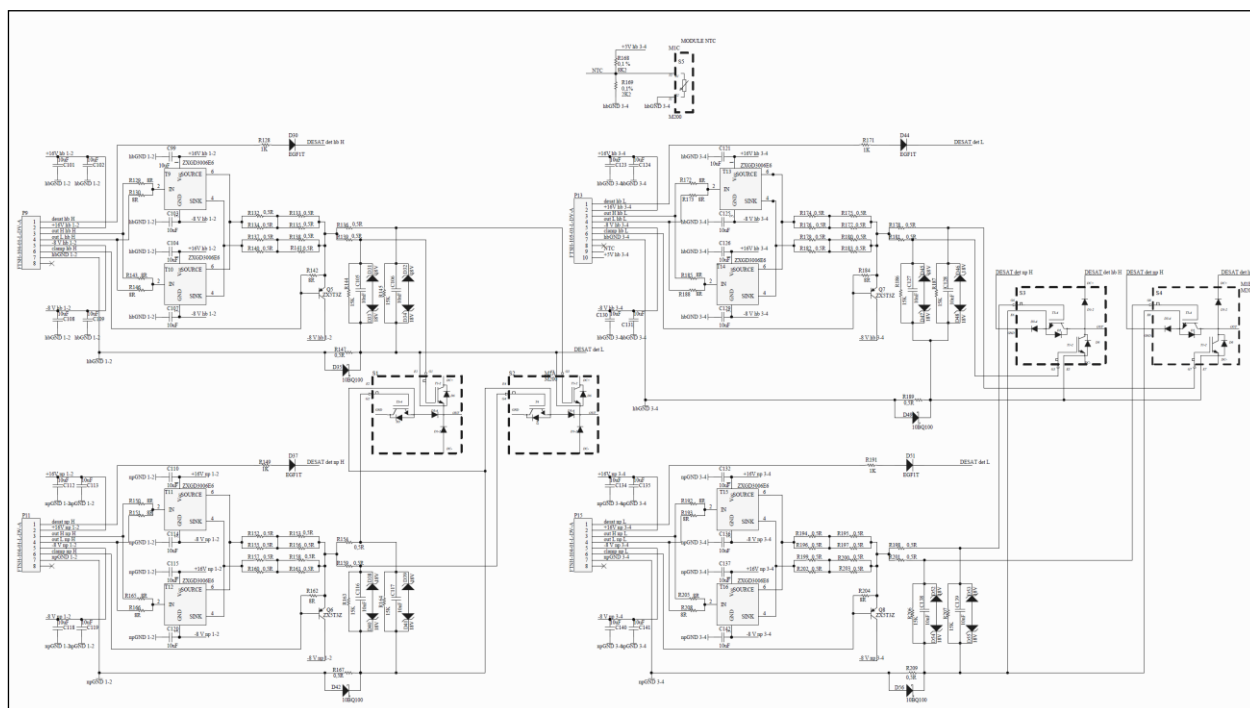
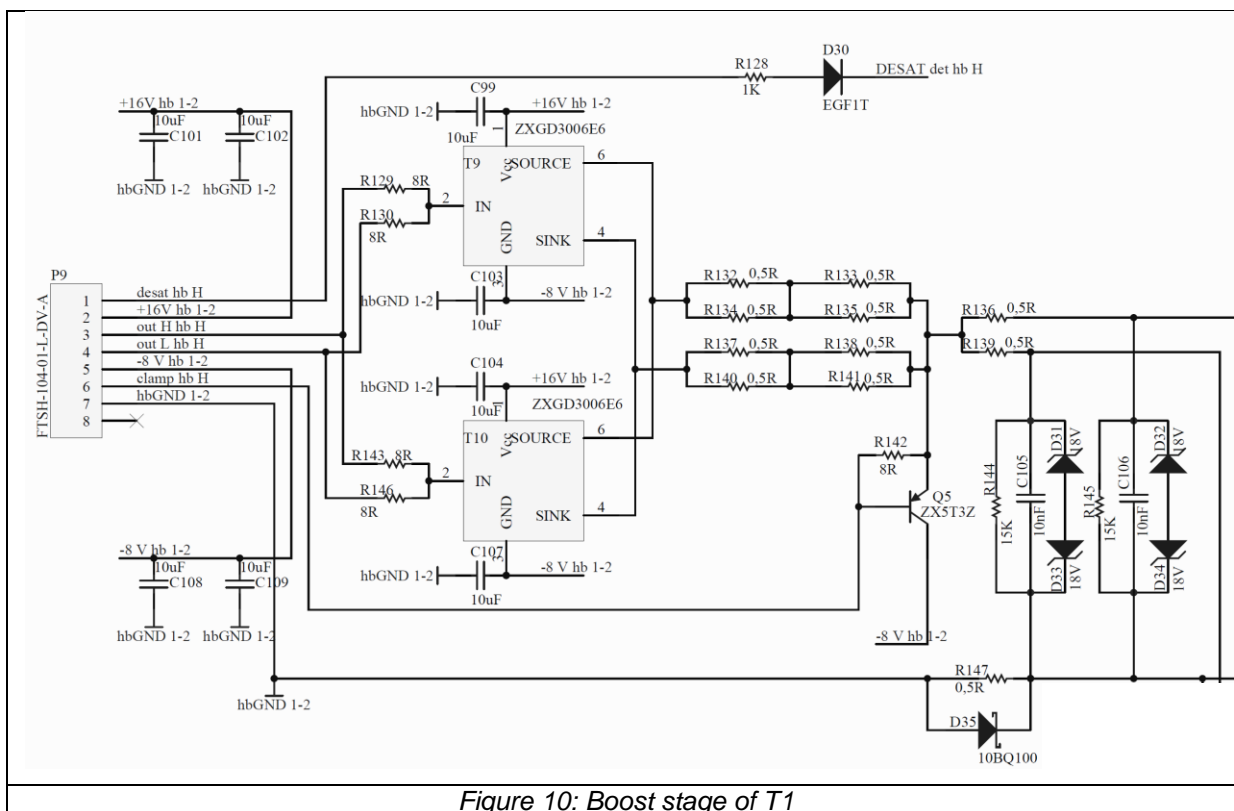
The pin assignment for the connectors is like the following:

