CoolSiC™-based power conversion board

REF-2LC50K6MRW2CD

About this document

Scope and purpose

This application note describes the 3-phase, bridge-based power conversion board REF-2LC50K6MRW2CD. It can be used for various power conversion applications and use cases, with a special focus on DC EV chargeing solutions.

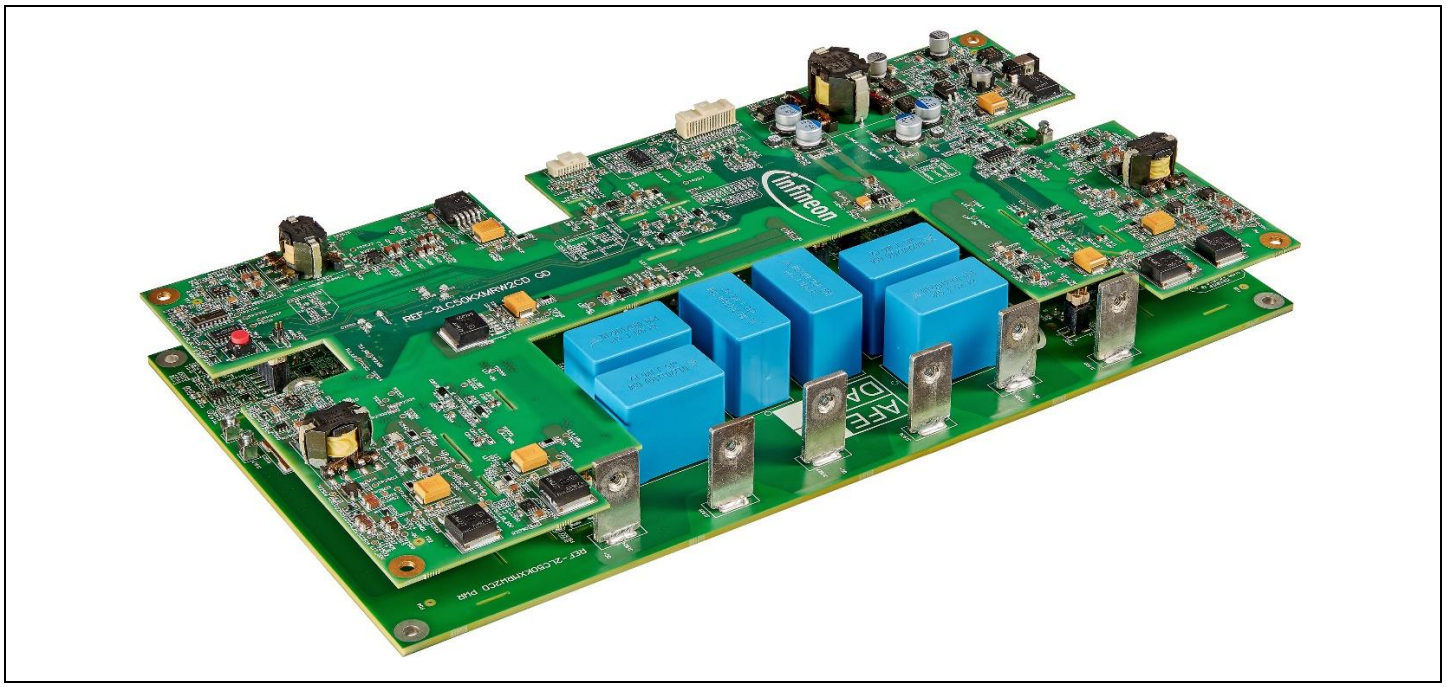
Intended audience

This document is meant for technical specialists working on DC EV charging solutions and similar power conversion domains..

Reference design and demonstration system

The reference design described in this document provides a blueprint of how to combine a well-defined set of the latest Infineon CoolSiC™ MOSFETs and EiceDRIVER™ drivers to build a compact power conversion board capable to handle up to 50 kW.

A DC EV charging demonstration system was assembled and tested at Infineon, which is the basis for the specification and measurement results mentioned in this document. Hardware for this power conversion boards is available on demand, but not for the complete demonstration system or other individual parts of it.



Power conversion board REF-2LC50K6MRW2CD

Note: *The power conversion board does not necessarily meet the safety, EMI, and quality standard requirements from, e.g., UL, CE, etc.*

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“Evaluation Boards and Reference Boards” shall mean products embedded on a printed circuit board (PCB) for demonstration and/or evaluation purposes, which include, without limitation, demonstration, reference and evaluation boards, kits and design (collectively referred to as “Reference Board”).

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Safety precautions

Note: *Please note the following warnings regarding the hazards associated with development systems.*

Table 1 **Safety precautions**

	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board 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.*
	**Warning:** *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. 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.*
	**Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires or perform maintenance work. 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 heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	**Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	**Caution:** *The evaluation or reference board contains parts and assemblies 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 followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	**Caution:** *A drive that is incorrectly applied or installed can lead to 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.*
	**Caution:** *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

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1 The power conversion board at a glance

1.1 Introduction

This user guide describes the design of the 2-level power conversion board REF-2LC50K6MRW2CD. This boards comprises of a power board carrying FF6MR12W2M1H_B11 Easy2B CoolSiC™ MOSFET modules in a B6 configuration and best-fitting 1ED3124MU12H EiceDRIVER™ gate drivers on a piggy-back gate driver board. Both boards are connected using board-to-board connectors to reduce the overall form factor and minimize the parasitic inductance in the gate driver switching loop.
This power conversion board can be used as a basic building block for realizing complex power converters, like Infineon's 50 kW DC EV charger reference design and demonstration system (REF-EV50KW2SICKIT).

The board can be used for various topologies in AC-DC and DC-DC power conversion stages and allows implementation with both liquid and air-cooled systems. The board is purely analog, with self-protected blocks that provide a broad range of integrated temperature, current, and voltage sensing features. This enables fast realization, control, and debugging of new converter designs, without being linked to any specific controller platform.

This concept also offers the flexibility of using Infineon's next generation, pin-compatible devices as well as advanced gate drivers to fine tune and optimize the power converter stage for any operating condition.

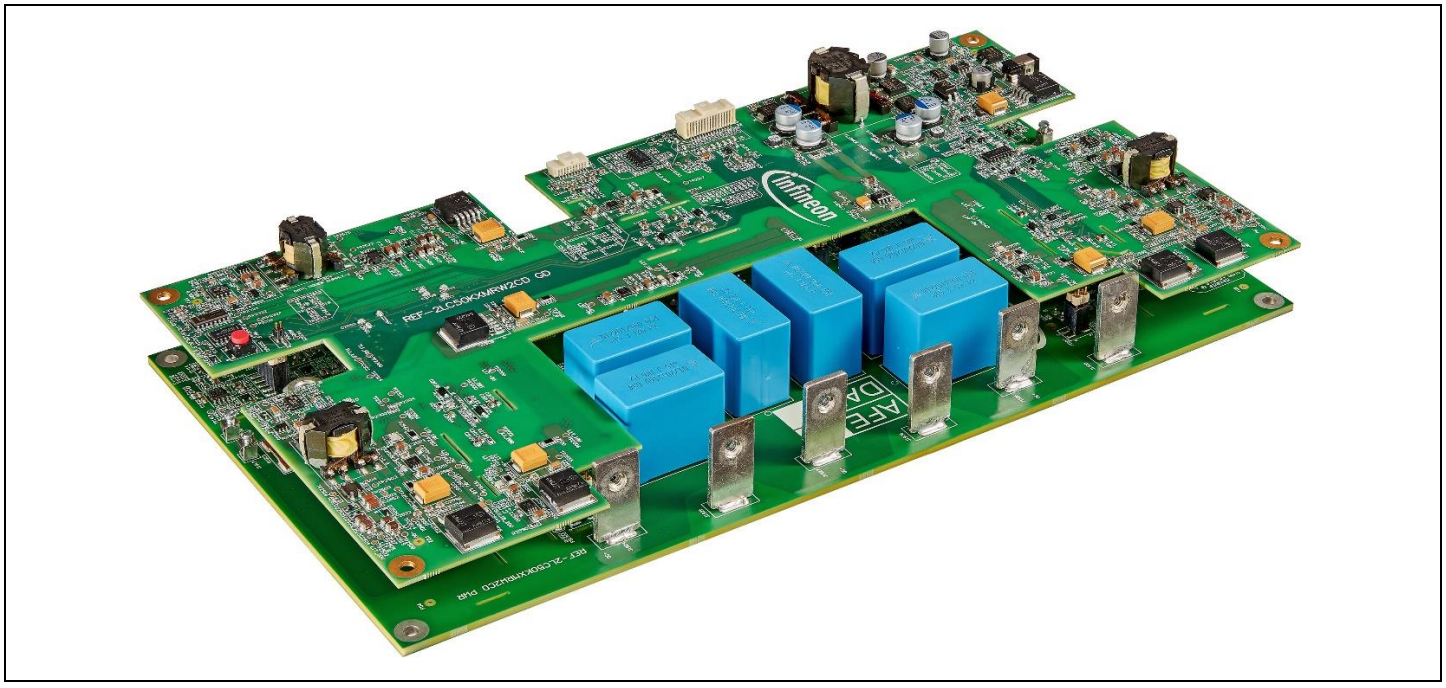


Figure 1 **Power conversion board REF-2LC50K6MRW2CD**

1.2 Design features

The power conversion board has the following main features:

- All sense signals are differential in nature for better noise immunity
- Software and hardware-based protections are independent of each other for maximum self protection with current, voltage, and temperature monitoring
- Pulse-width modulation (PWM) signals are level-shifted to the power control board for better noise performance
- The boards are equipped with hardware and software-based fault reset
- For AC and DC power input/output, press-fit type busbar connectors are used for reduced DC resistance and lower power loss
- The board has an emergency shutdown feature that can be activated using either software or hardware controls
- 3-phase bridge or B6 topolgy has been used. It is a common topology in power conversion systems. Therefore, a broad range of topologies can be implemented using the same power conversion board and different peripheral reactive components. For example, for the 50 kW DC EV charger demonstration system (REF-EV50KW2SICKIT), two types of topologies are realized using these power conversion boards with only a minor change of components as shown in Figure 2:
    - 2-level active front-end converter (AFE) for AC-DC conversion
    - 3-phase dual active bridge (DAB) converter for DC-DC conversion

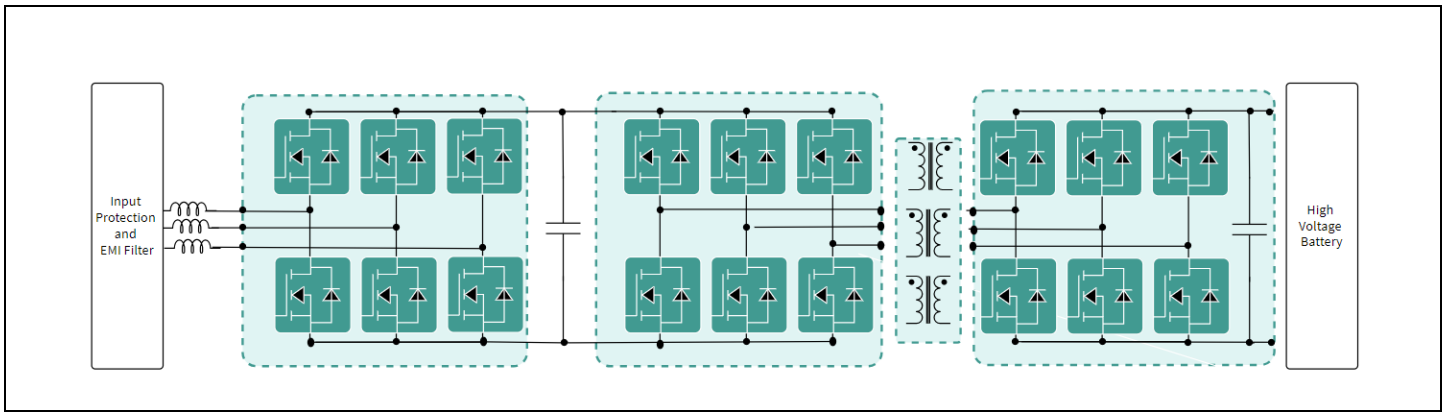


Figure 2 **50 kW EV charger implementation by 3-phase 2-level AC-DC and 3-phase DAB DC-DC converter**

As shown in the examples that follow, 2-level AC-DC converters, non-isolated multi-phase buck-boost converters, resonant 3-phase LLC or CLLC, 3-phase DAB or zero voltage switching (ZVS) converters can be realized by adopting suitable filters or transformer configurations.

The areas of application can be non-isolated DC-DC power stage for energy storage systems (ESS) as shown in Figure 3 , two-stage AC-DC-AC conversion systems for uninterrupted power supplies (UPS)/drives systems as shown in Figure 4, or integration of several energy sources in an EV charging ecosystem as shown in Figure 5.

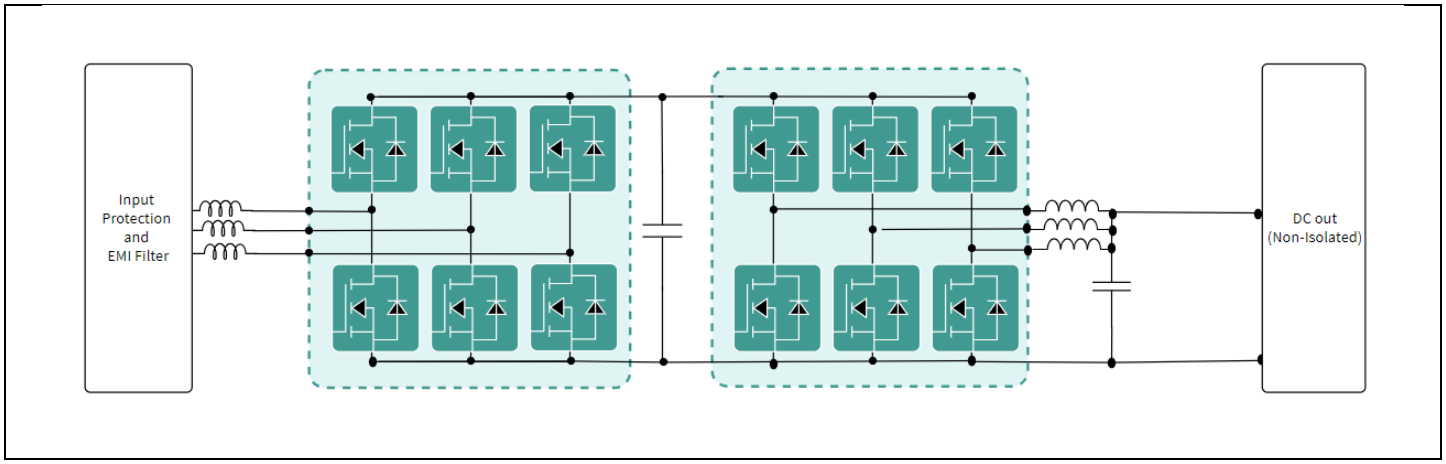


Figure 3 **Implementation of non-isolated multi-phase buck-boost DC-DC topology**

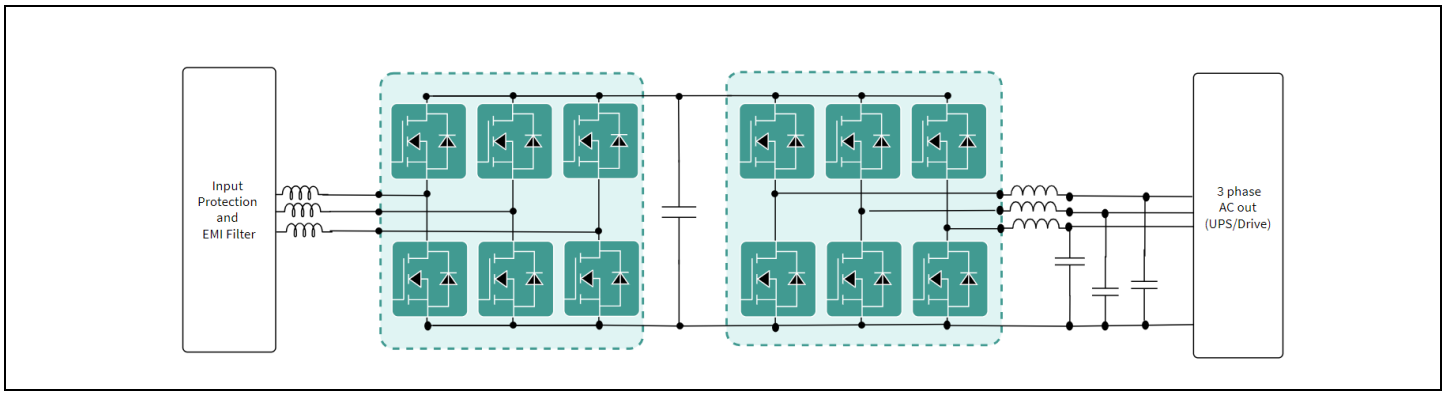


Figure 4 **Implementation of conventional AC-DC and DC-AC 2-level converter topology**

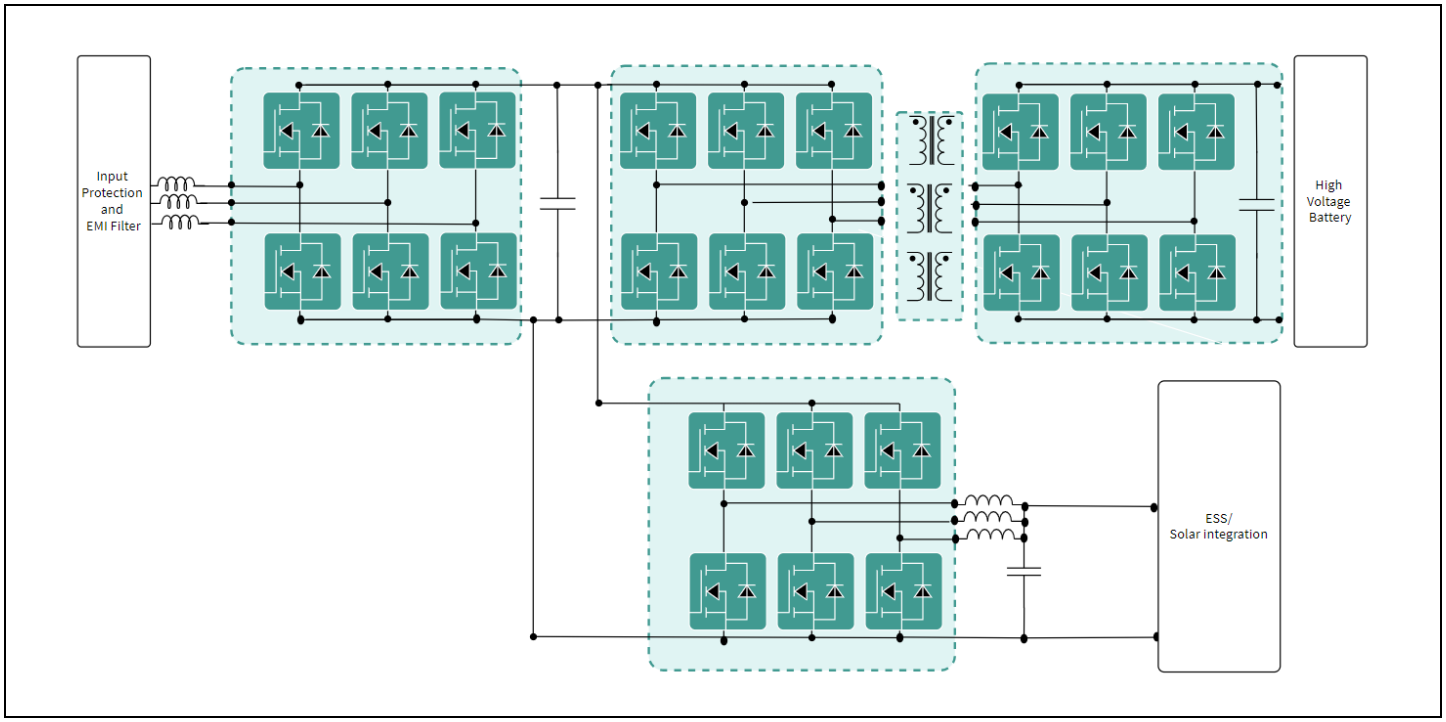


Figure 5 **Integration of different energy sources with same power conversion board**

1.3 Block diagram

Figure 6 highlights the main components from Infineon on the board.

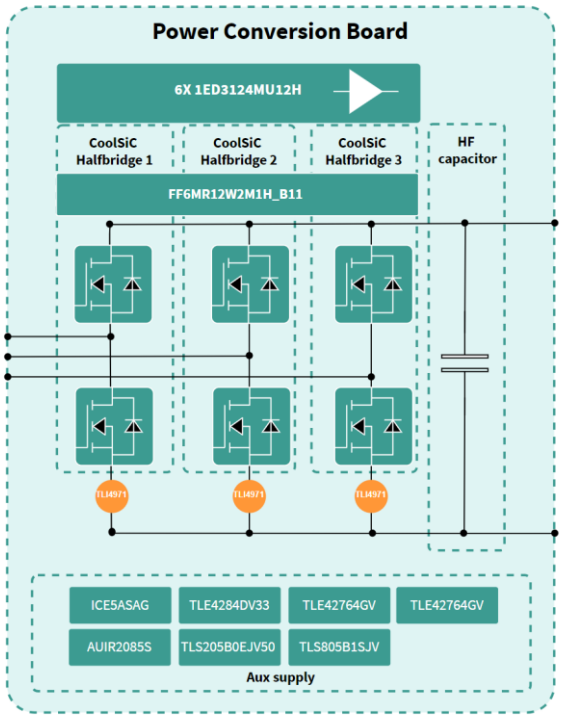


Figure 6 **Main Infineon components on the power conversion board**

Figure 7 is a more comprehensive diagram showing all the components on the boards.

