



TO247 3-Phase Inverter Evaluation Board

User's Guide

<High Voltage Safety Precautions>

◇ Read all safety precautions before use

Please note that this document covers only SiC Power MOSFET Evaluation Driver Board (SCT4013DRC15-EVK-A08) and its functions.
For additional information, please refer to the datasheet.

To ensure safe operation, please carefully read all precautions before handling the evaluation board



Depending on the configuration of the board and voltages used,

Potentially lethal voltages may be generated.

Therefore, please make sure to read and observe all safety precautions described in the red box below.

Before Use

- [1] Verify that the parts/components are not damaged or missing (i.e. due to the drops).
- [2] Check that there are no conductive foreign objects on board.
- [3] Be careful when performing soldering on the module and/or evaluation board to ensure that solder splash does not occur.
- [4] Check that there are no condensation or water droplets on the circuit board.

During Use

- [5] Be careful do not allow conductive objects to come into contact with the board.
- [6] **Brief accidental contact or even bringing your hand close to the board may result in discharge and lead to severe injury or death.**

Therefore, DO NOT touch the board with your bare hands or bring them too close to the board.

In addition, as mentioned above please exercise extreme caution when using conductive tools such as tweezers and screwdrivers.

- [7] If used under conditions beyond its rated voltage, it may cause defects such as short-circuit, depending on the circumstances, explosion or other permanent damages.
- [8] It is imperative to wear insulated gloves when handling equipment during operational procedures.

After Use

- [9] The ROHM Evaluation Board contains the circuit which stores high voltage. Since it stores the charges even after the connected power circuits are cut, please discharge the electricity after using it, and please deal with it after confirming such electric discharge.
- [10] Protect against electric shocks by wearing insulated gloves when handling.

This evaluation board is intended for use only in research and development facilities and should be handled **only by qualified personnel familiar with all safety and operating procedures.**

We recommend carrying out operations in a safe environment that includes the use of high voltage signage at all entrances, safety interlocks, and protective glasses.

TO247 3-Phase Inverter Evaluation Board

SCT4013DRC15-EVK-A08

This document outlines the complete evaluation of a three-phase inverter utilizing 750V Silicon Carbide (SiC) MOSFETs which are tailored for demanding applications such as photovoltaic (PV) inverters, uninterruptible power supplies (UPS), motor drives, switch-mode power supplies (SMPS), servers, and other industrial-grade applications.

Traditionally, inverter systems operating with a 400 V DC bus have relied on 750 V Insulated Gate Bipolar Transistors (IGBTs) as their switching elements. However, recent advances in silicon carbide (SiC) MOSFET technology provide notable improvements over IGBTs, such as reduced on-resistance, increased power density, faster switching performance, and higher overall efficiency. This design leverages these advantages by replacing conventional IGBTs with SiC MOSFETs, leading to better thermal characteristics, lower switching losses, and enhanced system reliability.

Key Components

- **SCT4013DRC15:** A robust SiC MOSFET with 13mΩ Rds(on) in a transistor outline package, is selected for its excellent thermal and electrical characteristics, making it ideal for this current application.
- **BM61S41RFV-CE2:** A high-speed, isolated gate driver with 4A source and sink current capability ensures precise and reliable switching of SiC MOSFETs, contributing to the overall efficiency and stability of the inverter system.
- **PSR100KTQFL3L00:** This resistor is ideal for current sensing in high power applications, especially in automotive and industrial grade applications due to its high-power dissipation and low resistance.
- **LMR1802G-LBTR:** low-noise, low input offset voltage CMOS operational amplifier, designed for high-precision analog signal processing in Industrial applications.
- **BM2SC123FP2:** Quasi-resonant AC/DC converter with built-in 1700V SiC-MOSFET. Application found in industrial equipment, AC adaptor, household appliances etc.

Typical Application Circuit

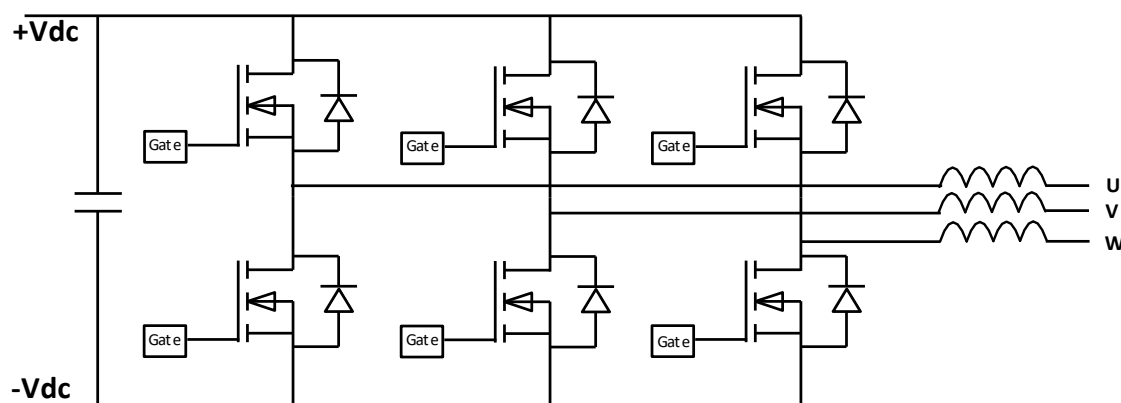


Figure 1. Application diagram

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1 Overview of the EVK

This manual provides instructions for using the EVK board to evaluate TO247 devices in a three-phase inverter configuration. Users are advised to read the manual thoroughly before starting any test. The board includes gate driver, sensing and Auxiliary (Aux) power supply board for driving gate signals and monitoring voltage and current.

Key features:

- **Compact Design:** Reduced cooling requirements and smaller footprint.
- **High Switching Frequency:** Optimizes the magnetics and filters.
- **Higher Efficiency:** Low $R_{DS(on)}$ of 13m Ω and a thermal resistance (R_{thJC}) of 0.37°C/W, the device offers reduced conduction and switching losses, along with improved thermal performance.
- **Scalable Architecture:** Easily adaptable for different power levels and applications.

2 Functional Block Diagram

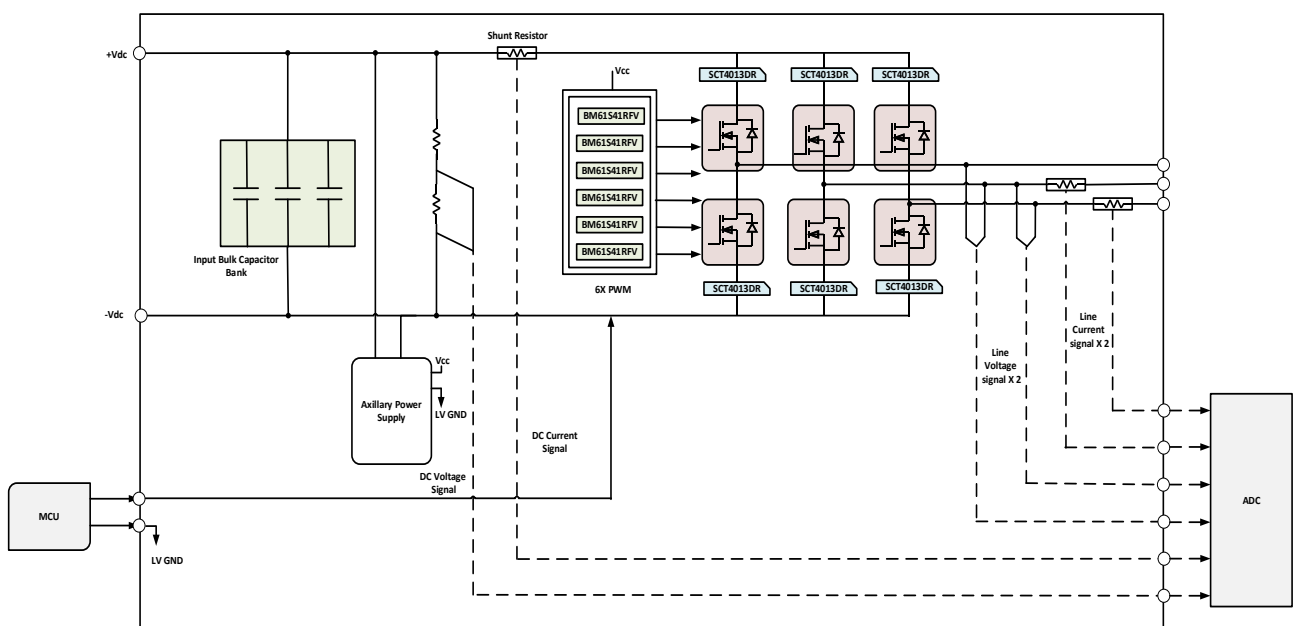


Figure 2. Three Phase Inverter Functional Block Diagram

2.1 Functional Description

The inverter operates through a series of well-defined stages:

DC Input Stage

This stage receives power from sources such as photovoltaic (PV) panels, battery banks, or rectified AC supplies. The input voltage should be regulated and conditioned to 400V_{dc} for ensuring stable operation of the power stage. External Input filtering and surge protection are implemented to safeguard against the voltage spikes and transient immunities.

Power Stage

The core of the inverter consists of six SiC MOSFETs (SCT4013DRC15). The MOSFETs are driven from the control circuitry to synthesize a sinusoidal AC waveform from the DC input. 2 snubber capacitances are provided for each leg of 3-phase H-bridge as well as the provision for diode and capacitance is given at each gate source.

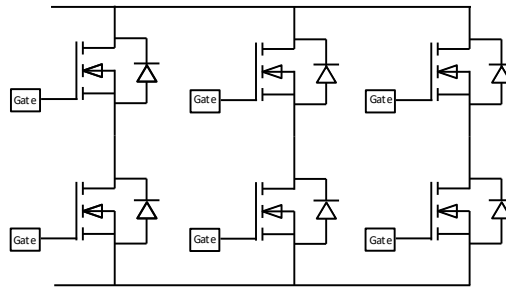


Figure 3. Power Stage circuit

Gate Driver Stage

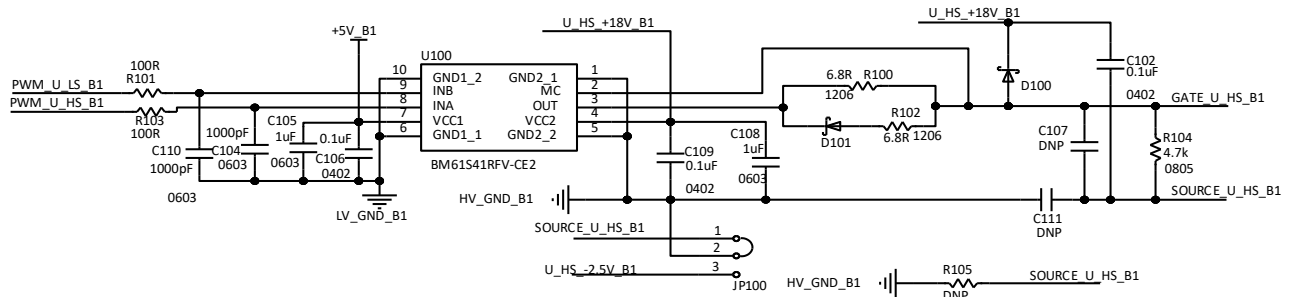


Figure 4. Gate driver circuit

Each SiC MOSFET is driven by a high-speed, isolated gate driver (BM61S41RFV-CE2) with isolation level of 3750Vrms. Isolation between control and power stages ensures safety and noise immunity, which is critical in high-voltage environments.

Gate resistors play a critical role in the performance and reliability of SiC MOSFET-based power circuits. When using a gate driver like the BM61S41RFV-CE2, selecting the appropriate gate resistor is essential to balance switching speed, EMI, and thermal performance.

Key Factors in Gate Resistor Selection

1. Switching Speed vs. EMI

Lower R_g results in faster switching but higher EMI and overshoot

Higher R_g slows switching, reducing EMI but increasing switching losses

2. Gate Charge and Drive Current

For detailed guidelines on gate driver circuit design, refer to the ROHM documentation provided at the link below -

Gate Drive Circuit Design Guidelines

3. Damping Oscillations

Use a series resistor close to the gate pin

Split gate resistors can be used for turn-on and turn-off control

Control Logic and PWM Generation

The inverter's control system typically implemented using an external MCU to generate precise PWM signals and regulate output voltage, frequency. It also monitors system parameters such as current, voltage, and temperature to implement protection features like overcurrent shutdown.

Inductive Load

CVE3527H-220M (22 μ H) from Sagami, with a DC saturation current of 28 A; 40 units are connected in series to achieve a total inductance of 880 μ H. The output of the inverter is used to drive 20A of current on to a balanced 3 phase star inductive load (880uH/28A).

