EVAL_10KW_3LANPC_SIC user guide

High power density design with multilevel topology

About this document

Scope and purpose

This document describes the use and operation of the EVAL_10KW_3LANPC_SIC Evaluation Kit. The evaluation kit is designed to evaluate and test the three-level active neutral-point-clamped (3L-ANPC) topology.

The kit aims to provide engineers and researchers with a platform to experiment, validate, and optimize 3L-ANPC power conversion systems in different applications such as solar, drives, and others with an input DC bus voltage, ideally of 500–600 V DC depending on the desired margin.

Intended audience

This document is intended for design engineers, technicians, and developers of electronic systems.

CoolSiC™

Infineon's 400 V CoolSiC™ MOSFETs offer exceptional performance in switching behavior and causes low conduction losses. These devices are designed to offer high efficiency and reliability, while maintaining low on-state resistance at low as well as high MOSFET junction temperatures. Its ability to turn off the device with zero gate bias makes the 400 V CoolSiC™ MOSFETs true "normally-off" devices.

The CoolSiC™ family supports applications such as the following:

- Energy Storage Systems
- Industrial drives
- Motor control and drives
- Renewables
- UPS

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Safety precautions

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

Table 1 Safety precautions

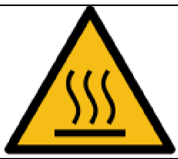
	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board contains DC bus capacitors which 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.*

Table of contents

1 Introduction

EVAL_10KW_3LANPC_SIC Evaluation Kit uses the three-level active neutral-point-clamped (3L-ANPC) topology and presents a distinct advantage over the commonly used two-level topologies. By employing series-connected capacitors, the 3L-ANPC topology effectively divides the DC link voltage into two equal halves thereby ensuring that each switch within the system is exposed to only half of the DC link voltage. This results in reduction of the switching losses by up to 50%.

Note: The DC bus capacitors should be minimized and voltage balancing scheme must be implemented in the optimization and commercialization phase of this converter. The DC bus capacitor values are oversized on this evaluation board because this is not included in the demo firmware.

EVAL_10KW_3LANPC_SIC Evaluation Board design can be used to drive any three-phase alternating current induction motor (ACIM) or permanent magnet synchronous motor (PMSM). This design comprises two boards:

- **Power board** which is a three-phase, three-level active neutral-point-clamp inverter.
- **Isolated power supply board** that generates isolated voltages for 18 different MOSFETs.

Both these boards are implemented on the FR4 PCB. See Figure 1 to see the assembled boards.

This design utilizes the following blocks:

- Power stage with CoolSiC™ G2 IMT40R011M2H 11.3 mΩ, max/400 V MOSFET
- Fast dual-channel isolated gate driver (4 A/8 A) – EiceDRIVER™ 2EDF7275F
- High-precision coreless current sensor XENSIV™ TLI4971-A120T5-U-E0001 – programmable current range
- XMC™ XMC4400 microcontroller drive card interface
- Isolated voltage generation with OptiMOS™ 5 power transistor BSZ099N06LS5 9.9 mΩ, max/60 V

The power stage is implemented on a four-layer FR4 PCB with an option to mount additional heatsinks on the back of the board to extend the power range of the inverter.

The following sections describe the individual functional blocks, their interconnection, and the supporting firmware. These components can be utilized in a working setup and the circuits can be adapted as per the requirements.

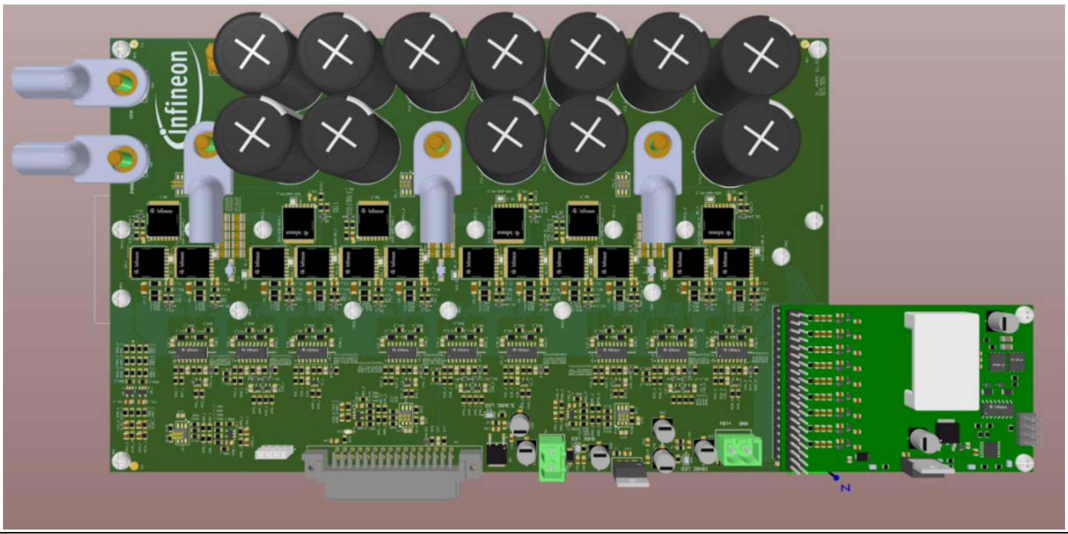


Figure 1 EVAL_10KW_3LANPC_SIC assembly

2 Hardware description

EVAL_10KW_3LANPC_SIC comprises the following hardware components:

- **Power board:** The power board provides the interconnections and the peripheral subsystems to functionally drive the half-bridges of the 3L-ANPC power inverter.
- **Isolated power supply board:** The isolated power supply board generates the gate driver supply voltages.
- Auxiliary power supply (18 V/1 A)
- Auxiliary power supply (5 V/1 A) - optional, but if not used, a small heatsink should be mounted on linear regulator G1
- **XMC™ XMC4400 Drive Card (KIT_XMC4400_DC_V1):** XMC™ XMC4400 Drive Card provides the control signals.

Figure 2 shows the building blocks from the top-level perspective.

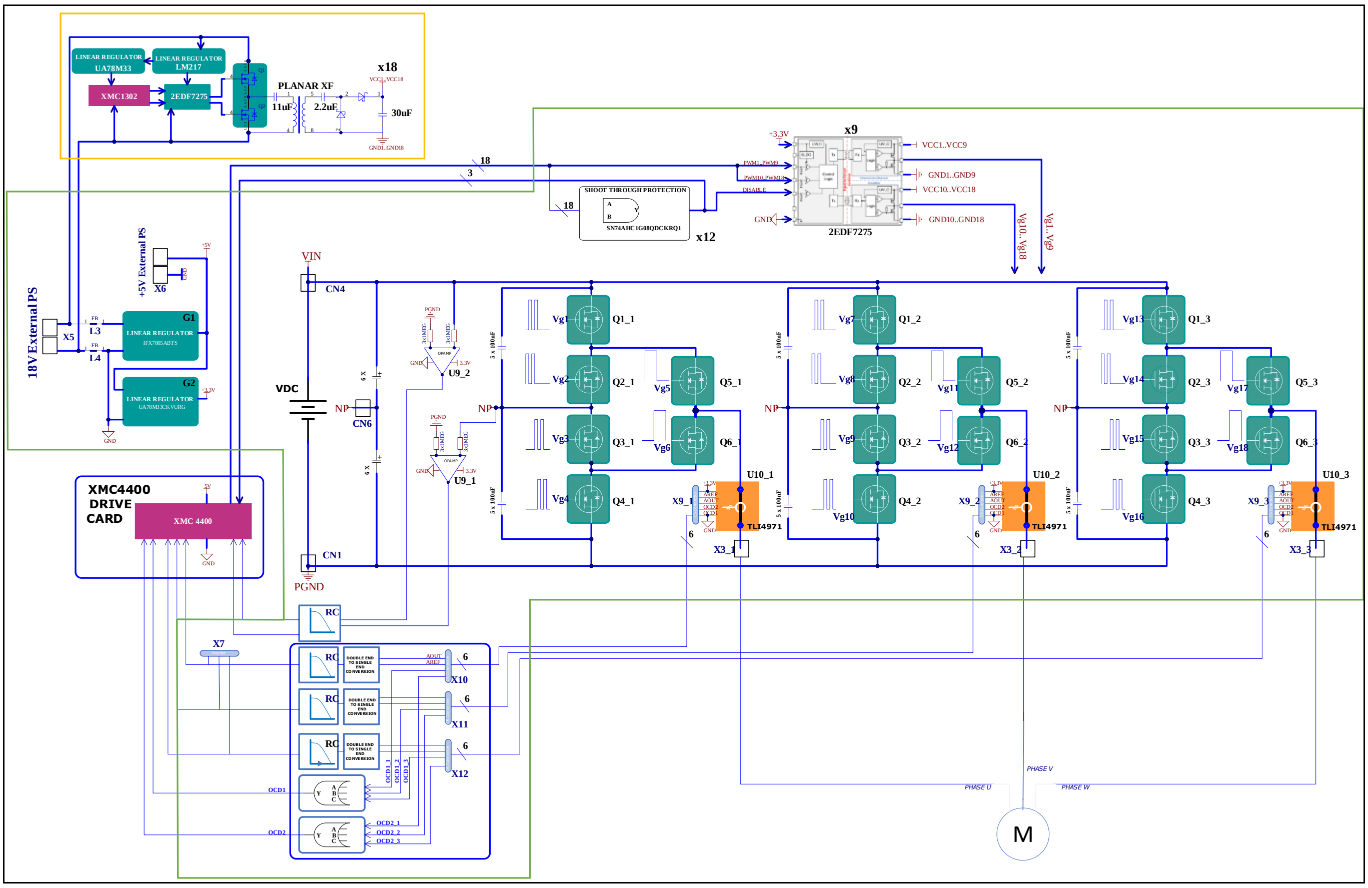


Figure 2 Top-level system overview

Power board

- High-voltage (HV)s side:
  - Interface to the HV supply
  - HV DC capacitor bank (electrolytic capacitors)
  - Three-phase MOSFET power stage
- Signal side:
  - Gate drivers

- Sensor signal processing (buffers and filters for current and temperature sensing)
- Connector for current sensor programmer

- Voltage supply:
  - 18 V to 5 V linear regulator
  - 5 V to 3.3 V linear regulator

Isolated power supply board

- Signal side:
  - Gate drivers
  - XMC™ XMC1300 to drive the forward converter
- Voltage supply:
  - 18 V to 5 V linear regulator
  - 5 V to 3.3 V linear regulator

3 Software setup

Prerequisites:

- EVAL_10KW_3LANPC_SIC power board
- Isolated power supply board
- XMC™ XMC4400 Drive Card
- 3 1 x 6 flat cable for current sensors
- KIT_XMC_LINK_SEGGER_V1

Additional equipment required for operation and evaluation:

- High-voltage power supply (600 V, 20 A)
- Auxiliary power supply (18 V, 1 A)
- Load

3.1 EVAL_10KW_3LANPC_SIC firmware

The firmware for power stage is an open-loop SINPWM modulator for three-phase systems. Default switching frequency is 10 kHz with 500 ns dead-time and 50 Hz line frequency. The 600 V_{DC} input would create ~212 $V_{AC\text{-}RMS}$ at the phase with respect to the neutral point.

The *3L_ANPC_Application_Kit.hex* file is flashed to the drive card via XMCFlasher. Connecting the USB cable to the board will only power up the debugger part because the XMC4400 Drive Card is isolated from the debugger. An additional supply of 5 V to the XMC4400 Drive Card is required to flash the MCU. The firmware is self-starting after the powerup and does not need any control input signal.

3.2 Isolated power supply firmware

The firmware for isolated power supply is an open-loop controller, which sends complementary PWM signals to a half bridge. Default switching frequency is 100 kHz with 100 ns dead-time and 20% duty cycle.

The *ForwardConverter18Output.hex* file is flashed to the isolated power supply board via XMCFlasher using KIT_XMC_LINK_SEGGER_V1. The firmware is self-starting after power-up and does not need any control.

4 EVAL_10KW_3LANPC_SIC Evaluation Kit

The following sections describe the EVAL_10KW_3LANPC_SIC Evaluation Kit highlighting its specifications, schematics, and layout.

4.1 Power board

The power board comprises 18 CoolSiC™ G2 IMT40R011M2H MOSFETs available in a TOLL package. The layout is optimized for switching behavior by minimizing and compensating the commutation loop inductance. This commutation loop ensures low switching losses and low voltage overshoot during transients.

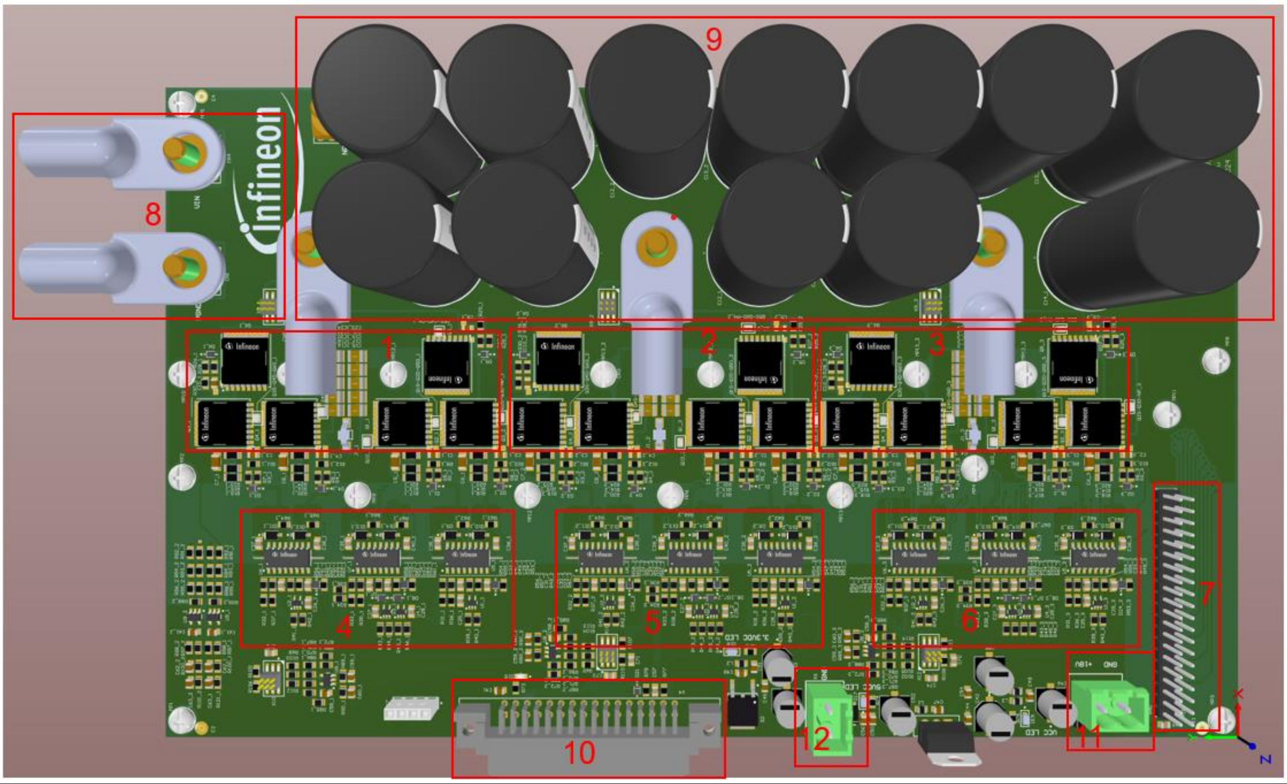


Figure 3 Power board in TOLL package

The following sections can be identified on the board:

- **1:** MOSFETs and connector for Phase A
- **2:** MOSFETs and connector for Phase B
- **3:** MOSFETs and connector for Phase C
- **4:** Gate driver and short-circuit protection for Phase A
- **5:** Gate driver and short-circuit protection for Phase B
- **6:** Gate driver and short-circuit protection for Phase C
- **7:** Connector for Isolated Power Supply Board
- **8:** Input DC bus power supply connectors
- **9:** DC link capacitors
- **10:** XMC™ XMC4400 Drive Card interface
- **11:** Connector for the auxiliary power supply (recommended voltage is 18 V)
- **12:** Connector for the auxiliary power supply 5 V/1AXMC4400 Drive Card power supply (5 V)

The proximity of the ceramic capacitors to the fast-switching loop ensures the DC bus stability and low-voltage overshoots during transients, which reduces the switching losses.