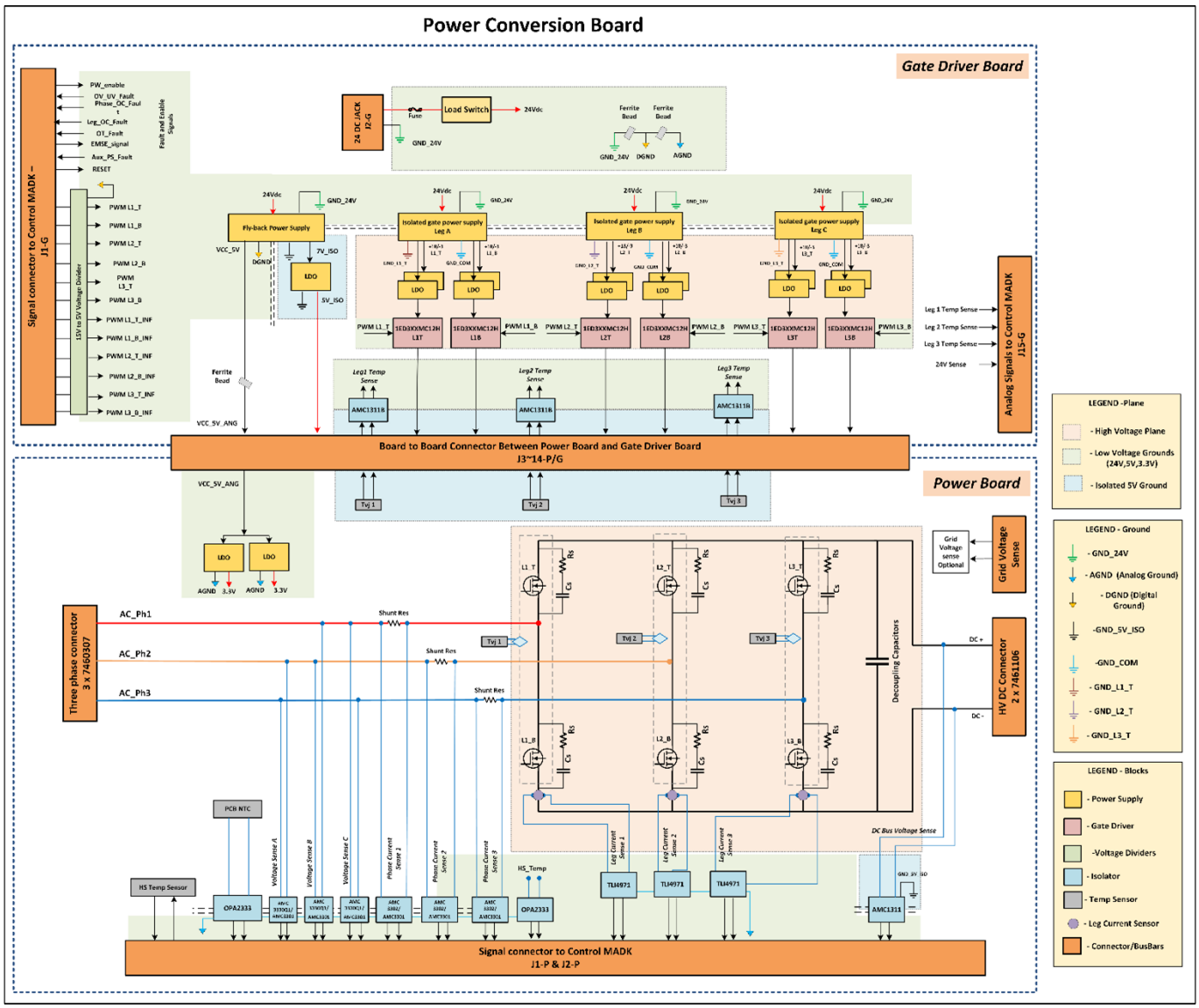


Figure 7 **Block diagram of the power conversion board**

1.4 Board parameters and technical data

Table 2 **Specifications of the power conversion board**

Parameter	Minimum value	Typical value	Maximum value	Unit
DC current range	-	150	-	A
AC voltage (L-L) measurement	-1100	0	+1100	V_{pk}
DC voltage measurement	0	800	1200	V_{dc}
AC-phase current measurement	-300	0	+300	A (I_{pk})
Leg current measurement	-120	0	+120	A
PCB temperature measurement	0	55	85	°C
Heatsink temperature measurement	0	55	85	°C
Leg temperature measurement	0	55	150	°C

Table 3 **Physical specifications of the power board**

Parameter	Value	Unit
Dimensions	290 x 155	mm^2
Thickness	2.86	mm
Copper thickness	4	oz
CoolSiC™ module	FF6MR12W2M1H_B11 (standard)	-
	FF4MR12W2M1H_B11 (optional)	

Table 4 **Physical specifications of the gate driver board**

Parameter	Value	Unit
Dimensions	290 x 155	mm
Thickness	1.6	mm
Copper thickness	1	oz
Gate driver	1ED3124MU12H	-

Table 5 **Variants**

Parameter		REF-2LC50K6MRW2CD	
Module		FF4MR12W2M1H_B11	FF6MR12W2M1H_B11
Gate drive	Positive voltage	18 V	18 V
	Negative voltage	-5 V	-3 V
	On-resistance	5.1 Ω	5.6 Ω
	Off-resistance	3.3 Ω	1.5 Ω
Phase AC voltage sense		Populated	Not populated
Phase AC current sense		Populated	Not populated

2 System and functional description

2.1 Description of the functional blocks

2.1.1 Switching devices

Infineon's CoolSiC™ MOSFET half-bridge module with EasyDUAL™ 2B package has a voltage capability of up to 1200 V with an inbuilt negative temperature coefficient (NTC) temperature sensor. The module comes with advanced PressFIT technology and is available with pre-applied thermal interface material (TIM).

The lowest ON resistance, low switching losses, and low stray inductance help the MOSFET provide the best efficiency over the full load range. Three half-bridges are placed in B6 configuration and a total of six switching devices are used in this design.

The module used is FF6MR12W2M1H_B11.

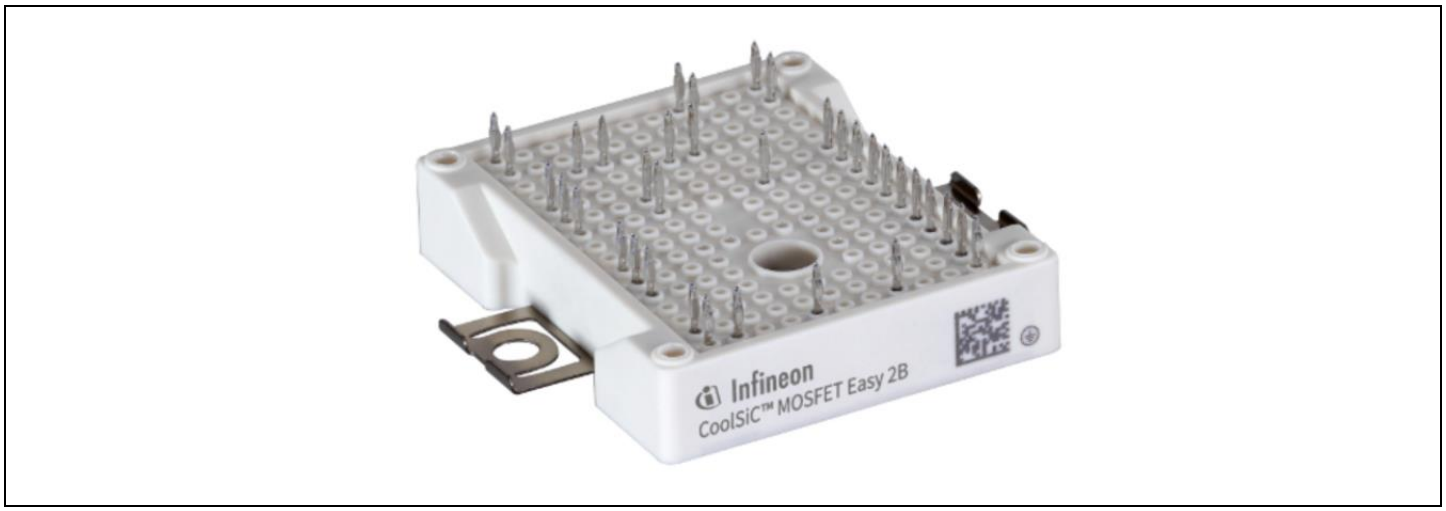


Figure 8 **CoolSiC™ MOSFET Easy 2B**

2.1.2 Gate drivers

Infineon's part number 1ED3124MU12H belongs to the EiceDRIVER™ family.

The part number 1ED3124MU12H is a single-channel isolated gate driver with 14 A typical sinking and sourcing peak output current in DSO-8 wide-body package. The driver can operate over a wide supply voltage range, either unipolar or bipolar.

The driver 1ED3124MU12H has a creepage distance of more than 8 mm that helps in isolation and provides:

- Separate sink and source output
- Accurate and stable timing
- Active shutdown to ensure a safe, insulated-gate bipolar transistor off-state in case the output chip is not connected to the power
- Short-circuit clamping to limit the gate voltage during short circuit

The gate driver is used to drive the SiC MOSFET modules and, therefore, provide isolation between the high voltage and the low voltage circuits. The SiC MOSFET modules are driven with a bipolar gate drive voltage of +18 V/-3 V. The gate driver circuit can be seen in Figure 9.

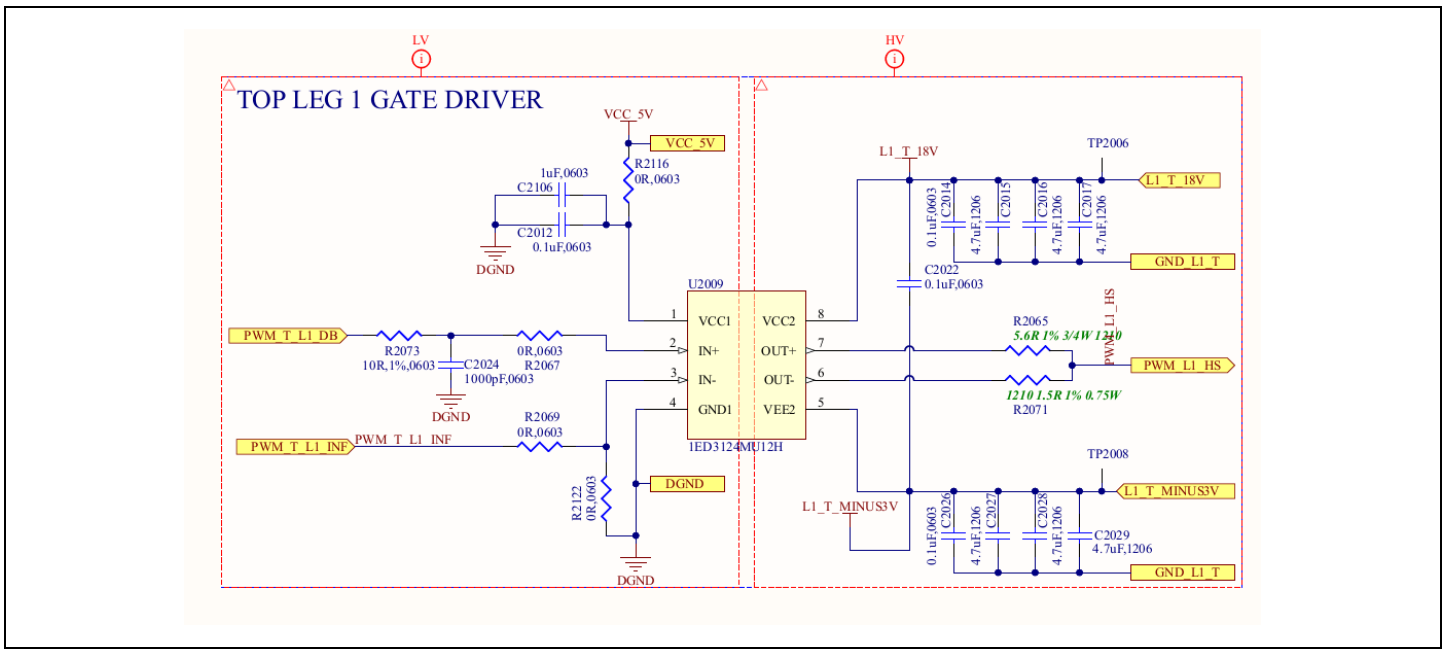


Figure 9 **Gate driver reference circuit**

2.1.3 Internal power supplies

The power conversion board requires an external 24 V supply for biasing all the internal components. The block diagram shown in Figure 10 illustrates the power supply architecture of the power conversion board. The dotted lines through the blocks indicate functional isolation. Explanation for each section and detailed diagrams are provided subsequently in the chapter.

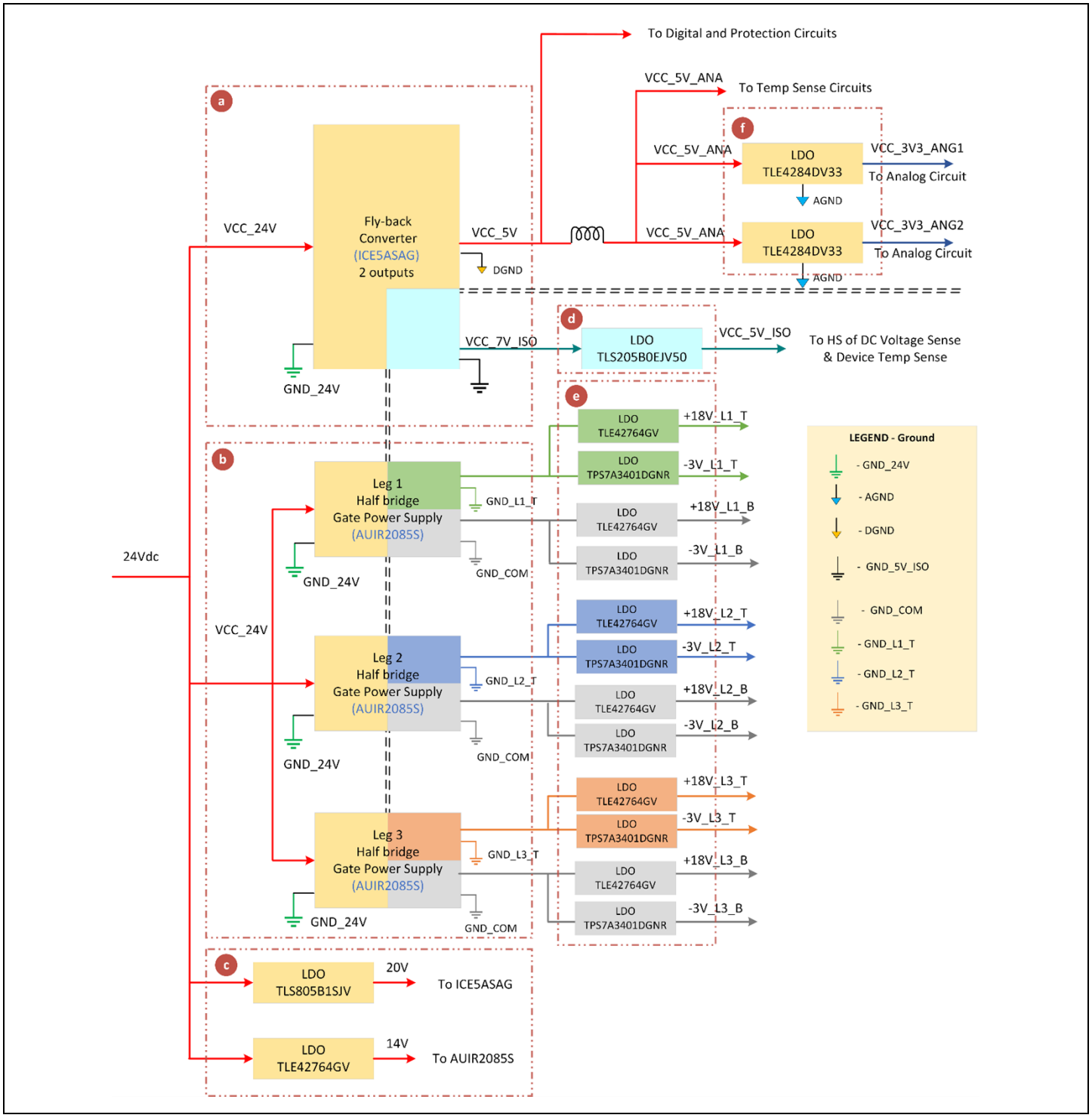


Figure 10 **Low voltage supply scheme**

(a) **Multi-output flyback converter (5 V and 7 V):** The flyback power supply generates two outputs – +5 V_{dc} (regulated) and +7 V_{dc} (unregulated) for signal conditioning, control, analog, and digital circuits. The ICE5ASAG, a 5th generation fixed frequency PWM controller, is used for the flyback power supply. It generates a fixed frequency PWM of 100 kHz to drive the external MOSFET. The output voltage of 5 V in the secondary side is fed back to the primary to regulate the output voltage.

Table 6 **Flyback power supply specifications**

Parameter	Minimum	Typical	Maximum	Unit
Input voltage	22.8	24	25.2	V_{dc}
Output voltage 1	4.75	5	5.25	V_{dc}
Output voltage 2	-	7	8	V_{dc}
Output current 1	-	-	650	mA
Output current 2	-	-	75	mA
Switching frequency	-	100	-	kHz
Flyback IC used	ICE5ASAG			-

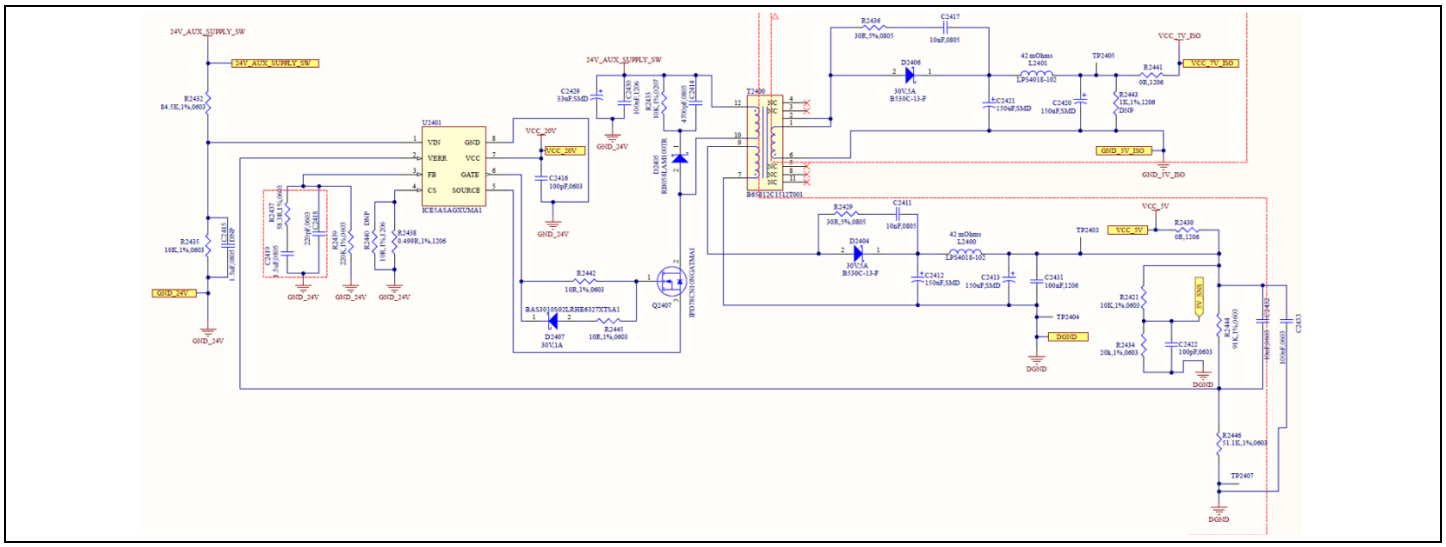


Figure 11 **Flyback converter**

(b) **Multi-output, half-bridge converter:** The gate driver board has a total of three half-bridge power supplies for three individual legs. The half-bridge driver IC, AUIR2085S, is used to generate 150 kHz fixed duty cycle PWM of 50% to the external MOSFETs for the half-bridge operation. The switching frequency of the half-bridge controller IC is programmable up to 150 kHz and currently set to 150 kHz. A low dropout regulator (LDO) is used to convert the 24 V supply to 20 V which is the V_{CC} to the half-bridge IC. The gate power supply consists of a half-bridge configuration with isolated output to generate +20 V and -9 V for the top and bottom switch of each leg of the SiC module. This output voltage is fed into two LDOs to generate +18 V and -3 V power supply for the gate drivers. Each leg has a separate gate driver power supply.