Connector P9, P11, P13, P15					
Pin	Signal P9	Signal P11	Signal P13	Signal P15	Comment
1	desat	desat	desat	desat	Desaturation protection
2	+16 V	+16 V	+16 V	+16 V	Positive supply
3	out high	out high	out high	out high	Signal for turn-on
4	out low	out low	out low	out low	Signal for turn-off
5	-8 V	-8 V	-8 V	-8 V	Negative supply
6	clamp	clamp	clamp	clamp	Miller clamping
7	GND	GND	GND	GND	Ground
8	n.c.	n.c.	n.c.	n.c.	not connected
9			NTC		NTC
10			+5 V		Supply for NTC

Table 6: Pin assignment for connectors, e.g. T3 – neutral point high side

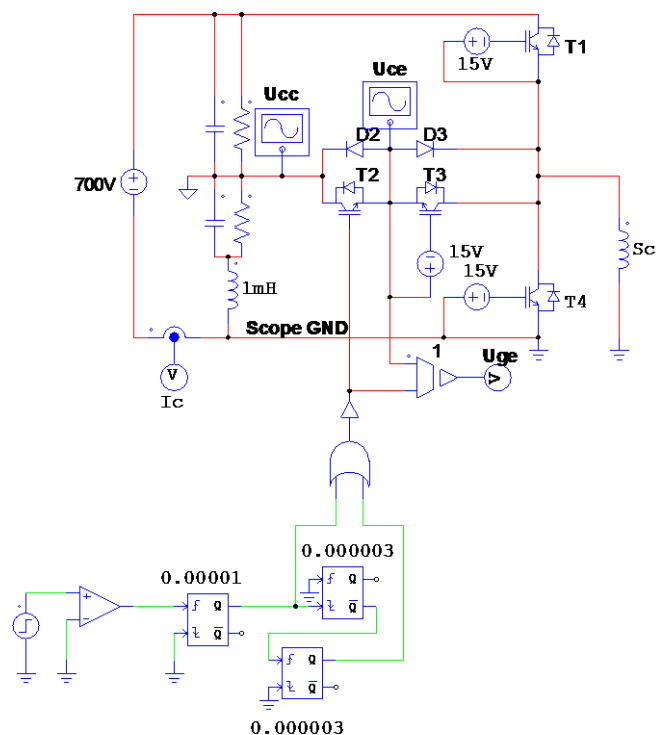
The PCB has two current boost stages that are connected in parallel to provide a high gate current when necessary. The module has two gate pins. Each for half of the nominal module current. A common gate resistor as well as separated gate resistors are used for the gates and the common emitter.

