TRCDRIVE pack™
Full SiC Module Evaluation Driver 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 full SiC module evaluation driver board (GD6112TRC3P-EVK-003) 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 not to 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 be 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 high voltage signage at all entrances, safety interlocks, and protective glasses.

Evaluation board for SiC MOSFET TRCDRIVE pack™

GD6112TRC3P-EVK-003

This user's guide explains how to use the evaluation board GD6112TRC3P-EVK-003 with ROHM's 4th generation SiC MOSFETs with TRCDRIVE pack™ package.

The GD Board is configured in a 3 phase full bridge set up and thus allows evaluations in 3 phase traction inverter operations. The board is equipped with isolated gate driver BM6112FV-C, isolated power supply required for the gate driver, LDO for 5V supply and easy to interface connectors for PWM signals.
This user's 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 has a short circuit protection function for the evaluation device. However, 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.

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Content

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 800 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. Overview

GD6112TRC3P-EVK-003 is a reference design of the 3 phase gate driver board (GD Board), which is designed with BST350T12P4PSAMPLE-EVK-002, TRCDRIVE pack™. The physical layout matches the pressfit pin layout of BSTP module. The user can refer to the schematic circuit, layout, and BOM, which is helpful when designing.

2.1. Appearance

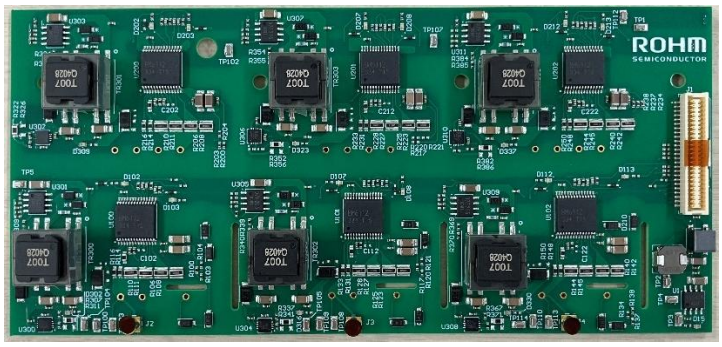


Figure 1. GD Board

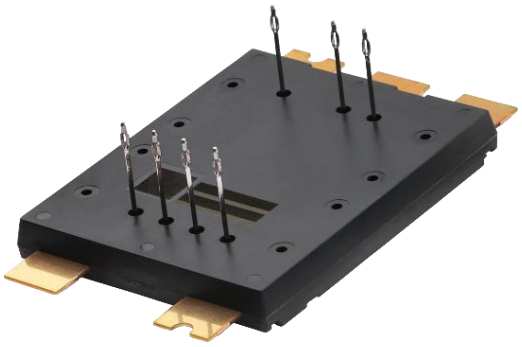


Figure 2. TRCDRIVE pack™

Figure 3. 3 phase Inverter EVK (assembled with KIT)

Table 1. SiC power module

Part Name	VDSS[V]	RDS(on)[mΩ]	Heat sink assembly	Module type
BST350T12P4PSAMPLE-EVK-002	1200	2.8	Ag Sinter	Small

Table 2. Key Components in the GD Board

	Part Number	Application
5V LDO	BD950N1WEFJ-CE2	Nano Cap™ LDO Regulator
Auxiliary IC	BD7F205EFJ-C	Isolated Type Fly-back Converter IC with Integrated Switching MOSFET
Gate Drive IC	BM6112FV-C	1ch Isolated Gate Driver

2.2. Feature

◆6 isolated gate driver circuit drive TRCDRIVE pack™ BSTP SiC module
◆3750Vrms isolation voltage gate driver circuit and maximum carrier frequency 30kHz
◆6 isolated power supply for +18V gate driver supply
◆Active miller clamp circuit and others surge suppression circuit
◆DESAT circuit can prevent power device destruction with soft turn-off function
◆Provide temperature-monitoring PWM signal from TRCDRIVE pack™ internal NTC thermistor