Table 7 **Half-bridge power supply specifications**

Parameter	Minimum	Typical	Maximum	Unit
Input voltage	22.8	24	25.2	V_{dc}
Output voltage 1, 3	20	-	24	V
Output voltage 2, 4	-10	-	-12	V
Output current 1, 2, 3, 4	-	60	-	mA
Switching frequency	-	150	-	kHz
Half-bridge IC	AUIR2085S			-

The gate drivers are provided with an isolated supply voltage derived from the gate driver power supply along with the LDO. The following figure shows the power supply architecture for the gate power supply.

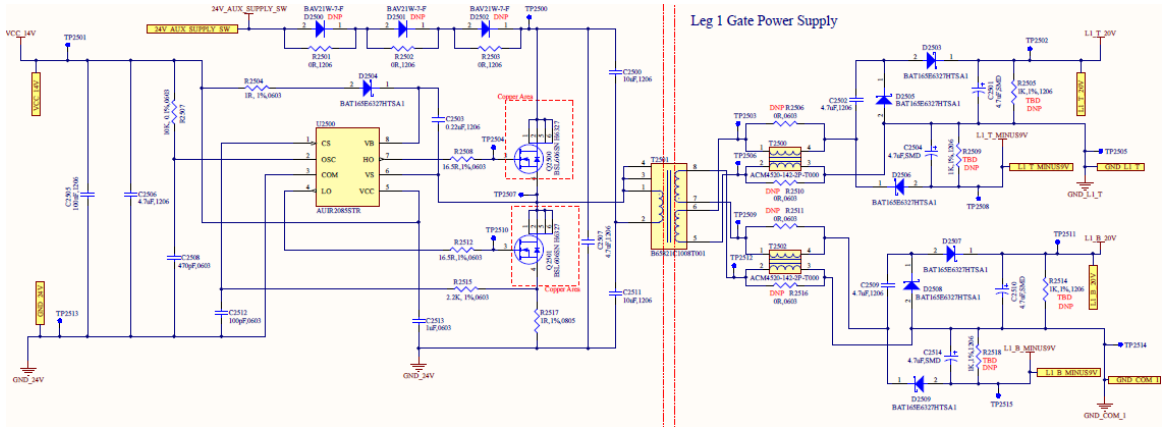


Figure 12 **Leg 1 gate power supply**

(c) **LDO for flyback and half-bridge controller IC:** The fixed frequency controller IC ICE5ASAG requires a V_{cc} voltage between 16.5 V to 24 V for operation. TLS805B1 LDO is used to provide 20 V from the 24 V input power supply for the flyback controller IC. The LDO has an adjustable wide output voltage range from 2.75 V to 42 V and an output current capacity of up to 50 mA. It is also equipped with output-current-limit and overtemperature protection.

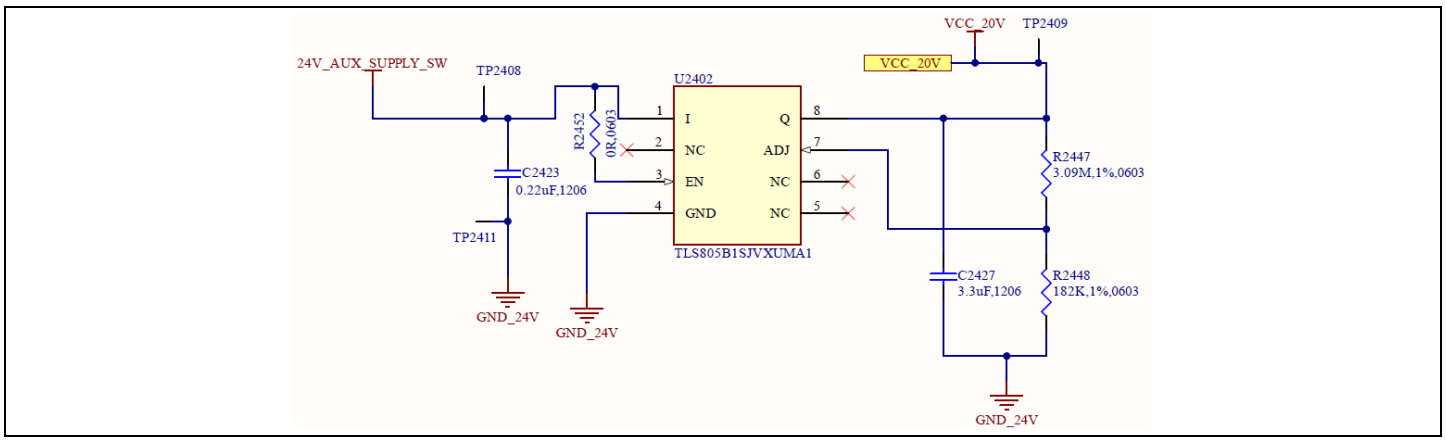


Figure 13 **LDO for gate driver IC**

Similar to the flyback controller IC, the half-bridge controller, IC AUIR2085S, requires a V_{cc} supply voltage between 10 V to 15 V for operation. The LDO TLE42764GV is used to provide a 14 V output from the 24 V input power supply. The LDO output can be adjusted from 2.5 V to 20 V by connecting the required voltage divider at the VA pin.

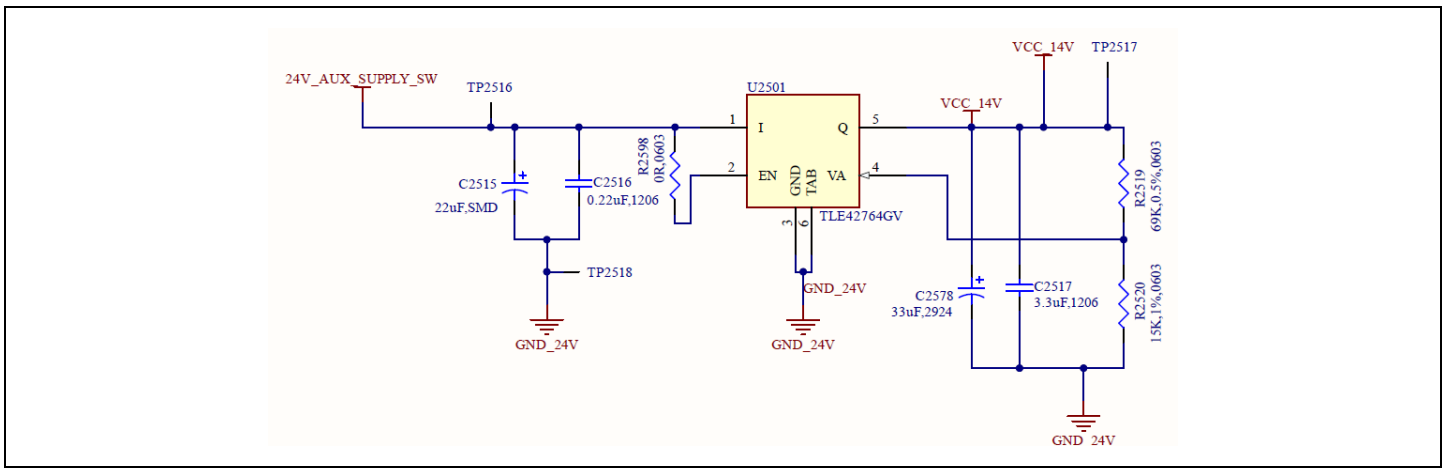


Figure 14 **LDO for flyback IC**

(d) **LDO for voltage and temperature sense:** The voltage and temperature sense isolation amplifier, AMC1311, requires a high side power supply of 5 V isolated. Therefore, from the 7 V unregulated output voltage of the flyback power supply, a fixed output voltage LDO, TLS205B0EJV50, is used to generate a 5 V output. The LDO is capable of an output current of up to 500 mA.

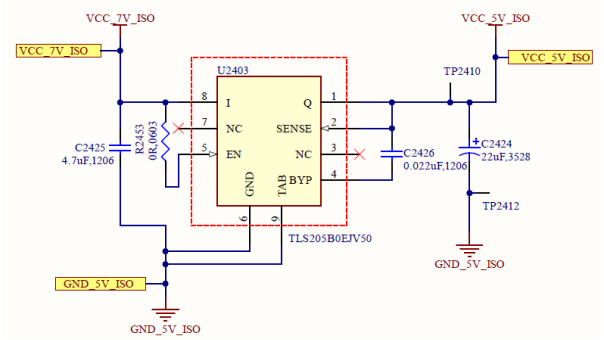


Figure 15 **LDO for voltage and temperature sense**

(e) **LDO for gate drivers:** The 20 V and -9 V outputs from the half-bridge converter should be regulated to 18 V and -3 V. The adjustable output voltage LDO, TLE42764GV, is used to generate a stable 18 V from the 20 V and provided to the gate driver. Similarly, the adjustable output voltage LDO, TPS7A3401, is used to generate -3 V from the -9 V and provided to the gate driver.

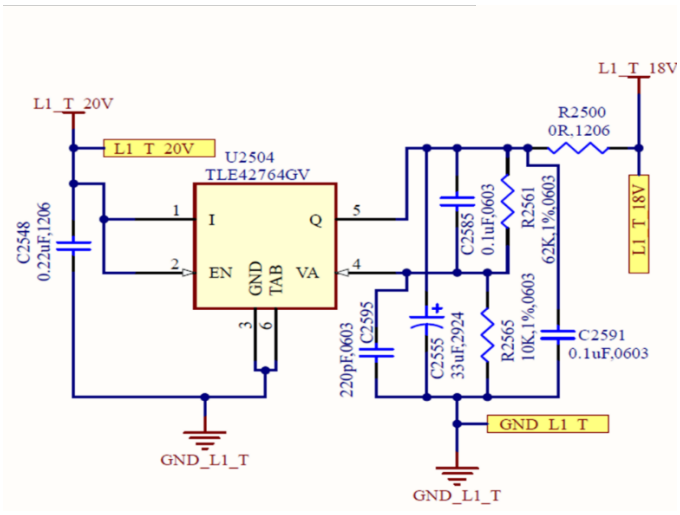


Figure 16 **18 V LDO for gate drivers**

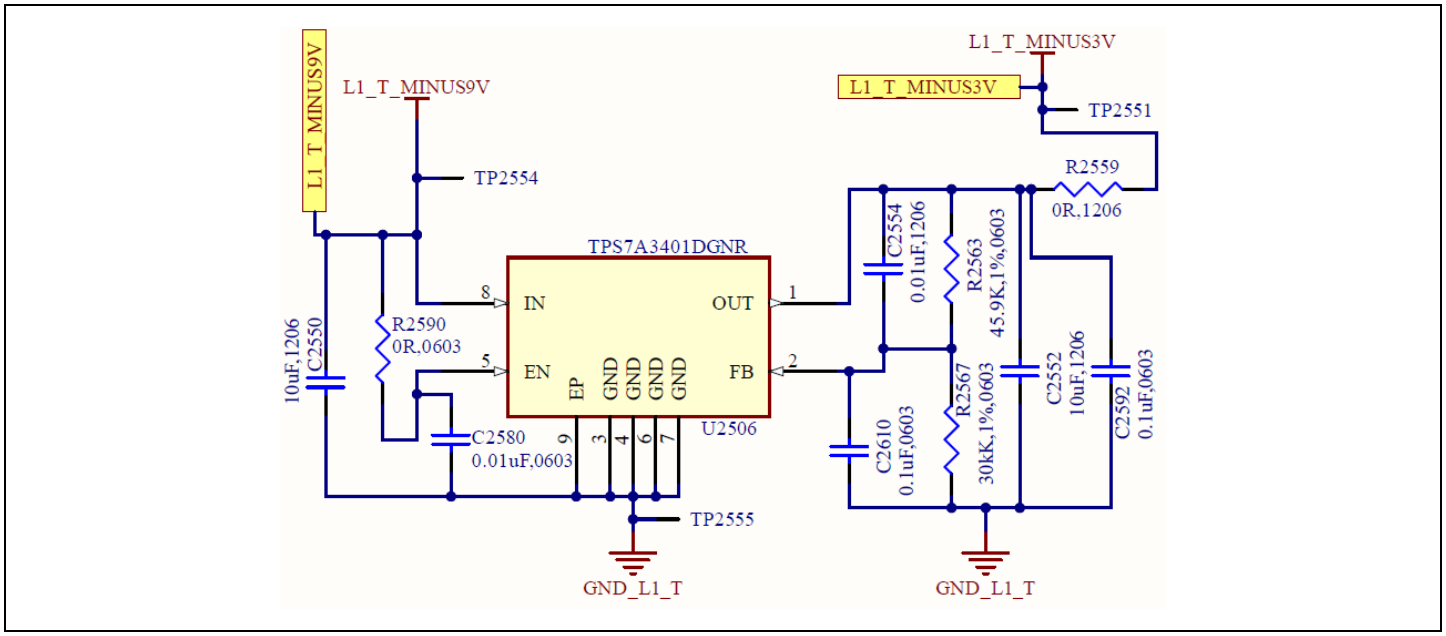


Figure 17 **-3 V LDO for gate drivers**

(f) **LDO for analog and digital circuits:** The isolation amplifiers in the power board for DC and AC voltage, current, and temperature sensing require a 3.3 V low side voltage for operation. Therefore, from the regulated 5 V non-isolated power supply from the secondary side of the flyback transformer a fixed output voltage LDO, TLE4284DV33, of 3.3 V is used to supply an output current of up to 1 A.

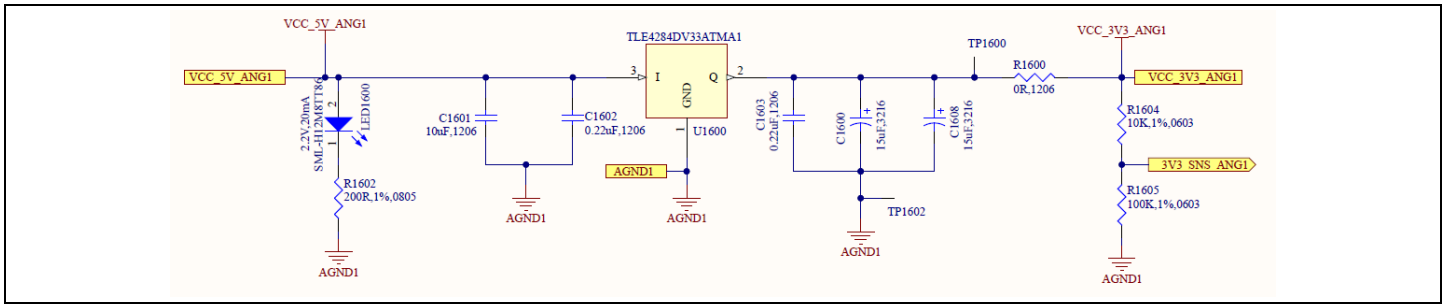


Figure 18 **LDO for analog and digital circuits**

2.1.4 Printed circuit board temperature sense

The NTC thermistor, B57452V5103H062, is used to measure the temperature of the printed circuit board (PCB). A voltage regulator circuit is used to provide a 3 V reference voltage to the amplifier. The temperature measurement of the thermistor ranges from -20°C to 100°C.

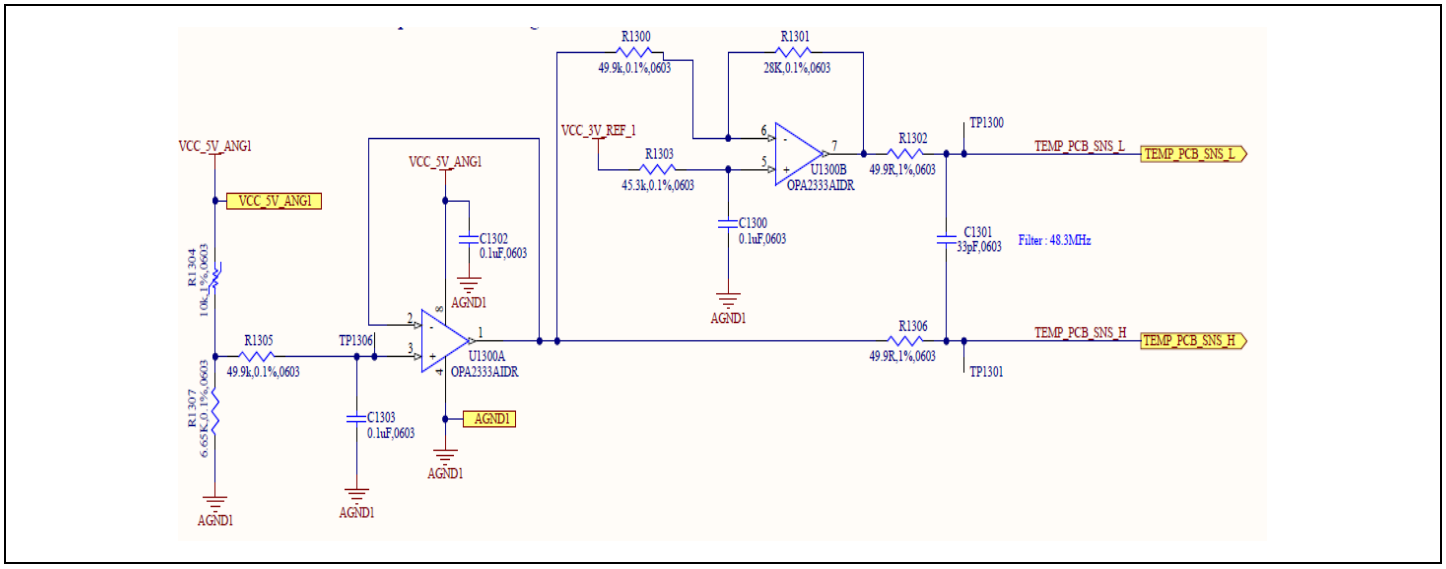


Figure 19 **PCB temperature sense**

2.1.5 Heatsink temperature sense

The screw type NTC thermistor, B57703M0103G040, is used to measure the heatsink temperature. The voltage regulator circuit is used to provide a 3 V reference voltage to the amplifier. The temperature measurement of the thermistor ranges from -20°C to 100°C.

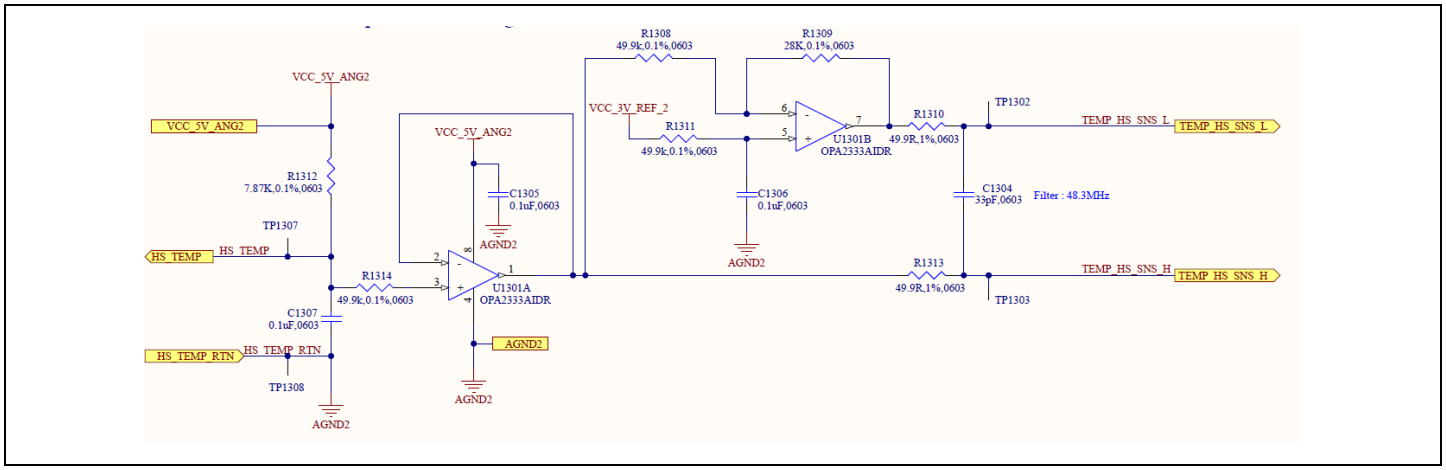


Figure 20 **Heatsink temperature sense**

2.1.6 Module leg temperature sense

The temperature of the power SiC module is measured with a module integrated NTC resistor. The NTC resistor is connected to a 5 V isolated upply with the resistor divider network. The resulting NTC voltage is fed to the power control board through an isolation amplifier, AMC1311, with a voltage gain of 2 V. Three such temperature sensing blocks measure each leg separately.