RC snubber footprints are added for each MOSFET, but not populated because of the clean switching behavior of the CoolSiC™ MOSFETs. The output signal from the current sensor is routed to the connectors (X9_1, X9_2, and X9_3) from which it is transmitted via a flat wire to the low-voltage section of the PCB.

4.1.1 Headers and connectors

See Table 2 for a list of headers and connectors of EVAL_10KW_3LANPC_SIC.

Table 2 EVAL_10KW_3LANPC_SIC headers and Connectors

Name	Description	Comment
X1	Power connector – Input voltage positive	Nominal: 600 V, Max: 640 V
X2	Power connector – Input voltage negative	–
X3	Power connector – Input voltage neutral point	Use only if two series battery power sources are available Max: 320 V
X3_1	Power connector – Phase A	Max: 20 arms
X3_2	Power connector – Phase B	Max: 20 arms
X3_3	Power connector – Phase C	Max: 20 arms
X4	XMC Drive Card connector	XMC4400 Drive Card (KIT_XMC4400_DC_V1)
X5	+18V Auxiliary supply connector	+18 V/0 V. Follow the marking on the PCB for correct polarity
X6	+5V Auxiliary supply connector	+5 V/0 V. Follow the marking on the PCB for correct polarity
X7	External current sensor feedback	Current sensor output test points
X8	Isolated power supply board connector	See Figure 1 for connection direction
X9_1	Current sensor feedback connector Phase A	1x6 flat cables
X9_2	Current sensor feedback connector Phase B	1x6 flat cables
X9_3	Current sensor feedback connector Phase C	1x6 flat cables
X10	Current sensor feedback connector Phase A	1x6 flat cables
X11	Current sensor feedback connector Phase B	1x6 flat cables
X12	Current sensor feedback connector Phase C	1x6 flat cables

4.1.2 Heatsink

To extend the power range of the inverter, attach the FR4 board (43 mm x 240 mm) to the heatsink via the 14 M3 screws.
Place a sufficiently thick thermal interface material (TIM) between the PCB and the heatsink.

Note: *WE-TGF-40006010 is recommended for high thermal conductivity (6W/m*K) and 1 mm thickness.*

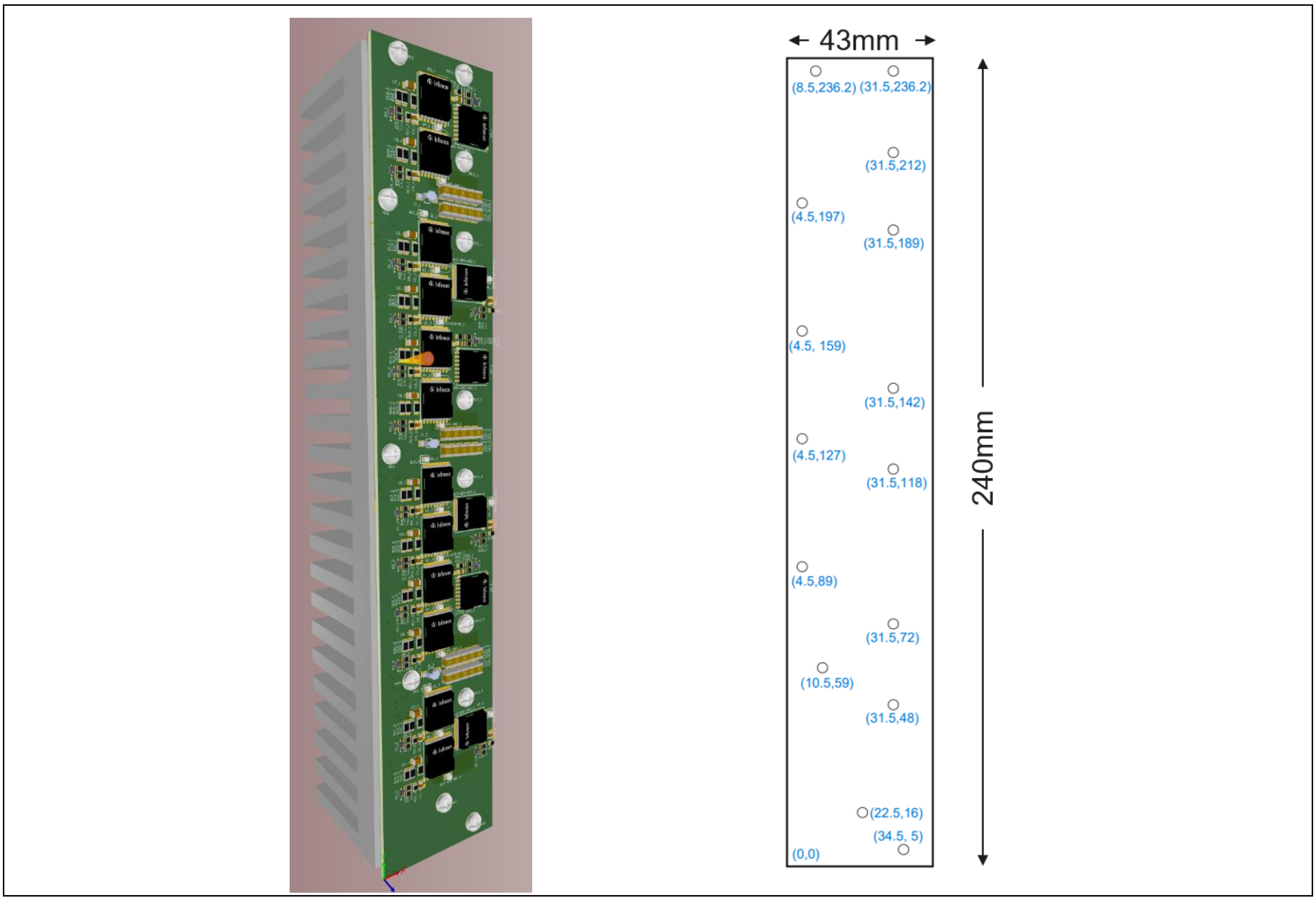


Figure 4 **Heatsink drill drawing**

4.1.3 XENSIV™ TLI4971 current sensor

The current sensor (Figure 5) uses the XENSIV™ TLI4971-A120T5-U-E0001 high-precision miniature coreless magnetic current sensor for AC and DC measurements with analog interface and dual fast overcurrent detection outputs. Infineon's well-established and robust Hall technology enables accurate and highly linear measurement of currents with a full measurement range up to ±120 A. The sensor's internal self-diagnostic feature avoids all negative effects (saturation, hysteresis), commonly known from the sensors using flux concentration techniques.

Features:

- Integrated current rail with typical 225 µΩ insertion resistance enables ultra-low power loss
- SMD package with small form factor (8x8 mm^2) for easy integration and board area saving
- Single supply voltage (3.1–3.5 V)
- Highly accurate, scalable, DC and AC current sensing
- Typical bandwidth of 240 kHz
- Very low sensitivity error overtemperature (max. 2.5%)
- Excellent stability of offset overtemperature and lifetime
- High robustness to voltage slew rates up to 10 V/ns
- Galvanic functional isolation up to 1150 V peak VIORM. Partial discharge capability of at least 1200 V (4 mm clearance and creepage)
- Differential sensor principle ensures superior magnetic stray field suppression for better immunity
- Two independent fast overcurrent detection (OCD) pins with configurable thresholds enable protection mechanisms for power circuitry (typical: 0.7 µs and max: 1 µs)
- T_S: -40 …+105°C
- Precalibrated sensor

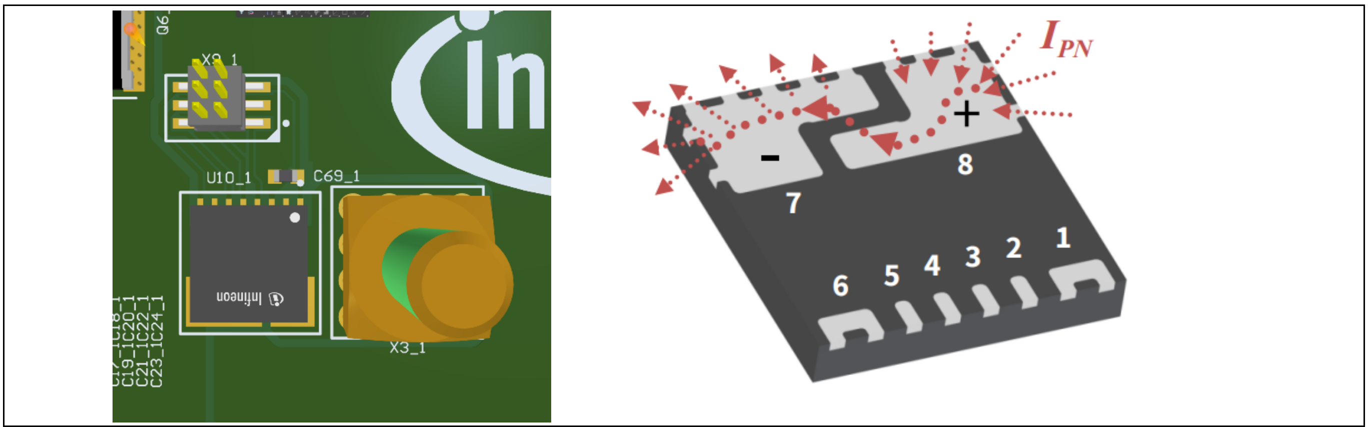


Figure 5 Current sensor PCB

Table 3 Current sensor connector pin description

Pin No.	Symbol	Function
1	V_{DD}	Supply voltage
2	G_{ND}	Ground
3	V_{REF}	Reference voltage I/O, analog signal output in fully differential mode
4	A_{OUT}	Analog signal output
5	O_{CD1}	Overcurrent detection output 1 (open drain output)
6	O_{CD2}	Overcurrent detection output 2 (open drain output)
7	IP-	Negative current terminal pin (current-out)
8	IP+	Positive current terminal pin (current-in)

4.1.3.1 XENSIV™ TLI4971-A120T5-U-E0001 settings and programming

XENSIV™ TLI4971-A120T5-U-E0001 has a sensitivity setting that can be set via the programming interface. The current sensor can be programmed in two ways:

- Individually before system insertion
- Programmed "in-system" by providing the appropriate interconnection between the sensor and the microprocessor.

By default, XENSIV™ TLI4971-A120T5-U-E0001 comes pre-configured to 120 A. Other pre-configured parameters are:

- Output mode is set to semi-differential mode.
- The quiescent voltage is set to 1.65 V.
- The OCD threshold of channel 1 is set to the factor 1.25 of the full-scale range.
- The OCD threshold of channel 2 is set to the factor 0.82 of the full-scale range.
- The pre-defined setting of the OCD deglitching filter time is set to 0 µs.
- The sensor is pre-configured to work in the non-ratiometric mode.
- The sensitivity and the derived measurement range (full scale) can be reprogrammed with The Infineon CUR SENSOR PROGRAMMER board according to the sensitivity ranges listed in Table 4.

Table 4 Sensitivity setting parameters

Sensitivity range	Value [mV/A]	Maximum current for FS [A]
S1	10	120
S2	12	100
S3	16	75
S4	24	50
S5	32	37.5
S6	48	25

4.1.4 CUR SENSOR PROGRAMMER board

The Infineon CUR SENSOR PROGRAMMER board is a utility board specially designed for interfacing TLI4971 and XENSIV™ TLE4972 Hall current sensors operating at 3.3 V supply levels. This board is compatible with all XENSIV™ TLI4971/TLE4972 three-phase evaluation boards and is used to performing live current level readouts, diagnostic checks (e.g., OCD check), EEPROM configuration, and calibration.

Figure 6 Current sensor programmer

Table 5 lists the pin description of the power board and is used to connect the CUR SENSOR PROGRAMMER board to program the TLI4971-A120T5-U-E0001 current sensor.

Table 5 Current sensor connector pin description – Power board

Pin no.	Symbol	Function
1	V_{REF}	Reference voltage I/O, analog signal output in fully differential mode
2	A_{OUT}	Analog signal output
3	G_{ND}	Ground
4	O_{CD1}	Overcurrent detection output 1 (open drain output)
5	V_{DD}	Supply voltage
6	O_{CD2}	Overcurrent detection output 2 (open drain output)

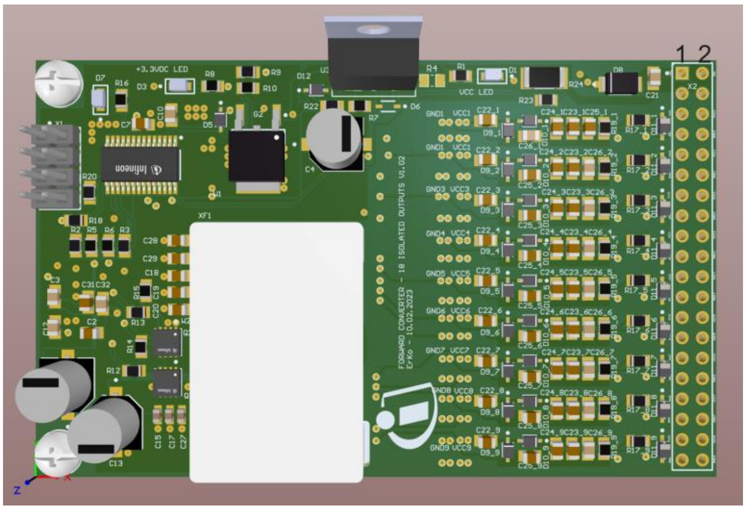
4.1.5 Isolated power supply board

The isolated power supply board generates 18 isolated output voltages, each equal to the input voltage. The board operates in an open-loop mode and utilizes a planar transformer with windings integrated on the PCB, and employs a forward converter driven by a half-bridge configuration. The transformer includes a series capacitor that plays a crucial role in resetting the transformer.