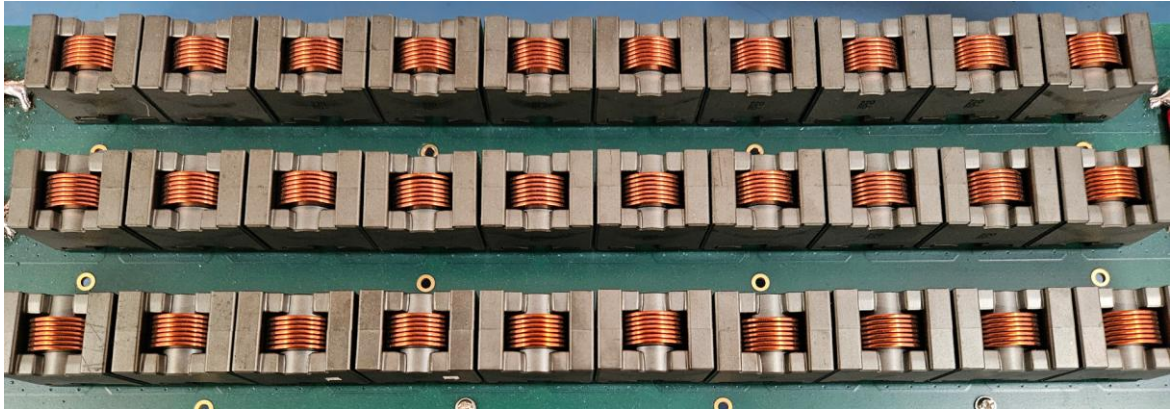


Figure 5. Inductive Load for three Phase Inverter Testing

Thermal Management

In this Reference design we have considered **LAM 5 170 ME** customised heat sink from fisher electronics to meet the thermal requirement for 10kVA and 25A of continuous current using a forced cooling (Fan) method.

LAM 5 170 ME Heat sink Specifications

Table 1. Heat Sink Specifications

Attribute	Specification
Series	LAM 5
Dimensions (W x H x L)	50 mm x 50 mm x 170 mm
Thermal Resistance	Vary with the Air flow

DC0502024M2B-2T0 – 24VDC Axial Fan Specifications - [DC0502024M2B-2T0](#)

Table 2. Fan Specifications

Parameter	Specification
Dimensions	50mm x 50mm x 20mm
Rated Voltage	24VDC
Current Rating	0.210 A
Power Consumption	5.04 W
Speed	6400 RPM
Air Flow	17.6 CFM (0.493 m ³ /min)
Noise Level	36 dB(A)
Operating Temperature	-10°C to +70°C (14°F to 158°F)
Lifetime	70,000 hours @ 40°C

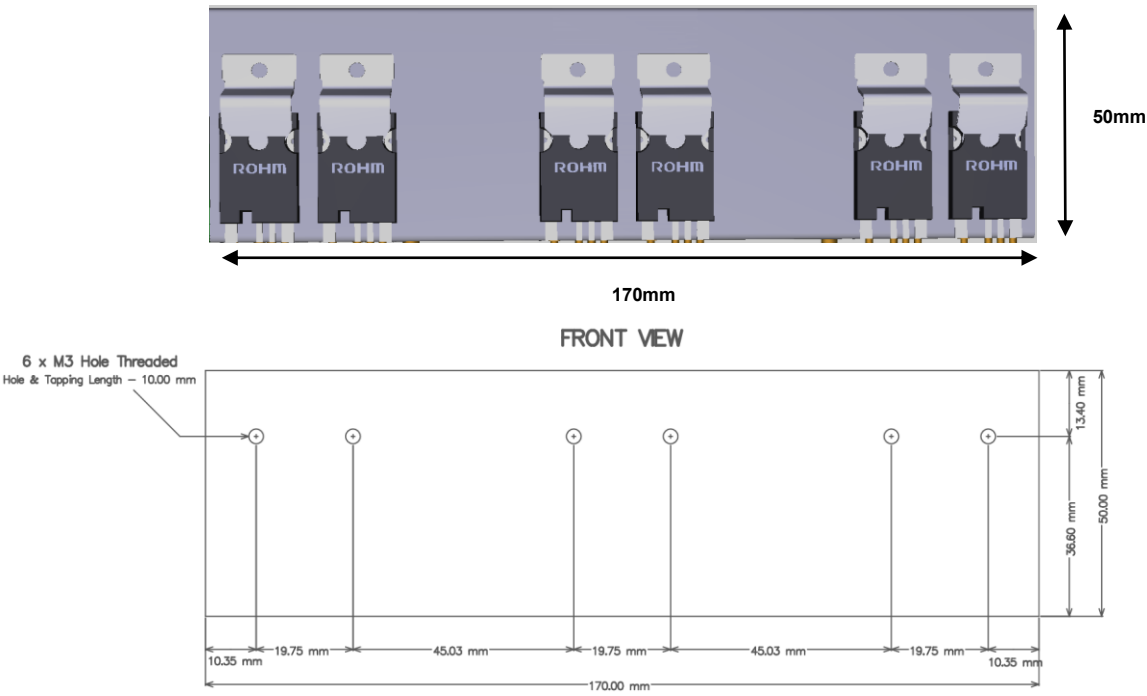


Figure 6. Screw and Clip placement for the MOSFET on heat sink

THFM 1 Spring Specifications

Table 3. Spring clip Specifications

Parameter	Specification
Part Number	THFM 1
Mounting Type	Screw mounting
Spring Force	55 N
Material Thickness	0.8 mm
Dimensions (L x W x H)	15 mm x 10.4 mm x 30 mm
Fixing Hole Diameter	3.2 mm

Heat sink mounting

Ensure the screw is positioned exactly as shown in the diagram and verify that the clip is securely fastened in its designated location.

3 Electrical Specifications

3.1 Inverter Board Specifications

Below are the specifications to which the inverter board has been tested. All the specifications are considering room temperature(@25°C), if not, otherwise mentioned.

Table 4. Power Board Specifications

Parameter	Specs				Remark
	Min	Typical	Max	Unit	
DC-Input Voltage	-	400		Vdc	
Output Current (cont.)	-	25	27	Arms	Rated output @ 25kHz – 80KHz
Switching Frequency		25 - 80		kHz	Rated output ~12KVA
Dimension	-	250.00 x 145.00	-	mm	

3.2 Current and Voltage Sensing Board Specifications

Table 5. Voltage Sensing Board Specifications

Parameter	Spec				Remark
	Min	Typical	Max	Unit	
Measurement range	0	400		Vdc	
Conversion Ratio	-	0.955	-	mV/V	Practical observation @400Vdc, 26A, 25KHz PWM
Dimension	-	30.00x 28.00	-	mm	

Table 6. Current Sensing Board Specifications

Parameter	Spec				Remark
	Min	Typical	Max	Unit	
Measurement range	0	27	-	A	RMS Current
Conversion Ratio	-	8.58	-	mV/A	Practical observation @400Vdc, 26A, 25KHz PWM
Dimension	-	30.00 x 28.00	-	mm	

3.3 Gate Driver Board

Table 7. Gate Driver Board Specifications

Parameter	Spec				Remark
	Min	Typical	Max	Unit	
Output Voltage	-	18	-	V	
Minimum Pulse Width	60	-	-	nsec	
Time delay	-	-	65	nsec	
Dimension	-	32.6 X 27.6	-	mm	

3.4 Aux Board

Table 8. Aux Board Specifications

Parameter	Specs				Remark
	Min	Typical	Max	Unit	
DC-Input Voltage	300	400	450	V	
DC Output Voltage 1	-	12	-	V	
DC Output Voltage 2	-	24	-	V	
Output Current 1	-	600	-	mA	
Output Current 2	-	600	-	mA	
Load Regulation	< 5			%	Contant DC Voltage = 400V
Line Regulation	<2			%	Constant Load Current, Iout = 500mA (From both 12V and 24V output)
Output Ripple	< 5			%	400Vdc, 500mA
Dimension	-	100.00 X 65.00	-	mm	

4 Sensing

A common sensing board is used for sensing the DC voltage, phase voltage as well as phase currents. The primary reason behind using a single board is to reduce the design as well as the inventory maintenance complexity.

Two stage amplification is used with first stage being isolation amplifier and second stage a non-inverting amplifier with the offset of 1.65V/2.5V (depends on microcontroller type). The gain calculation of the sensing board is below –

Input voltage to the sensing circuit - V_{in}

Fixed gain from isolation amplifier - 8.2

Input to the non-inverting amplifier,

$$V_{in(opamp)} = 8.2 * V_{in}$$

Output of non-inverting amplifier,

$$V_{out}(V) = V_{in(opamp)} * \frac{39}{18} + 1.65 \text{ or } 2.5$$

$V_{out}(V)$ will appear at the J103 connector. Check connections at the connector for specific sensing. For reference generation, 2.5V/ 1.65V specific circuit can be populated as per the requirement.

Note: 1.65V reference voltage is used for sense board testing for development of this user guide.

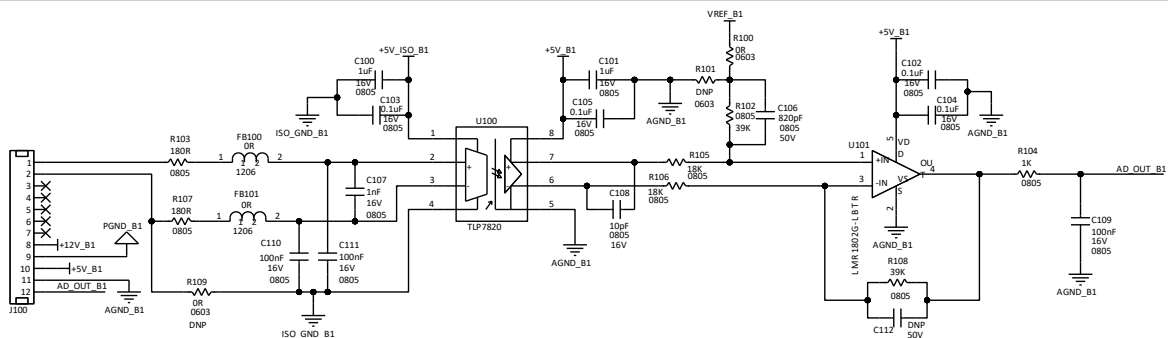


Figure 7. Sensing Circuit

4.1 VDC Sensing

The DC voltage is obtained by measuring the potential difference between the DC positive and negative rails. A resistor divider network is implemented as depicted in Figure 8.

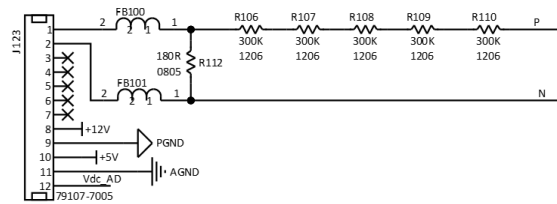


Figure 8. DC Voltage Sensing

The waveform is captured using the oscilloscope. The measurement point is taken at 38-pin connector (J103).



Figure 9. DC bus voltage sensing output measured at sensing board

To avoid the ringing at $V_{out}(V)$, The ADC sample should be taken at no switching region.

After eliminating the probe noise, the maximum peak-to-peak noise is 905.7mV and measurement accuracy of found was within 2.5%.

4.2 Output Phase Current Sensing

Phase current is sensed via a shunt resistor placed on the phase line. The resulting voltage drop is amplified using a differential amplifier stage (refer Figure 10), and the conditioned signal is digitized through an ADC and fed back to the controller for monitoring and control.

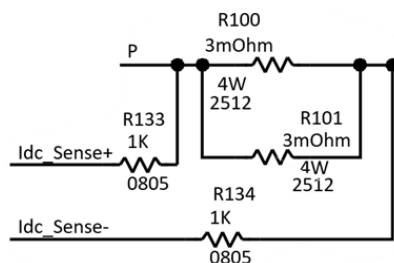


Figure 10. Phase Current Sensing Circuit

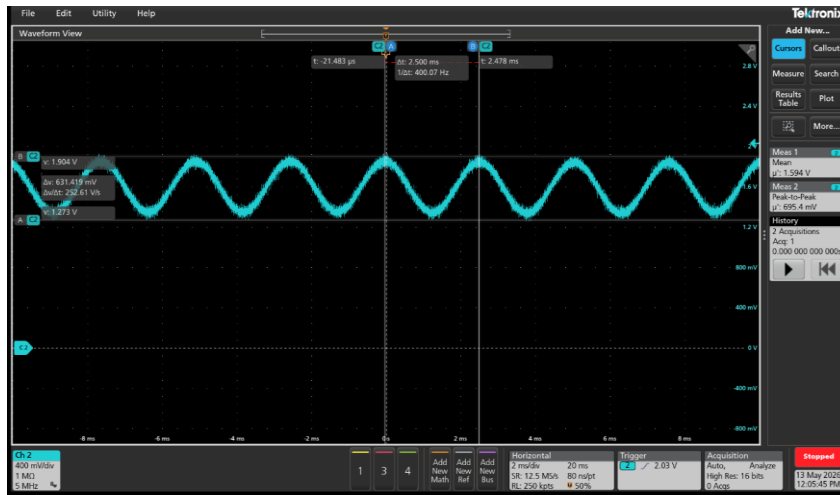


Figure 11. Phase to Phase Current Sensing

Figure 11 shows a test waveform captured with a time division of 2ms/div. The peak-to-peak phase current of 631mV is observed. A practical gain of 8.58mV/A is obtained from the circuit. Ripples are observed due to switching noise and a caution to avoid switching region needs to be taken while sampling ADCs. Please note that current calibration is required before closed loop implementation.

