EVAL_MTR_5x6_GaN evaluation board for motor drive applications

Based on CoolGaN™ Transistors, compatible with Si MOSFETs

About this document

Scope and purpose

This document provides an overview of the EVAL_MTR_5x6_GaN evaluation board, including its main features, configuration for operation, pin assignment, and mechanical dimensions.

The EVAL_MTR_5x6_GaN evaluation board was developed to support customers during their first steps in designing systems with the 100 V, 1.5 mΩ (Max.) CoolGaN™ Transistor in a top-side-cooled 5 mm × 6 mm RQFN package. It is optimized for motor drive applications with relatively high switching frequencies, i.e., 100 kHz or higher.

The evaluation board includes an aluminum heat spreader, mounting hardware, and thermal interface material (TIM) pad. This dual-sided cooling approach allows customers to simulate board attachment to a metal housing and take full advantage of the exposed-die RQFN package.

This document also provides information on how to make this board work with Si MOSFETs by replacing all GaN transistors with MOSFETs of the same package. An example is OptiMOS™ 6 ISC027N10NM6 power MOSFET 100 V, 2.7 mΩ device in SuperSO8 package (5 mm × 6 mm) package.

Intended audience

This document is intended for system application engineers who want to improve space utilization and seek inspiration for their next motor drive designs, for low-voltage applications up to 48 V and 40 A_{RMS} motor phase current.

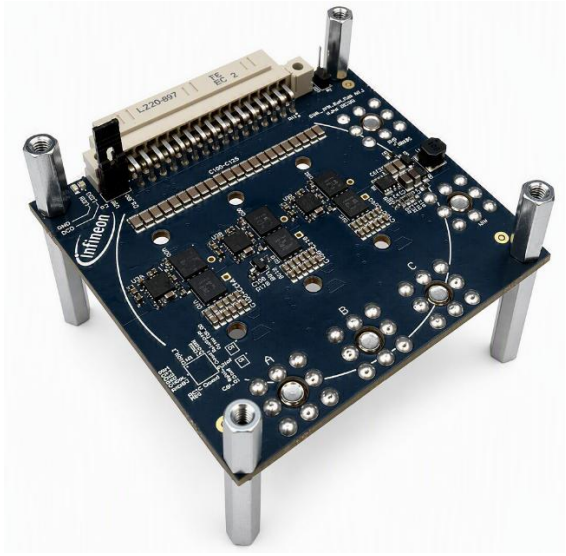


Figure 1 Evaluation board EVAL_MTR_5x6_GaN

Note: This document is for the EVAL_MTR_5x6_GaN reference board with V1.0 and above.

About this product group

Target applications

- Low-voltage motor drives
- 48 V three-phase motor inverters
- High-power-density motor-control systems
- High-frequency motor-drive applications
- Permanent-magnet synchronous motor drives
- Battery-powered industrial and robotic motor systems

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1 Introduction

EVAL_MTR_5x6_GaN is a high-power-density evaluation board for low-voltage inverters. This board includes six IGD015S10S1 CoolGaN™ Transistor 100 V devices in a half-bridge configuration for al l of the three phases. The half-bridge transistors are driven by an EiceDRIVER™ 2EDF7258G gate driver, and the output phase current is sensed by a XENSIV™ TLE4973 magnetic current sensor. The board can be connected with different controller cards.

The block diagram shown in Figure 2 is a schematic of fundamental circuits.

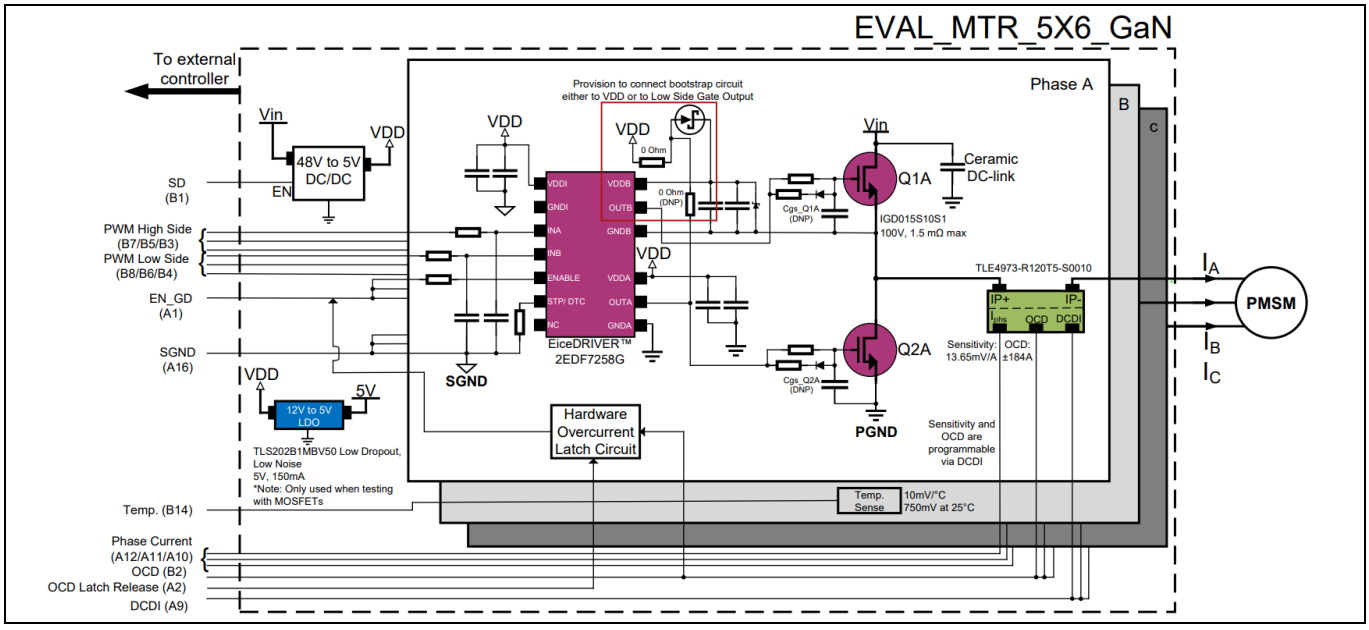


Figure 2 Block diagram of EVAL_MTR_5x6_GaN including key parameters and pinout

The evaluation board was developed to demonstrate the high-power densities achievable with a size of 71 mm × 76 mm, and an active area of 60 mm × 40 mm × 6 mm, in which all the transistors and the main components of the three half-bridges are located. This is thanks to the reduction of bulk capacitance and the high switching frequency operation (≥100 kHz) of the inverter without a large power loss penalty. Moreover, IGD015S10S1 CoolGaN™ Transistor 100 V is a top-side cooling device on an exposed-die RQFN package that can efficiently extract heat and provide more space for a top-bottom PCB implementation.

EVAL_MTR_5x6_GaN includes an aluminum heat spreader that can be easily adapted to the frame of the final system or a bigger heatsink. The thermal connection is done with a gap filler.

Each half-bridge is driven by a dual-channel gate driver in bootstrap configuration. The power stage is protected against overtemperature and phase overcurrent with sensors mounted on the board. There is a dedicated hardware overcurrent latch circuit, which protects the inverter from any overcurrent fault.

Each phase current of the power stage is sensed with Hall-effect current sensors that are galvanically isolated and protected with overcurrent protection (OCP). The input voltage is sensed with a voltage divider to control the undervoltage and overvoltage conditions.

1 Introduction

Note: Environmental conditions were considered in the design of EVAL_MTR_5x6_GaN. 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 must be used for functional testing only.

Note: Reference boards are not subject to the same procedures as regular products regarding returned material analysis (RMA), process change notification (PCN), and product discontinuation (PD). Reference boards must be handled by trained specialists only.

2 Design features

EVAL_MTR_5x6_GaN is an evaluation board equipped with the latest generation of Infineon's CoolGaN™ Transistors in combination with a complementary EiceDRIVER™ gate driver and XENSIV™ current sensor with current reel out of the chip.

Main components:

- CoolGaN™ Transistor 100 V [1], 1.5 mΩ (max.) in a 5 mm × 6 mm RQFN package
- EiceDRIVER™ 2EDF7258G [2] gate driver for GaN transistors and MOSFETs
- XENSIV™ TLE4973-R120T5-S0010 [3] magnetic coreless current sensor for AC and DC currents

The reference design characteristics are:

- 48 V nominal input voltage
- High-power-density design in a 71 mm × 76 mm PCB with four layers of 70 µm (2 oz.) copper
- Ceramic capacitor DC-link for lowest equivalent series resistance (ESR) and high current ripple handling
- Optimized power loop inductance allowing for nanosecond switching transients and minimal overshoot
- 5 V auxiliary supply included
- Overcurrent detection with programmable threshold
- Heatsink and mounting hardware included as a part of the kit

2.1 Highlighted products

2.1.1 CoolGaN™ Transistors 100 V

CoolGaN™ Transistors [1] offer fundamental advantages over silicon. In particular, the higher critical electrical field makes them attractive for power semiconductor devices with specific on-state resistance and smaller capacitances compared to silicon MOSFETs – a great solution for high-speed or high-frequency switching applications. GaN transistors can then be operated with reduced dead-times, which results in higher efficiency and enables passive cooling. Operation at high switching frequencies allows the quantity of passive components to shrink, which improves system reliability and density.

2.1.2 EiceDRIVER™ 2EDF7258G gate driver

EiceDRIVER™ 2EDF7258G [2] is a dual-channel isolated gate driver IC optimized for compatibility with Infineon CoolGaN™ Transistors, and is also compatible with other GaN transistors and silicon MOSFETs. This gate driver includes several key features that enable a high-performance system design with CoolGaN™ Transistors, dead-time control (DTC), 5 A sourcing and 9 A sinking peak current capability, 300 V(RMS) input-to-output isolation voltage which makes this driver capable to be used in high-voltage systems such as 72 V or 96 V.

2.1.3 XENSIV™ TLE4973 magnetic current sensor

XENSIV™ TLE4973 [3] is a high-precision, miniature, coreless magnetic current sensor designed for AC and DC current measurements. It features an analog interface and fast overcurrent detection (OCD) with programmable threshold and sensitivity settings. Infineon's well-established and robust monolithic Hall technology enables accurate and highly linear measurement of the magnetic field generated by current flow. By default, the sensitivity is programmed to 13.65 mV/A, and the OCD threshold is set to ±184 A. With a typical sensitivity of 13.65 mV/A, the sensor can measure currents up to 120 A. All negative effects (e.g., saturation, hysteresis) commonly known from open loop sensors using flux concentration techniques are avoided.

2.1.4 OPTIREG™ TLS202B1V50 low-dropout voltage regulator

TLS202B1V50 [4] is a monolithic, integrated fixed linear voltage post regulator for load currents up to 150 mA. The IC regulates an input voltage from 2.7 V to 18 V with a precision of ±3%. TLS202B1V50 is specially designed for applications requiring very low standby currents. The device is available in a very small surface-mounted PG-SCT595 package. The device implements circuits for output current limitation and overtemperature shutdown for protection against overcurrent and overtemperature faults.

Note: This LDO is only be used when working with MOSFETs.

2.2 Specifications

Table 1 EVAL_MTR_5x6_GaN board specification

Parameter	Value	Conditions/comment
Input		
Nominal input voltage	48 V	–
Maximum input voltage	75 V	Reverse Standoff Voltage (Typ.) of D1 (SMBJ75A)
Undervoltage lockout (UVLO)	14 V	Minimum voltage to turn off the DC-DC converter
Maximum input current	40 A	Maximum in steady state; limit depends on the amount of copper and the dissipation of the board. *Note: The board does not have any current protection on the input side.*
Power max (electrical input)	2 kW	48 V, T_a = 25°C, with heat spreader
Output		
Current per phase leg (max)	30 A_{RMS}	48 V, T_a = 25°C, 100 kHz, Tmax case = 120°C, natural convection, no heat spreader, and no forced air (in steady state)
	38 A_{RMS}	48 V, T_a = 25°C, Tmax case = 110°C, natural convection, with heat spreader (in steady state)
	50 A_{RMS}	48 V, T_a = 25°C, no forced air with heat spreader, ≤30 seconds
Switching frequency		
Nominal switching frequency	100 kHz	
Minimal switching frequency	50 kHz	May require additional DC capacitance
Current feedback		
Sensitivity	13.65 mV/A	±2%
Overcurrent detection (OCD)	184 A	User-programmable
Offset	2.5 V	–
DC-link voltage feedback		
Sensitivity	23 mV/V	±1%

Parameter	Value	Conditions/comment
Onboard supply		
+5 V	±2%	Used for supplying power to the gate drivers, TLE4973 current sensors, temperature sensor and HW OC latch circuit
+5 V	±3%	Used for supplying power to TLE4973 current sensors, temperature sensor, and HW OC latch circuit when working with MOSFETs
System environment		
Ambient temperature	0°C to 85°C	Non-condensing, maximum relative humidity of 95%
Maximum temperature	Up to 130°C	The temperature is acquired by the sensor (U6B)
PCB characteristics		
Material	High TG FR4 material (PCL370HR)	4 layers (1 PTH via), 70 µm copper each for a total board thickness of 2.5 mm
Dimensions	71 mm × 76 mm × 18 mm	Height with connector

2.3 Board description

Figure 3 and Figure 4 show the bottom and top sides of the EVAL_MTR_5x6_GaN evaluation board, respectively.

