EVAL_FAN_XMC_PFD7

100 W motor drive evaluation board with FOC sensorless control

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About this document

This application note provides an overview of the evaluation board **EVAL_FAN_XMC_PFD7**, including its main features, key data, pin assignments, schematics and layout. It also describes how to quickly get started with this demo PCB and take advantage of Infineon's **CoolMOS™ PFD7** superjunction MOSFETs, **CoolSET™** quasi-resonant (QR) flyback controller and **XMC1000** series microcontroller. A step-by-step getting started guide can be found **here**.

EVAL_FAN_XMC_PFD7 is a 100 W motor drive evaluation board with FOC sensorless control, which demonstrates Infineon's CoolMOS™ technology for motor drives by introducing a complete system-level solution using a discrete inverter to control and drive three-phase motors.

The evaluation board EVAL_FAN_XMC_PFD7 for motor drive applications was developed to support customers in the first stages of designing inverter applications with discrete solutions.

Scope and purpose

To demonstrate the two-level inverter stage with Infineon's CoolMOS™ PFD7 superjunction MOSFETs. Additionally to show the control algorithm that helps reduce reverse-current hard-commutation stress by offering synchronous rectification (SR) to a sensorless field-oriented BLDC/PMSM control (FOC) with feedback current loop, by using the XMC1000 series microcontroller. This enables manufacturers to minimize time-to-market and also reduces the bill of materials (BOM).

The Infineon components used in the 100 W motor drive evaluation board are:

- **IPN60R2K0PFD7S** 600 V CoolMOS™ PFD7 MOSFET
- **2ED28073J06F** 600 V half-bridge gate driver IC
- **XMC1302-T038X0200** 32-bit microcontroller with ARM® Cortex®-M0
- **ICE5QR4770AG** quasi-resonant CoolSET™ flyback controller
- **IFX1763XEJV50** low drop-out voltage regulator
- **BSS314PE** P-channel small-signal MOSFET
- **BSS138N** N-channel small-signal MOSFET
- **BAT54-03W** Si Schottky diode

Intended audience

This application note is intended for all technical specialists who aim to reduce system cost and improve efficiency, which in turn will enable longer run-time and reduce time-to-market.

Table of contents

1 Safety precautions

In addition to the precautions listed throughout this manual, please read and understand the following statements regarding hazards associated with development systems.

Table 1 Precautions

	**Attention:** The ground potential of the EVAL_FAN_XMC_PFD7 system is biased to a negative DC bus voltage potential. When measuring voltage waveforms by oscilloscope, the scope's ground needs to be isolated. 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.
	**Attention:** Only personnel familiar with the drive and associated machinery should plan or implement the installation, start-up and subsequent maintenance of the system. Failure to comply with this may result in personal injury and/or equipment damage.
	**Attention:** The surfaces of the drive may become hot, which may cause injury.
	**Attention:** The EVAL_FAN_XMC_PFD7 system contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing this assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines.
	**Attention:** An incorrectly applied or installed drive can result in component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.
	**Attention:** Remove and lock out power from the drive before you disconnect or reconnect wires or perform a service. Wait three 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.
	**Attention:** The EVAL_FAN_XMC_PFD7 system contains DC bus capacitors which take time to discharge after removal of the mains supply. Before working on the drive system, wait three 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.

2 Introduction

The EVAL_FAN_XMC_PFD7 evaluation board is available from Infineon. The features of this board are described in the features section of this document, and the document also provides information to enable users to copy, modify and qualify the design for production according to their own specific requirements.

The EVAL_FAN_XMC_PFD7 evaluation board uses the µC/Probe™ XMC™ platform. µC/Probe™ XMC™ is a Windows-based application that allows you to read and write the memory of XMC™ microcontrollers during run-time in a non-intrusive way, with a graphical dashboard to enable visualization of real-time data of critical control loops in motor control and fine-tune your motor parameters to meet target applications.

This board can be easily interfaced through XMC™ Link. XMC™ Link is an isolated debug probe for all XMC™ microcontrollers. The debug probe is based on SEGGER J-Link debug firmware, which enables use with DAVE™ and all major third-party compiler/IDEs known from the wide ARM® ecosystem.

This evaluation board is designed to give a complete solution for sensorless motor drives, using CoolMOS™ technology as a discrete solution for the power stage. The board is equipped with all assembly groups for sensorless FOC. It provides a single-phase AC connector, rectifier, QR controller CoolSET™ for bias circuit, DC-link and three-phase output for power. It contains emitter-shunts for current sensing (CS) and a voltage divider for DC-link voltage measurement.

2.1 Description

The EVAL_FAN_XMC_PFD7 motor drive demo board comes with AC input voltage and 100 W max. output power to drive a three-phase BLDC/PMSM motor with FOC sensorless mode suited to fan and pump applications, due to the CoolMOS™ PFD7 and XMC1000 microcontroller used inside this board.

This board does not only offer a SR algorithm to reduce reverse-current hard-commutation stress and sensorless FOC, but also this algorithm gives the user the option to change switching frequency and choose between two-phase or three-phase modulation (seven-segment space-vector modulation (SVM) or five-segment SVM), which helps to reduce switching losses and EMI signature and improve total efficiency, resulting in reliable and compact system designs. The BOM is minimized, while meeting the minimum requirements for target applications.

2.2 Summary of features

- Low BOM cost due to the CoolMOS™ PFD7 and XMC™ algorithm
- Highly efficient solution
- Sensorless FOC
- Ease of use with graphical user interface (GUI)

2.3 Benefits

- High efficiency
- Cost effective
- Simplified design
- Accelerated time-to-market

2.4 Target applications

- Major home appliances
- Small home appliances

3 Main features

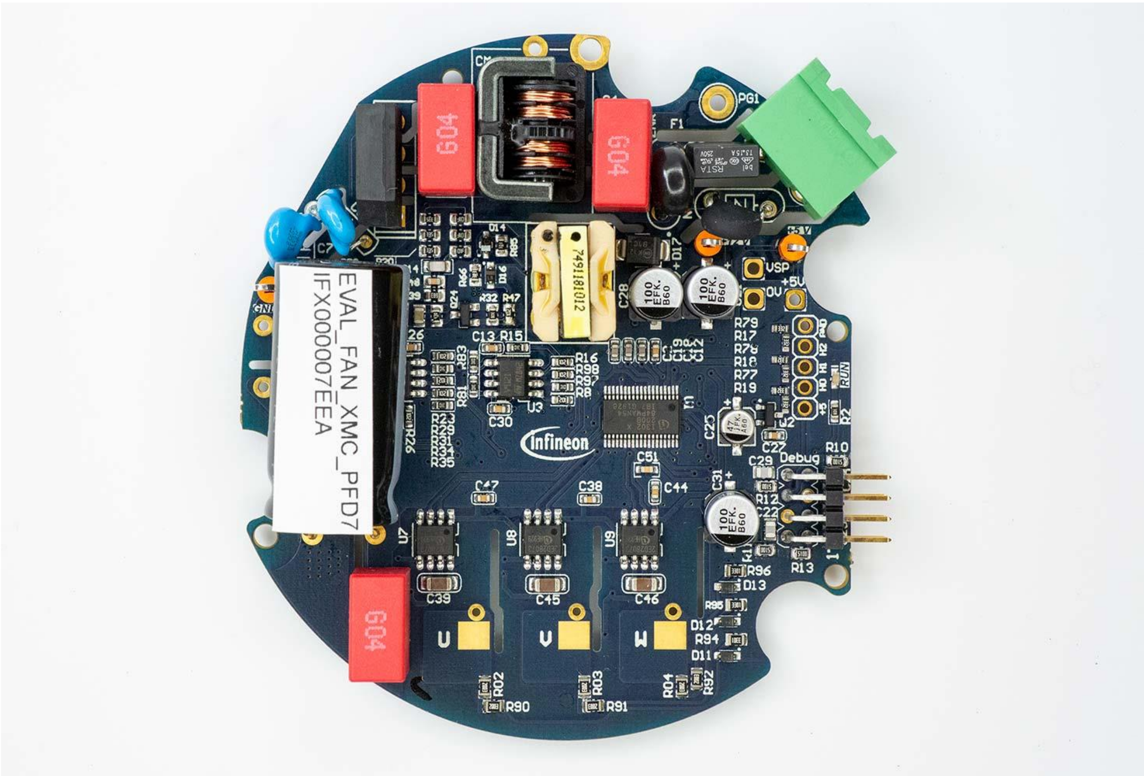


Figure 1 EVAL_FAN_XMC_PFD7 board

The EVAL_FAN_XMC_PFD7 is a complete evaluation board for motor drive application. The kit demonstrates Infineon's discrete power superjunction MOSFET CoolMOS™ PFD7 technology for motor drives.

Main features:

- Maximum input voltage: 265 V AC or 370 V DC
- Minimum input voltage: 85 V AC or 120 V DC
- Output power for applied motor: up to 100 W without heatsink
- On-board EMI filter
- Current sensing for each phase configured by default
- Sensing of DC-link voltage
- +12 V auxiliary power supply based on QR flyback
- Compact design using 600 V CoolMOS™ PFD7, op-amp for current sensing and comparator
- On-board demodulator for speed and on/off control using potentiometer
- Highly efficient and cost effective
- Hardware and software overcurrent protection (OCP)
- Overvoltage (OV) and undervoltage (UV) detection
- Based on 32-bit ARM® Cortex™-M0 core-based microcontroller
- Firmware based on XMC1000 sensorless FOC motor control library
- Fully customized for drain pumps, air-conditioning, outdoor fan and ceiling fan applications
- FOC sensorless algorithm
- PCB size customized for cooling fan design
- PCB diameter: 87 mm

3.1 Key data

CoolMOS™ PFD7 is Infineon's latest series with an integrated fast body diode. It is the ideal choice for motor drive applications, for example in home appliances, in which there is a need for high efficiency at light load conditions.

