CoolSiC™ MOSFET motor drives evaluation board for 7.5 kW

EVAL-FS33MR12W1M1HM5

About this document

Scope and purpose

This application note provides an overview of the evaluation board EVAL-FS33MR12W1M1HM5 including its main features, key data, pin assignments and mechanical dimensions.

EVAL-FS33MR12W1M1HM5 is a complete evaluation board including a 3-phase SiC power module for motor drive applications. In combination with control boards equipped with the M5 32-pin interface connector such as the XMC DriveCard 4400, it features and demonstrates Infineon's CoolSiC™ MOSFETs in motor drives.

The evaluation board EVAL-FS33MR12W1M1HM5 was developed to support customers during their first steps designing applications with the sixpack power module FS33MR12W1M1H_B11. The module has a rated blocking voltage of 1200 V at a typical on-state resistance of 33 mOhm. It is optimized for motor drive applications with a very high frequency switching operation.

Intended audience

This application note is intended for power electronic engineers evaluating the use of CoolSiC™ devices in drives applications.

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1 Safety precautions

Table 1 Precautions

	Caution: The DC link potential of the EVAL-FS33MR12W1M1HM5 system is connected to the grid input. When measuring voltage waveforms by oscilloscope, high-voltage differential probes must be used. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.
	Caution: The EVAL-FS33MR12W1M1HM5 system contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.
	Caution: Only personnel familiar with the drive and ancillary machinery should plan or perform installation, start-up and subsequent maintenance of the system. Failure to comply may result in personal injury and/or equipment damage.
	Caution: The surfaces of the drive may become hot, which may cause injury.
	Caution: The EVAL-FS33MR12W1M1HM5 system contains parts and subassemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not observed. If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines.
	Caution: A drive, incorrectly applied or installed, can result in component damage or in the reduction of product lifetime. Wiring or application errors such as undersized motors, provision of incorrect or insufficient AC supply, or excessive ambient temperature may result in system malfunction.
	Caution: Remove or disconnect power from the drive before you disconnect or reconnect wires or perform service. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.
	Caution: The EVAL-FS33MR12W1M1HM5 system is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials which are unnecessary for system installation may result in overheating or abnormal operating conditions.

2 Introduction

The EVAL-FS33MR12W1M1HM5 evaluation board is part of the iMOTION™ Modular Application Design Kit for motor drives (iMOTION™ MADK).
The MADK platform is intended for use at various power stages with different control boards. These boards can easily be interfaced via the iMOTION™ MADK-M5 32-pin interface connector to control boards such as the XMC DriveCard 4400 or XMC DriveCard 1300.
This evaluation board is designed as an easy-to-use power stage based on Infineon's 3-phase power modules. The board is equipped with shunts in the phase output enabling the implementation of sensorless control. It provides a three-phase AC connector, EMI filter, rectifier, and a 3-phase output for connecting the motor. The power stage also contains isolated current, voltage and temperature sensing circuits.
The EVAL-FS33MR12W1M1HM5 evaluation board is available via regular Infineon distribution partners as well as on Infineon's website. The features of this board are described in the design feature chapter of this document. The remaining paragraphs provide information enabling customers to copy, modify and qualify the design for production according to their own specific requirements.
Environmental conditions were considered in the design of the EVAL-FS33MR12W1M1HM5. The design was tested as described in this document, but not qualified in terms of safety requirements, manufacturing and operation over the entire operating temperature range or lifetime. The boards provided by Infineon are subject to functional testing only.
Evaluation boards are not subject to the same procedures as regular products regarding Returned Material Analysis (RMA), Process Change Notification (PCN) and Product Discontinuation (PD). Evaluation boards are intended to be used under laboratory conditions and by trained specialists only.

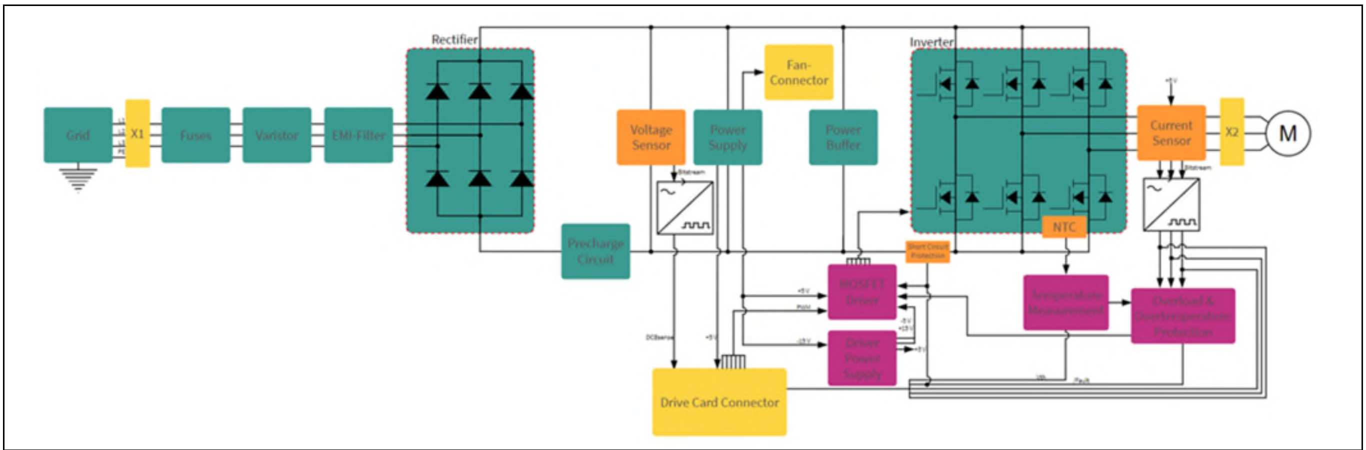


Figure 1 The block diagram of the EVAL-FS33MR12W1M1HM5

The block diagram of the EVAL-FS33MR12W1M1HM5 is depicted in Figure 1. This evaluation board includes an EMI filter, a line rectifier with a soft power-up circuit, an auxiliary power supply to provide 5 V, and the silicon carbide sixpack power module FS33MR12W1M1H_B11. All measuring and control signals are available on a 32-pin drive card interface connector. The hardware circuit relative to overtemperature and overcurrent protection is also included in this power board.

The signal part of the evaluation board is fully separated from the power part by a basic insulation. Whereas the power components are connected to the mains, the signal part is earthed by the input connector. The design can be easily upgraded to a safe electrical insulation by replacing the present MOSFET drivers and the auxiliary power supply transformer (T650, TR200, TR201) by parts with an appropriate safety approval.

3 Design features

EVAL-FS33MR12W1M1HM5 is an evaluation board for motor drive applications comprising the silicon carbide sixpack power module FS33MR12W1M1H_B11. Combined in a kit with one of the available MADK control board options, it demonstrates Infineon's silicon carbide power-module technology.

Main features:

- EasyPACK™ 1B 1200 V / 33 mΩ sixpack module with CoolSiC™ MOSFET
- Lead-free terminal plating; RoHS compliant
- Low inductive design
- Integrated NTC temperature sensor

The evaluation board characteristics are:

- Input voltage 340~480 V_{AC}
- Maximum 7.5 kW motor power output
- On-board EMI filter
- Basic insulation between power and signal part
- Isolated current sensing with ΔΣ-ADC
- Isolated sensing of dc-link voltage by ΔΣ-ADC
- Thermistor output
- Overload and short-circuit hardware protection
- Overtemperature hardware protection
- All six switches turn off during protection
- Rugged gate driver technology with stability against transient and negative voltage
- Auxiliary power supply with 5 V
- Measurement test points compatible with standard oscilloscope probes
- PCB is 259 mm x 204 mm and has four layers of 35 µm copper each
- RoHS compliant

Table 2 EVAL-FS33MR12W1M1HM5 board specifications

Parameters	Values	Conditions / Comments
Input		
Voltage	340 – 480 V_{rms}	
Current	16 A_{rms}	Input 400 V_{AC}, Ta = 25 °C
Output		
Power (3 phases) maximal with mains line choke	7.5 kW	Input 400 V_{AC}, f_{PWM} = 18 kHz, T_a = 25°C, T_h = 70°C, forced convection cooling
Power (3 phases) without mains line choke	6 kW	Input 400 V_{AC}, f_{PWM} = 18 kHz, T_a = 25°C, T_h = 70°C, forced convection cooling, limited by input current
Current per leg at f_{nom}	16 A_{rms}	Input 400 V_{AC}, f_{PWM} = 18 kHz, T_a = 25°C, T_h = 70°C, forced convection cooling
Current per leg at f_{max}	8 A_{rms}	Input 400 V_{AC}, f_{PWM} = 100 kHz, T_a = 25°C, T_h = 70°C, forced convection cooling
DC bus voltage		
Typical DC bus voltage	530 V – 670 V	
Brown-in Aux supply	480 V	
Brown-out Aux supply	300 V	Minimum required voltage to use the internal low voltage power supply
Maximum DC bus voltage	690 V	
Switching frequency		
Nominal switching frequency f_{nom}	18 kHz	
Maximal switching frequency f_{max}	100 kHz	
Current feedback		
Analogue output	18.41 mV/A	
Digital output	3.3 V	ΔΣ bitstream @ 20 MHz
DC link voltage feedback		
Analogue output	1.257 mV/V	
Digital output	3.3 V	ΔΣ bitstream @ 20 MHz
Protection		
Output current trip level	32 A_{peak}	Disables driver stage for 30 ms
Temperature trip level	100 °C	Disables driver stage for 30 ms
On board power supply		
+5 V	± 2 %	Used for primary side of MOSFET drivers and for the controller board
+6 V	± 10 %	Used for analogue circuits
-5 V	± 10 %	Used for analogue circuits
-15 V	± 5 %	Used for driver supply

Parameters	Values	Conditions / Comments
System environment		
Ambient temperature	From 0 to 50 °C	Non-condensing, maximum RH of 95 %
PCB characteristics		
Material	FR4, 1.6 mm thickness	4 layers, 35 µm copper thickness
Dimensions	259 mm x 204 mm	

3.1 Functional groups

The next two figures illustrate the functional groups on the top and bottom side of the evaluation board. The functional groups are explained in Table 3.