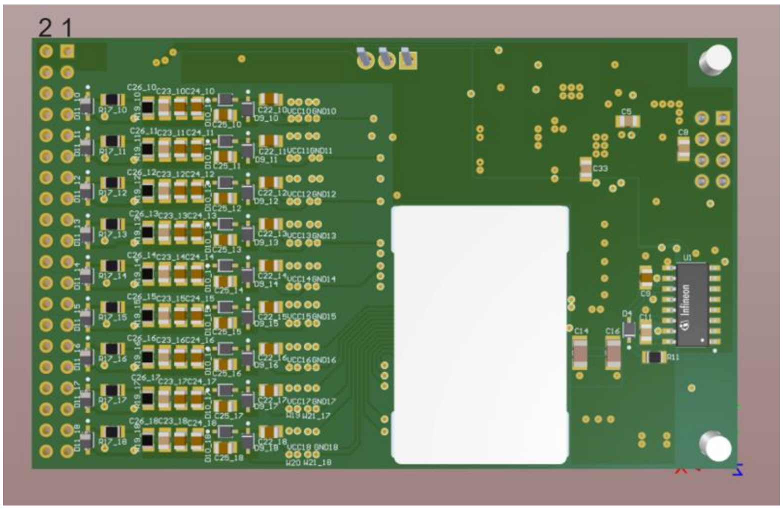
The functioning principle of the isolated output voltage is as follows:

- Pin1 (dotted) is the positive input for the isolated power supply board; Pin2 is the return.
- Pin3 and Pin4 are empty.
- Pin5(+) with Pin7(-) and Pin6 (+) with Pin8(+) construct the isolated voltages for the gate driver network.

The other 16 isolated voltages are constructed with the same principle as described.



(a)



(b)

Figure 7 (a) Isolated power supply board top side view; (b) bottom side view

4.2 XMC™ XMC4400 Drive Card

XMC™ XMC4400 Drive Card (KIT_XMC4400_DC_V1) interfaces the power board. The X4 connector on the power board is connected to X302 (MAB32B2) on the drive card.

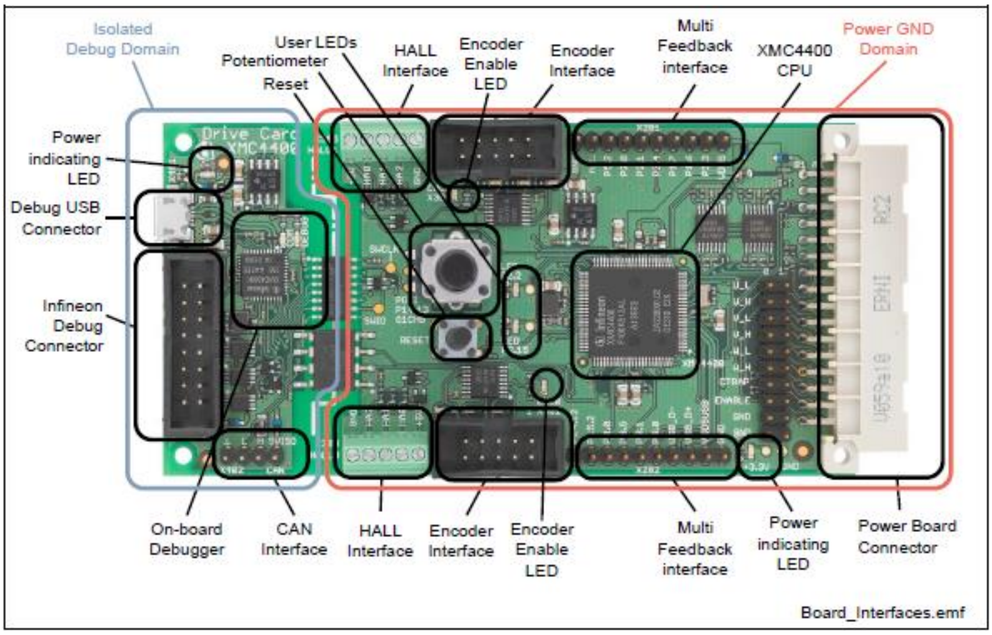


Figure 8 KIT_XMC4400_DC_V1 Drive Card

4.3 XMC™ Link (KIT_XMC_LINK_SEGGER_V1)

XMC™ Link (KIT_XMC_LINK_SEGGER_V1) is an isolated debug probe for all XMC™ microcontrollers. The debug probe is based on the SEGGER J-Link debug firmware, which enables the use with DAVE™ and all common third-party compiler/IDEs (Altium Limited, Atollic, ARM/KEIL, IAR Systems, iSystem, and Rowley Associates) known from the wide Arm® ecosystem. See Figure 21 for connection to the isolated power supply board.

Note: KIT_XMC_LINK_SEGGER_V1 is required to program isolated power supply board.

Figure 9 XMC™ Link – functional isolated debug probe

5 Schematics

5.1 Power board

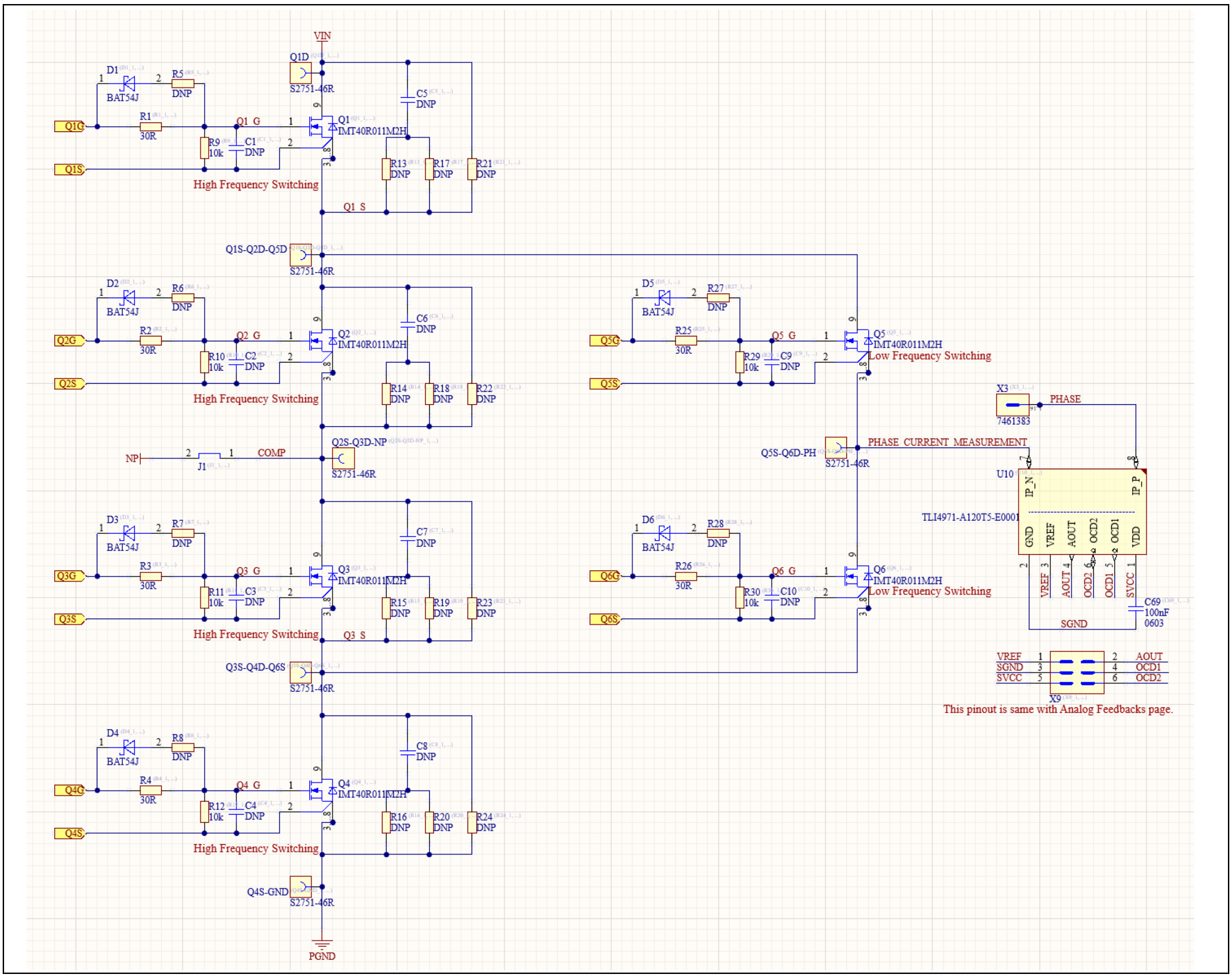


Figure 10 Power board schematic – one phase

Note: *The "DNP" markings indicated next to component in the schematic are optional. On default, they are not populated on the board.*

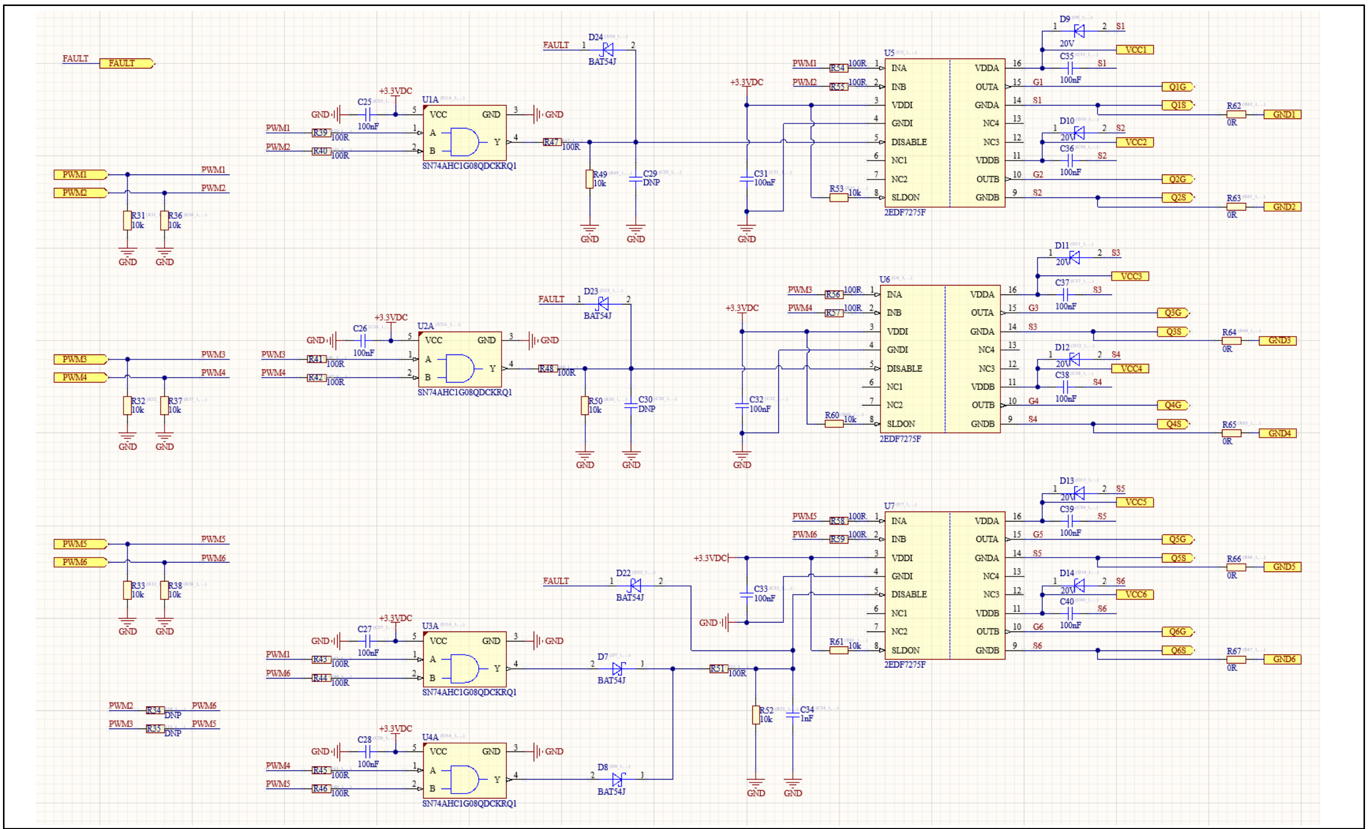


Figure 11 Gate driver logic and protection schematic – one phase

- Logic gates U1A, U2A, and U4A (AND gates) are implemented as a shoot-through protection for the half bridges.
- EiceDRIVER™ 2EDF7275 isolated gate drivers are used to isolate the power stage from the controller stage.
- The Zener diodes D9, D10, D11, D12, D13, and D14 protect the gate drivers from the overshoots that might occur from the isolated power supply board.