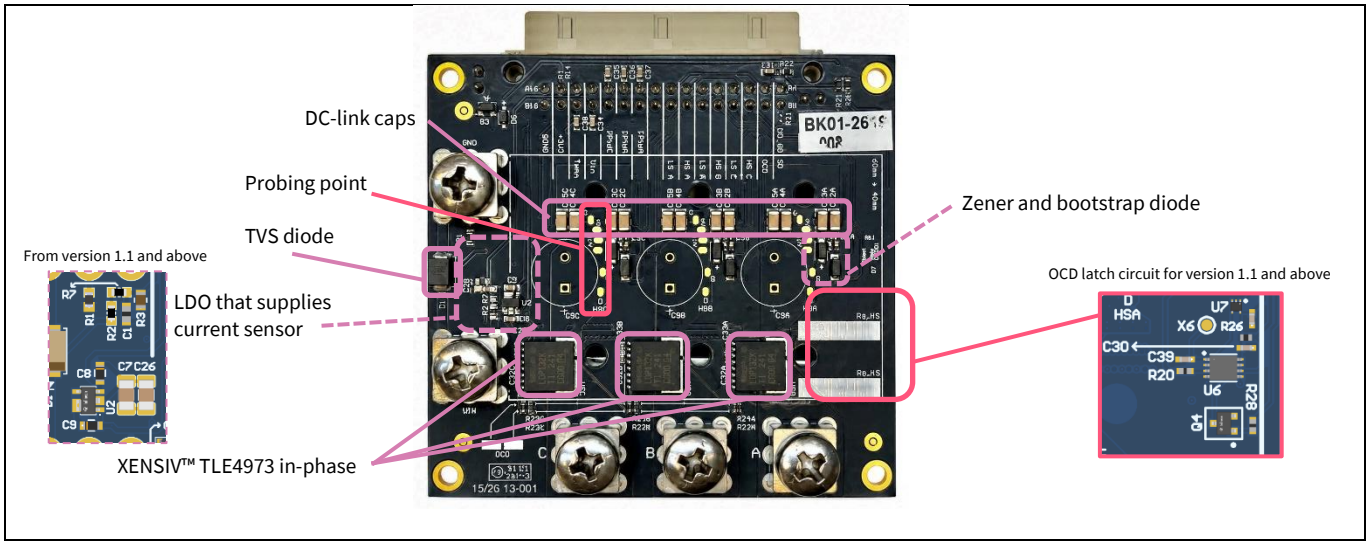


Figure 3 Overview of the top part of the EVAL_MTR_5x6_GaN board

2 Design features

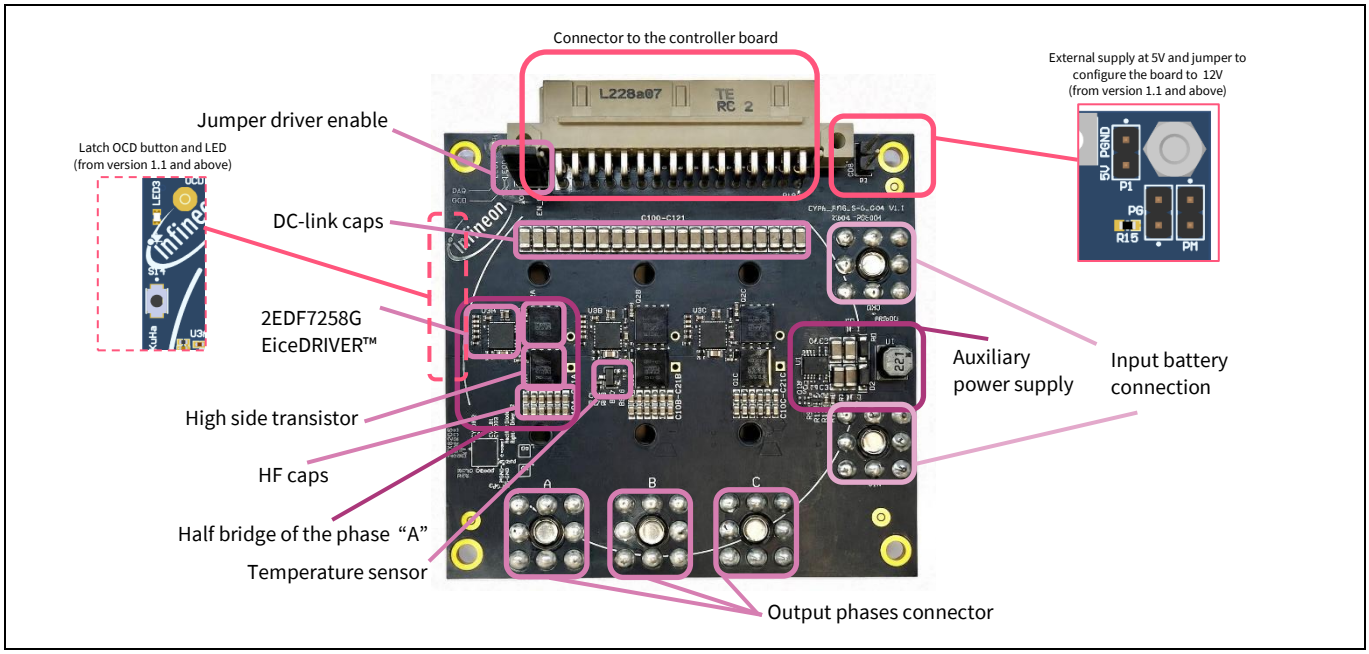


Figure 4 Overview of the bottom part of the EVAL_MTR_5x6_GaN board

Table 2 gives an overview of the pinout of the 32-pin female connector for board. The female connector can be used to connect to the XMC™ drive card or other external controller boards. It is important to remember that pin numbering on the external XMC™ drive card will be reversed on EVAL_MTR_5x6_GaN, compared to X9.

Table 2 X7 pinout for connection to external control card for board below version 2.0

Pin no.	Description	Details
A1	Enable for the gate driver	Place R14 (DNP by default) to enable the gate driver from the MCU
A2	OCD latch release	OCD latch can be removed by the MCU by pulling this pin LOW
A3	NC	–
A4	NC	–
A5	NC	–
A6	NC	–
A7	NC	–
A8	NC	–
A9	DCDI	Current sensor configuration can be performed in-situ through a one-wire UART-based interface called Digital Control Diagnostic Interface (DCDI)
A10	Iphs C	13.65 mV/A, 2.5 V ±3% offset, current flowing out of the inverter is positive
A11	Iphs B	13.65 mV/A, 2.5 V ±3% offset, current flowing out of the inverter is positive
A12	Iphs A	13.65 mV/A, 2.5 V ±3% offset, current flowing out of the inverter is positive
A13	NC	–
A14	NC	–

Pin no.	Description	Details
A15	NC	–
A16	SGND	–
B1	SD	Place R21 (DNP by default) for enabling the onboard DC-DC converter from the MCU
B2	OCD	Motor phase OCD. Active LOW; all phases ORed together
B3	PWM HS C	Active HIGH, 3.3 V
B4	PWM LS C	Active HIGH, 3.3 V
B5	PWM HS B	Active HIGH, 3.3 V
B6	PWM LS B	Active HIGH, 3.3 V
B7	PWM HS A	Active HIGH, 3.3 V
B8	PWM LS A	Active HIGH, 3.3 V
B9	NC	–
B10	NC	–
B11	NC	–
B12	NC	–
B13	V_{DC} sense	V_{IN} voltage divider, 50 mV/V ±1%
B14	Temp sense	–
B15	NC	–
B16	5V	Possibility to supply 5 V to external MCU by placing R18 (DNP by default). *Note: Current draw must not exceed 50 mA.*

2.4 Heat spreader mounting

For evaluation, the EVAL_MTR_5x6_GaN board includes a metal heat spreader to emulate mounting the PCB to a metal chassis. The following items are provided for mounting the heat spreader onto the PCB:

- Six M1.6 × 6 mm screws
- Three thermal interface material (TIM) pads, each of 47 mm × 22 mm (T-Global TG-A1250, 1 mm thickness) or gap filler
- One aluminium heat spreader/heatsink with integrated standoffs and alignment pins

The heat spreader guarantees heat extraction from the top of the device, as shown in Figure 5. The TIM needs to be compressed to 50% of the normal thickness (1 mm). Usually, the distance between the top of the device and the heatsink ranges from 500 µm to 600 µm. It is recommended to tighten the mounting screws carefully by hand with a screwdriver. A torque wrench is required for safe assembly to avoid over-tightening.

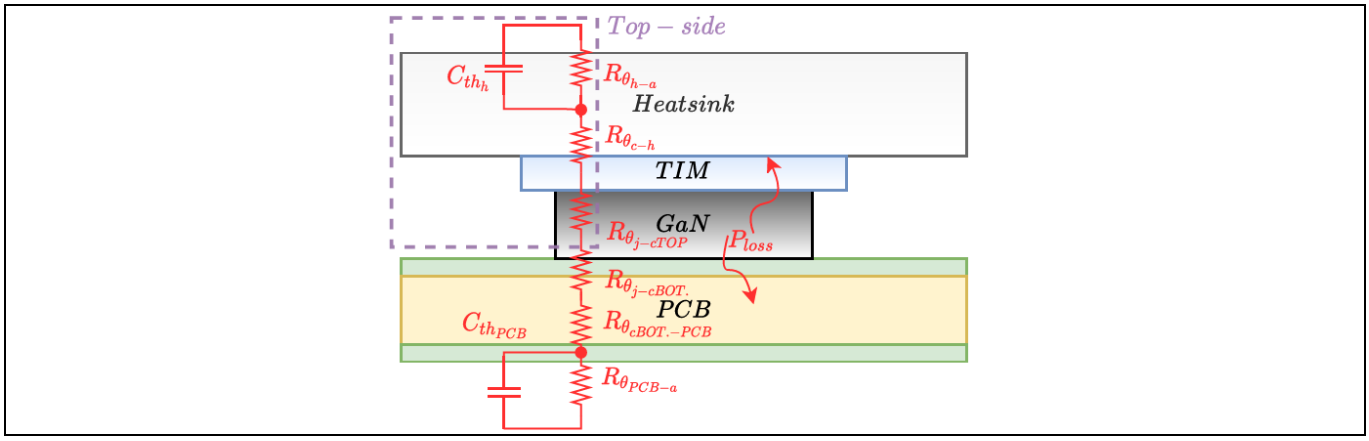


Figure 5 **Cross-section showing the assembly of heat spreader with TIM applied to a single device for top-side cooling**

The placement of the TIM is shown in Figure 6 (left). The protective plastic film on the TIM must be removed before use. The assembled reference board with the heat spreader is shown in Figure 6, on the right.

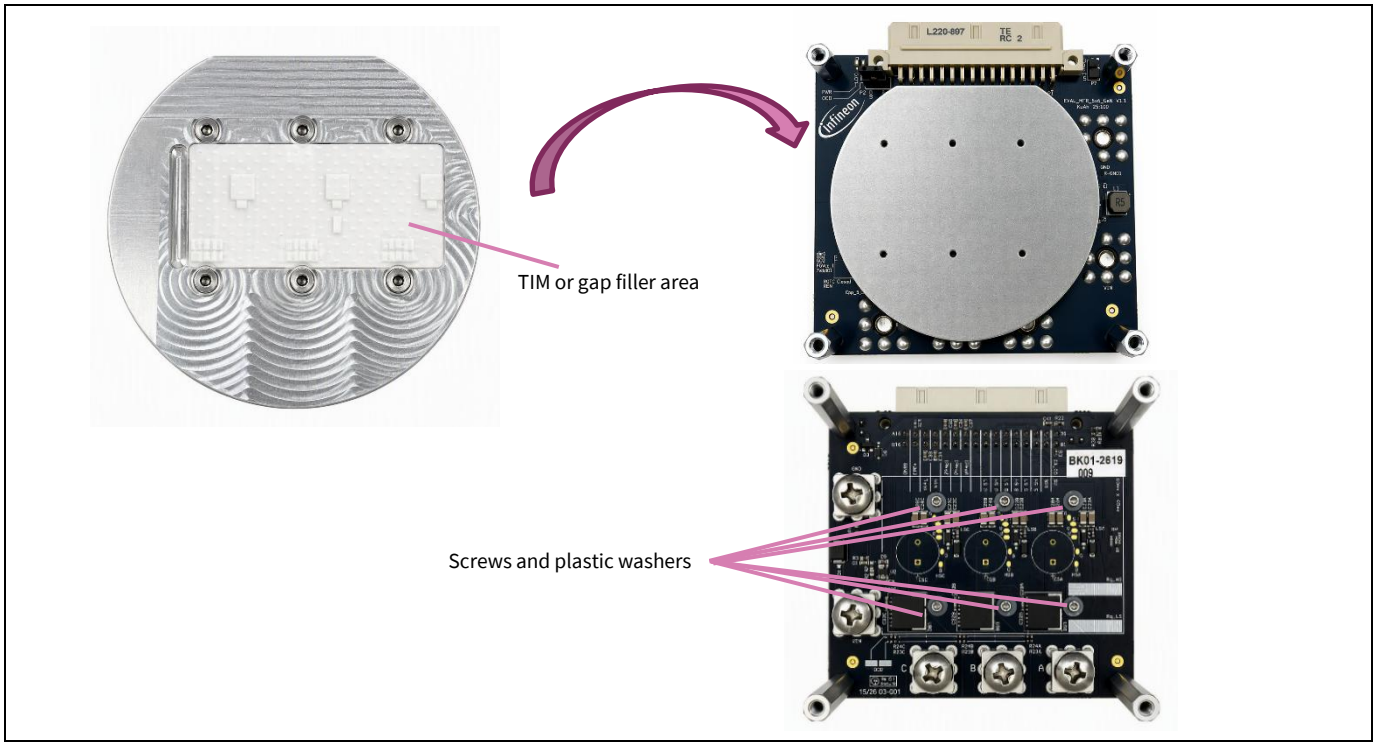


Figure 6 **Left: Placement of TIM across CoolGaN™ Transistor in half-bridge. Right: Fully assembled evaluation board with heat spreader**

3 Schematic and layout

3.1 Overview

A schematic overview of the motor drive is shown in Figure 7. The schematic can be divided into three core components:

- **Half-bridge (HB):** This block has the CoolGaN™ half-bridge with current sensing and the DC-link/HF capacitors (shown once in the schematic in Figure 7, but repeated thrice as identical phases 1, 2, and 3)
- **Auxiliary supply (AuxSup):** This block has all the housekeeping supplies. The 5 V supplies the gate driver and the current sensors
- **Control:** This block contains the pinout of the M5 connector (32 pins), which contains all the main signals from the three in-phase current sensors and the PWM for the gate driver, and the OCD protection circuit
- **DC-Link (Cap):** This block reports all the MLCC capacitors mounted on board as main DC-link

In addition, press-fit connectors X1 and X2 are used for the battery input of the board. The phase connections to the motor (phases 1, 2, and 3) are connected through X3, X4, and X5.