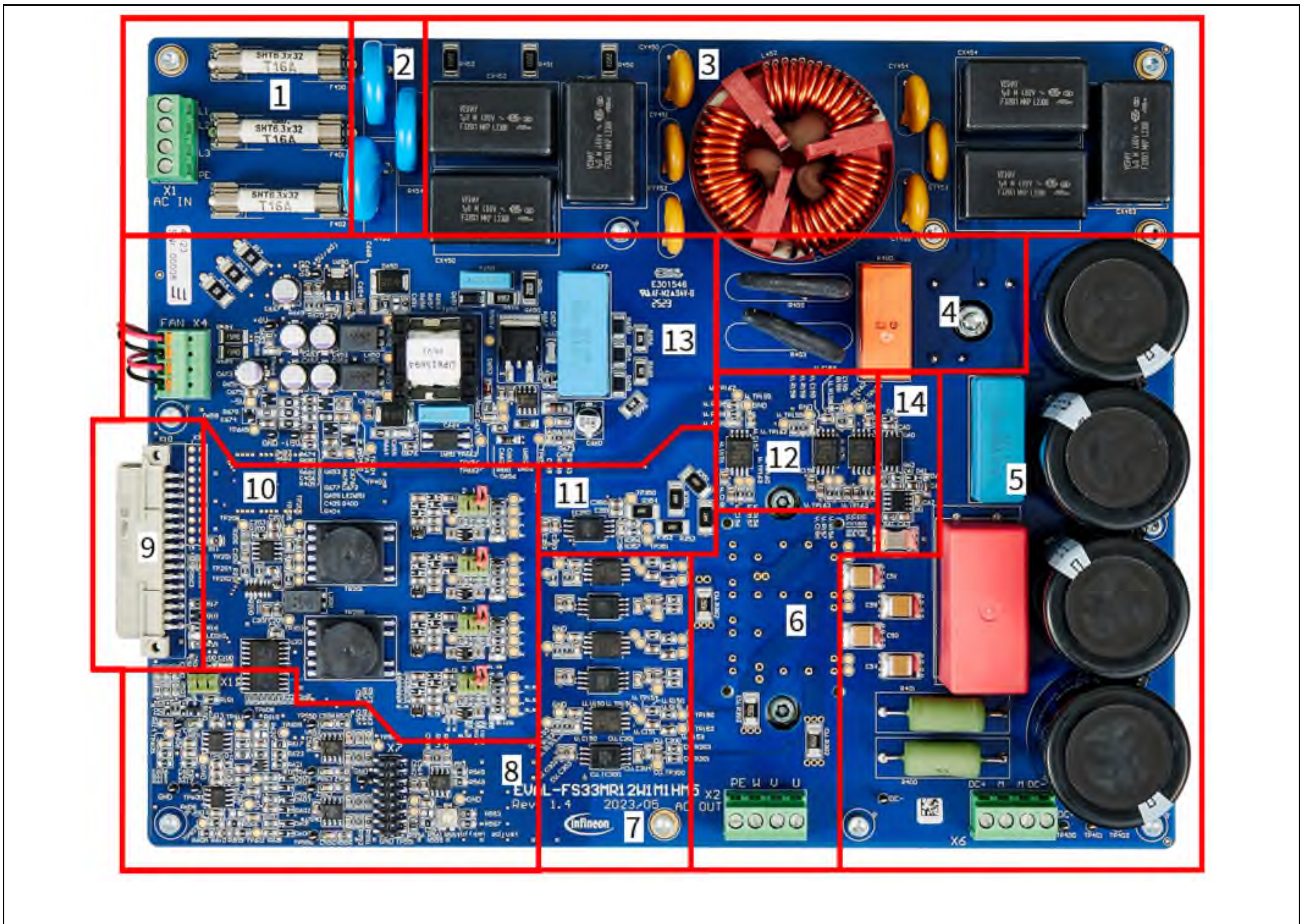


Figure 2 Top view of the EVAL-FS33MR12W1M1HM5

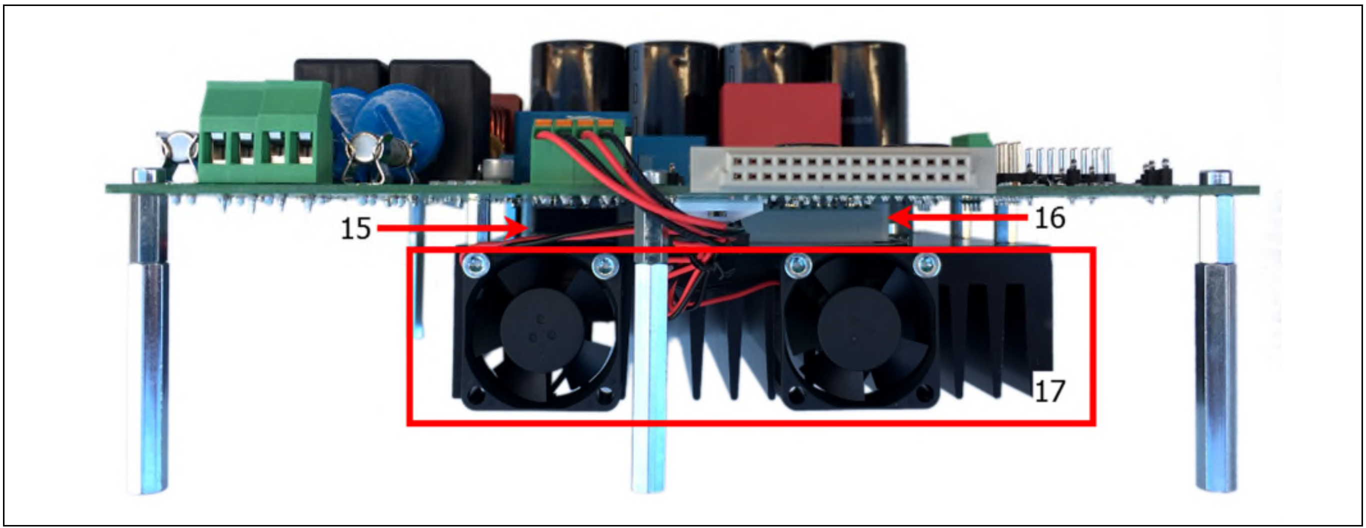


Figure 3 Side view of the EVAL-FS33MR12W1M1HM5

Table 3 Functional groups of EVAL-FS33MR12W1M1HM5

Nr.	Functional groups
1	AC input connector with fuses
2	Varistors for overvoltage protection
3	EMI filter
4	Rectifier with precharge relay and precharge NTC resistors
5	DC-bus capacitors, balancing resistors and DC-bus connector
6	Power module FS33MR12W1M1H_B11 with phase current shunts
7	High-side MOSFET drivers with ΔΣ-DACs for shunt sensors
8	Low-pass filter of ΔΣ-signals and overcurrent comparators
9	Connector for controller
10	Isolated power supply for MOSFET drivers
11	DC-bus voltage measurement with ΔΣ-DAC
12	Low-side MOSFET drivers
13	Flyback converter for auxiliary supply
14	Overcurrent detection and measuring shunt
15	Rectifier mounted on heatsink
16	Power module mounted on heatsink
17	Heatsink with fans

3.2 Pin assignment

General information about the connectors of the EVAL-FS33MR12W1M1HM5 evaluation board is reported.

Table 4 includes the details of the AC input connector X1.

Table 4 X1 – AC line connector

No.	Pin	Details
1	Line phase 1	
2	Line phase 2	
3	Line phase 3	
4	EARTH	

Table 5 provides the details of the motor side connector X2.

Table 5 X2 – Motor side connector

No.	Pin	Details
1	EARTH	Connect to X1/4 via heatsink No connection without heatsink!
2	U	Connect to motor phase W
3	V	Connect to motor phase V
4	W	Connect to motor phase U

Table 6 provides the pin assignments of driver board connector X10. This connector is the interface to the controller board.

Table 6 X10 – Power board connector

No.	Pin	Details
A1	-	-
A2	-	-
A3	-	-
A4	-	-
A5	-	-
A6	-	-
A7	-	-
A8	-	-
A9	-	-
A10	I_W	Phase W current sense output, scale 76.56 mV/A, offset 2.5 V
A11	I_V	Phase V current sense output, scale 76.56 mV/A, offset 2.5 V
A12	I_U	Phase U current sense output, scale 76.56 mV/A, offset 2.5 V
A13	-	-
A14	-	-
A15	-	-
A16	GND	Ground

No.	Pin	Details
B1	/ENABLE	/ENABLE signal – if high drivers are disabled
B2	/FAULT	/FAULT signal – active low when overcurrent or overtemperature is detected
B3	PWMWH	3.3 V compatible logic input for high-side gate driver-Phase W
B4	PWMWL	3.3 V compatible logic input for low-side gate driver-Phase W
B5	PWMVH	3.3 V compatible logic input for high-side gate driver-Phase V
B6	PWMVL	3.3 V compatible logic input for low-side gate driver-Phase V
B7	PWMUH	3.3 V compatible logic input for high-side gate driver-Phase U
B8	PWMUL	3.3 V compatible logic input for low-side gate driver-Phase U
B9	-	-
B10	-	-
B11	-	-
B12	-	-
B13	DCBsense	DC bus voltage sense output, scale 5 mV/V (1/200)
B14	VTH	Thermistor voltage output, 100°C = 0.448 V
B15	-	-
B16	VCC	On board 5 V supply, max. 120 mA

Table 7 denotes the details of the fan connector X4. The connector is provided for two fans with a nominal voltage of 12 V cooling the heatsink. The maximum output current is limited to 180 mA. The connector is connected via two series resistors to a supply of 15 V. Consequently, it is possible to drive most fans with a nominal voltage of 12 V in the power range of 0.6 W to 1 W in their allowed voltage range.

Table 7 X4 – DC bus connector

S. No.	Pin	Details
1	Fan1-	Connected via 8.2 Ω resistor to -15 V, max. 180 mA
2	Fan1*	Connected via 8.2 Ω resistor to GND, max. 180 mA
3	Fan2-	Connected to Fan1-
4	Fan2+	Connected to Fan1+

Table 8 includes the details of the DC bus connector X6.

Table 8 X6 – DC bus connector

S. No.	Pin	Details
1	DC+	Connected to positive side of DC-bus capacitor
2	DC M	Connected to midpoint of DC-bus capacitor Do not connect load at this point!
3	DC- M	
4	DC-	Connected to negative side of DC-bus capacitor

The following table provides the details of the X7 digital measurement connector.

Table 9 X7 – ΔΣ measurement connector

S. No.	Pin	Details
1	Clock_Iu	20 MHz clock output, signal level 5 V
2	GND	
3	DS_Iu	ΔΣ modulated output of current measurement, phase U, signal level 5 V, 50% positive equals 0 A, 89.06% positive equals +25 A, 10.94% positive equals -25 A
4	GND	
5	Clock_Iv	20 MHz clock output, signal level 5 V
6	GND	
7	DS_Iv	ΔΣ modulated output of current measurement, phase V, signal level 5 V, 50% positive equals 0 A, 89.06% positive equals +25 A, 10.94% positive equals -25 A
8	GND	
9	Clock_Iw	20 MHz clock output, signal level 5 V
10	GND	
11	DS_Iw	ΔΣ modulated output of current measurement, phase W, signal level 5 V, 50% positive equals 0 A, 89.06% positive equals +25 A, 10.94% positive equals -25 A
12	GND	
13	Clock_Vdc	20 MHz clock output, signal level 5 V
14	GND	
15	DS_Vdc	ΔΣ modulated output of DC link voltage measurement, signal level 5 V, 50% positive equals 0 V, 89.06% positive equals 851 V
16	GND	

3.3 Analogue measurement adjustment

In order to achieve a precise measurement of the output currents and a symmetric overcurrent detection, the offset voltage of the analogue signals must be adjusted. All relevant parts for the adjustment of the offset voltage are shown in Figure 4.

Figure 4 Relevant parts for offset adjustments

The DC-bus voltage measurement has only a small deviation; consequently, there is no offset compensation necessary.

To adjust the current offset, simply vary R554 at no load until either the software readings of the currents are zero or the voltages at the currents' test points reach almost 2.5 V. Due to component tolerances, an exact adjustment of all three currents to zero at the same time will not be possible.

Additional information about the circuit itself can be found in the chapter "Digital to analogue converter".

4 Schematics and layout

4.1 Overview

An overview of the board's schematics is given in Figure 5. Basically, the schematic can be divided into four subcategories: the input circuit of the converter, the auxiliary supply, the power stage and the measurements. The external controller board has to be connected to the evaluation board by the X10 driver board connector. The logical ground is connected to earth by the resistors R12 to R14.

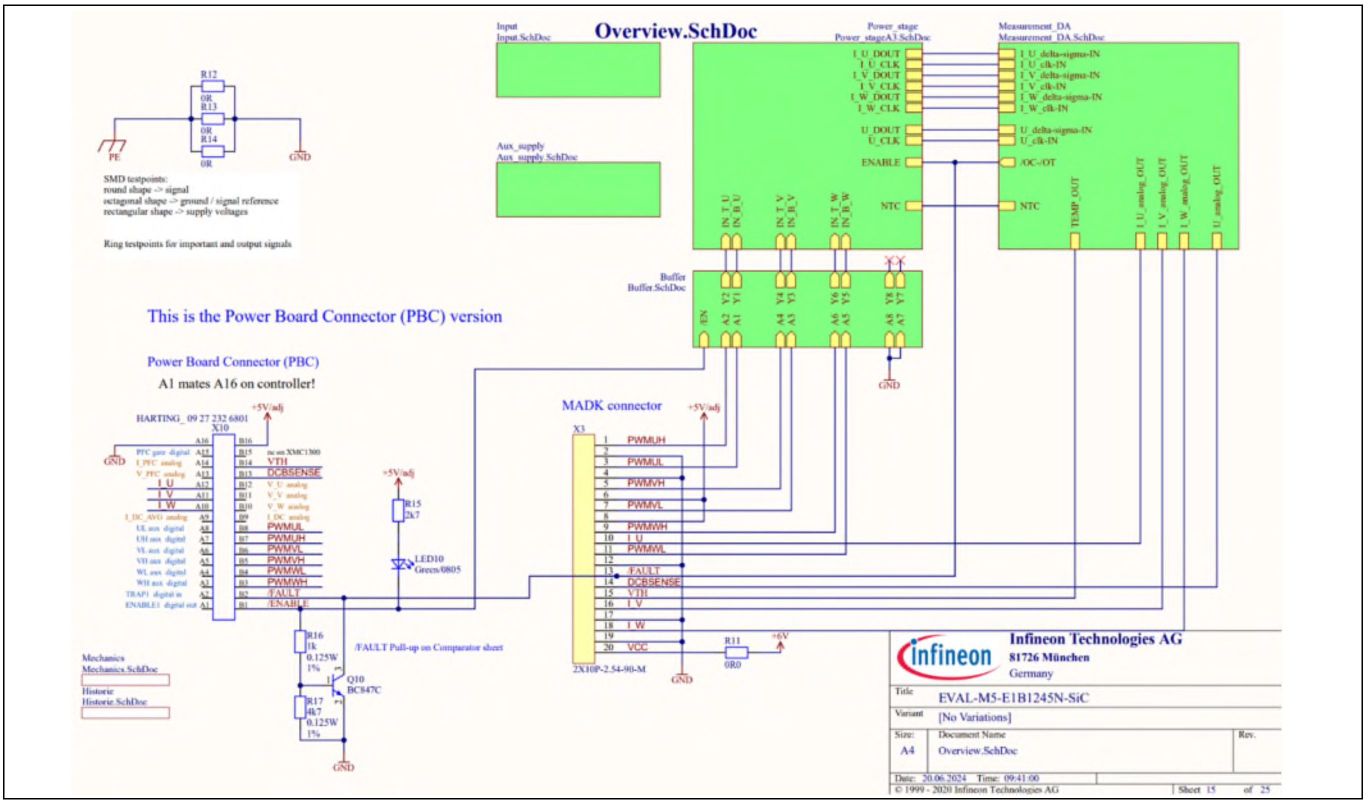


Figure 5 Overview and driver board connector

4.2 Input circuit

The input circuit is shown in Figure 6. It is equipped with two NTC resistors which limit the inrush current. The resistors are bypassed after the start of the auxiliary supply and a constant delay time. The DC-bus consists of four electrolytic capacitors and one film capacitor as well as four ceramic capacitors for the high-frequency ripple currents. The electrolytic capacitors are series-connected and balanced with two resistors.