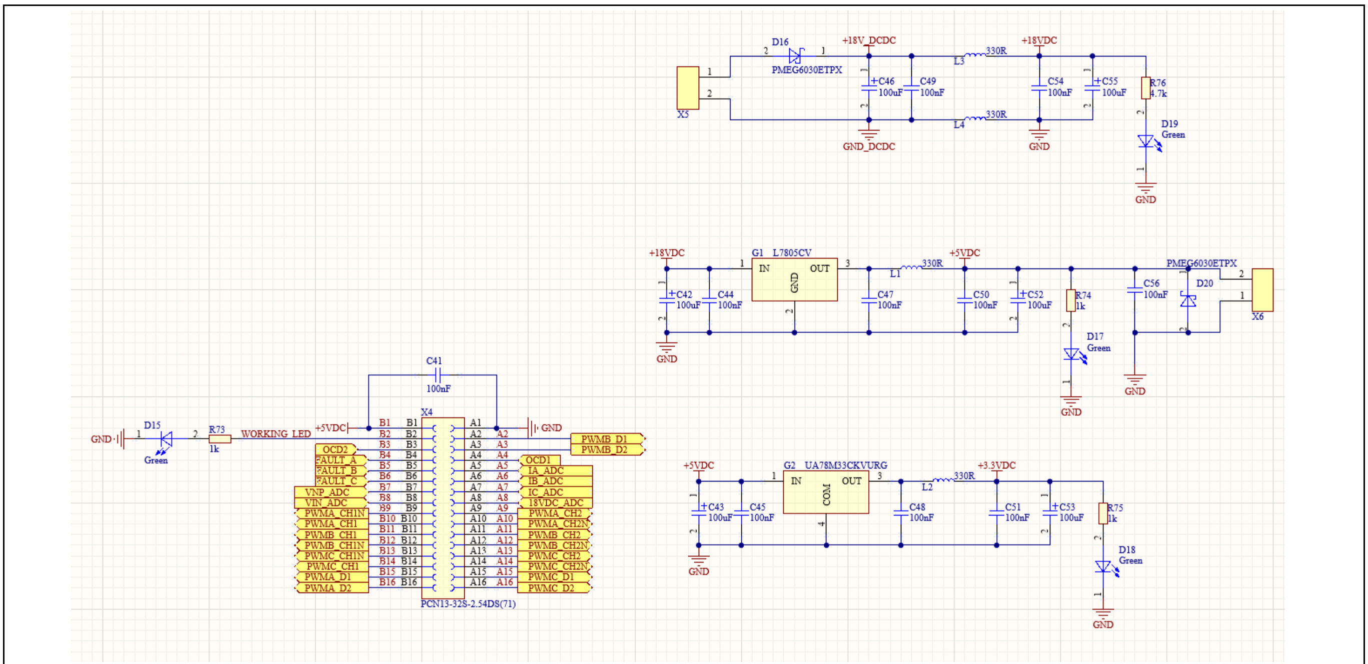


Figure 12 Linear voltage regulators and controller connector

- Diode D16 is used for reverse voltage protection.
- The voltage used at connector X5 is used to create the isolated voltages for the gate drivers. The driving voltage of the MOSFETs can be adjusted through the voltage used here.
- For the CoolSiC™ MOSFETs, the recommended driving voltage is +18 V/0 V.
- The 5 V G1 linear regulator requires a heatsink to control the temperature but it also can be bypassed by applying 5.1 V to the X6 connector. See Figure 13 for auxiliary supply connections.

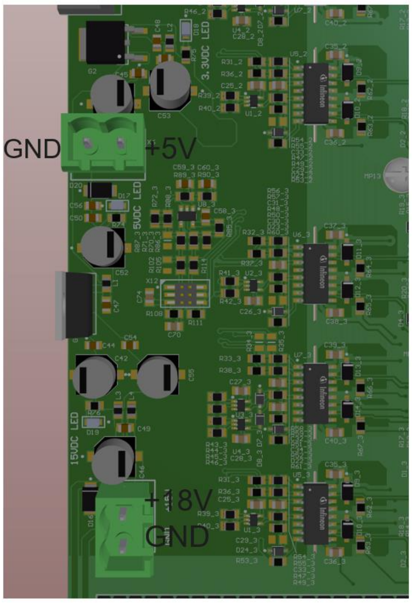


Figure 13 Auxiliary supply connections

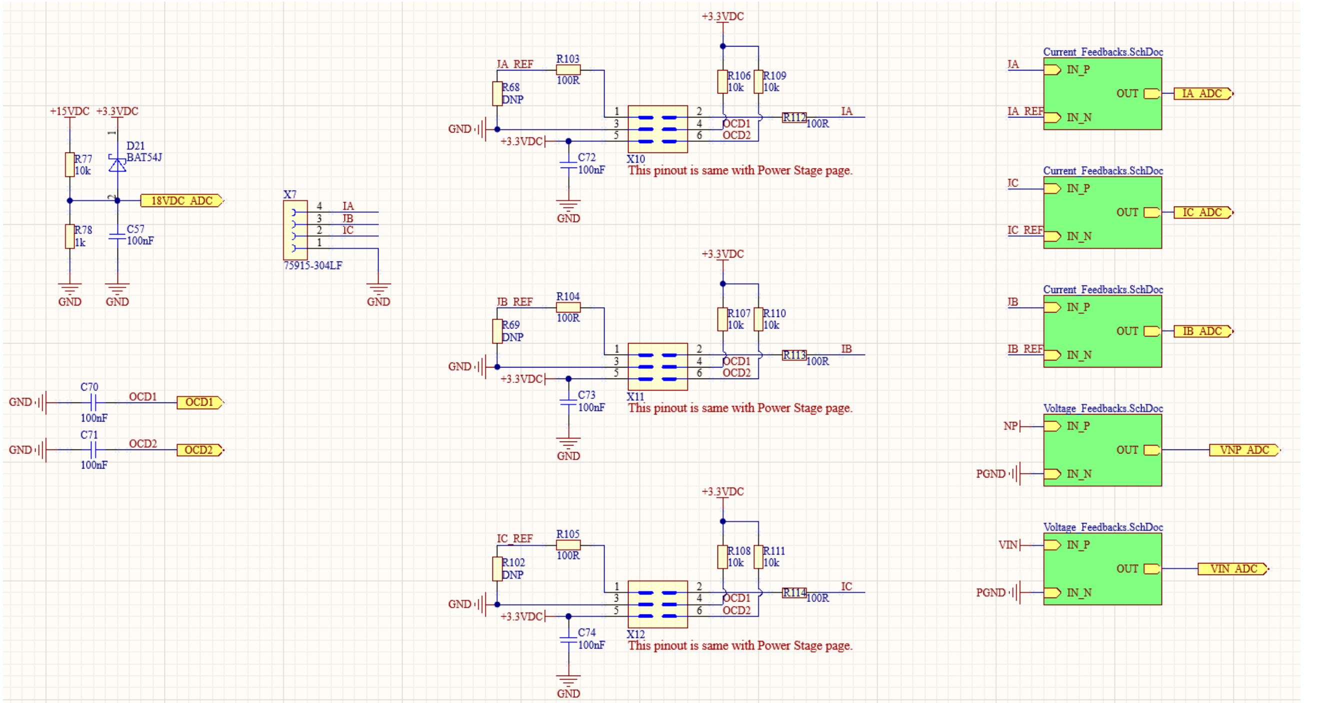


Figure 14 Analog feedback schematic

The three-phase current sense signals are taken from X9_1, X9_2, X9_3 through 1 x 6 flat cable and carried to the signal processing section of the power board. See Figure 15 for the current sensor cable connection.

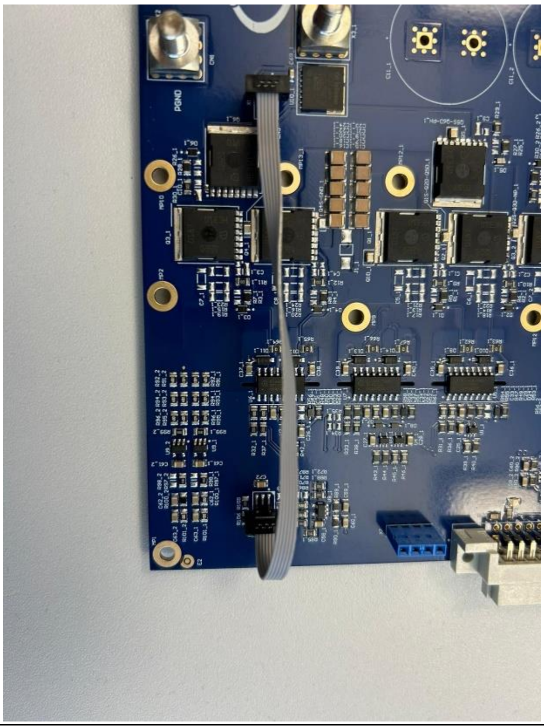


Figure 15 Current sensor cable connection

The connector X7 also has three-phase output current sense information and can be used either as test points or as connection to external ADC pins for processing and control. See Figure 16 for the pinout.

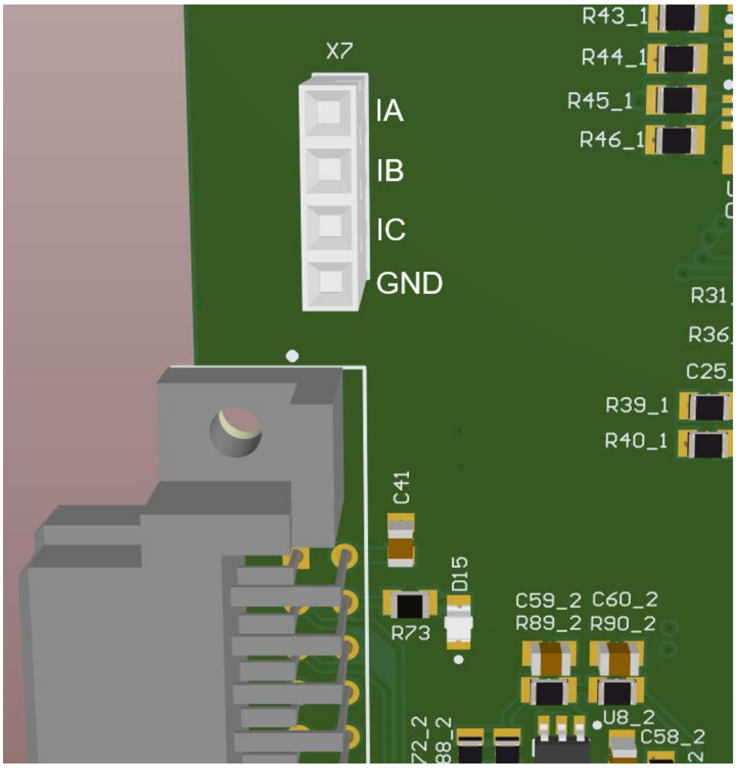


Figure 16 Current feedback test points

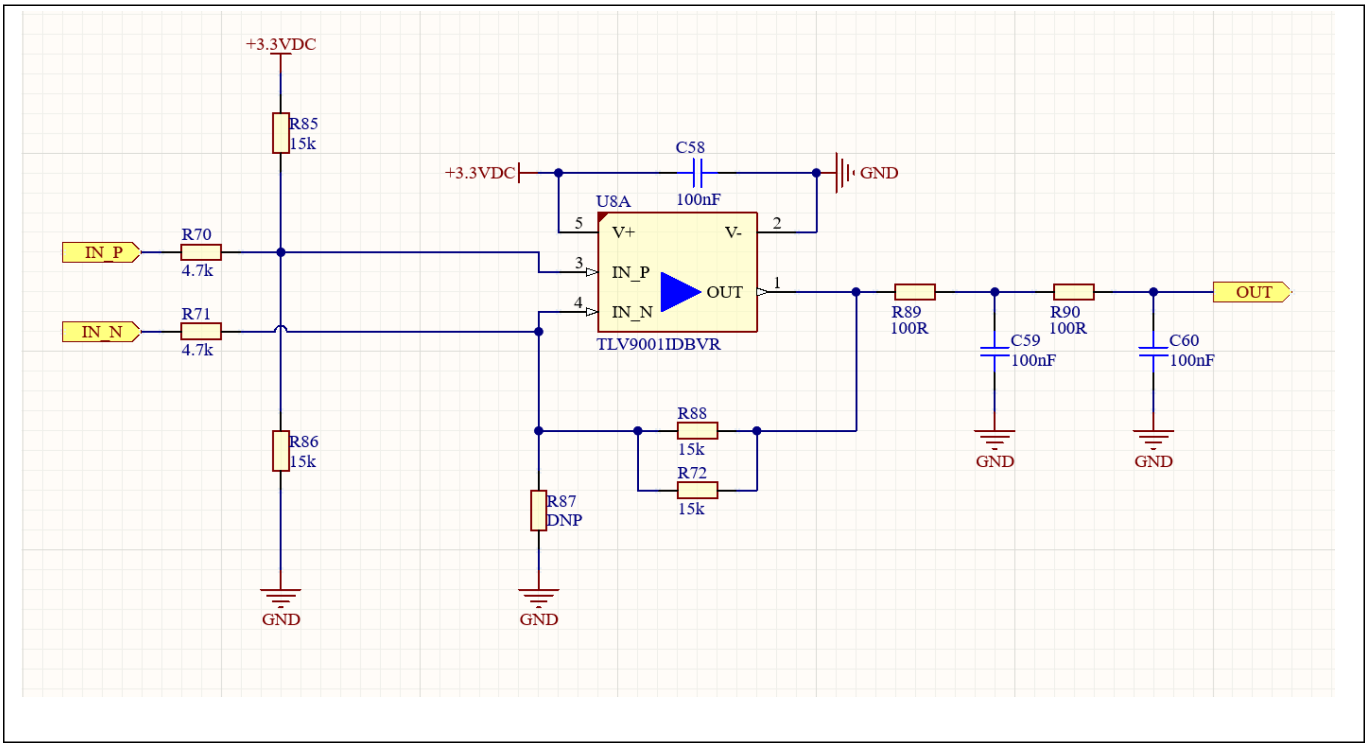


Figure 17 Current feedback schematic

The current feedback circuit in Figure 17 converts the double-ended current feedback signals to single-ended signals with a gain of 3.19 V and an offset of 1.65 V. The components R89, C59, R90, and C60 form a second-order low-pass filter with a cutoff frequency of 6 kHz.