The schematic to drive the IGBT is shown in the next figure as an example for T1. The schematics for T2 – T4 are the same.



## 4 Short Circuit Protection

The short circuit protection has been tested by using critical inductance for the short ( $S_c$ ). Critical inductance means that the inductance is so small that  $di/dt$  is high enough not to be able to be detected by the current sensing of the inverter. On the other hand the inductance is so big that the IGBT can temporary saturate due to the high  $di/dt$  and so the IGBT has to withstand  $du/dt$  after the short circuit protection is activated by the desaturation sensing.



The interpretation of the curves is the following.

At „0“ time the T2 IGBT is getting a positive gate voltage and it saturates. The emitter voltage, „magenta“ rises to the collector voltage, „green“. The current, „blue“ on the short circuit impedance starts to increase rapidly. Current range is 1000A / DIV. At about 4000A collector current the IGBT desaturation sensing is activated and the soft turn off is initiated, At „1“ time the gate drive circuit switches to the first turn off level of 10Vs. At time „2“ the IGBT desaturates in a soft manner due to the reduced gate drive voltage and the gate drive settles to 10V. As the IGBT is not turned off, there is no dangerous  $du/dt$  to cause RBSOA infringement and the overvoltage spike on the IGBT is also small.

The short circuit current at a value of about 5000A partly commutes into the freewheeling diode (inverse diode of T4). The IGBT is conducting a current limited by its transfer current characteristics at 10V gate voltage. At time „3“ the IGBT gate voltage is totally switched off to -8V and the IGBT releases the rest of current. As the majority of the short circuit current is already flowing through the freewheeling diode and as there is no voltage change on the IGBT ( $du/dt$ ) at this moment there will be no dangerous voltage overshoot and turn off safe operating area for the IGBT will be fulfilled.