3. System Overview

3.1. Function Block Diagram

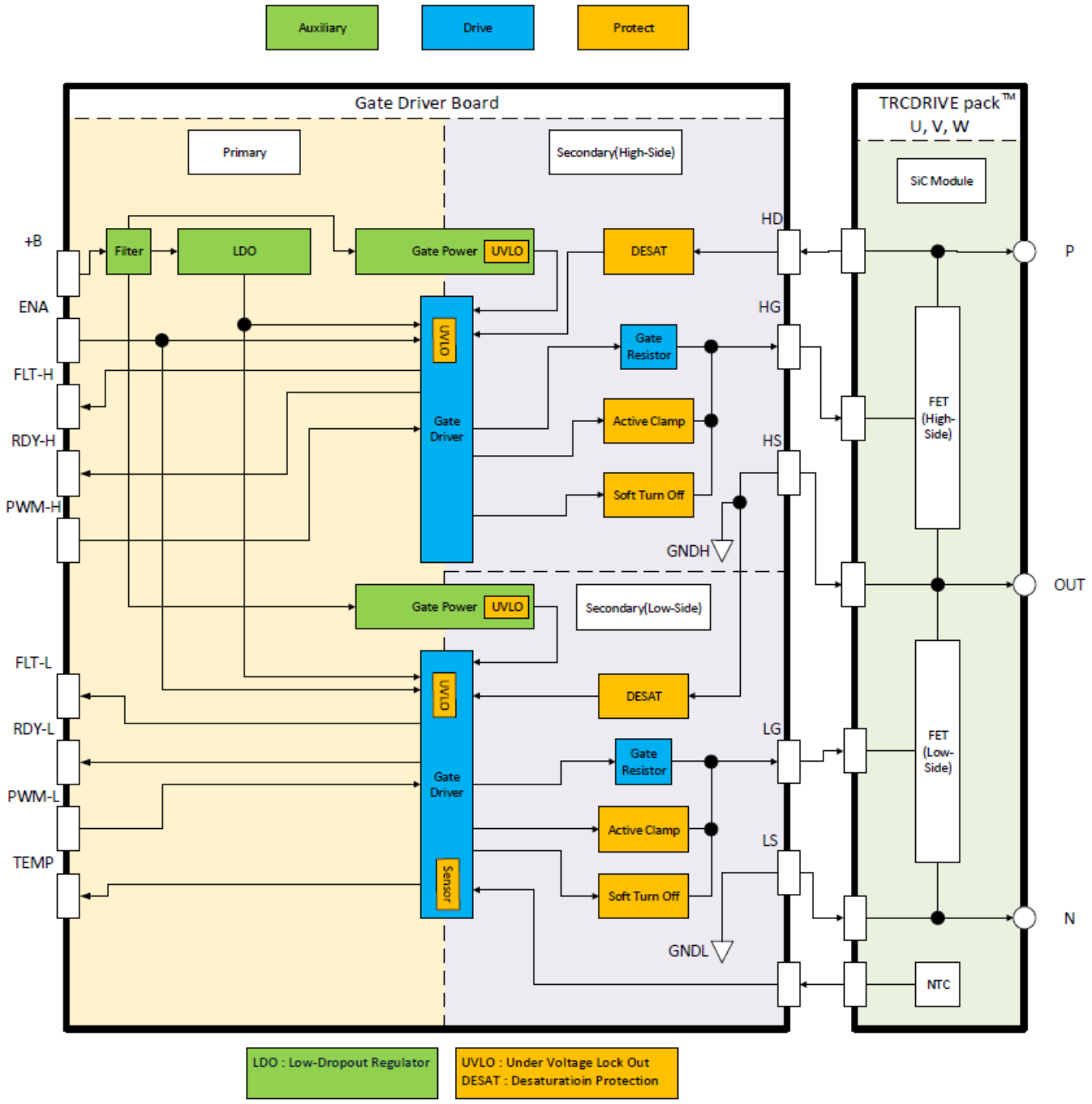


Figure 4. Function Block Diagram

3.2. Function Block Description

This section explains the functions of the GD Board.

- Gate Power
  Gate Power is an isolated flyback circuit, BD7F205EFJ-C, to power the gate driver circuit. The output of the Gate Power is 18V and -3V. The user can choose GND or -3V for VEE2 by jumpers and the default is GND.

- Gate Driver and Gate Resistor
  Gate driver circuit contains a gate driver IC, BM6112FV-C, and gate driver resistor. Turn-on and turn-off gate resistors are separated, and each has 2 resistors in parallel.

