4^{th} Generation SiC MOSFET (TO-263-7L) Half Bridge Evaluation Board User's Guide

User's Guide

<High Voltage Safety Precautions>

◇ Read all safety precautions before use

Please note that this document covers only the SCT4036KW7 evaluation board 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 the 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 is no condensation or water droplets on the circuit board.

During Use

[5] Be careful to 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 or, depending on the circumstances, explosion or other permanent damages.
[8] Be sure to wear insulated gloves when handling is required during operation.

After Use

[9] The ROHM Evaluation Board contains the circuits which store the 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 by handled **only by qualified personnel familiar with all safety and operating procedures.** We recommend carrying out operation in a safe environment that includes the use of signs such as "high voltage test underway", using a cover with safety interlocks and wearing protective goggles.

Evaluation board for SiC MOSFET SCT4036KW7

HB2637L-EVK-301

This manual explains how to use the evaluation board HB2637L-EVK-301 with ROHM's 4th generation SiC MOSFETs with TO-263-7L package.

The evaluation board is configured in a half bridge set up and thus allows evaluations in different operations modes such as buck, boost, synchronous buck/boost and inverter operations. The board is equipped with two SiC MOSFETs (SCT4036KW7), isolated gate driver BM61S41RFV-C, isolated power supply required for the gate driver, LDO for 5V supply and easy to interface connectors for PWM signals.

This user guide contains a schematic of the evaluation board, a Bill of Material list (BOM) and also description on the overall functioning of the evaluation board. Additionally, the user guide contains important notices and warnings that need to be carefully reviewed prior to use of the board.

This evaluation board does not have a short circuit protection function for the evaluation device. Therefore, even with the normal evaluation method, if the usage deviates from the electrical specifications (maximum current, etc.) of the evaluation device selected by the customer, the device may be severely damaged with a popping sound. Therefore, never use the evaluation board in a way that deviates from the specifications of the evaluation device. Also, take precautions to prevent fragments from scattering and use protective equipment in case severe damage occurs.

Important Notice

This evaluation board is intended for **product evaluation in a research and development context only** and is not intended for resale to end consumers and it is not authorized for end customer or household use. This board may not comply with CE or similar standards (including, but not limited to the EMC directive 2004/EC/108) and may not fulfil other requirements of the country it will be operated in by the user. The user shall ensure that the evaluation board will be handled in a way that is compliant with all the standards and regulations in the country it will be operated in.

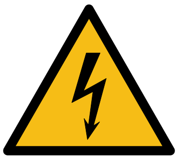
The evaluation board provided here has only been subjected to functional testing under typical load conditions. The design of this evaluation board is tested by ROHM only as described in the user guide for this board. The design is not qualified in terms of safety requirements, manufacturing and operation over the entire operating temperature range or lifetime.

This evaluation board may only be used by authorized personnel that is properly trained in recognizing and dealing with the dangers of testing high voltage equipment and generally experimenting with high voltage circuits. Ensure you review this user guide as it contains important safety warnings. At all times, follow the applicable safety rules for dealing with high voltages. Do not connect or disconnect any wires or probes to the evaluation board, while it is connected to a power supply. Take care that capacitors on the board have discharged fully before touching any part of the board. Always place the evaluation board under appropriate covers, such as in a Perspex box, to protect against accidental touching of high voltage parts BEFORE applying a voltage supply to the board.

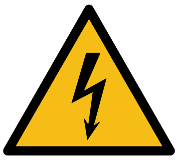
Contents

1. Safety Precautions

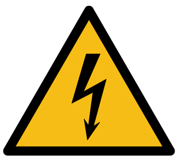
Caution: This evaluation board may only be used by authorized personnel that is properly trained in recognizing and dealing with the dangers of testing high voltage equipment and generally experimenting with high voltage circuits. This board should only be used in a lab facility properly equipped for the safe testing of power electronic systems at the relevant voltage levels. Failure to comply may result in damage to equipment, personal injury or death.



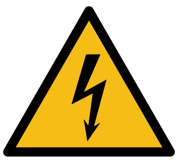
Warning: The DC link and input voltage of this board may reach up to 900 V. Ensure that only suitable high voltage differential probes are used to measure at this voltage. Failure to do so may result in damage to equipment, personal injury or death.



Warning: This evaluation board contains DC bus capacitors which take time to discharge after removal of the power supplies. Before working on the evaluation board wait at least six minutes after deactivating all connected power supplies to ensure that the capacitors have discharged to a safe level.



Warning: Ensure that you use only appropriate measurement equipment for the voltage levels present on the board. Ensure not to ground live parts through unsuitable measurement probes or tie different grounds together using passive probes. Suitable high voltage differential probes should be used. Failure to do so may result in damage to equipment, personal injury or death



Warning: Before disconnecting, connecting or reconnecting wires or measurement probes to the board or before touching the board or performing any manipulations on the board ensure that all external power is removed or disconnected from the board and at least six minutes have passed to ensure the capacitors have discharged to a safe level and then ensure that the capacitor voltages have dropped to a safe level.
Failure to do so may result in damage to equipment, personal injury or death.

Caution: The heatsink and some component surfaces on the evaluation board may become hot during testing and remain hot for a certain time after turn-off. Take appropriate measures while handling the board after use. Failure to do so may cause personal injury.

Caution: Incorrect connection of power supplies or loads can damage the board. Carefully review the information in this document.

2. Introduction

The evaluation board is a four layered PCB with dimensions of approximately 120 mm by 100 mm. Figure 1 shows the picture of the board with and without a heatsink. It is to be noted that a heatsink is not supplied with the board. A recommended heatsink that can be used with this board will be introduced in a later section of this manual.

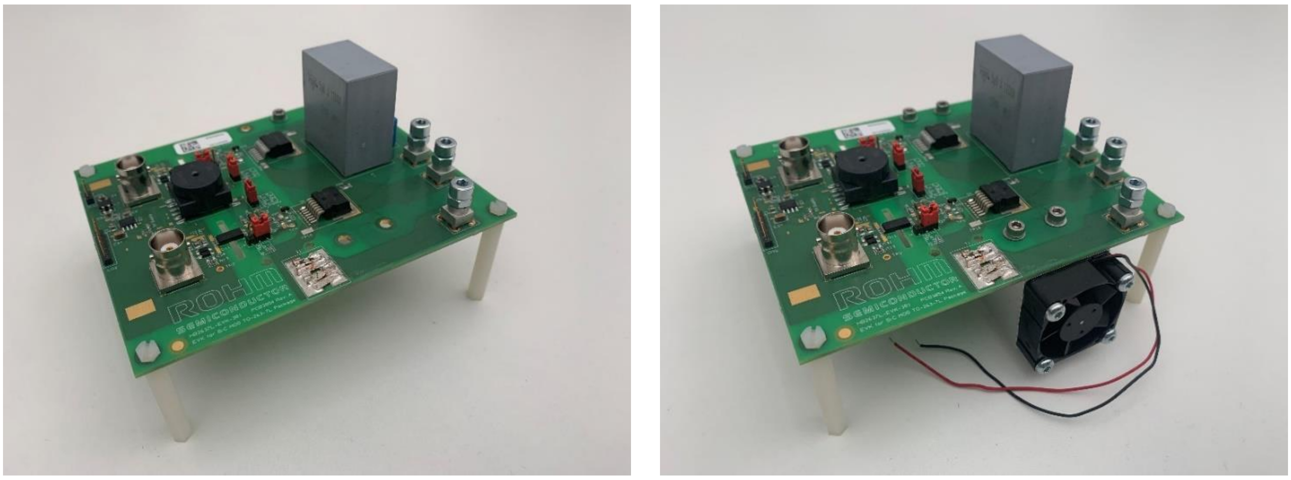


Figure 1: Evaluation board without heatsink (left) and with heatsink (right)

With this board the following tests are possible:

1. Double pulse testing to evaluate the switching characteristics of the SiC MOSFET
2. Evaluate the switching characteristics with different gate resistors and gate drive voltages
3. Continuous power testing in buck, boost or inverter configuration to evaluate the thermal performance of the SiC MOSFETs

3. Key Features

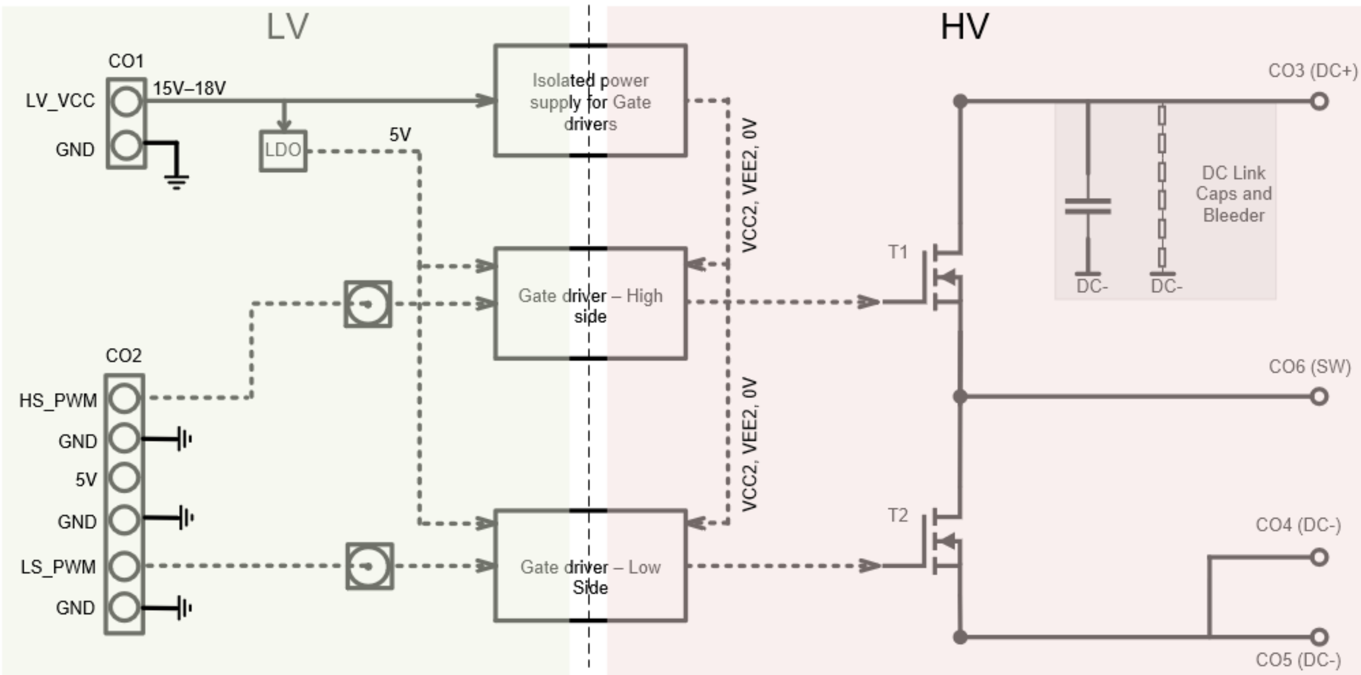


Figure 2: Block diagram of evaluation board

Figure 2 shows a simple block diagram of the evaluation board. The board is powered through a 15V~18V external power supply.