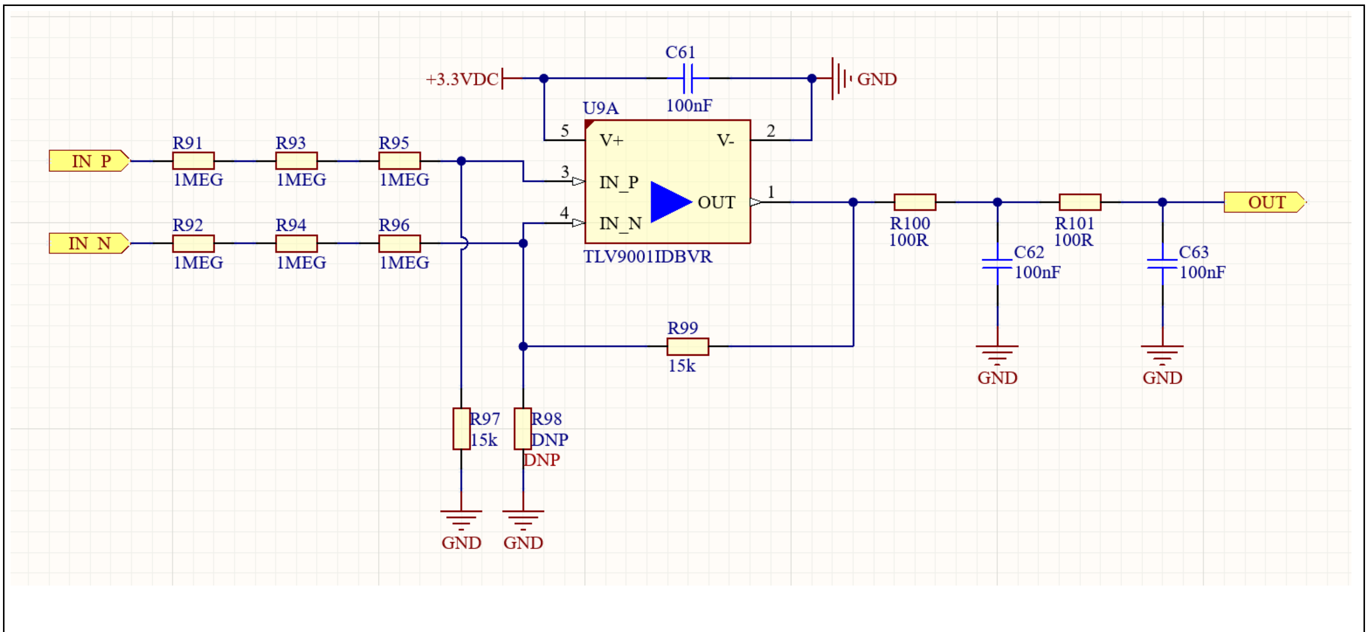


Figure 18 Voltage feedback schematic

The voltage feedback circuit in Figure 18 converts the high-voltage input to a low-voltage input for the microcontroller. The series connection of R91, R93, and R95 forms a voltage divider with R97, which has a ratio of 1/200. Input voltage of 600 V will be equal to 3 V at the input of the controller. There is no galvanic isolation but the isolation between the power and control grounds is 3 mΩ in this configuration. The components R100, C62, R101, and C63 form a second-order low-pass filter with cutoff frequency equal to 6 kHz.

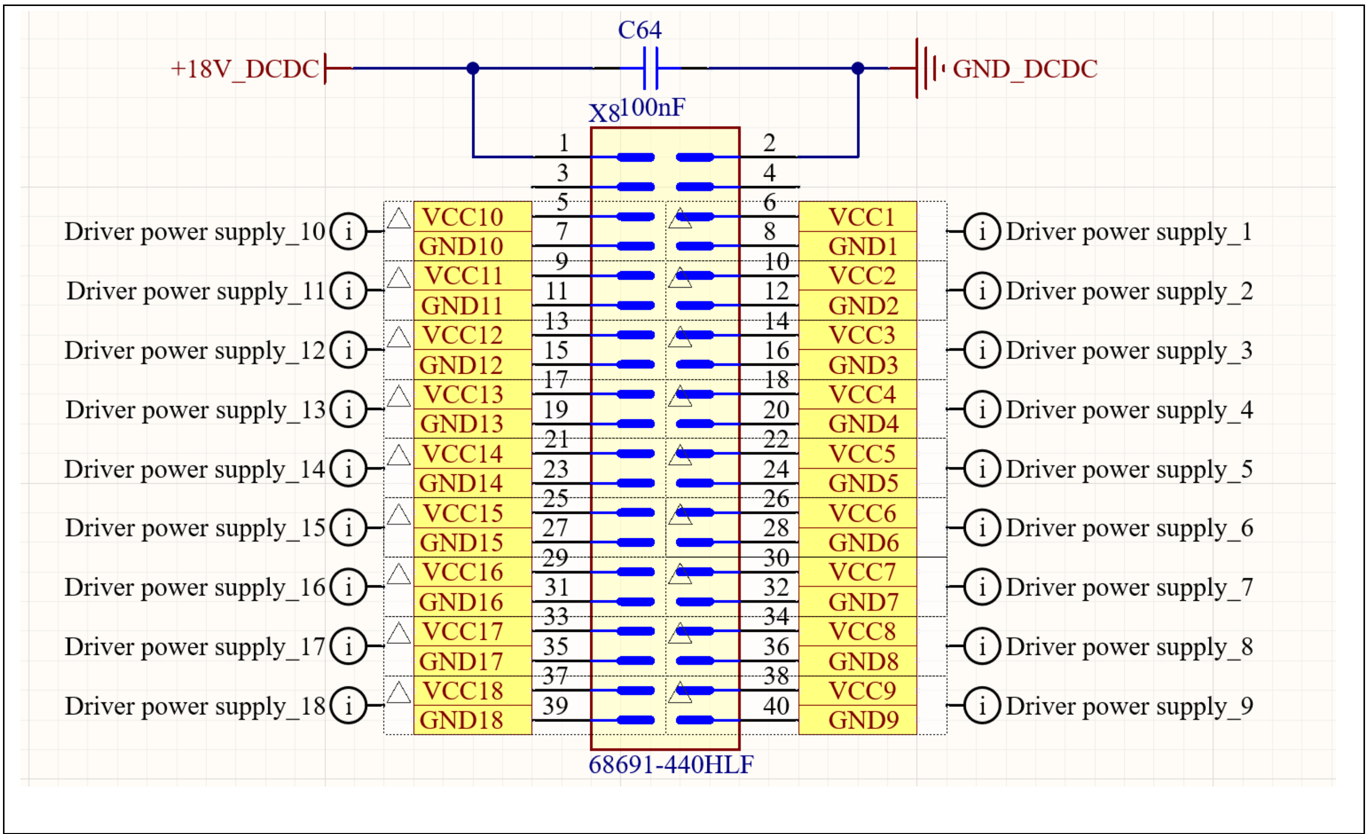


Figure 19 Isolated power supply board interface

For isolated power supply board, a standard 2.54 mm 2 x 20 pin header is used. The pin1 of connector X8, which has a dot on the PCB, is the positive supply while Pin2 is the ground. The created isolated voltage supplies for the gate drivers are taken through this connector in differential pairs.

5.2 Isolated power supply board

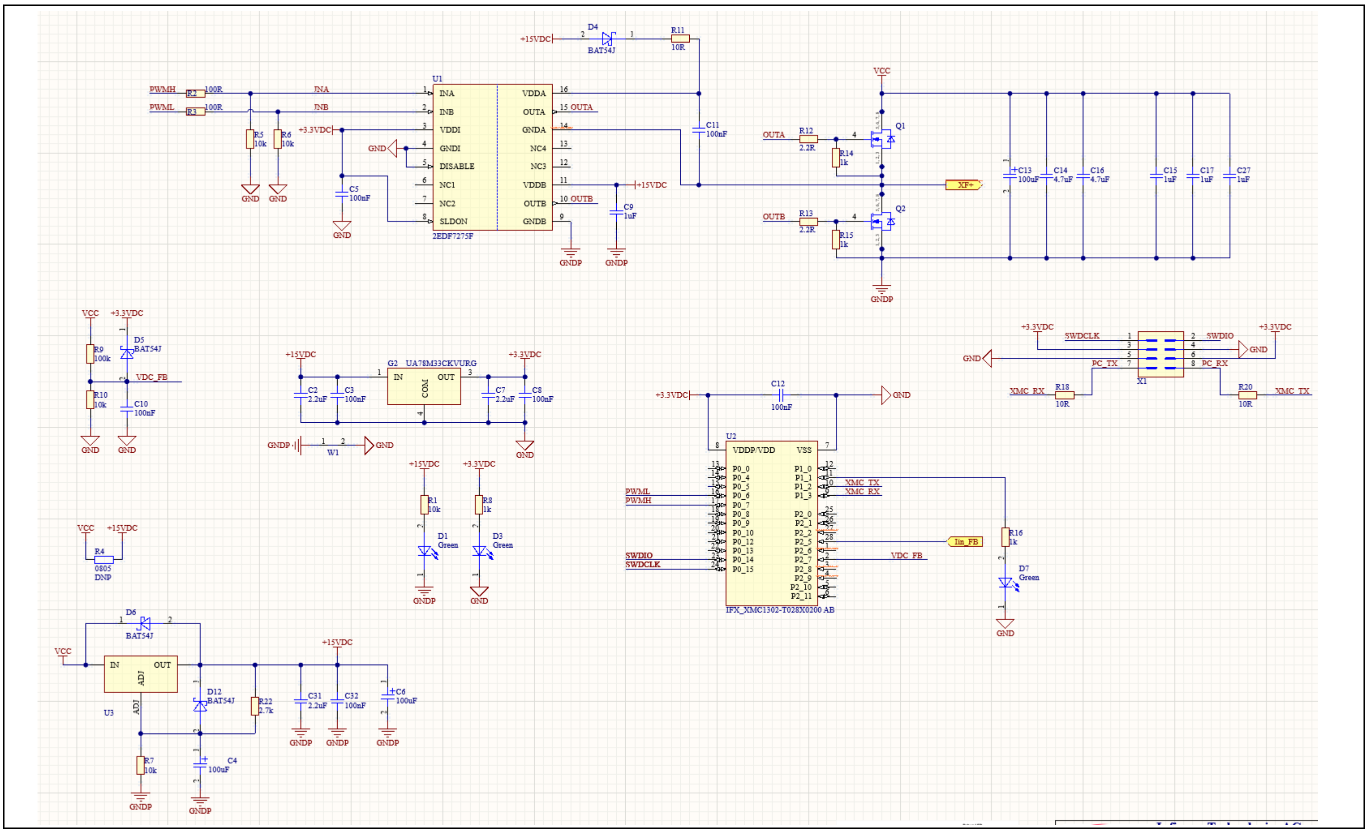


Figure 20 Isolated power supply board

For the control of the isolated gate voltage creation, XMC™ XMC1302 is used. The duty cycle and the frequency of the PWM can be controlled with the firmware. The resistors R9, R10 and C10 form a voltage divider for analog input. To program this board, XMC debugger is required. X1 connector can be used both for programming and UART communications. The pin1 SWDCLK, which has a dot on the PCB needs to be connected to Pin1 (red) of the debugger as shown in Figure 21.

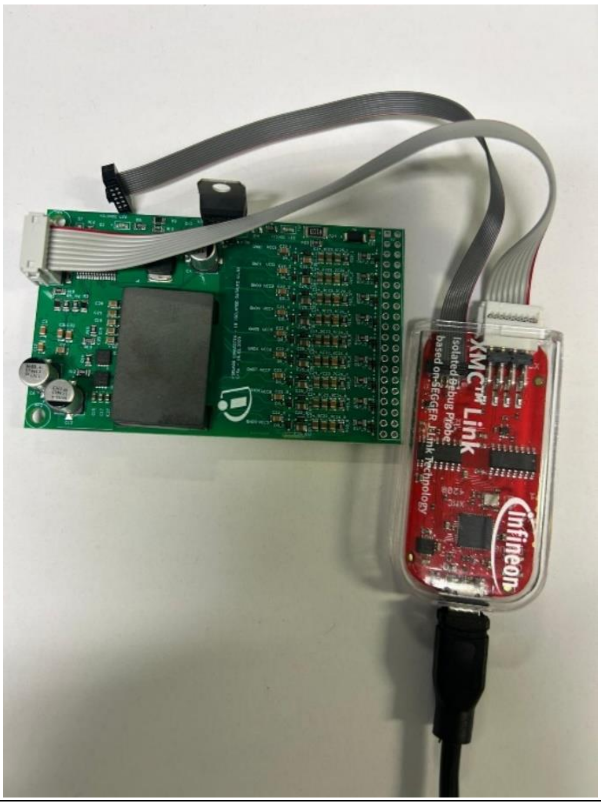


Figure 21 XMC™ Link connection to the isolated power supply board

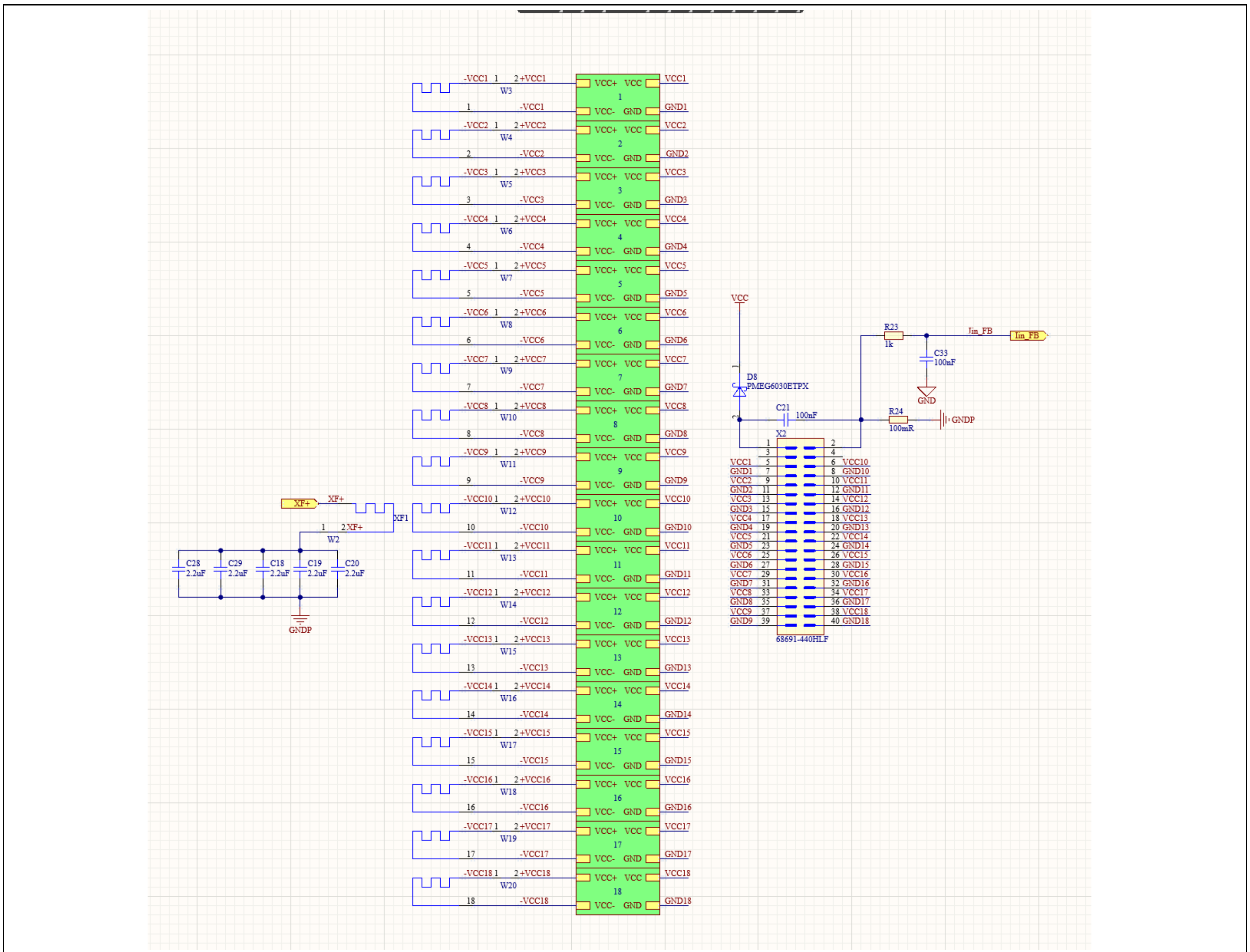


Figure 22 **Isolated power supply board – secondary side circuit for each of the 18 windings of the transformer**

The forward converter is constructed without the reset winding. C18, C19, C20, C28, and C29 are in a series with the transformer. These capacitors are discharged when the output is low. The transformer is implemented with windings constructed on the PCB and an external EEQ30 ferrite core B66506G0000X197 from EPCOS-TDK.