- Active miller clamp
  The Active miller clamp function of BM6112FV-C is engaged to prevent SiC module from self-turn-on when it is in the off-state. When the output of the gate driver is low, the external MOSFET will be turn on to keep the Gate pin low. Please refer to the BM6112FV-C datasheet, which provides more information.

- DESAT and Soft Turn Off
  When the Drain-Source voltage of SiC module during on state exceeds VSCDET, SCP function will be activated. As consequence, the gate drive output will be set to "L" level and the SiC module will be turned off through soft turn-off resistances. The FLT signal will be set to "L" level and the LED will be turned on. This protection will be latched. To restart the fault state, the ENA pin must have a rising edge (L→H transition), and Drain-Source voltage of the SiC module must be is less than VSCDET. When the SCP function is deactivated, FLT will be set to "Hi-Z" level and the gate drive output will be enabled again.

The desaturation voltage (V_{DESAT}) is determined by the I-V curve of the SiC datasheet. However, SiC I-V curve does not show the desaturation area obviously. Therefore, the safe operating area (SOA) graph should be considered as well. According to the SOA, 500A is about 11V, so V_{DESAT} should be lower than 11V. Due to the reference value of in the datasheet, the calculation is as follows.

$$V_{DESAT} = V_{SCDET} \times \frac{R3 + R2}{R3} - V_{FD1}$$

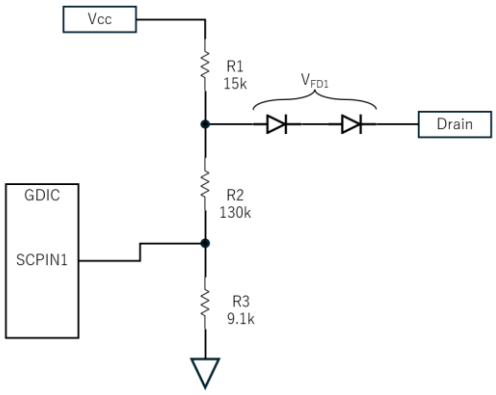


Figure 5. DESAT circuit

$$V_{DESAT} = 0.7 \times \frac{9.1 + 130}{9.1} - 0.7 \times 2 = 9.3V$$

- UVLO

  The gate driver IC, BM6112, and the flyback IC, BD7F205EFJ-C, have UVLO function. The SiC cannot turn on when this protection is triggered. Please refer to the IC datasheet for more information.

- Temperature Monitoring

  BM6112FV-C is equipped with the temperature monitoring function to monitor NTC voltage from the power module, and the output is a PWM signal. The user can monitor the "TEMP" output and design OTP (over temperature protection) on programming. The output signal of the function is a +5V PWM signal, which duty is changeable depending on the temperature.