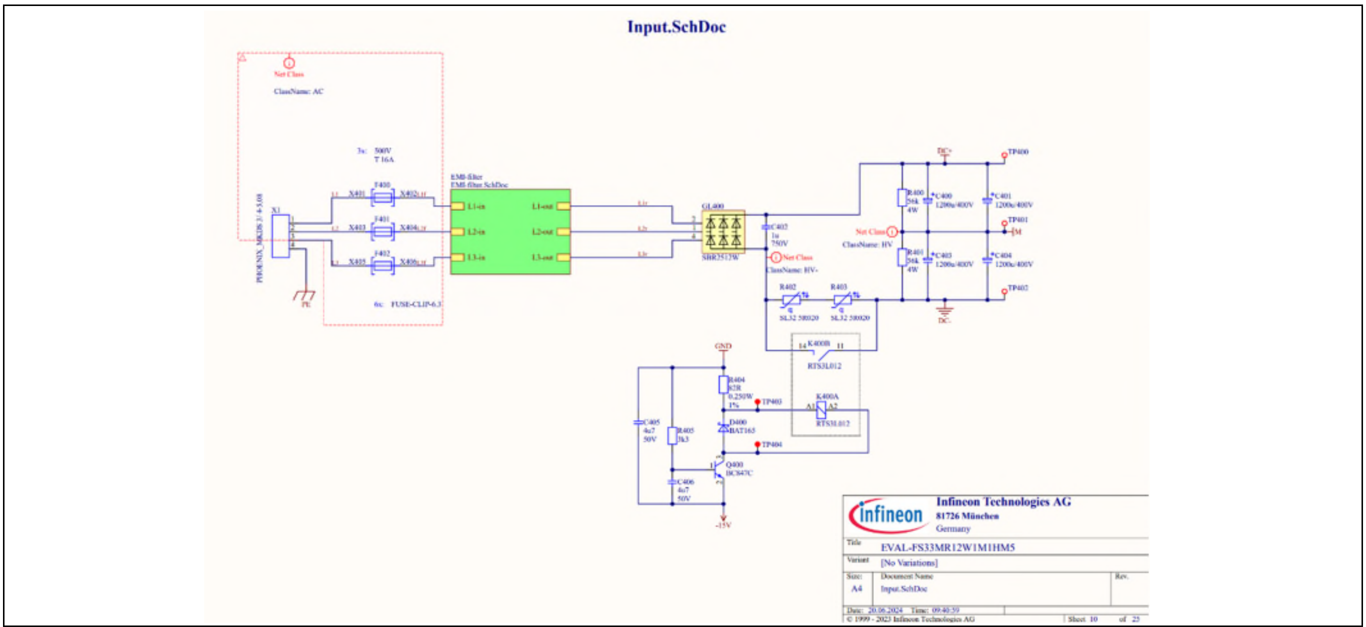


Figure 6 Mains input and precharge circuit

4.3 EMI filter

The EVAL-FS33MR12W1M1HM5 is equipped with an EMI filter circuit to present a complete solution. Please note that the board is not qualified for connection to public grids. A laboratory power supply, an isolation transformer or any other isolation device is required. The circuit is depicted in Figure 7.

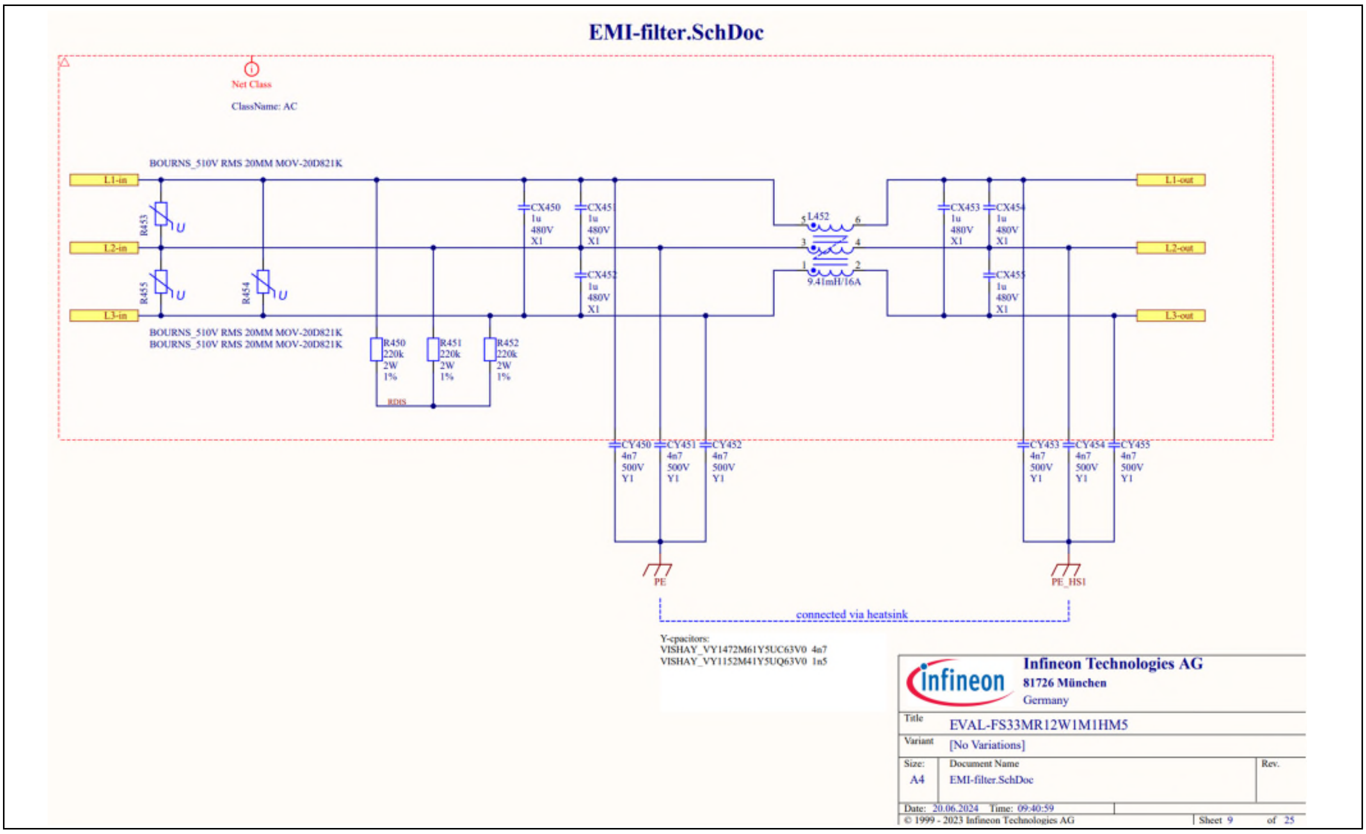


Figure 7 EMI filter

The EMI filter is designed to minimize high-frequency emissions to the connected grid. Lower harmonics of the grid current are not suppressed. An additional mains line choke must be used to fulfil harmonic standards. In addition, a mains line choke reduces the crest factor of the input current. Hence, an external choke allows higher rms input currents leading to a higher output power. Without an additional mains line choke, an output power of approx. 6 kW can be achieved at 400 V line voltage.

However, the conducted EMI emission strongly depends on several operating conditions like the connected motor, used switching frequency, etc. Consequently, the implemented filter does not necessarily meet the required standard. If necessary, a Vacuumschmelze W 424-53 ring core, or similar, with three turns, can be added to the supply lines as a common mode choke to further reduce the conducted EMI.

4.4 Auxiliary supply

All supply voltages are generated by a flyback converter, supplied from the DC-bus. It starts operation at a bus voltage of 477 V_{dc}, which corresponds to approximately 340 V_{ac} input voltage. The supply circuit is implemented with an Infineon ICE5QSAG control IC. The supply voltages are isolated from the DC-bus potential by a basic insulation. The complete schematic is shown in Figure 8.

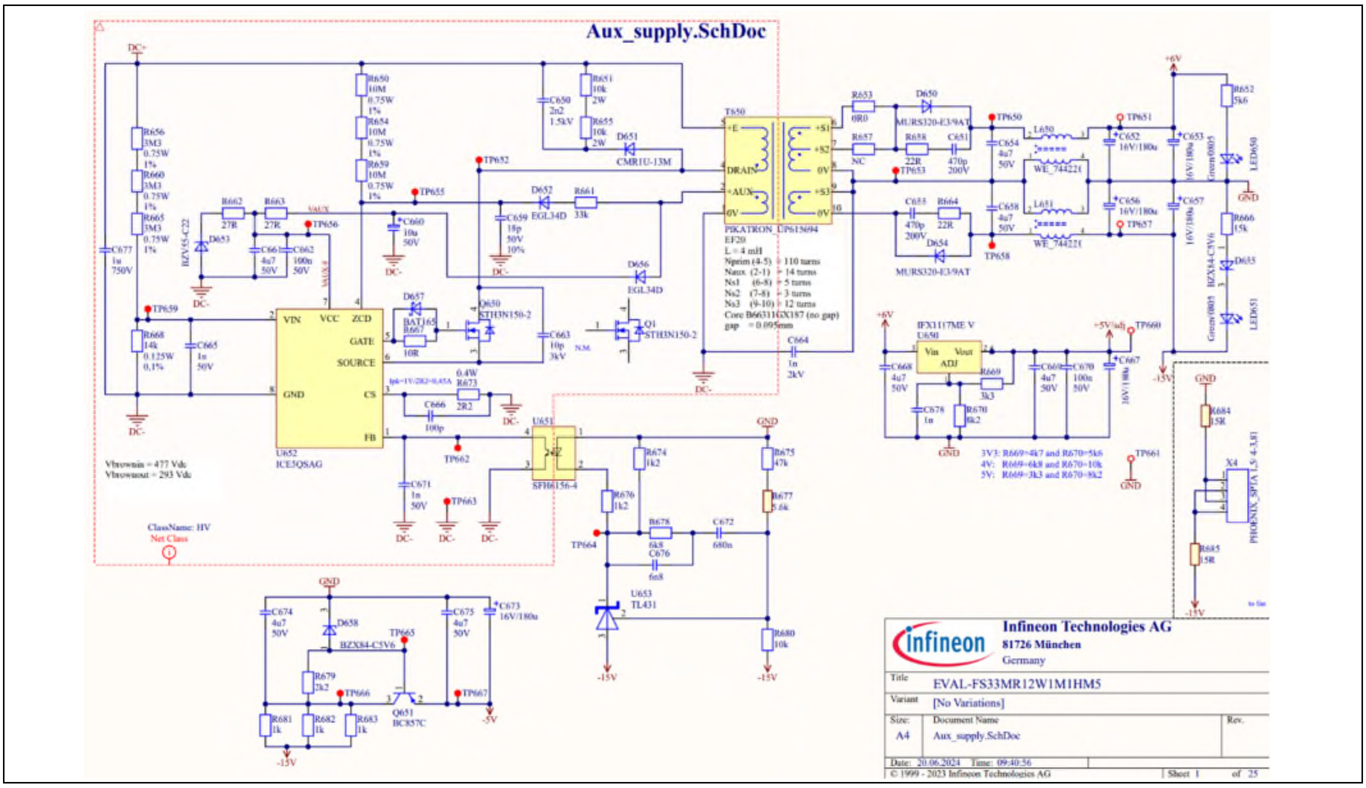


Figure 8 Auxiliary supply

The flyback converter generates three voltages. The auxiliary winding on the primary side of the transformer generates an unregulated 17.6 V supply for the control IC itself. On the transformer's secondary side, two output voltages are generated: a regulated 15 V and indirect regulated +6 V. The 15 V supply voltage is mainly used for the MOSFET driver supply circuit. From this voltage, a -5 V supply voltage is derived by a linear regulator used for the negative supply for the analogue circuitry of the board. The positive analogue supply is directly connected to the +6 V supply. This voltage rail is also used to generate the +5 V for the controller and overcurrent threshold generations.

If the EVAL-FS33MR12W1M1HM5 is to be used with low DC-bus voltages below the start-up threshold of the flyback converter, it is possible to supply it with an external power supply. Therefore, the test points TP651, TP656 and TP661 can be used. These test points are labelled with their corresponding voltage on the PCB. The points are depicted in Figure 9.