The fast reverse-recovery of CoolMOS™ PFD7 offers designers the benefits of reduced stress on the device while the body diode is not fully recovered, and an extra safety margin for repetitive hard-commutation in designs, which translates to reduced design-in effort and ease of use.

- 600 V technology with integrated fast body diode
- Low switching losses due to low Q_{rr}, t_{rr} at repetitive commutation on the body diode
- Controllable di/dt and dv/dt
- Low Q_{oss}
- On-chip ESD protection according to HBM class 2
- $R_{DS(on)}$ up to 360 mΩ in SOT-223 package

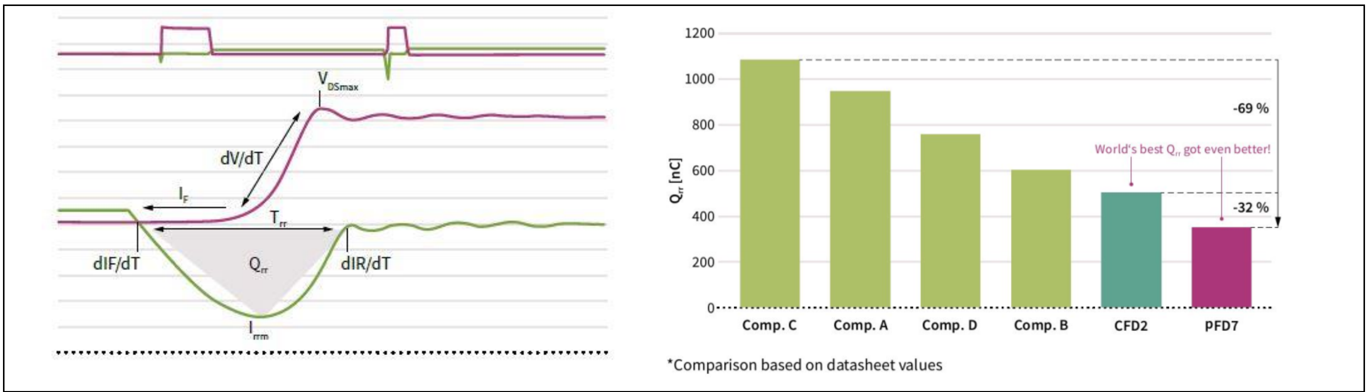


Figure 2 Highest reliability from lowest reverse-recovery charge and reverse-recovery time

For further information on the CoolMOS™ PFD7, such as static and dynamic electrical behavior, as well as thermal and mechanical characteristics, please refer to the **datasheet** of the IPN60R2K0PFD7S. **Table 2** provides the absolute maximum ratings of the IPN60R2K0PFD7S.

Table 2 Absolute maximum ratings of CoolMOS™ IPN60R1K5PFD7S

Symbol	Description	Min.	Max.	Unit
V_{DSS}	MOSFET blocking voltage	–	600	V
I_D at T = 25°C	DC output current per MOSFET	–	3.0	A
P_d at TC = 25°C	Maximum power dissipation per MOSFET	–	6	W
T_J	Operating junction temperature	-55	150	°C
T_C	Operating case temperature	-55	150	°C
T_S	Storage temperature	-55	150	°C
V_{SD}	Diode forward voltage	1.0		V
t_{rr}	Reverse-recovery time	34		ns
Q_{rr}	Reverse-recovery charge	0.05		µC

3.1.1 Comparing the superjunction MOSFET with IGBT

In conduction mode, the unipolar MOSFET acts like a resistor. In contrast, a bipolar IGBT device behaves like a resistor in series with a diode. **Figure 3** illustrates similar conduction losses for MOSFET and IGBT modules. However, as the load current is reduced, the IGBT voltage remains relatively constant and the MOSFET voltage reduces linearly based on its $R_{DS(on)}$. In motor drive applications where the switching frequency is around 20 kHz, the conduction losses are the dominant losses in the application, especially at partial load points where the $R_{DS(on)}$ of the MOSFET plays the key role of improving light load efficiency.

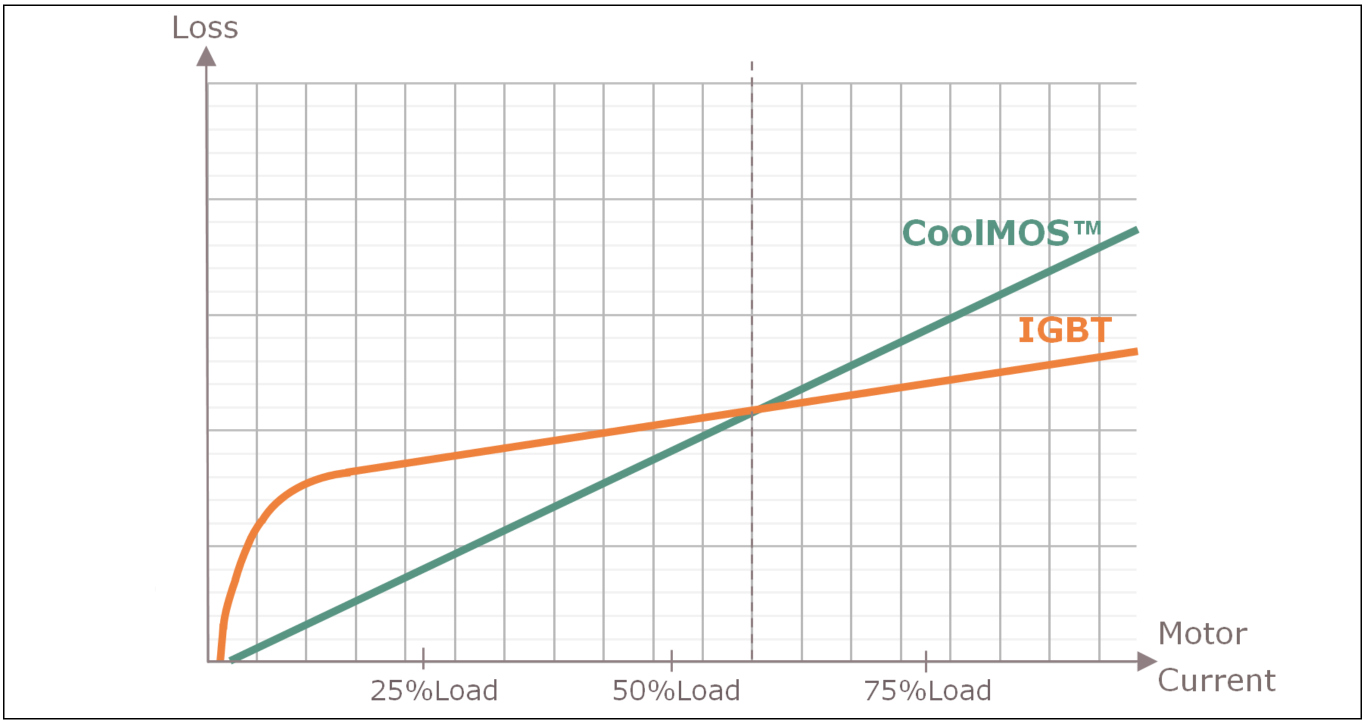


Figure 3 Conduction loss comparison (at the same current rating)

3.2 Specifications of the evaluation board EVAL_FAN_XMC_PFD7

Table 3 shows the important specifications of the evaluation board EVAL_FAN_XMC_PFD7.

Table 3 EVAL_FAN_XMC_PFD7 board specifications

Parameters	Value	Conditions
Input		
Voltage	85 to 264 V_{rms}	
Frequency	50/60 Hz	
Input current	1.5 A_{rms}	
Output		
Power (three phases)	100 W	
Current per leg	500 mA	
DC bus		
Maximum DC bus voltage	370 V	
Minimum DC bus voltage	120 V	
Current FB		
Phase CS devices R61, R62, R71	0.05 Ω	The default configuration uses three shunts sensing in the emitter paths – IU+, IV+, IW+
Overall current protection devices R57	0.25 Ω	
Protections		
Output current trip level	2.4 A	Configured by either changing shunt resistors or adapting comparator threshold
On-board power supply		
12 V	12 V ±5 %, max. 250 mA	Used for inverter gate driver power
5 V	5 V ±5 %, max. 50 mA	Used for microcontroller supply and CS and OCP circuit

3.2.1 Functional groups

Figure 4 and **Figure 5** show the functional groups of the EVAL_FAN_XMC_PFD7 evaluation board.