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17:34:00

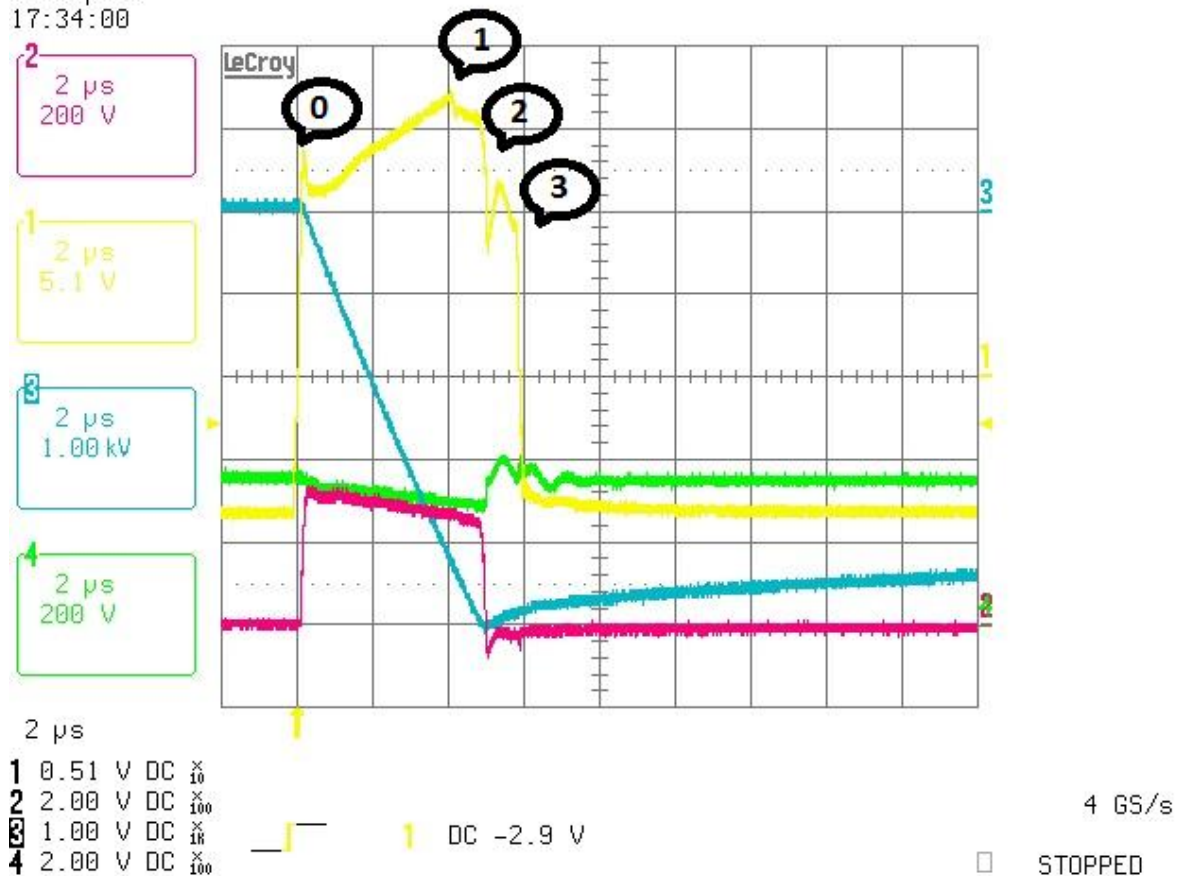
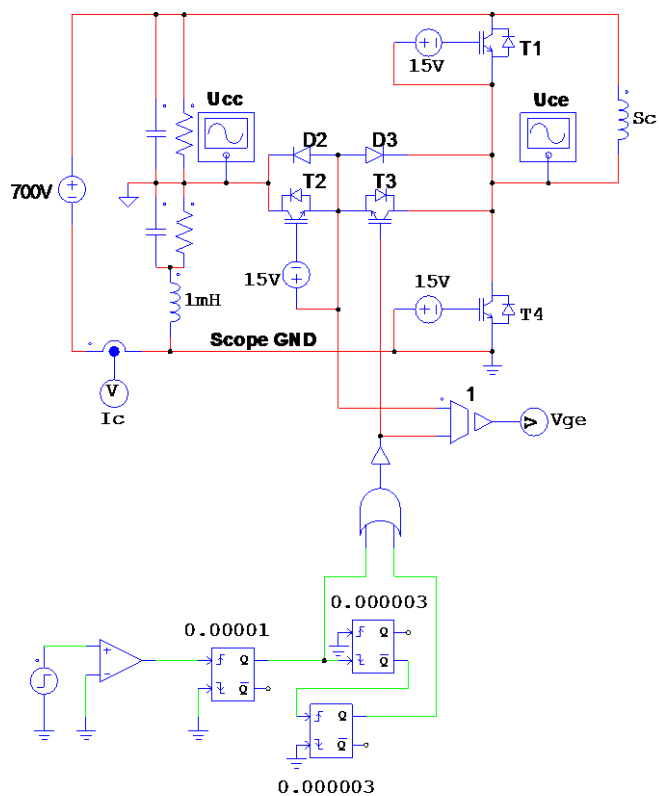


Figure 13: Schematic and waveforms of T2 NP high IGBT short circuit measurement

The short circuit protection is checked for all 4 IGBTs.