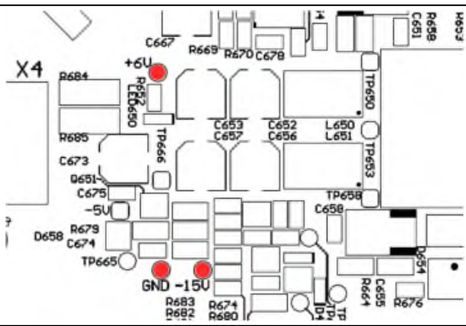


Figure 9 Major power supply test points

4.5 Power stage

The schematic of the power stage is shown in Figure 10. The three-phase legs of the sixpack power module FS45R12M1W1_B11 are connected to one film capacitor and four ceramic capacitors. Two of the ceramic capacitors are connected directly to the power module in front of the current measuring shunt. For the film capacitors, two alternate packages can be mounted. Both high-frequency capacitor types are placed as close as possible to the power module to minimize overvoltage at switching. Only two of the ceramic capacitors are connected in front of the shunt to limit short-circuit energy. The DC-bus is led through to the X6 connector.

The current measuring shunt is used to detect output short-circuits. An overcurrent protection circuit is used to monitor the shunt voltage and to disable all switches in overcurrent condition.

At each phase the output current is measured by a shunt resistor. The shunt voltages are measured by galvanic isolated ΔΣ-DACs. Their supply is derived from an additional voltage level of the top-side driver supply circuit. The voltage of the DC-bus is measured by a voltage divider and the same isolated ΔΣ-DAC supplied from an additional driver voltage of the low-side driver supply. The functionalities of these blocks are explained below.

The NTC of the power module is used for generating a temperature-related measuring voltage V_{th}.

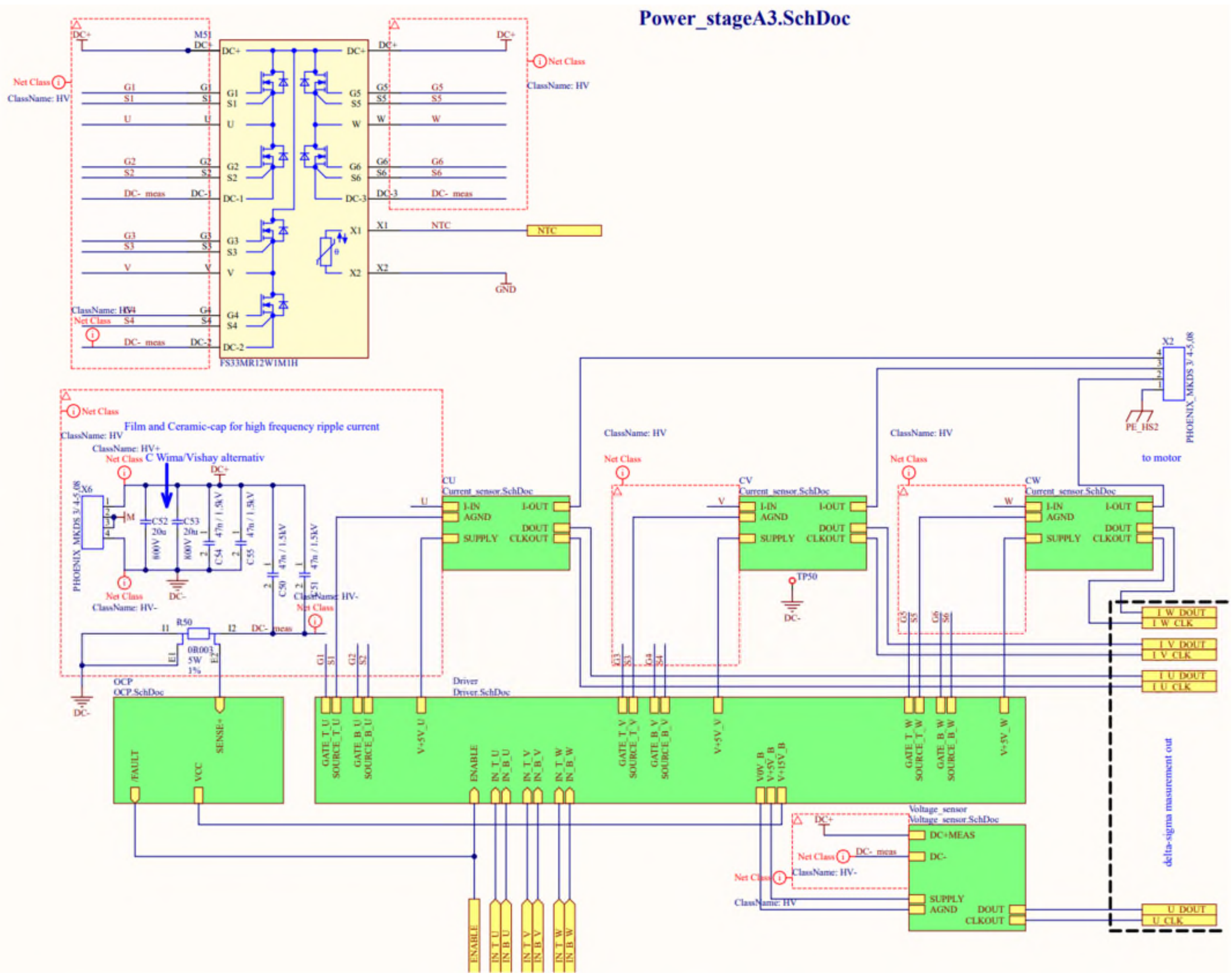


Figure 10 Power stage

4.6 Driver circuit

Each of the six MOSFETS is driven by Infineon's MOSFET EiceDRIVER 1EDI20H12AH without any special circuitry at the output. The positive input is protected by an additional glitch filter and a pull-down resistor. All negative inputs are connected together and are used for a global /ENABLE signal. The circuit which is used for each phase leg is shown in **Error! Reference source not found.**.

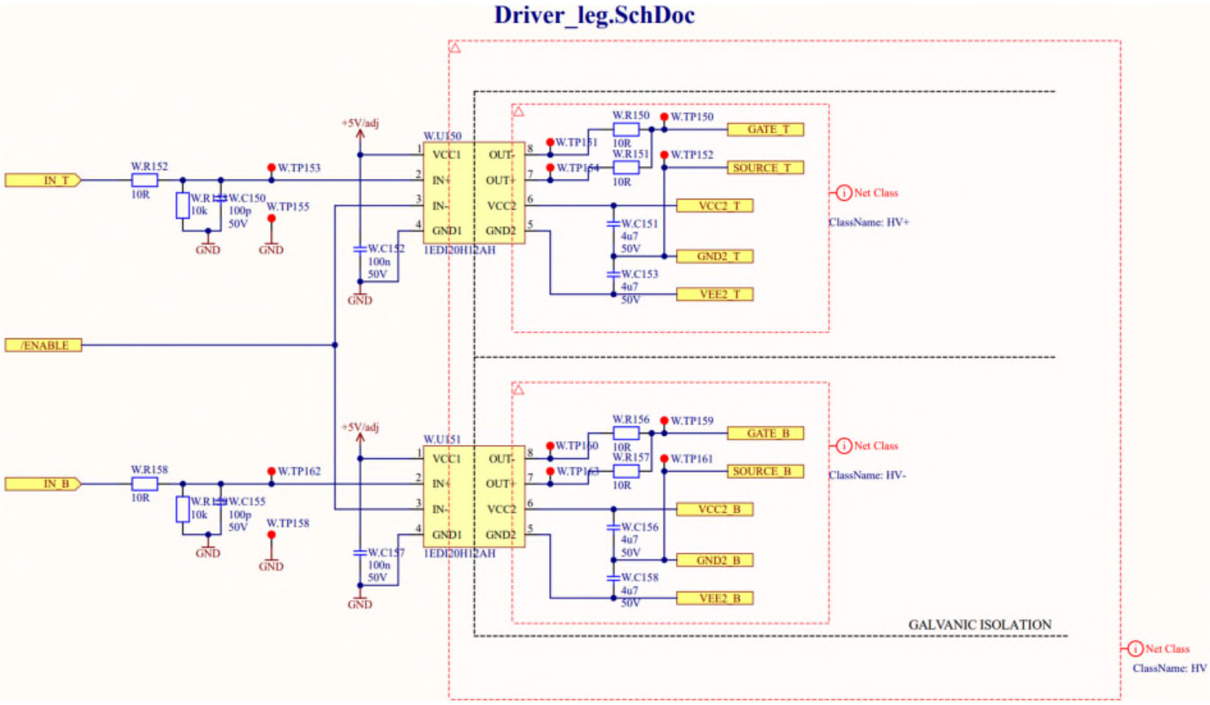


Figure 11 Driver circuit for one-phase leg

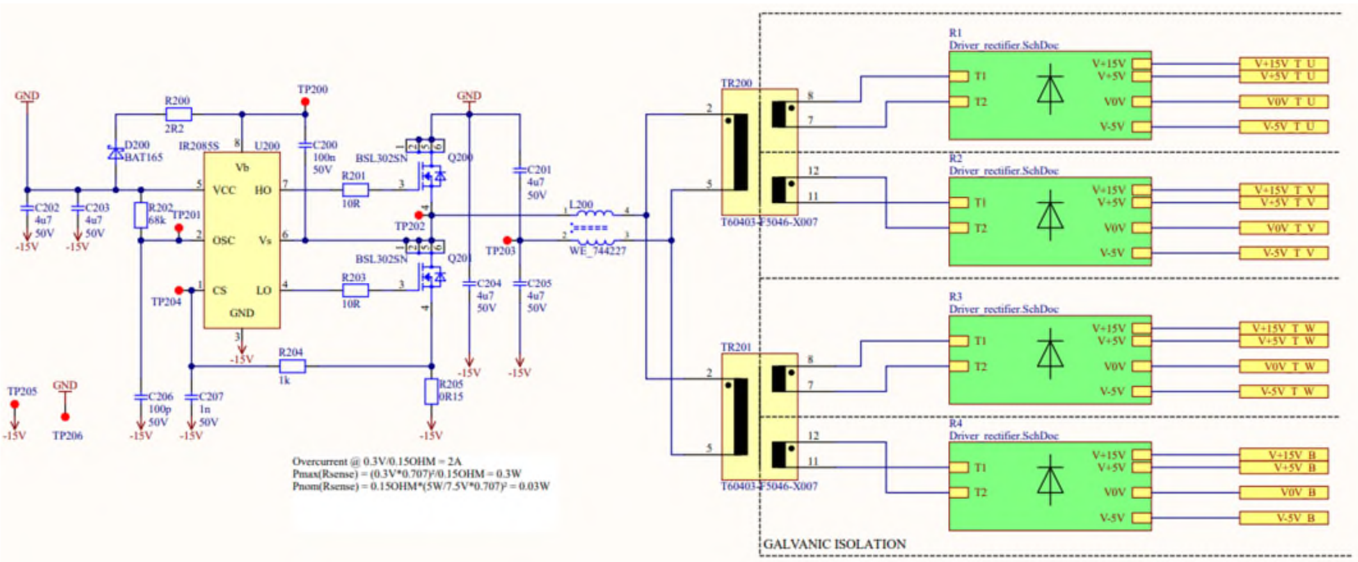


Figure 12 Driver power supply

The rectifier circuit generates three voltage levels for each driver: a regulated negative voltage for safely turning off the power MOSFET, +15 V for turning on the power MOSFET, and additionally +5 V for the additional current and voltage measurement. The circuit is shown in Figure 13.