4.3 Phase to Phase Voltage Sensing

Phase-to-phase voltage is sensed using a resistor divider network connected between two phase lines.

The resulting differential voltage is amplified and digitized via an ADC and fed back to the controller for real-time monitoring and control.

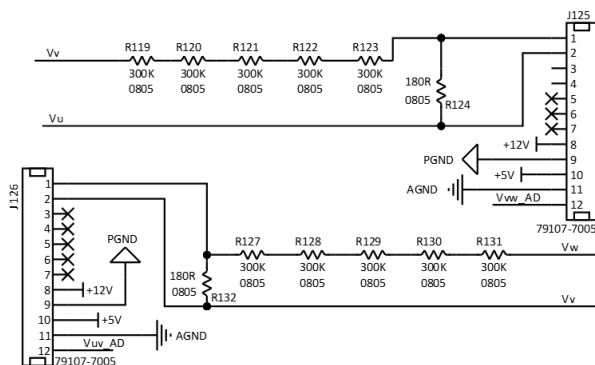


Figure 12. Sensed Phase to Phase Voltage Circuit

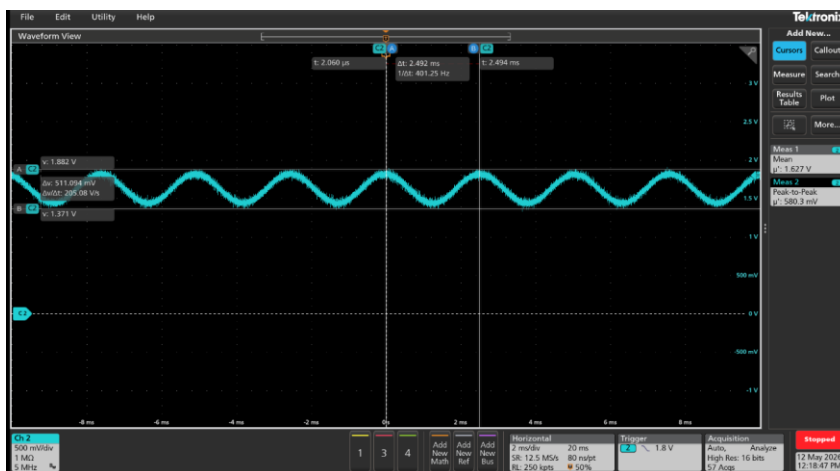


Figure 13. Phase-to-Phase Voltage Sensing Waveform

Figure 13 shows the test waveform captured at the oscilloscope with a 5MHz bandwidth and a time division of 2ms/div. The peak-to-peak phase voltage of 511mV is observed along with the offset of 1.65V. A practical gain of 0.955mV/V is obtained. A caution to avoid switching region needs to be taken while sampling ADCs and calibration is required for closed loop implementation.

Gate Driver Design

ROHM's BM61S41RFV-CE2 is a single-channel isolated gate driver. This device offers a high isolation rating of 3750Vrms and features a typical Under-Voltage Lockout (UVLO) threshold of 15V, making it well-suited for SiC MOSFET applications. It also includes active Miller clamp protection to prevent unintended turn-on of the MOSFET. The gate driver is powered with 5V on the primary side and 18V on the secondary side.

Features:

- Galvanic isolation between input and output (3750 Vrms)
- Active Miller clamp for enhanced switching performance
- Under-voltage lockout (UVLO) on both input and output sides
- Fast propagation delay: 65ns max
- Minimum input pulse width: 60ns
- Automotive-grade reliability (AEC-Q100 Grade 1)

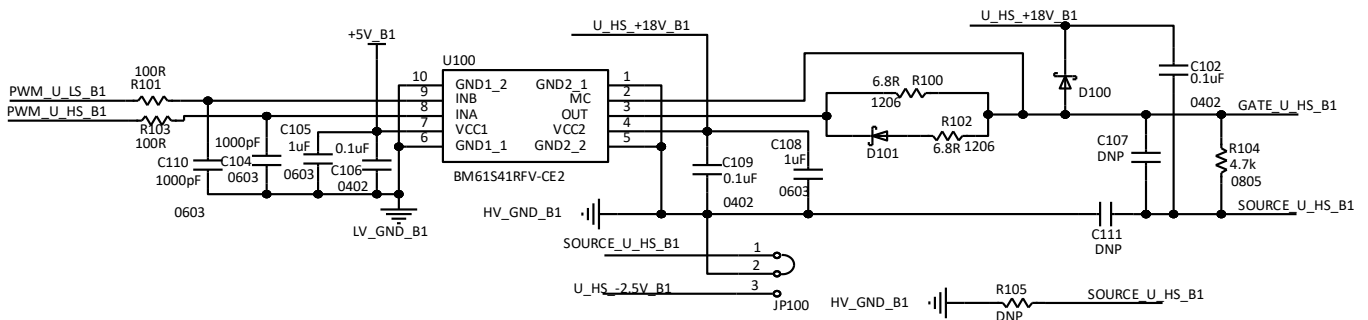


Figure 14. Gate Driver Circuit

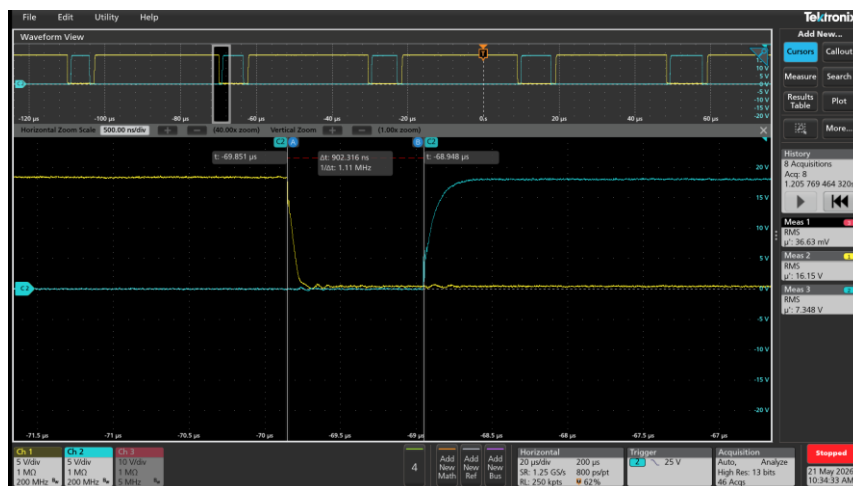


Figure 15. High Side (Yellow) and Low Side (Blue) gate pulse

Aux Board Design

Aux board is designed for providing the 12V power supply to gate driver boards and sensing boards and powers the 24V heatsink FAN. Aux board uses ROHM's BM2SC123FP2, a quasi-resonant AC/DC converter with built-in 1700V SiC-MOSFET.

Features of BM2SC123FP2:

- Active Built-in 1700V SiC-MOSFET
- VCC Under-voltage lockout (UVLO), Over Voltage Protection (OVP)
- Soft start function etc.

Aux board has been tested externally with variable load current. Figure 16 and Figure 17 shows the load and line regulation graphs. Effective load regulation of the aux board is less than 5% with a maximum load of 600mA from both 12V and 24V output line. The line regulation is less than 2% with input voltage varying from 300V to 450V.