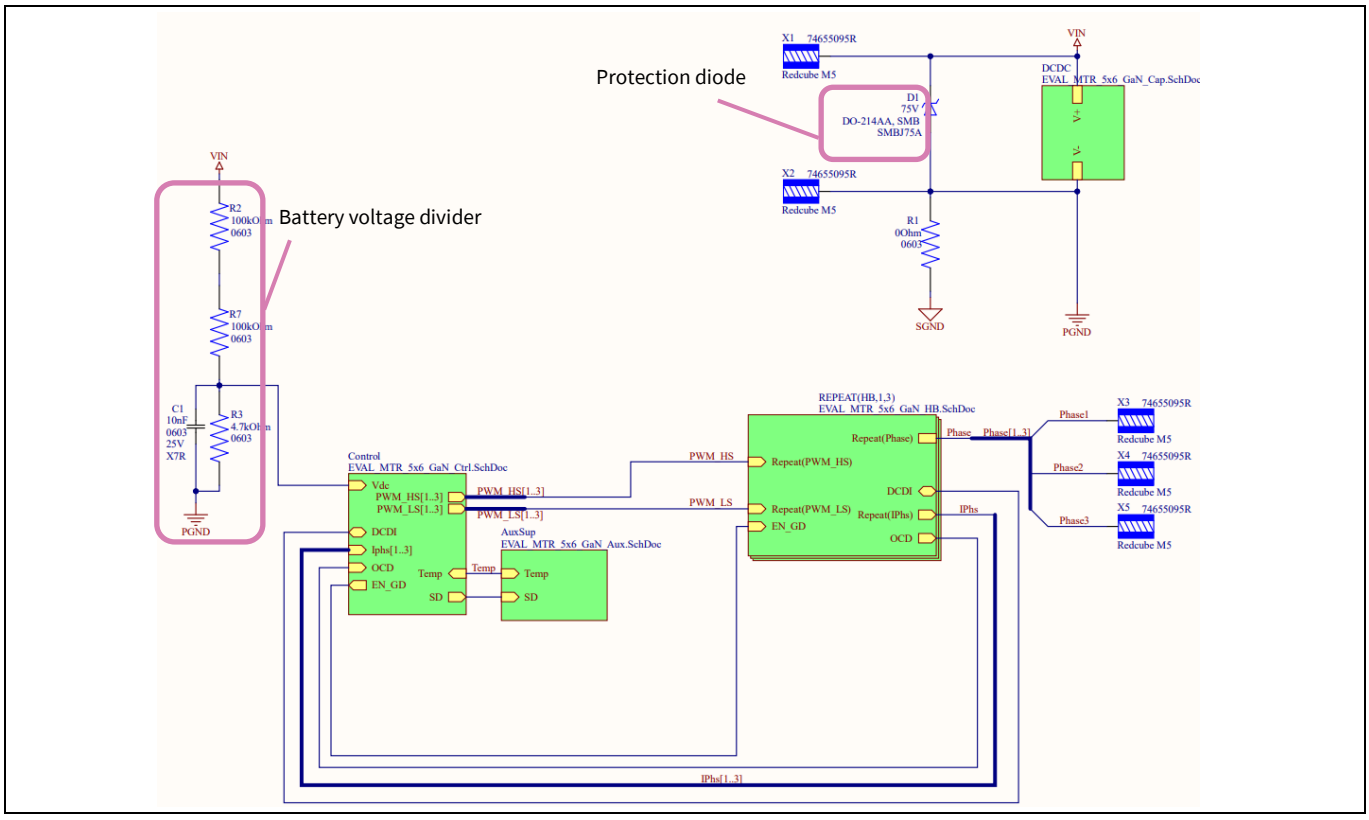


Figure 7 System-level overview of the motor drive schematic

3.2 Half-bridge (HB) and DC-link (Cap)

The schematic of a single CoolGaN™ half-bridge is shown in Figure 8. The primary building block for the motor drive is an optimized half-bridge circuit, with CoolGaN™ Transistor 100 V in 5 mm × 6 mm RQFN lead-frame packages with exposed dies for dual-sided cooling. The half-bridge design is optimized for low-power loop inductance by coplanar field compensation, achieving an inductance of less than 500 pH for each pair of low-side and high-side transistors. The gate loops are also designed to minimize common-source inductance while optimizing the gate driver circuits by reducing the number of connections.

3 Schematic and layout

A single path from the gate driver to the transistors is provided to reduce or increase the turn-on and turn-off transition, with a gate resistor and an external C_{gs} capacitor placeholder is provided for each device.

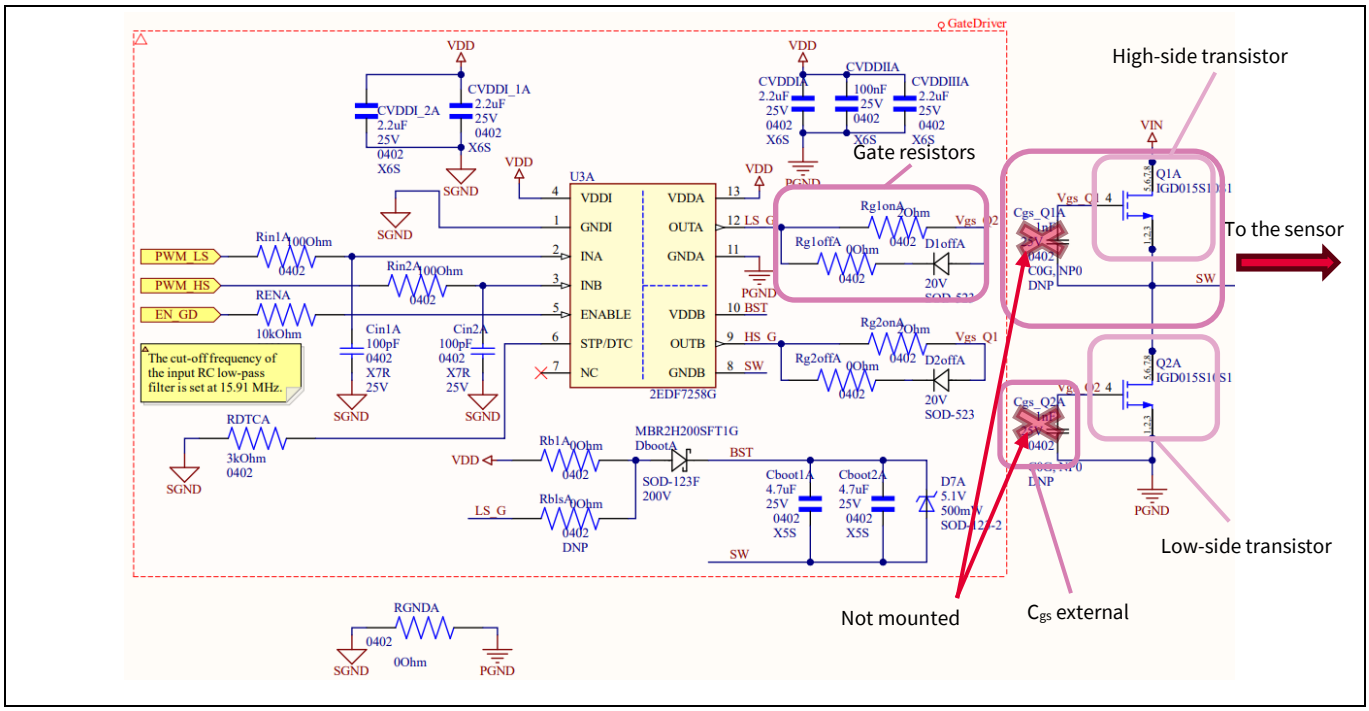


Figure 8 Schematic of the power stage including a gate driver for a single half-bridge

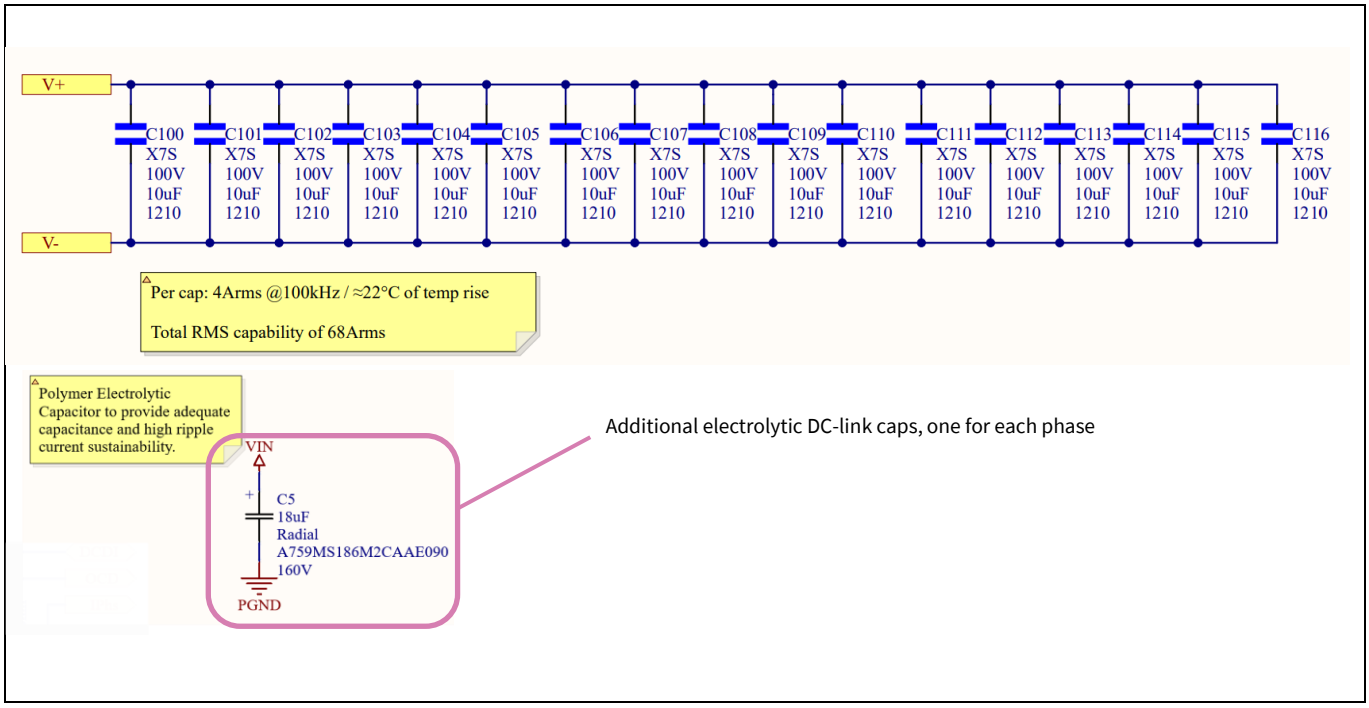


Figure 9 Schematic of the bulk capacitance for a single half-bridge

3.2.1 Gate driver

EiceDRIVER™ 2EDF72x8G [2] is a dual-channel isolated gate driver IC designed to drive Si MOSFETs and GaN transistors. 2EDF72x8G is available in a 13-pin SON package with exposed pads, 1.6 mm input-to-output creepage and 1.2 mm output channel-to-channel creepage.