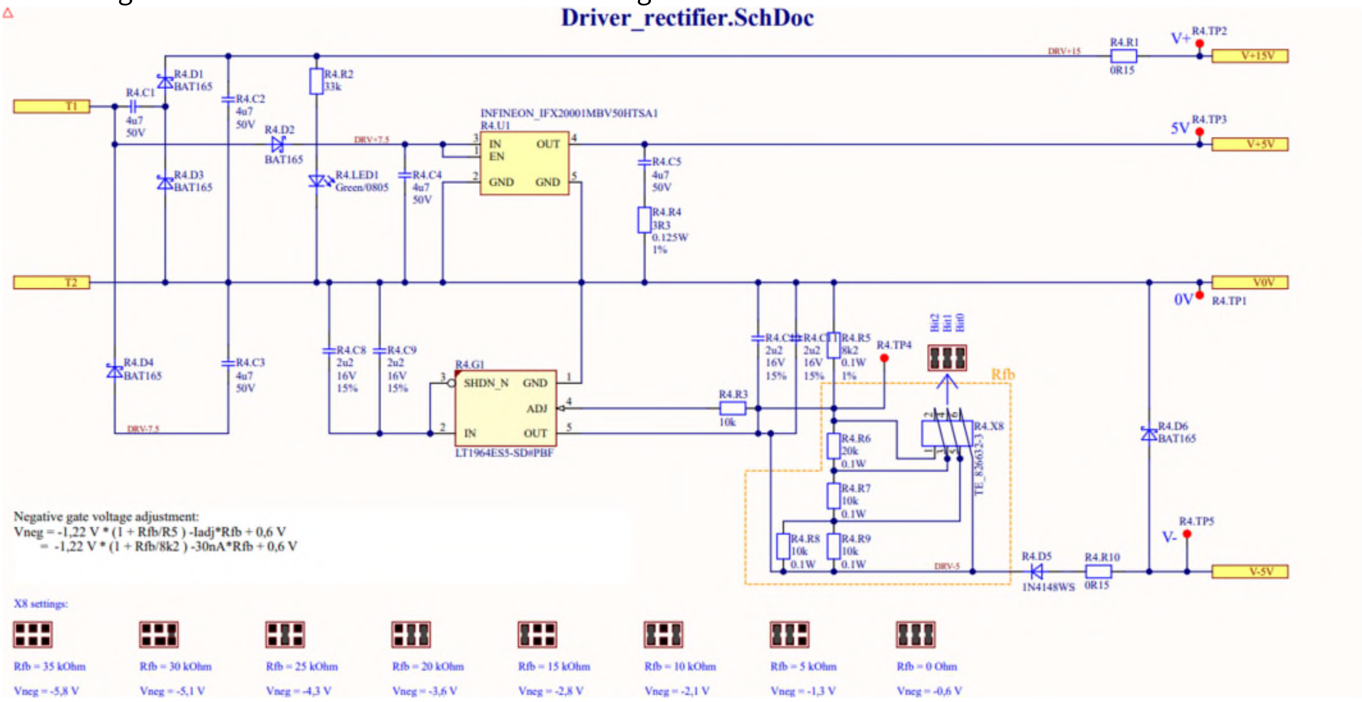


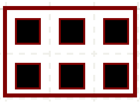
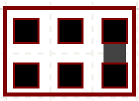
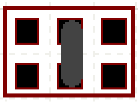
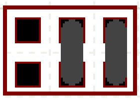
Figure 13 Rectifier circuit of driver power supply

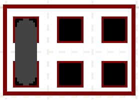
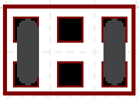
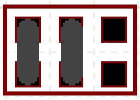
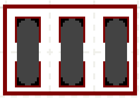
The regulated negative voltage can be adjusted in eight steps by placing jumpers on the X8 pin header. This adjustment must be done for each rectifier circuit separately. By placing the jumpers in this way, the feedback resistor of the negative voltage regulator is changed. Consequently, its output voltage can be adjusted. The selectable voltages are shown in Table 10.

Additionally, it is possible to use real 0 V turn-off voltage if R10 is removed and TP1 is connected to TP5. Be careful when adjusting the negative voltage! Load conditions might occur which could lead to the undesired turn-on of the power switches.

The jumpers must not be changed under switching conditions.

Table 10 X8 pin header negative gate voltage selection

Jumper setting	Negative gate voltage
	-5.6 V
	-4.9 V
	-4.2 V
	-3.5 V

Jumper setting	Negative gate voltage
	-2.8 V
	-2.0 V
	-1.3 V
	-0.6 V

4.7 Thermistor output

The temperature of the power module is measured with the module-integrated NTC resistor. The NTC resistor is connected to 5 V via a series resistor of 10 kΩ. The resulting NTC voltage is fed to the control board via an amplifier with a voltage gain of two. If necessary, the signal level can be changed by exchanging the resistors R617, R620, R621 and R623. The evaluation circuit is depicted in Figure 14.

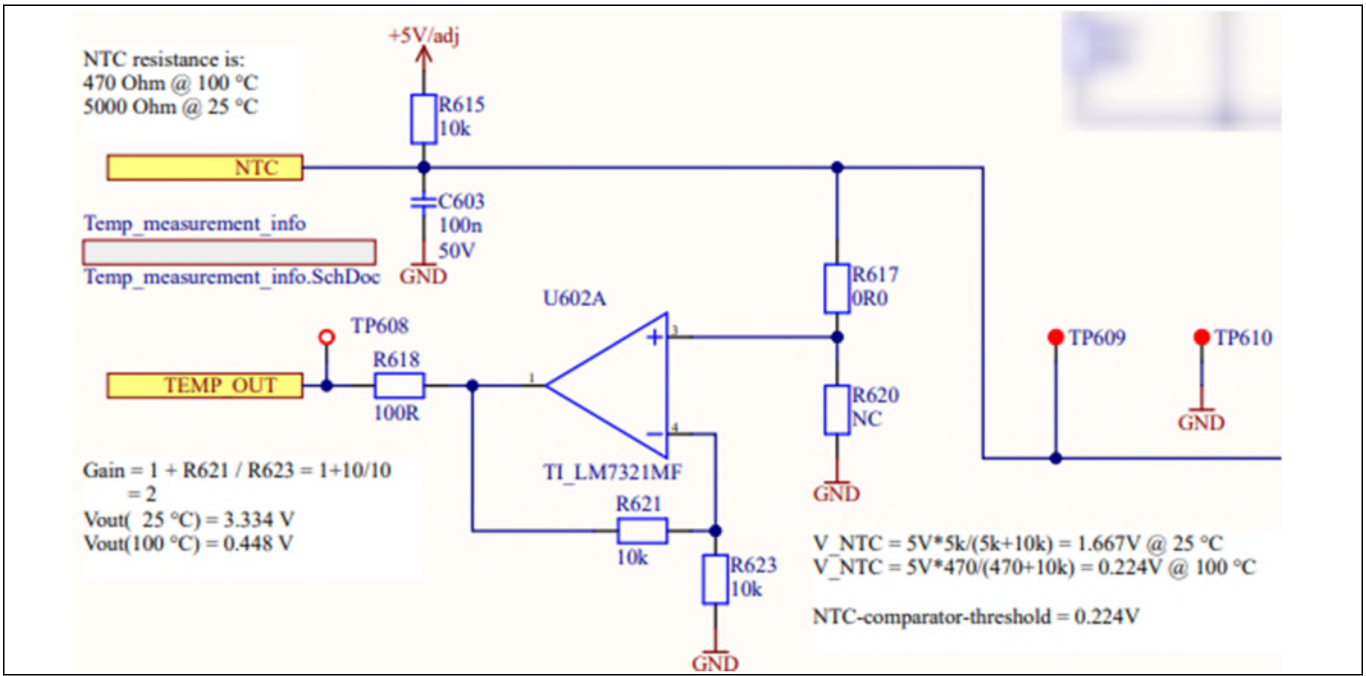


Figure 14 Evaluation circuit for NTC measurement

The dependency of the generated output voltage vs. the power module temperature is shown in Figure 15.

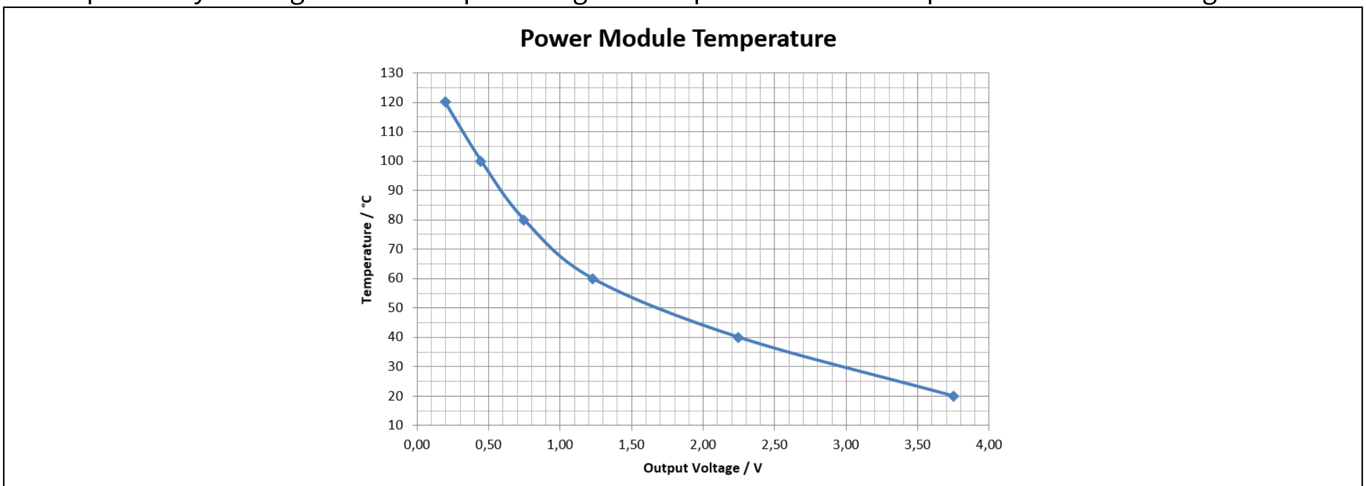


Figure 15 Power module temperature output

4.8 Current measurement

The three-phase currents are measured by shunt resistors. Each shunt voltage is measured by a galvanically isolated ΔΣ-modulator. The modulator generates a ΔΣ-modulated bitstream output with a clock frequency of 20 MHz. The circuit can be seen in Figure 16. The modulator is supplied via the +5 V output from the rectifier circuit.

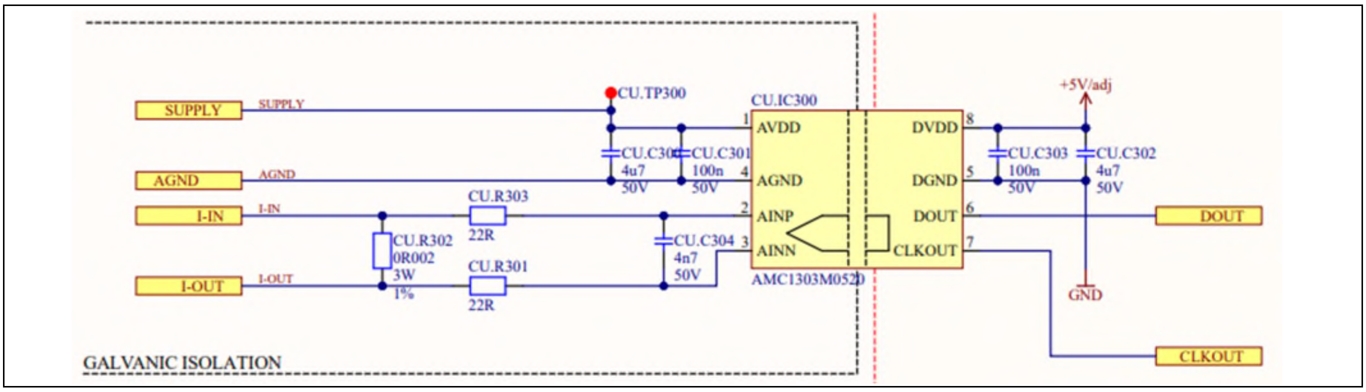


Figure 16 **Phase-current measurement**

4.9 Voltage measurement

Similar to the current measurement, the DC-bus voltage is measured via a voltage divider and the galvanically isolated ΔΣ-modulator. The circuit can be seen in Figure 17.