30-Sep-13  
17:19:14

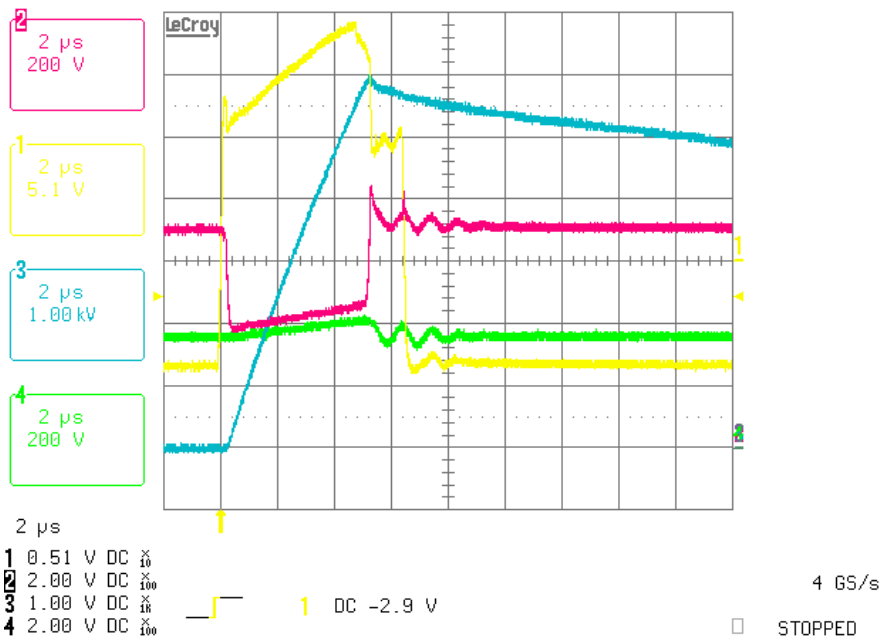
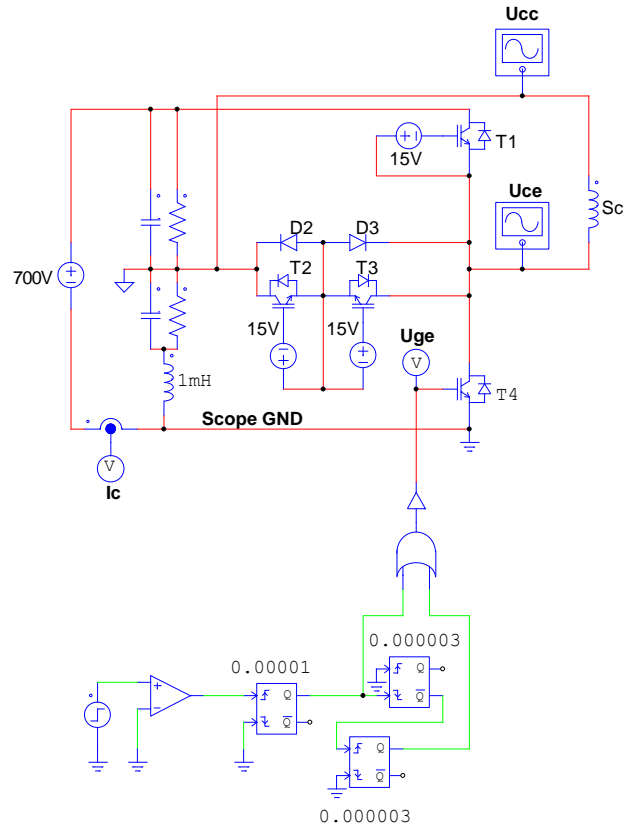