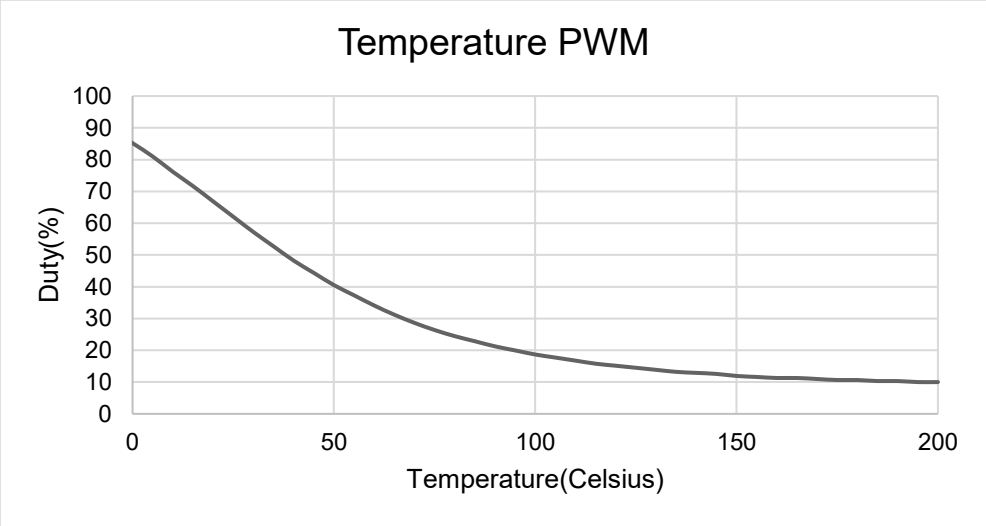


Figure 6. Temperature-PWM duty of "TEMP" terminal

3.3. Power Block Diagram

Figure 7 shows the auxiliary power of GD Board and key components

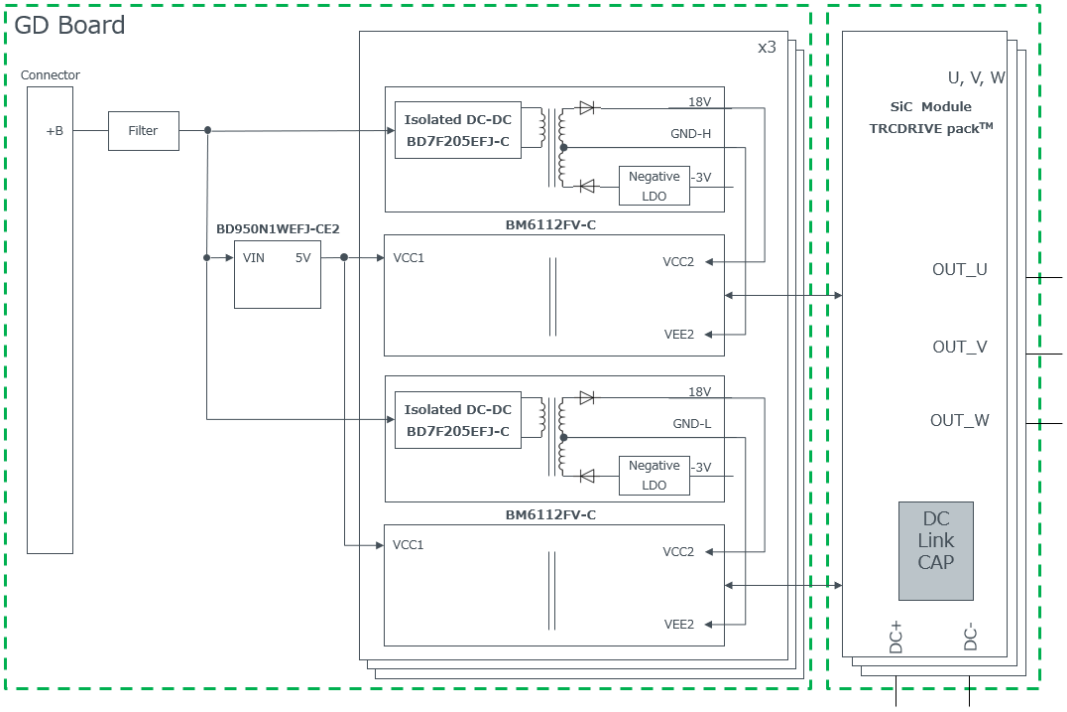


Figure 7. Power Block Diagram

4. I/O Description

This GD Board is equipped with a connector, J1, which the user can utilize input signal and output to evaluate their inverter system. Also, this section explains each I/O signal meaning.

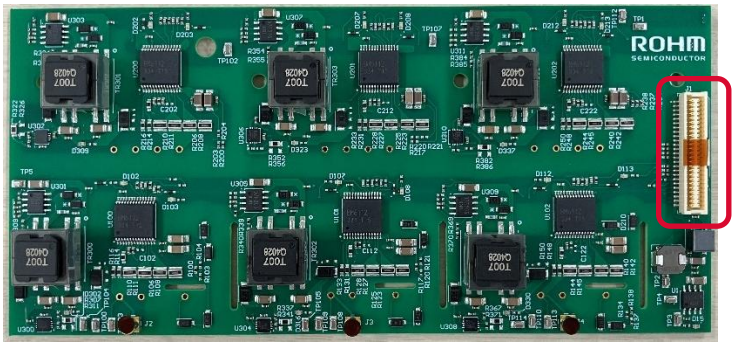


Figure 8. J1 location on the GD Board

4.1. Controller Interface

This section explains the signal which can control the GD Board function

Table 3. J1 Controller Singal List

Pin No.	Pin Name	I/O	details
31	ENA	I	Enabling signal pin. When ENA is "H" level, output is enabled When ENA is "L" level, output is disabled
33	IN_WH	I	Input signal for W High side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
35	IN_WL	I	Input signal for W Low side SiC-MOSFET

			"H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
37	IN_VH	I	Input signal for V High side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
39	IN_VL	I	Input signal for V Low side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
41	IN_UH	I	Input signal for U High side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
43	IN_UL	I	Input signal for U Low side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low

4.2. Output Signal Interface

This section explains the signal which the GD Board offers. The user can monitor the system status by signal.