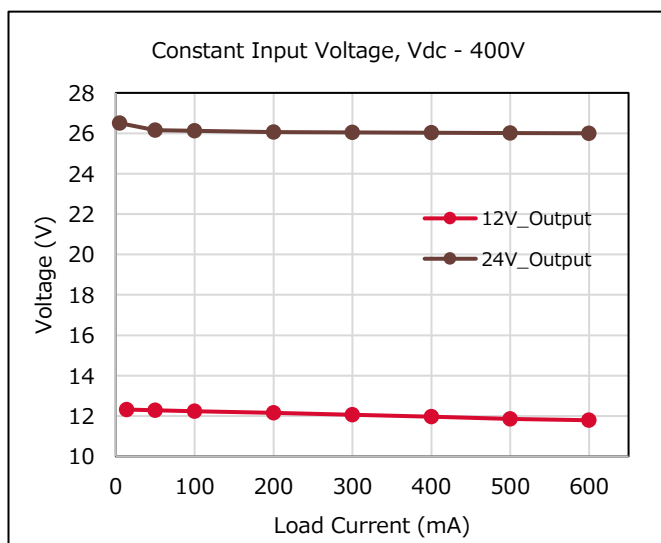


Figure 16. Load Regulation

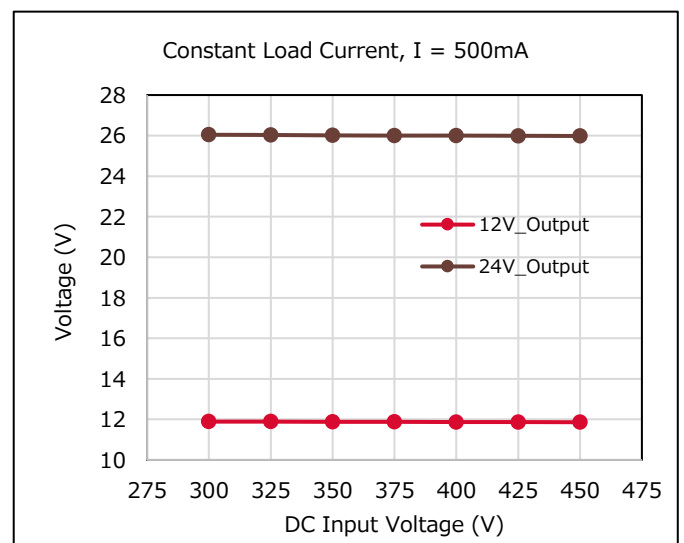


Figure 17. Line Regulation

5 Board Dimensions

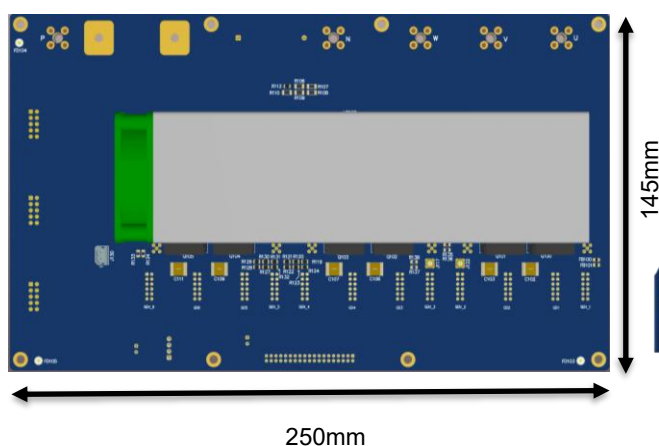


Figure 18. Power Board Bottom View

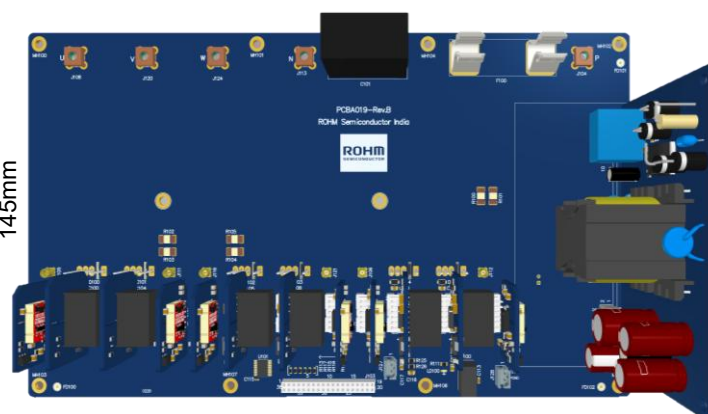


Figure 19. Power Board Top View

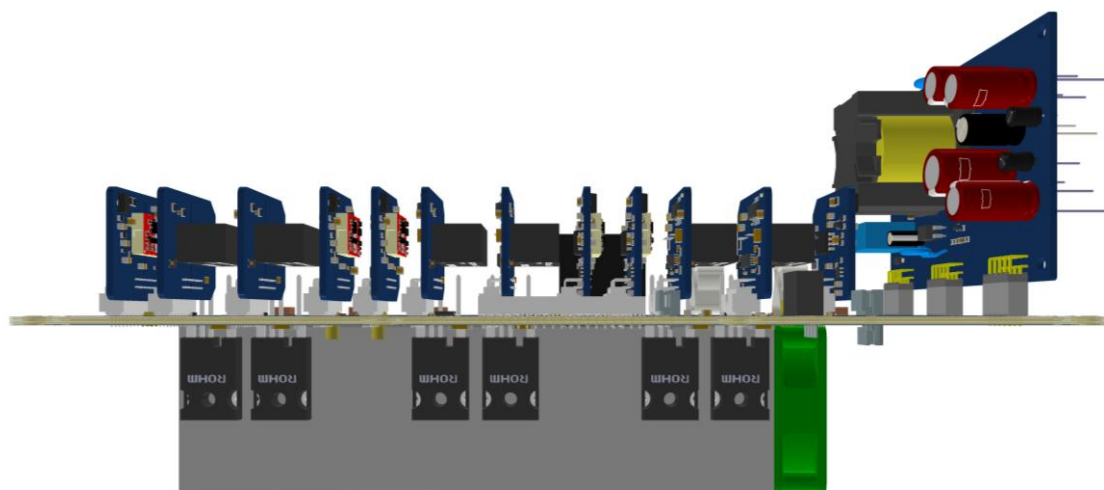


Figure 20. Power Board Side View

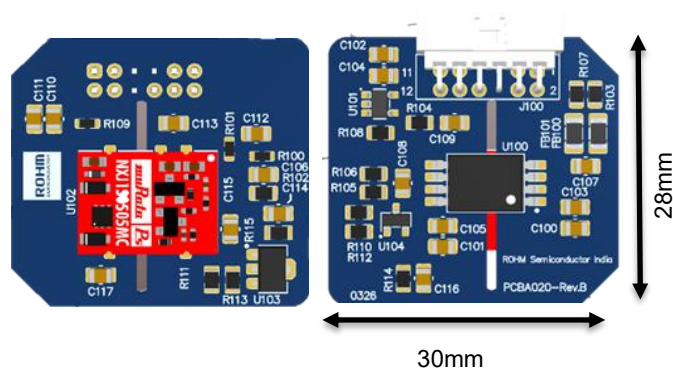


Figure 21. Sensing Board Top and Bottom View

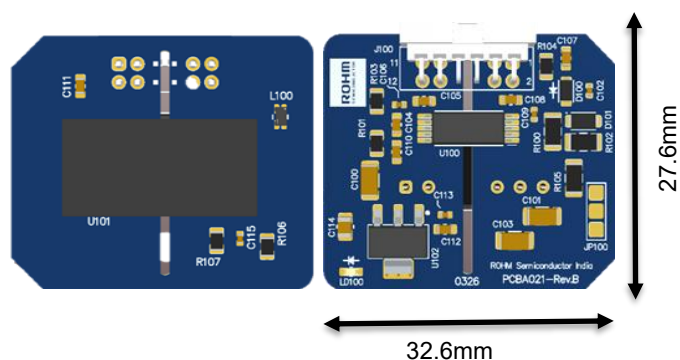


Figure 22. Gate driver Board Top and Bottom View

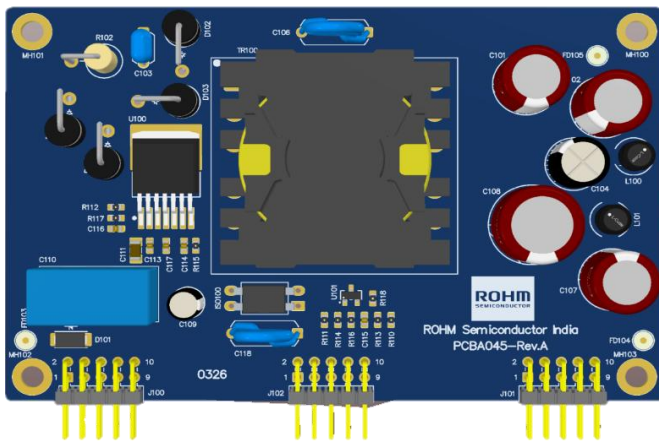


Figure 23. Aux Board Top View

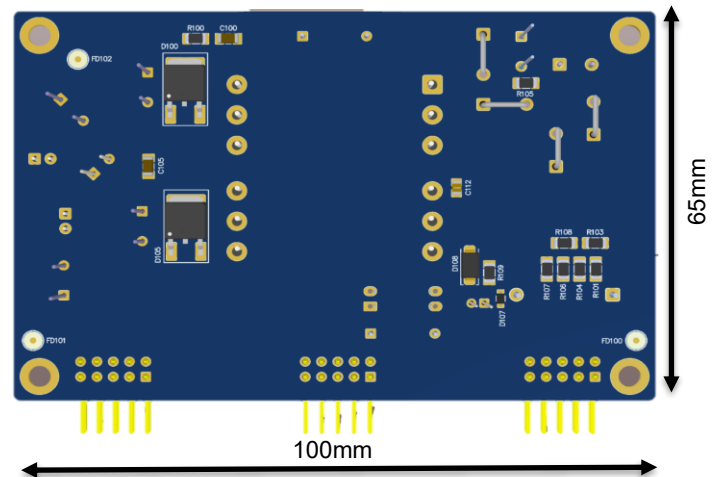


Figure 24. Aux Board Bottom View

6 Wiring Connection Diagram

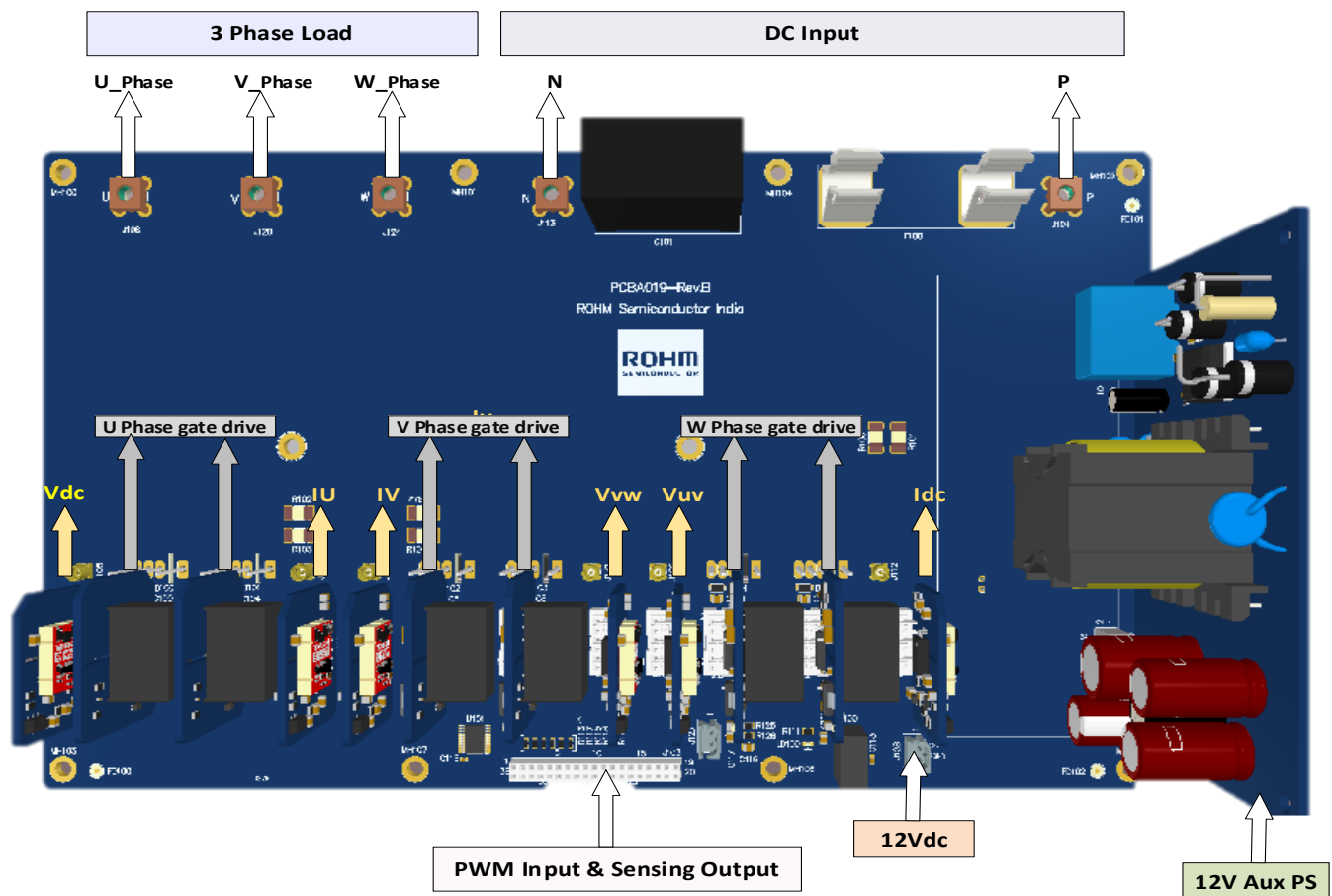


Figure 25. Wiring Diagram for the Board Connection

Note: When the Auxiliary (Aux) board is utilized, the provision of external 12 V (connector J128) and 24 V (connector J130) power supplies to the inverter is not required.

6.1 Board Terminal Connection

Table 9. Board terminal & connector Connection

Pin No	Connection Point	Comment
1	P	Input DC
2	N	Neutral
3	U, V, W	Phase Terminal
4	J125, J126, J123	Voltage Sensing Connector
5	J100, J107, J115	Current Sensing Connector
6	J101, J102, J109, J110, J118, J119	Gate Driver Board connector*
7	J103	PWM Signals
8	J128	12V Connector
9	J130	24V Connector

- Connect all gate driver boards to their respective positions on the main board using designated connectors.
- Attach voltage and current sensing boards to the appropriate input/output terminals as per the wiring diagram (Fig 21).
- Verify that the cooling fan is properly mounted and connected to the 24V supply on the main board.

7 Pre-Power Checks

Before powering the system, perform the following checks:

- **Visual Inspection:** Ensure all components are securely mounted, connectors are properly seated, and no foreign objects are present.
- **Continuity Test:** Verify that there are no short circuits between power rails and ground.
- **Polarity Check:** Confirm correct polarity of DC input, fan supply, and signal connections.
- **Gate Driver Status:** Verify proper isolation and ensure gate driver connectivity with external PWM signals before powering the DC input.
- **Dead Time Validation:** Ensure appropriate dead time is configured between high-side and low-side gate pulses. Confirm timing aligns with the 120° phase shift requirement for three-phase operation.
- **Cooling System:** Ensure the fan is operational and airflow is unobstructed.
- **Signal Verification:** Confirm PWM signals are present and correctly mapped to gate driver inputs.

8 Operation

8.1 Power-Up Sequence

The power-up process ensures safe initialization of all subsystems before the inverter begins operation. It involves sequential activation and verification of components to prevent damage and ensure system stability.

i. Control System Initialization

- Power on the external MCU.
- MCU begins executing firmware and initializes communication with sensing boards and gate drivers.

ii. Sensing System

- Voltage and current sensing boards begin monitoring input/output conditions.
- Ensure sensing accuracy and signal integrity before proceeding.

iii. Gate Driver Readiness

- Gate drivers receive PWM signals from the MCU via the 38-pin connector (J103).

iv. DC-Input

- Gradually apply DC input voltage 0 to 400V to the inverter.
- Monitor voltage rises and ensures it remains within safe limits.

v. MOSFET Switching Activation

MCU enables PWM output to gate driver. (PWM control signals will be generated using a TI DSPIC, following the specified parameters), The PWM outputs are active-low due to the inverting buffer in the signal path. As a result, a logic HIGH at the controller appears as a logic LOW at the downstream device.

- SiC MOSFETs begin switching, generating modulated AC waveform.

vi. Output Verification

- Measure output voltage and frequency.
- Confirm balanced three-phase output and correct waveform shape.
- Check for abnormal noise, heating, or waveform distortion.

If external 12V and 24V power supply to be used. Please follow below instructions before step 1,

- Connect the 24V supply to the J130 fan, confirm the air flow direction.
- Connect the 12V supply to the J128 connector for powering up gate drive and sensing Board.