A total of three supplies are generated on the board. There is a LDO for generating 5V from the input supply of 15~18V on the connector CO1. This 5V is necessary for powering the input side of the isolated gate drivers. The other two are the isolated power supplies required to supply the HV side of the isolated gate drivers.

The isolated power supply is realized with a simple half bridge converter that outputs two positive rails (VCC2) and two negative rails (VEE2) necessary for high side and low side devices respectively.

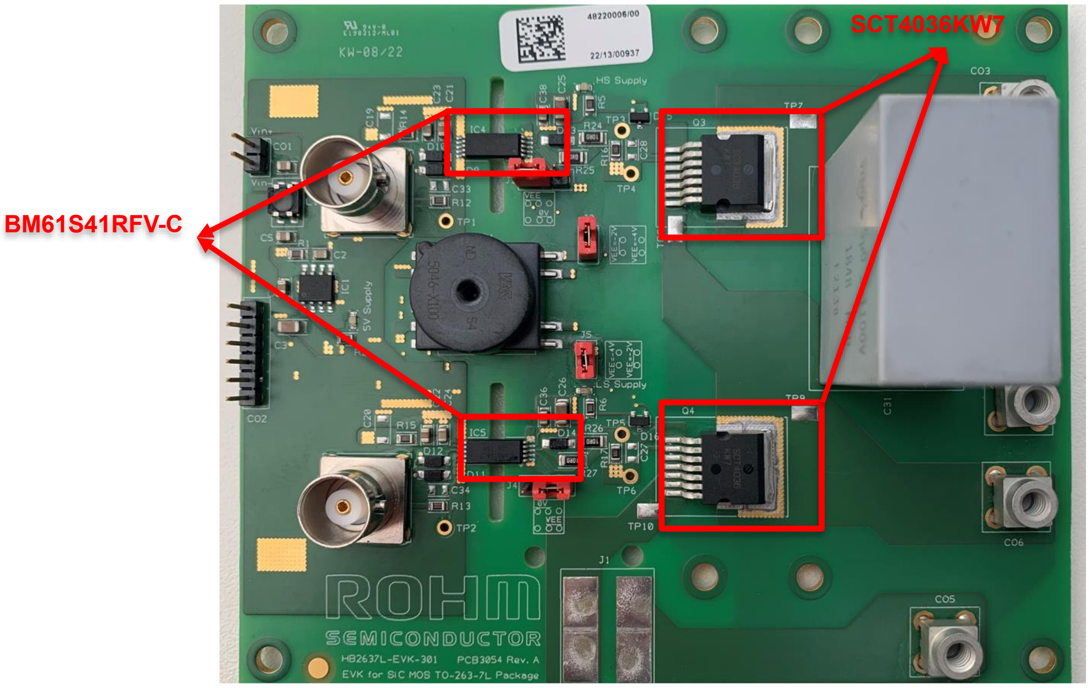


Figure 3: Top view of the board with key components marked

3.1 Connector assignments

There are a total of 6 connectors on the evaluation board. Figure 4 shows the picture of connectors CO1 and CO2 with the respective pin assignments.

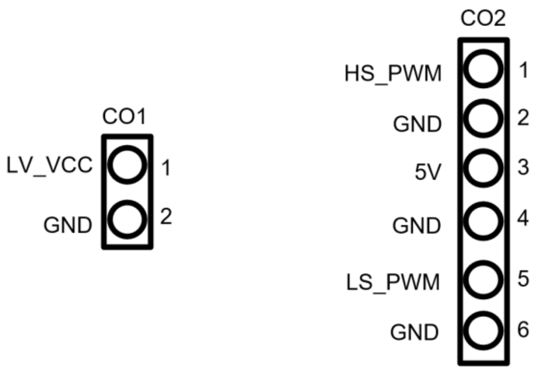


Figure 3: Pin assignment of CO1 (left) and CO2 (right)

CO1 is the board power supply input connector. A voltage of 15~18V needs to be applied to this connector to get the board running. The 5V supply required for the board as well as the isolated power supply required for the gate drivers are powered through this supply. CO2 is the interface for PWM signals required for the gate driver. Pin1 and Pin5 of connector CO2 are high side gate driver input PWM and low side gate driver input PWM respectively. Additionally, ton this board two BNC connectors are also provided, through which user can easily apply PWM signals directly from a pulse generator.

The other connectors available on the board CO3, CO4, CO5, CO6 are power connectors which must be connected to DC+, DC-, DC- and switch node respectively.

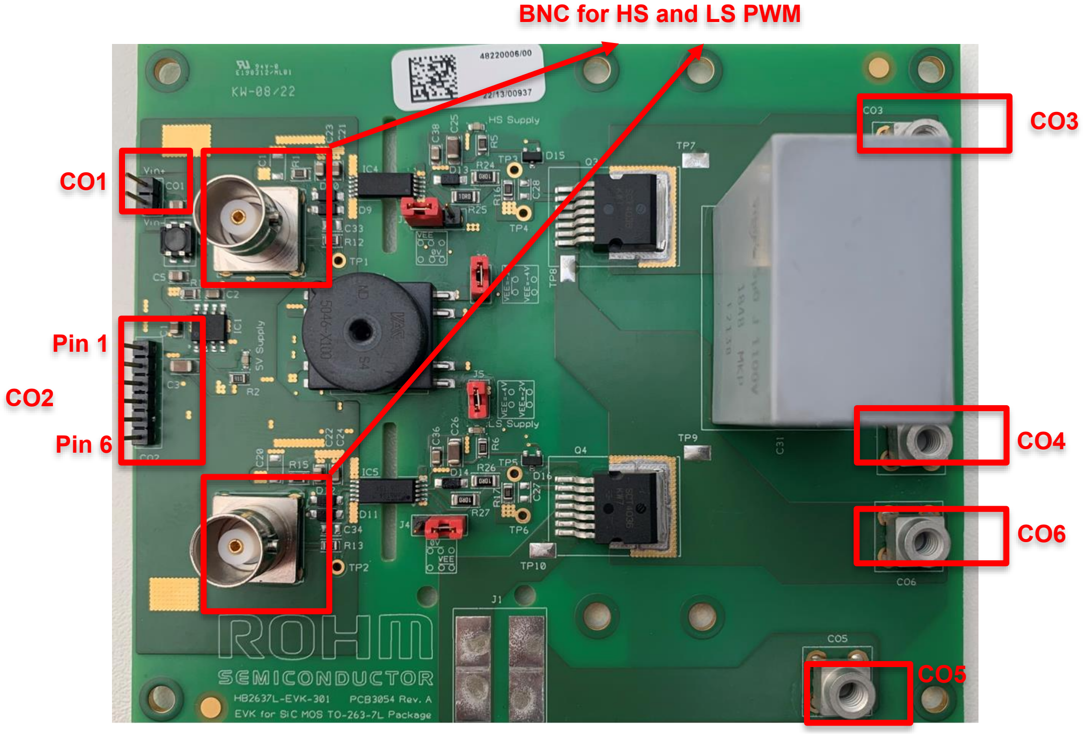


Figure 4: Top view of the board with all connectors marked

3.2 LED Indications

A total of three power supplies are generated on the board. The board has a LDO for generating 5V from the input supply of 15~18V on the connector CO1. This 5V is necessary for powering the input side of the isolated gate drivers. The other two power supplies are the isolated power supplies required to supply the HV side of the isolated gate drivers. For each of the power supplies available on board, a LED indication has been provided. As soon as the input voltage of 15-18V has been applied to the board, the LDO generates the 5V and lights up the LED "5V Supply". Simultaneously the isolated power supplies for each of the drivers are also available and the LEDs "HS Supply" and LS Supply" lights up.

Figure 5 shows the location of these LEDs. It must be noted that the board is functional only if all these three LEDs are lit.

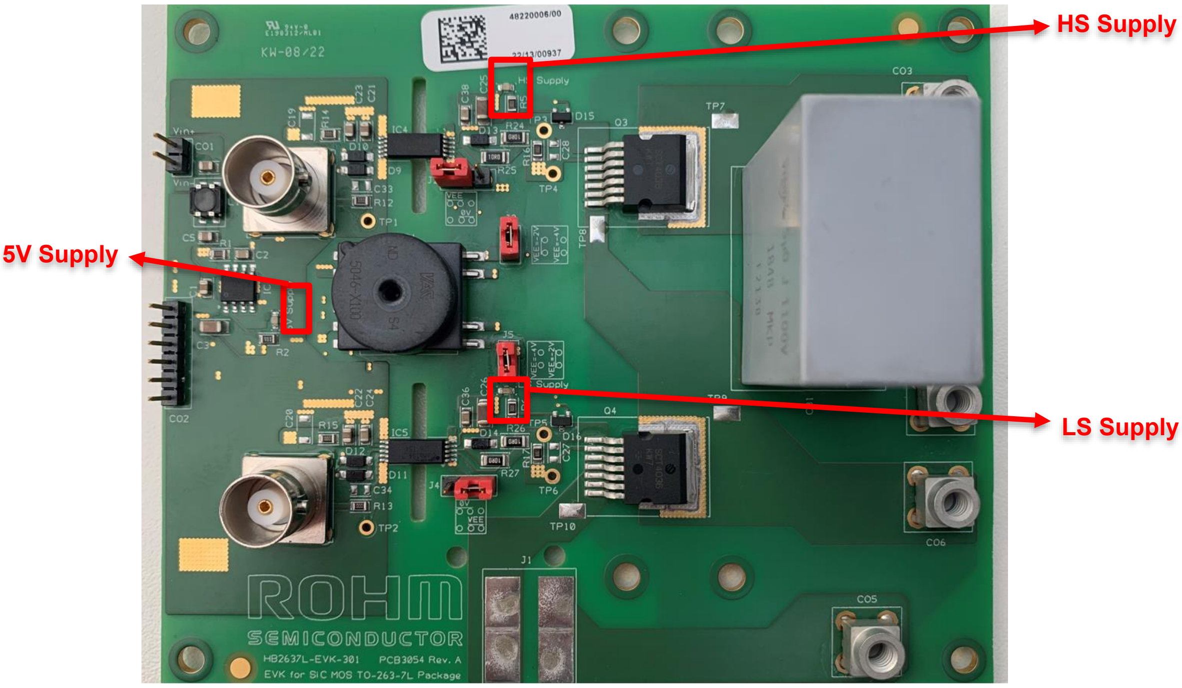


Figure 5: Top view of the board with LED locations

3.3 Isolated Power Supply and setting the gate drive voltage

The isolated power supply is realized with a simple half bridge converter which operates at a constant switching frequency of 100kHz and 50% duty cycle. Positive and negative drive voltages that are necessary for high side and low side devices are generated from this isolated power supply.