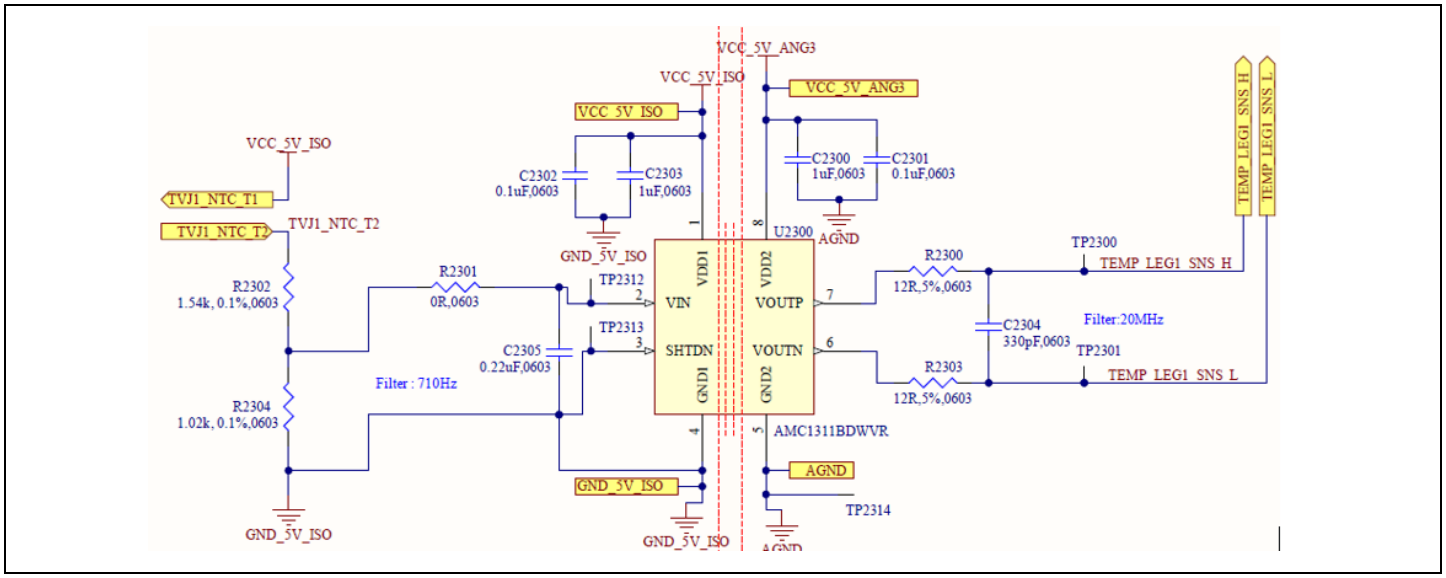


Figure 21 **Module leg temperature sense**

2.1.7 AC line-to-line voltage sense

The isolation amplifiers are used to measure the AC input voltage for all three phases. The voltage is scaled down using the resistor network and provided as an input to the amplifier. A filter circuit is provided to eliminate any noise in the input signal. The amplifier, AMC3330, isolates the high voltage input with the low voltage output and provides an amplified signal based on the voltage gain of the amplifier. The differential signals are then given to the power control board for a single-ended conversion that is then fed to the microcontroller. The differential signals are used for hardware fault detection and protection. The amplifier has an internal DC-DC converter that eliminates the requirement of an additional supply for the HV side. Each one of the three voltage sensing blocks is measured between line-to-line. The maximum voltage at the isolation amplifier's input is ±1 V. The resistor network for the voltage divider between line-to-line is set up to keep the peak voltage of the isolation amplifier's input below ±1 V.

The AC line-to-line voltage is measured for the closed loop of the AFE stage for power factor correction. Also, the 3-phase input and output of the transformer is measured to check any voltage imbalance between the phases.

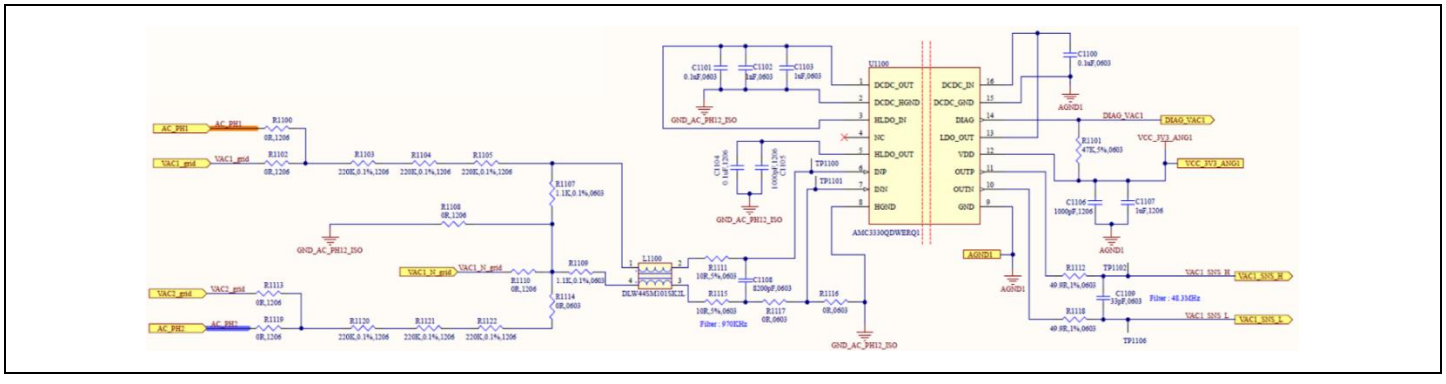


Figure 22 **AC line-to-line voltage measurement**

2.1.8 DC voltage sense

The DC output voltage must be monitored for output voltage regulation. The voltage feedbacks are isolated through an isolation amplifier AMC1311. The IC has an input voltage range of 2 V and an input impedance of 1 GΩ. Unity gain differential outputs with an isolation of 5 kV from the inputs. The input is scaled down to a 2 V range using a resistor network. The isolated amplified differential outputs are sent to the control board for a single-ended conversion which is then fed to the microcontroller.

To get a regulated DC bus voltage of 800 V, the DC bus voltage is measured in the AFE closed loop stage. Also, the DC voltage is measured at the charger output for closed loop control of the DAB converter stage.

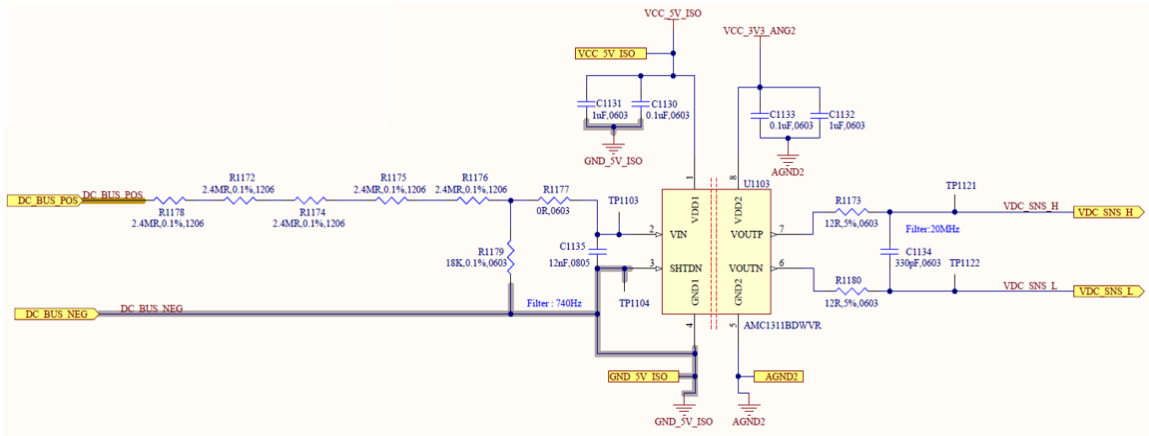


Figure 23 **DC voltage measurement**

2.1.9 24 V DC voltage sense

A voltage of 24 V generated from an external power source or switched mode power supply board (SMPS) is used as an input voltage for all internal power supplies through the DC jack. As the voltage is provided from an external source, monitoring the voltage is required to ensure that the voltage is within the specified range. A voltage divider circuit is used to get the 24 V sense voltage, before and after the series pass MOSFET. The sense signal (24V_SNS_SW) is then fed to the microcontroller to receive the enabled signal from the power control board only if the voltage is within the allowed range of 24 V.

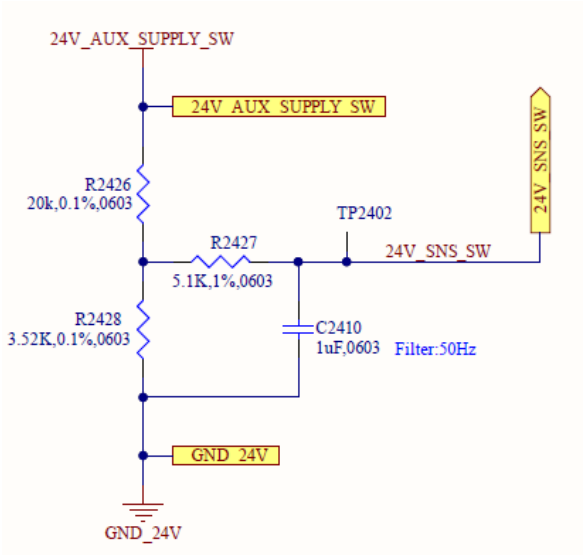


Figure 24 **24 V DC voltage measurement block diagram**

2.1.10 Phase current sense

Phase currents are measured using a current shunt resistor along with the isolation amplifier. To ensure that the current is in-phase with the voltage, the grid phase currents are measured for AFE. To make sure that the transformer is not saturating and to protect the switches from high current, the phase currents in the DAB converter primary phase and secondary phase can be measured as well.

The shunt value of 300 µΩ has a maximum voltage drop of 50 mV across to carry 160 A in the AFE stage. The shunt value of 100 µΩ has a maximum voltage of 30 mV for carrying 300 A in the DAB stage. A shunt resistor, from the manufacturer Vishay, with part number WSLP5931L3000FEB is used for the AFE stage and another with part number WSLP5931L1000FEA is used for the DAB stage measurement.

AMC3302 is a precision isolation amplifier with an output separated from the input circuitry. The device prevents noise currents on a high common-mode voltage line from entering the local ground and damaging or interfering with the sensitive circuitry. The device provides galvanic isolation between the high and low voltage sides. This amplifier has an internal DC-DC converter and, therefore, requires a single supply voltage. The isolated amplified differential outputs are sent to the power control board for a single-ended conversion which is then fed to the microcontroller.

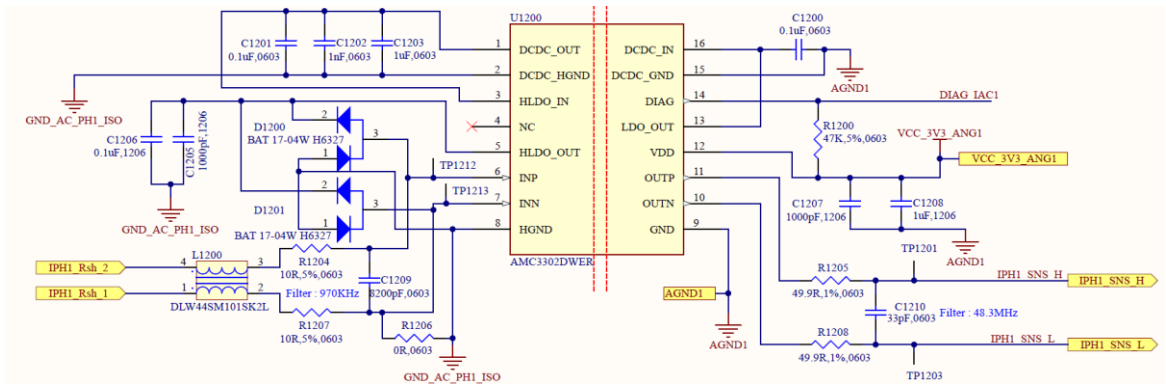


Figure 25 **Phase current measurement block diagram**

2.1.11 Leg current sense

The current sensor, TLI4971, measures the leg current for the three legs in the power conversion board. TLI4971 is a high-precision, miniature, coreless magnetic current sensor for AC and DC measurements with an analog interface and dual fast overcurrent detection (OCD) outputs. The IC must be programmed for a differential output mode of operation and the OCD threshold values have to be programmed.

OCD1 and OCD2 have two threshold values each. OCD2 is provided to the microcontroller for software protection and OCD1 is for hardware protection.

Differential outputs are provided to the power control board for measuring the phase current.

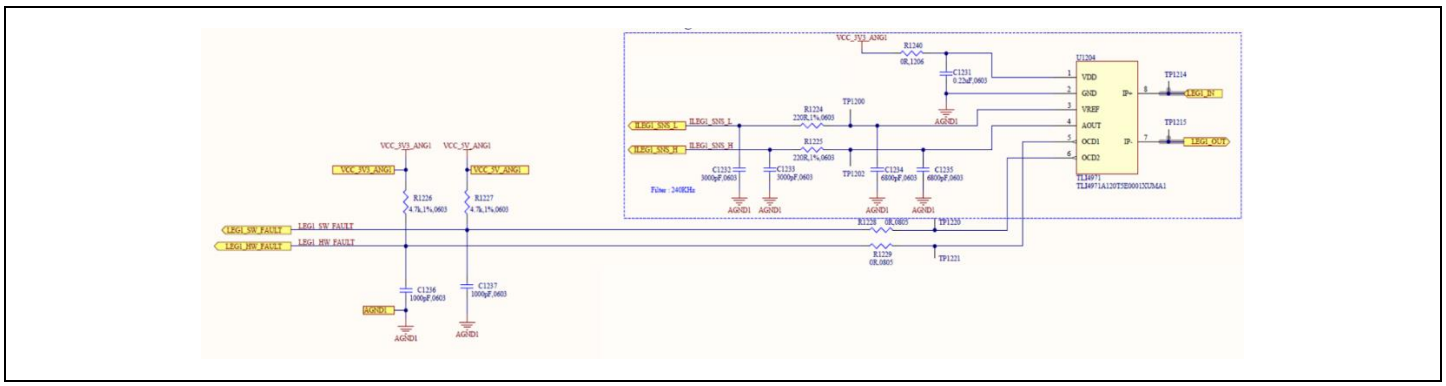


Figure 26 **Leg current sense**

2.1.12 Decoupling capacitors

A decoupling capacitor is used to minimize or suppress a high frequency voltage ripple. To eliminate the voltage ripple, the capacitor absorbs it. Film capacitors that are placed adjacent to the bridge network are used for this. The capacitance value of these capacitors should be greater than the capacitance of the snubber capacitors.

A total of six decoupling capacitors (B32654A1154J000/B32654A1224J000) are mounted on the board, each of 0.15 uF/0.22 uF, to minimize the voltage ripple and maintain constant output voltage.

The decoupling capacitors are highlighted in Figure 27 by blue blocks.

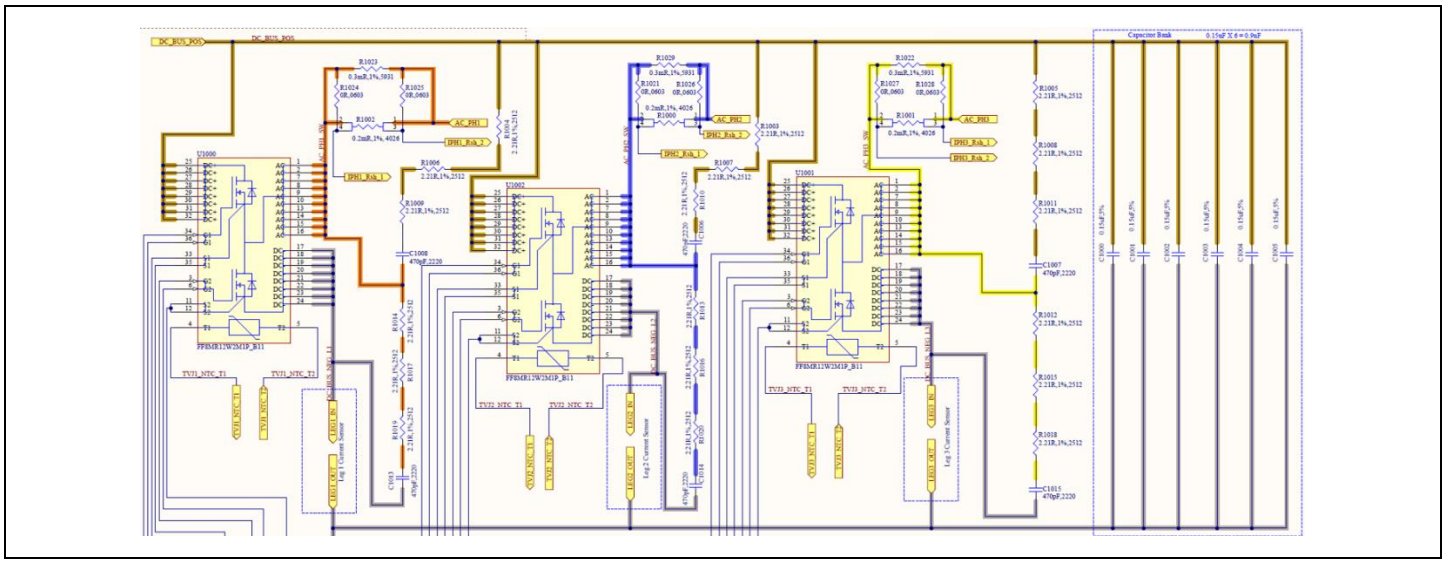


Figure 27 **Decoupling capacitors**

2.1.13 Snubber circuit

Snubber circuits limit the current and voltage stress on the semiconductor devices during turn ON and turn OFF transitions.

To reduce oscillations caused by switching, resistor-capacitor (RC) snubbers are placed close to the switching devices. To protect the MOSFETs during turn ON and turn OFF transitions, a separate RC snubber is implemented for each MOSFET. This snubber circuit reduces the voltage spike across the switch and the ringing frequency.

The snubber components are highlighted in Figure 28 by blue blocks.

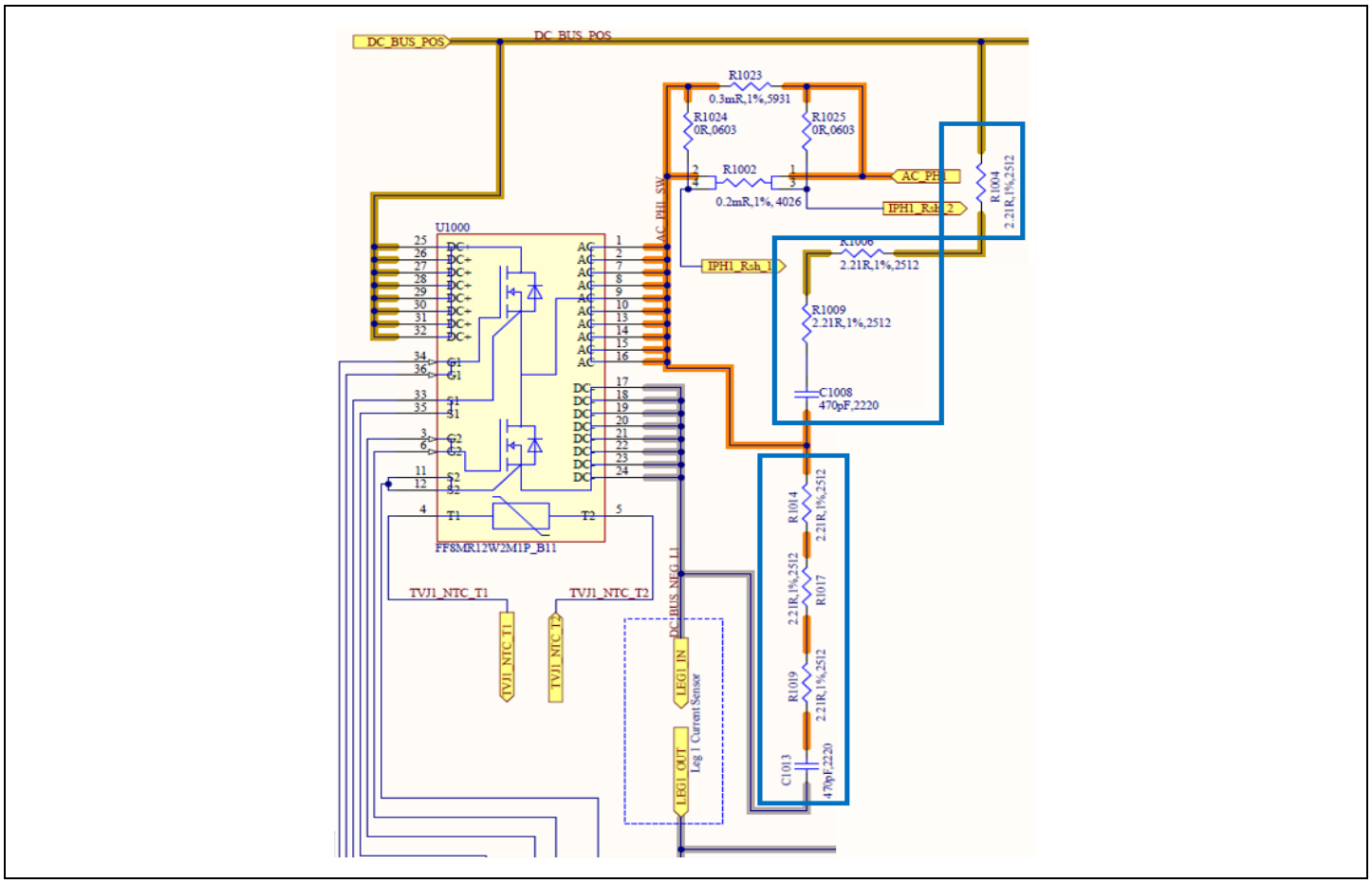


Figure 28 **Snubber components**

2.1.14 Level shifter

A level shifter or voltage level translator is a circuit used to translate the signal from one voltage level to another. Thereby allowing compatibility between devices with different voltage requirements.