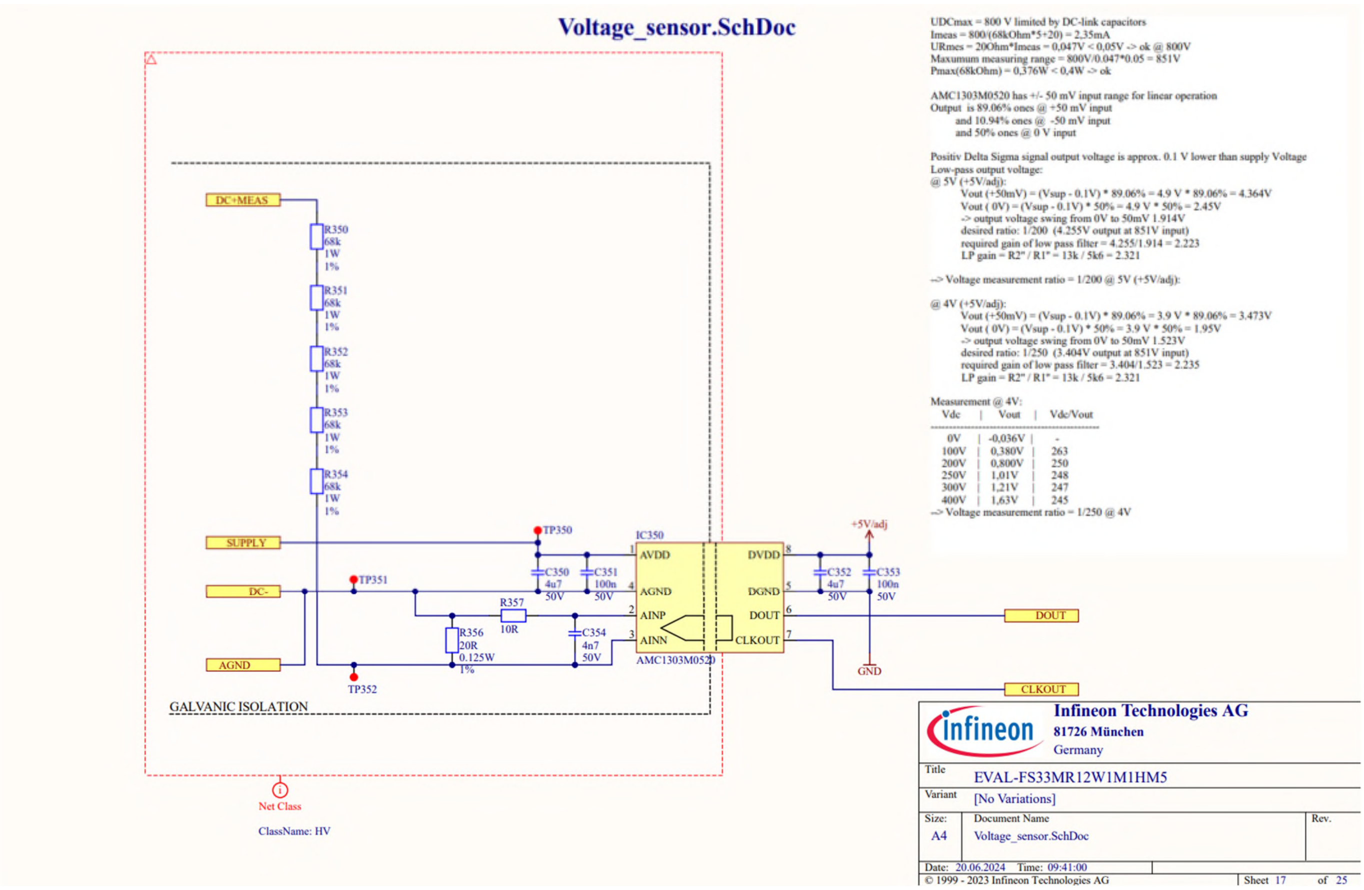


Figure 17 **DC-bus voltage measurement**

4.10 Digital-to-analogue converter

The evaluation board contains four discrete digital-to-analogue converters to generate analogue signals from the digital ΔΣ-modulated bit streams. The analogue signals are used for the on-board protection as well as for the external controller. The conversion is done by second-order low pass filters with approximately 6.5 kHz bandwidth. The circuit is shown in Figure 18**Error! Reference source not found.**. At zero input, the ΔΣ-converter generates a bitstream with 50% duty cycle. For offset adjustment, the reference voltage of the low pass filters can be adjusted via the R5564 potentiometer for all three currents. The four ΔΣ-modulated bitstreams can be measured directly at the X7 pin headers.

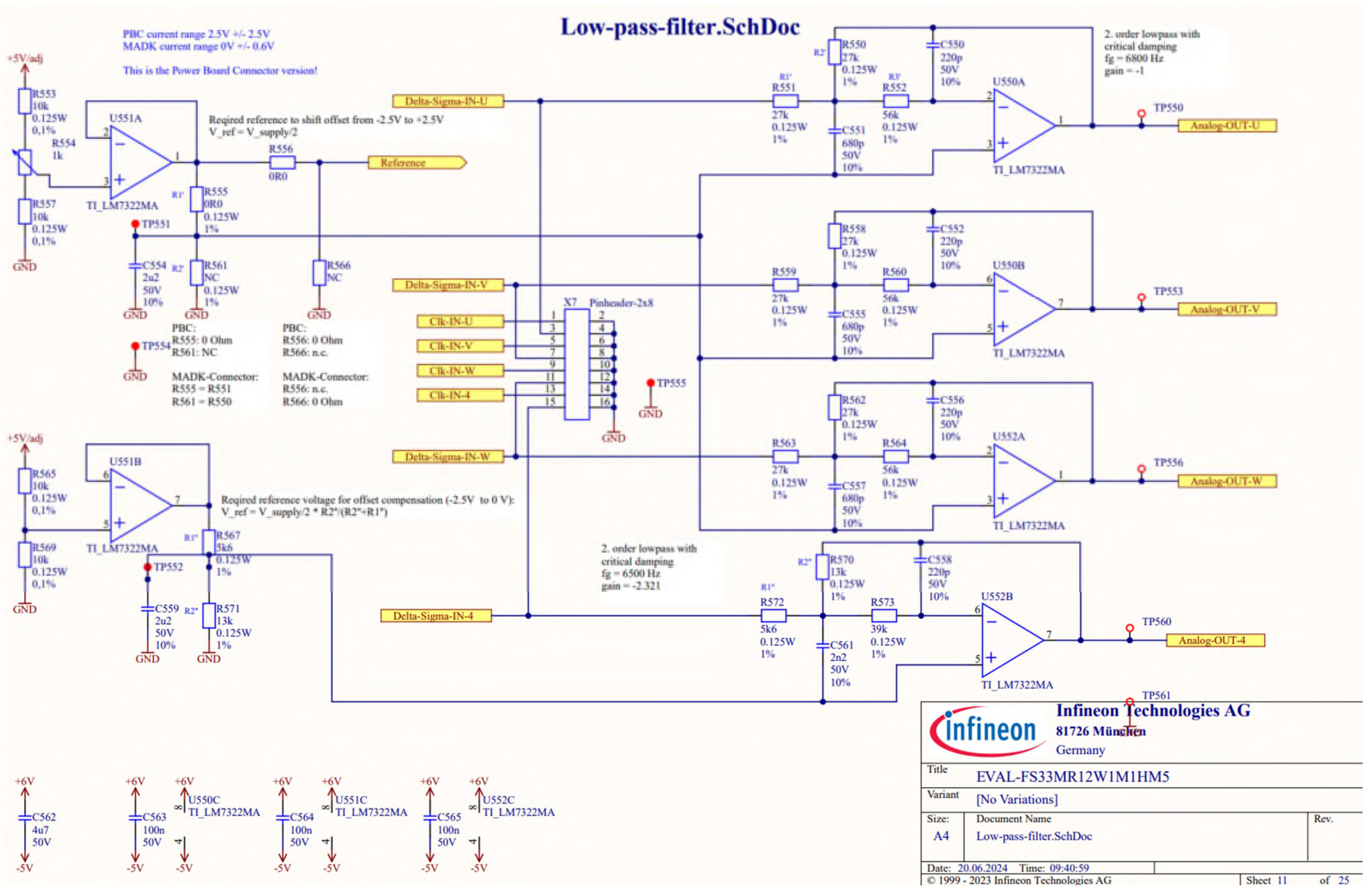


Figure 18 Measurement digital-to-analogue conversion

The EVAL-FS33MR12W1M1HM5 evaluation board is equipped with an overcurrent and overtemperature protection. If an overcurrent or overtemperature event is detected, the /FAULT signal is pulled low and the MOSFET drivers are simultaneously disabled for around 30 ms. The circuit is depicted in Figure 19.

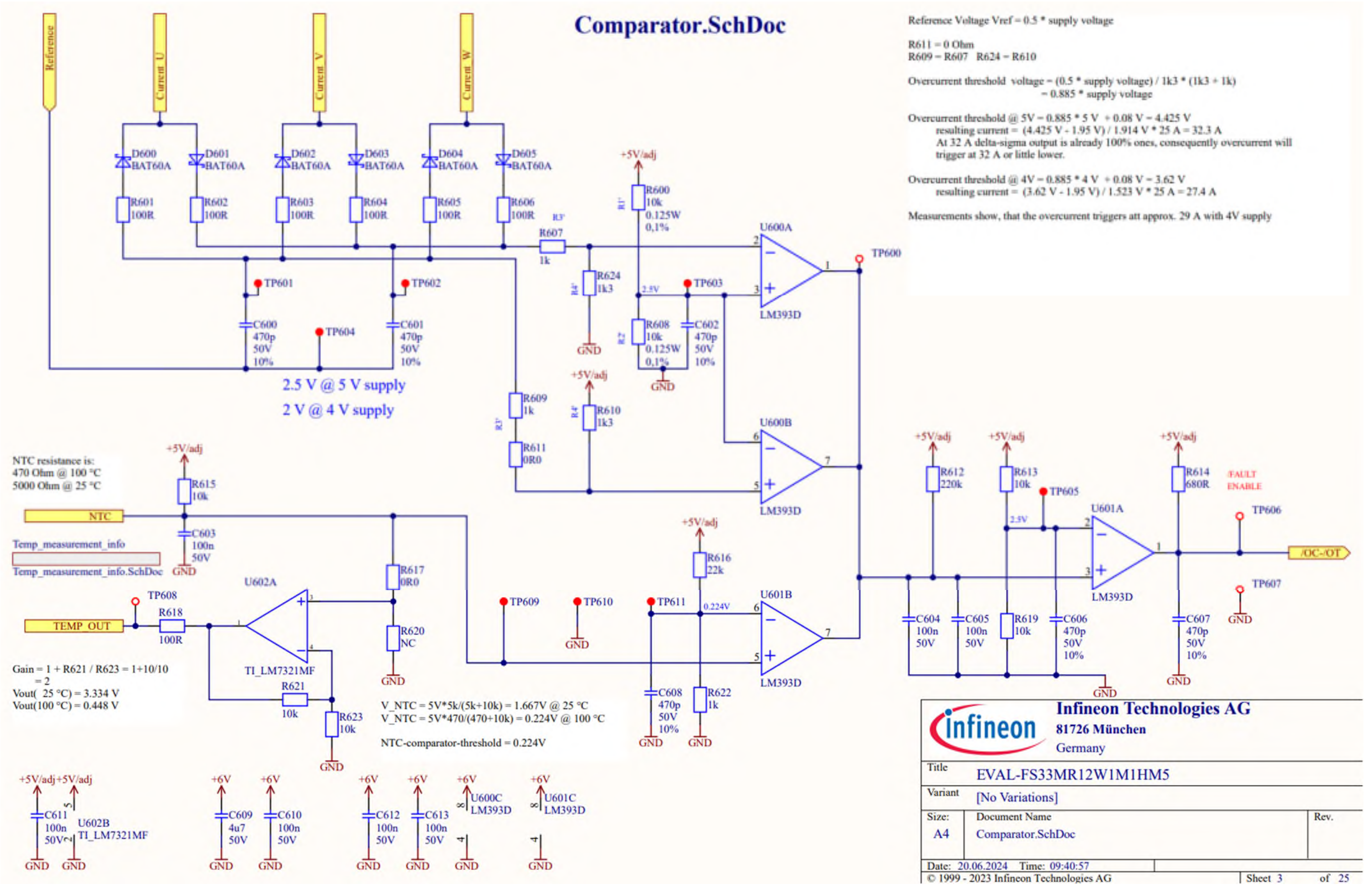


Figure 19 Protection circuit and temperature measurement

The overcurrent detection is provided with six ultra-low forward-voltage drop diodes (D600 … D605) which rectify the peak current of each phase. The peak positive value and the peak negative value are compared with a threshold value. If one value is exceeded, the /FAULT signal is triggered.

The overtemperature detection directly monitors the NTC voltage. A voltage below 0.224 V triggers the /FAULT signal. This threshold corresponds to a measured temperature of 100°C.

4.11 Overcurrent / Short-circuit protection

The circuit which monitors the voltage across a 3 mΩ shunt placed in the DC-path of the power module is shown in Figure 20. A low-side driver with an overcurrent protection feature is used here. The driver stage itself is unused. The Infineon 1ED44176N01F has 0.5 V overcurrent trigger threshold. This leads to a nominal current threshold of 167 A.

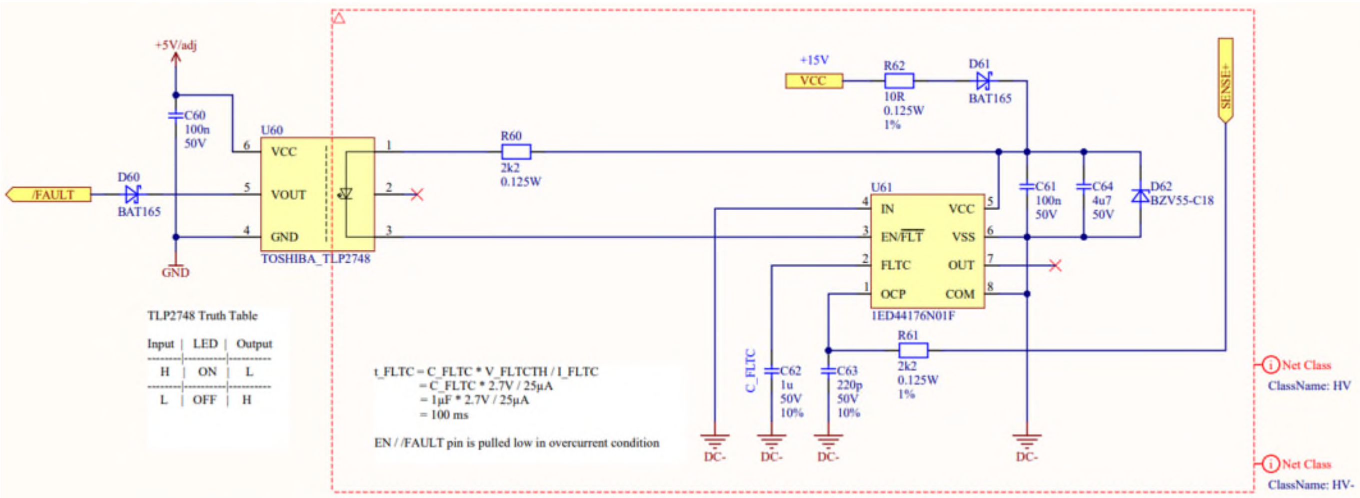


Figure 20 Short-circuit protection

A low pass filter (R61/C63) is placed at the OCP pin of the IC. Its time constant of 484 ns is required to block high voltage spikes at fast current rises due to the parasitic inductance of the measuring shunt and its connection.