Figure 14: Schematic and waveforms of T3 NP low IGBT short circuit measurement



30-Sep-13  
17:46:09

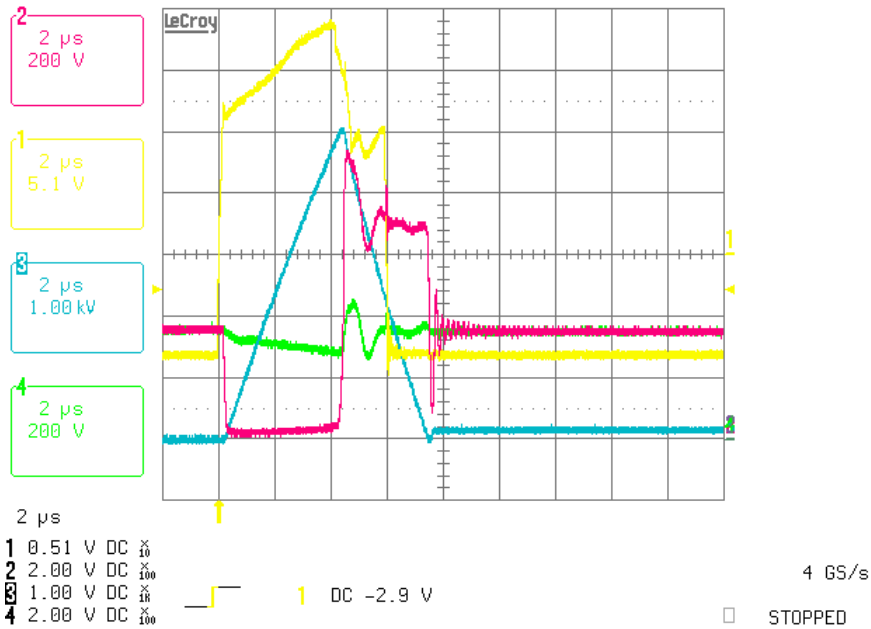


Figure 15: Schematic and waveforms of T4 HB low IGBT short circuit measurement





## 5 BOM

### 5.1 BOM Thermal Module

Item	Quantity	Un	Component	BOM component	Material Group	Released manufacturers	Layout positions
0010	1,000	PC	311823	CGD-M200-PCB_TH(Rev03; SAMPLE	PCB		
0011	1,000	PC	300780	C-10nF-50V-10%-X7R-0805-CM(I)	Capacitors below 500V	08055C103KAT2A AVX	C14
0022	1,000	PC	300737	C-1uF-25V-10%-X7R-0805-PM	Capacitors below 500V	08053C105KAT2A AVX; C0805C105K3RAC KEMET	C15
0025	1,000	PC	303142	C-10uF-25V-10%-X7R-1206-PM	Capacitors below 500V	GRM31CR71E106KA12L Murata	C13
0030	1,000	PC	311002	HCNW2611-300E-DIP8; SAMPLE	Optoelectronics	HCNW2611-300E AVAGO Opto-coupler	OP1
0040	1,000	PC	311007	CONNECTOR-4PIN/2ROWS-2.54mm-PM; SAMPLE	Connectors	826953-2 TE CONNECTIVITY/AMP; (0,1" AMPMODU Header)	P300
0050	2,000	PC	300748	R-470R-1%-TK100-0805-CM(I)	Resistors	WR08X4700FTL WALSIN	R5, R6
0060	1,000	PC	311029	R-499K-1%-TK100-0805-PM; SAMPLE	Resistors	CRCW0805499KFKEA VISHAY	R7
0070	1,000	PC	311005	SFH756V-PM; SAMPLE	Miscellaneous	SFH756V AVAGO Transmitter	U5
0080	1,000	PC	311030	IC-LTC6992CS6-1-SOT363-6L-PM; SAMPLE	Ics incl. Driver	LTC6992CS6-1xTRMPBF-PWM LINEAR TECHNOLOGY	U6

### 5.2 BOM Control Module

Item	Quantity	Un	Component	BOM component	Material Group	Released manufacturers	Layout positions
0005	1,000	PC	312042	CGD-M200-PCB_CTR(Rev04); SAMPLE	PCB		
0010	5,000	PC	300737	C-1uF-25V-10%-X7R-0805-PM	Capacitors below 500V	08053C105KAT2A AVX C0805C105K3RAC KEMET	C200-C201, C207, C250, C251
0020	1,000	PC	310998	C-47pF-100V-NPO-0805-PM; SAMPLE	Capacitors	MCCA000394-MLCC Multicomp	C202
0030	6,000	PC	303142	C-10uF-25V-10%-X7R-1206-PM	Capacitors below 500V	GRM31CR71E106KA12L Murata	C203, C204, C205, C206, C209, C210
0035	1,000	PC	311040	C-100pF-50V-10%-X7R-0805-PM; SAMPLE	Capacitors	MCCA001270 Multicomp	C252
0040	1,000	PC	300774	C-470pF-50V-5%-COG-0805-CM(I)	Capacitors below 500V	CC0805JRNPO9BN471 YAGEO	C208
0045	2,000	PC	311323	R-100R-1%-TK100-0805; Sample	Resistors	CRCW0805100RFKABC Vishay	R1, R2
0050	1,000	PC	310999	LED-HSMF-C155-(Red/Green)-SMD-PM; SAMPLE	LEDs	HSMF-C155-LED (3.2*2.7*1.1) AVAGO	D200
0060	1,000	PC	303928	DI-BZX84C10-SOT23	Diodes	BZX84C10 NXP-Semiconductor	D201
0070	2,000	PC	311002	HCNW2611-300E-DIP8; SAMPLE	Optoelectronics	HCNW2611-300E AVAGO Opto-coupler	OP200, OP201
0080	1,000	PC	311007	CONNECTOR-4PIN/2ROWS-2.54mm-PM; SAMPLE	Connectors	826953-2 TE CONNECTIVITY/AMP; (0,1" AMPMODU Header)	P200
0090	2,000	PC	311008	CONNECTOR-8PIN-1.27mm-MT-PM; SAMPLE	Connectors	FTSH-104-001-F-MT-TR Samtec	P201, P202
0100	1,000	PC	300748	R-470R-1%-TK100-0805-CM(I)	Resistors	WR08X4700FTL WALSIN	R200
0110	3,000	PC	300749	R-1K-1%-TK100-0805-CM(I)	Resistors	WR08X1001FTL WALSIN	R201, R202, R204
0120	1,000	PC	310982	R-15K-1%-TK100-0805-PM; SAMPLE	Resistors	CRCW080515K0FKEAHP Vishay	R203
0130	1,000	PC	303237	R-4K7-1%-0805-PM	Resistors	CR21410FL ASJ CRCW08054K7FKE3 VISHAY-BCC 2322 734 64702 L Phycomp RC0805FR-074K7L YAGEO RK73H2ATTD4701F KOA	R205
0140	1,000	PC	300758	R-10K-1%-TK100-0805-CM(I)	Resistors	WR08X1002FTL WALSIN	R206
0150	1,000	PC	310408	MC78L05ACDR2G; Sample	Ics incl. Driver	MC78L05ACDR2G Fairchild	REF200
0160	1,000	PC	311004	SFH551/1-1V-PM; SAMPLE	Miscellaneous	SFH551/1-1V AVAGO	U200
0170	1,000	PC	311005	SFH756V-PM; SAMPLE	Miscellaneous	SFH756V AVAGO	U201
0180	1,000	PC	311006	IC-TD350ID-SO14-PM; Sample	Ics incl. Driver	TD350ID ST Microelectronics	U202