PWM signals are sent from the power control board to the gate driver board. Voltage levels are shifted to 15 V in the power control board to prevent the loss of signals during board to board signal transfer. A level shifter is used in the gate driver board to translate the voltage from 15 V to 5 V and then this voltage is fed to the deadband generation circuit.

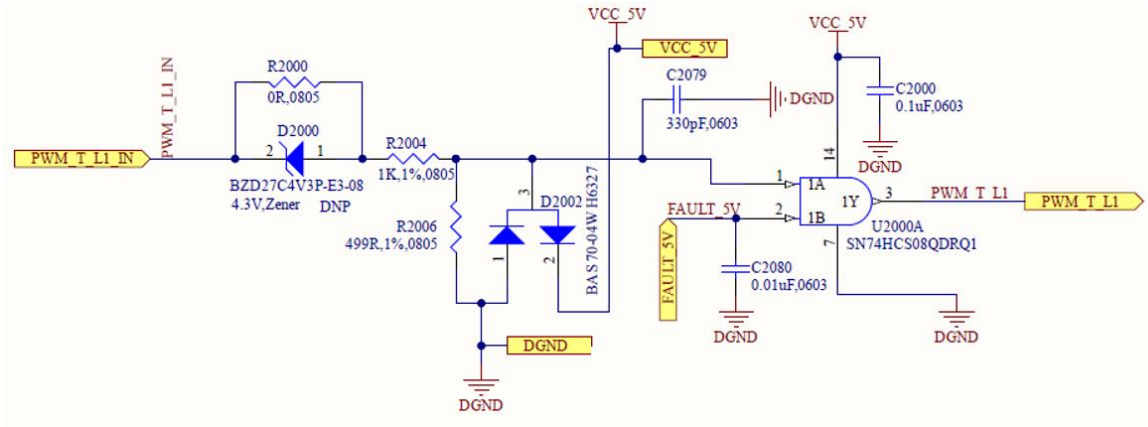


Figure 29 **Level shifter circuit**

2.1.15 Deadband generation

The top and bottom MOSFETs are switched with complementary gate pulses with adequate deadtime. The design of this deadtime is important for the converter operation. Apart from ensuring that the complementary MOSFETs do not get shorted, another very important function of the deadtime is to provide a zero-voltage switching operation. Too less or too high a deadtime affects the converter operation and efficiency. Each leg of the SiC module has a separate deadband generation circuit.

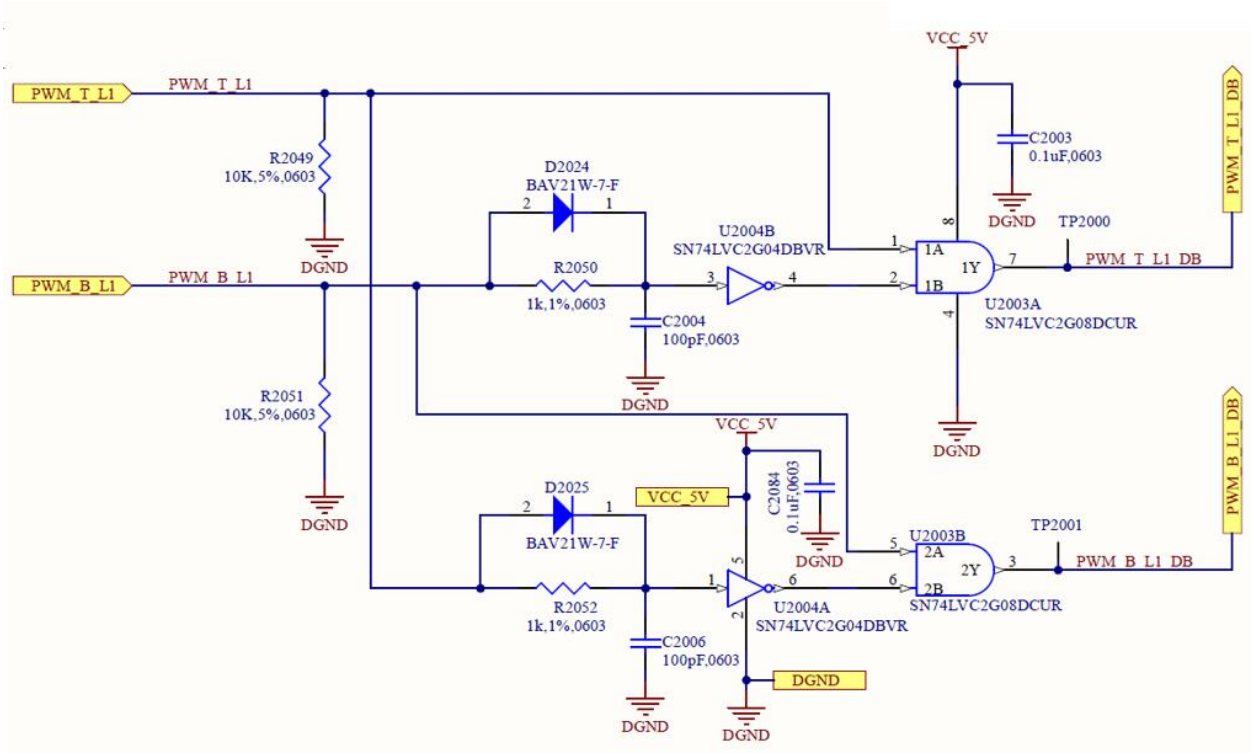


Figure 30 **Deadband generation**

2.1.16 Isolation coordination

The high voltage and low voltage domains of the power conversion boards are isolated from each other using isolation amplifiers, transformers, and gate drivers with a minimum isolation of 5 kV_{rms}.

The high voltage domain includes the 3-phase AC, DC+, DC-, gate drive power supply, and the high side power supply for isolation amplifiers.

The low voltage domain includes a 24 V regulated input power supply, 5 V and 3.3 V power for low power amplifiers, PWM control, protection, and signal conditioning circuitry.

All PCB mounting holes and enclosures are connected to the protective earth.

Creepage distance for isolation in the PCB, considering the minimum clearance required, is as follows:

Table 8 **Creepage distances**

		DC +	DC -	Phase A	Phase B	Phase C	Ground	SELV
		Nominal operating RMS voltage (V) for creepage calculation						
DC +	Creepage distance		800	461	461	461	400	400
DC -		5.5		461	461	461	400	400
Phase A		5.5	5.5		400	400	230	231
Phase B		5.5	5.5	5.5		400	230	231
Phase C		5.5	5.5	5.5	5.5		230	231
Ground		8	8	8	8	8		24
SELV		8	8	8	8	8	8	

	Functional isolation
	Basic isolation
	Reinforced isolation

The operating voltages are calculated using the following formula:

$V_{ph,dc+} = \sqrt{(V_{ph,gnd})^2 + (V_{dc+,gnd})^2}$; for operating voltage between AC phase and DC+/-

$V_{dc+,gnd} = 0.5 \text{ x } V_{dc+}$; for operating voltage between DC+/- to ground

High voltage to high voltage isolation (functional isolation): The Easy 2B CoolSiC™ MOSFET has a clearance of 5.5 mm between the DC+ / DC- and AC pads. Throughout the layout, for a functional isolation between high voltage domains, a minimum of 5.5 mm creepage is maintained in the external layers with pollution degree 2. For internal layers, pollution degree 1 and 3.5 mm creepage are considered.

High voltage to low voltage isolators (reinforced isolation): The isolation amplifiers used in the power board are capable of 7000 V_{pk} of reinforced isolation. Between the HV and LV pins of the isolation differential amplifier, the creepage distance is 7.4 mm. Therefore, 8 to 15 mm creepage is maintained throughout the power board's PCB layout. The TLI4971 current sensor IC used for leg current sensing is capable of an isolation of 2500 V_{rms}.

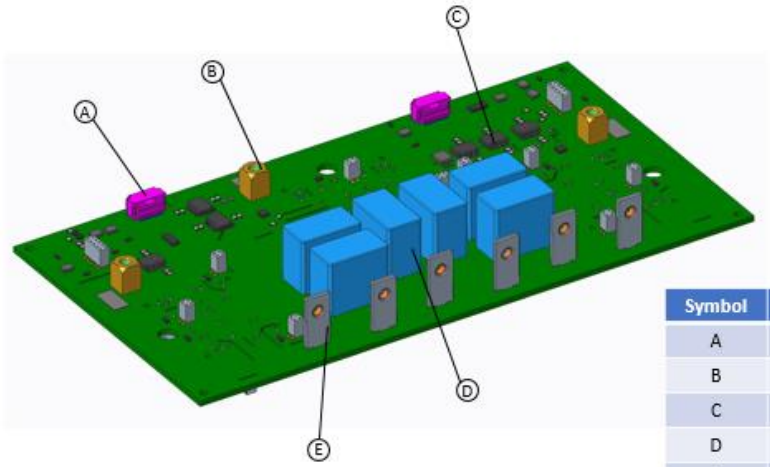
Low voltage isolated supply for temperature and voltage sense: The isolated power supply and transformer used for temperature and voltage measurement can withstand an isolation of up to 5 kV.

Gate driver and gate power supply: The single-channel gate driver IC 1ED3124MU12H is capable of an isolation of 5.7 kVrms between the LV and HV domains. Also, the isolation transformer used in the gate driver power supply is capable of an isolation of 5 kV between the primary (LV) domain and the secondary (HV) domain.

3 Layout, bill of materials, and connectors

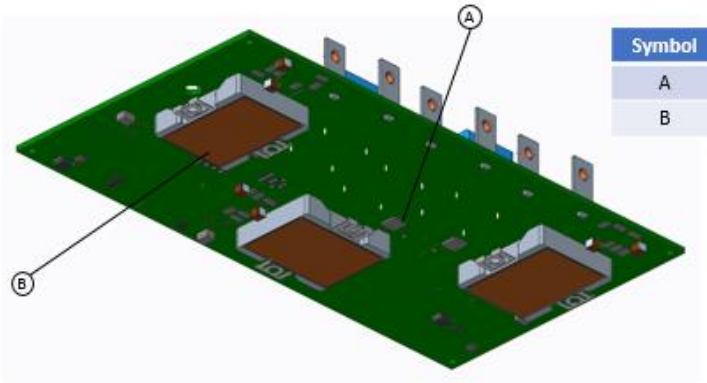
3.1 Layout of the power board

3.1.1 Mechanical layout



Symbol	Description
A	LV Signal Connector
B	AC Bus Bar Connector
C	Isolation Amplifiers
D	High Frequency Film Capacitor
E	DC Bus Bar Connector

Figure 31 **Mechanical layout of the power board (top view)**



Symbol	Description
A	TLI4971 Leg Current Sensor
B	Easy 2B Cool SiC MOSFET

Figure 32 **Mechanical layout of the power board (bottom view)**

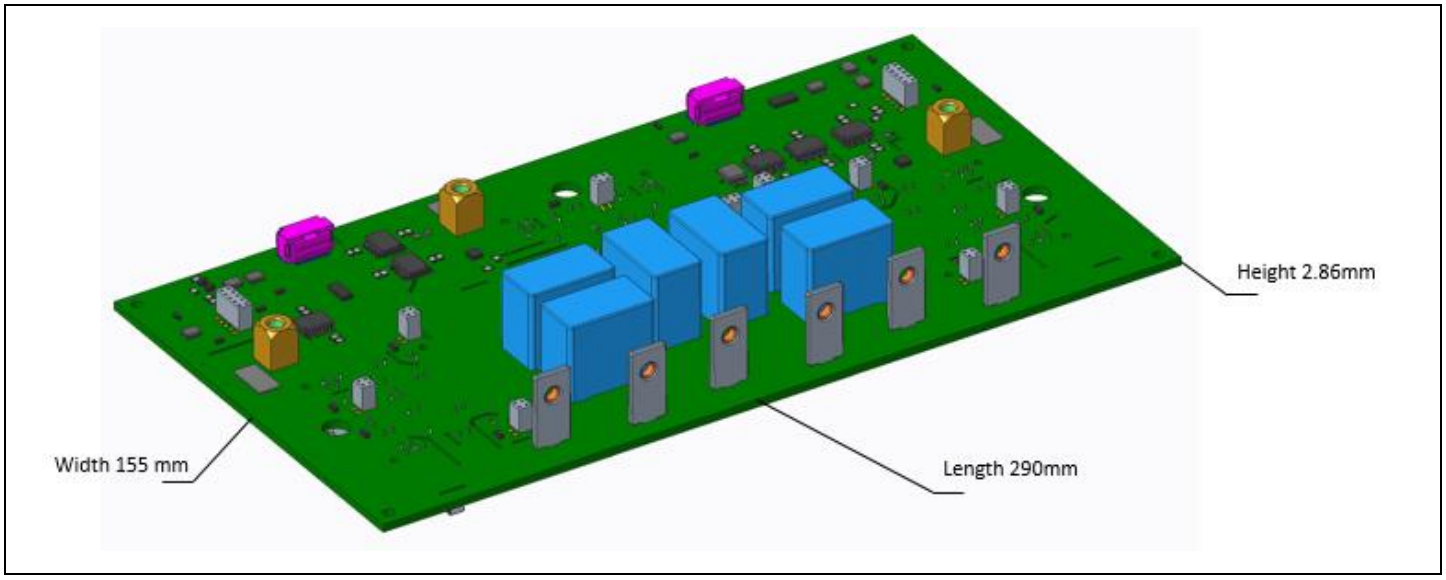


Figure 33 **Mechanical dimensions of the power board**

3.1.2 Electrical layout

The power board is a six layer board made of FR4 material. Table 8 lists the layer stack up of the board. Figures 33–38 show the electrical layout of the board.

Table 9 **Power board layer stack up**

Layer	Name	Material	Thickness (mm)
	Top overlay	-	-
	Top solder	Solder resist	0.02
1	Top layer or layer 1	Copper	0.14
	Dielectric 1	FR-4	0.25
2	Layer 2	Copper	0.14
	Dielectric 2	FR-4	0.617
3	Layer 3	Copper	0.14
	Dielectric 3	FR-4	0.25
4	Layer 4	Copper	0.14
	Dielectric 4	FR-4	0.617
5	Layer 5	Copper	0.14
	Dielectric 5	FR-4	0.25
6	Bottom layer or layer 6	Copper	0.14
	Bottom solder	Solder resist	0.02
	Bottom overlay	-	-