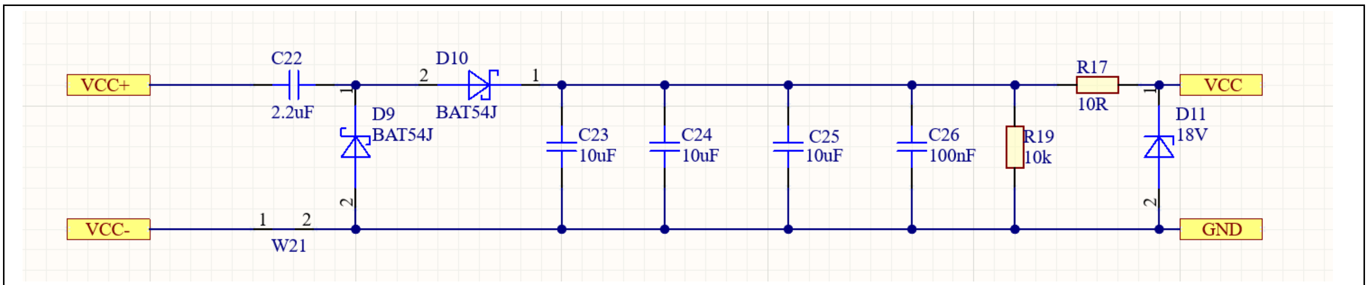


Figure 23 **Isolated power supply board – rectifier**

6 PCB layout

6.1 Power board

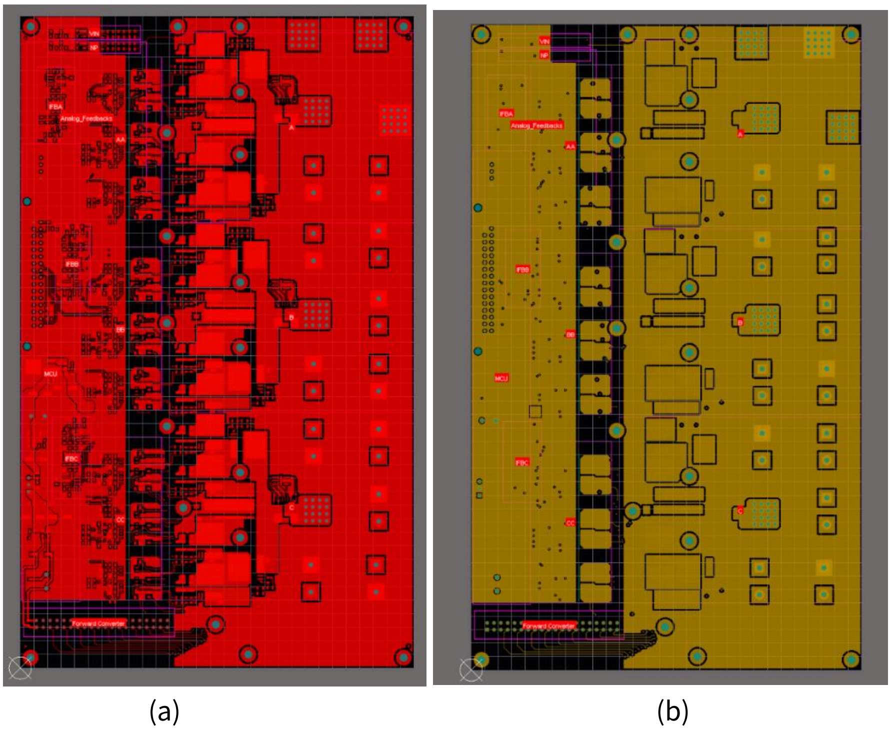


Figure 24 **(a) Layer 1 (Top); (b) Layer 2 (Bottom)**

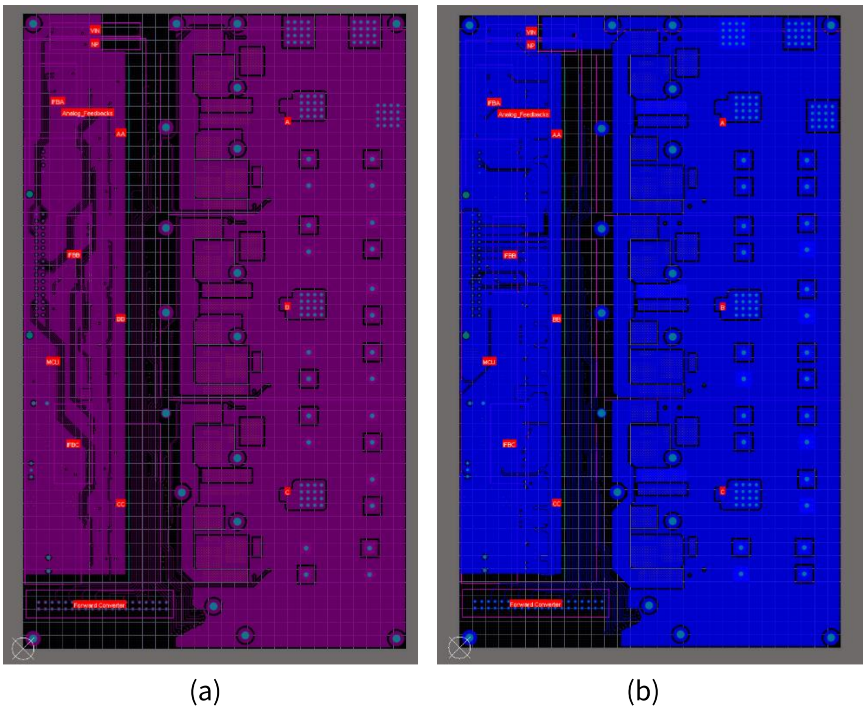


Figure 25 **(a) Layer 3; (b) Layer 4 (Bottom)**

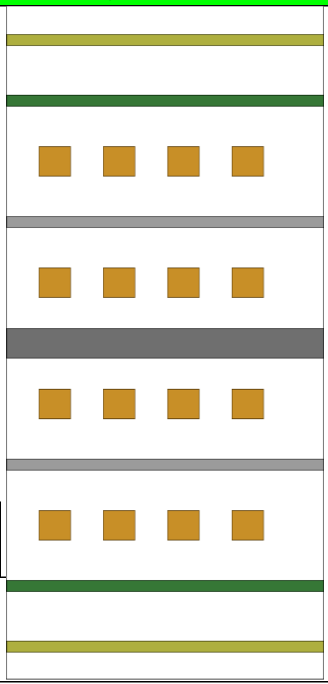
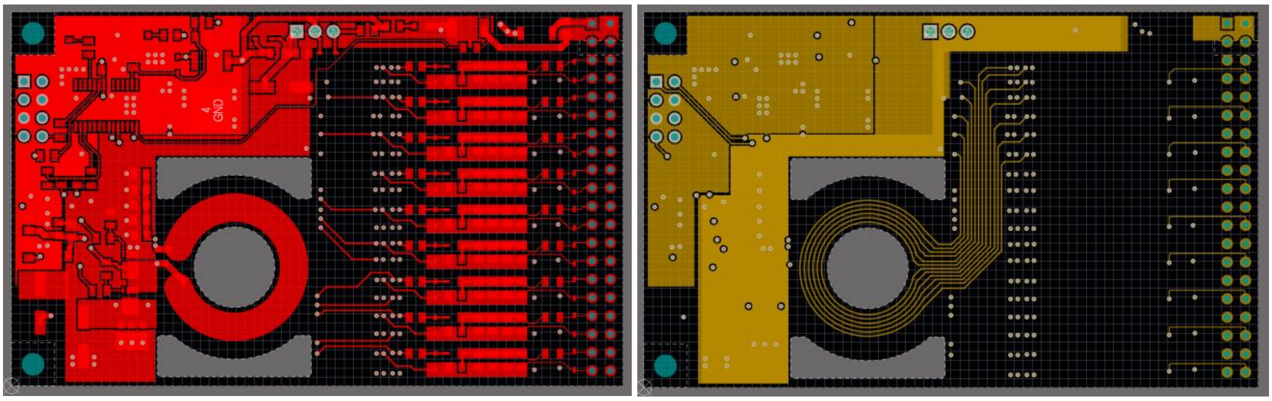
Stack up		Layer stack			
No.	**Board layer stack**	**Name**	**Material**	**Thickness**	**Constant**
1		Top paste			
2		Top overlay			
3		Top solder	Solder resist	0.020 mm	3.5
4		Layer 1	Copper	0.070 mm	
5		Dielectric1	FR-4	0.220 mm	4.3
6		Layer 2	Copper	0.070 mm	
7		Core	FR-4	1.000 mm	4.3
8		Layer 3	Copper	0.070 mm	
9		Dielectric2	FR-4	0.220 mm	4.3
10		Layer 4	Copper	0.070 mm	
11		Bottom solder	Solder resist	0.020 mm	3.5
12		Bottom overlay			
13		Bottom paste			

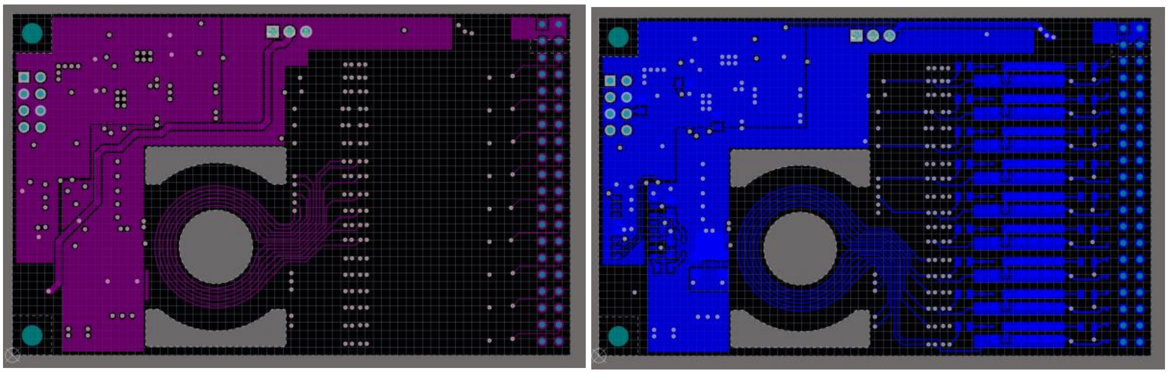
Figure 26 **Power board stack up**

6.2 Isolated power supply board



(a) (b)

Figure 27 (a) Layer 1 (Top); (b) Layer 2 (Bottom)



(a) (b)

Figure 28 (a) Layer 3; (b) Layer 4 (Bottom)

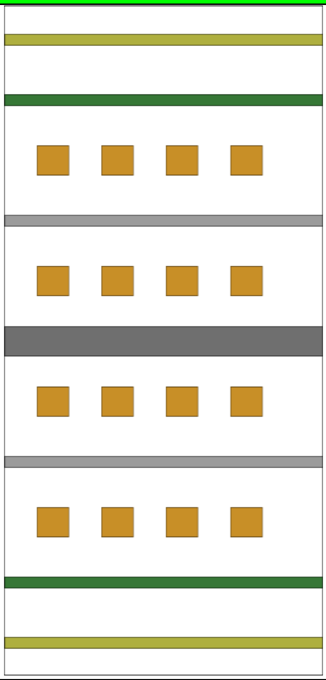
Stack up		Layer stack			
No.	Board layer stack	Name	Material	Thickness	Constant
1		Top paste	–	–	–
2		Top overlay	–	–	–
3		Top solder	Solder resist	0.020 mm	3.5
4		Layer 1	Copper	0.035 mm	
5		Dielectric1	FR-4	0.110 mm	4.29
6		Layer 2	Copper	0.035 mm	
7		Core	FR-4	1.200 mm	4.29
8		Layer 3	Copper	0.035 mm	
9		Dielectric2	FR-4	0.110 mm	4.29
10		Layer 4	Copper	0.035 mm	
11		Bottom solder	Solder resist	0.020 mm	3.5
12		Bottom overlay	–	–	–
13		Bottom paste	–	–	–

Figure 29 **Isolated power supply board stack up**

7 Bill of materials

7.1 Power board

Table 6 Power board BoM

Designator	Quantity	Description	Manufacturer	Manufacturer order number
C11_1, C12_1, C13_1, C14_1	12	CAP / ELCO / 270uF / 400V / 20% / Aluminiumelectrolytic / -25°C to 105°C / 10.00mm Pitch X 23.50mm Dia X 52.00mm H body / THT / -	Nichicon	LGW2G271MELZ50
C15_1, C15_2, C15_3, C16_1, C16_2, C16_3, C17_1, C17_2, C17_3, C18_1, C18_2, C18_3, C19_1, C19_2, C19_3, C20_1, C20_2, C20_3, C21_1, C21_2, C21_3, C22_1, C22_2, C22_3, C23_1, C23_2, C23_3, C24_1, C24_2, C24_3	30	CAP / CERA / 100nF / 500V / 10% / X7R (EIA) / -55°C to 125°C / 1210(3225) / SMD / -	Kemet	C1210C104KCRACTU
C25_1, C25_2, C25_3, C26_1, C26_2, C26_3, C27_1, C27_2, C27_3, C28_1, C28_2, C28_3, C31_1, C31_2, C31_3, C32_1, C32_2, C32_3, C33_1, C33_2, C33_3, C35_1, C35_2, C35_3, C36_1, C36_2, C36_3, C37_1, C37_2, C37_3, C38_1, C38_2, C38_3, C39_1, C39_2, C39_3, C40_1, C40_2, C40_3, C57, C64, C70, C71, C72, C73, C74	46	CAP / CERA / 100nF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	Kemet	C0805C104J5RAC
C34_1, C34_2, C34_3	3	CAP / CERA / 1nF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	Kemet	C0805C102K5RACTU
C41, C44, C45, C47, C48, C49, C50, C51, C54, C56, C58_1, C58_2, C58_3, C59_1, C59_2, C59_3, C60_1, C60_2, C60_3, C61_1, C61_2, C62_1, C62_2, C63_1, C63_2	25	CAP / CERA / 100nF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	MuRata	GRM21BR71H104JA01
C42, C43, C46, C52, C53, C55	6	CAP / ELCO / 100uF / 25V / 20% / Aluminiumelectrolytic / -55°C to 125°C / 6.60mm L X 6.60mm W X 8.00mm H / - / -	Panasonic	EEHZC1E101XP
C69_1, C69_2, C69_3	3	CAP / CERA / 100nF / 25V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Kemet	C0603C104J3RAC
D1_1, D1_2, D1_3, D2_1, D2_2, D2_3, D3_1, D3_2, D3_3, D4_1, D4_2, D4_3, D5_1, D5_2, D5_3, D6_1, D6_2, D6_3, D7_1, D7_2, D7_3, D8_1, D8_2, D8_3, D21, D22_1, D22_2, D22_3, D23_1, D23_2, D23_3, D24_1, D24_2, D24_3	34	Schottky barrier single diode	Nexperia	BAT54J
D9_1, D9_2, D9_3, D10_1, D10_2, D10_3, D11_1, D11_2, D11_3, D12_1,	18	Zener Voltage Regulator, 20V	ON Semiconductor	MMSZ5250BT1G