3.3.1 Adjusting the positive drive voltage

A simple open loop control has been implemented for the isolated power supply generation. Hence to adjust the positive drive voltage the input supply on the CO1 has to be adjusted accordingly.

The recommended gate source voltage of ROHM SiC MOSFET SCT4036KW is 15-18V. However, driving with 18V proves to be more efficient.

For a gate drive voltage of 18V approximately 15.5V is necessary at the connector CO1. Gate drive voltages lower than 16V are not possible because the undervoltage lock out level the gate driver used BM61S41RFV-C lies at 15.5V.

3.3.2 Adjusting the negative drive voltage

Some SiC MOSFETs might require a negative gate turn off voltage and for some a 0V turn off is enough. The recommended turn off voltage of SCT4036KW7 is 0V.

However, to provide flexibility for the user to test the SiC MOSFET SCT4036KW7 with negative gate voltages, jumpers have been provided to adjust between 0V turn off and negative gate turn off.

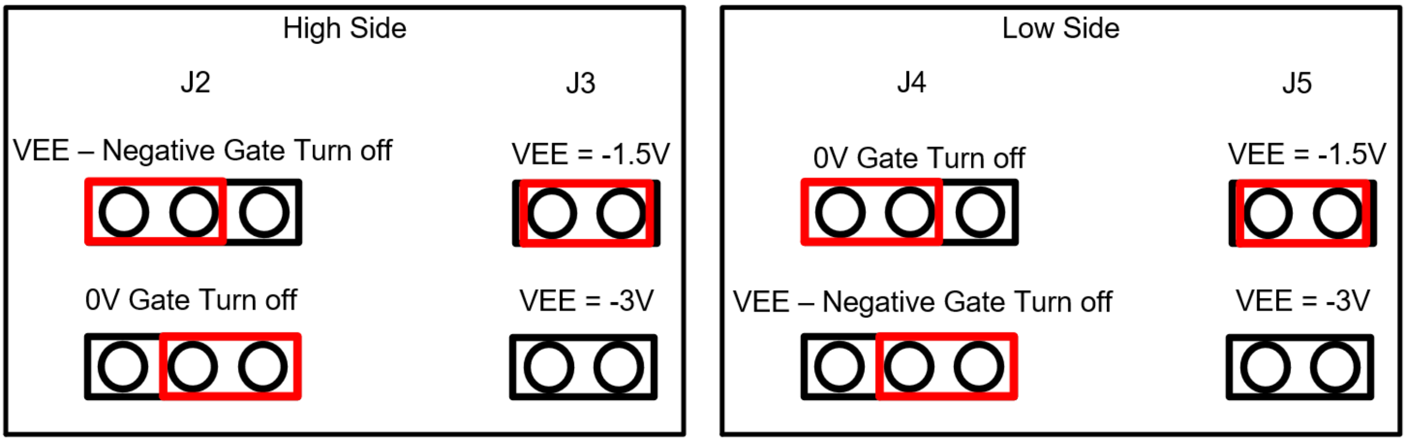


Figure 6: Jumper configurations for choosing the turn off gate drive voltage

Jumpers J2 and J4 are used to select between a negative gate turn off and a 0V gate turn off for high side device and low side device respectively. If a negative gate turn off is chosen, jumpers J3 and J4 can be used to select between -1.5V or -3V for high side device and low side device respectively. In Figure 6 various configurations are shown on how to select between negative gate turn off and 0V.

The user must decide the appropriate turn-on/turn-off drive voltages and then adjust the input supply at connector CO1 and accordingly place jumpers J2-J4.

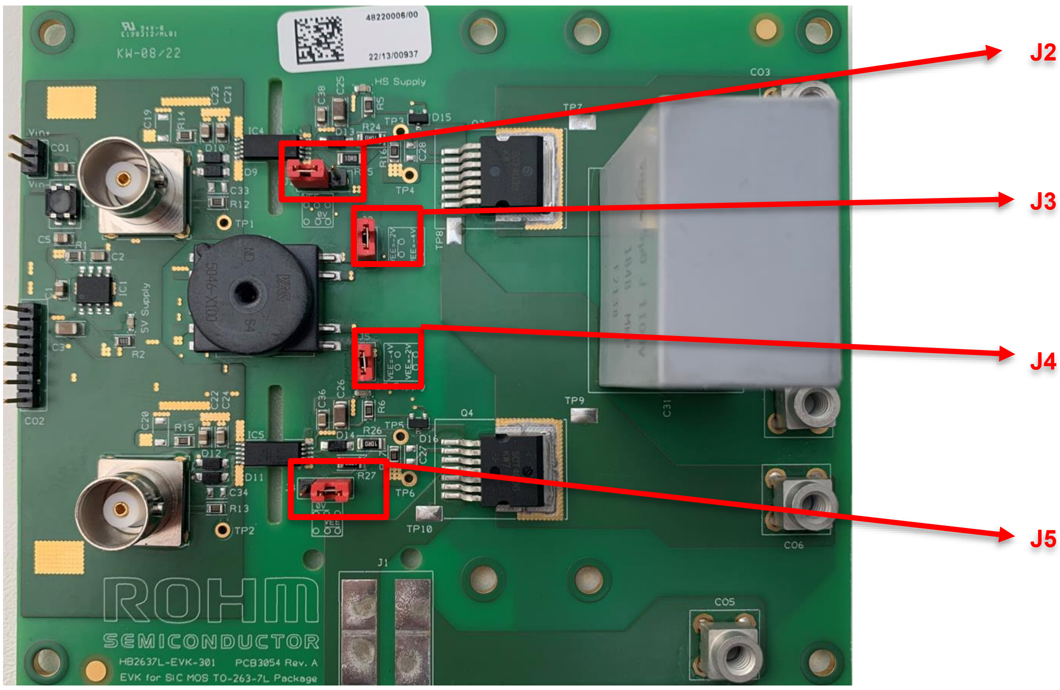


Figure 7: Top view of the board with the jumper locations for adjusting turn off gate drive voltage

3.4 Setting the gate resistors

Gate resistors are provided to adjust the switching speed of the SiC MOSFETs and along with diodes (D13 and D14), turn on and turn off speeds can be made different.

Turn on gate resistor: High side (R24), Low side (R26)
Turn off gate resistor: High side (R25), Low side (R27)

On the board, turn on gate resistance and off gate resistance are 5Ω and 10Ω respectively. Users can adjust the gate resistor value to their wish as per the application requirements.

Additional gate-source capacitance (C27, C28) has been provided to control the di/dt of the SiC MOSFET. In this board these capacitors are left unmounted and if a need arises user can place a capacitor that meets the application requirement. Figure 8 shows the mounted state of the gate drive circuit.

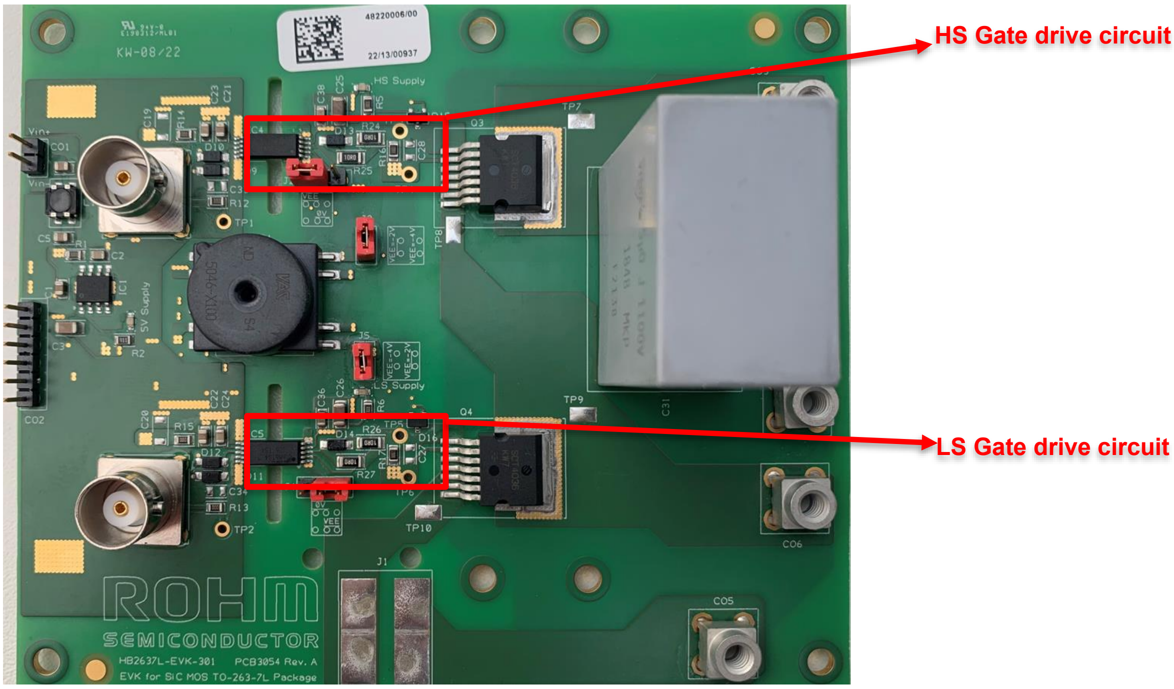


Figure 8: Top view of the board with the locations of gate resistors

3.5 Test Point Locations

A total of 10 test points has been provided on this board to monitor the important signals during the electrical characterization process of the SiC MOSFETs. Table 1 shows the list of the test points and their purpose.