EiceDRIVER™ 2EDF72x8G offers optional shoot-through protection (STP) and dead-time control (DTC), allowing operation as a dual-channel low-side, dual-channel high-side, or half-bridge gate driver with configurable dead-time. With excellent common-mode transient immunity (CMTI), low part-to-part skew, and fast signal propagation, the device is well suited for fast-switching power-conversion systems.

The schematic of the gate driver section is shown in Figure 10. In this evaluation board, EiceDRIVER™ 2EDF7258G is configured to provide a peak source current of 5 A. Because the gate driver does not include an active internal bootstrap switch, a Zener diode clamps the voltage during dead-time if the GaN transistor exhibits a high V_{DS} voltage drop [6]. Alternatively, this condition can be avoided by installing the unmounted resistor and removing Rb1 . This supplies the bootstrap capacitor from the low-side gate driver output pin, which is disabled during dead-time to prevent overcharging [6].

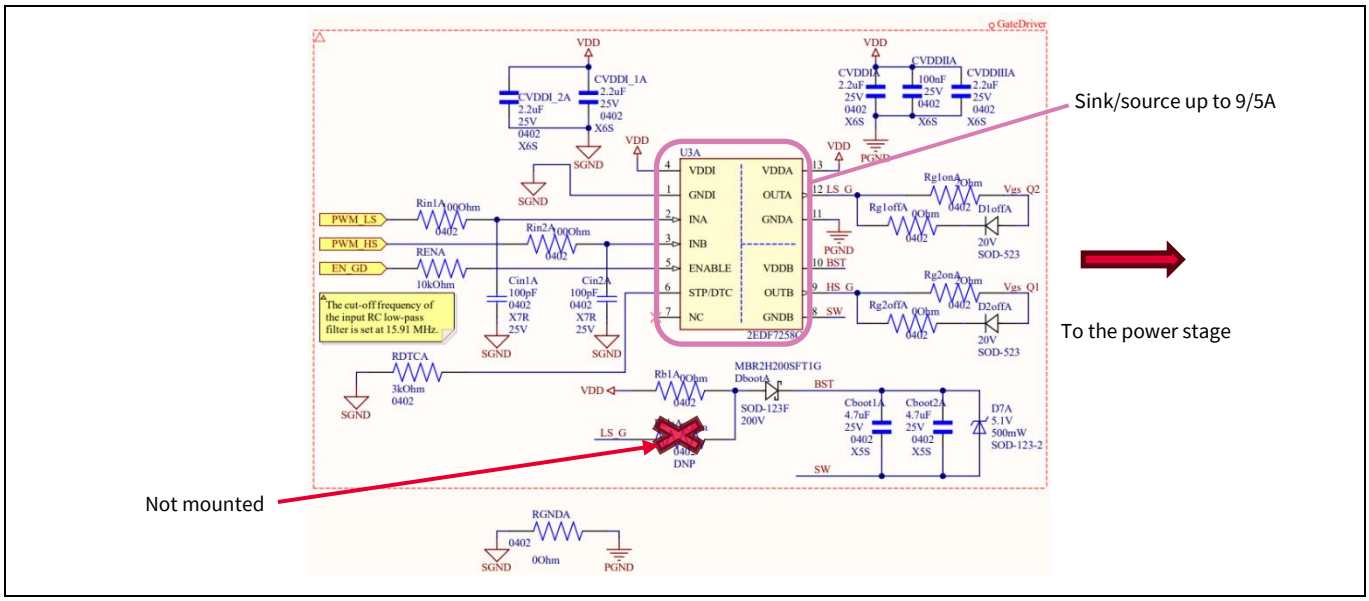


Figure 10 Schematic of the gate driver for the single half-bridge

3.2.2 Current sensing

In-phase current sensing was chosen instead of low-side shunt current sensing to fully optimize the high-frequency power loop inductance of the half-bridge and minimize the common-source inductance in gate loops. TLE4973 is a Hall-effect sensor with the current acquired out of the package, which avoids potential common-mode transient immunity issues with differential amplifiers and higher current capability. A well-isolated in-phase current sensor is more immune to voltage transients and provides accurate readings for field-oriented control (FOC) of the motor.

To provide bidirectional current measurement, the output voltage for 0 A is offset by half of the supply voltage, i.e., 2.5 V under nominal conditions. For the highest accuracy, an offset calibration is recommended before supplying current to the motor. This is typically a part of the control software.

In addition to an isolated readout of the phase current, TLE4973 provides overcurrent detection capabilities on the OCD that can be changed with a programmer and a single-wire connection with a dedicated programmer

[7] using open-drain outputs. A threshold of 184 A is used by default. Figure 11 provides information on the placements of the sensors.

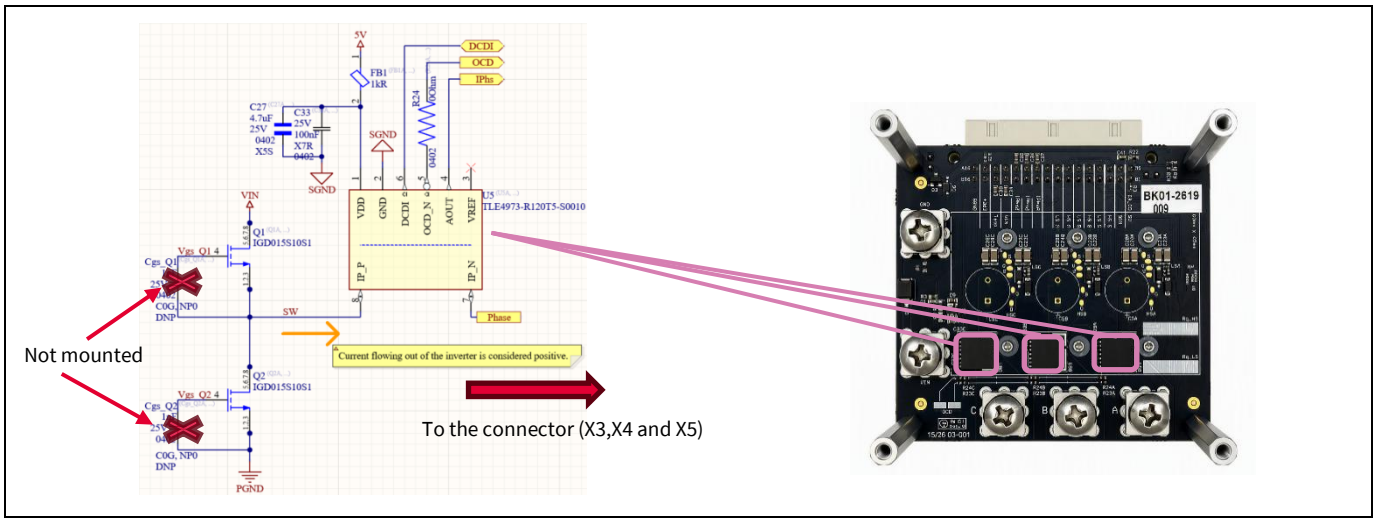


Figure 11 Schematic of the current sensor and location on the board

3.2.3 Half-bridge (HB) layout

The recommended layout for a CoolGaN™ Transistor [5] half-bridge is shown in Figure 12. The two high-frequency loops for gate current and drain current are oriented perpendicular to each other to minimize common-source inductance or cross-coupling.

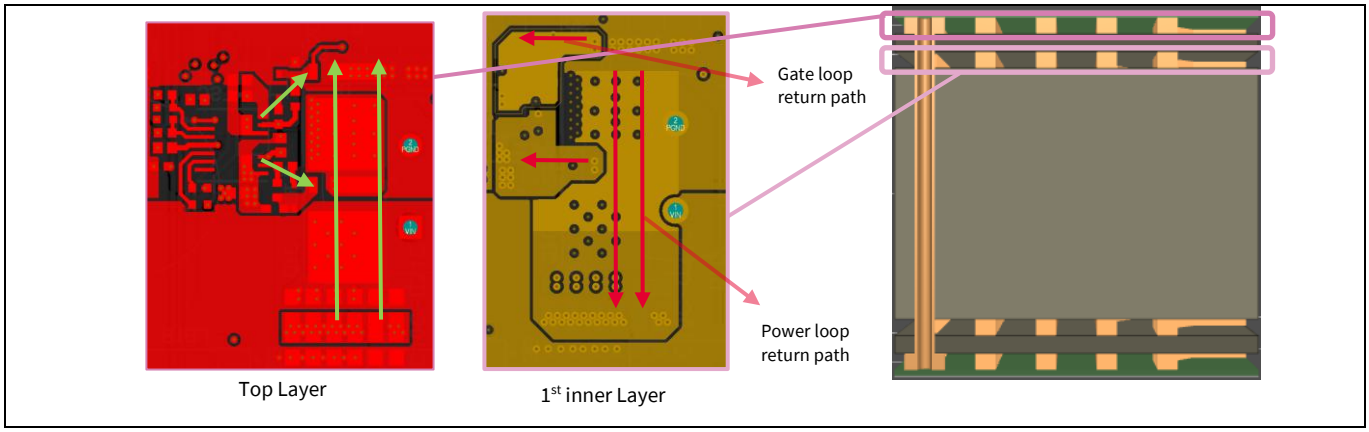


Figure 12 Half-bridge layout; arrows indicate the flow of drain switching currents and stack-up

The phase node, shown in Figure 13, is replicated on the second inner layer and bottom layers to guarantee less coupling between the layer pair.

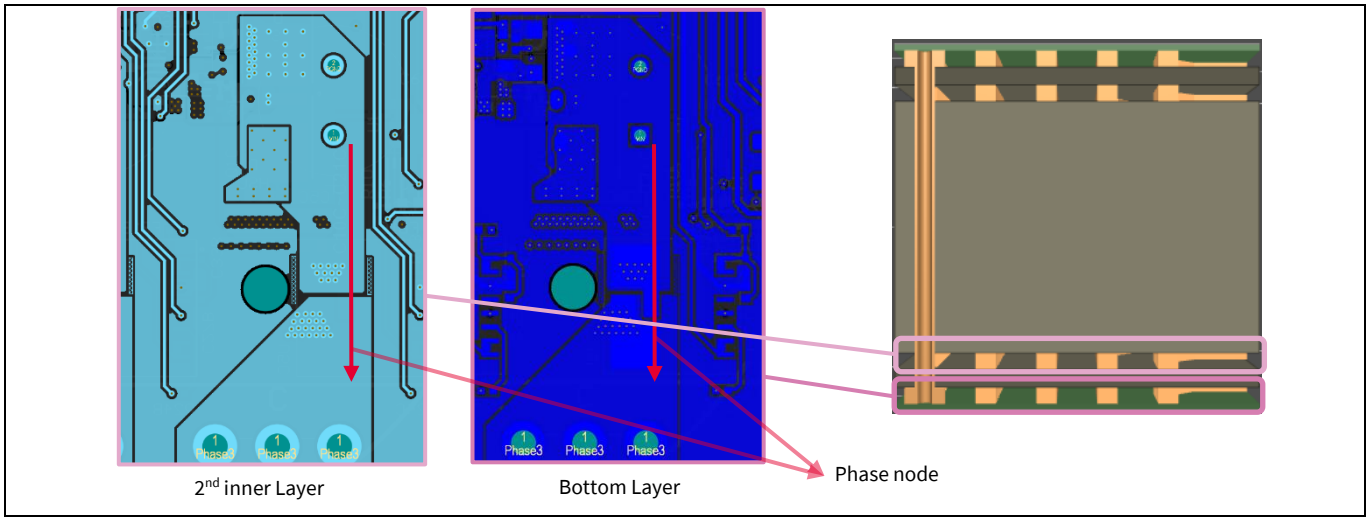


Figure 13 Layout of the phase node and stack up

3.3 Power supply manager

An onboard DC-DC converter generates a 5 V rail from the VIN supply (see Figure 14). This 5 V rail directly sets the gate voltage applied to the CoolGaN™ Transistors through the EiceDRIVER™ 2EDF7258G gate drivers and also powers the current sensors and latch circuitry. During MOSFET testing (refer section 4.6), the gate drivers are supplied from the 12 V rail, while an onboard LDO generates the required 5 V supply for the remaining circuits.

The DC-DC converter features a RUN pin and starts operating only when VIN exceeds 14 V. A green LED located in the top-left corner indicates the status of the DC-DC converter. The upper voltage limit is determined by the protection diode (D1).