Designator	Quantity	Description	Manufacturer	Manufacturer order number
D12_2, D12_3, D13_1, D13_2, D13_3, D14_1, D14_2, D14_3				
D15	1	CHIPLED, Green Colour, 570nm	OSRAM Opto Semiconductors	LG R971-KN-1
D16, D20	2	DIODE SCHOTTKY 60V 3A SOD128	Nexperia	PMEG6030ETPX
D17, D18, D19	3	LED GREEN CLEAR SMD	OSRAM Opto Semiconductors	LG M67K-H1J2-24-Z
G1	1	Positive Voltage Regulator ICs	STMicroelectronics	L7805CV
G2	1	µA78Mxx Positive-Voltage Regulator, 7V - 25V Input Voltage, 5.0V Output (Operating Temperature 0°C to 125°C)	Texas Instruments	UA78M05CKVURG3
J1_1, J1_2, J1_3	3	Jumper-0.64mm Thick Copper	Keystone Electronics	5100
L1, L2, L3, L4	4	IND / FERR / 330R / 1.5A / 25% / -55°C to 125°C / - / 0805(2012) / Inductor,Chip;2.00mm L X 1.25mm W X 1.05mm H / SMD / -	MuRata	BLM21PG331SN1D
MP1, MP2, MP3, MP4, MP5, MP6, MP7, MP8, MP9, MP10, MP11, MP12, MP12_1, MP12_2, MP12_3, MP13, MP13_1, MP13_2, MP13_3	19	M3 X 6mm Pan Head,Cross Head Metric Screw, 5.6mm X 2.4mm Head, Nylon 6,6	Duratool	D00687
Q1D_1, Q1D_2, Q1D_3, Q1S-Q2D-Q5D_1, Q1S-Q2D-Q5D_2, Q1S-Q2D-Q5D_3, Q2S-Q3D-NP_1, Q2S-Q3D-NP_2, Q2S-Q3D-NP_3, Q3S-Q4D-Q6S_1, Q3S-Q4D-Q6S_2, Q3S-Q4D-Q6S_3, Q4S-GND_1, Q4S-GND_2, Q4S-GND_3, Q5S-Q6D-PH_1, Q5S-Q6D-PH_2, Q5S-Q6D-PH_3	18	Test Point, Surface Mount, Finish- Tin Over Nickel	Harwin	S2751-46R
R1_1, R1_2, R1_3, R2_1, R2_2, R2_3, R3_1, R3_2, R3_3, R4_1, R4_2, R4_3, R25_1, R25_2, R25_3, R26_1, R26_2, R26_3	18	RES / STD / 30R / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805(2012) / SMD / -	Vishay	CRCW080530R0FK
R9_1, R9_2, R9_3, R10_1, R10_2, R10_3, R11_1, R11_2, R11_3, R12_1, R12_2, R12_3, R29_1, R29_2, R29_3, R30_1, R30_2, R30_3, R31_1, R31_2, R31_3, R32_1, R32_2, R32_3, R33_1, R33_2, R33_3, R36_1, R36_2, R36_3, R37_1, R37_2, R37_3, R38_1, R38_2, R38_3, R49_1, R49_2, R49_3, R50_1, R50_2, R50_3, R52_1, R52_2, R52_3, R53_1, R53_2, R53_3, R60_1, R60_2, R60_3, R61_1, R61_2, R61_3, R77, R106, R107, R108, R109, R110, R111	61	RES / STD / 10k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805FR-0710KL

Designator	Quantity	Description	Manufacturer	Manufacturer order number
R39_1, R39_2, R39_3, R40_1, R40_2, R40_3, R41_1, R41_2, R41_3, R42_1, R42_2, R42_3, R43_1, R43_2, R43_3, R44_1, R44_2, R44_3, R45_1, R45_2, R45_3, R46_1, R46_2, R46_3, R47_1, R47_2, R47_3, R48_1, R48_2, R48_3, R51_1, R51_2, R51_3, R54_1, R54_2, R54_3, R55_1, R55_2, R55_3, R56_1, R56_2, R56_3, R57_1, R57_2, R57_3, R58_1, R58_2, R58_3, R59_1, R59_2, R59_3, R89_1, R89_2, R89_3, R90_1, R90_2, R90_3, R100_1, R100_2, R101_1, R101_2, R103, R104, R105, R112, R113, R114	67	RES / STD / 100R / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW0805100RFK
R62_1, R62_2, R62_3, R63_1, R63_2, R63_3, R64_1, R64_2, R64_3, R65_1, R65_2, R65_3, R66_1, R66_2, R66_3, R67_1, R67_2, R67_3	18	RES / STD / 0R / 125mW / 0R / 0ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805JR-070RL
R70_1, R70_2, R70_3, R71_1, R71_2, R71_3	6	RES / STD / 4.7k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805(2012) / SMD / -	Vishay	CRCW08054K70FK
R72_1, R72_2, R72_3, R85_1, R85_2, R85_3, R86_1, R86_2, R86_3, R88_1, R88_2, R88_3, R97_1, R97_2, R99_1, R99_2	16	RES / STD / 15k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW080515K0FK
R73, R74, R75, R78	4	RES / STD / 1k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805FR-071KL
R76	1	RES / - / 4.7k / 125mW / 1% / 100ppm/K / - / 0805 / SMD / -	Bourns	CR0805-FX-4701GLF
R91_1, R91_2, R92_1, R92_2, R93_1, R93_2, R94_1, R94_2, R95_1, R95_2, R96_1, R96_2	12	RES / - / 1MEG / 125mW / 1% / 100ppm/K / - / 0805 / SMD / -	Multicomp	MCMR08X1004FTL
U1_1, U1_2, U1_3, U2_1, U2_2, U2_3, U3_1, U3_2, U3_3, U4_1, U4_2, U4_3	12	Single 2-Input AND Gate	Texas Instruments	SN74AHC1G08QDCKRQ1
U5_1, U5_2, U5_3, U6_1, U6_2, U6_3, U7_1, U7_2, U7_3	9	Fast, Robust, Dual-Channel, Functional and Reinforced Isolated MOSFET Gate-Driver with Accurate and Stable Timing	Infineon Technologies	2EDF7275F
U8_1, U8_2, U8_3, U9_1, U9_2	5	Low-Power, RRIO, 1-MHz Operational Amplifier for Cost-Sensitive Systems	Texas Instruments	TLV9001IDBVR
U10_1, U10_2, U10_3	3	A high precision miniature coreless magnetic current sensor for AC and DC measurements with analog interface and two fast over-current detection outputs	Infineon Technologies	TLI4971-A120T5-E0001
X1, X2, X3, X3_1, X3_2, X3_3	6	Terminals WP-SHFU Pin-Plate 16Pin M5 Shank 180A	Wurth Elektronik	7461383
X4	1	Through Hole Socket, Right angle 2.54mm pitch, 16X2 pin, double row	Hirose Connectors	PCN13-32S-2.54DS(71)

Designator	Quantity	Description	Manufacturer	Manufacturer order number
X5, X6	2	Term Block HDR 2POS VERT 5.08mm	Würth Electronic	691311500102
X7	1	Connector, 2.54mm Pitch, 4Pins, Receptacle, Vertical	Amphenol	75915-304LF
X8	1	High temperature thermoplastic material, High retention force onto PCB, Bergstik Header	Amphenol	68691-440HLF
X9_1, X9_2, X9_3, X10, X11, X12	6	SMT Micro Header, 1.27mm pitch, 6 pin, Vertical, Double Row	Samtec	FTSH-103-01-L-DV-TR
C11_1, C12_1, C13_1, C14_1	12	CAP / ELCO / 270uF / 400V / 20% / Aluminiumelectrolytic / -25°C to 105°C / 10.00mm Pitch X 23.50mm Dia X 52.00mm H body / THT / -	Nichicon	LGW2G271MELZ50
C15_1, C15_2, C15_3, C16_1, C16_2, C16_3, C17_1, C17_2, C17_3, C18_1, C18_2, C18_3, C19_1, C19_2, C19_3, C20_1, C20_2, C20_3, C21_1, C21_2, C21_3, C22_1, C22_2, C22_3, C23_1, C23_2, C23_3, C24_1, C24_2, C24_3	30	CAP / CERA / 100nF / 500V / 10% / X7R (EIA) / -55°C to 125°C / 1210(3225) / SMD / -	Kemet	C1210C104KCRACTU
C25_1, C25_2, C25_3, C26_1, C26_2, C26_3, C27_1, C27_2, C27_3, C28_1, C28_2, C28_3, C31_1, C31_2, C31_3, C32_1, C32_2, C32_3, C33_1, C33_2, C33_3, C35_1, C35_2, C35_3, C36_1, C36_2, C36_3, C37_1, C37_2, C37_3, C38_1, C38_2, C38_3, C39_1, C39_2, C39_3, C40_1, C40_2, C40_3, C57, C64, C70, C71, C72, C73, C74	46	CAP / CERA / 100nF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	Kemet	C0805C104J5RAC
C34_1, C34_2, C34_3	3	CAP / CERA / 1nF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	Kemet	C0805C102K5RACTU
C41, C44, C45, C47, C48, C49, C50, C51, C54, C56, C58_1, C58_2, C58_3, C59_1, C59_2, C59_3, C60_1, C60_2, C60_3, C61_1, C61_2, C62_1, C62_2, C63_1, C63_2	25	CAP / CERA / 100nF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	MuRata	GRM21BR71H104JA01
C42, C43, C46, C52, C53, C55	6	CAP / ELCO / 100uF / 25V / 20% / Aluminiumelectrolytic / -55°C to 125°C / 6.60mm L X 6.60mm W X 8.00mm H / - / -	Panasonic	EEHZC1E101XP
C69_1, C69_2, C69_3	3	CAP / CERA / 100nF / 25V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Kemet	C0603C104J3RAC
D1_1, D1_2, D1_3, D2_1, D2_2, D2_3, D3_1, D3_2, D3_3, D4_1, D4_2, D4_3, D5_1, D5_2, D5_3, D6_1, D6_2, D6_3, D7_1, D7_2, D7_3, D8_1, D8_2, D8_3,	34	Schottky barrier single diode	Nexperia	BAT54J

Designator	Quantity	Description	Manufacturer	Manufacturer order number
D21, D22_1, D22_2, D22_3, D23_1, D23_2, D23_3, D24_1, D24_2, D24_3				
D9_1, D9_2, D9_3, D10_1, D10_2, D10_3, D11_1, D11_2, D11_3, D12_1, D12_2, D12_3, D13_1, D13_2, D13_3, D14_1, D14_2, D14_3	18	Zener Voltage Regulator, 20V	ON Semiconductor	MMSZ5250BT1G
D15	1	CHIPLED, Green Colour, 570nm	OSRAM Opto Semiconductors	LG R971-KN-1
D16, D20	2	DIODE SCHOTTKY 60V 3A SOD128	Nexperia	PMEG6030ETPX
D17, D18, D19	3	LED GREEN CLEAR SMD	OSRAM Opto Semiconductors	LG M67K-H1J2-24-Z
G1	1	Positive Voltage Regulator ICs	STMicroelectronics	L7805CV
G2	1	µA78Mxx Positive-Voltage Regulator, 7V - 25V Input Voltage, 5.0V Output (Operating Temperature 0°C to 125°C)	Texas Instruments	UA78M05CKVURG3
J1_1, J1_2, J1_3	3	Jumper-0.64mm Thick Copper	Keystone Electronics	5100
L1, L2, L3, L4	4	IND / FERR / 330R / 1.5A / 25% / -55°C to 125°C / - / 0805(2012) / Inductor,Chip;2.00mm L X 1.25mm W X 1.05mm H / SMD / -	MuRata	BLM21PG331SN1D
MP1, MP2, MP3, MP4, MP5, MP6, MP7, MP8, MP9, MP10, MP11, MP12, MP12_1, MP12_2, MP12_3, MP13, MP13_1, MP13_2, MP13_3	19	M3 X 6mm Pan Head,Cross Head Metric Screw, 5.6mm X 2.4mm Head, Nylon 6,6	Duratool	D00687
Q1D_1, Q1D_2, Q1D_3, Q1S-Q2D-Q5D_1, Q1S-Q2D-Q5D_2, Q1S-Q2D-Q5D_3, Q2S-Q3D-NP_1, Q2S-Q3D-NP_2, Q2S-Q3D-NP_3, Q3S-Q4D-Q6S_1, Q3S-Q4D-Q6S_2, Q3S-Q4D-Q6S_3, Q4S-GND_1, Q4S-GND_2, Q4S-GND_3, Q5S-Q6D-PH_1, Q5S-Q6D-PH_2, Q5S-Q6D-PH_3	18	Test Point, Surface Mount, Finish- Tin Over Nickel	Harwin	S2751-46R
R1_1, R1_2, R1_3, R2_1, R2_2, R2_3, R3_1, R3_2, R3_3, R4_1, R4_2, R4_3, R25_1, R25_2, R25_3, R26_1, R26_2, R26_3	18	RES / STD / 30R / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805(2012) / SMD / -	Vishay	CRCW080530R0FK
R73, R74, R75, R78	4	RES / STD / 1k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805FR-071KL
R76	1	RES / - / 4.7k / 125mW / 1% / 100ppm/K / - / 0805 / SMD / -	Bourns	CR0805-FX-4701GLF
R91_1, R91_2, R92_1, R92_2, R93_1, R93_2, R94_1, R94_2, R95_1, R95_2, R96_1, R96_2	12	RES / - / 1MEG / 125mW / 1% / 100ppm/K / - / 0805 / SMD / -	Multicomp	MCMR08X1004FTL