Test Point	Purpose	Location
TP1	High side PWM input	LV Side
TP2	Low side PWM input	LV Side
TP3	High side gate	HV Side
TP4	High side driver source	HV Side
TP5	Low side gate	HV Side
TP6	Low side driver source	HV Side
TP7	High side drain	HV Side
TP8	High side source	HV Side
TP9	Low side drain	HV Side
TP10	Low side source	HV Side

Table 1 : Test points on the board and purpose

For gate source monitoring using optical probes for example, single pin headers that act as receptacles can be soldered on test points TP3, TP4, TP5 and TP6.

Figure 9 shows the locations of the test points on the board.

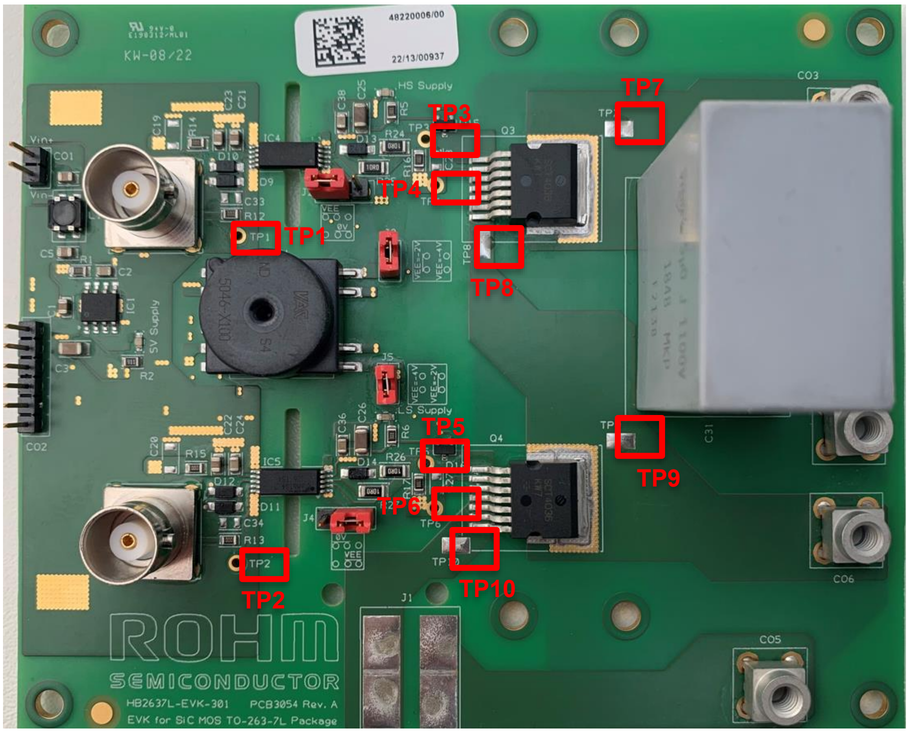


Figure 9: Top view of the board with the test point locations

3.6 Device Current Measurement

For low side device current measurement using Rogowski coil, two slots are provided through which the probe can be inserted. Rogowski coil probes with various loop and wire diameters are available. The slots provided mainly fit the probe loop of 25mm diameter and wire diameter of 1.7mm. Figure 10 depicts the usage of a Rogowski coil for current measurements. For device current measurement using Rogowski coil, it is mandatory to short the jumper J1.

Figure 9: Current measurement set up with Rogowski coil

The frequency bandwidth of most of the Rogowski probes are limited upto 30MHz, whereas co-axial shunts support several hundreds of MHz. In this board, there is a provision to use co-axial shunts for device current measurements. As shown in Figure 10, on jumper J1, co-axial shunt can be soldered. It must be noted that a low inductive co-axial shunt must be used for measurements otherwise unnecessary oscillations can lead to characterization errors. Since the measurements using co-axial shunts are non-isolated and the ground of the oscilloscope is directly connected to the DUT source, care must be taken to use appropriate DC power supply and load that will support this.

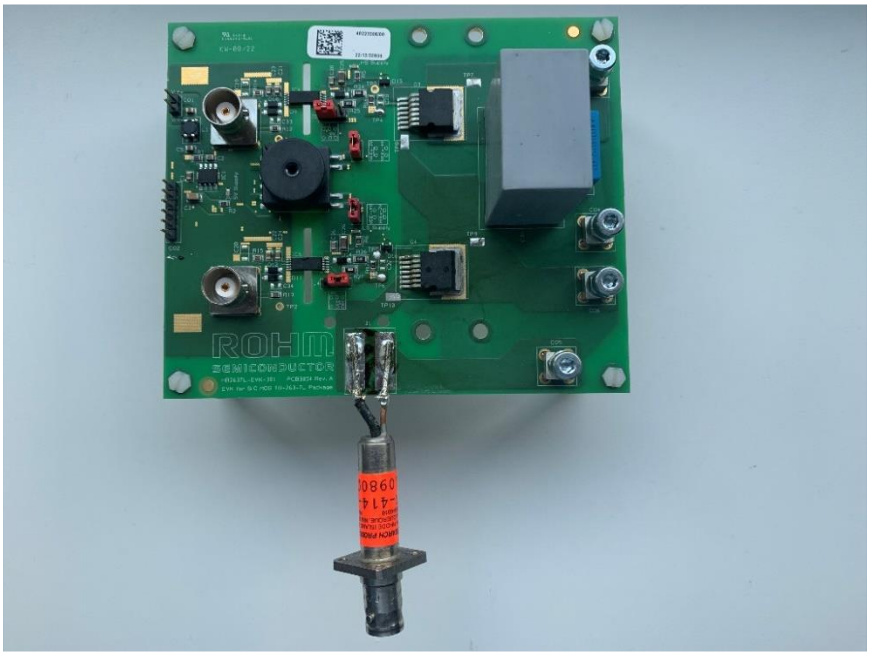


Figure 10: Current measurement set up with a co-axial shunt

3.7 Mounting Heatsink

The evaluation board is mainly thought for electrical characterization using double pulse tests. For these tests, a heatsink is not necessary since the power device is not continuously stressed. However, if measurements in continuous power operation are needed then depending on output power requirement a heatsink must be mounted.

On this board, underneath the drain pad of each SiC MOSFET, a total of 370 vias that are filled and capped according to IPC 4761 Typ VII are provided. All the four layers (top, inner layer 1, inner layer 2 and bottom) are connected through and through with these filled and capped vias. On the bottom layer, the copper is exposed so that a heatsink with a thermal interface material can be mounted. Figure 11 shows the bottom side of the PCB with exposed copper and filled/capped vias.

The recommended thermal interface sheets are SIL pad 2000 from Henkel adhesives or dual side stickable WL 404 11 from Fischer Elektronik. The heatsink LAM 3 100 5 from Fischer Elekronik is recommended. In order to mount this heatsink, four mounting holes as shown in Figure 11 are provided. This heatsink has to be mounted underneath the board and M3 screws can be used to secure it on to the board. The heatsink and the thermal interface must be mounted in such a way that air gaps between the board – thermal interface material – heatsink are avoided. The fan for heatsink requires 5V and the onboard available 5V supply from pin 3 of connector CO2 can be used for this purpose.

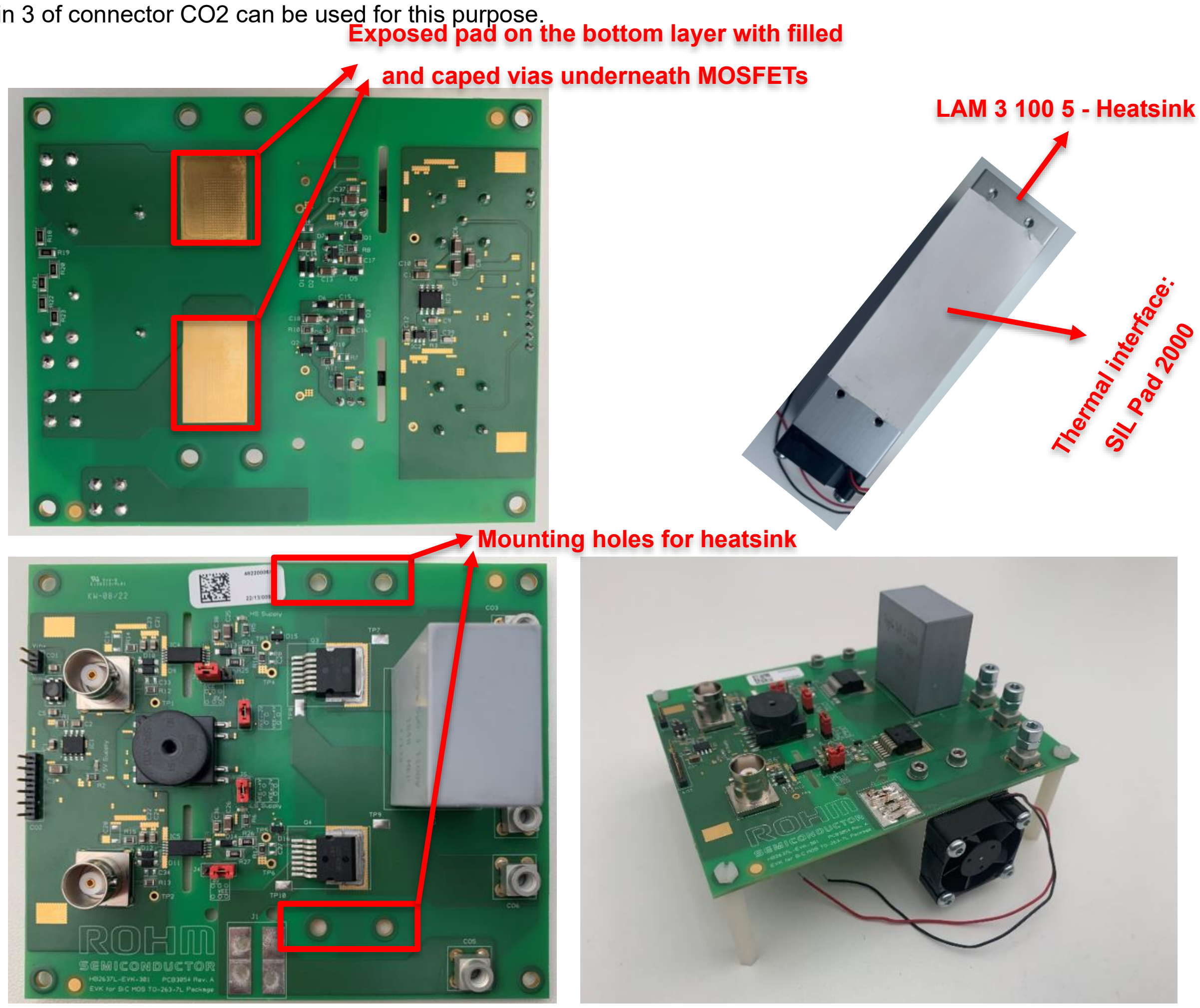


Figure 11: Board bottom view with exposed copper and filled/capped vias (top left), thermal interface material with heatsink (top right), Mounting holes for heatsink (bottom left), evaluation board mounted with heatsink (bottom right)

4. Starting Up the Board and Tests

The below procedures must be followed before beginning with the tests.