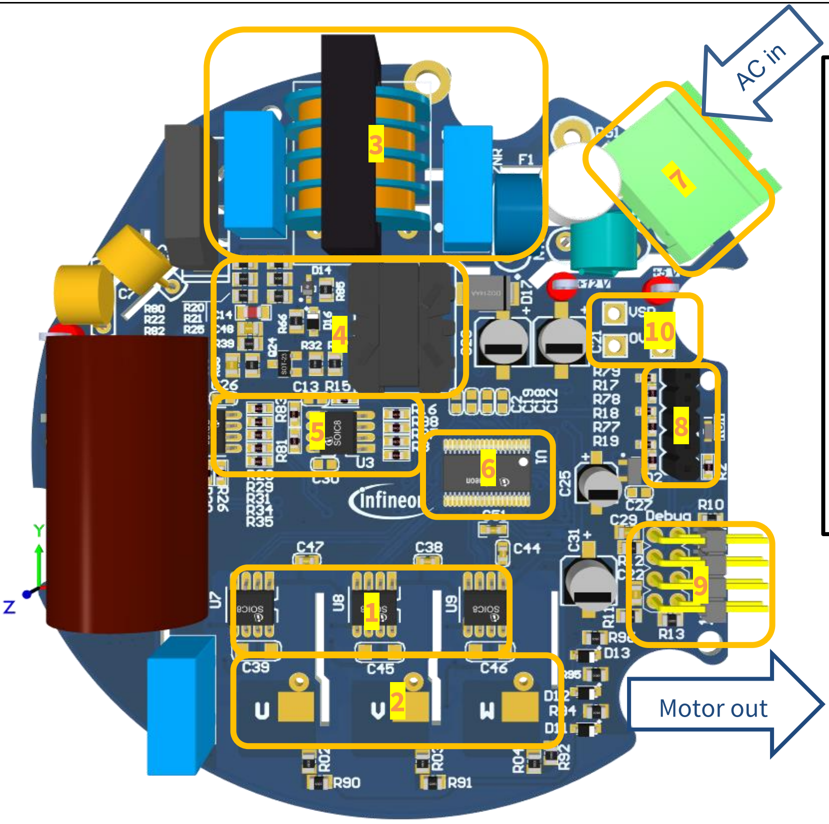
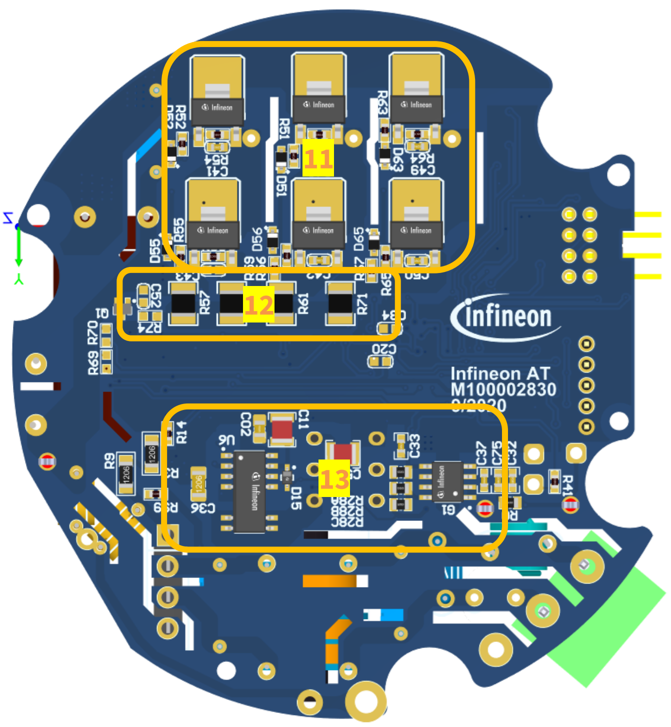


Figure 4 Functional groups of the EVAL_FAN_XMC_PFD7 evaluation board's top side



11. Inverter stage CoolMOS™ PFD7
12. Shunt resistors
13. On-board power supply 12 V and 5 V generation

Figure 5 Functional groups of the EVAL_FAN_XMC_PFD7 evaluation board's bottom side

4 Pin assignments

4.1 AC-line connector

This section gives general information on the connectors in the EVAL_FAN_XMC_PFD7 evaluation board. **Figure 6** includes the details of the line connector. It is possible to connect DC voltage to the AC connector, and in this case a permanent DC current will be conducted through the rectifier bridge. Maximum ratings are valid for AC as well as DC conditions. It is recommended to observe the temperature of the rectifier bridge. Because of this rectifier, the DC supply's polarity at the connector is of no concern. The evaluation board is protected by an on-board fuse rated 3 A.

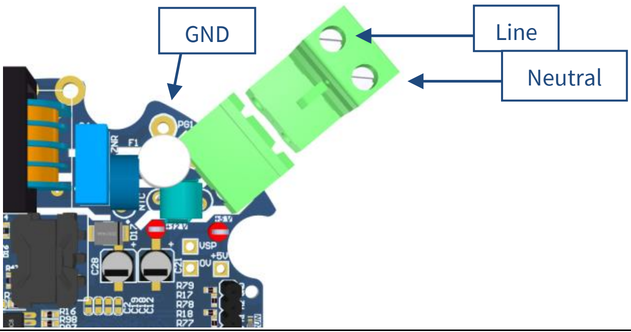


Figure 6 Line connector

4.2 Motor side connector

Figure 7 shows details of the three-phase motor side connection.

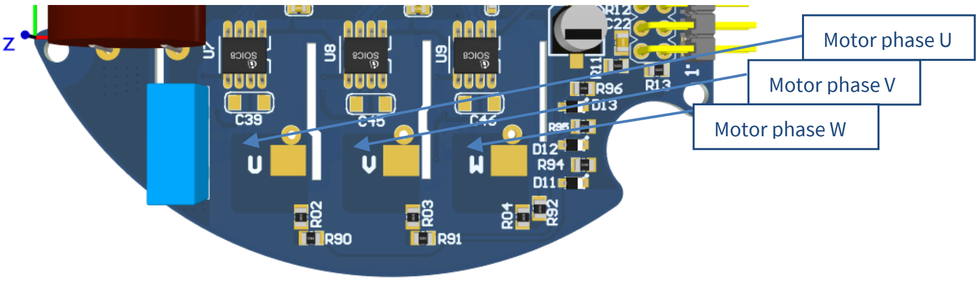


Figure 7 Motor side connector

4.3 Speed control potentiometer

Figure 8 shows details of the motor speed control potentiometer connection.

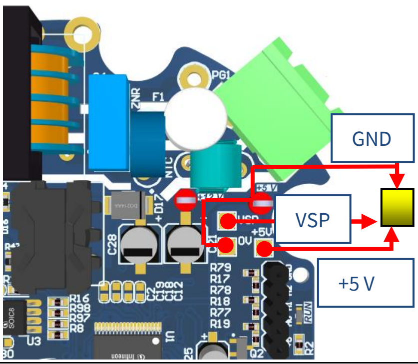


Figure 8 Speed control potentiometer connector

4.4 8-pin debug connector

The EVAL_FAN_XMC_PFD7 supports debugging via serial wire debug (SWD) and serial port debug (SPD). **Figure 9** shows details of the pin assignment.

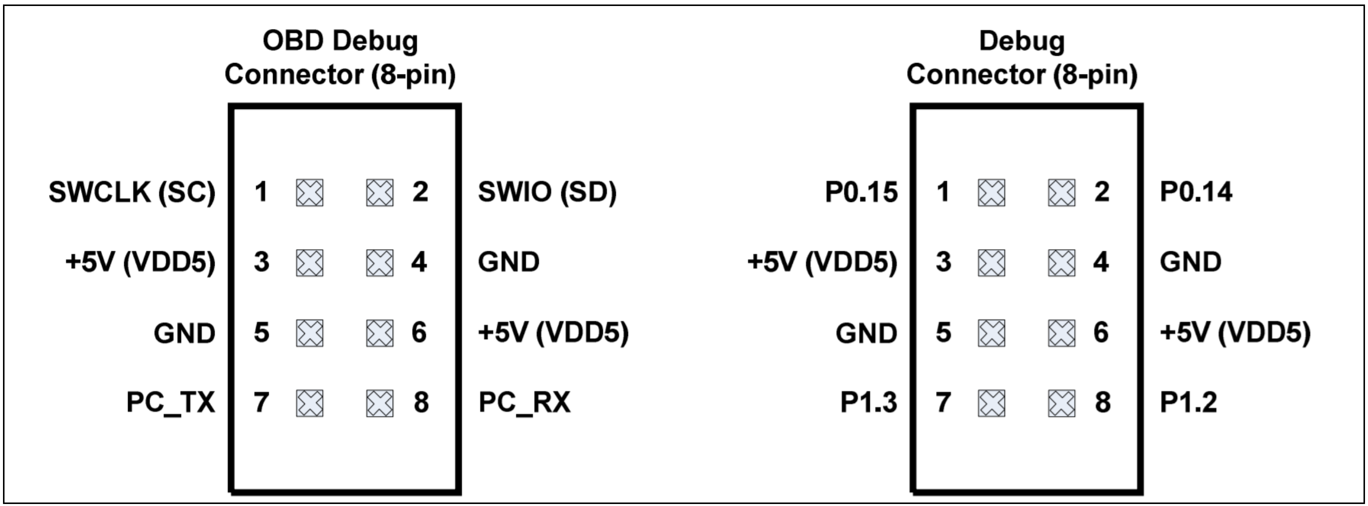


Figure 9 Pin assignment of the eight-pin debug connector

The default debug connections used in the EVAL_FAN_XMC_PFD7 are as follows:

- SWD:
  - SWIO/SPD – P0.14 (SWD0)
  - SWCLK – P0.15 (SWD0)
- Full duplex UART communication via a virtual COM port:
  - PC_RXD – P1.2 USIC0CH1.DOUT0
  - PC_TXD – P1.3 USIC0CH1.DX0A

4.5 Hall sensor connector

The EVAL_FAN_XMC_PFD7 provides Hall connectors as indicated in **Figure 10**. The Hall sensor interface provides a pull-up resistor for each Hall sensor signal as well as +5 V power supply for the Hall sensors.

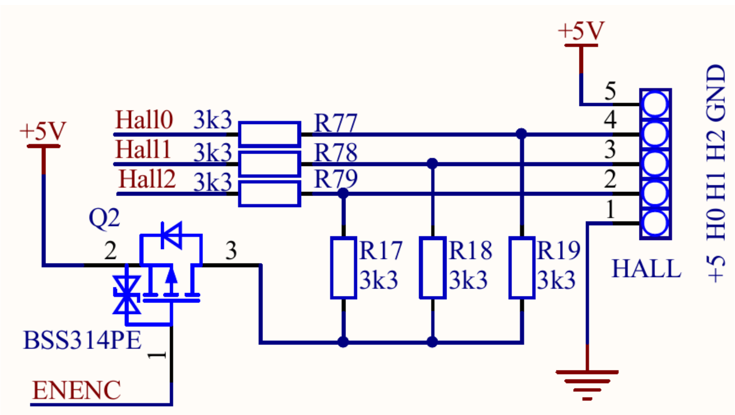


Figure 10 Hall sensor connector

5 Schematics and layout

To meet individual customer requirements and make the EVAL_FAN_XMC_PFD7 evaluation board a basis for development or modification, all necessary technical data such as schematics, layout and components are included in this chapter.