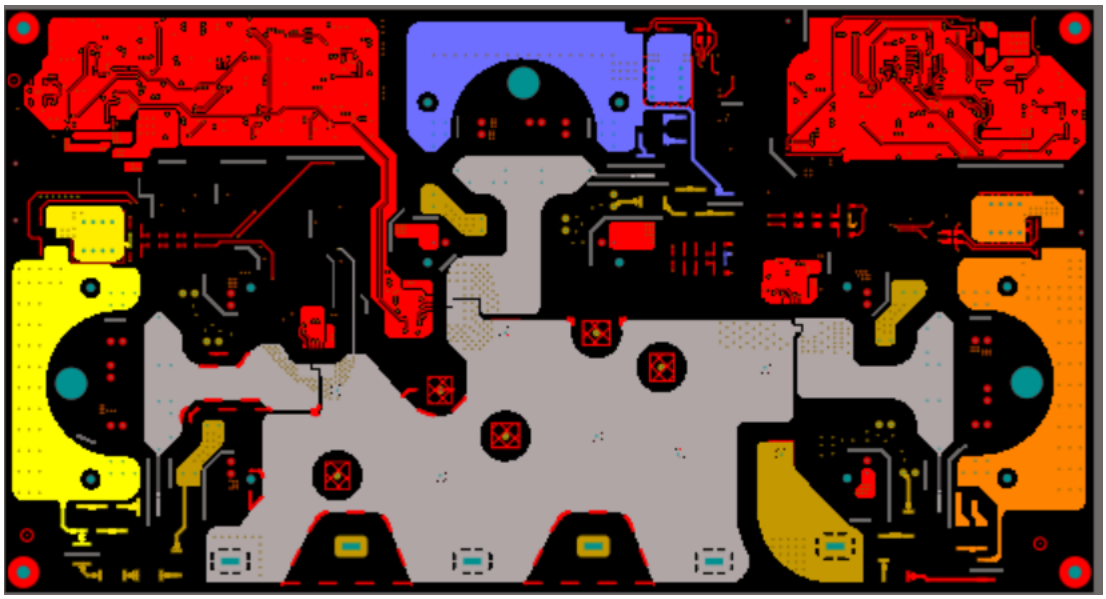


Figure 34 **Top layer or layer 1**

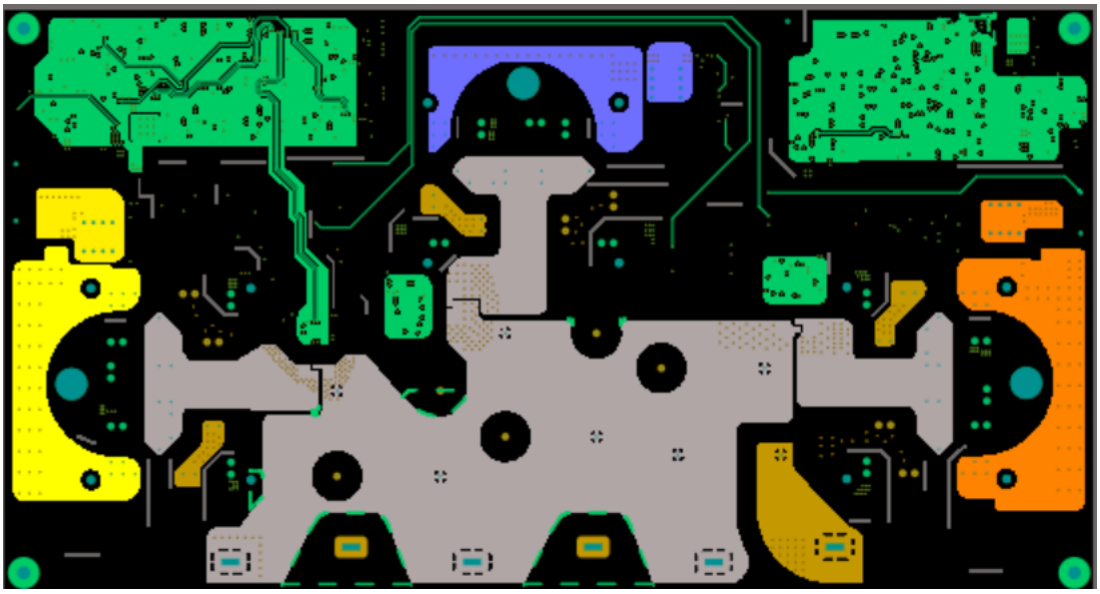


Figure 35 **Layer 2**



Figure 36 **Layer 3**

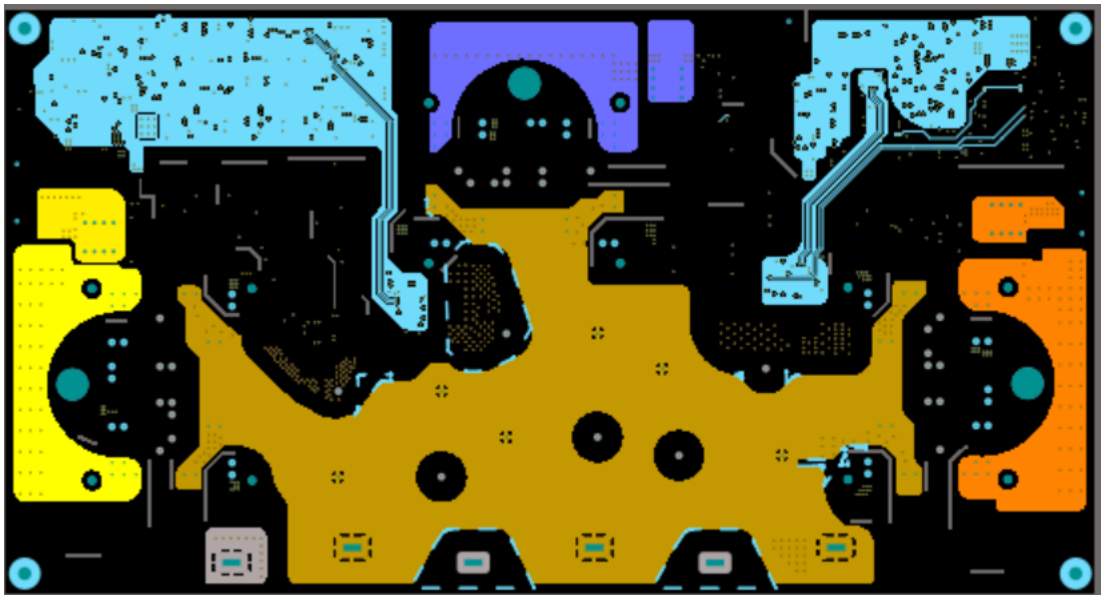


Figure 37 **Layer 4**

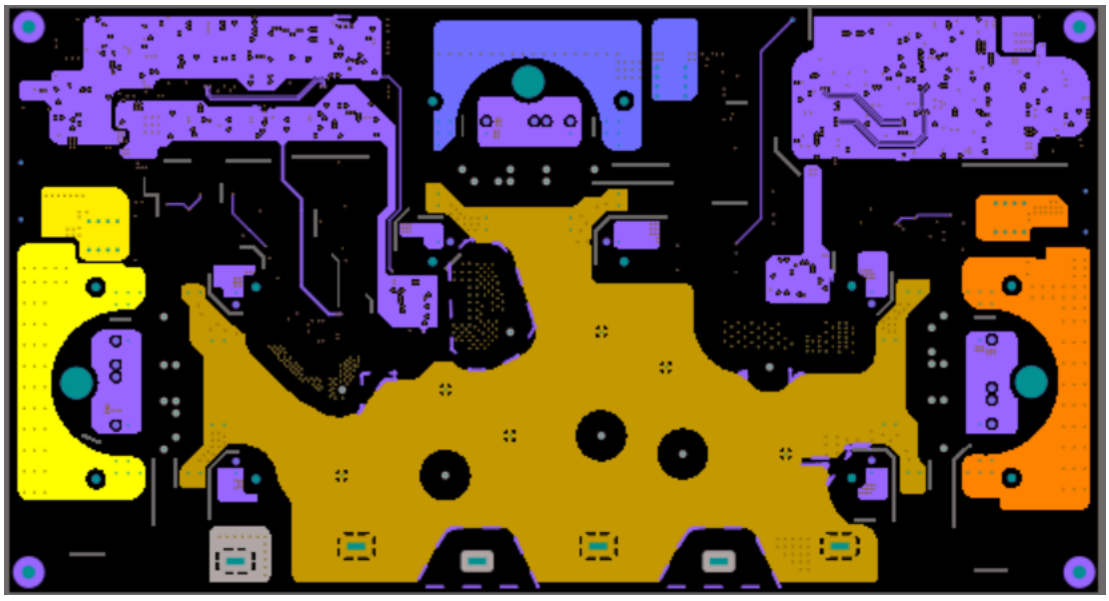


Figure 38 **Layer 5**

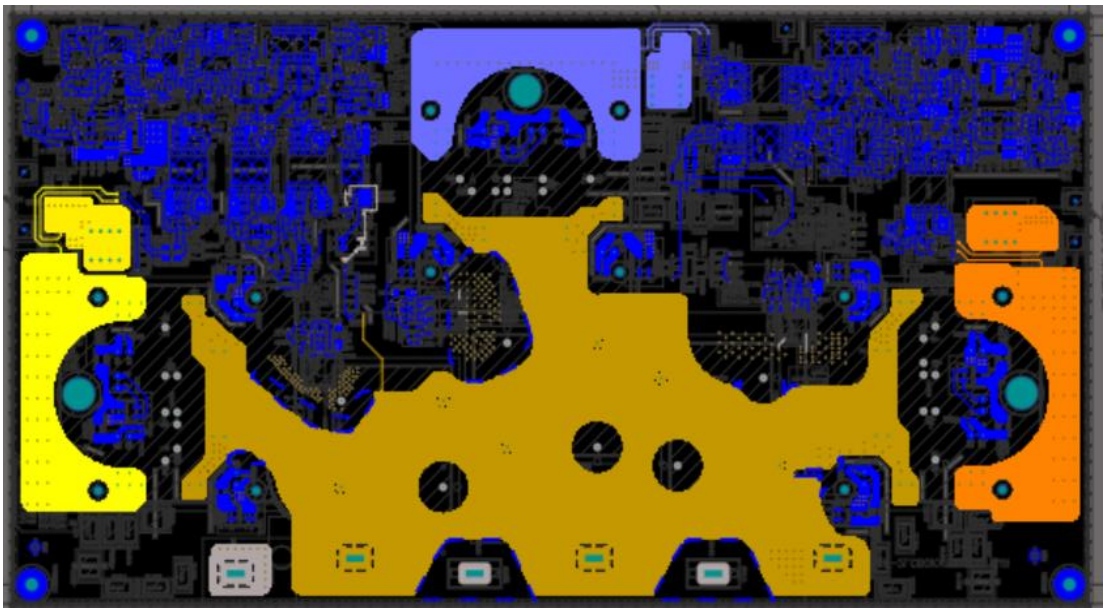


Figure 39 **Layer 6 or bottom layer**

3.1.3 Module mounting on a heat sink

For instructions on how to mount the module on the PCB and the heatsink, please refer to AN2023-07.

The power conversion board is provided with pressed-in modules, and only one mounting hole. Therefore, the screws used to fix the module to the heat sink will need to be fixed from below the heat sink using self-clinching nuts. The drawing of the recommended heat sink can be seen in the Appendix. This method was used only for the purpose of evaluation, A professional design should only refer to the method show in the following application note AN2023-07.

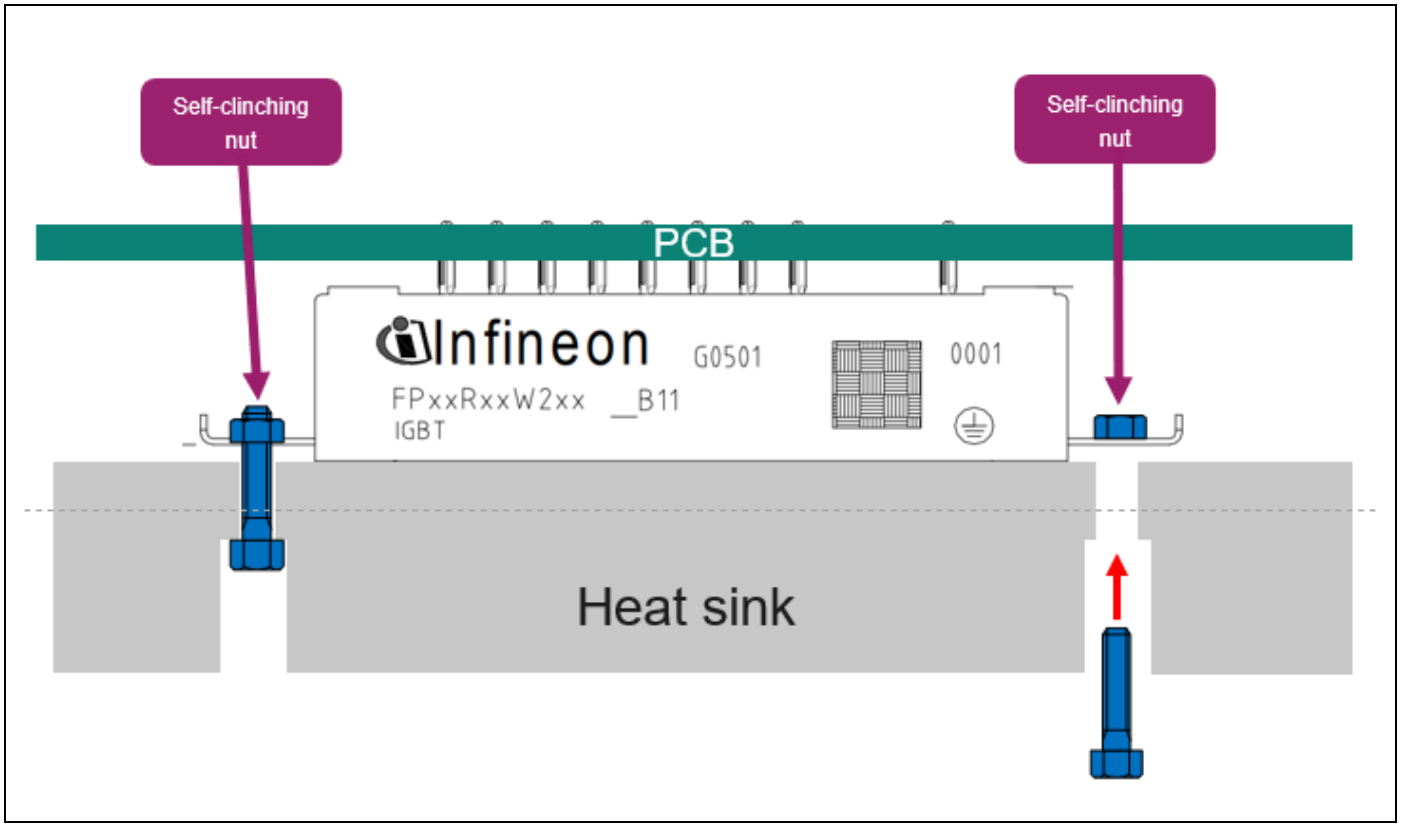
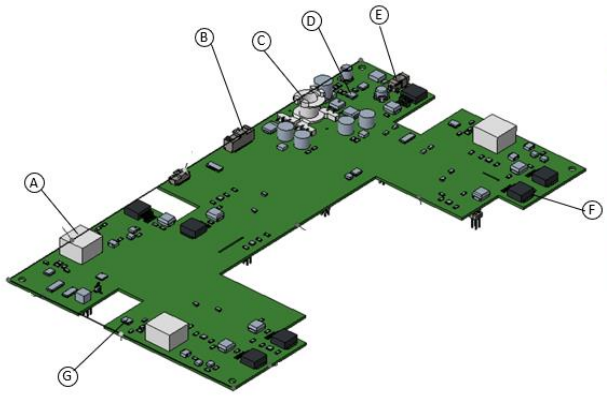


Figure 40 **Mounting the module on the heatsink using a self-clinching nut**



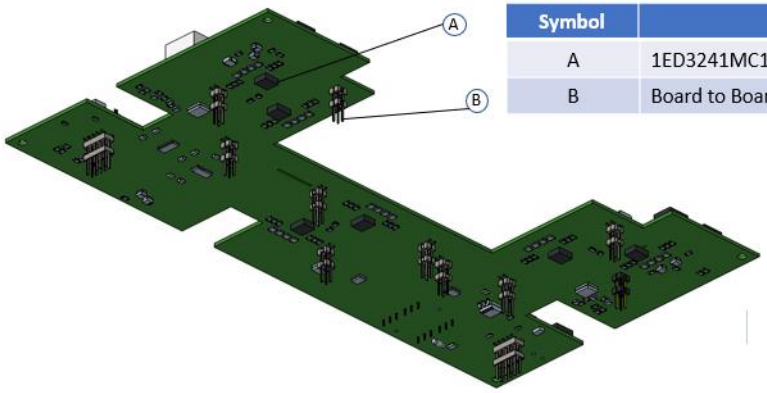
Figure 41 **Mounting the module on the heatsink (example)**

3.1.4 Mechanical layout



Symbol	Description
A	Half bridge Gate Power Supply Transformer
B	LV Signal Connector
C	Fly back Power Supply Transformer
D	ICE5ASAG Fly back Controller IC
E	24V DC Jack
F	TLE42764GV LDO
G	AUIR2085S Half Bridge Driver IC

Figure 42 **Mechanical layout of the gate driver board (top view)**



Symbol	Description
A	1ED3241MC12H/ 1ED3124MU12H Gate Driver IC
B	Board to Board Connectors

Figure 43 **Mechanical layout of the gate driver board (bottom view)**

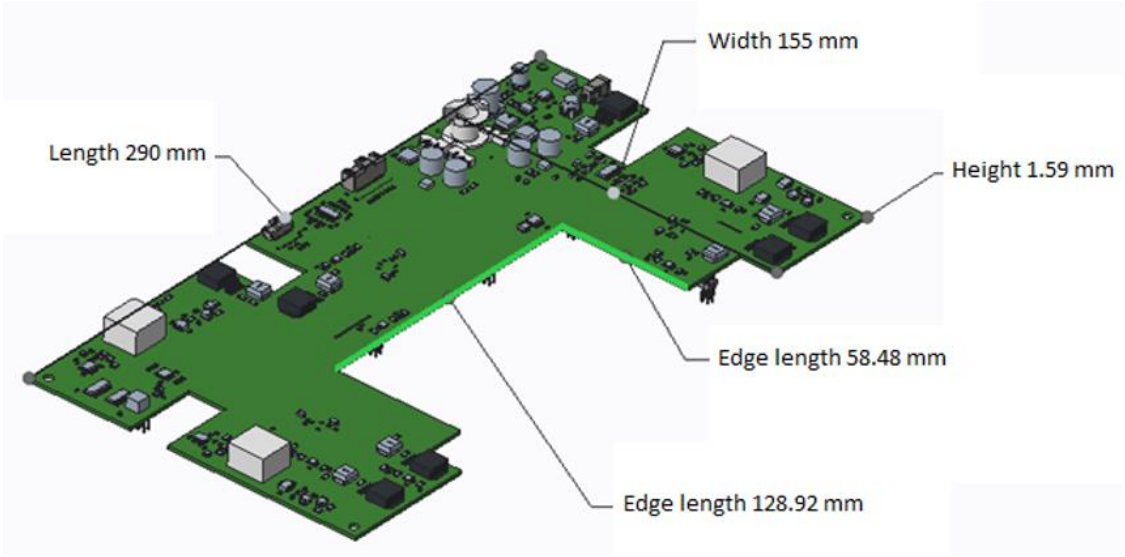


Figure 44 **Mechanical dimensions of the gate driver board**

3.1.5 Electrical layout

The gate driver board is an eight layer board made of PP-006 material. Table 9 lists the layer stack up of the board. Figures 42–49 show the electrical layout of the board.

Table 10 **Gate driver board layer stack up**

Layer	Name	Material	Thickness (mm)
	Top overlay	-	-
	Top solder	Solder resist	0.02
1	Top layer or layer 1	Copper	0.035
	Dielectric 1	PP-006	0.128
2	Layer 2	Copper	0.035
	Dielectric 2	Isola 185HR	0.3
3	Layer 3	Copper	0.035
	Dielectric 3	PP-006	0.128
4	Layer 4	Copper	0.035
	Dielectric 4	Isola 185HR	0.3
5	Layer 5	Copper	0.035
	Dielectric 5	PP-006	0.128
6	Layer 6	Copper	0.035
	Dielectric 6	Isola 185HR	0.3
7	Layer 7	Copper	0.035
	Dielectric 7	PP-006	0.128
8	Bottom layer or layer 8	Copper	0.035
	Bottom solder	Solder resist	0.02
	Bottom overlay	-	-