1. Mounting spacers and screws have been provided in a separate packet along with the board. Before starting any kind of tests, these spacers must be mounted.
2. Solder pin headers on all the necessary test points of the signals that are to be measured.
3. If the device current is to be measured with a Rogowski coil, ensure that jumper J1 is shorted and if co-axial shunt is used then it must be soldered on to J1.
4. Decide if a 0V turn off or negative gate turn off is necessary and then place the jumpers J2, J3, J4 and J5 accordingly. Do not leave the jumpers J2 and J4 open.
5. Decide if a simple double pulse measurement is to be performed or if a measurement in continuous power operation has to be performed. For double pulse tests heatsink need not be mounted, but for continuous operation heatsink might be needed
6. Supply 15-18V at the connector CO1 and check for correct polarity.
7. Three LEDs: 5V Supply, HS Supply and LS Supply must be lit.
8. Digital pulse signal interfaces for high side or low side should be connected to CO2 (pin 1-2 and 5-6) or the BNC adaptors
9. Connect DC+ of high voltage supply to CO3 and DC- to CO4. It has to be noted that a 5uF capacitor is available on board, but in most cases an external bulk capacitor has to connected for voltage stabilization. The applied voltage on this connector must not exceed 900V.
10. Depending on type of the test and load, connect the load appropriately.
11. The board can now be tested.

4.1 Evaluation Board set up for various tests

The board can be used for performing simple double pulse tests for switching loss measurement of the SiC MOSFET and also to evaluate the body diode behavior. Figure 12 shows the setup of the board for characterization of low side SiC MOSFETs.

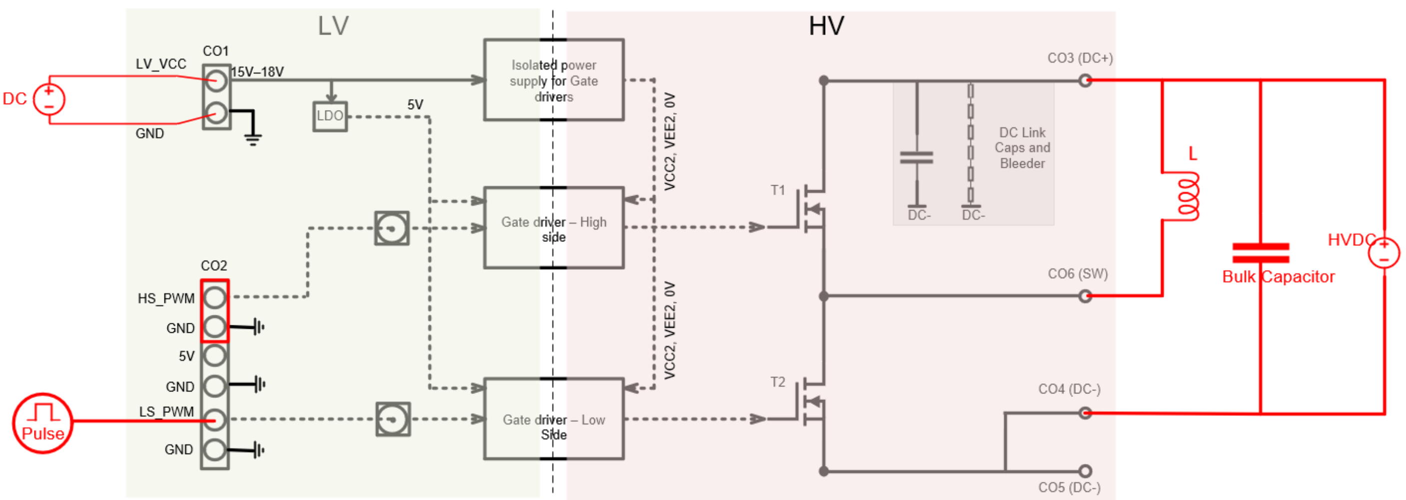


Figure 12: Double pulse test set up for low side device characterization

To characterize the low side device, a jumper must be placed across HS_PWM and GND of the connector CO2. Provide the necessary pulse on the LS_PWM pin of connector CO2 or at the BNC connector provided on the board. Choose the appropriate inductor and the pulse width such that the required drain current for the test is achieved. On board a 5uF bulk capacitor is already provided, however depending on the test current level, an external bulk capacitor will be required to minimize the DC link voltage drop.

Set the required HVDC voltage and do not exceed above 900V. For performing the double pulse measurements, a heatsink is not required.

Other topologies such as buck, boost, synchronous buck/boost, 2-level inverter are also possible. For such topologies depending on output power a heatsink might be required. Figures 14, 15 and 16 show the setup and connection required for a synchronous buck, synchronous boost and 2-level inverter respectively.