Table 9. System Specifications

Parameter	Spec			
	Min	Typical	Max	Unit
Carrier Frequency	0.57	1	1.2	kHz
Switching Frequency	25	-	80	kHz
Dead Time	-	900	-	nsec
Modulation Index (m)	0.35	-	0.42	
Duty Cycle Resolution	Depends on controller; higher resolution gives smoother control			
Synchronization	Carrier and reference signals must be synchronized			

8.2 Performance**8.2.1 Test bench Configuration**

Table 10. Test Equipment List

S. No.	Name	Model	Description
1	Kikusui DC Power Supply	PXB20K – 1500	Input DC Voltage
2	Tenma DC Power Supply	72 – 10505	Auxiliary supply for FAN & Digital circuits
3	Inductive Load	880uH / Phase	Star Connection
4	Hioki Power Analyzer	PW6001	Parameter monitoring (I/P and O/P voltage and current)
5	Tektronix Oscilloscope	MSO44	Capture Gate Signals, Phase Current & Voltage
6	Tektronix Differential Probe	THDP0200	Measure Vgs, Vuv, Vvw & Vwu
7	Tektronix Current Probe	TRCP0600	Measure Iu, Iv & Iw

8.2.2 Double Pulse Test (DPT)

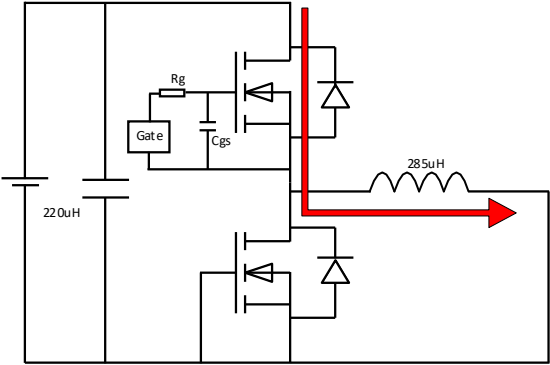
Purpose of DPT:

The double pulse test is used to validate the switching characteristics of **SCT4013DRC15**. It helps to measure the followings:

1. Turn-on & Turn-off Losses
2. Drain to Source (Vds) Surge Voltage & Current Overshoot
3. Switching speed

Key Definitions –

1. V_{ds_max} – Maximum voltage appeared at drain-source terminals of high side MOSFET.
2. di/dt – Rate of change of drain current from 10% to 90% of maximum drain current value during turn-on and 90% to 10% of final value during turn-off.
3. dv/dt – Rate of change of drain-source voltage from 90% to 10% of final value during turn-on and 10% to 90% of maximum Vds value during turn-off.

Test Circuit	Test Conditions														
 <p>Figure 26. Double Pulse Circuit</p>	<p>Table 11: Double Pulse Test condition</p> <table> <tr> <td>V_{dc}</td><td>400V</td></tr> <tr> <td>V_{gs_off}</td><td>0V</td></tr> <tr> <td>V_{gs_on}</td><td>18V</td></tr> <tr> <td>I_d</td><td>50A</td></tr> <tr> <td>R_{g_on}</td><td>6.8 Ω</td></tr> <tr> <td>R_{g_off}</td><td>6.8 Ω in parallel with 6.8 Ω</td></tr> <tr> <td>C_{gs_ext}</td><td>DNP</td></tr> </table>	V_{dc}	400V	V_{gs_off}	0V	V_{gs_on}	18V	I_d	50A	R_{g_on}	6.8 Ω	R_{g_off}	6.8 Ω in parallel with 6.8 Ω	C_{gs_ext}	DNP
V_{dc}	400V														
V_{gs_off}	0V														
V_{gs_on}	18V														
I_d	50A														
R_{g_on}	6.8 Ω														
R_{g_off}	6.8 Ω in parallel with 6.8 Ω														
C_{gs_ext}	DNP														

Measurement of Phase W:

CH1	High Side Drain to Source Voltage (100V/div)
CH2	Low Side Gate to source Voltage(5V/div)
CH3	High Side Gate to Source Voltage (10V/div)
CH4	Drain Current (10A/div)

Turn ON:

- $V_{ds_max} = 512.9V$
- $dv/dt = 13.32 \text{ GV/sec}$ and $di/dt = 2.24 \text{ GA/sec}$
- Turn On loss= 0.165mJ

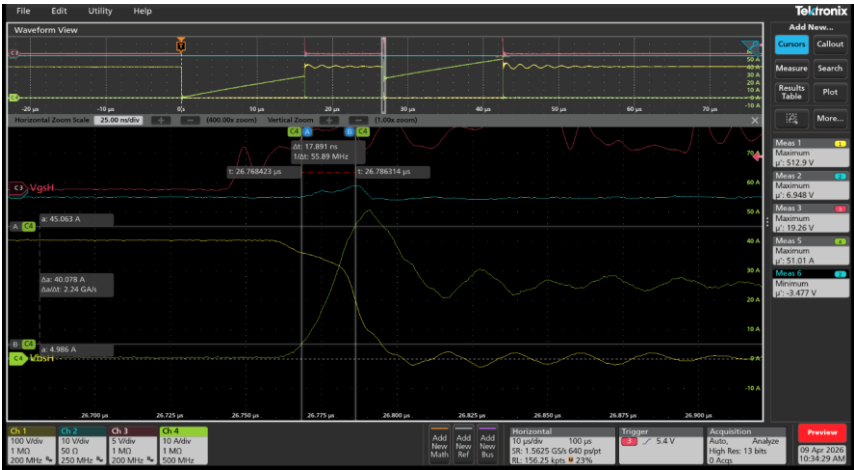


Figure 27. $di/dt_{turn\ on}$

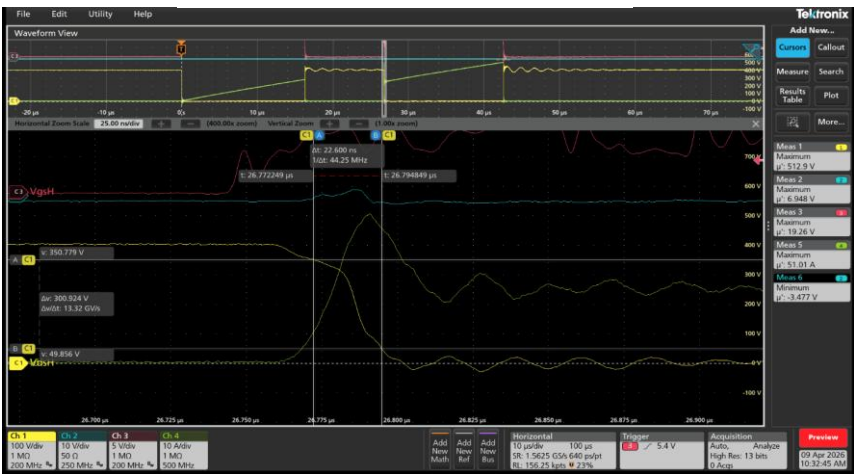


Figure 28. $dv/dt_{turn\ on}$

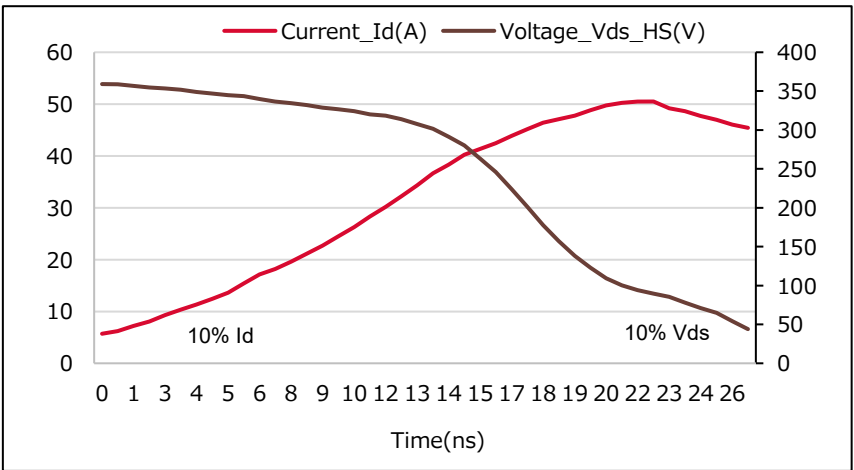


Figure 29. Turn on losses

Turn OFF

- $V_{ds_max} = 510.5V$
- $dv/dt = 25.36GV/sec$ and $di/dt = 1.85GA/sec$
- Turn-off = 0.182ms

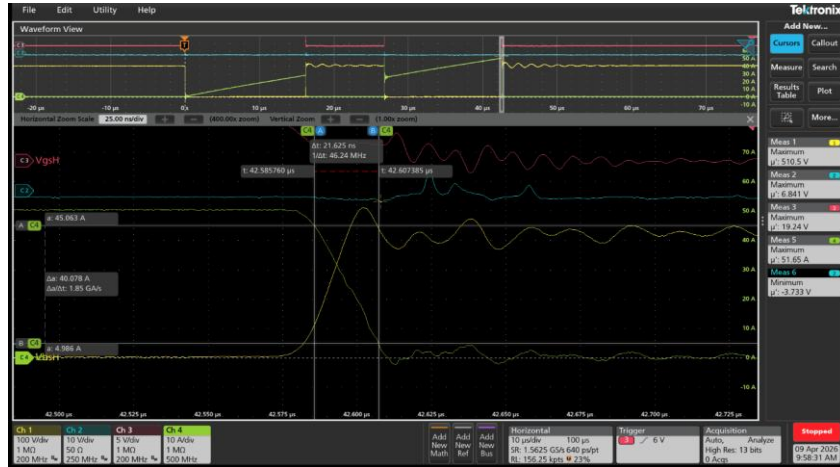


Figure 30. di/dt_turn off

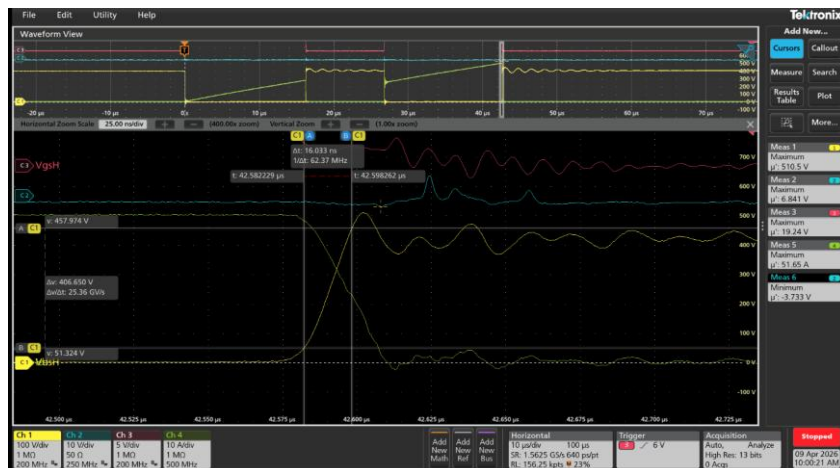


Figure 31. dv/dt_turn off

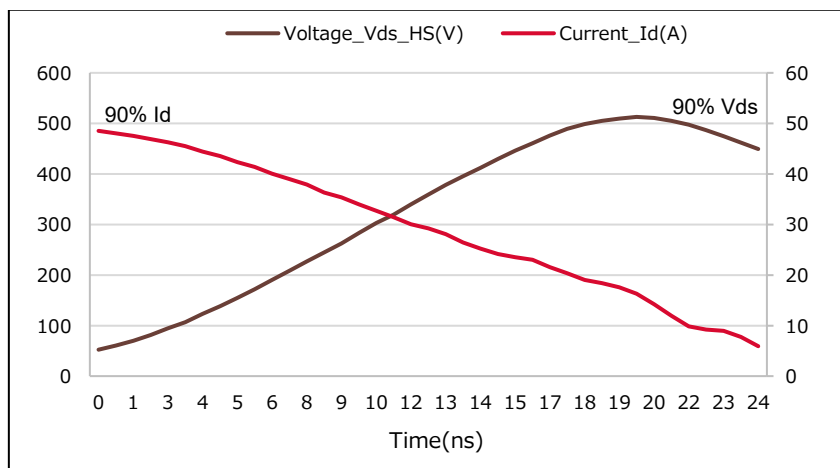


Figure 32. Turn off losses

8.2.3 Test Setup

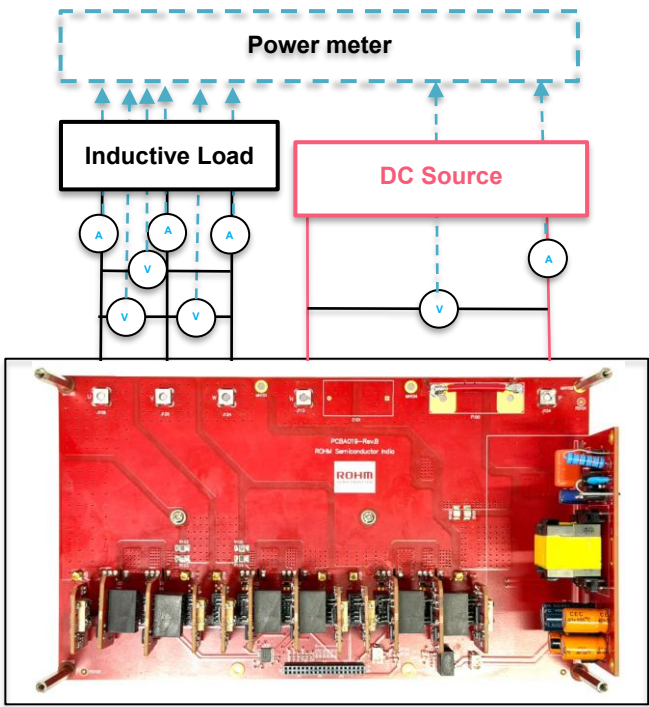


Figure 33. Test Measurement Diagram

Below is the image of phase-to-phase voltage at 400V, 25KHz and 26A. The modulation index is 0.42. the RMS voltage is around 189V.