5.1 EMI input filter and rectifier circuit

Figure 11 depicts the schematic from the AC-line input connector to the rectified DC bus voltage. This circuitry includes a passive EMI filter consisting of elements C4, C5, CM, C3 and C7, a 2 A/600 V rectifier block U2, and an NTC inrush current-limiting NTC for surge current protection. Two electrolytic capacitors C10, C6 and ceramic capacitor C9 are used for buffering the rectified DC bus voltage DC+. The design is protected by a 3 A fuse F1 on the line input terminal L1.

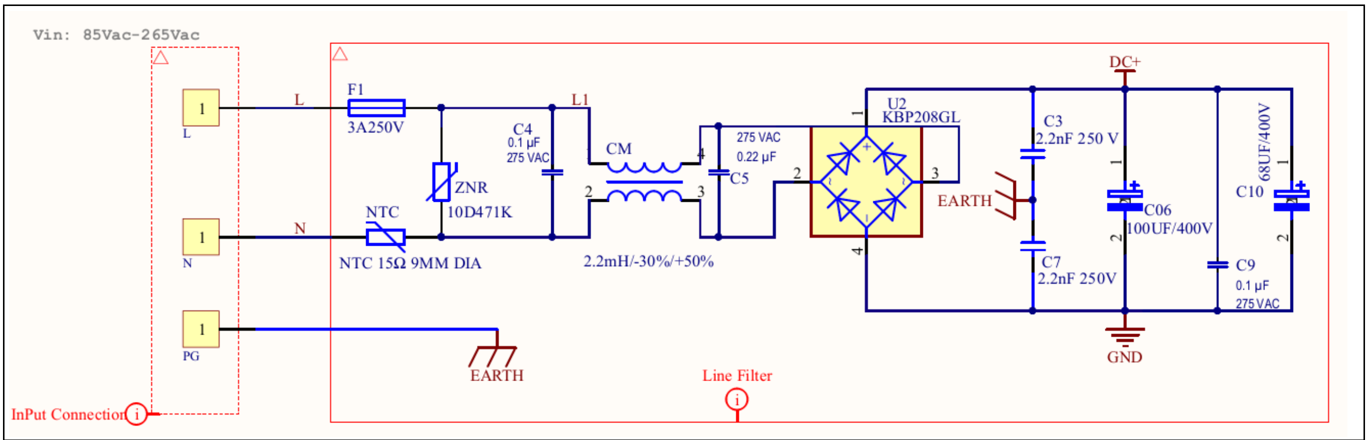


Figure 11 **Schematic for EMI input filter and AC-DC section of the EVAL_FAN_XMC_PFD7 evaluation board**

5.2 Three-phase inverter using CoolMOS™ PFD7

The three-phase power inverter is implemented using six CoolMOS™ PFD7s (**IPN60R2K0PFD7S**). Each inverter leg has its own shunt in the low-side path for phase current measurement. In addition, the common DC-link current can be measured by its own shunt.

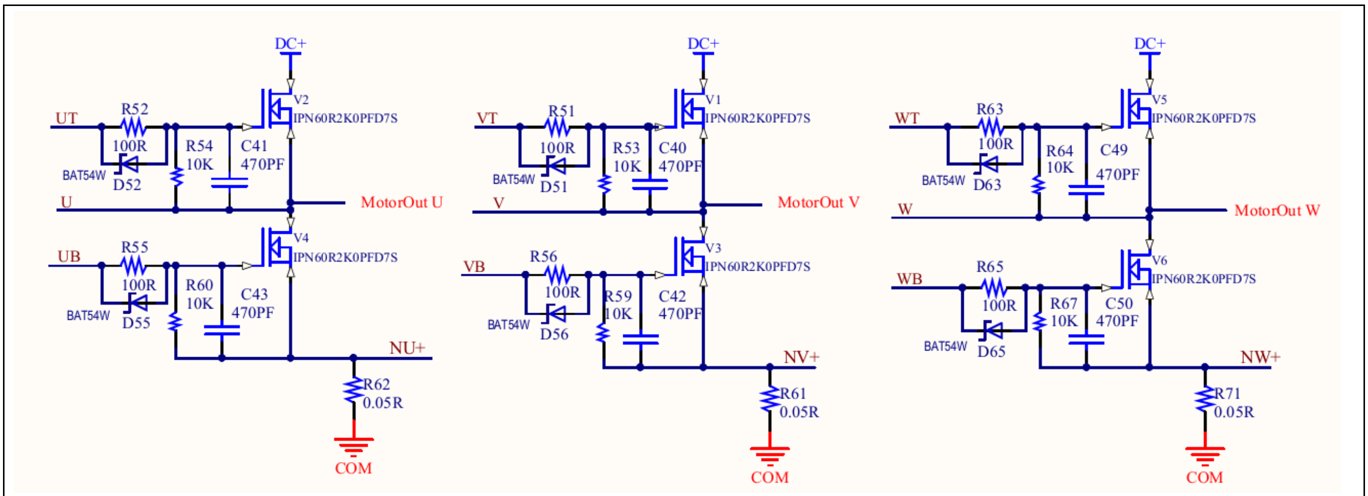


Figure 12 **Schematic of the three-phase inverter on the EVAL_FAN_XMC_PFD7 evaluation board**

The inverter section is implemented as shown in **Figure 12**. The design includes the same gate circuit for the high-side and low-side MOSFETs. The R_{Gon} = 100 Ω is used to reduce turn-on dv/dt = 5 V/ns, leading to less di/dt for the low-side body diode and reverse-recovery.

Adding C_{gs} = 0.47 nF reduces C_{rss}/C_{iss} ratio for less drain-gate (Miller) coupling gain, removing any gate oscillation, and improving EMI.

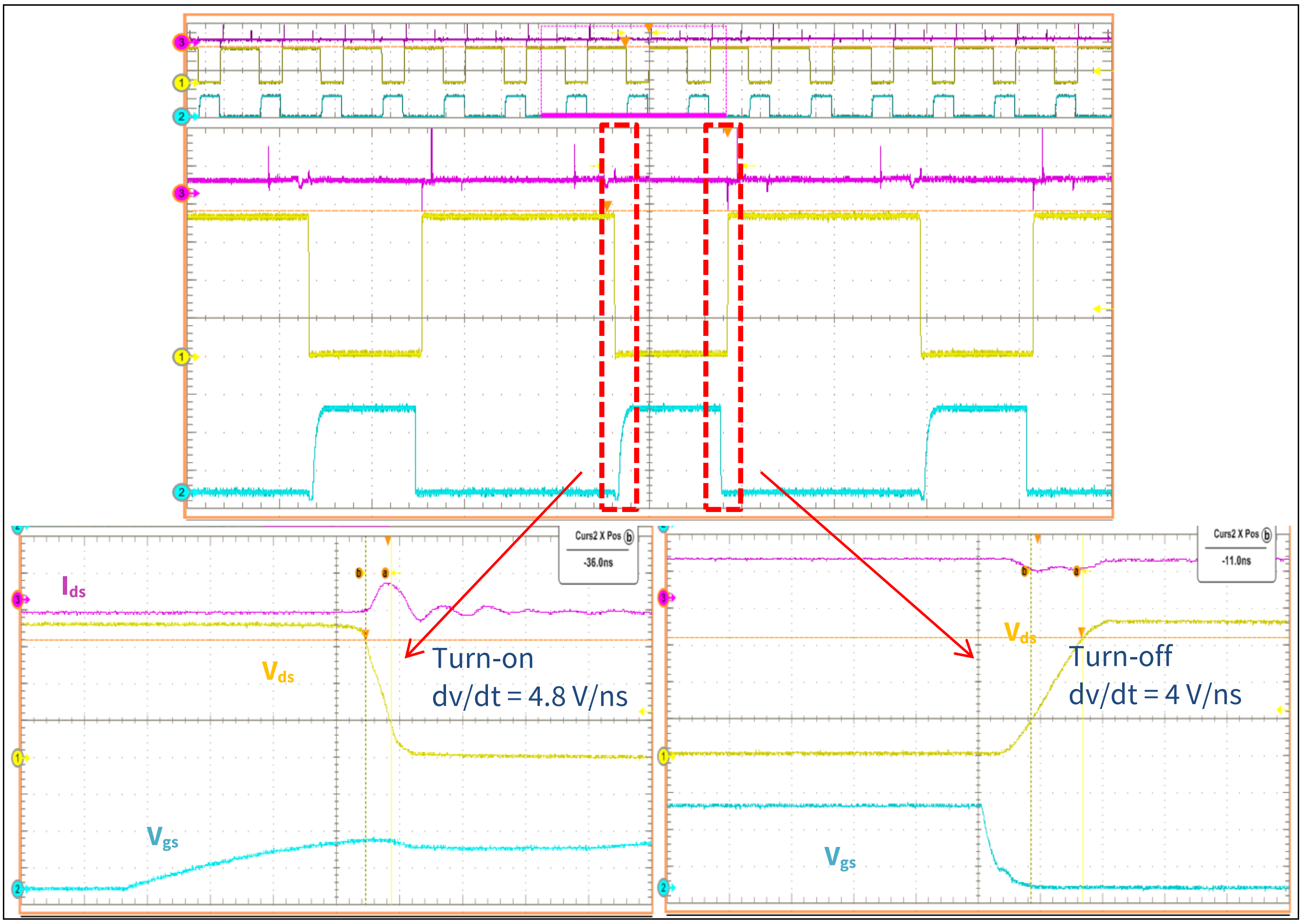


Figure 13 Controlled dv/dt

5.3 Power supply

Figure 14 depicts the schematic of the control power supply available on the EVAL_FAN_XMC_PFD7 board. The bias supply using the CoolSET™ ICE5QR4770AG operates from an AC input voltage from 85 V AC to 265 V AC providing a non-isolated +12 V output. The linear regulator (**IFX1763XEJV50**) generates +5 V from the +12 V provided by the flyback circuit. The +5 V power supply is used to supply the overcurrent comparator circuit and the XMC microcontroller.