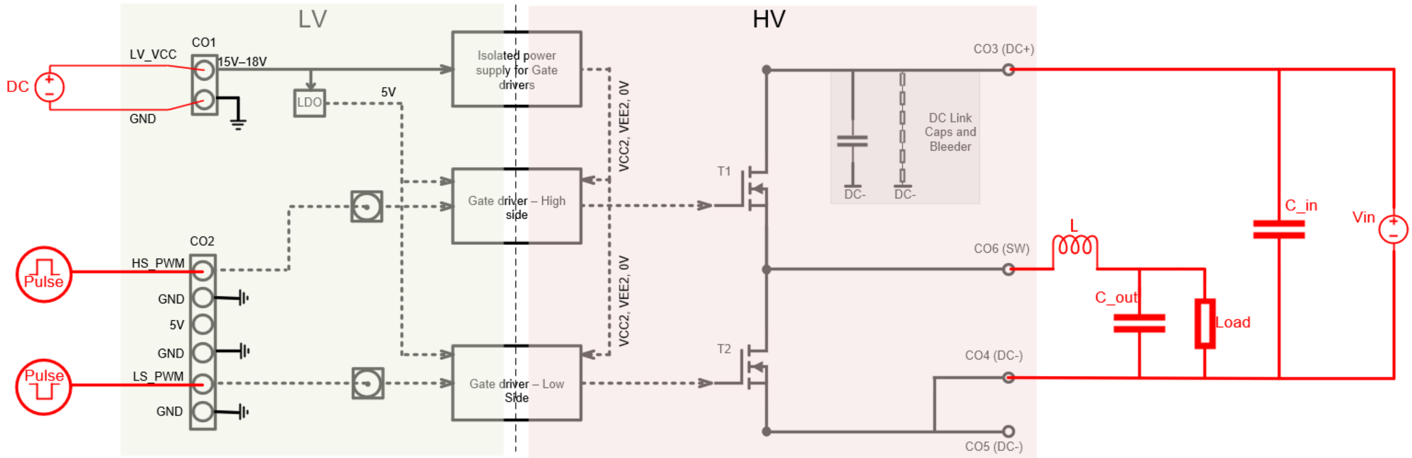


Figure 14: Synchronous Buck Converter test set up

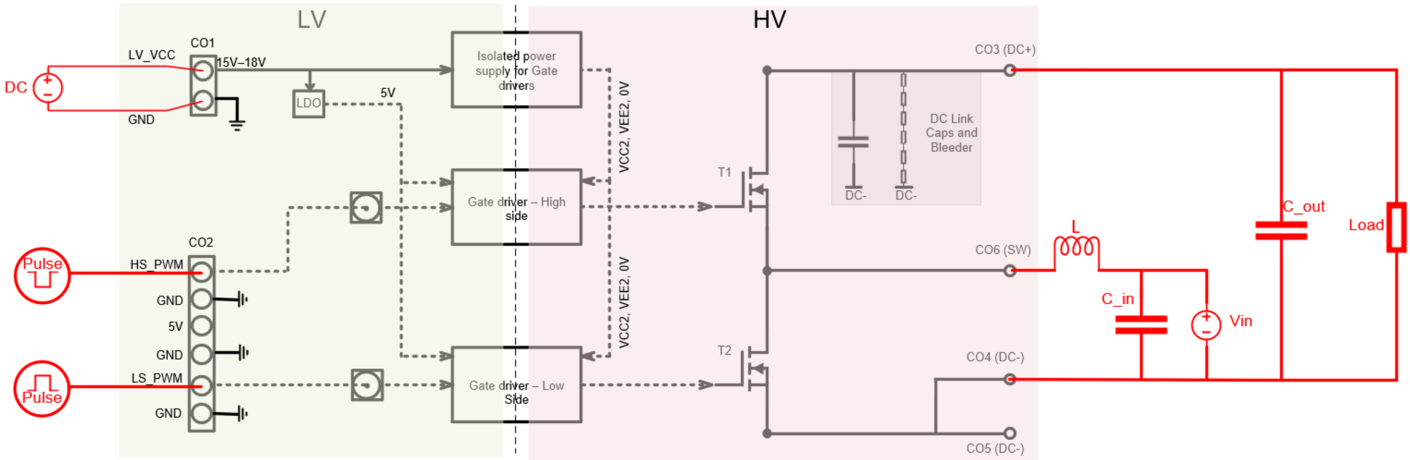


Figure 15: Synchronous Boost Converter test set up

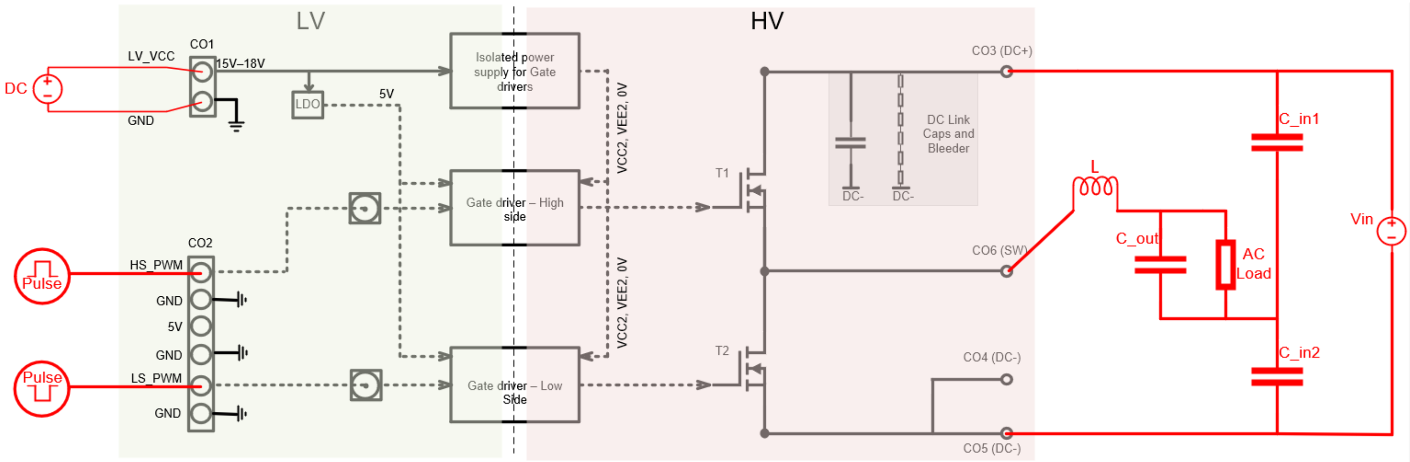


Figure 16: 2-level inverter

- Follow the mounting procedure as explained in section 3.8 of the manual and mount the heatsink if required accordingly
- Supply 15~18V at the connector CO1 to power the board
- Set the pulses for HS_PWM and LS_PWM with required switching frequency, pulse width and deadtime as necessary. Connect accordingly at the connector CO2 or use the BNC connector
- Choose the input capacitor, output capacitor and inductor as per requirement. Check the connections of input, output capacitors, inductor and load for each of the topologies as shown in Figures 12, 13 and 14
- Set the required input voltage and adjust/increase the load slowly as required by keeping an eye on the case temperature of the SiC MOSFET

Figure 17 shows the efficiency measurements in buck operation of SiC MOSFETs SCT4036KW7 and SCT4062KW7 with this evaluation board.