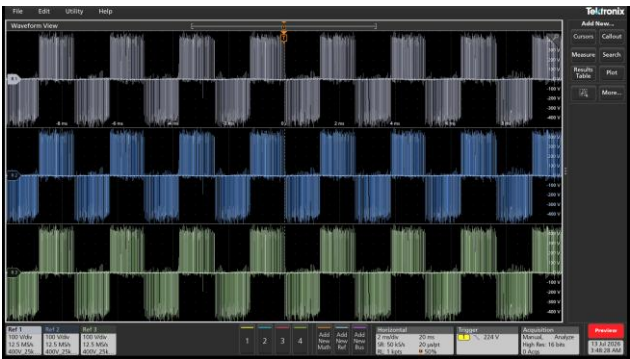


Figure 34. Phase-Phase Voltage

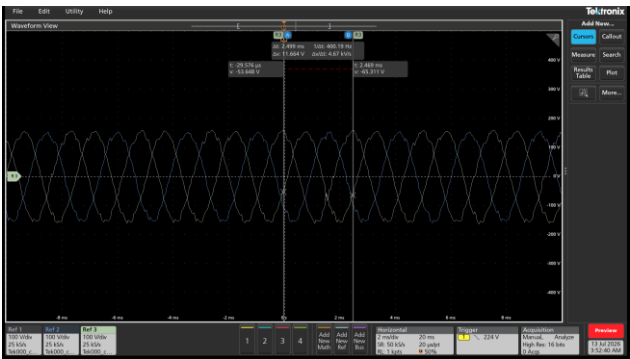


Figure 35. Phase-Phase Voltage at Lower Sampling Rate

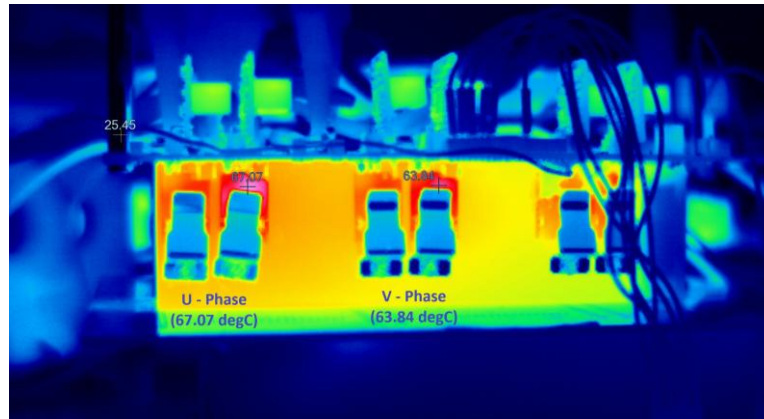


Figure 36. Thermal image by Thermal Camera

Figure 36 contains the thermal image focused on the MOSFETs and heat sink. The operating current is 25A at 25KHz switching frequency. The temperatures marked at MOSFETs are saturated/ final temperature at the mentioned condition.

Figure 37 - 39 are the thermal characterization graphs obtained by testing the board at different conditions and checking the effective rise in temperature at the board. The highest temperature is observed at the MOSFETs on the board. The graphs are plotted by subtracting the highest temperature point with the ambient temperature.

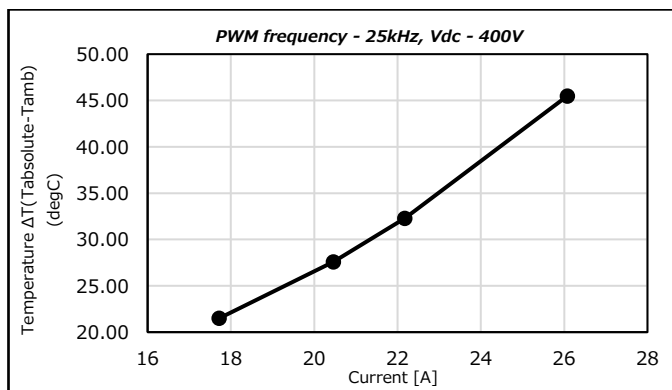


Figure 37. Phase Current Vs Temperature

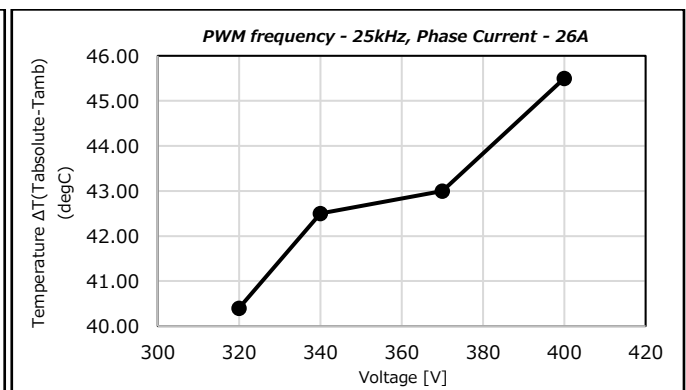


Figure 38. DC Input Voltage Vs Temperature

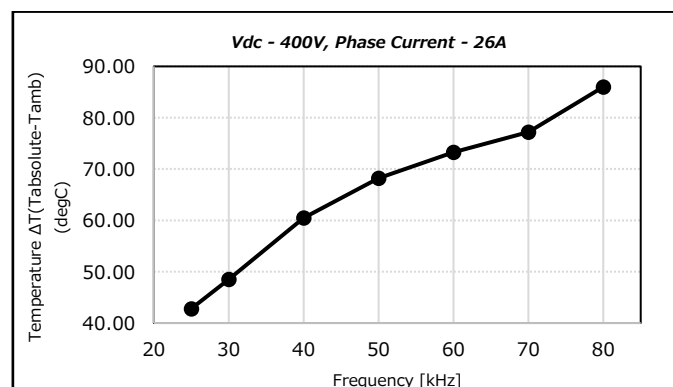


Figure 39. PWM Frequency Vs Temperature

Note: All the tests are conducted at high voltage and high current. Take caution before starting the test. Preliminary training for HV testing is mandatory.

10 Bill of Material

Power Board BOM

Table 12. Main Board BOM

Sl. No.	Designator	Value	Description	Package	Qty	Manufacturer	Part Number
1	C100, C104, C105, C108, C110, C114	1000pF	Capacitor, SMD, Ceramic, 1000pF, 50V, 5%, 0805, X5R	0805	6	Murata	GCM216R71H102JA37D
2	C101	3uF	Parallel Capacitors, SMD, Ceramic, 3uF, 1.1kV, 5%, Th, CA	Th	1	Wurth	890734427005CS
3	C102, C103, C106, C107, C109, C111	0.2uF	Parallel Capacitors, SMD, Ceramic, 0.2uF, 630V, 5%, 2 J lead, CA	2 J lead	6	TDK	CAA572C0G2J204J640L J
4	C112	10uF	Capacitor, SMD, Ceramic, 10uF, 25V, 10%, 0805, X7S	0805	1	KEMET	C2012X7S1E106K125AE
5	C113	1uF	Capacitor, SMD, Ceramic, 1uF, 35V, 10%, 0603, X7R	0603	1	TDK	CGA3E1X7R1V105K080 AC
6	C115	0.1uF	Capacitor, SMD, Ceramic, 0.1uF, 50V, 10%, 0402, X7R	0402	1	TDK	CGA2B3X7R1H104K050 BB
7	C116	10nF	Capacitor, SMD, Ceramic, 10nF, 16V, 5%, 0805, X5R	0805	1	KEMET	C0805C103J4JACTU
8	C117	1uF	Capacitor, SMD, Ceramic, 1uF, 16V, 10%, 0805, X5R	0805	1	KEMET	C0805C105K4RACAUTO
9	D100, D101, D102, D103, D104, D105		Schottky Diodes & Rectifiers 40V 1A 2-Pin, SMD		6	ROHM	RB160MM-40TR
10	F100	Fuse Holder	FUSE, TH, Fuse Holder		1	Littelfuse	LSRK045.T
11	FAN100x	FAN	FAN, Axial, 24V, 3W		1	Wakefield Thermal	DC0502024M2B
12	FB100, FB101		Resistor 0R	1206	2	ROHM	PMR18EZPJ000
13	HS100	N44	Heatsink, N44		1	FISHER	LAM 5 170 ME
14	J100, J101, J102, J107, J109, J110, J115, J118, J119, J123, J125, J126		Connector, TH, 12 positions, 79107-7005		12	Molex	79107-7005
15	J103		Connector, TH, 38 positions, 79107-7068		1	Molex	79107-7068
16	J104, J108, J113, J120, J124		Connector, TH, 74650074R		5	Würth Elektronik	74650074R
17	J105, J106, J111, J112, J116, J117, J121, J122		Connector RF, TH, 5 positions, 0734151472		8	MOLEX	734151472
18	J114, J129, J131	CON_H DR_2x5 Z	Connector, TH, 10 positions, CON_HDR_2x5_Z		3	SAMTEC	SSW-105-01-G-D
19	J127, J128, J130		Connector, TH, 2 positions, DIP 5.08x2N		3	MOLEX	22-03-5025
20	LD100		LED, SMD, GREEN 0603,	0603	1	ROHM	SML-D12P8WT86
21	Q100, Q101, Q102, Q103, Q104, Q105	SCT401 3DRC15	MOSFET, N CH, SCT4013DRC15		6	ROHM	SCT4013DRC15
22	R100, R101, R102, R103, R104, R105	3mOhm	Shunt Resistor, SMD, 3mOhm, 1%, 2512, 4W	2512	6	ROHM	PSR100KTQFL3L00
23	R106, R107, R108, R109, R110	300K	Resistor, SMD, 300K, 200V, 1%, 1206, 500mW	1206	5	ROHM	ESR18EZPF3003
24	R111	470R	Resistor, SMD, 470R, 1%, 0805, 400mW	0805	1	ROHM	ESR10EZPD4700
25	R112, R124, R132	180R	Resistor, SMD, 180R, 5%, 0805, 500mW	0805	3	ROHM	ESR10EZPJ181
26	R113, R114, R115, R116, R117, R118	12K	Resistor, SMD, 12K, 1%, 0603, 250mW	0603	6	ROHM	ESR03EZPD1202
27	R119, R120, R121, R122, R123, R127, R128, R129, R130, R131	300K	Resistor, SMD, 300K, 200V, 1%, 0805, 500mW	0805	10	ROHM	ESR10EZPF3003
28	R125	10K	Resistor, SMD, 10K, 1%, 0805, 400mW	0805	1	ROHM	ESR10EZPD1002
29	R126	56R	Resistor, SMD, 56R, 1%, 0805, 400mW	0805	1	ROHM	ESR10EZPD56R0
30	R133, R134, R135, R136, R137, R138	1K	Resistor, SMD, Resistor, 1K, 150V±1%, 0805, 0.40W	0805	6	ROHM	ESR10EZPF1001
31	U100	NME120 5SC	Isolated DC/DC Converters - Through Hole 1W 12-5V SIP SINGLE DC/DC	(SOP-8)	1	Murata	NME1205SC
32	U101		Buffers & Line Drivers Automotive octal buffers and line drivers with 3-state outputs -40 to 125	20-TSSOP	1	TI	SN74HCS240QPWRQ1