### 5.3 BOM Current Booster Module

Item	Quantity	Un	Component	BOM component	Material Group	Released manufacturers	Layout positions
0010	1,000	PC	311822	CGD-M200-PCB_OUT(Rev03); SAMPLE	PCB		
0020	32,000	PC	303142	C-10uF-25V-10%-X7R-1206-PM	Capacitors below 500V	GRM31CR71E106KA12L Murata	C99, C101-104, C107-110, C112-115, C118-121, C123-126, C129-132, C134-137, C140-142
0050	4,000	PC	311039	DI-EGF1T-E3/67A-DO214BA-PM; SAMPLE	Diodes	EGF1T-E3/67A VISHAY (1300V, 1A)	D30, D37, D44, D51
0060	16,000	PC	311037	DI-SMAZ16V-SMAZ-PM; SAMPLE	Diodes	SMAZ16V DIODES (Zener, 16V, 1W)	D31-34, D38-41, D45-48, D52-55
0070	4,000	PC	311038	DI-VS-10BQ100PBF-SMB-PM; SAMPLE	Diodes	VS-10BQ100PBF Vishay (Schottky, 100V, 1A, 10BQ100 IR	D35, D42, D49, D56
0090	3,000	PC	311041	CONNECTOR-8PIN-1.27mm-SMD-FTSH8; SAMPLE	Connectors	FTSH-104-04-L-DV-A-P SAMTEC	P9, P11, P15
0100	1,000	PC	311042	CONNECTOR-10PIN-1.27mm-SMD-FTSH10; SAMPLE	Connectors	FTSH-105-04-L-DV-A-P SAMTEC	P13
0110	4,000	PC	311035	TR-ZXST3ZTA-SOT89-PM; SAMPLE	Transistors	ZXST3ZTA DIODES (pnp, 40V, 5.5A)	Q5-Q8
0120	4,000	PC	300749	R-1K-1%-TK100-0805-CM(I)	Resistors	WR08X1001FTL WALSIN	R128, R149, R171, R191
0130	20,000	PC	311034	R-8R2-5%-TK200-0805-PM; SAMPLE	Resistors	CRCW08058R20JNEAIF VISHAY	R129-130, R143, R146, R150-151, R165-166, R172-173, R185, R188, R192-193, R205, R208, R142, R162, R184, R204
0140	32,000	PC	311032	R-R51-1%-TK100-0805-PM; SAMPLE	Resistors	RCWE0805R510FKEA VISHAY	R132-R135, R137-138, R140-141, R152-153, R155-158, R160-161, R174-177, R179-180, R182-183, R194-197, R199-200, R202-203
0150	12,000	PC	311033	R-R510-1%-TK100-1210-PM; SAMPLE	Resistors	RCWE1210R510FKEA VISHAY	R136, R139, R147, R167, R154, R159, R178, R181, R189, R198, R201, R209
0170	8,000	PC	310982	R-15K-1%-TK100-0805-PM; SAMPLE	Resistors	CRCW080515K0FKEAHP Vishay	R144-145, R163-164, R166-167, R206-207
0180	1,000	PC	311043	R-8K2-0.1%-TK25-0805-PM; SAMPLE	Resistors	CPF08058K2E1 TE CONNECTIVITY/NEOHM	R168
0190	1,000	PC	311044	R-2K2-0.1%-TK25-0805-PM; SAMPLE	Resistors	PAT0805E2201B5T5 VISHAY	R169
0210	8,000	PC	311036	TR-ZXGD3006E-SOT23-6-PM; SAMPLE	Transistors	ZXGD3006E6TA DIODES ZETEX (MOSFET)	T9-T16