5.4 QR controller (CoolSET™)

The QR CoolSET™ series continues to deliver design agility and miniaturization. The CoolSET™ is an integrated power management IC with a 700 V avalanche rugged CoolMOS™, start-up cell and QR current-mode flyback PWM controller in a DSO-12 package. This new series offers the possibility of higher efficiency and better EMI performance. The digital frequency reduction feature ensures a very stable operation with decreasing load change and the fold-back correction keeps the maximum power limits within the tolerance desired by SMPS designers. The active burst mode (ABM) operation during low power consumption provides best-in-class power consumption during standby.

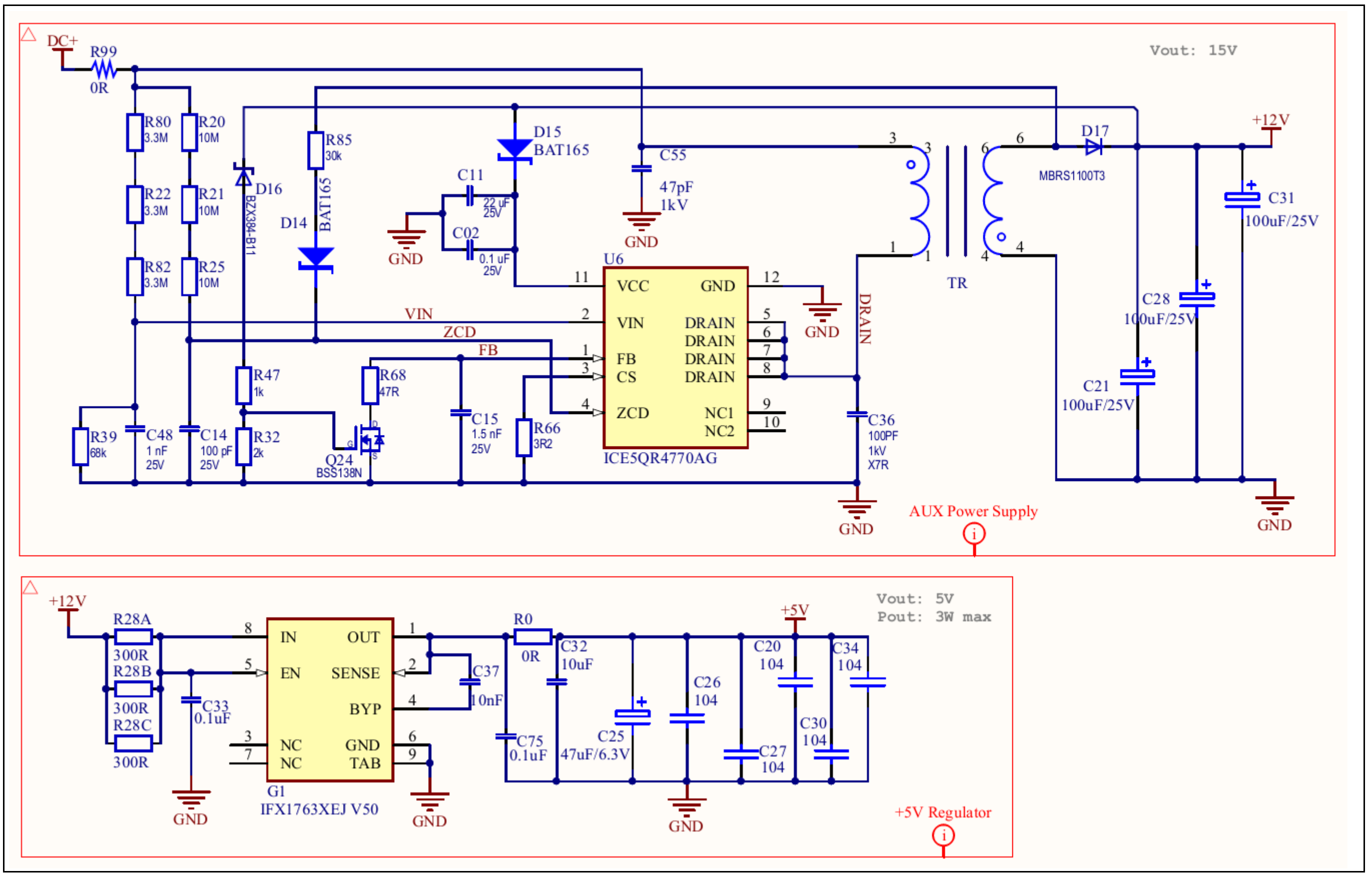


Figure 14 **Power supply section of the EVAL_FAN_XMC_PFD7 evaluation board**

5.4.1 System benefits

The 3 W power supply that provides the +12 V and +5 V voltage rails is designed using a QR flyback converter topology using the fifth-generation QR CoolSET™ (**ICE5QR4770AG**). With the CoolMOS™ integrated in this IC, it simplifies the design and layout of the PCB. The improved novel digital frequency reduction with proprietary QR operation offers lower EMI and higher efficiency for a wide AC range by reducing the switching frequency difference between low-line and high-line. The enhanced ABM power enables flexibility in standby power operation range selection and QR operation during ABM. As a result, the system efficiency over the entire load range is significantly improved compared to a conventional free-running QR converter implemented with only maximum switching frequency limitation at light load. In addition, numerous adjustable protection functions have been implemented in ICE5QR4770AG to protect the system and customize the IC for the chosen application. The CoolSET™ controller also has protections in case of failure modes such as brown-out or line overvoltage, V_{CC} overvoltage/undervoltage, open control-loop or overload, output overvoltage, overtemperature, V_{CC} short-to-ground, and CS short-to-ground. Under any of these conditions the device enters into protection mode. By means of the cycle-by-cycle peak current limitation, the dimensions of the transformer and the current rating of the secondary diode can both be optimized. Thus, a cost effective solution can be easily achieved.

The efficiency improvement of the new CoolSET™ (**ICE5QR4770AG**) design can be seen in **Figure 15**. The efficiency improvement is between 10.4 percent and 25 percent over the 1 W to 6 W load range, compared to the old generation of CoolSET™ (**ICE3RBR4765JG**).

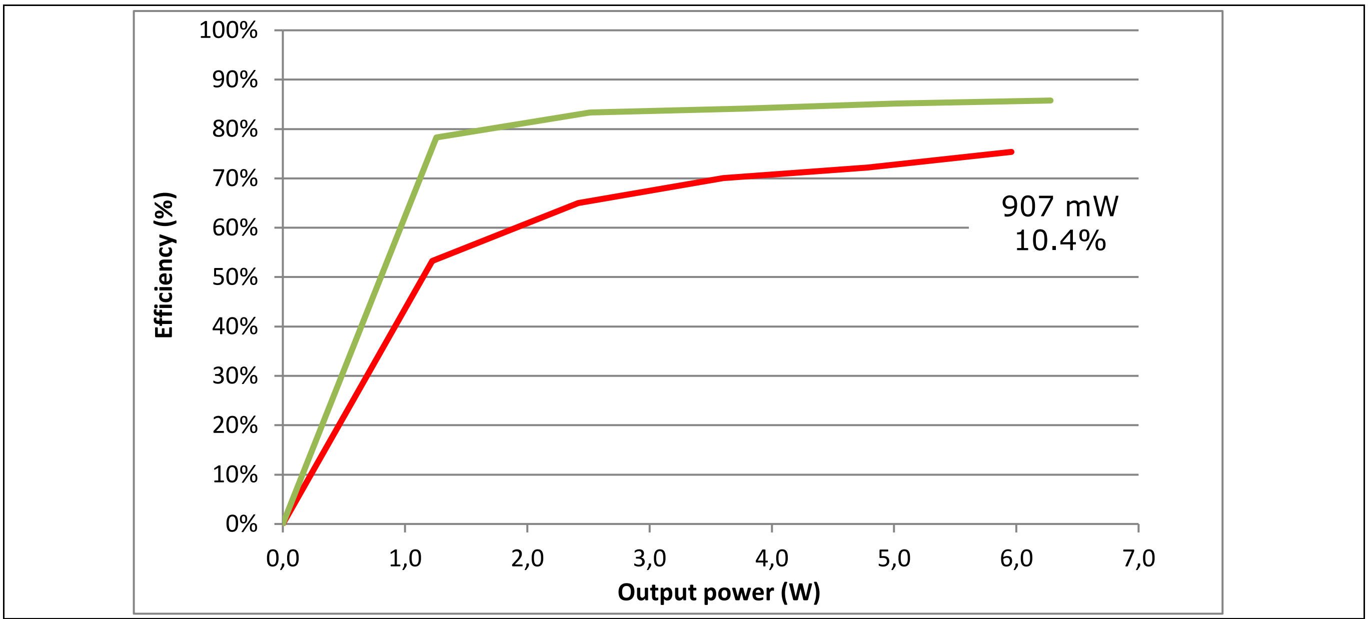


Figure 15 Efficiency comparison – new CoolSET™ (ICE5QR4770AG) vs. old CoolSET™(ICE3RBR4765JG)

5.4.2 CoolMOS™ C3 to P7 benefits

The old generation of CoolSET™ used the C3 CoolMOS™ technology. By switching to the latest P7 CoolMOS™ technology the benefits of the latest technology can be gained. The gate driving losses of the device are lower and the $R_{DS(on)}$ change vs. temperature is lower than the previous generation of devices. The P7 also has lower output capacitance energy storage vs. voltage, but in this design some of these benefits are reduced by the additional C_{DS} capacitor that needs to be added for the snubberless operation, as stated below.