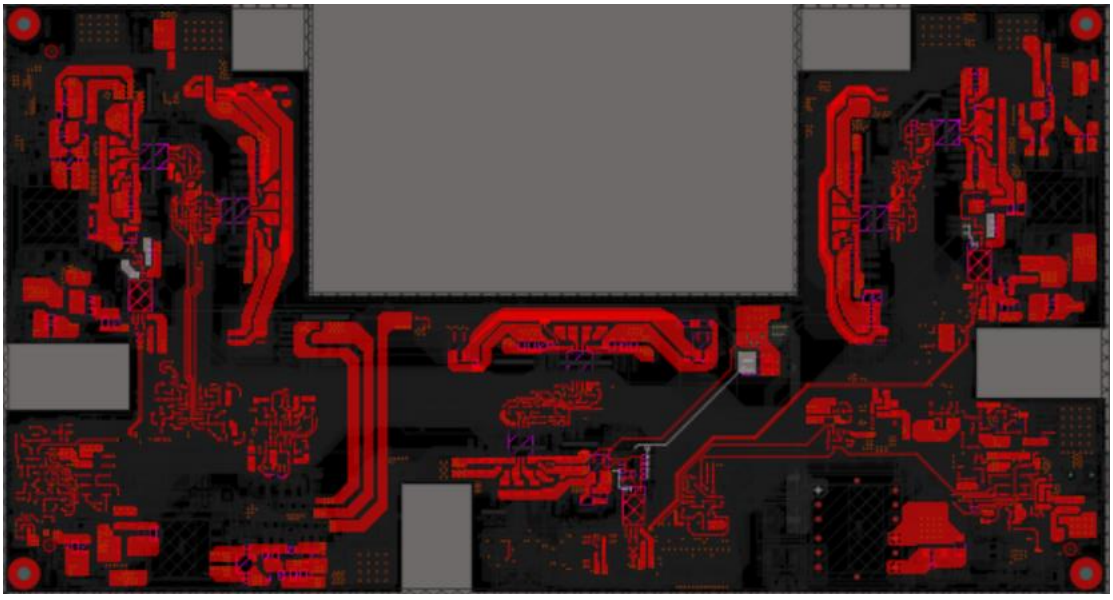


Figure 45 **Top layer or layer 1**

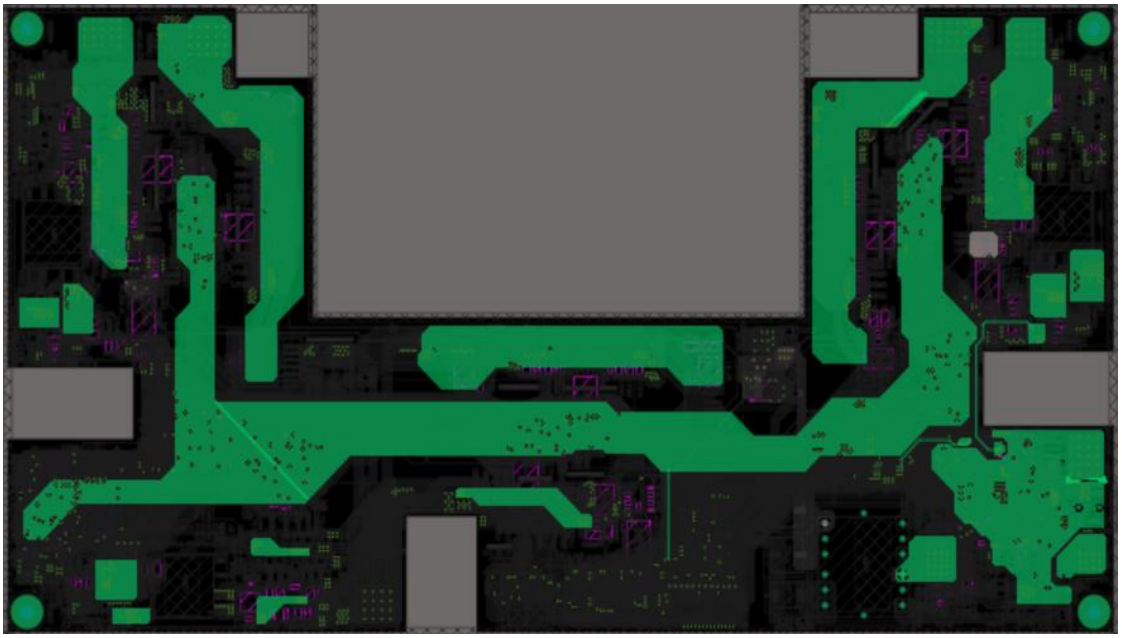


Figure 46 **Layer 2**

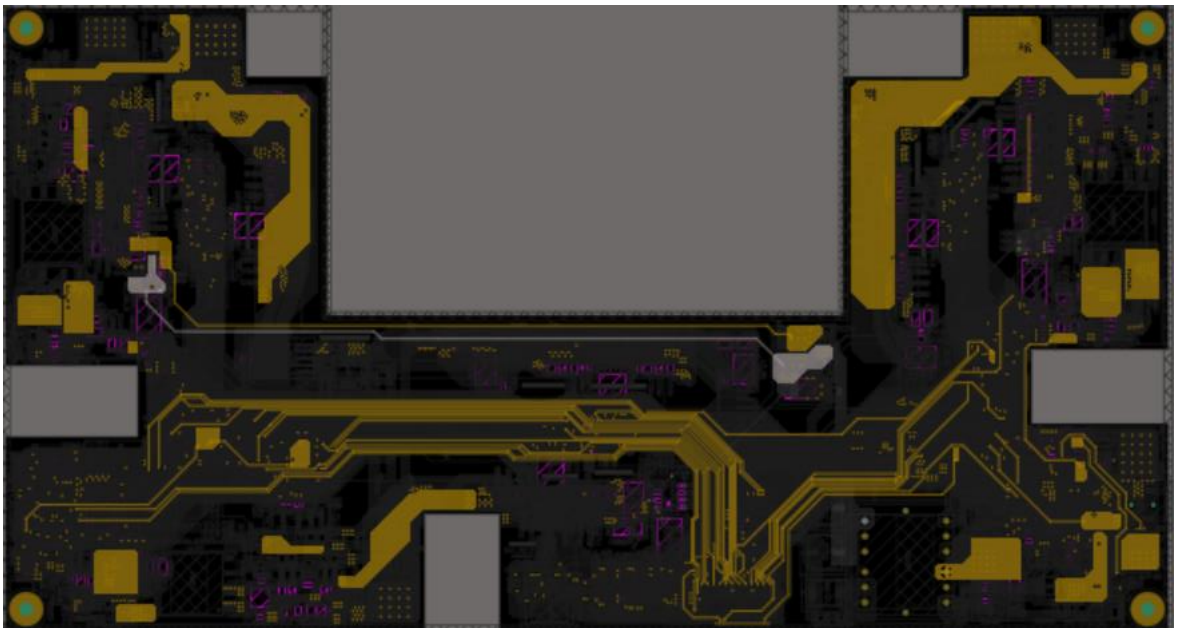


Figure 47 **Layer 3**

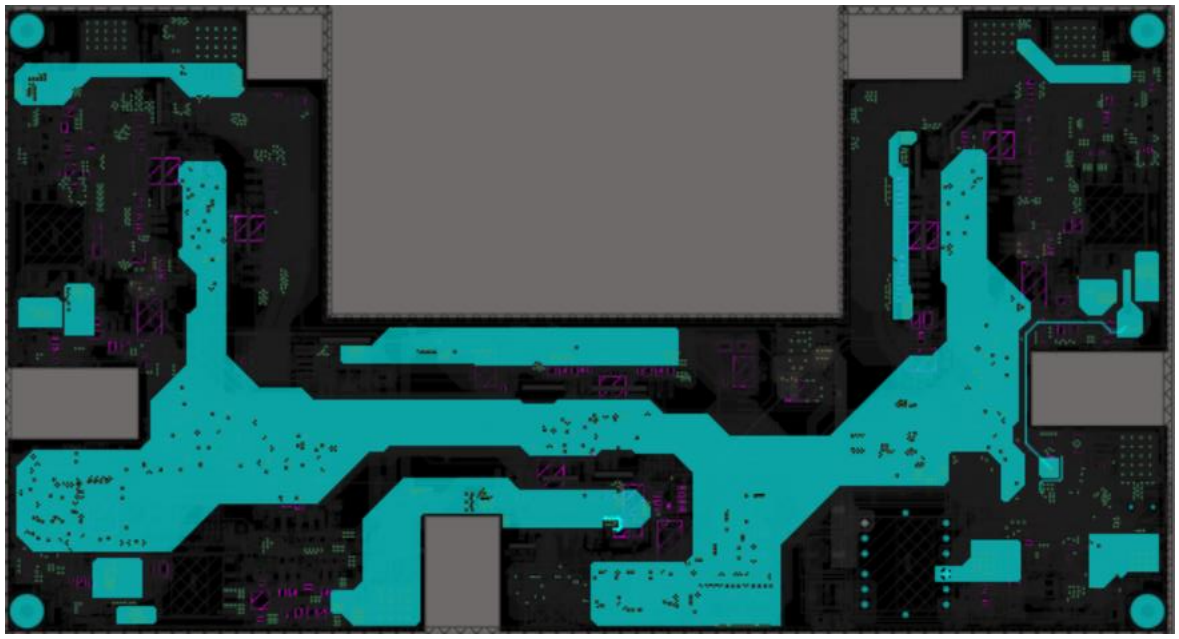


Figure 48 **Layer 4**

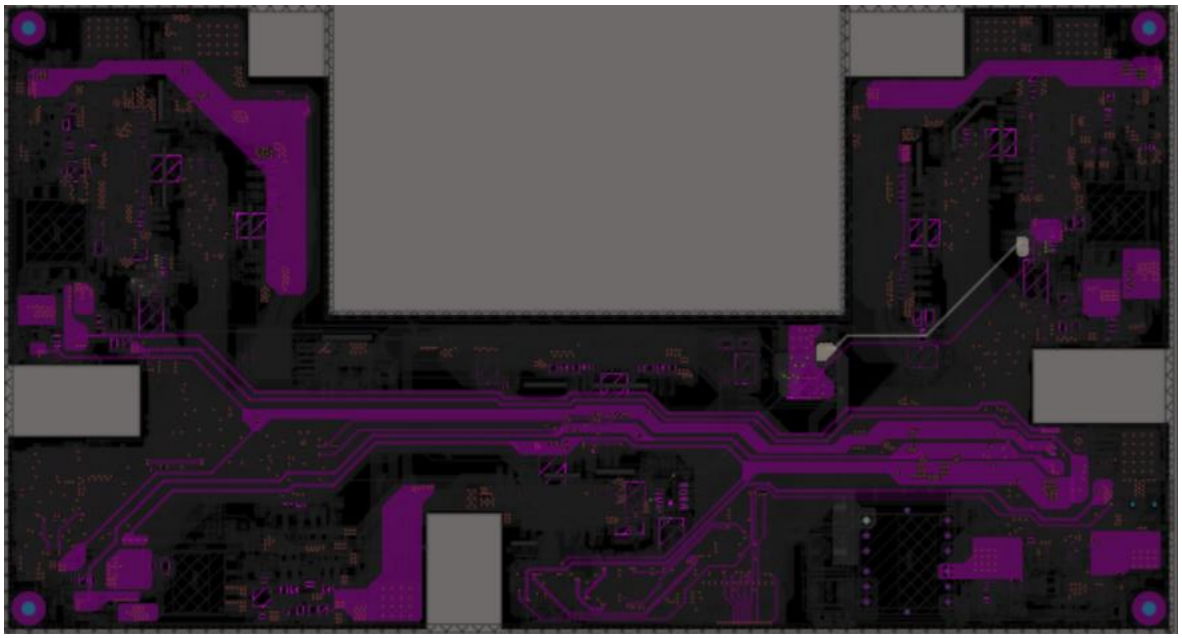


Figure 49 **Layer 5**

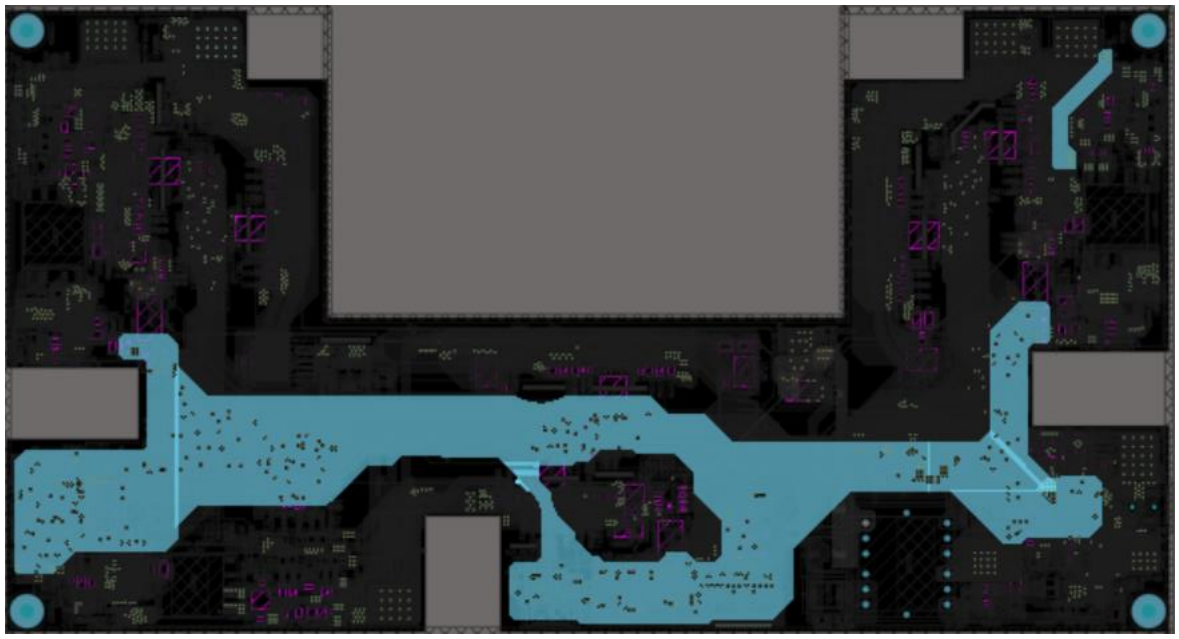


Figure 50 **Layer 6**

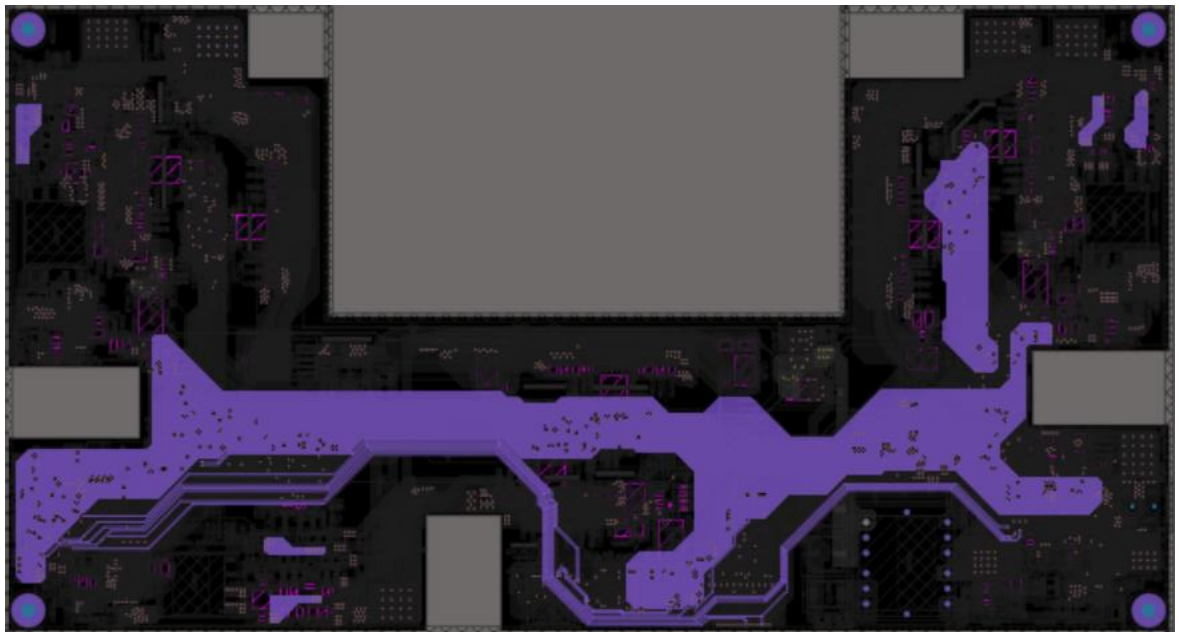


Figure 51 **Layer 7**

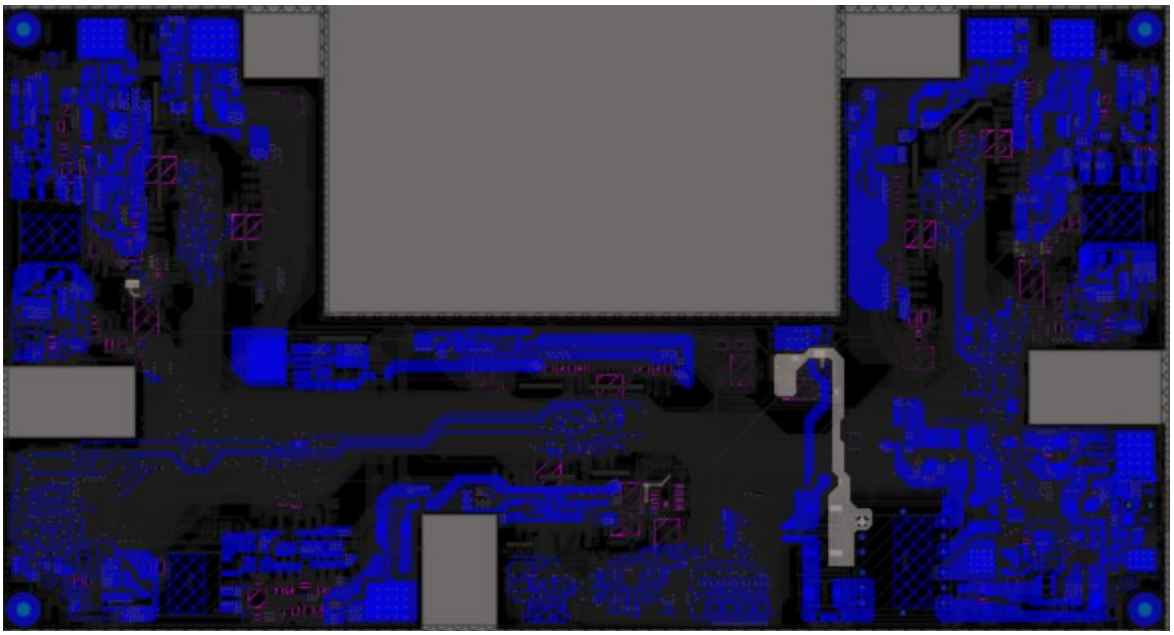


Figure 52 **Layer 8 or bottom layer**

3.2 Connector details

3.2.1 Power board

The power board has three major connectors as detailed in the following sections.

3.2.1.1 Signal connector

Signal connectors interface the power board and the power control board.

Table 11 **Connectors between power conversion and control board**

Designator	Connector	Description	Manufacturer	Manufacturer part number
J1921, J1922	Low voltage signal connector	1.25 mm pitch, micro-lock plus PCB header, dual row, right-angle, surface mount, tin-bismuth plating, positive lock, 20 circuits, tape and reel, black	Molex	505448-2071

3.2.1.2 Board-to-board connectors

The board-to-board connectors interface the power board and the gate driver board.

Table 12 **Board-to-board connectors**

Designator	Connector	Description	Manufacturer	Manufacturer part number
J1914, J1915	Diagnostics and LV power connector	10-position receptacle connector surface mount	Samtec	SSW-105-22-F-D-VS
J1901, J1905, J1908	Board-to-board connectors for Leg 1 PWM	4-position receptacle connector surface mount	Samtec	SSW-102-22-G-D-VS-TR
J1902, J1906, J1909	Board-to-board connectors for Leg 2 PWM	4-position receptacle connector surface mount	Samtec	SSW-102-22-G-D-VS-TR
J1903, J1907, J1910	Board-to-board connectors for Leg 3 PWM	4-position receptacle connector surface mount	Samtec	SSW-102-22-G-D-VS-TR
J1913	Isolated power supply	4-position receptacle connector surface mount	Samtec	SSW-102-22-G-D-VS-TR

3.2.1.3 Power connectors

Table 13 **Power connectors**

Designator	Connector	Description	Manufacturer	Manufacturer part number
J1925, J1928, J1900, J1926, J1927, J1904	DC positive and negative power connectors	Customized connector for mounting busbars/lugs	Customized	
J1911, J1912, J1916	Three AC power connectors	4-position receptacle connector surface mount	Würth Electronics	7461084

3.2.2 Gate driver board

The gate driver board has two major categories of connectors as detailed in the following sections.

3.2.2.1 Signal and LV power connectors

Signal and LV power connectors interface the gate driver board, the power control board, and the SMPS board.

Table 14 **Gate driver board connectors**

Designator	Connector	Description	Manufacturer	Manufacturer part number
J2912	Low voltage signal connector	1.00 mm pitch, pico-clasp PCB header, single row, right-angle, surface mount, 0.10 µm gold plated, positive lock, 10 circuits	Molex	2023961007
J2914	Low voltage signal connector	CONN HEADER SMD R/A 30 POS 1 MM	Molex	2035663007
J2913	24 V auxiliary supply connector	CONN PWR JACK 0.7 X 2.35 MM SOLDER	CUI Devices	PJ1-023-SMT-TR

3.2.2.2 Board-to-board connectors

The board-to-board connectors interface the power board and the gate driver board.

Table 15 **Board-to-board connectors for the gate driver board**

Designator	Connector	Description	Manufacturer	Manufacturer part number
J2909, J2910	Diagnostics and LV power connector	10-position header spacer connector, 0.100” (2.54 mm), gold surface mount	Samtec	HW-05-09-G-D-395-SM
J2901, J2904, J2906	Board-to-board connectors for Leg 1	4-position header spacer connector, 0.100” (2.54 mm), gold surface mount	Samtec	HW-02-09-G-D-385-SM
J2902, J2905, J2907	Board-to-board connectors for Leg 2	4-position header spacer connector, 0.100” (2.54 mm), gold surface mount	Samtec	HW-02-09-G-D-385-SM
J2900, J2903, J2908	Board-to-board connectors for Leg 3	4-position header spacer connector, 0.100” (2.54 mm), gold surface mount	Samtec	HW-02-09-G-D-385-SM
J2911	Isolated power supply	4-position header spacer connector, 0.100” (2.54 mm), gold surface mount	Samtec	HW-02-09-G-D-385-SM

3.3 Bill of materials (BoM)

The latest, detailed BoM can be downloaded after product registration using the serial number of the purchased power conversion board.

3.3.1 Power board

Table 16 **Main components BOM**

Description	Manufacturer	Manufacturer Part Number
Diodes - General purpose, power, switching RF DIODE	Infineon Technologies	BAT 17-04W H6327
Half-bridge 1200 V CoolSiC™ MOSFET Module	Infineon Technologies	FF4MR12W2M1H_B11/ FF6MR12W2M1H_B11
Current sensor	Infineon Technologies	TLI4971A120T5E0001XUMA1
Linear voltage regulator IC 1 Output 1A PG-TO252-3-11	Infineon Technologies	TLE4284DV33ATMA1

3.3.2 Gate driver board

Table 17 **Main components BOM**

Description	Manufacturer	Manufacturer Part Number
Schottky diodes and rectifiers Lw VF Schottky diode 30 V, 1 A	Infineon Technologies	BAS3010S02LRHE6327XTSA1
P-Channel MOSFET	Infineon Technologies	IRFR9024NTRLPBF
N-Channel MOSFET	Infineon Technologies	IPD78CN10NGATMA1
MOSFET N-Ch 60 V 4 .5A TSOP-6	Infineon Technologies	BSL606SN H6327
Single channel isolated gate driver	Infineon Technologies	1ED3124MU12H
Flyback controller	Infineon Technologies	ICE5ASAGXUMA1
Linear voltage regulator IC 1 output 50 mA	Infineon Technologies	TLS805B1SJVXUMA1
Linear voltage regulator IC 1 output 500 mA	Infineon Technologies	TLS205B0EJV50XUMA1
50% Duty cycle half-bridge driver	Infineon Technologies	AUIR2085STR
Linear voltage regulator IC 1 output 400 mA TO-263-5	Infineon Technologies	TLE42764GV

4 Test results

This chapter shows some of the verification test results.

4.1 Double pulse test (DPT)

DPT was performed on one of the low-side MOSFETs for the two module variants. For more details on the test-setup, please refer to [1].