## 5.1 BOM Power Supply Module

Item	Quantity	Un	Component	BOM component	Material Group	Released manufacturers	Layout positions	Ch
0005	1,000	PC	312124	CGD-M200-PCB_IN(Rev05); SAMPLE	PCB			*
0010	48,000	PC	303142	C-10uF-25V-10%-X7R-1206-PM	Capacitors below 500V	GRM31CR71E106KA12L Murata	C1, C2, C5, C6, C7, C8, C11, C12, C101, C102, C105, C106, C107, C108, C111, C112, C201, C202, C205, C206, C207, C208, C211, C212, C301, C302, C305, C306, C307, C308, C311, C312, C401, C402, C405, C406, C407, C408, C411, C412, C501, C502, C505, C506, C507, C508, C511, C512	*
0015	4,000	PC	310840	C-22uF-25V-10%-X7R-1210-PM	Capacitors below 500V	GRM32ER71E226KE15L Murata GRM32ER71E226KE15K Murata	C3, C4, C9, C10	
0050	3,000	PC	311010	CONNECTOR-8PIN-1.27mm-FLE8-PM; SAMPLE	Connectors	FLE-104-01-G-DV-A-P-TR SAMTEC	P1, P9, P10	
0060	1,000	PC	311011	CONNECTOR-10PIN-1.27mm-FLE10-PM; SAMPLE	Connectors	FLE-105-01-G-DV-A-K-TR SAMTEC	P2	
0080	4,000	PC	311013	CONNECTOR-10PIN-1.27mm-FTSH10-PM; SAMPLE	Connectors	FTSH-105-01-L-DV-A SAMTEC	P5, P8, P13, P14	
0090	1,000	PC	311014	CONNECTOR-2PIN-2.5mm-HDR1X2-PM; SAMPLE	Connectors	MC34605 MULTICOMP;(Header Square pin)	P17	
0100	4,000	PC	311879	IC-IGC136-15W_DC/DC_CONVERTER; Sample	Ics incl. Driver	IG136-15W MicroPower Direct (DC/DC converter) Ausgang 15V/100mA, -8V/40 mARoHS	U1-U4	*

## 5.2 BOM Master

Item	Quantity	Un	Component	BOM component	Material Group	Released manufacturers	Layout positions
0010	4,000	PC	210671	DRV-M200-PCB_CTR(Rev54); Sample			
0020	1,000	PC	210622	DRV-M200-PCB_TH(Rev53); Sample			
0030	1,000	PC	210672	DRV-M200-PCB_IN(Rev54); Sample			
0040	1,000	PC	210673	DRV-M200-PCB_OUT(Rev54); Sample			
0050	4,000	PC	311047	HEX-STANDOFF-L8mm-M2.5X6-D2.5X5; Sample	Steel Nuts	ETTINGER - 05.20.208SPACER, M2.5/D2.5-8	
0060	4,000	PC	311559	SCREW-M2.5X6_DIN7985; Sample	Steel Screws	M2.56 PRA2MCS100 DURATOOL	
0070	1,000	PC	311130	CRIMP-HOUSING-2.5mm-2way; SAMPLE	Connectors	MC34469 Multicomp;	
0080	2,000	PC	311131	CRIMP-PIN-24-28 AWG; SAMPLE	Connectors	24-28AWG(2318TF) Multicomp;	

## 5.3 BOM Slave

Item	Quantity	Un	Component	BOM component	Material Group	Released manufacturers	Layout positions
0020	1,000	PC	210622	DRV-M200-PCB_TH(Rev53); Sample			
0030	1,000	PC	210672	DRV-M200-PCB_IN(Rev54); Sample			
0040	1,000	PC	210673	DRV-M200-PCB_OUT(Rev54); Sample			
0050	4,000	PC	311047	HEX-STANDOFF-L8mm-M2.5X6-D2.5X5; Sample	Steel Nuts	ETTINGER - 05.20.208SPACER, M2.5/D2.5-8	
0060	4,000	PC	311559	SCREW-M2.5X6_DIN7985; Sample	Steel Screws	M2.56 PRA2MCS100 DURATOOL	
0070	1,000	PC	311130	CRIMP-HOUSING-2.5mm-2way; SAMPLE	Connectors	MC34469 Multicomp;	
0080	2,000	PC	311131	CRIMP-PIN-24-28 AWG; SAMPLE	Connectors	24-28AWG(2318TF) Multicomp;	