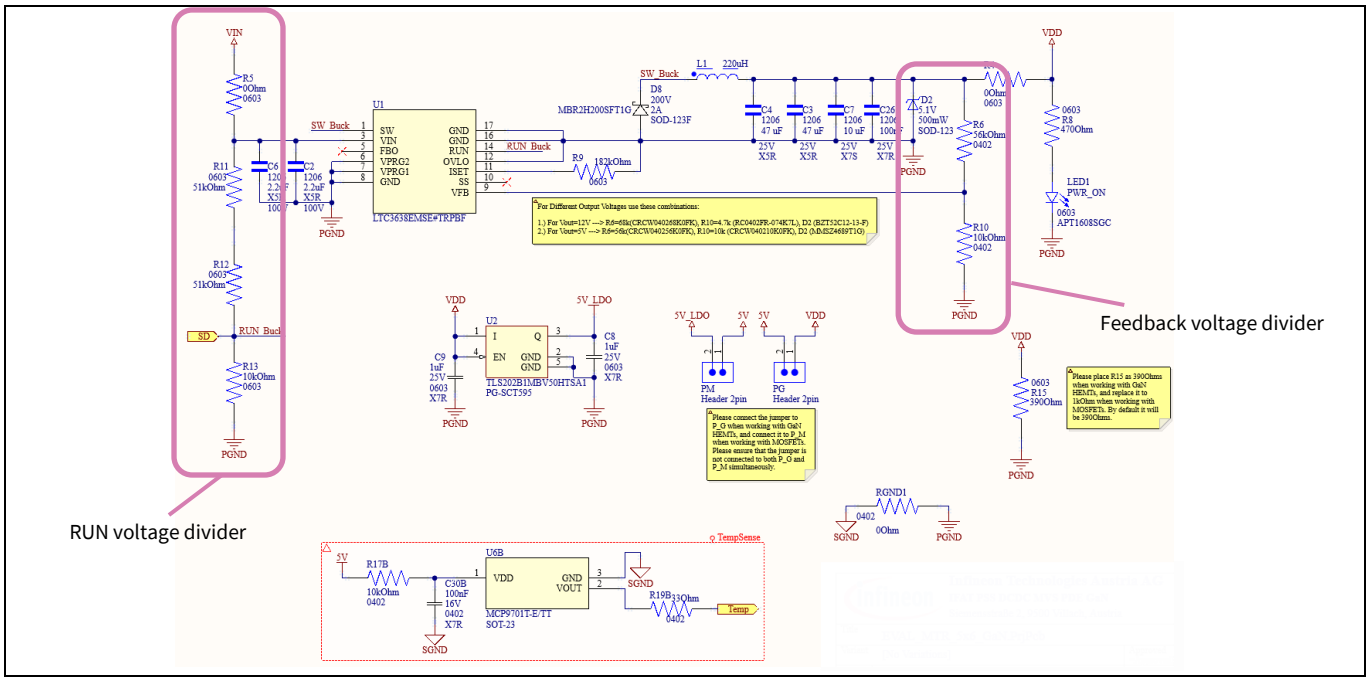


Figure 14 Schematic of the auxiliary power supply and temperature sensor

3.4 Control

The control card interface (DIN 41612, 32-pin, female) with supporting circuits is shown in Figure 15 for versions 1.0 and later. The pinout is compatible with Infineon's PSOC™ Control C3 kit and KIT_XMC4400_DC_V1 control card, which can also be used with other microcontrollers. The control board can be supplied with less than 25 mA from the onboard DC-DC converter from the 5 V rail, using the solder jumpers R18.

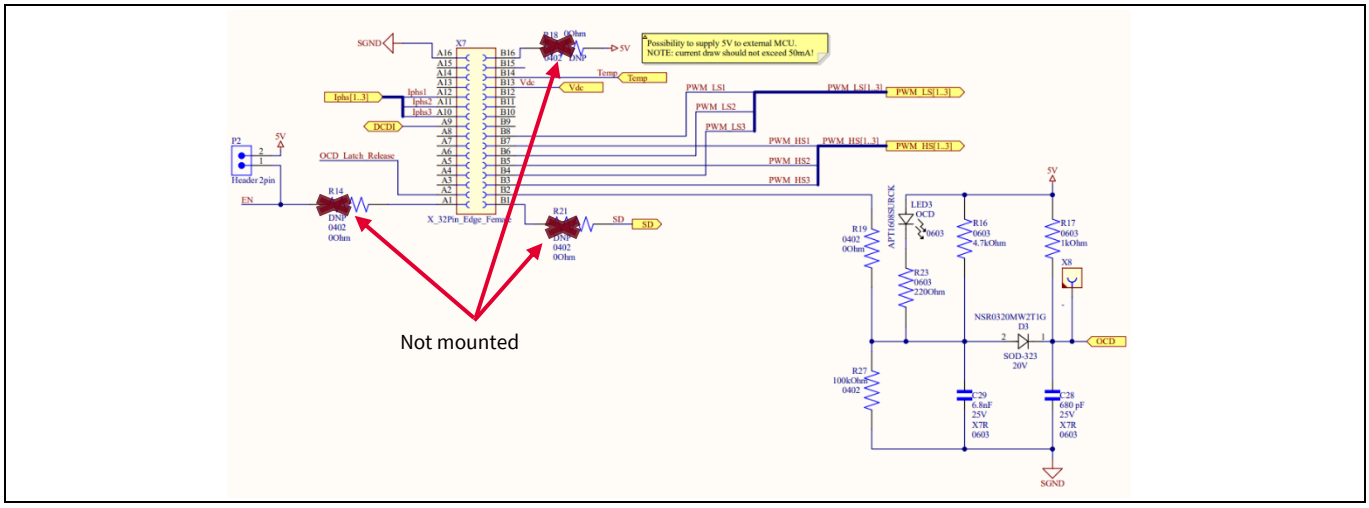


Figure 15 Schematic of the pin header or control card interface

3.4.1 Temperature sensing

A temperature sensor (Figure 16) is connected directly to the signal ground potential, with a scale factor of 10 mV/°C (or 20 mV/°C depending on the mounted parts, check Bill of materials) and 750 mV offset at 25°C.

The temperature readout of the sensor is a measurement of the PCB near the CoolGaN™ Transistors, but it is not a direct readout of their junction temperatures. Therefore, it is recommended to choose a conservative threshold, e.g., 80°C or 1.3 V. This value will further depend on the heat spreader design, the selected TIM, and airflow conditions.

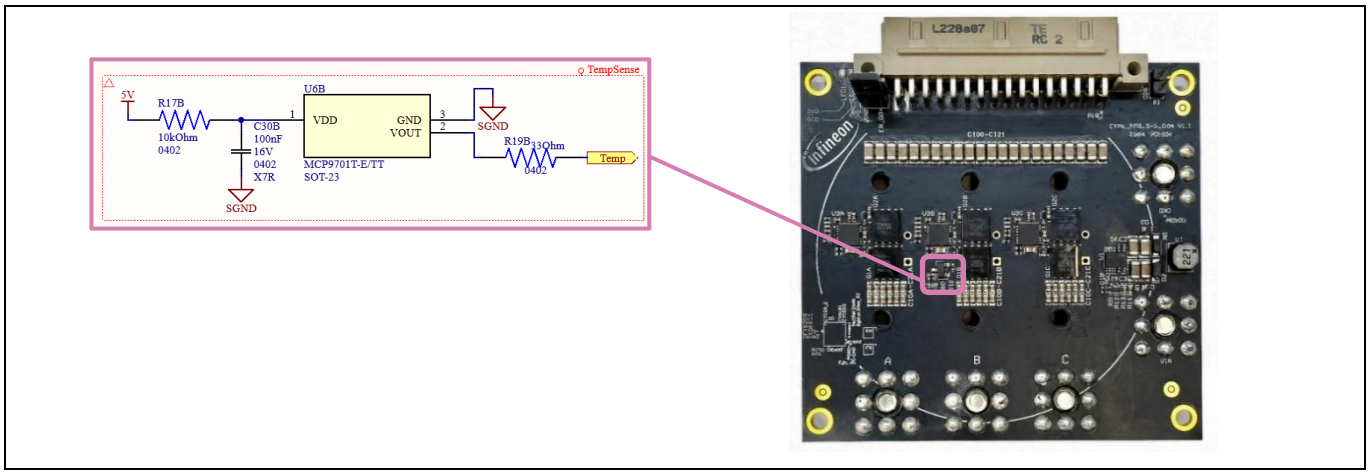


Figure 16 Overview of the bottom part of EVAL_MTR_5x6_GaN board

3.4.2 Overcurrent protection circuit

In the overcurrent detection (OCD) circuit, the OCD outputs from all phases current sensors are ORed together and connected to a NAND gate (U7). The output of the NAND gate is then connected to the clock (CLK) input of a D flip-flop (U6). The inverted output of the D flip-flop is connected to the enable signals of all three gate drivers. Refer to Figure 17 for the OCD circuit schematic.

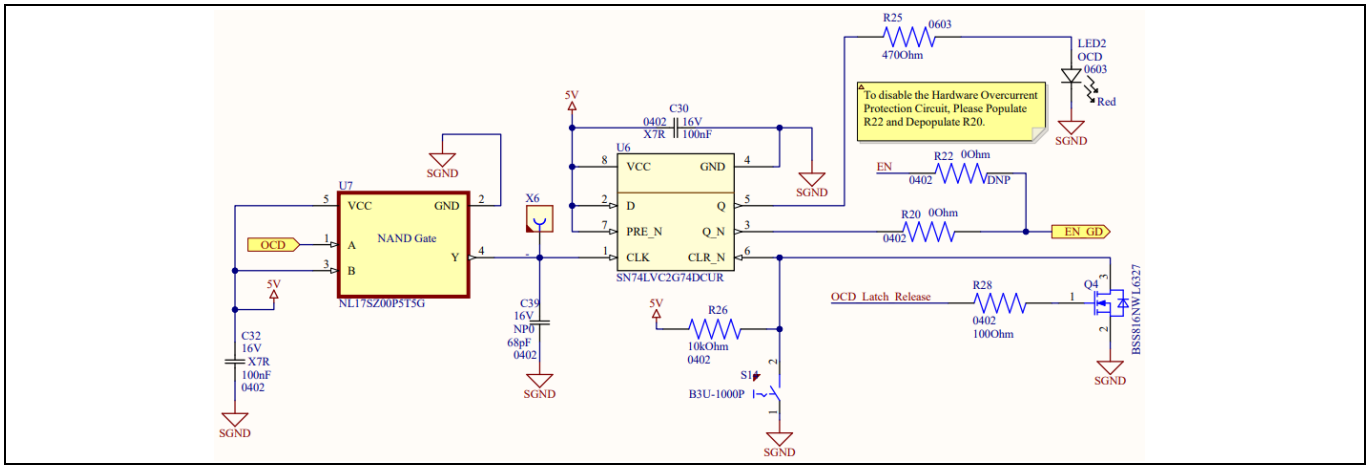


Figure 17 Overcurrent detection circuit

This circuit latches the gate driver's enable signal in the LOW state until the S1 switch is manually pressed or the latch is released by the MCU via the OCD Latch Release pin (A2) on the X7 connector.

Note: In the event of an unintended OCD trigger during the initial power-up, please reset the OCD latch using S14 or the OCD Latch Release.

4 Supported user modifications

EVAL_MTR_5x6_GaN is a flexible evaluation board to support designs using CoolGaN™ Transistors in motor drive applications. To cater to different needs, the board supports several user modifications.

4.1 External supply rail

For investigation of gate drive patterns and the first-check of the microcontroller, power the EVAL_MTR_5x6_GaN evaluation board with an external auxiliary supply, as the onboard auxiliary power supply will not be available in this condition. This can be accomplished by desoldering R4 and supplying 5V directly to the connector, as shown in Figure 18.

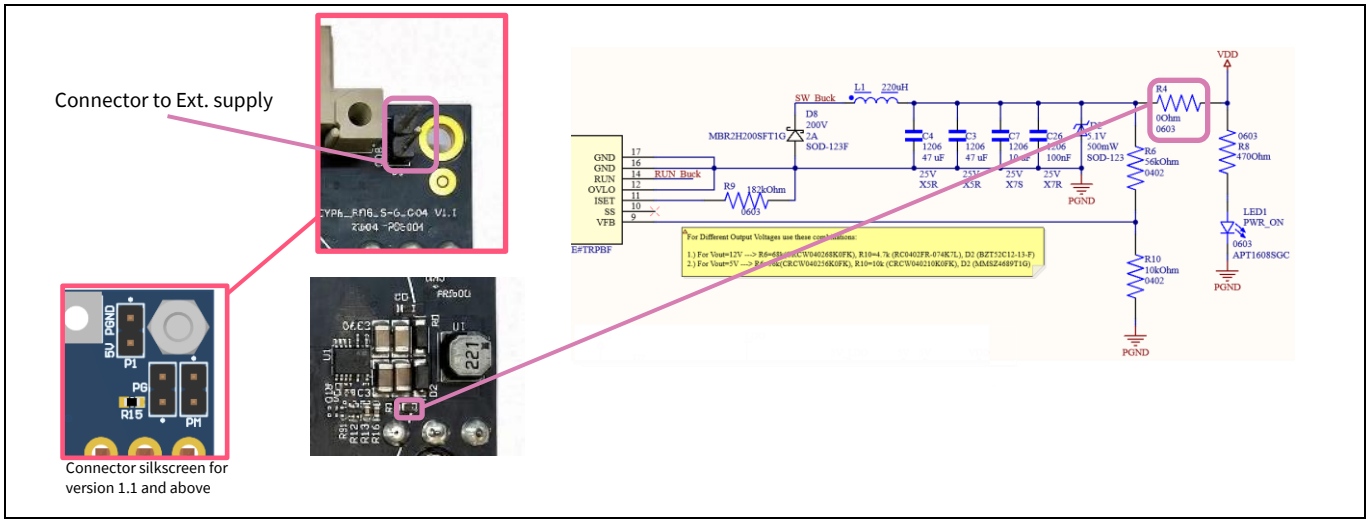


Figure 18 Connection for external supply

4.2 Additional bulk capacitance

For switching frequencies below 100 kHz, it might be necessary to add additional bulk capacitance, depending on the cable length and impedance of the power supply. This can be accomplished by inserting a leaded electrolytic capacitor in the additional place shown in Figure 20; the silkscreen reports the “+” pin of the capacitors.