If an overcurrent is detected, the EN/FAULT pin of the driver is pulled low and the LED of the connected optocoupler turns on. Hence, the isolated side of the optocoupler turns low and the /FAULT signal is pulled low. Consequently, all MOSFET drivers are turned off. The overall time delay from overcurrent to MOSFET gate low is approximately 1 µs.

The circuit is supplied via the low-side gate driver supply. This supply is referenced to the source of the low-side MOSFETs which is in front of the shunt. Consequently, the supply of the OCP protection is decoupled with a diode (D61) and buffered with a capacitor (C64). This leads to a voltage drop of approximately 1 V in overcurrent condition, however, this is still sufficient to supply the circuit.

4.12 PCB layout

The layout of this board is especially designed for evaluation purposes. Consequently, it has several test points and is not necessarily suited for continuous operation at full load. The PCB has four electrical layers with 35 µm copper. The size is 204 mm x 259 mm. The PCB thickness is 1.6 mm. For more details on the layout design and the latest Gerber-files, contact our technical support team.

Figure 21 and Figure 22. show the top and bottom assembly of the evaluation board, respectively.

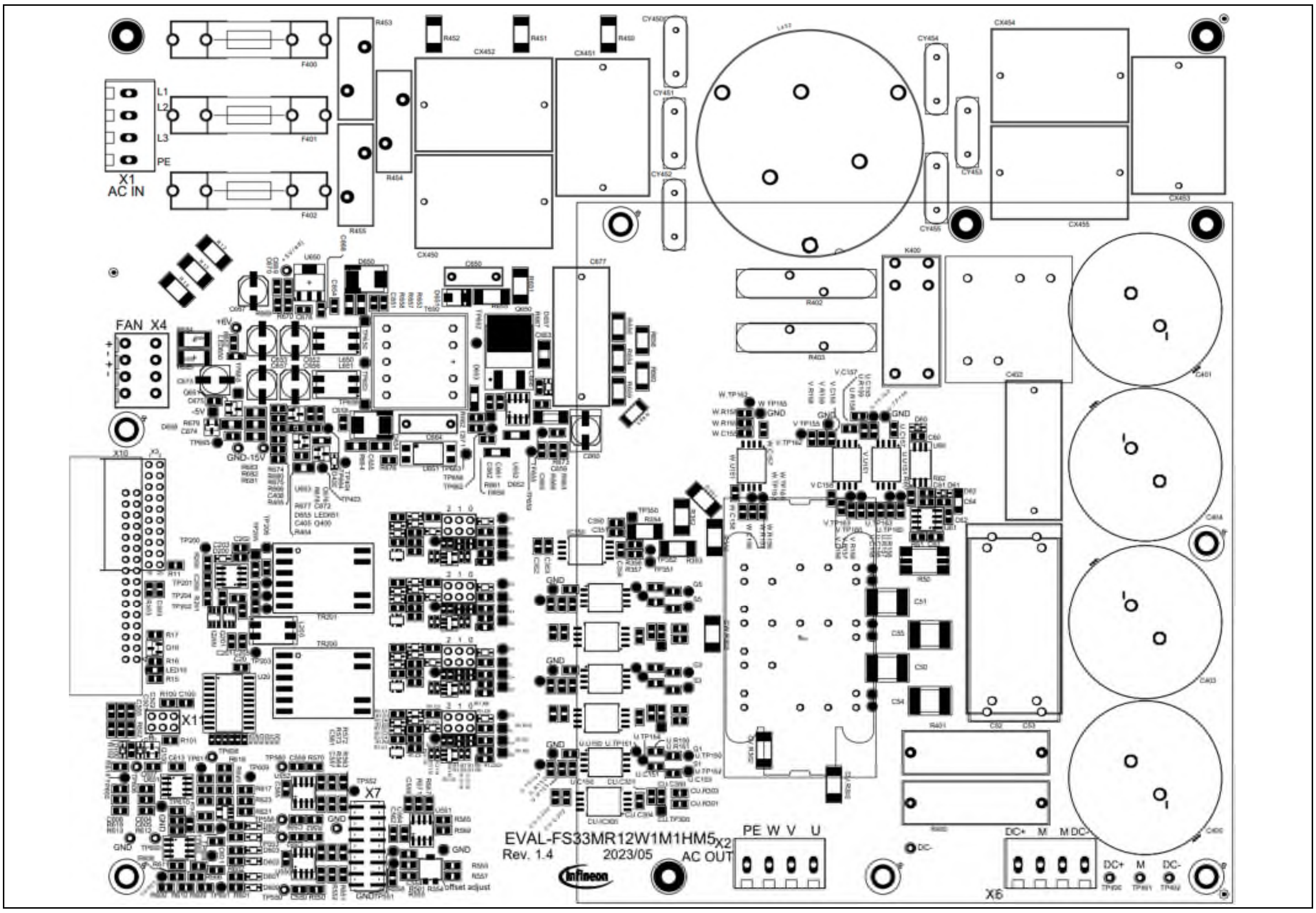


Figure 21 Top assembly print of the EVAL-FS33MR12W1M1HM5 evaluation board

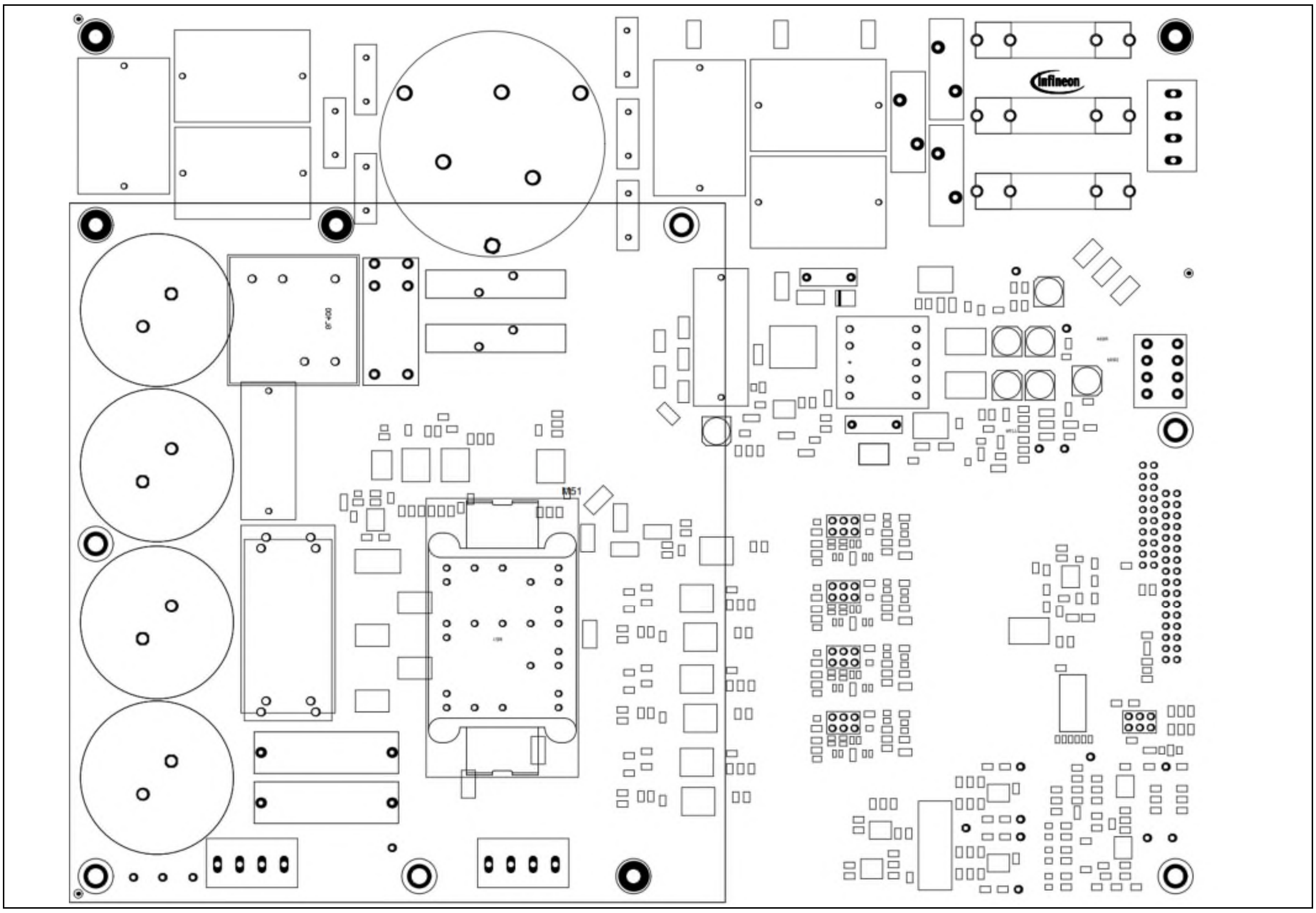


Figure 22 Bottom assembly print of the EVAL-FS33MR12W1M1HM5 evaluation board

5 Bill of material

Table 11 Bill of material

No.	Qty.	Part description	Designator	Part number	Manufacturer
1	4	Voltage Regulator	R1.U1, R2.U1, R3.U1, R4.U1	IFX20001MBV50HTSA1	Infineon
2	1	Voltage Regulators	U650	IFX1117ME V	Infineon
3	1	Quasi-Resonant Controller	U652	ICE5QSAG	Infineon
4	6	Silicon Schottky Diode	D600, D601, D602, D603, D604, D605	BAT60A	Infineon
5	1	MOSFET/IGBT Low Side Driver	U61	1ED44176N01F	Infineon
6	1	CoolSiC Trench MOSFET	M51	FS33MR12W1M1H_B11	Infineon
7	6	MOSFET Single Channel Driver	U.U150, U.U151, V.U150, V.U151, W.U150, W.U151	1EDI20H12AH	Infineon
8	1	Common Mode Chokes / Filters	L200	WE_744227	Würth Elektronik
9	2	Common Mode Chokes / Filters	L650, L651	WE_744221	Würth Elektronik

6 Measurements

The following chapter provides some typical measurements made with the EVAL-FS33MR12W1M1HM5 evaluation board. The board is supplied by a 400 V grid and is connected at the output to a symmetrical RL-load illustrated in Figure 23.

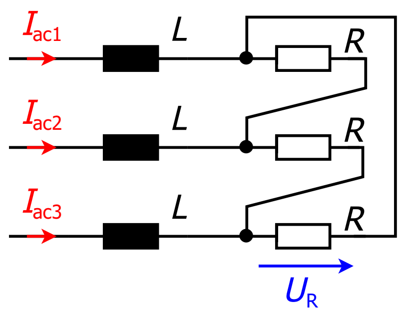


Figure 23 Test load

The value of the inductance is 1.5 mH and the value of the resistor is 23 Ohm. With a nominal output current of 16 A_{RMS}, the output power is about 5.9 kW. The switching frequency was set to 18 kHz. The following screenshot shows the related measurement.