5.4.3 Quasi-resonant flyback controller

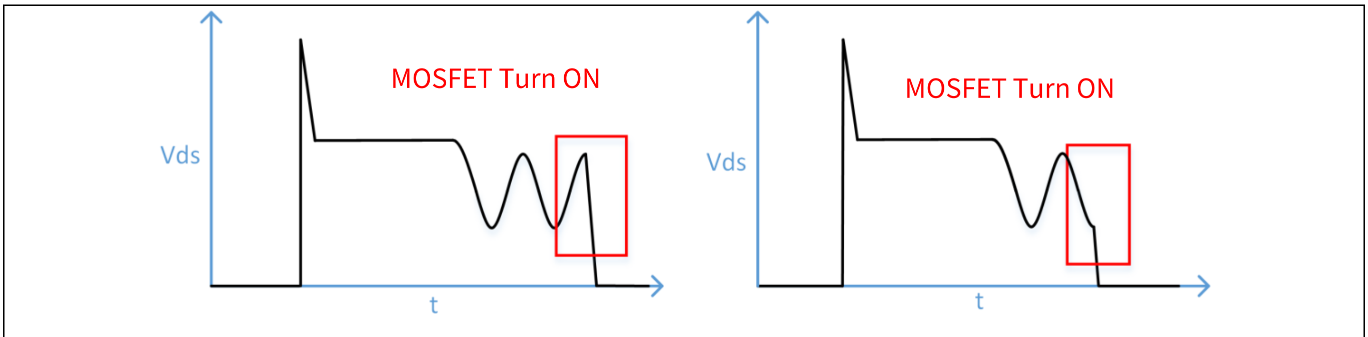


Figure 16 Fixed-frequency flyback primary MOSFET drain source waveform (left) vs. a QR flyback primary MOSFET drain source waveform (right)

The QR flyback helps to reduce the switching losses in the MOSFET by using the DCM resonant period of the flyback and then only turning on the MOSFET in this valley.

Since the turn-on switching losses are a function of V^2, this reduces the overall system switching losses. This has the added benefit of lowering the amount of switched energy, which helps reduce switching noise from the converter, resulting in lower radiated and conducted emissions.

$$P_{sw\_on} = 0.5 f_{sw} C_{OSS} V_{DS}^2$$

5.4.4 Snubberless design

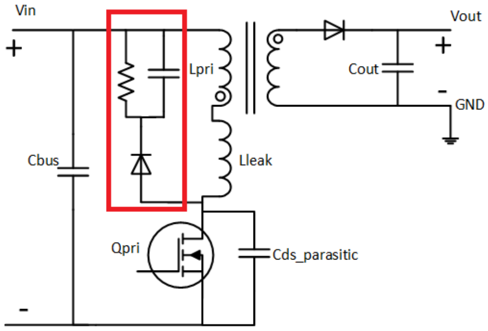


Figure 17 Snubber network

The RCD snubber network dissipates energy every switching cycle regardless of the load, since the RCD capacitor is charged up to the reflected voltage of the secondary. By removing the snubber network and switching to a snubberless design the overall efficiency is improved. This requires an additional 100 pF capacitor on the drain source of the MOSFET in order to provide energy storage for the leakage energy at full load. This still results in a net efficiency improvement over the RCD snubber network, takes up less board area and reduces the design cost. A 10 percent margin was kept from the drain source breakdown voltage to the peak drain source voltage seen on the MOSFET during full load and maximum DC input voltage operation.

5.5 CS and OCP circuit

Figure 18 shows the motor phase CS and OCP circuitry. The design offers hardware and software current detection, and the average current flow through the DC-link shunt resistor is sampled every cycle of PWM. This value is read to detect overcurrent. Once this condition occurs, the reference motor speed is scaled down by a factor until the current is within the limit defined in the user configuration file. Moreover, the three-phase motor currents are sensed separately though the differential operation amplifiers and sent back to the microcontroller through IU, IV and IW. In addition, the overall current of the motor is sensed through the shunt resistor R57, which activates the switch Q1 that in return sends a fault signal to the microcontroller to interrupt pulse-width modulation (PWM) and immediately stop all output to the motor.

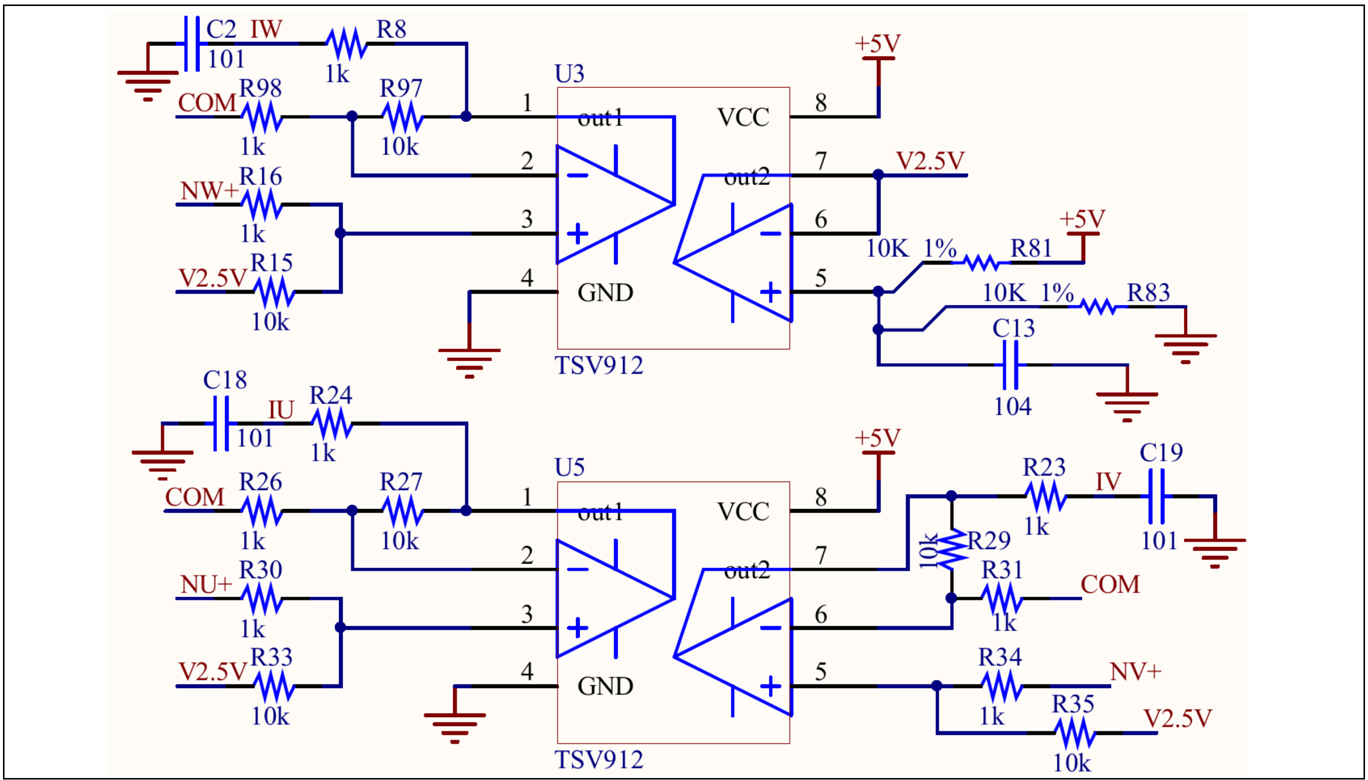


Figure 18 Overcurrent circuit

The EVAL_FAN_XMC_PFD7 provides an op-amp, which amplifies the voltage drop over the shunt per phase with a gain of 10 (see waveforms in **Figure 19**). The amplified voltage information is sent back to the microcontroller through IU, IV and IW. The amplified voltage is calculated with $V = I_{shunt} \times R_{shunt} \times 10$.

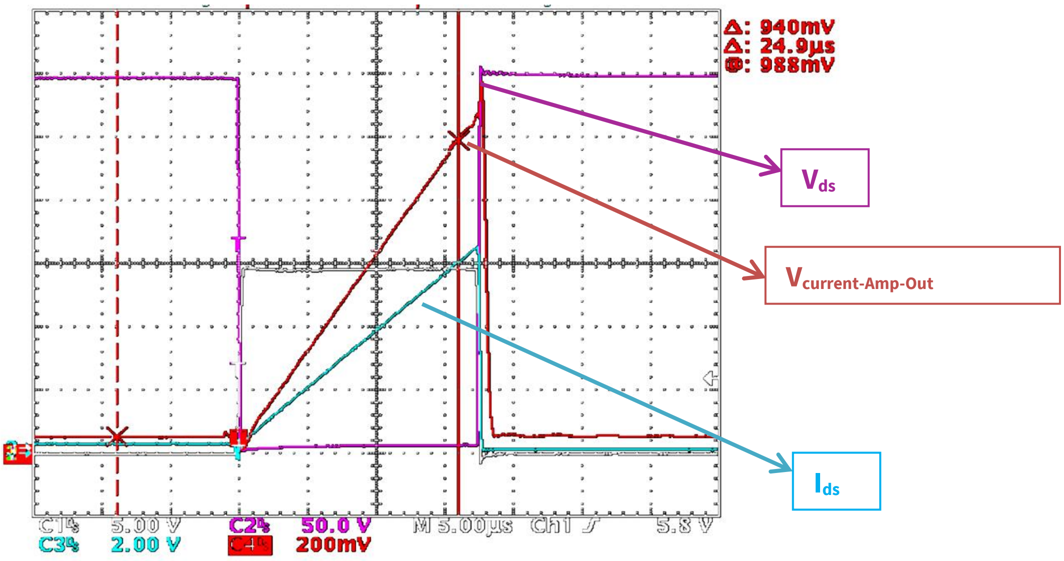


Figure 19 **Current amplifier output and corresponding drain current**

5.6 DC-link voltage measurement

Pin 2.4 of the microcontroller provides access to the DC-link voltage. **Figure 20** provides the DC bus sense resistor details.