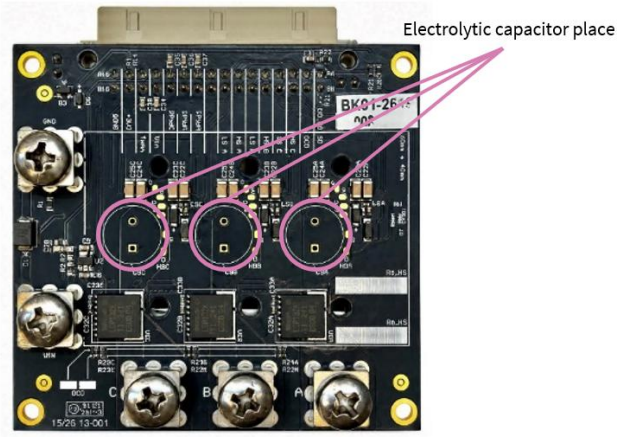


Figure 19 Additional electrolytic capacitor with a step of 5 mm

4.3 V_{DS} and V_{GS} measurements

The EVAL_MTR_5x6_GaN evaluation board provides onboard probing points of critical waveforms, such as V_{DS} and V_{GS}, as shown in Figure 20. To ensure accurate waveforms, a tight probing loop is recommended. For example, a short ground spring can be used between the probe tip and the board. A longer wire connection (more than 1 cm) with ground leads is not recommended, even with a twisted pair connection, because this will significantly worsen the measurement fidelity.

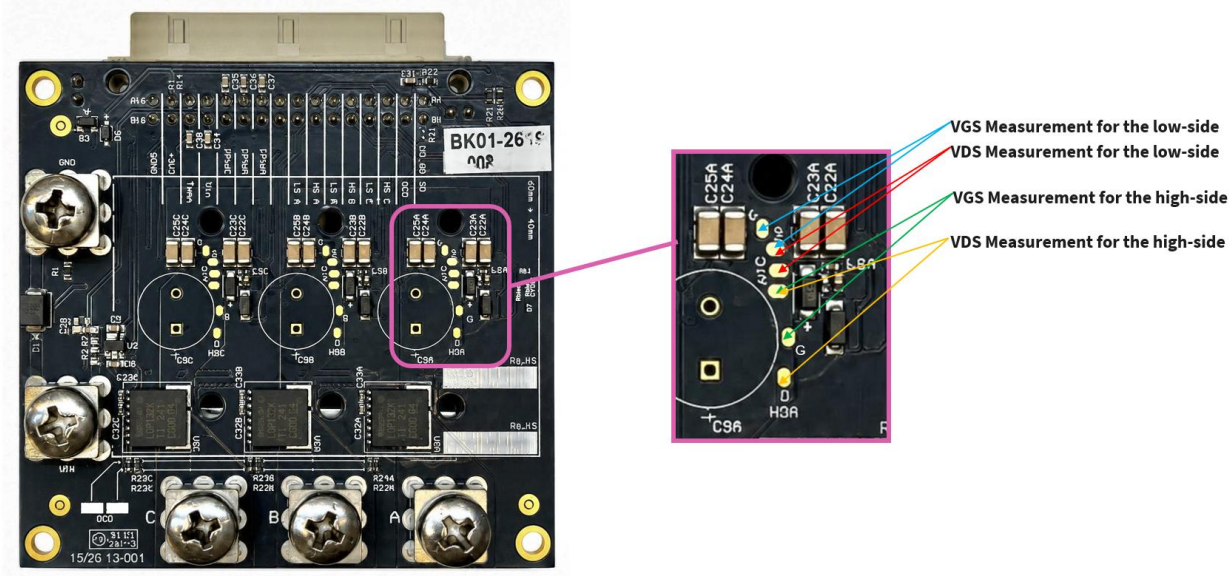


Figure 20 Measurement points for the V_{DS} and V_{GS} low-side

4.4 UVLO and battery voltage divider

The UVLO of the main DC-DC converter, which steps down the main power connection, can be tuned for a lower battery voltage (e.g., 36 V). To do this, change the resistor R62 with a simple voltage divider relationship as per Equation 1. See Figure 21.

$$V_{UVLO} = \frac{102\ k\Omega + R13}{R13} \cdot 1.21\ V$$

Equation 1 Tuning the UVLO for a lower battery voltage

A voltage is acquired at the main battery power connection, which is necessary for the microcontroller to run the FOC algorithm. This partition can be changed by the resistor R3 using the following relationship:

$$V_{input\ max} = \frac{200\ k\Omega + R3}{R3} \cdot 3.3\ V$$

Equation 2 Changing the voltage partition at the main battery

The EVAL_MTR_5x6_GaN board includes a battery voltage divider able to handle a supplied voltage up to 144 V DC, but the protection diode (D1, SMBJ75A) is rated for 75 V that needs to be disconnected, and R3 should be tuned to change the rating.

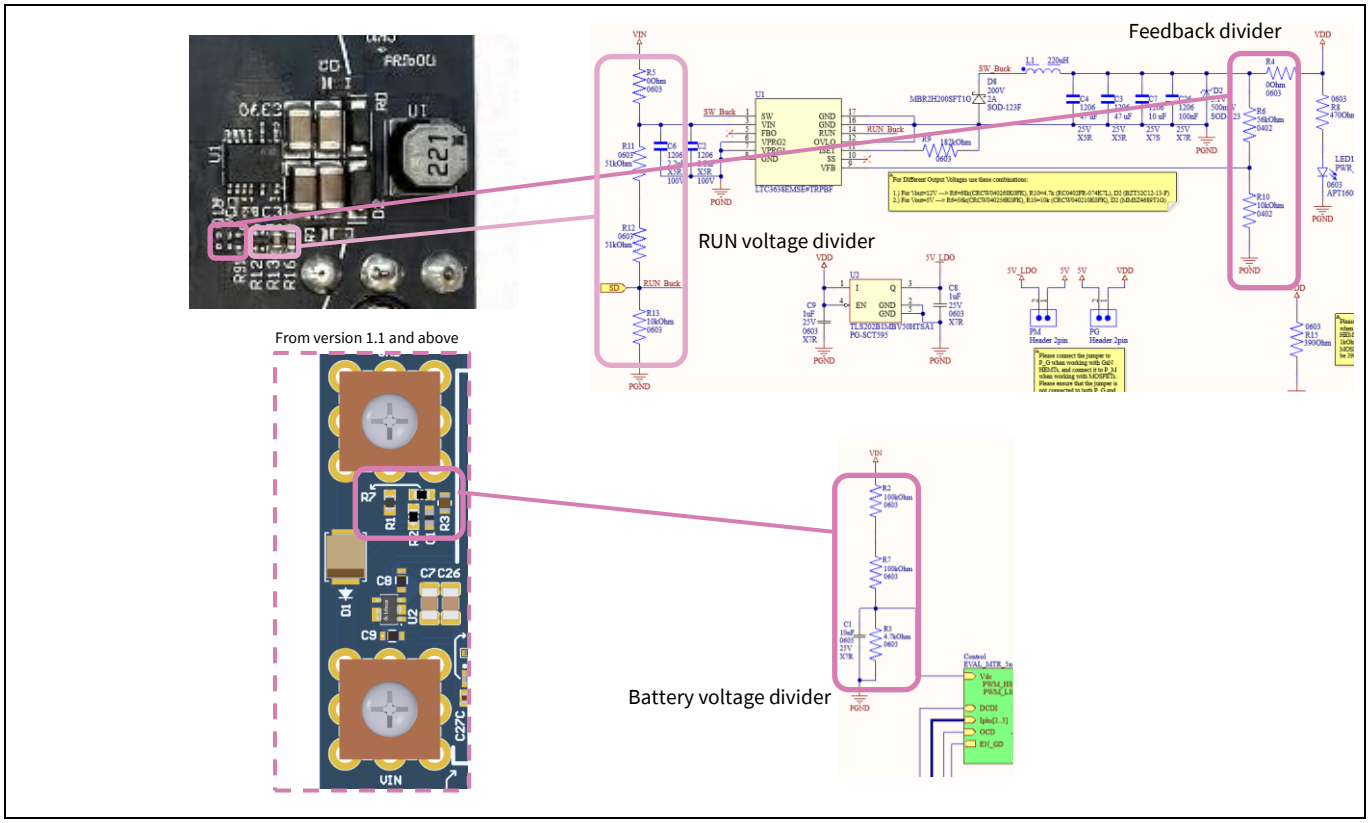


Figure 21 RUN, feedback divider, and battery voltage divider

4.5 Gate resistor and C_{gs} external replacements

The EVAL_MTR_5x6_GaN board is equipped with a gate resistor and external C_{gs} (by default DNP) to slow down dV/dt when it is requested. Figure 22 shows the placement of the gate resistors and external C_{gs}.

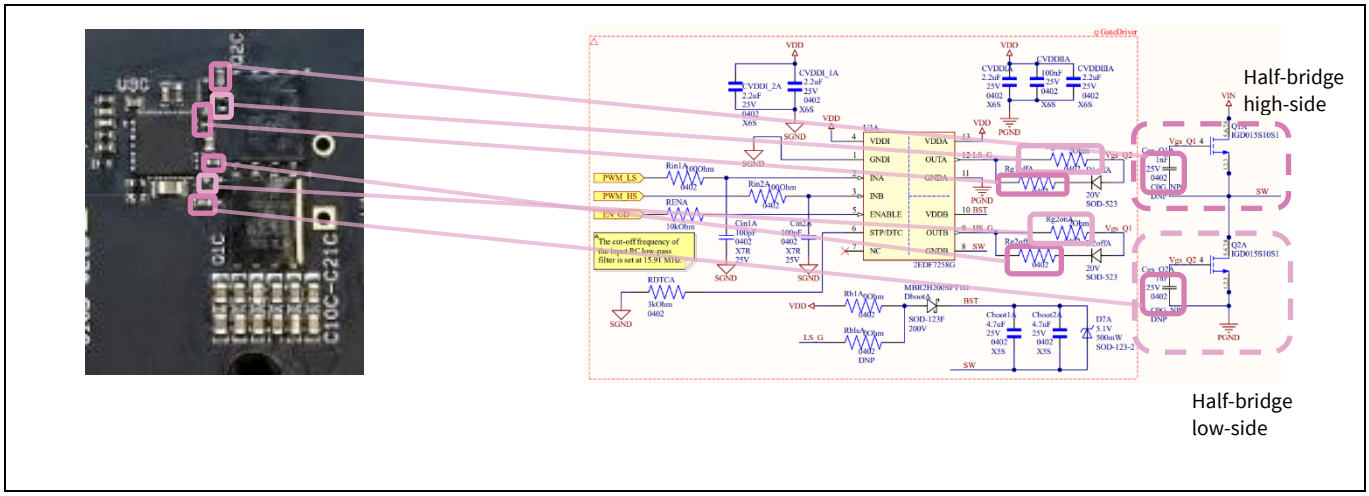


Figure 22 Schematic and of the single half-bridge and gate driver placement

4.6 Jumper configuration for MOSFET compatibility

In order to test the board with MOSFETs, you need to make the following three changes:

1. Replace all GaN transistors with MOSFETs of the same package. An example is OptiMOS™ 6 ISC027N10NM6 power MOSFET 100 V, 2.7 mΩ device in SuperSO8 package (5 mm × 6 mm) package