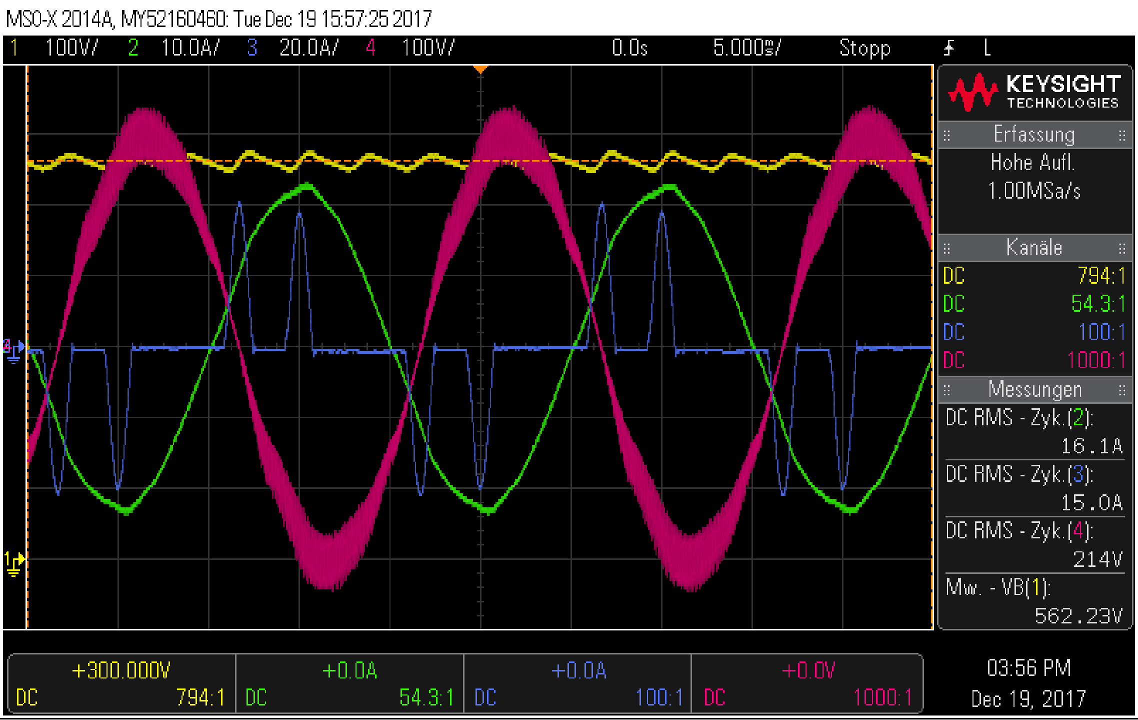


Figure 24 Measurement waveforms with test load

The output phase current (green) and the resistor voltage (red) are almost sinusoidal, whereas the input line current (blue) shows the typical waveform of a capacitor charging current. Due to its high crest factor, the rms-value is as high as 15 A, even at only 6 kW input power. The yellow signal shows the rectified DC-bus voltage of about 562 V.

6.1 Thermal measurements

After the board was powered for over an hour at the above-mentioned load conditions, the following thermal images were made. At the same time, the NTC temperature was measured with T_{Modul} ≈ 92 °C.

Figure 25 Thermal image of evaluation board at 18 kHz switching frequency

Figure 26 Thermal image of input area

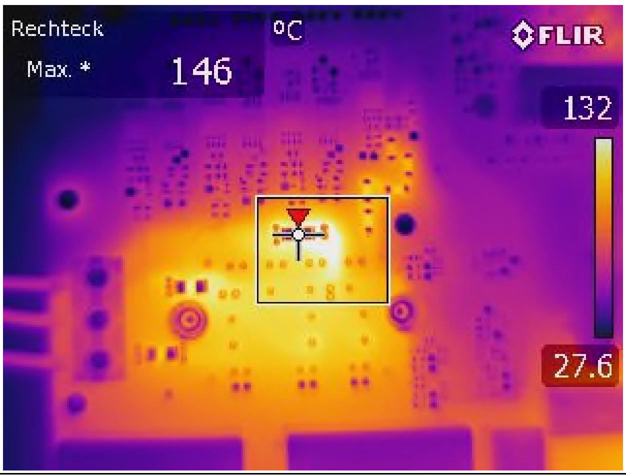


Figure 27 Thermal image of power module area

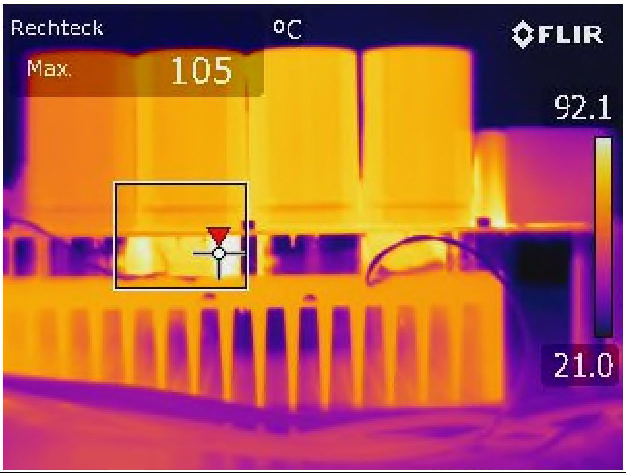


Figure 28 Thermal image of power module and rectifier (side view)

To evaluate the thermal behavior of the EVAL-FS33MR12W1M1HM5 evaluation board at 100 kHz switching frequency, the current was reduced until the same module temperature of TModul ≈ 92 °C was measured. This point was reached at 8 ARMS output current. Figure 29 shows the thermal image at this operating point.

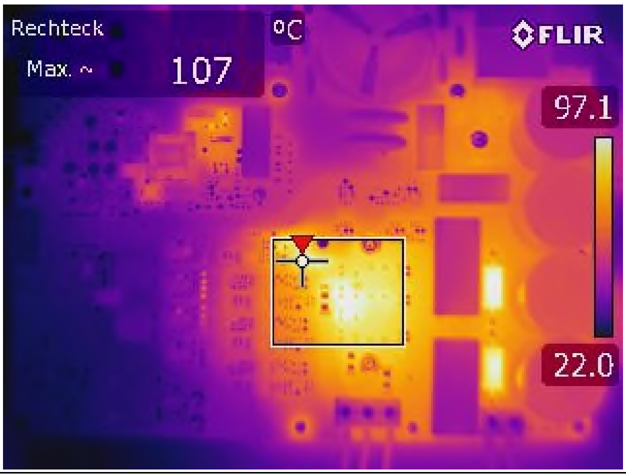


Figure 29 Thermal image of evaluation board at 100 kHz switching frequency

6.2 EMI measurements

The conducted EMI emission of the evaluation board was measured according to DIN EN 55011, connected to the grid via a 32 A – LISN. In Figure 30, the emission and the threshold limits for industrial use (DIN EN 55011, class A, group 1, ≤ 20 kVA) can be found. As one can see, the limits have almost been reached.

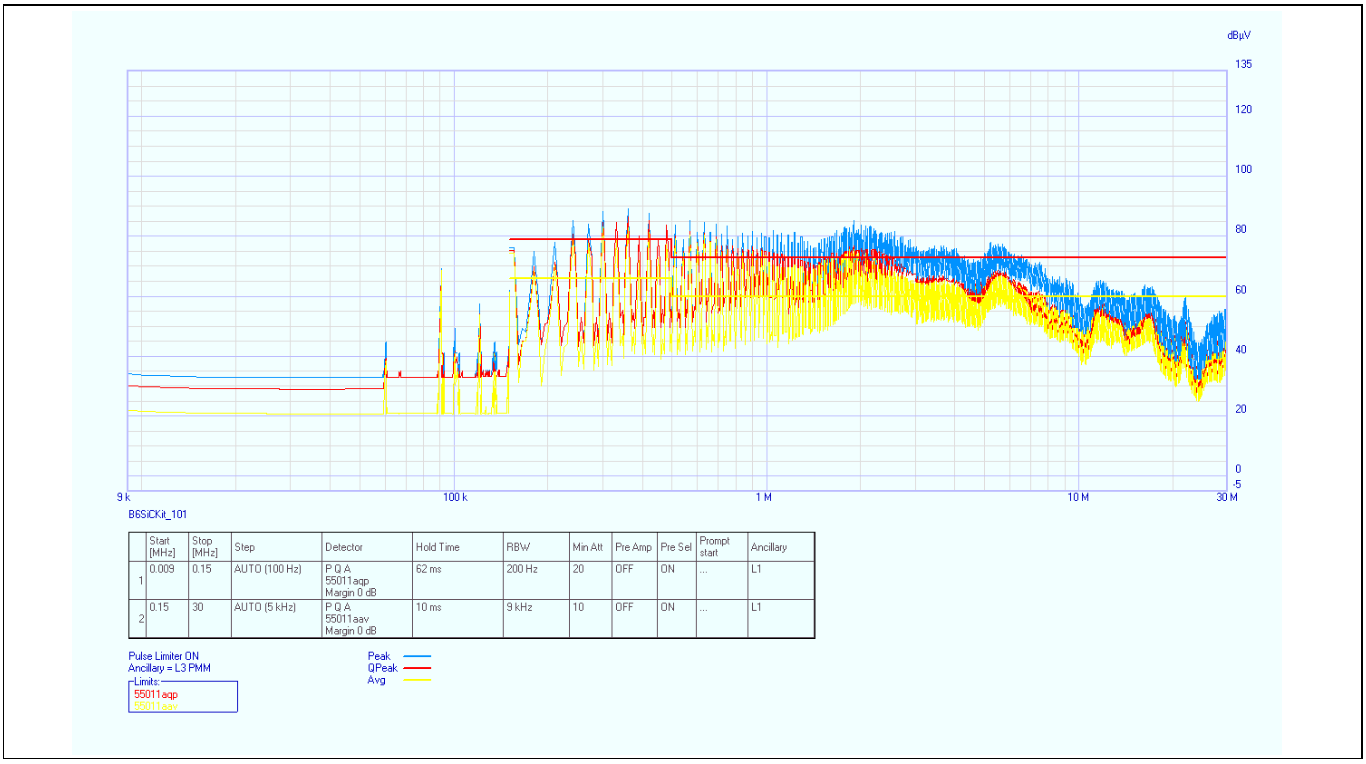


Figure 30 Conducted EMI emission

The emissions can be damped under the limits by using a small external common mode choke. The next figure shows the result using a Vacuumschmelze W 424-53 choke with three turns.

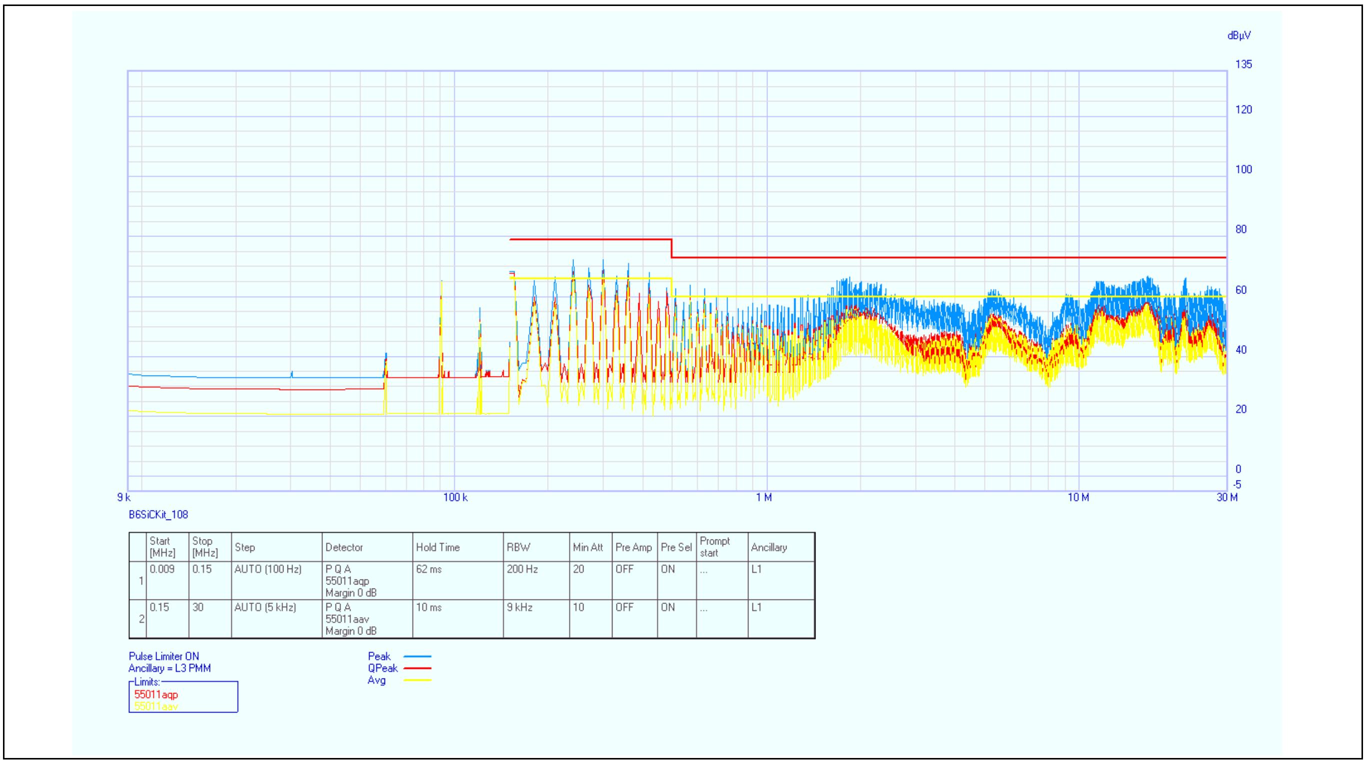


Figure 31 Conducted EMI emission with small external common mode choke

7 References

[1] Datasheet Infineon FS33MR12W1M1H_B11

[2] Datasheet of Infineon Eice-Driver 1EDI20H12AH

[3] Datasheet of Texas Instruments isolated ΔΣ-Modulator AMC1303M2520

Revision History

Major changes since the last revision

Page or Reference	Description of change
1.0	Initial version

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