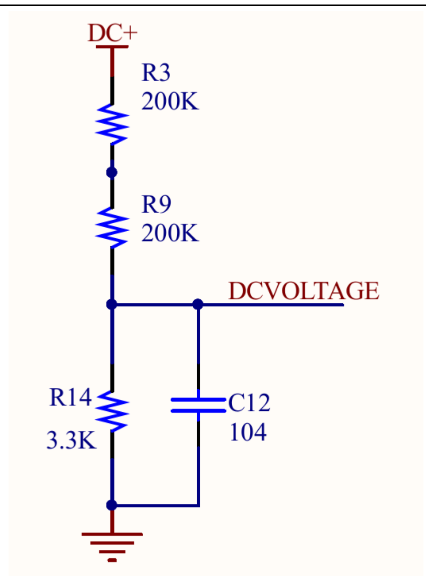


Figure 20 **The DC bus sense resistor on the EVAL_FAN_XMC_PFD7 evaluation board**

The $DC_{VOLTAGE}$ provides input to the microcontroller with a voltage range of 0 V to 5 V on pin 2.4, reflecting a DC bus voltage range of 0 V to 400 V. If no feedback is desired from the $DC_{VOLTAGE}$ pin, R3 or R9 should be removed to avoid HV on the connector.

5.7 Output voltage (B_{EMF}) signal dividers

The power inverter outputs can be monitored at signals B_{EMF_U}, B_{EMF_V} and B_{EMF_W} with a ratio of 611 V:5 V. See **Figure 21** for details.

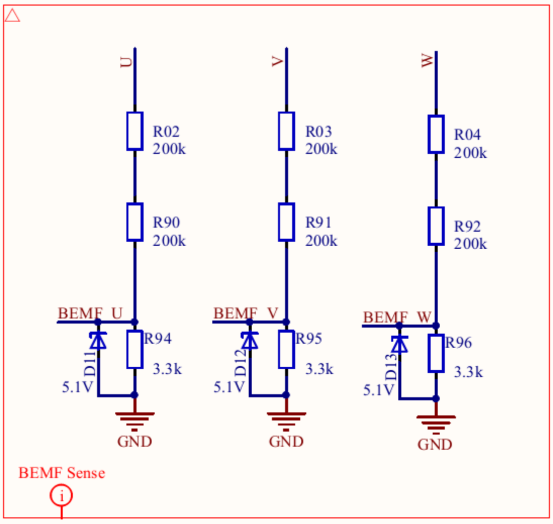


Figure 21 Output voltage (B_{EMF}) signal dividers

5.8 EiceDRIVER™ 2EDN non-isolated gate driver for MOSFETs

5.8.1 Introduction

The **2ED28073J06F** is a high-voltage, high-speed power MOSFET and IGBT driver with independent high- and low-side referenced output channels. Proprietary HVIC and latch-immune CMOS technologies enable ruggedized monolithic construction. The logic input is compatible with standard CMOS or LSTTL output, down to 3.3 V logic. The output drivers feature a high-pulse current buffer stage designed for minimum driver cross-conduction. The floating channel can be used to drive N-channel power MOSFETs or IGBTs in the high-side configuration, which operates up to 600 V.

5.8.2 Main features

- Maximum blocking voltage +600 V IGBT/MOSFET gate drive
- Matched propagation delays
- Input logic compatibility
- Undervoltage lockout (UVLO) protection
- Advanced input filter
- Short-pulse/noise rejection
- Integrated bootstrap functionality
- Qualified according to JEDEC (high-temperature stress tests for 1000 h) ESD according to HBM class 2

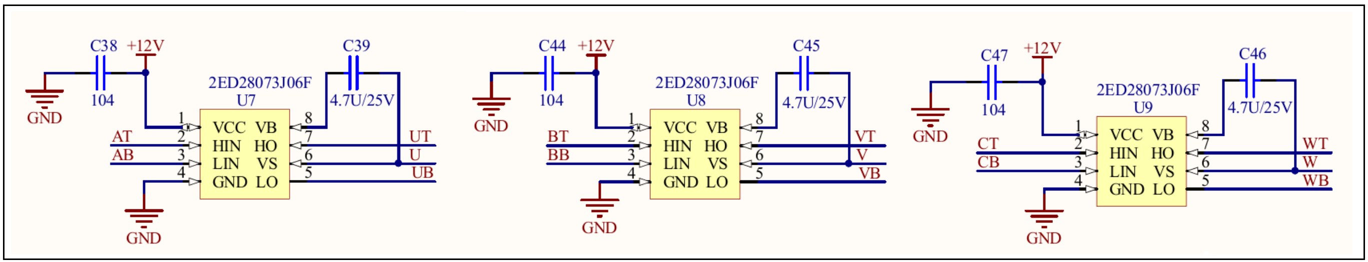


Figure 22 Power inverter – gate driver

The +12 V supply V_{CC} is monitored by the 2EDN28073. In case of UV the driver output is switched off. The thresholds are typically V_{CC}UV+ = 8.9 V (positive going) and V_{CC}UV– = 7.7 V (negative going).

The three capacitors C39, C45 and C46 are used as bootstrap capacitors to provide the necessary floating supply voltages.

6 Board information

6.1 Board layout

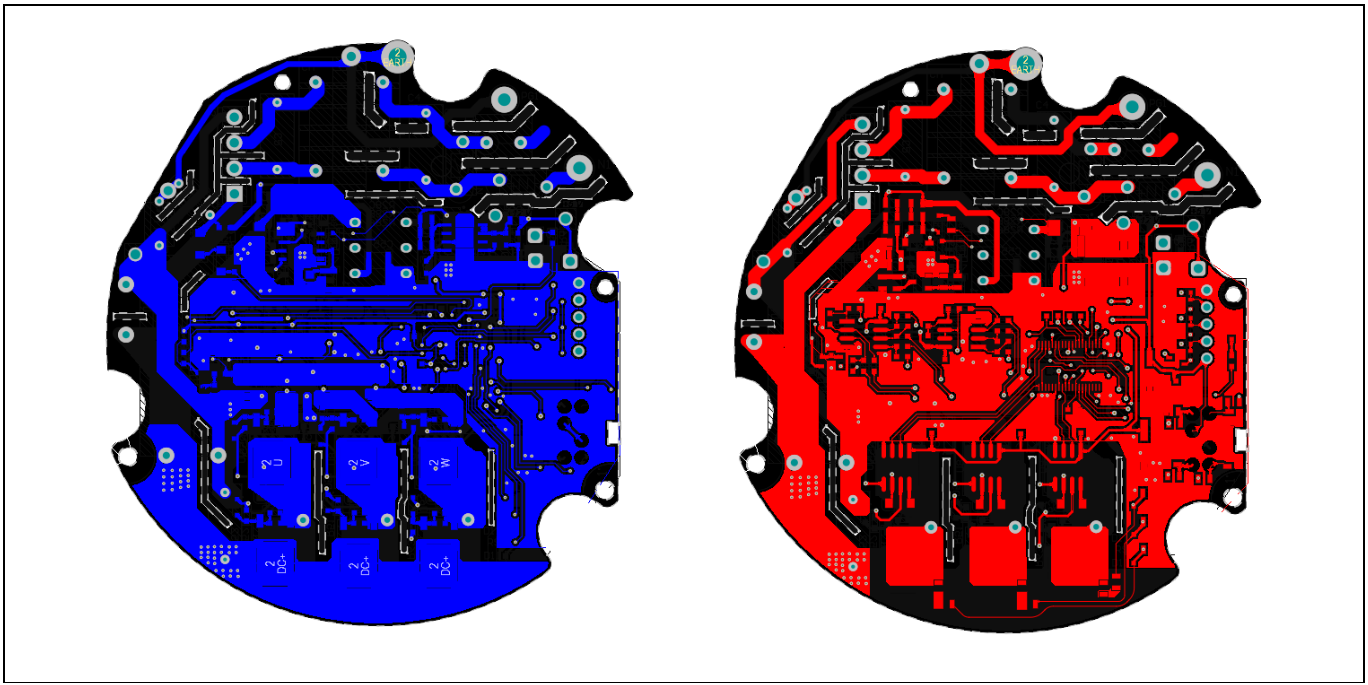
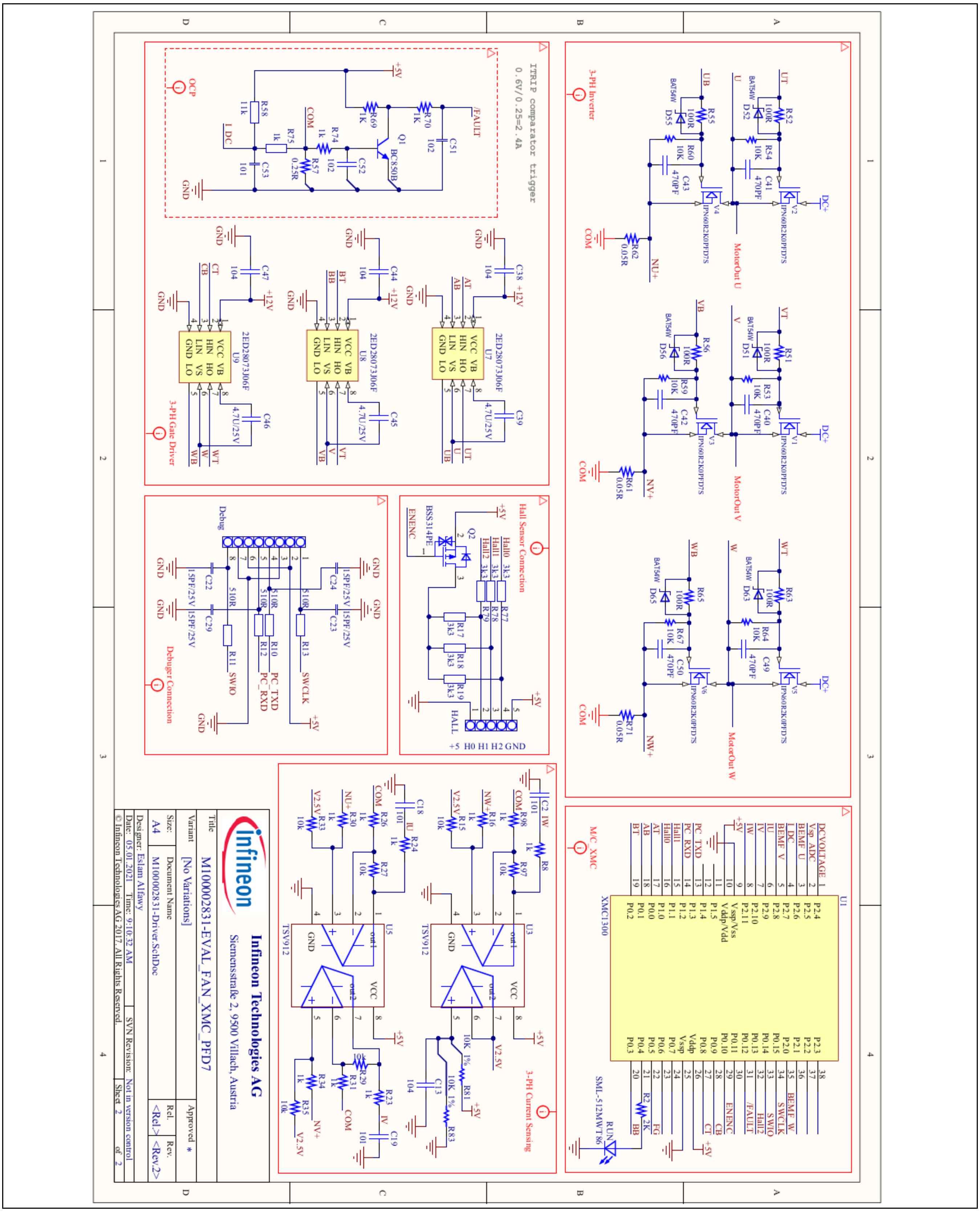