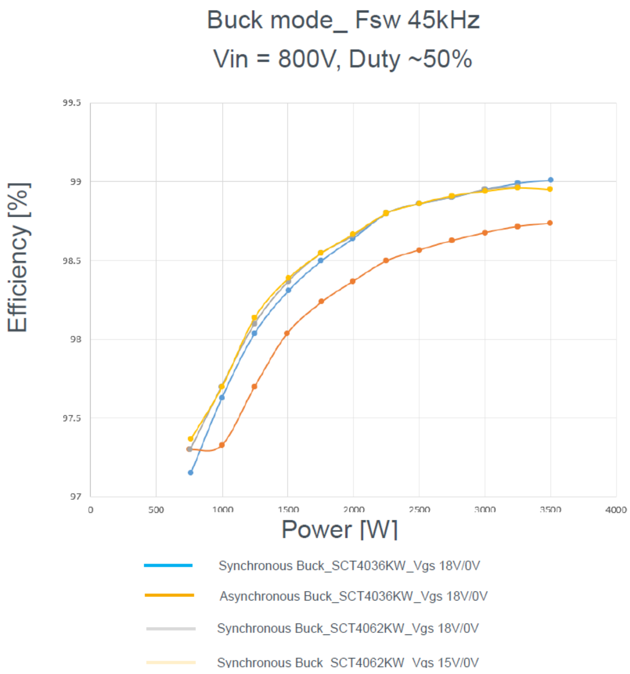


Figure 17: Efficiency Measurement in Buck operation

5. Schematic and BOM

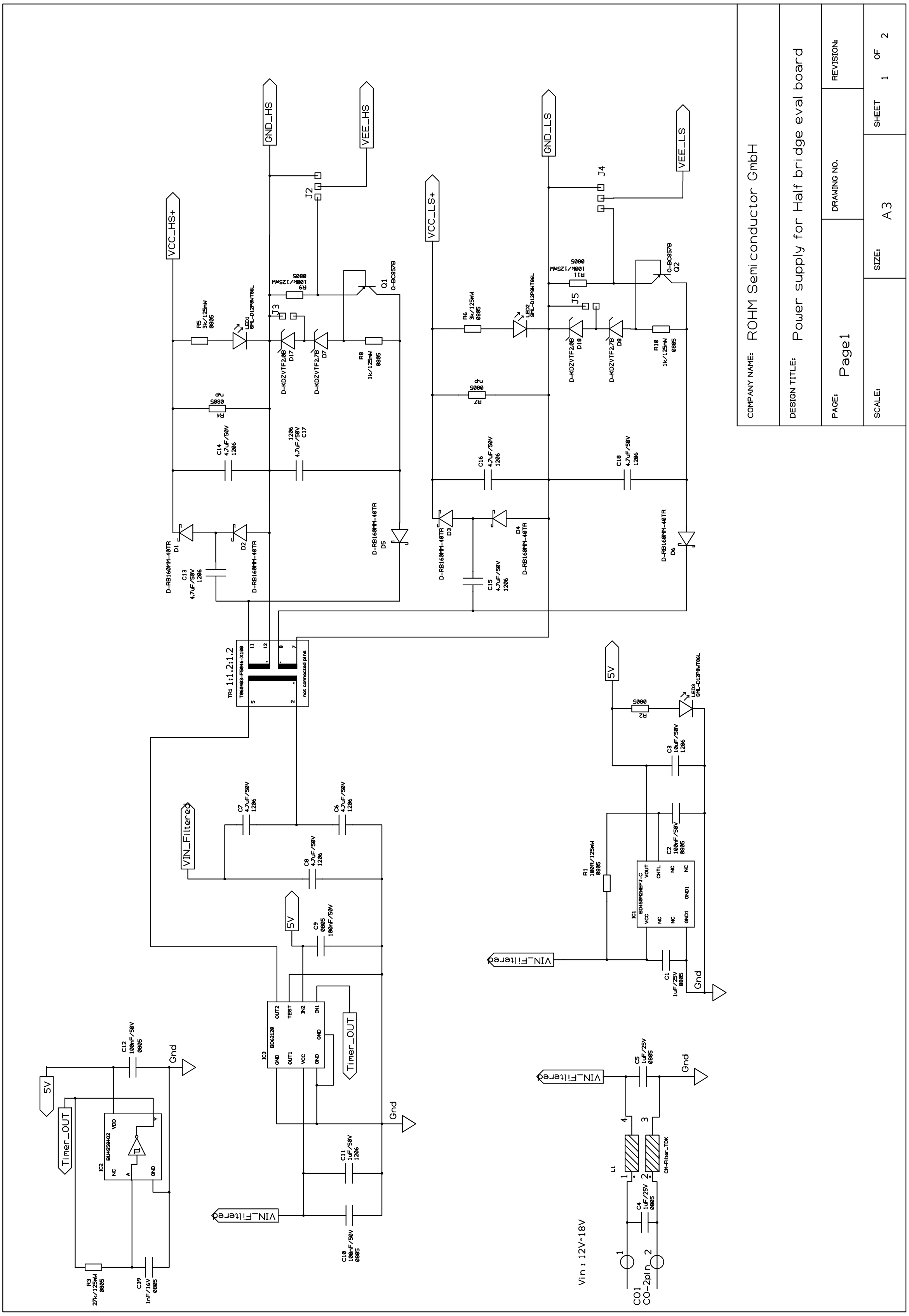


Figure 18: Schematic of the Power Supply Circuit

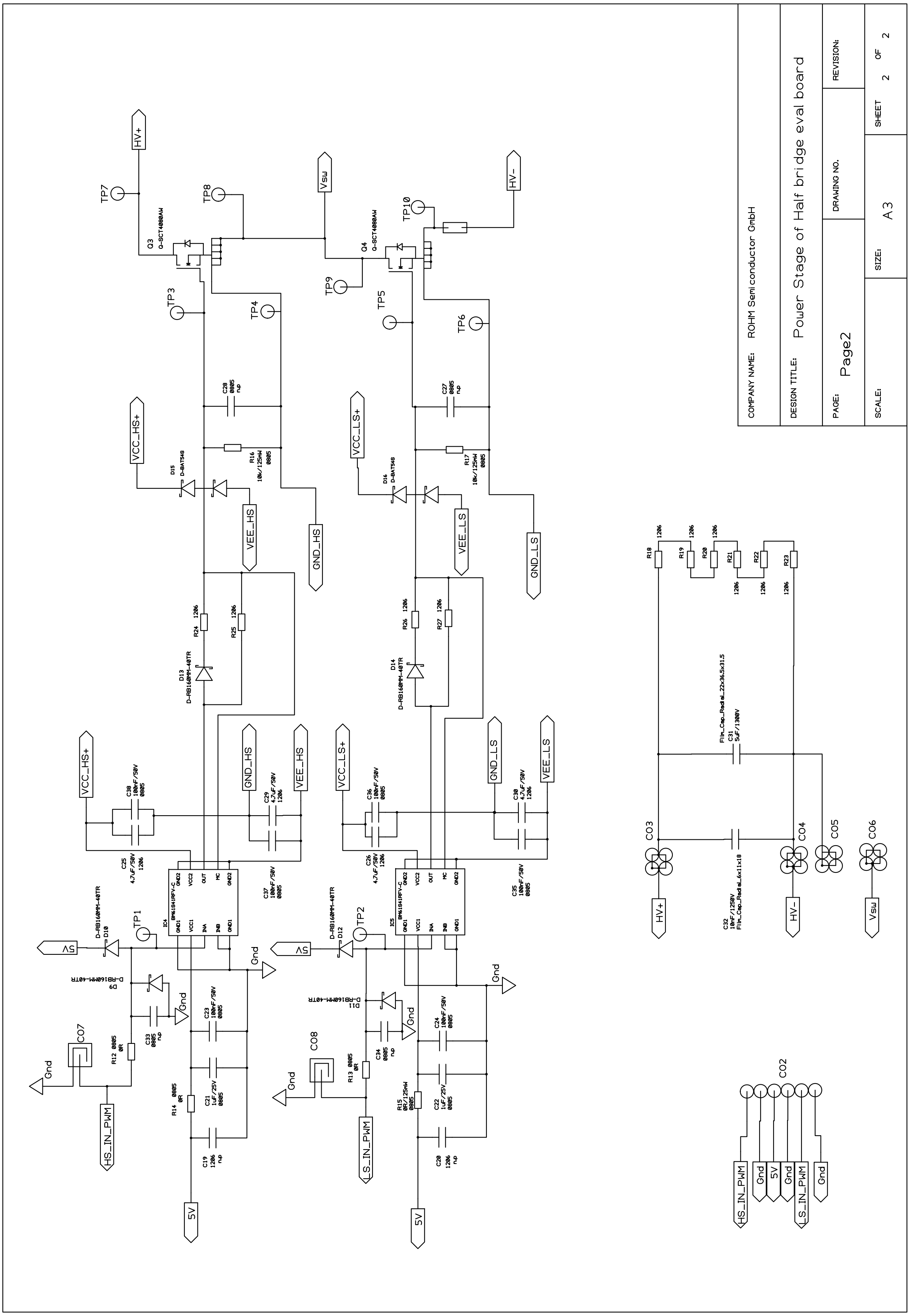


Figure 19: Schematic of the Power Stage

Item	Part Name	Description	Manufacturer	Manufacturer Part Number
Capacitors				
1	C1, C4, C5, C21, C22	Ceramic Capacitor, 1uF/25V/0805/X7R/10%	Taiyo Yuden	UMF212B7105KGHT
2	C3	Ceramic Capacitor, 10uF/50V/1206/X7R/ 10%	Murata	GRT31CR61H106KE01L
3	C2, C9, C10, C12, C23, C24, C35, C36, C37, C38	Ceramic Capacitor, 100nF/50V/0805/X7R/10%	Kemet	C0805C104K5RAC7411
4	C6, C7, C8, C11, C13, C14, C15, C16, C17, C18, C25, C26, C29, C30	Ceramic Capacitor, 4.7uF/50V/X7R/1206/10%	Murata	GRM31CR71H475KA12K
5	C31	Film Capacitor/5uF/1100V/10%/Radial	Open	Open
6	C32	Film Capacitor/10nF/1250V/10%/Radial	EPCOS/TDK	B32652A7103K
7	C39	Ceramic Capacitor, 1000pf/25V/C0G/0805/1%	Kemet	C0805C102F3GACTU
Connectors and Jumpers				
8	CO1, J3, J5	2 Pin header, 2.54mm pitch	TE Connectivity	5-146281-2
9	CO2	6 Pin header, 2.54mm pitch	TE Connectivity	5-146281-6
10	J2, J4	3 Pin header, 2.54mm pitch	TE Connectivity	5-146281-3
11	CO3, CO4, CO5, CO6	Redcube screw terminal, 30A	Würth	74650174R
Diodes				
12	D1, D2, D3, D4, D5, D6, D9, D10, D11, D12, D13, D14	Schottky diode/40V/1A	ROHM	RB160MM-40TR
13	D15, D16	Dual Schottky Diode, 30V, 200mA	Nexperia	BAT54S
14	D7, D8	Zener diode, 1000mW, 5mA	ROHM	KDZVTF2.7B
15	D17, D18	Zener diode, 1000mW, 5mA	ROHM	KDZVTF2.0B
16	LED1, LED2, LED3	Green LED	ROHM	SML-D13M8W
ICs				
17	IC1	LDO/3~42V/200mA	ROHM	BD540M2WEFJ
18	IC2	1-ch Schmitt trigger inverter gate	ROHM	BU4S584G2
19	IC3	DC Brushed motor driver 2A	ROHM	BD62120AEFJ
20	IC4, IC5	Isolated Gate Driver 3.75kVrms, 4A output	ROHM	BM61S41RFV-C
Transistors and MOSFETs				
21	Q1, Q2	PNP Transistor, -45V, 100mA	ROHM	BC857BT116 (Package: SST3)
22	Q3, Q4	1200V SiC MOSFET, 7pin, SMD package	ROHM	SCT4036KW7
Resistors				
23	R1	100ohm/125mW/1%/0805	ROHM	MCR10EZPF1000
24	R2	910ohm/125mW/1%/0805	Open choice	Open choice
25	R3	27kohm/125mW/1%/0805	Open choice	Open choice
26	R5, R6	3kohm/125mW/1%/0805	ROHM	ESR10EZPF3001
27	R8, R10	1kohm/125mW/1%/0805	ROHM	ESR10EZPF1001
28	R9, R11	100kohm/125mW/1%/0805	ROHM	ESR10EZPF1003
29	R12, R13, R14, R15	0ohm Jumper	ROHM	MCR10EZP000
30	R16, R17	10kohm/125mW/1%/0805	ROHM	ESR10EZPF1002
31	R18, R19, R20, R21, R22, R23	1Mohm/250mW/1%/1206	ROHM	ESR18EZPF1004
32	R24, R25, R26, R27	10ohm/750mW/1%/1206	Open choice	Open choice
CM Filter and Trafo				
33	L1	Common mode filter	TDK	ACM4520-142-2P-T000
34	TR1	Gate drive transformer 1:1.2:1.2	Vacuum-schmelze	T60403-F5046-X100
Not mounted				
35	C19, C20, C27, C28, C33, C34, R4, R7, J1	Not placed/not mounted (n.p)		