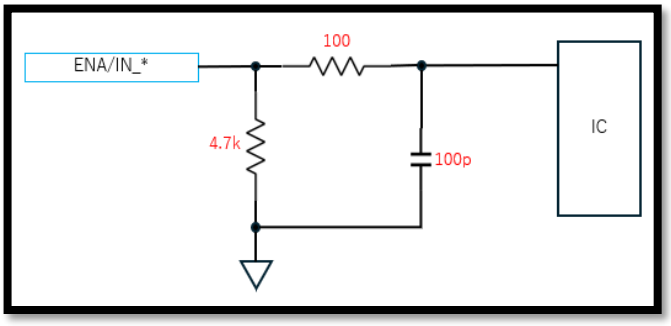
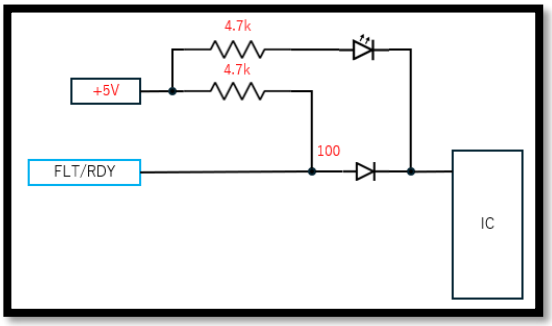
Table 4. Output Signal List

Pin No.	Pin Name	I/O	details
11	TEMP_U	O	U phase Power Module contains build-in NTC, and GD Board provides temperature monitor function
13	TEMP_V	O	V phase Power Module contains build-in NTC, and GD Board provides temperature monitor function
15	TEMP_W	O	W phase Power Module contains build-in NTC, and GD Board provides temperature monitor function
21	RDY_H	O	Abnormal signal pin(High side). Normal: "H", When Fault(UVLO or OSFB) : "L"
23	RDY_L	O	Abnormal signal pin(Low side). Normal: "H", When Fault(UVLO or OSFB) : "L"
25	FLT_H	O	Fault signal pin(High side). Normal: "Hi-Z", When fault: "L"
27	FLT_L	O	Fault signal pin(Low side). Normal: "Hi-Z", When fault: "L"

4.3. I/O Equivalent Circuit

The user must prepare the input PWM module and I/O circuit by themselves. This section explains the input signal equivalent circuit. There are 2 types of I/O circuits.

Table 5. I/O circuits

ENA/IN_*	FLT/RDY
ENA and IN_*(input PWM signal) are a pull-down circuit	FLT and RDY are a pull-up circuit and equipped with a LED
	

5. Absolute maximum Ratings

Table 6. Maximum Rating

Parameter	Symbol	Minimum	Maximum	Unit
Input Supply Voltage	B+	9.0	15.0	V
Input Signal Voltage	ENA, PWM-H, PWM-L	2.0	7.0	V
Switching Frequency	fsw	10	30	kHz

6. Electrical Specifications

Table 7. Electrical Specifications

Parameter	Symbol	Min	Typ	Max	Units	Conditions
AUX Power Supply Block (BD7F205EFJ-C)						
Input voltage range	+B	9.0	12.0	15.0	V	
Output voltage(+18V)	+18V	16.2	18.0	19.8	V	
Output voltage(-3V)	-3V	-2.7	-3.0	-3.3	V	
Output current(+18V)	$I_{OUT+18V}$	-	-	130	mA	
Output current(-3V)	I_{OUT-3V}	-	-	130	mA	
Maximum output power	P_{OUT}	-	-	2.9	W	
UVLO	V_{UVLOH}	7.1	7.6	8.2	V	Refer to IC's datasheet
	V_{UVLOL}	6.0	6.9	7.9	V	Refer to IC's datasheet
Primary side LDO (BD950N1G-C)						
Input voltage range	+B	9.0	12.0	15.0	V	Refer to IC's datasheet
Output voltage(+5V)	+5V	4.9	5.0	5.1	V	Refer to IC's datasheet
Output current	I_{OUT+5V}	-	-	65.4	mA	
Gate Driver Block (BM6112FV-C)						
Primary side input voltage range	V_{CC1}	4.9	5.0	5.1	V	Refer to IC's datasheet
Secondary side input voltage range	V_{CC2}	16.2	18.0	19.8	V	
Secondary side negative bias voltage range	V_{EE2}	-	0	-	V	
UVLO (primary side)	V_{UVLO1H}	4.05	4.25	4.45	V	Refer to IC's datasheet
	V_{UVLO1L}	3.95	4.15	4.35	V	Refer to IC's datasheet
UVLO (secondary side)	V_{UVLO2H}	11.5	12.5	13.5	V	Refer to IC's datasheet
	V_{UVLO2L}	10.5	11.5	12.5	V	Refer to IC's datasheet
Switching frequency	f_{SW}	10	-	30	kHz	
DESAT voltage	V_{DESAT}	-	9.3	-	V	for short circuit protection 5.5V~9.3 are recommended