Gate Driver Board BOM

Table 13. Gate driver BOM

Sl. No.	Designator	Value	Description	Package	Qty	Manufacturer	Part Number
1	C100, C101, C103, C200, C201, C203, C300, C301, C303, C400, C401, C403, C500, C501, C503, C600, C601, C603	10uF	Multilayer Ceramic Capacitors MLCC - SMD/SMT CGA 1206 35V 10uF X7R 20%	1206	18	TDK	CGA5L1X7R1V106M160AC
2	C102, C106, C109, C113, C115, C202, C206, C209, C213, C215, C302, C306, C309, C313, C315, C402, C406, C408, C413, C415, C502, C506, C509, C513, C515, C602, C606, C609, C613, C615	0.1uF	Multilayer Ceramic Capacitors MLCC - SMD/SMT CGA 0402 50V 0.1uF X7R 10%	0402	30	TDK	CGA2B3X7R1H104K050BB
3	C104, C110, C204, C210, C304, C310, C404, C410, C504, C510, C604, C610	1000pF	Multilayer Ceramic Capacitors MLCC - SMD/SMT CGA 0603 35V 1uF X7R 10%	0603	12	Murata	GCM188R71H102KA37J
4	C105, C107, C108, C111, C112, C205, C207, C208, C211, C212, C305, C307, C308, C311, C312, C405, C407, C408, C411, C412, C505, C507, C508, C511, C512, C605, C607, C608, C611, C612	1uF	Multilayer Ceramic Capacitors MLCC - SMD/SMT CGA 0603 35V 1uF X7R 10%	0603	30	TDK	CGA3E1X7R1V105K080AC
5	C114, C214, C314, C414, C514, C614	10uF	Capacitor, SMD, Ceramic, 10uF, 25V, 10%, 0805, X7S	0805	6	KEMET	C2012X7S1E106K125AE
6	D100, D200, D300, D400, D500, D600		Schottky Barrier Diodes, SMD, SOD-323HE-2	SOD-323HE-2	6	ROHM	RB160VAM-60TR
7	D101, D201, D301, D401, D501, D601		Diode Schottky		6	ROHM	RB160MM-40TR
8	J100, J200, J300, J400, J500, J600		Connector, TH, 12 positions		6	MOLEX	1511193112
9	L100, L200, L300, L400, L500, L600	20mH	Common Mode Choke, TH, 20mH, 400V AC		6	Murata	DLW21PH201XQ2L
10	LD100, LD200, LD300, LD400, LD500, LD600		Standard LEDs - SMD Green	0603	6	ROHM	SML_D12P8WT86
11	R100, R102, R200, R202, R300, R302, R400, R402, R500, R502, R600, R602	6.8R	Resistor, SMD, 6.8R, 1%, 1206, 500mW	1206	12	ROHM	ESR18EZPF6R80
12	R101, R103, R107, R201, R203, R207, R301, R303, R307, R401, R403, R407, R501, R503, R507, R601, R603, R607	100R	Resistor, SMD, 100R, 1%, 0805, 400mW	0805	18	ROHM	ESR10EZPF1000
13	R104, R204, R304, R404, R504, R604	4.7k	Resistor, SMD, 4.7k, 1%, 0805, 400mW	0805	6	ROHM	ESR10EZPD4701
14	R105, R205, R305, R405, R505, R605	0R	Resistor, SMD, 0R, 1%, 1206	1206	6	ROHM	PMR18EZPJ000
15	R106, R206, R306, R406, R506, R606	470R	Resistor, SMD, 470R, 0.5%, 0805, 400mW	0805	6	ROHM	ESR10EZPD4700
16	U100, U200, U300, U400, U500, U600		Gate Drivers Isolation Voltage 3750 Vrms 1ch Gate Driver	SSOP-B10W	6	ROHM	BM61S41RFV-CE2
17	U101, U201, U301, U401, U501, U601		Isolated DC/DC Converters - Through Hole DC/DC TH 12-18/2.5V		6	Murata	NXJ1S1205MC-R13
18	U102, U202, U302, U402, U502, U602		LDO, SMD, IC, BD450M2WFP3-CE2, 3.3V, SOT223-4(F)	SOT223-4(F)	6	ROHM	BD450M2WFP3-CE2

Sensing Board BOM

Table 14. Sensing Board BOM

SI no	Designator	Value	Description	Package	Qty	Manufacturer	Part Number
1	C100, C101, C113, C114, C115, C200, C201, C213, C214, C215, C300, C301, C313, C314, C315, C400, C401, C413, C414, C415, C500, C501, C513, C514, C515, C600, C601, C613, C614, C615	1uF	Capacitor, SMD, Ceramic, 1uF, 16V±5%, 0805, X7R	0805	30	KEMET	C0805C105J4RAC7210
2	C102, C103, C104, C105, C202, C203, C204, C205, C302, C303, C304, C305, C402, C403, C404, C405, C502, C503, C504, C505, C602, C603, C604, C605	0.1uF	Capacitor, SMD, Ceramic, 0.1uF, 16V, 5%, 0805, U2J	0805	24	KEMET	C0805C104J4JACAUTO
3	C106, C206, C306, C406, C506, C606	820pF	Capacitor, SMD, Ceramic, 820pF, 50V, 5%, 0805, C0G	0805	6	KEMET	C0805C821J5GACAUTO
4	C107, C207, C307, C407, C507, C607	1nF	Capacitor, SMD, Ceramic, 1nF, 16V, 0805, X8R	0805	6	KEMET	C0805C102G4HACAUTO
5	C108, C208, C308, C408, C508, C608	10pF	Capacitor, SMD, Ceramic, 10pF, 16V, 10%, 0805, X8R	0805	6	KEMET	C0805C100K4HACAUTO
6	C109, C110, C111, C209, C210, C211, C309, C310, C311, C409, C410, C411, C509, C510, C511, C609, C610, C611	100nF	Capacitor, SMD, Ceramic, 100nF, 16V±5%, 0805, X7R	0805	18	KEMET	C0805C104J4RACTU
7	C117, C217, C317, C417, C517, C617	10uF	Capacitor, SMD, Ceramic, 10uF, 16V, 10%, 0805, X5R	0805	6	Murata	GRT21BR61C106KE01L
8	FB100, FB101, FB200, FB201, FB300, FB301, FB400, FB401, FB500, FB501, FB600, FB601	0R	Resistor, SMD, 0R, 1%, 1206	1206	6	ROHM	PMR18EZPJ000
9	J100, J200, J300, J400, J500, J600		Connector, TH, 12 positions, 1511193112, 125 VAC		6	Molex	1511193112
10	R100, R101, R109, R200, R201, R209, R300, R301, R309, R400, R401, R409, R500, R501, R509, R600, R601, R609	0R	Resistor, SMD, 0R, 0603	0603	18	ROHM	SFR03EZPJ000
11	R102, R108, R202, R208, R302, R308, R402, R408, R502, R508, R602, R608	39K	Resistor, SMD, 39K, ±5%, 0805, 0.4W, 2/5W	0805	12	ROHM	ESR10EZPJ393
12	R103, R107, R203, R207, R303, R307, R403, R407, R503, R507, R603, R607	180R	Resistor, SMD, 180R, 5%, 0805, 500mW	0805	3	ROHM	ESR10EZPJ181
13	R104, R204, R304, R404, R504, R604	1K	Resistor, SMD, 1K, ±1%, 0805, 0.4W, 2/5W	0805	6	ROHM	ESR10EZPF1001
14	R105, R106, R205, R206, R305, R306, R405, R406, R505, R506, R605, R606	18K	Resistor, SMD, 18K, 1%, 0805, 0.5W	0805	12	ROHM	ESR10EZPJ183
15	R110, R210, R310, R410, R510, R610	1.6K	Resistor, SMD, 1.6K, ±5%, 0805, 0.4W, 2/5W	0805	6	ROHM	ESR10EZPJ162
16	R111, R211, R311, R411, R511, R611	36K	Resistor, SMD, 36K, 5%, 0805, 0.5W	0805	6	ROHM	ESR10EZPJ363
17	R112, R212, R312, R412, R512, R612	3.3K	Resistor, SMD, 3.3K, ±5%, 0805, 0.4W, 2/5W	0805	6	ROHM	ESR10EZPF3301
18	R115, R215, R315, R415, R515, R615	10K	Resistor, SMD, 10K, ±5%, 0805, 0.4W, 2/5W	0805	6	ROHM	ESR10EZPF1002
19	U100, U200, U300, U400, U500, U600		Optically Isolated Amplifiers COUPLER ISOLATION	11-6B1A	6	Toshiba	TLP7820
20	U101, U201, U301, U401, U501, U601		Operational Amplifiers - Op Amps 5uV Offset Voltage SSOP5	SSOP5	6	ROHM	LMR1802G-LBTR
21	U102, U202, U302, U402, U502, U602		Isolated DC/DC Converters - SMD DC/DC SM 1W 12V-5V Single	(SOP-8)	6	Murata	NXJ1S1205MC-R13
22	U104, U204, U304, U404, U504, U604		PRECISION SHUNT REGULATOR, SMD	SOT-23-3	6	TI	TLV431BQDBZRQ1

Aux Board BOM

SI no	Designator	Value	Description	Package	Qty	Manufacturer	Part Number
1	C100	680pF	CAP NP, SMD, Ceramic, 680pF, 630V, 1%, 1206, COG	1206	1	MURATA	GRM31B5C2J681FW01L
2	C101, C102, C107	470uF	CAP POL, TH, Electrolytic, 470uF, 35V, 20%, 105°C	TH	3	UNITED CHEMI-CON	EKZE350ELL471MJ20S
3	C104	220uF	CAP POL, TH, Electrolytic, 220uF, 35V, 20%, 105°C	TH	1	NICHICON	UHD1V221MPD
4	C105, C111	10uF	CAP NP, SMD, Ceramic, 10uF, 50V, 10%, 1206, X7T	1206	2	MURATA	GRM31CD71H106KE11
5	C108	680uF	CAP POL, TH, Electrolytic, 680uF, 35V, 20%, 105°C	TH	1	UNITED CHEMI-CON	EKZE350ELL681MK20S
6	C109	22uF	CAP POL, TH, Electrolytic, 22uF, 50V, 20%, -40°C ~ 105°C	TH	1	NICHICON	UHD1H220MDD
7	C110	33nF	CAP NP, TH, BOX, 33nF, 1600V, 5%	TH	1	TDK	B32672L1333J
8	C113	100nF	CAP NP, SMD, Ceramic, 100nF, 100V, 10%, 0603, X7R	603	1	MURATA	GRM188R72A104KA35D
9	C114, C117	1000pF	CAP NP, SMD, Ceramic, 1000pF, 100V, 10%, 0603, X7R	603	2	TAIYO YUDEN	HMK107B7102KA-T
10	C115	0.1uF	CAP NP, SMD, Ceramic, 0.1uF, 100V, 20%, 0603, X7R	603	1	TAIYO YUDEN	HMK107B7104MA-T
11	C116	47pF	CAP NP, SMD, Ceramic, 47pF, 250V, 5%, 0603, COG	603	1	MURATA	GRM1885C2E470JW07
12	D100		Diode, SMD, Schottky, 150V, 350V, 5A-150	350V	1	ROHM	RFN5BM3SFH
13	D101	Diode_S	Diode, SMD, SIGNAL, Diode_S, 1200V, 1A	1A	1	SHINDENGEN	D1FK120
14	D102, D103		USB TVS Diode, TH, TVS, 1500W, -55°C ~ +175°C	TH	2	LITTLEFUSE	1.5KE200A
15	D104, D106	UF4007	Diode, TH, SIGNAL, 1000V, DO-41, 1A-150°C	DO-41	2	ON SEMI	UF4007
16	D105		Diode, SMD, Schottky, 150V, 150V, 6A-150	150V	1	ROHM	RB098BGE150
17	D108	US1M	Diode, SMD, US1M, 1000V, SMA, 1A-50°C ~ 150°C	DO-214AC	1	Diotec Semiconductor	US1M
18	ISO100		Optoisolator, SMD, IC, 4-DIP	4-DIP	1	SHARP	PC817X2NIP1B
19	J100, J101, J102	CON_HD R_2x5_Z	Connector, TH, 10 Positions, CON_HDR_2x5_Z		3	SAMTEC	TSW-105-08-G-D-RA
20	L100	2.2uH	Inductor, TH, 2.2uH, 20%, 6.3A	TH	1	Würth	7447462022
21	L101	3.3uH	Inductor, TH, 3.3uH, 20%, 6.3A-125	TH	1	Würth	7447462033
22	R100, R105, R109	10R	Resistor, SMD, 10R, 5%, 1206, 0.25W	1206	3	ROHM	KTR18EZPJ100
23	R101, R104, R106	390K	Resistor, SMD, 390K, 5%, 1206, 0.25W	1206	3	ROHM	KTR18EZPJ394
24	R102	62k	Resistor, TH, 62k, 5%, TH, 2W	TH	1	VISHAY	PR03000206202JAC00
25	R103, R108	2.2M	Resistor, SMD, 2.2M, 5%, 1206, 0.25W	1206	2	ROHM	KTR18EZPJ225
26	R107	300K	Resistor, SMD, 470k, 5%, 1206, 0.25W	1206	2	ROHM	KTR18EZPJ304
27	R110, R113	47k	Resistor, SMD, 47k, 1%, 0603, 0.1W	603	2	ROHM	SFR03EZPF4702
28	R111	1.5k	Resistor, SMD, 2k, 1%, 0603, 0.1W	603	1	ROHM	SFR03EZPF1501
29	R112	100k	ResistorSMD100k350V1%06030.1W	603	1	ROHM	KTR03EZX1003
30	R114	1k	Resistor, SMD, 1k, 1%, 0603, 0.1W	603	1	ROHM	SFR03EZPF1001
31	R115	30k	Resistor, SMD, 30k, 5%, 0603, 0.1W	603	1	ROHM	SFR03EZPJ303
32	R116	10k	Resistor, SMD, 10k, 1%, 0603, 0.1W	603	1	ROHM	SFR03EZPF1002
33	R117	12k	Resistor, SMD, 12k, 1%, 0603, 0.1W	603	1	ROHM	SFR03EZPF1202
34	R118	24.9k	Resistor, SMD, 24.9k, 1%, 0603, 0.1W	603	1	ROHM	SFR03EZPF2492
35	R119	510m	High Power Thick Film Chip (AEC-Q200), 1%	2512	1	ROHM	MCR100LJQPF1
36	R120, R121	24.9k	Resistor, SMD, 24.9k, 1%, 0603, 0.1W	603	1	ROHM	SFR03EZPF2492
37	TR100	PQ3220	Transformer, TH, PQ3220, PQ3220, 12 Pin VERTICAL	12 Pin	1	Custom	Custom
38	U100		DC/DC IC, SMD, -40°C ~ 105°C	(TO263-7L)	1	ROHM	BM2SC123FP2
39	U101		Shunt Regulator, TH, AS431	SOT-23	1	Diodes Inc	AS431BNTG-G1