6. PCB Layout

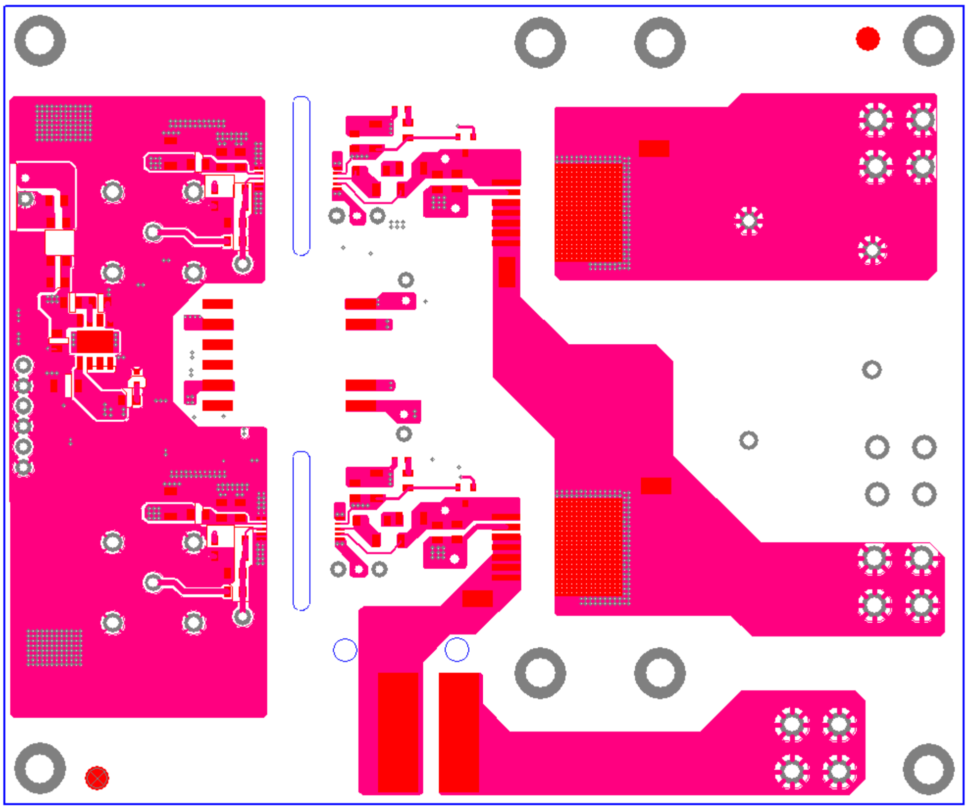


Figure 20: Top Layer

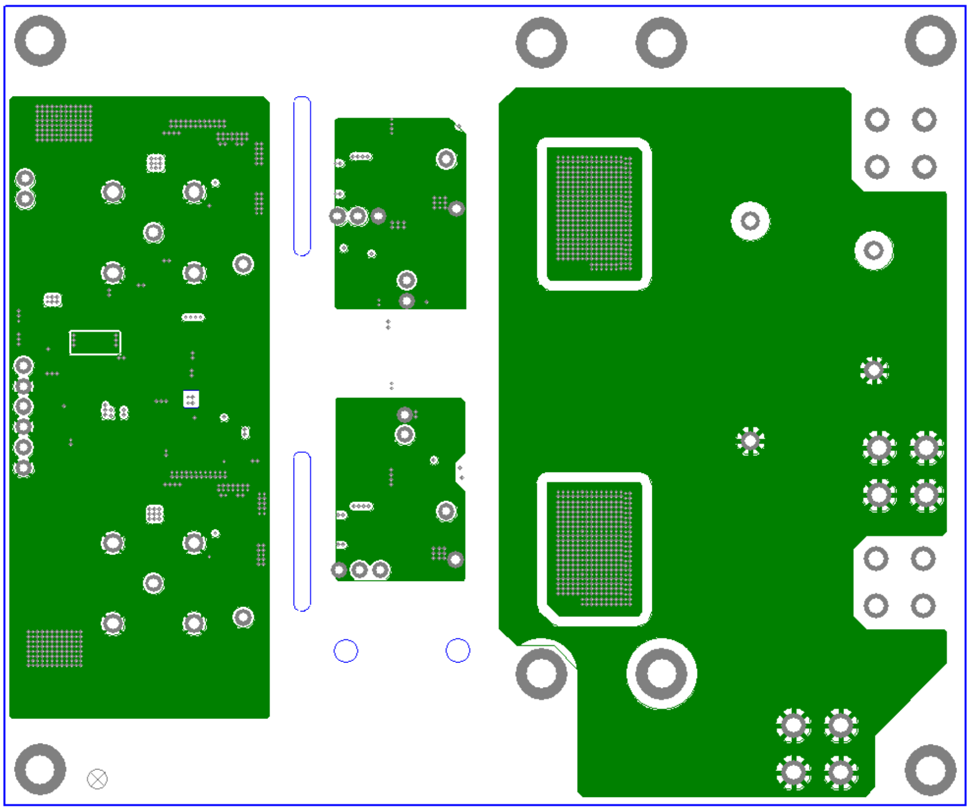


Figure 21: Inner Layer1

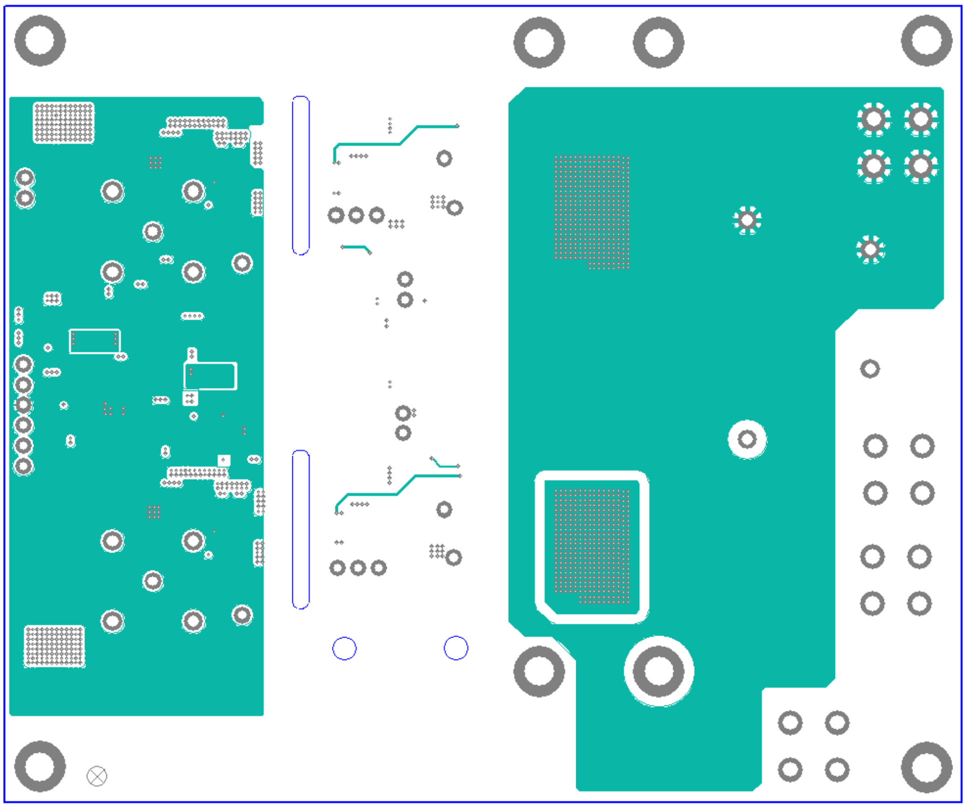


Figure 22: Inner Layer2

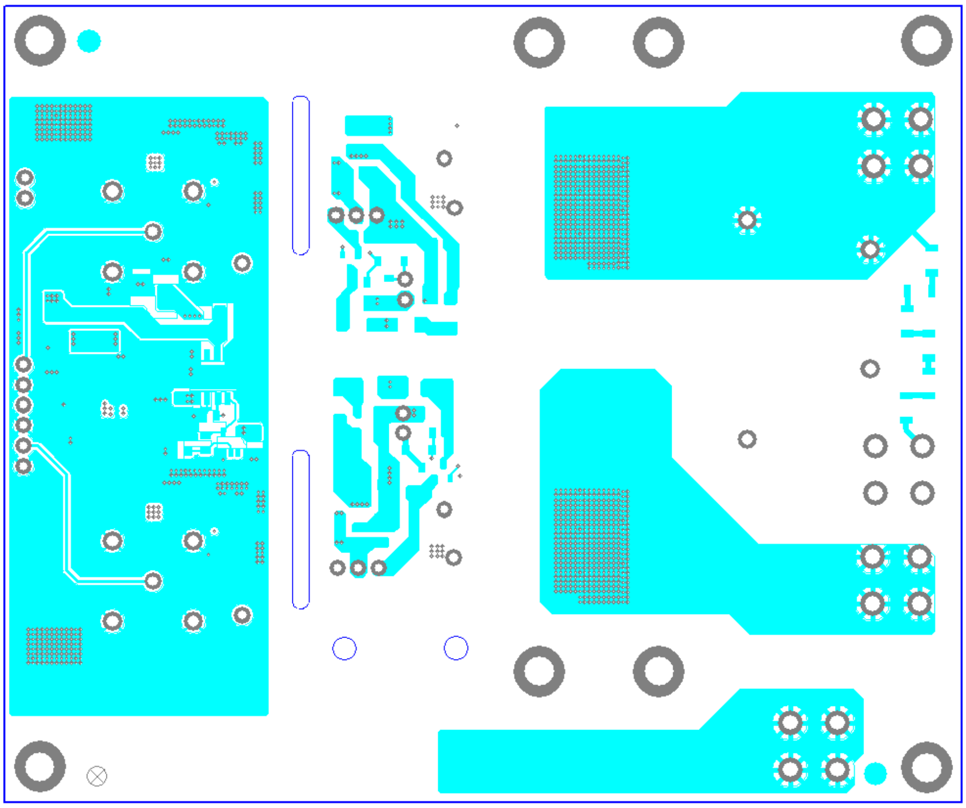


Figure 23: Bottom Layer

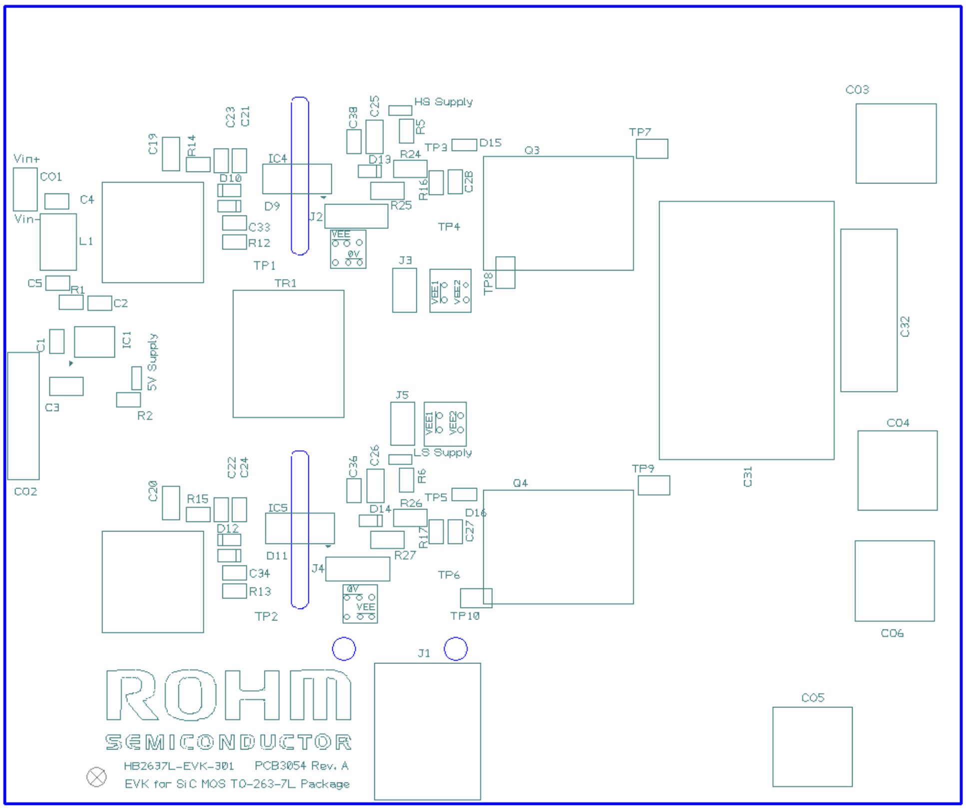


Figure 24: Silkscreen Top

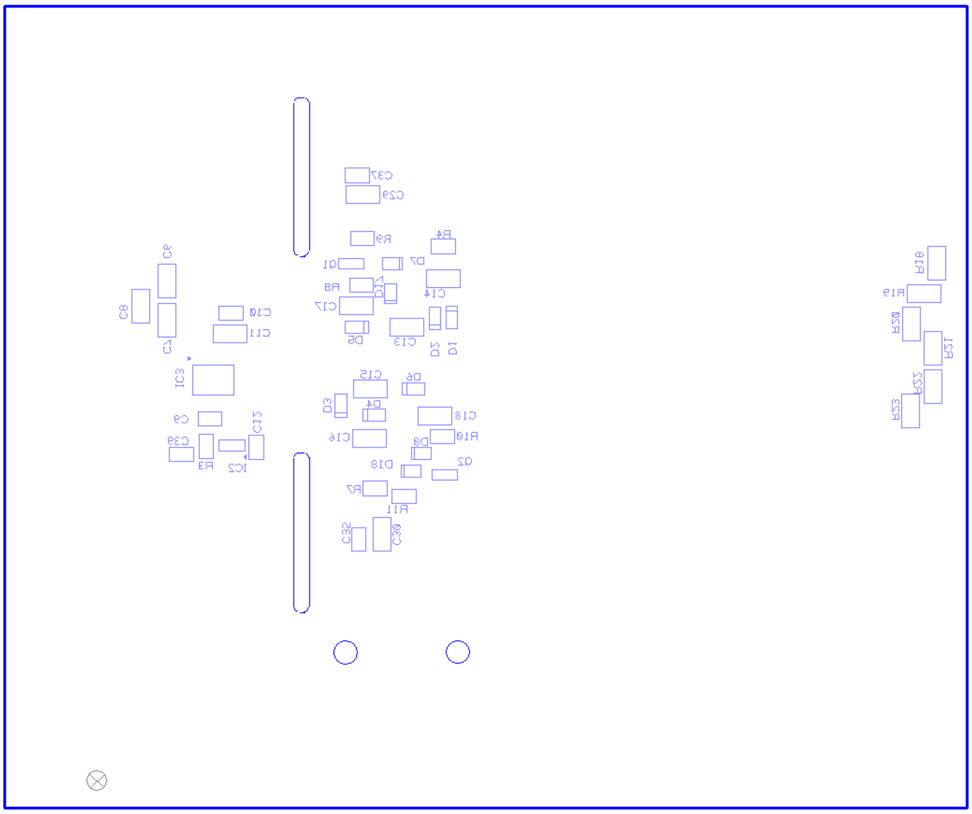


Figure 25: Silkscreen Bottom

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