Channel 1: V_{DS}, channel 2: I_{DS}, channel 3: V_{GS_LS}, channel 4: V_{GS_HS}

The conditions for the test are:

- T = 25 °C
- V = 850 V
- I = 100 A

4.1.1 FF4MR12W2M1H_B11

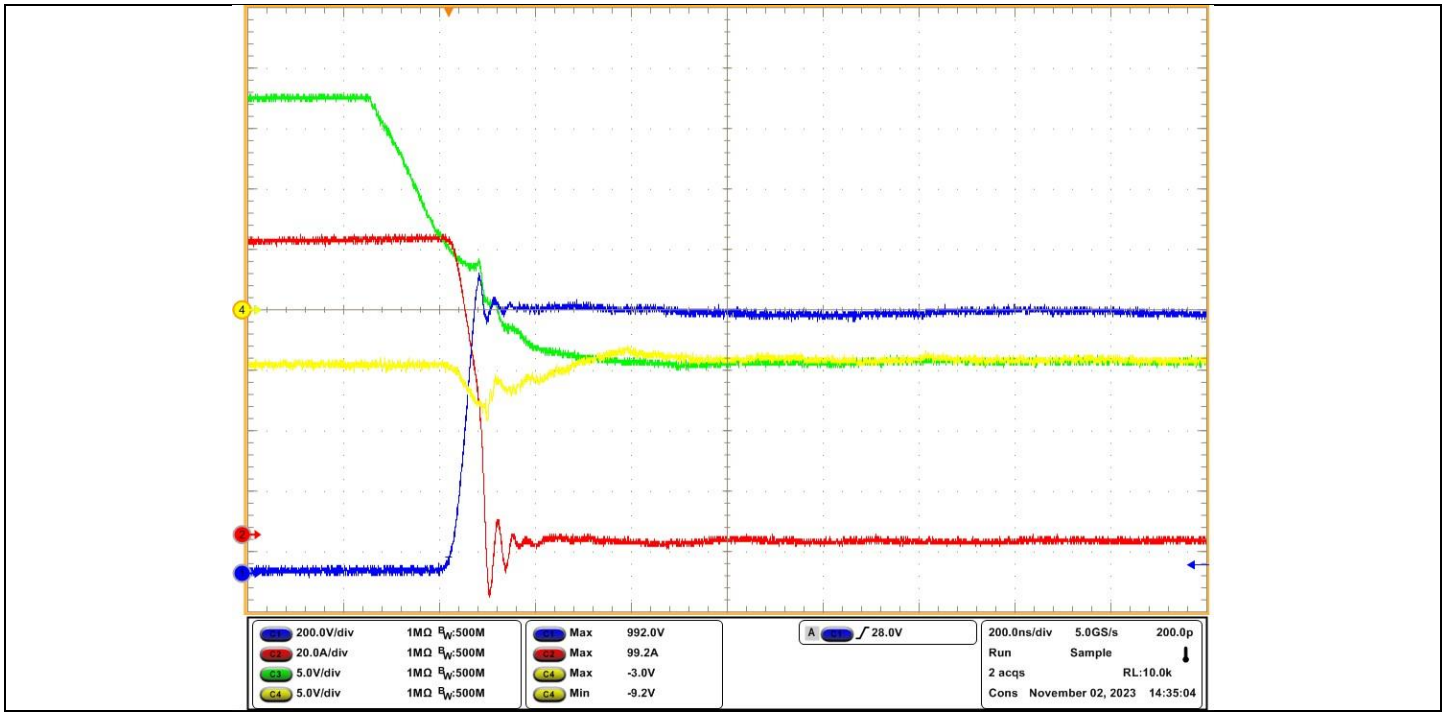


Figure 53 **Turn-off waveform**

4.1.2

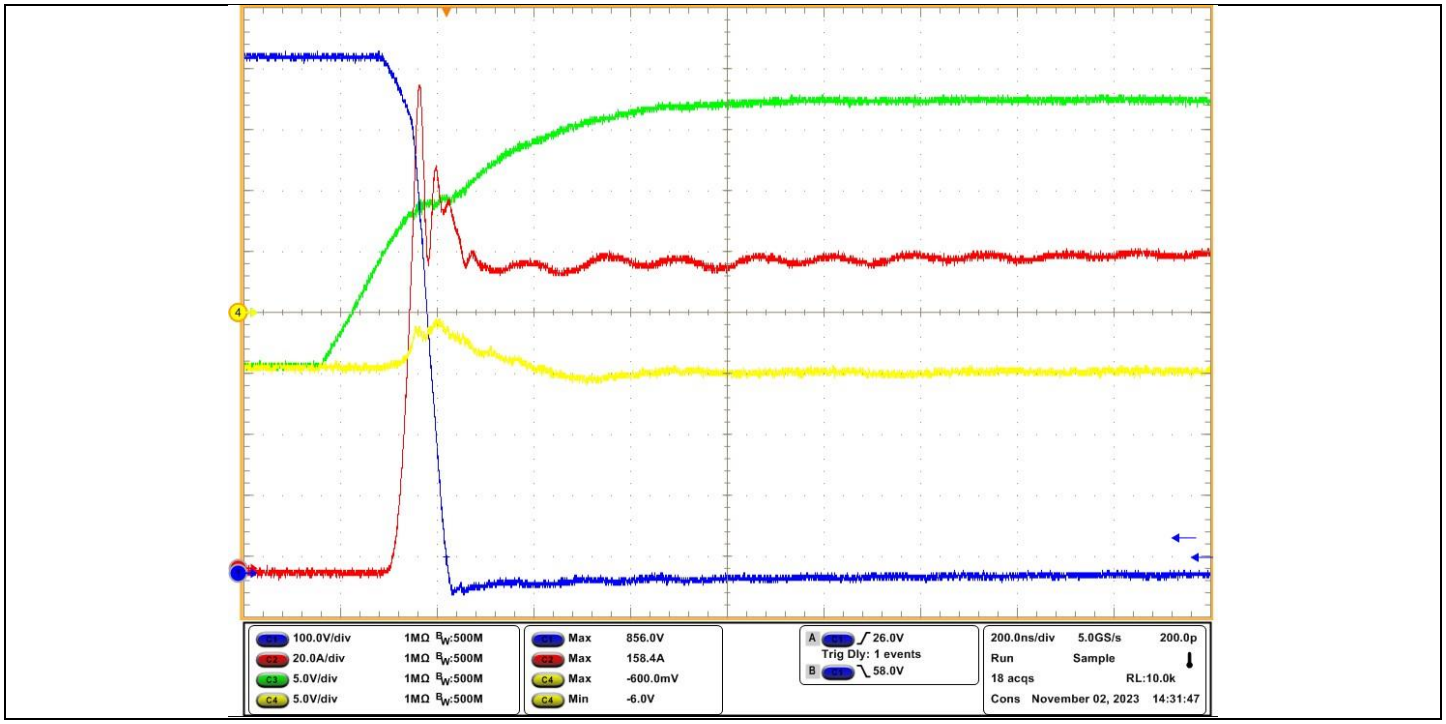


Figure 54 **Turn-on waveform**

4.1.3 FF6MR12W2M1H_B11

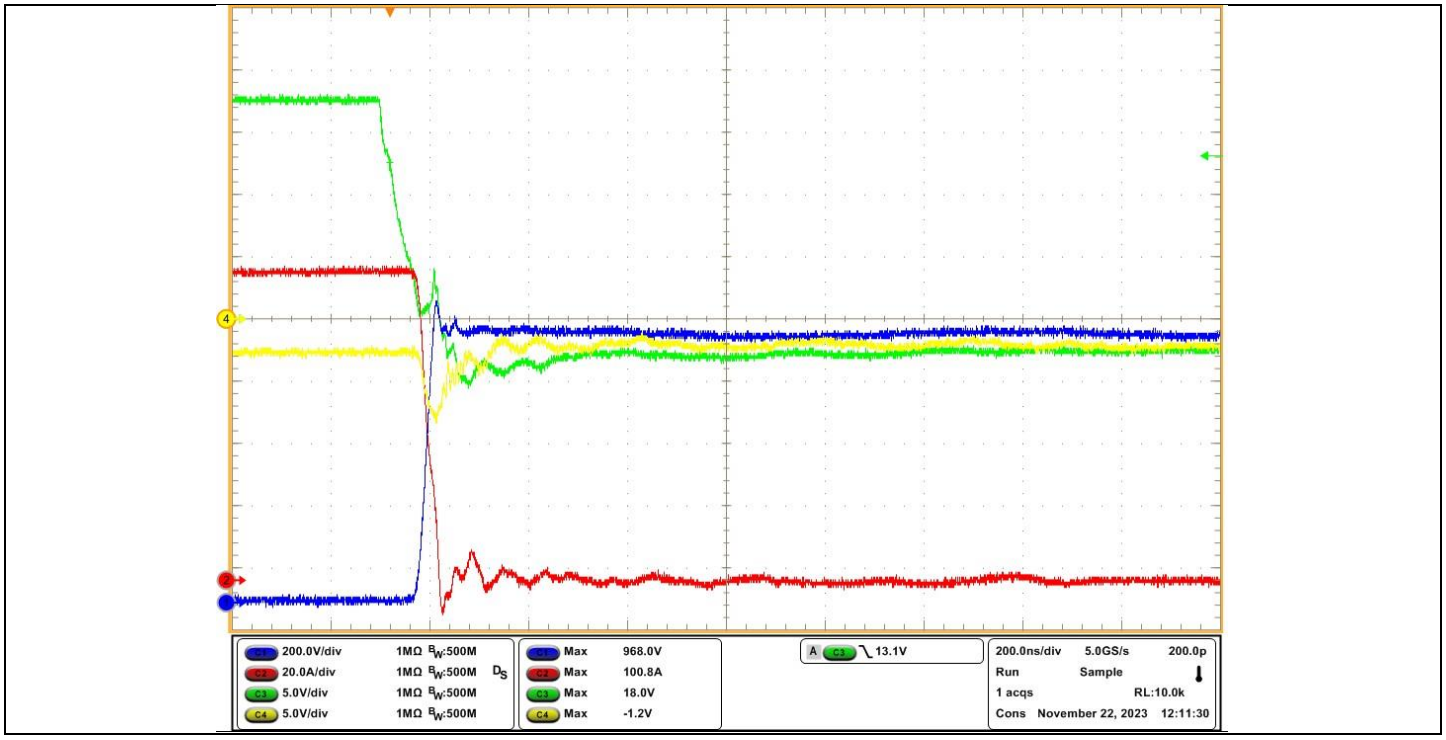


Figure 55 **Turn-off waveform**

4.1.4

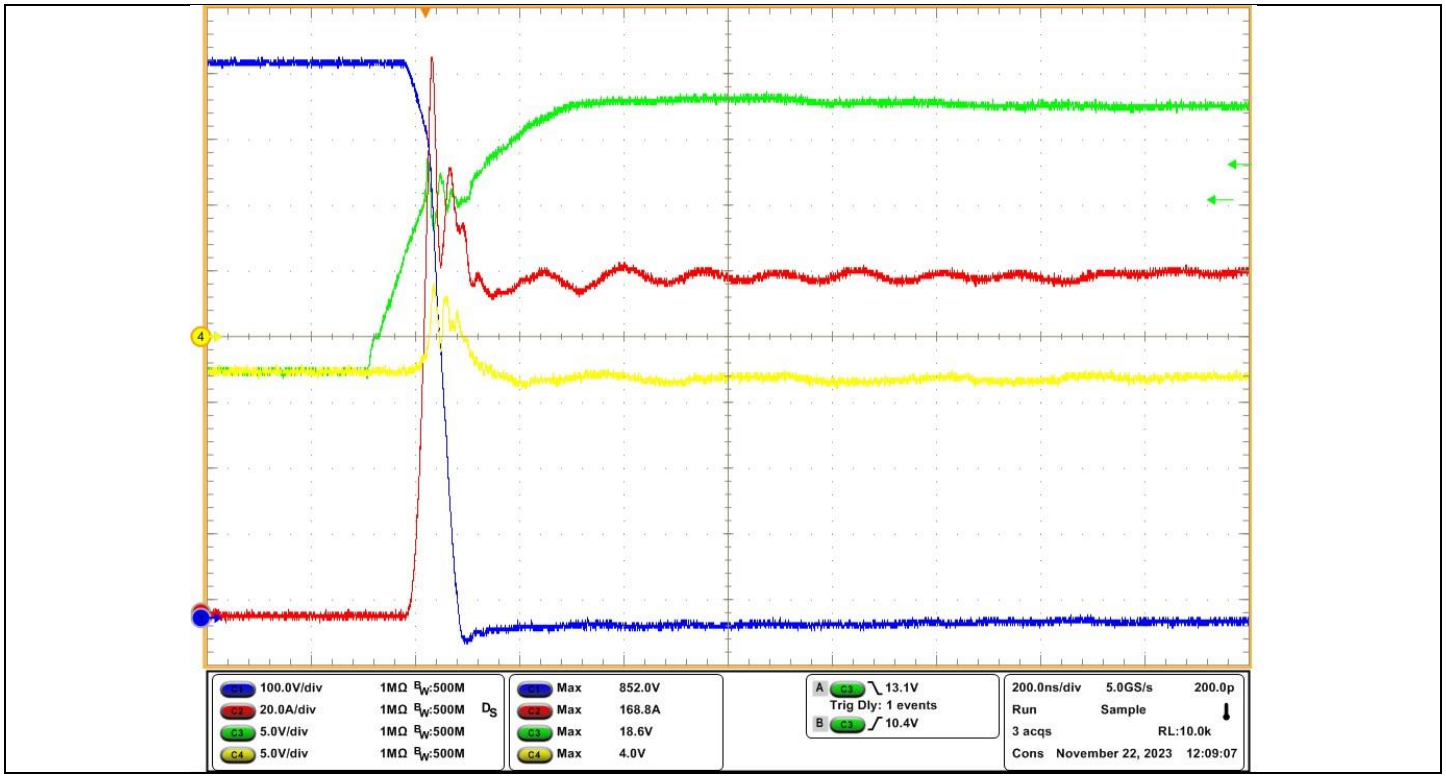


Figure 56 **Turn-on waveform**

4.2 AC line-to-line voltage sense test results

Using a function generator, a 2 V_{pk-pk}, 50 Hz signal was provided to the input of isolation amplifiers for measuring the AC voltage. The output differential voltages were captured on an oscilloscope.

Table 18 **Test results of the AC line-to-line voltage sense circuit**

Section	Input values	Respective AC line-to-line voltage	Expected outcome parameters	Lower limit	Upper limit	Actual results	Status
AC1 voltage sensing	0.8952 V	1073 V	SNS_H	2.270	2.397	2.332	PASS
			SNS_L	0.509	0.583	0.550	PASS
	0.512 V	615 V	SNS_H	1.895	2.011	1.951	PASS
			SNS_L	0.885	0.927	0.927	PASS
	0.0775 V	93.59 V	SNS_H	1.466	1.570	1.519	PASS
			SNS_L	1.314	1.410	1.370	PASS
AC2 voltage sensing	0.8544V	1026 V	SNS_H	2.232	2.357	2.301	PASS
			SNS_L	0.548	0.623	0.604	PASS
	0.4038 V	485 V	SNS_H	1.788	1.900	1.845	PASS
			SNS_L	0.992	1.080	1.051	PASS
	0.0596 V	71.63 V	SNS_H	1.448	1.551	1.483	PASS

			SNS_L	1.332	1.429	1.392	**PASS**
AC3 voltage sensing	0.8544 V	1026 V	SNS_H	2.232	2.357	2.259	**PASS**
			SNS_L	0.548	0.623	0.620	**PASS**
	0.4038 V	485 V	SNS_H	1.788	1.900	1.838	**PASS**
			SNS_L	0.992	1.080	1.039	**PASS**
	0.0596 V	71.63 V	SNS_H	1.448	1.551	1.491	**PASS**
			SNS_L	1.332	1.429	1.385	**PASS**

4.3 Phase current sense test results

Using a function generator, a 90 mVpk-pk 50 Hz signal was provided to the input of isolation amplifiers for measuring the phase current. The output differential voltages were captured on an oscilloscope.

Table 19 **Test results of the phase current sense circuit**

Section	Input values	Respective AC line-to-line voltage	Expected outcome parameters	Lower limit	Upper limit	Actual results	Status
Phase current sensing	42 mV	-140 A	Output Voltage SNS_H - SNS_L	-1.705 V	-1.739 V	-1.71 V	**PASS**
	10.38 mV	36 A	Output Voltage SNS_H - SNS_L	0.438 V	0.447 V	0.442 V	**PASS**
	44 mV	145 A	Output Voltage SNS_H - SNS_L	1.766 V	1.801 V	1.782 V	**PASS**

4.4 DC voltage sense test results

DC voltages of 100 V, 200 V, 400 V, 600 V, 800 V, 900 V, and 1000 V were applied to the DC power connector. Both the input voltage to the isolation amplifier and the output voltage were captured.

Table 20 **Test results of the DC voltage sense circuit**

Section	Input voltage DC	Expected outcome parameters	Lower limit	Upper limit	Actual results	Status
DC voltage sensing	100- V DC	Input Voltage V_IN	0.149	0.150	0.149	PASS
		Output Voltage SNS_H - SNS_L	0.149	0.150	0.149	PASS
	200 V DC	Input Voltage V_IN	0.299	0.300	0.299	PASS
		Output Voltage SNS_H - SNS_L	0.298	3.010	0.299	PASS
	400 V DC	Input Voltage V_IN	0.598	0.600	0.599	PASS
		Output Voltage SNS_H - SNS_L	0.597	0.601	0.597	PASS
	600 V DC	Input Voltage V_IN	0.897	0.900	0.899	PASS
		Output Voltage SNS_H - SNS_L	0.895	0.902	0.896	PASS
	700 V DC	Input Voltage V_IN	1.046	1.051	1.047	PASS
		Output Voltage SNS_H - SNS_L	1.044	1.053	1.045	PASS
	800 V DC	Input Voltage V_IN	1.196	1.201	1.197	PASS
		Output Voltage SNS_H - SNS_L	1.193	1.203	1.194	PASS
	900 V DC	Input Voltage V_IN	1.345	1.351	1.348	PASS
		Output Voltage SNS_H - SNS_L	1.343	1.353	1.344	PASS
	1000 V DC	Input Voltage V_IN	1.495	1.501	1.497	PASS
		Output Voltage SNS_H - SNS_L	1.492	1.504	1.493	PASS

4.5 Temperature test results

A potentiometer was used to emulate the NTCs. The voltage drop was provided as an input to the amplifier and the respective differential output was captured.

Table 21 **Test results of the temperature sense circuit**

Section	Input voltage drop	Respective temp (°C)	Expected outcome parameters	Lower limit	Upper limit	Actual results	Status
PCB temp. measurement	0.98 V	0°C	SNS_H	0.961	0.997	0.982	PASS
			SNS_L	4.106	4.203	4.117	PASS
	1.9944 V	25°C	SNS_H	1.983	2.011	2.002	PASS
			SNS_L	3.534	3.634	3.553	PASS
	4.361 V	100°C	SNS_H	4.342	4.381	4.362	PASS
			SNS_L	2.215	2.304	2.220	PASS
Heatsink temp. measurement	4.022 V	0°C	SNS_H	4.002	4.055	4.022	PASS
			SNS_L	2.406	2.423	2.412	PASS
	2.797 V	25°C	SNS_H	2.772	2.824	2.797	PASS
			SNS_L	3.094	3.114	3.101	PASS
	0.395 V	100°C	SNS_H	0.380	0.415	0.395	PASS
			SNS_L	4.434	4.465	4.448	PASS
MOSFET leg temp. measurement	0.685 V	25°C	SNS_H	1.70	1.82	1.778	PASS
			SNS_L	1.05	1.12	1.094	PASS

5 Appendix

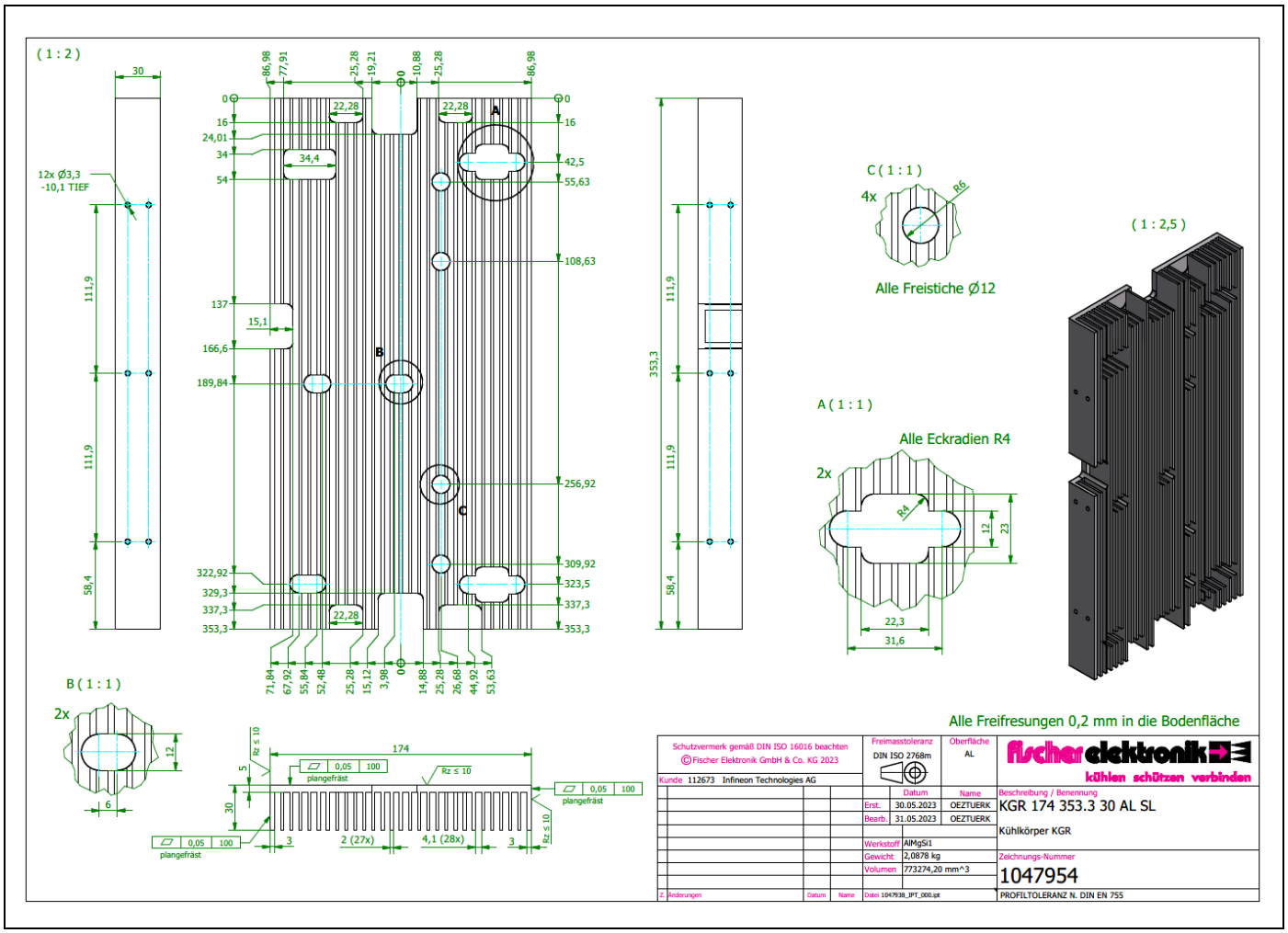


Figure 57 **Heatsink used for the power conversion board**

6 References

[1] https://www.infineon.com/dgdl/Infineon-Double_pulse_testing-Bodos_power_systems-Article-v01_00-EN.pdf?fileId=5546d46271bf4f920171ee81ad6c4a1f

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