2. Remove the J1 jumper from the PG header pins and place it on the PM header pins, as shown in Figure 23

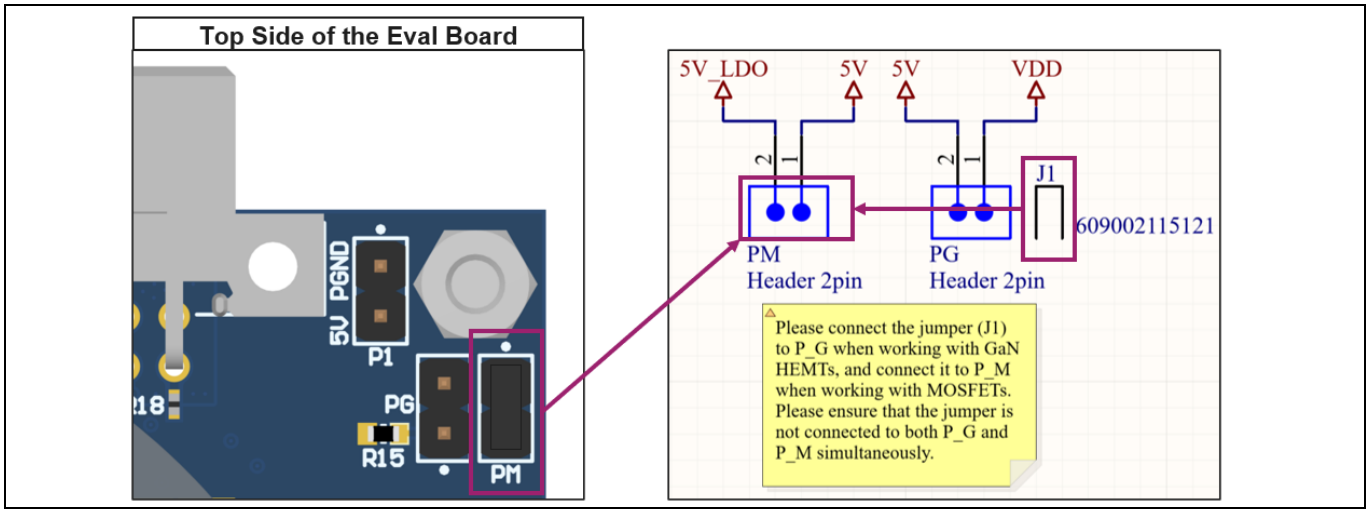


Figure 23 Placement of jumper J1 for MOSFET compatibility

3. Adjust the DC-DC regulator output voltage to the desired MOSFET gate-drive voltage by replacing the R6 and R10 resistors on the board. Refer to Equation 3 for the resistor value calculations and Figure 22 for the component placement

$$VDD = \frac{R6+R10}{R10} \cdot 0.8\,V$$

Equation 3 Changing the voltage partition at the main battery

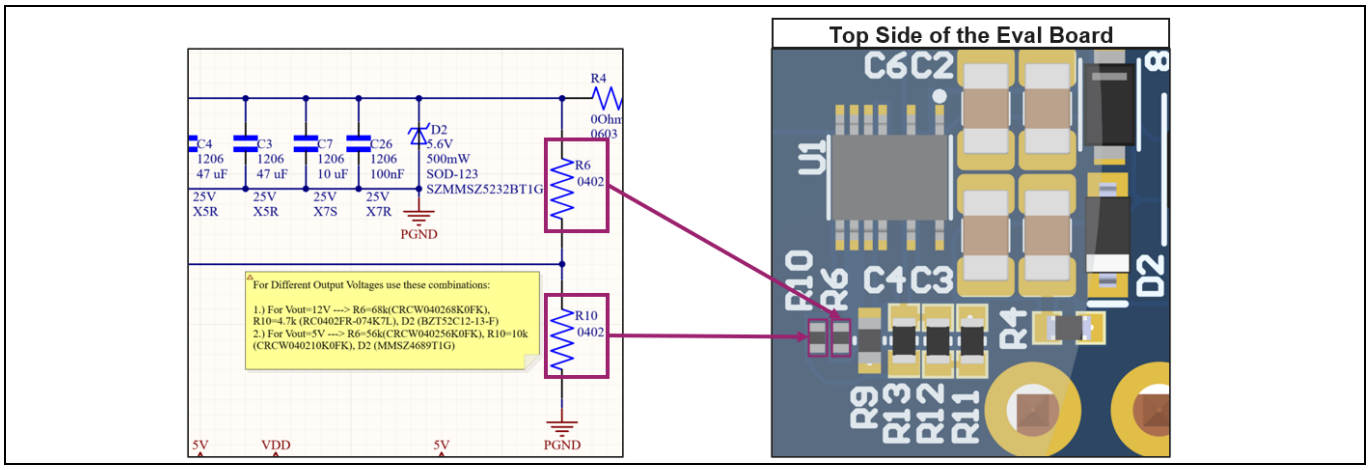


Figure 24 Resistive divider placement for DC-DC output voltage adjustment

5 Measurements

Here are some typical measurements that can be observed with the EVAL_MTR_5x6_GaN evaluation board for reference.

5.1 V_{DS} measurement

Figure 25 shows an example measurement of low-side V_{DS} (also called phase node V_{ph}) using the test pads shown in Figure 20, and the respective phase current I_{out} at V_{IN} = 48 V. dV/dt is measured between 10% and 90% of the waveform at the I_{out} peak, as well as the max value of this transition (dV/dt (max.)). Usually, the board is configured with a 30 ns of dead time.

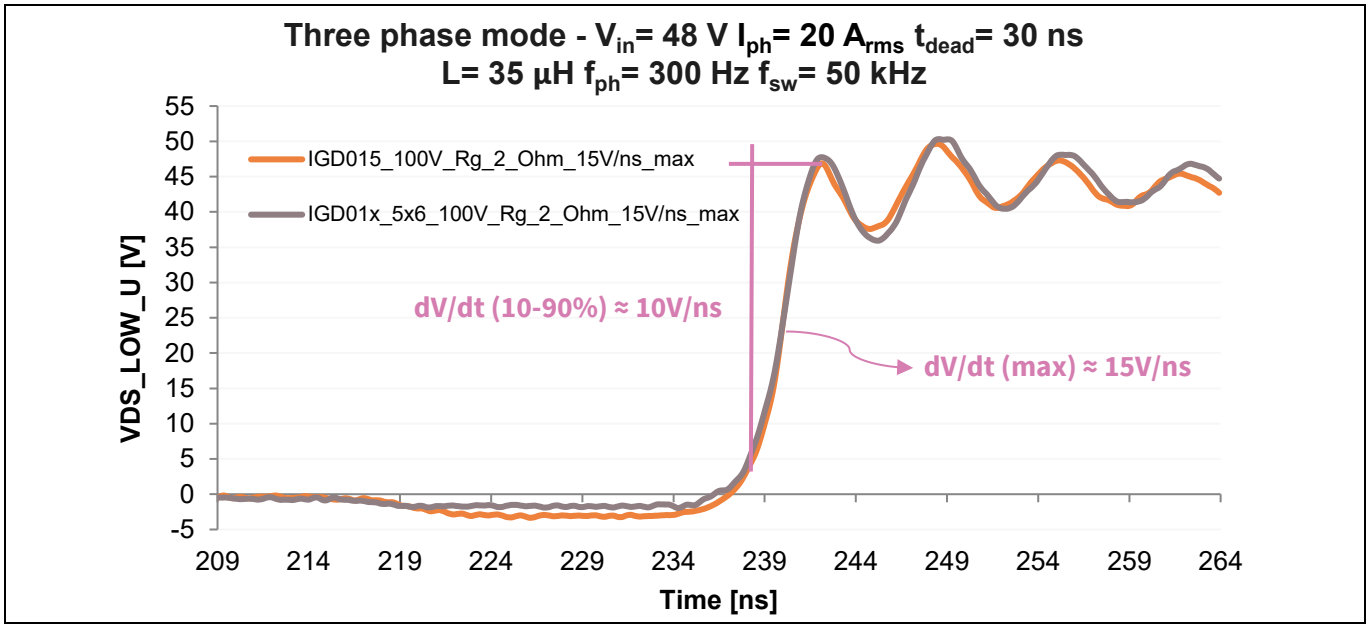


Figure 25 Phase node voltage during high-side hard turn-on

5.2 Measurement of losses: RL load with different gate drive options

Measurements of the RL load with the setup shown in Figure 26 are necessary to evaluate the losses under different conditions, with gate drivers, and the type of cooling used.

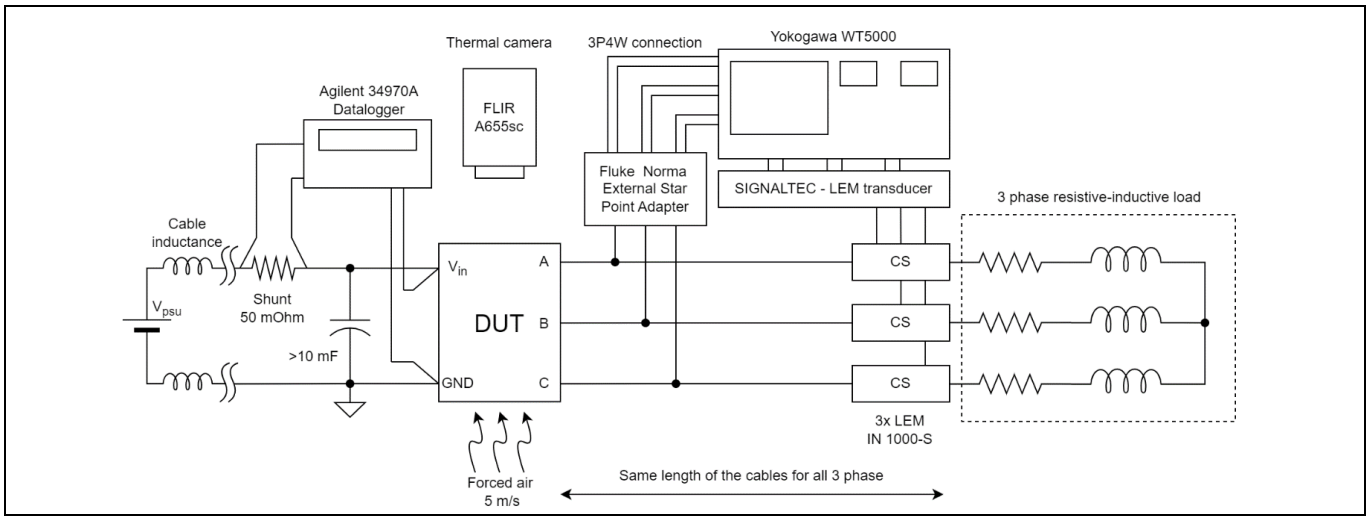


Figure 26 Measurement setup

5 Measurements

Figure 27 and Figure 28 show the losses measured with two different conditions. The plots show the difference in losses at heavy loads for natural convection and natural convection with heatsink. The corresponding temperature variation is also shown in Figure 27 and Figure 28, which are captured with a thermal camera as shown in Figure 29.

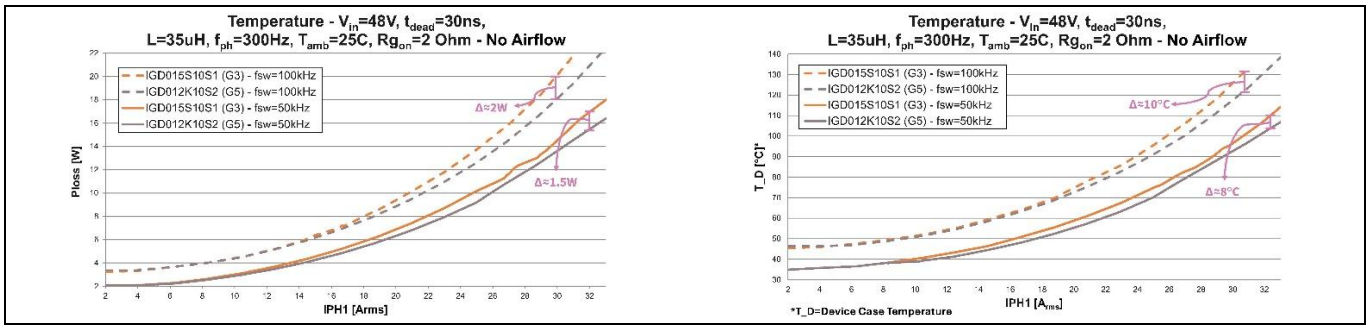


Figure 27 Measurement of losses and temperature of the evaluation design without heatsink

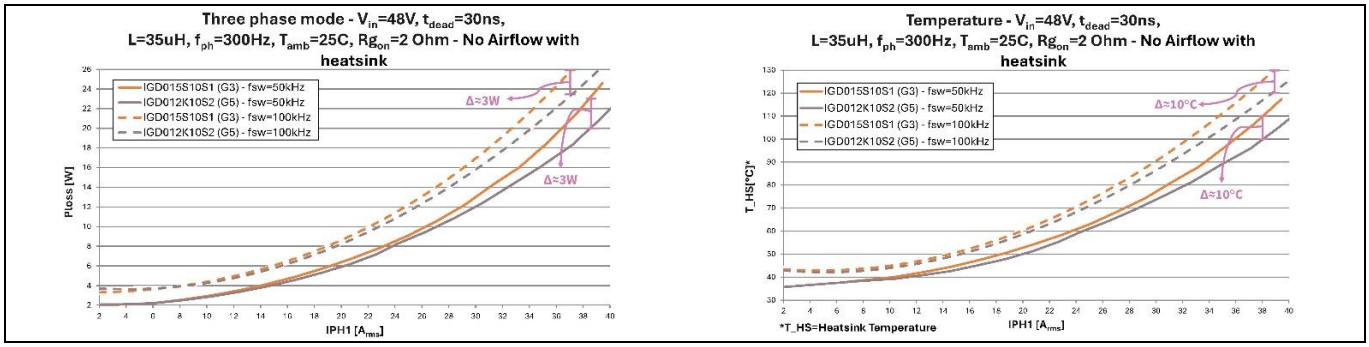


Figure 28 Measurement of losses and temperature of the evaluation design with heatsink

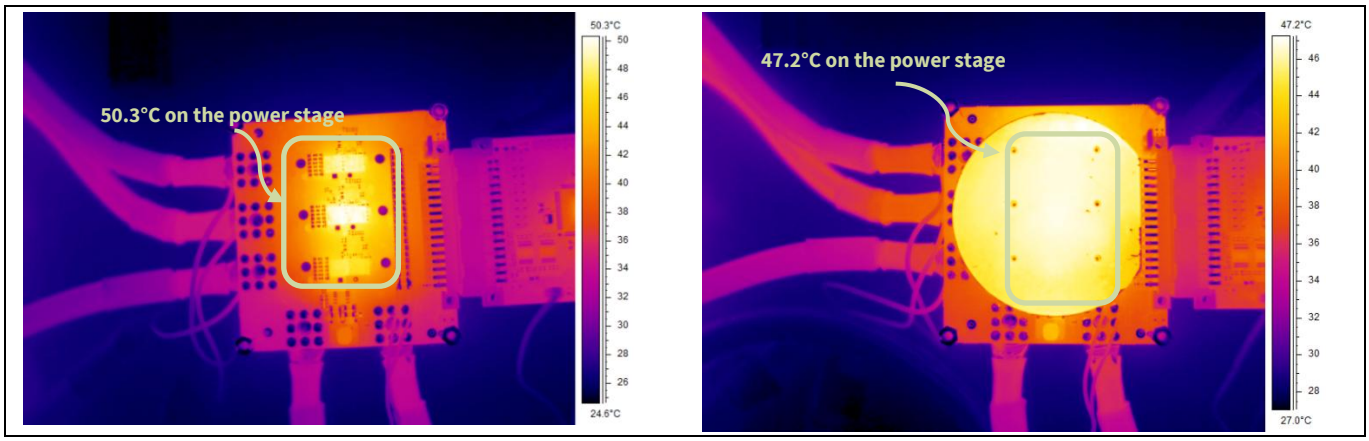


Figure 29 PCB temperature during the test with RL load at f_{sw} = 50 kHz in still air; (left) without heatsink applied at 16 A_{RMS}; (right) with heatsink applied at 16 A_{RMS}

6 Note for the first start of the board

The section reports the notes related to the first run of the board and limitations on the control side.