Figure 23 Board layout top view (right) and bottom view (left)

7 Board schematics



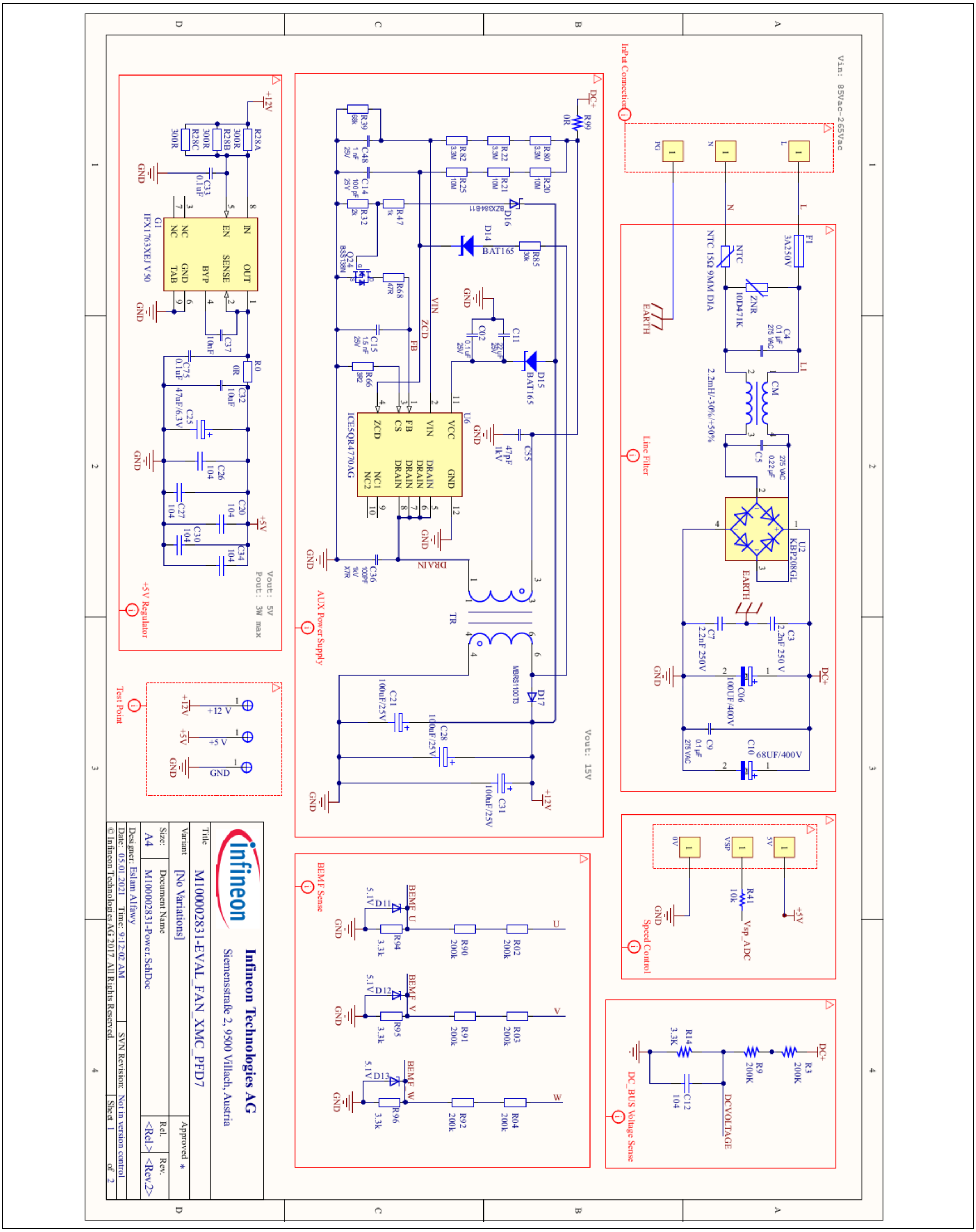


Figure 24 Schematics of the board

8 Bill of materials

Table 4 BOM

No.	Ref.	Description	Package	Manufacturer
1	**V1, V2, V3, V4, V5, V6**	**IPN60R2K0PFD7S**	**TO-252AA**	**Infineon**
2	**G1**	**IFX1763XEJ V50**	**SO-8**	**Infineon**
3	**U1**	**XMC1302_TSSOP38**	**TSSOP38**	**Infineon**
4	**Q2**	**BSS314PE**	**SOT-323**	**Infineon**
5	**U7, U8, U9**	**2ED28073J06F**	**SO-8**	**Infineon**
6	**U6**	**ICE5QR4770AG**	**DSO12**	**Infineon**
7	**Q24**	**BSS138N**	**SOT-323**	**Infineon**
8	**D14, D15**	**BAT165**	**SOD-323**	**Infineon**
9	**D52, D55, D51, D56, D63, D65**	**BAT54W**	**SOD-323**	**Infineon**
10	Q1	BCW60C	SOD323	NXP
11	U3, U5	TSV912	SO-8	ST
12	F1	3 A to 250 V	0034.6019	Schurter
13	LED	LED	SMD0603	Any
14	NTC	NTC 15 Ω 9 mm diameter	B57153S0150M000	Epcos
15	ZNR	Varistor	MOV-10D471KTR	BOURNS
16	TR	7491181012	Offline transformer	Würth Elektronik
17	U2	KBP208GL	800 V, 2 A, KBP, 4-pin	Diode Bridge
18	CM	SSRH7HS-M17023	1.5 mH, 2 A, model PLA10	Murata
19	C2, C18, C19, C532, C14	Ceramic capacitor 100 pF/25 V	SMD 0603	Any
20	C3, C7	2.2 nF/250 V	Ceramic capacitor	Any
21	C4, C5, C9	0.1 µF/275 V AC	890324023023	Würth Elektronik
22	C10	100 µF/400 V	400KXW100MEFC16X30	Rubycon
23	C12, C13, C26, C27, C30, C38, C44, C47, C02, C34, C20, C33, C75	0.1 µF/25 V	SMD 0603	Any
24	C22, C23, C24, C29	15 pF/25 V	SMD 0603	Any
25	C25	47 µF/6.3 V	SMD	Panasonic
26	C28, C52, C51	100 µF/25 V	SMD	Panasonic
27	C32	10 µF/25 V	SMD 0603	Any
28	C37	10 nF/25 µ	SMD 0603	Any
29	C39, C45, C46	4.7 µF/25 V	SMD 1206	Any
30	C40, C41, C42, C43, C49, C50	470 pF/25 V	SMD 0603	Any

31	C11	22 µF/25 V	SMD 1210	Any
32	C15	1.5 nF/25 V	SMD 0603	Any
33	D17	MBRS1100T3	SMB	Any
34	D16	BZX384-B11	SOD323	Nexperia
35	D11, D12, D13	MM3Z5V1ST1G -5.1V	SMA_SUB	ON Semiconductor
36	R2, R32	2 k	SMD 0603	Any
37	R02, R03, R04, R90, R91, R92	200 k	SMD 0603	Any
38	R3, R9	200 k	SMD 1206	Any
39	R8, R16, R23, R24, R26, R30, R31, R34, R98, R69, R70, R74, R75	1 k	SMD 0603	Any
40	R10, R11, R12, R13, R51, R52, R55, R56, R63, R65	510 R	SMD 0603	Any
41	R15, R27, R29, R33, R35, R41, R53, R54, R59, R60, R64, R67, R97, R81, R83	10 k	SMD 0603	Any
42	R17, R18, R19, R77, R78, R79, R14	3.3 k	SMD 0603	Any
43	R28A, R28B, R28C	300 R	SMD 0603	Any
44	R58	11 k	SMD 0603	Any
45	R99, R0	0 R	SMD 0603	Any
46	R20, R230, R25	10 M	SMD 0603	Any
47	R20, R21, R25	3.3 M	SMD 0603	Any
48	R85	30 k	SMD 0603	Any
49	R39	68 k	SMD 0603	Any
50	R68	47 R	SMD 0603	Any
51	R66	3R2	SMD 0603	Any
52	R61, R62, R71	0.05 R ±1 percent	R-sense SMD1206	Any
53	R57	0.25 R ±1 percent	R-sense SMD1206	Any

9 Revision history

Document version	Date of release	Description of changes
V 1.0	24-02-2021	First release

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