11 PCB Layout

Power Board PCB Layout

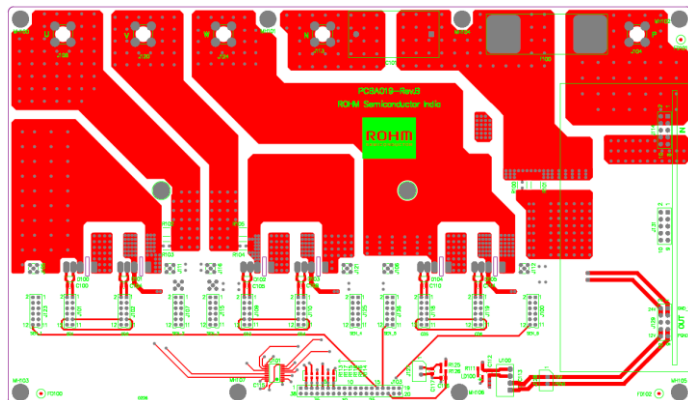


Figure 44. Top Layer

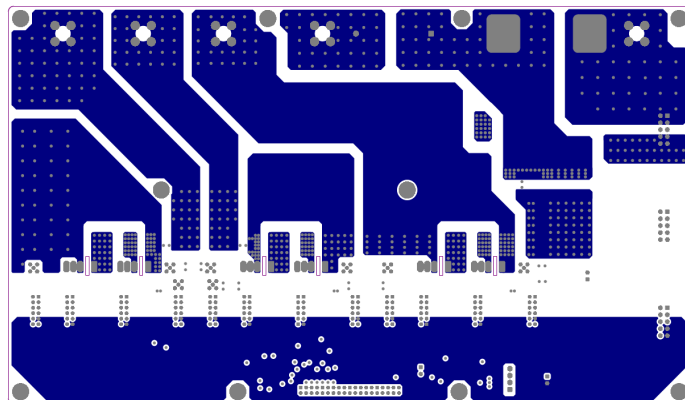


Figure 45. Mid Layer 1

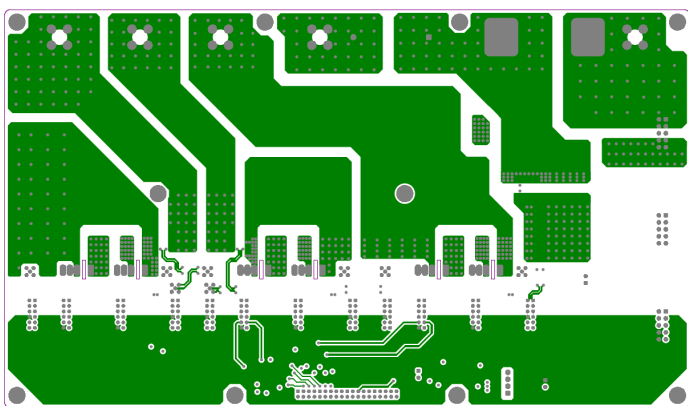


Figure 46. Mid Layer 2

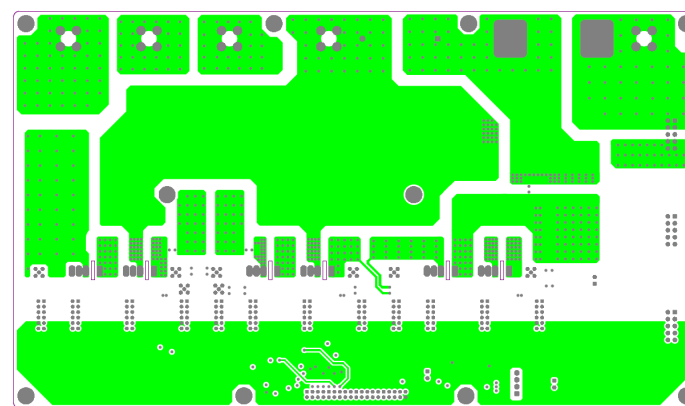


Figure 47. Mid Layer 3

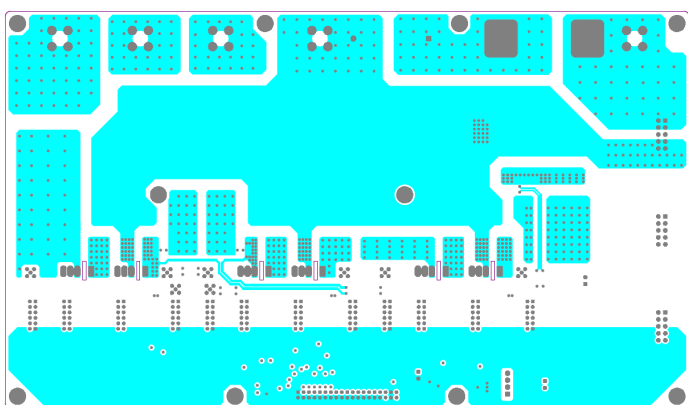


Figure 48. Mid Layer 4

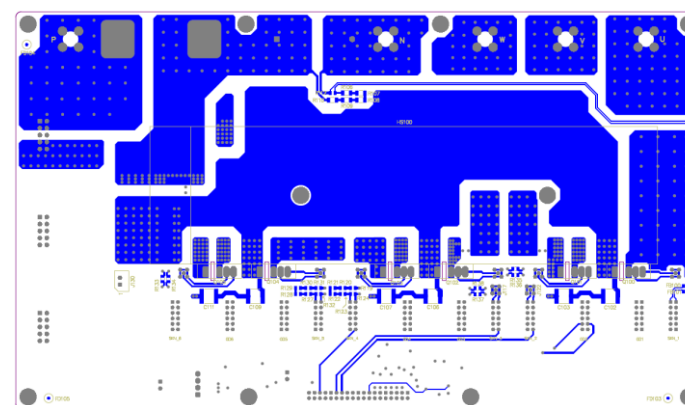


Figure 49. Bottom layer

Sensing Board PCB Layout

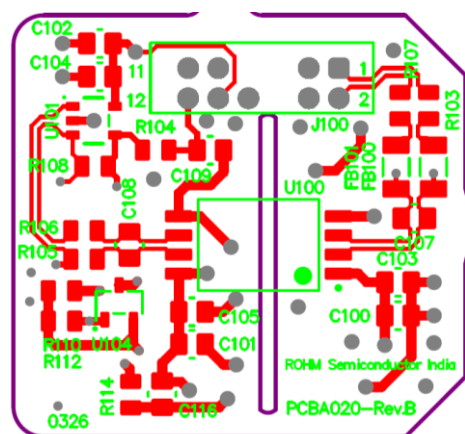


Figure 50. Top Layer

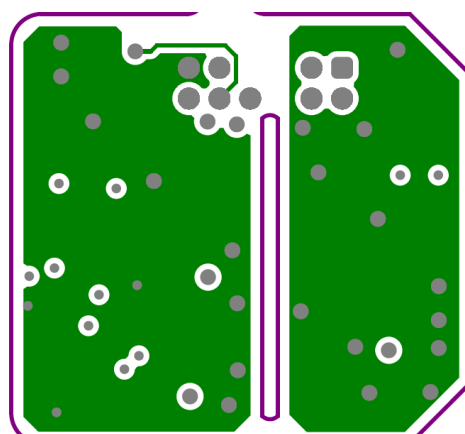


Figure 51. Mid-1 Layer

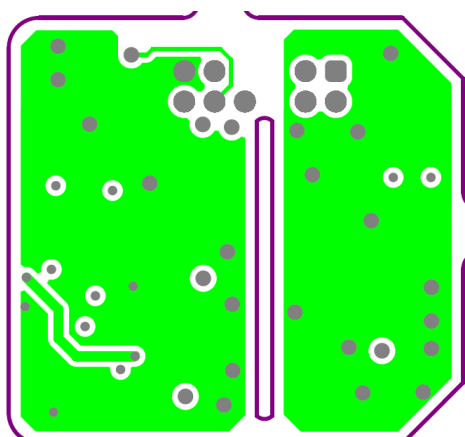


Figure 52. Mid-2 Layer

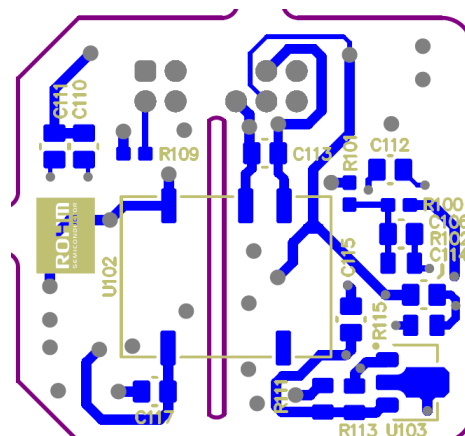
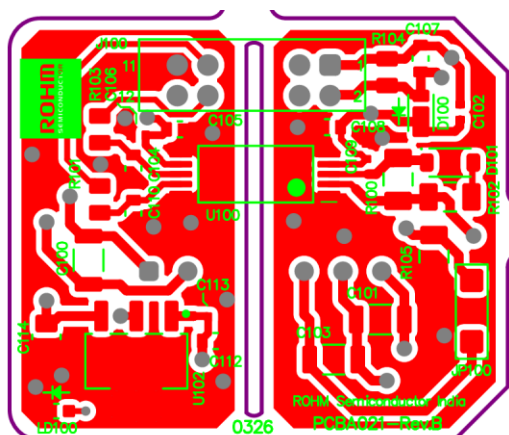


Figure 53. Bottom Layer

Gate Driver Board PCB Layout



Aux Board PCB Layout

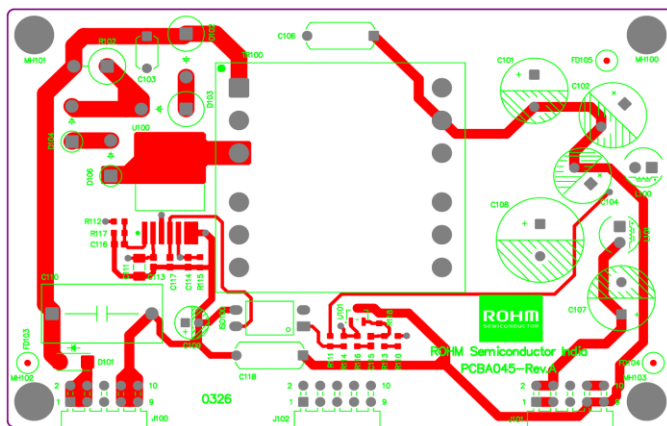


Figure 56. Top Layer

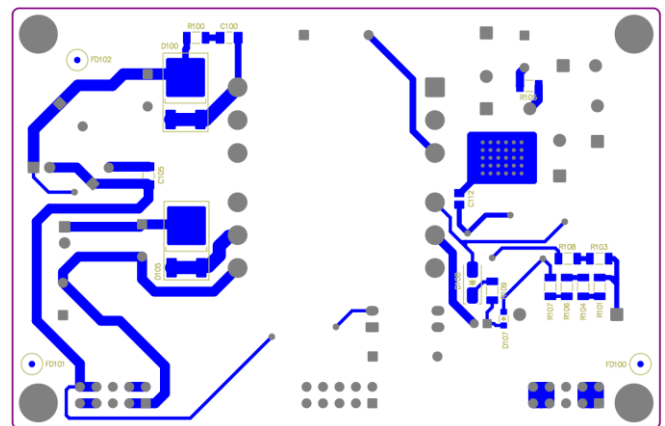


Figure 57. Bottom Layer

12 Troubleshooting

This section lists frequently encountered problems during operation and their recommended solutions.

Table 13. Trouble Shooting

Issue	Possible Cause	Recommended Fix
No output voltage	Input power not connected	Check input terminals and power source
Overtemperature	Poor ventilation or fan failure	Inspect cooling system
Inverter not starting	Faulty control signal or configuration	Verify control wiring and settings

13 Revision History

Revision	Date	Description of change
1	July 2026	Initial version

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