- The duty cycle of the PWM cannot be greater than 99% with a switching frequency PWM of 100 kHz
- The current sensor depends on the PCB manufacturer's pressing process; a first tuning is required for a new board. That can be handled by an open-loop control to have a fixed phase current and an external sensor to compare the measured data from the sensor on the board (TLE4973)
- Main input current is not limited on the board (no current protection). Any inrush current needs to be limited from the power supply

7 Bill of materials

Table 3 Bill of materials for EVAL_MTR_5x6_GaN

No.	Qty.	Part description	Designator	Part number	Manufacturer	Alternative parts/ comments
1	1	10 nF	C1	CC0603KRX7R8BB103	Yageo	–
2	2	2.2 µF	C2, C6	CL31A225KC9LNNC	Samsung Electro-Mechanics	–
3	2	47 µF	C3, C4	C3216X5R1E476M160AC	TDK	–
4	3	18 µF	C5A, C5B, C5C	A759MS186M2CAAE090	Kemet	DNP
5	1	10 µF	C7	CL31Y106KAKVPJE	Samsung Electro-Mechanics	–
6	2	1 µF	C8, C9	C1608X7R1E105K080AB	TDK Corporation	–
7	36	100 nF	C10A, C10B, C10C, C11A, C11B, C11C, C12A, C12B, C12C, C13A, C13B, C13C, C14A, C14B, C14C, C15A, C15B, C15C, C16A, C16B, C16C, C17A, C17B, C17C, C18A, C18B, C18C, C19A, C19B, C19C, C20A, C20B, C20C, C21A, C21B, C21C	C0603C104K1RACTU	Kemet	–
8	12	220 nF	C22A, C22B, C22C, C23A, C23B, C23C, C24A, C24B, C24C, C25A, C25B, C25C	C1206C224KARACAUTO	Kemet	–
9	1	100 nF	C26	C1206C104K3RECTU	KEMET	–
10	6	4.7 µF	C27A, C27B, C27C, Cboot2A, Cboot2B, Cboot2C	GRM155C61E475ME15J	Murata Electronics	–
11	6	6.8 nF	C29, C34, C35, C36, C37	GCJ188R71E682KA01D	Murata Electronics	–
12	1	680 pF	C28	885012206058	Würth Elektronik	–
13	3	100 nF	C30, C30B, C32	GCM155R71C104KA55D	Murata Electronics	–

7 Bill of materials

No.	Qty.	Part description	Designator	Part number	Manufacturer	Alternative parts/ comments
14	3	100 nF	C33A, C33B, C33C	GRM155R71E104KE14J	Murata Electronics	–
15	1	100 nF	C38	C0603C104K3RACTM	Kemet	–
16	1	68 pF	C39	885012005030	Würth Elektronik	–
17	17	10 µF	C100, C101, C102, C103, C104, C105, C106, C107, C108, C109, C110, C111, C112, C113, C114, C115, C116	GRM32EC72A106KE05L	Murata Electronics	–
18	3	4.7 µF	Cboot1A, Cboot1B, Cboot1C	GRM155C61E475ME15J	Murata	–
19	6	1 nF	Cgs_Q1A, Cgs_Q1B, Cgs_Q1C, Cgs_Q2A, Cgs_Q2B, Cgs_Q2C	GRT1555C1E102JA02J	Murata Electronics	DNP
20	6	100 pF	Cin1A, Cin1B, Cin1C, Cin2A, Cin2B, Cin2C	885012205038	Würth Elektronik	–
21	12	2.2 µF	CVDDI_1A, CVDDI_1B, CVDDI_1C, CVDDI_2A, CVDDI_2B, CVDDI_2C, CVDDIA, CVDDIB, CVDDIC, CVDDIIIA, CVDDIIIB, CVDDIIIC	GRM155C81E225KE11D	Murata	–
22	3	100 nF	CVDDIIA, CVDDIIB, CVDDIIC	GRM155C81E104KA12D	Murata	–
23	1	75 V	D1	SMBJ75A	Bourns Inc.	–
24	6	20 V	D1offA, D1offB, D1offC, D2offA, D2offB, D2offC	NSR0520V2T1G		Alternate: RB520S30T5G
25	1	5.6 V	D2	SZMMSZ5232BT1G	onsemi	–
26	1		D3	NSR0320MW2T1G	onsemi	–
27	3	5.1 V	D7A, D7B, D7C	MMSZ4689T1G	onsemi	–
28	1	200 V	D8	MBR2H200SFT1G	onsemi	–
29	3	200 V	DbootA, DbootB, DbootC	MBR2H200SFT1G	onsemi	–

7 Bill of materials

No.	Qty.	Part description	Designator	Part number	Manufacturer	Alternative parts/ comments
30	3	1kR	FB1A, FB1B, FB1C	BLM15AX102SN1D	Murata	–
31	6	M1.6 × 6mm	HSS1, HSS2, HSS3, HSS4, HSS5, HSS6	293268	RS-PRO	–
32	1	Jumper	J1, J2	609002115121	Würth Elektronik	Place J1 jumper on PG Pin Header and Place J2 jumper on P2 Pin Header
33	1	Inductor	L1	74404054221	Würth Elektronik	–
34	1	Power On LED	LED1	APT1608SGC	Kingbright	–
35	2	OCD LED	LED2, LED3	APT1608SURCK	Kingbright	–
36	1	2pin Header	P1, P2, PG, PM	61300211121	Würth Elektronik	Do not place a jumper on P1 Header in any case.
37	6	GaN HEMT	Q1A, Q1B, Q1C, Q2A, Q2B, Q2C	IGD015S10S1	Infineon Technologies	Alternate: IGD012K10S2
38	1	P-channel enhancement mode FET	Q3	BSS215P	Infineon Technologies	–
39	1	N-Channel Small Signal MOSFET	Q4	BSS816NW	Infineon Technologies	Alternate: BSS214NW
40	3	0 Ω	R1, R4, R5	CRCW06030000Z0EA	Vishay Dale	–
41	2	100 kΩ	R2, R7	CRCW0603100KJNEAHP	Vishay Dale	–
42	3	4.7 kΩ	R3, R16	CRCW06034K70FKEAHP	Vishay Dale	–
43	1	1 kΩ	R17	CRCW06031K00FKEAHP	Vishay Dale	–
44	1	56 kΩ	R6	CRCW040256K0FKED	Vishay	–
45	2	470 Ω	R8, R25	RCS0603470RJNEA	Vishay Dale	–
46	1	182 kΩ	R9	ERJ-3EKF1823V	Panasonic Electronic Components	–
47	9	10 kΩ	R10, R17B, R26, RDTCA, RDTCB, RDTCC, RENA, RENB, RENC	CRCW040210K0FKED	Vishay Dale	–

7 Bill of materials

No.	Qty.	Part description	Designator	Part number	Manufacturer	Alternative parts/ comments
48	3	3 kΩ	RDTCA, RDTCB, RDTCC	CRCW04023K00FKEDC	Vishay Dale	–
49	2	51 kΩ	R11, R12	RT0603BRD0751KL	YAGEO	–
50	1	10 kΩ	R13	CRCW060310K0JNEAH P	Vishay Dale	–
51	18	0 Ω	R20, R24A, R24B, R24C, Rb1A, Rb1B, Rb1C, Rg1offA, Rg1offB, Rg1offC, Rg2offA, Rg2offB, Rg2offC, RGND1, RGND2, RGNDA, RGNDB, RGNDC	RMCF0402ZT0R00	Stackpole Electronics Inc, Stackpole International	–
52	7	0 Ω	R14, R18, R21, R22, RblsA, RblsB, RblsC	RMCF0402ZT0R00	Stackpole Electronics Inc, Stackpole International	DNP
53	1	390 Ω	R15	RCS0603390RJNEA	Vishay Dale	DNP
54	1	0 Ω	R19	RMCF0402ZT0R00	Stackpole Electronics Inc, Stackpole International	–
55	1	33 Ω	R19B	ERJ-2GEJ330X	Panasonic Electronic Components	–
56	1	220 Ω	R23	ERJ-3GEYJ221V	Panasonic Industry	–
57	1	100 kΩ	R27	ERJ-2GEJ104X	Panasonic Industry	–
58	1	100 Ω	R28	CRCW0402100RFKEDH P	Vishay Dale	–
59	6	2 Ω	Rg1onA, Rg1onB, Rg1onC, Rg2onA, Rg2onB, Rg2onC	CRCW04022R00FKED	Vishay Dale	–
60	6	100 Ω	Rin1A, Rin1B, Rin1C, Rin2A, Rin2B, Rin2C	CRCW0402100RFKEDC	Vishay Dale	–
61	4	HEX STANDOFF M3X0.5 (Female, Female)	S1, S2, S3, S4	970150321	Würth Elektronik	–

7 Bill of materials

No.	Qty.	Part description	Designator	Part number	Manufacturer	Alternative parts/ comments
62	4	HEX STANDOFF M3X0.5 (Male, Female)	S5, S6, S7, S8	971300321	Würth Elektronik	–
63	5	M5x6	S9, S10, S11, S12, S13	RS-PRO 9087693	RS-PRO	–
64	1	B3U-1000P	S14	B3U-1000P	Omron	–
65	1	TG-A1250-100-100-1.0	TIM1	TG-A1250-100-100-1.0	T-Global Technology	–
66	1	Buck switching regulator	U1	LTC3638EMSE#TRPBF	Analog Devices Inc	–
67	1	Linear voltage regulator	U2	TLS202B1MBV50HTSA1	Infineon Technologies	–
68	3	Gate driver	U3A, U3B, U3C	2EDF7258G	Infineon Technologies	–
69	3	Current sensor	U5A, U5B, U5C	TLE4973-R120T5-S0010	Infineon Technologies	–
70	1	Gate driver	U6	SN74LVC2G74DCUR	Texas Instruments	–
71	1	Current sensor	U6B	MCP9701T-E/TT	Microchip	–
72	1	NAND gate	U7	NL17SZ00P5T5G	onsemi	–
73	5	8 Pin screw Terminal, M5	X1, X2, X3, X4, X5	74655095R	Würth Elektronik	–
74	2	Test pad	X6, X8		-	–
75	1	Connector	X7	294722-E	TE Connectivity Erni	–
76	1	Heatspreader, 64mm	X_H_S		Custom Heat Sink	–
77	6	Nylon Plain Washers, M2.5, RoHS	W1, W2, W3, W4, W5, W6	30417288	RS PRO	–

8 Related resources

- Webpage: Gallium nitride (GaN)
- Infineon Developer community: GaN

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[1] Infineon Technologies AG: *Datasheet for Infineon CoolGaN™ Transistors (2026)*; Available online

[2] Infineon Technologies AG: *Datasheet for EiceDRIVER™ 2EDF7258G, Compact 300 V rms dual-channel isolated gate driver with 5 A / 9 A output current in 4x4 13pin SON with Thermal Pads;* Available online

[3] Infineon Technologies AG*: Datasheet for TLE4973 high precision coreless current sensor for industrial applications in 8 x 8 mm SMD package;* Available online

[4] Infineon Technologies AG: *Datasheet for TLS202B1MB V50 post voltage regulator (2023)*; Available online

[5] Infineon Technologies AG: *Designing an optimized half-bridge DC-DC converter with medium-voltage CoolGaN™ Transistors (2025)*; Available online

[6] Infineon Technologies AG: Gate driver considerations for CoolGaN™ in low-voltage motor drive applications *(2026);* Available online

[7] Infineon Technologies AG: TLE4973 current sensor bootkit programmer *(2025);* Available online

Revision history

Document revision	Date	Description of changes
V 1.0	2026-10-01	Initial version

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