Designator	Quantity	Description	Manufacturer	Manufacturer order number
U1_1, U1_2, U1_3, U2_1, U2_2, U2_3, U3_1, U3_2, U3_3, U4_1, U4_2, U4_3	12	Single 2-Input AND Gate	Texas Instruments	SN74AHC1G08QDCKRQ1
U5_1, U5_2, U5_3, U6_1, U6_2, U6_3, U7_1, U7_2, U7_3	9	Fast, Robust, Dual-Channel, Functional and Reinforced Isolated MOSFET Gate-Driver with Accurate and Stable Timing	Infineon Technologies	2EDF7275F
U8_1, U8_2, U8_3, U9_1, U9_2	5	Low-Power, RRIO, 1-MHz Operational Amplifier for Cost-Sensitive Systems	Texas Instruments	TLV9001IDBVR
U10_1, U10_2, U10_3	3	A high precision miniature coreless magnetic current sensor for AC and DC measurements with analog interface and two fast over-current detection outputs	Infineon Technologies	TLI4971-A120T5-E0001
X1, X2, X3, X3_1, X3_2, X3_3	6	Terminals WP-SHFU Pin-Plate 16Pin M5 Shank 180A	Wurth Elektronik	7461383
X4	1	Through Hole Socket, Right angle 2.54mm pitch, 16X2 pin, double row	Hirose Connectors	PCN13-32S-2.54DS(71)
X5, X6	2	Term Block HDR 2POS VERT 5.08mm	Würth Electronic	691311500102
X7	1	Connector, 2.54mm Pitch, 4Pins, Receptacle, Vertical	Amphenol	75915-304LF
X8	1	High temperature thermoplastic material, High retention force onto PCB, Bergstik Header	Amphenol	68691-440HLF
X9_1, X9_2, X9_3, X10, X11, X12	6	SMT Micro Header, 1.27mm pitch, 6 pin, Vertical, Double Row	Samtec	FTSH-103-01-L-DV-TR
3	MP14, MP15, MP16	6 Position Cable Assembly Rectangular Socket to Cable	Samtech Inc	FFSD-03-S-04.00-01

7.2 Isolated power supply

Table 7 Isolated power supply board BoM

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
26	C2, C7, C18, C19, C20, C22_1, C22_2, C22_3, C22_4, C22_5, C22_6, C22_7, C22_8, C22_9, C22_10, C22_11, C22_12, C22_13, C22_14, C22_15, C22_16, C22_17, C22_18, C28, C29, C31	CAP / CERA / 2.2uF / 25V / 20% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	MuRata	GCM21BR71E225MA73
27	C3, C5, C8, C10, C11, C12, C21, C26_1, C26_2, C26_3, C26_4, C26_5, C26_6, C26_7, C26_8, C26_9, C26_10, C26_11, C26_12, C26_13, C26_14, C26_15, C26_16, C26_17, C26_18, C32, C33	CAP / CERA / 100nF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	Kemet	C0805C104J5RAC
3	C4, C6, C13	CAP / ELCO / 100uF / 25V / 20% / Aluminiumelectrolytic / -55°C to 125°C / 6.60mm L X 6.60mm W X 8.00mm H / - / -	Panasonic	EEHZC1E101XP
1	C9	CAP / CERA / 1uF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	MuRata	GCM21BR71H105KA03
2	C14, C16	CAP / CERA / 4.7uF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 1206(3216) / SMD / -	TDK Corporation	C3216X7R1E475K160AC
3	C15, C17, C27	CAP / CERA / 1uF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	TDK Corporation	CGA3E1X7R1E105K080AC
54	C23_1, C23_2, C23_3, C23_4,	CAP / CERA / 10uF / 25V / 20% / X5R (EIA) /	MuRata	GRM21BR61E106MA73

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
	C23_5, C23_6, C23_7, C23_8, C23_9, C23_10, C23_11, C23_12, C23_13, C23_14, C23_15, C23_16, C23_17, C23_18, C24_1, C24_2, C24_3, C24_4, C24_5, C24_6, C24_7, C24_8, C24_9, C24_10, C24_11, C24_12, C24_13, C24_14, C24_15, C24_16, C24_17, C24_18, C25_1, C25_2, C25_3, C25_4, C25_5, C25_6, C25_7, C25_8, C25_9, C25_10, C25_11, C25_12, C25_13, C25_14, C25_15, C25_16, C25_17, C25_18	-55°C to 85°C / 0805(2012) / SMD / -		
3	D1, D3, D7	LED GREEN CLEAR SMD	OSRAM Opto Semiconductors	LG M67K-H1J2-24-Z
39	D4, D5, D9_1, D9_2, D9_3, D9_4, D9_5, D9_6, D9_7, D9_8, D9_9, D9_10, D9_11, D9_12, D9_13, D9_14, D9_15, D9_16, D9_17, D9_18, D10_1, D10_2, D10_3, D10_4, D10_5, D10_6, D10_7, D10_8, D10_9, D10_10, D10_11, D10_12, D10_13, D10_14, D10_15, D10_16, D10_17, D10_18, D12	Schottky barrier single diode	Nexperia	BAT54J
1	D8	DIODE SCHOTTKY 60V 3A SOD128	Nexperia	PMEG6030ETPX

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
18	D11_1, D11_2, D11_3, D11_4, D11_5, D11_6, D11_7, D11_8, D11_9, D11_10, D11_11, D11_12, D11_13, D11_14, D11_15, D11_16, D11_17, D11_18	Low-power voltage regulator diode	Nexperia	BZX384-C18,115
1	G2	µA78Mxx Positive-Voltage Regulator, 7V - 25V Input Voltage, 5.0V Output (Operating Temperature 0°C to 125°C)	Texas Instruments	UA78M05CKVURG3
2	MP1, MP2	M3 X 6mm Pan Head,Cross Head Metric Screw, 5.6mm X 2.4mm Head, Nylon 6,6	Duratool	D00687
2	Q1, Q2	OptiMOS Power-Transistor, 60 V	Infineon Technologies	BSZ099N06LS5
23	R1, R5, R6, R7, R10, R19_1, R19_2, R19_3, R19_4, R19_5, R19_6, R19_7, R19_8, R19_9, R19_10, R19_11, R19_12, R19_13, R19_14, R19_15, R19_16, R19_17, R19_18	RES / STD / 10k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805FR-0710KL
5	R8, R14, R15, R16, R23	RES / STD / 1k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805FR-071KL
1	R9	RES / STD / 100k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW0805100KFK
21	R11, R17_1, R17_2, R17_3, R17_4, R17_5, R17_6, R17_7, R17_8,	RES / STD / 10R / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW080510R0FK

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
	R17_9, R17_10, R17_11, R17_12, R17_13, R17_14, R17_15, R17_16, R17_17, R17_18, R18, R20			
2	R12, R13	RES / STD / 2.2R / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW08052R20FK
1	R22	RES / STD / 2.7k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW08052K70FK
1	R24	RES / STD / 100mR / 1W / 1% / 100ppm/K / -55°C to 155°C / 2010 / SMD / -	Bourns	CRM2010-FX-R100 E LF
1	U1	Fast, Robust, Dual-Channel, Functional and Reinforced Isolated MOSFET Gate-Driver with Accurate and Stable Timing	Infineon Technologies	2EDF7275F
1	U2	32-bit processor core Microcontroller, Temp. Range(-40°C - +105 °C), 14 ADC Channels, 200 Kbytes Flash	Infineon Technologies	XMC1302-T028X0200 AB
1	U3	Linear Voltage Regulator IC Positive Adjustable 1 Output 1.5A TO-220	STMicroelectronics	LM217T
1	X1	Through hole .025 SQ Post Header, 2.54mm pitch, 8 pin, vertical, double row	Samtec	TSW-104-07-F-D
1	XF1	Uncoated 3C95 Ferrite Core EQ Type 1.181" (30.00mm) Length 0.787" (20.00mm) Width	Ferroxcube	EQ30-3C95

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
		Diameter 0.315" (8.00mm) Height		
2	MP1, MP2	Hex Standoff Threaded M3x0.5 Stainless Steel 0.591" (15.00mm)	RAF Electronic Hardware	M1262-3005-SS-20
2	MP3, MP4	M3 X 6mm Pan Head,Cross Head Metric Screw, 5.6mm X 2.4mm Head, Nylon 6,6	Duratool	D00687

8 Test results

8.1 Power board turn ON and turn OFF waveforms

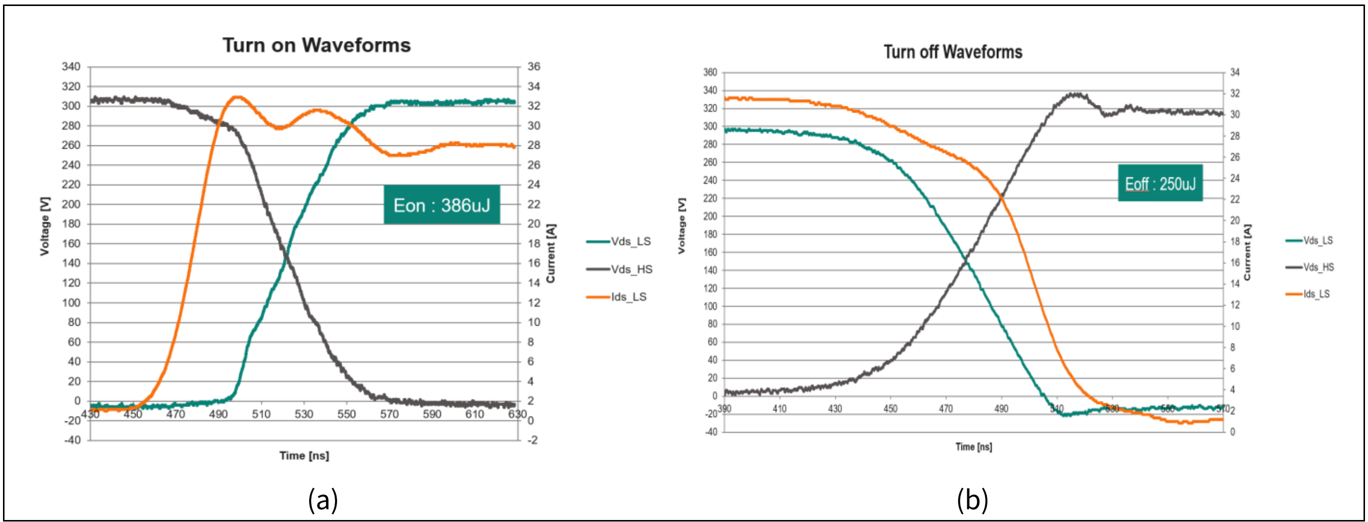


Figure 30 (a) Turn ON waveforms; (b) turn OFF waveforms

Both turn ON and turn OFF waveforms show clear transition with dv/dt lower than 5 V/ns. For this test, 18 V gate driver voltage together with 30 Ω gate driver resistor is used for 600 V input voltage (300 V on half bridge) at 30 A test current.

8.2 Thermal tests

Four different thermal tests were run without heatsink. Figure 31 shows the thermal test conditions.

THERMAL TEST CONDITIONS												
Test No	V_{DC} [V]	Iphs [A]	Vphs [V]	S [kVA]	$R_{G(on)}$ [Ω]	$R_{G(oFF)}$ [Ω]	fsw [kHz]	Dead Time [ns]	Modulator	Modulation Index	Load	Total Caps [uF]
#1	600	10	210	6.51	30	30	10	500	SinPWM	1	RL	3880
#2	600	12	210	7.49	30	30	10	500	SinPWM	1	RL	3880
#3	600	13	210	8.33	30	30	10	500	SinPWM	1	RL	3880
#4	600	15	210	9.74	30	30	10	500	SinPWM	1	RL	3880

Figure 31 Thermal test conditions

See Figure 32 for MOSFET nomenclature for the thermal tests.

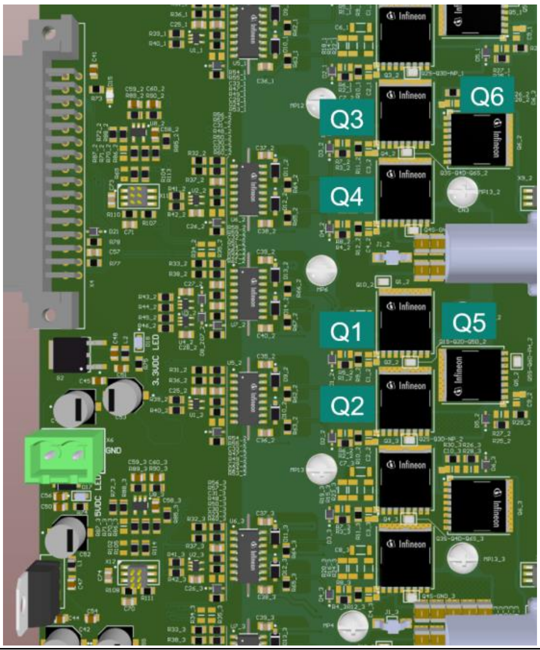


Figure 32 Thermal test MOSFET locations

Middle phase is selected for the MOSFET temperature measurements since they are in the middle of the board and experience higher temperatures during the tests. Figure 33 shows the results of each individual MOSFET temperature at different power levels.

Test No	Tcase_Q1 (°C)	Tcase_Q2 (°C)	Tcase_Q3 (°C)	Tcase_Q4 (°C)	Tcase_Q5 (°C)	Tcase_Q6 (°C)	Iph (A_rms)	Vph (V_rms)	S (VA)	Power Factor	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
#1	76	72	77	80	70	75	10.34	210	6514	0.99	6473.7	6449.1	24.7	99.62
#2	86	80	86	90	79	84	11.89	210	7491	0.99	7444.8	7415.8	29	99.61
#3	92	85	92	98	86	92	13.22	210	8329	0.99	8278.7	8245.3	33.3	99.60
#4	112	103	111	117	103	110	15.46	210	9740	0.99	9684.3	9642.4	41.9	99.57

Figure 33 Thermal test results without heatsink

Figure 34 shows thermal test results with 250 mm x 45 mm x 19 mm heatsink (base thickness: 6 mm).

Test No	Tcase_Q1 (°C)	Tcase_Q2 (°C)	Tcase_Q3 (°C)	Tcase_Q4 (°C)	Tcase_Q5 (°C)	Tcase_Q6 (°C)	Iph (A_rms)	Vph (V_rms)	S (VA)	Power Factor	Pin (W)	Pout (W)	Ploss (W)	Efficiency (%)
#5	69	65	64	68	65	66	14.66	210	9236	0.99	9182.0	9143.4	39	99.58

Figure 34 Thermal test results with heatsink

References

[1] Infineon Technologies AG: *KIT_XMC_LINK_SEGGER_V1 webpage*; Available online

[2] Infineon Technologies AG: *KIT_XMC4400_DC_V1 webpage*; Available online

[3] Infineon Technologies AG: *Current sensors webpage*; Available online

Revision history

Document revision	Date	Description of changes
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