7. Application

This section would describe the GD Board function, and the user can understand what they can do with this board.

7.1. GD Board and Power Module

This GD Board can drive BST350T12P4PSAMPLE and operate the 3 phase motor as a traction inverter. The user can use this GD Board and power module to conduct the following test:

- Double pulse test
- 3 phase inverter continuous test

8. Hardware and Test Setup

This section would explain the hardware setting, which the user can utilize or modify correctly.

8.1. Gate Resistor

The switching speed can be adjusted by the value of gate resistors. In the initial state, gate resistors are mounted, so the user does not have to do any soldering.

There are 2 parallel resistors on turn on circuit and turn off circuit, so the actual resistor would be half of the resistor value. Figure 9 shows the gate resistor on schematic circuit. Table 2 and table 3 show the designator and initial value. Figure 10 shows the location of the gate resistor in schematics. Turn-on resistors are connected to GDIC pin 12, and turn-off resistors are connected to GDIC pin 13.

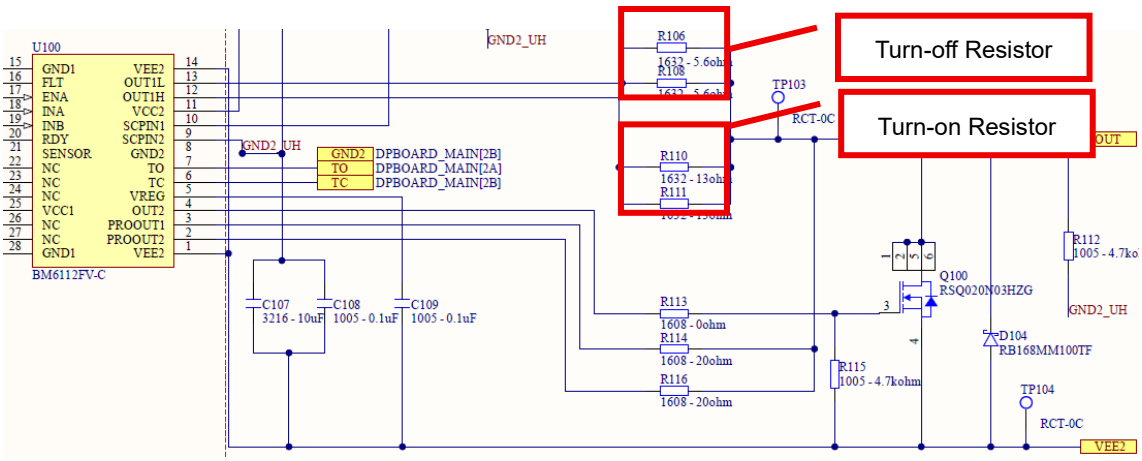


Figure 9. gate resistor in schematics

Table 8. gate resistor designator

	UH	UL	VH	VL	WH	WL
Turn-on R	R110, R111	R210, R211	R127, R128	R227, R228	R144, R145	R244, R245
Turn-off R	R106, R108	R206, R208	R123, R125	R223, R225	R140, R142	R240, R242

Table 9. initial gate resistor value

	Initial gate resistor	
	Turn ON	Turn OFF
Package	LTR18(0612)	LTR18(0612)
Value(Ω)	13	5.6
Practical value(Ω) (2 parallel)	6.5	2.8

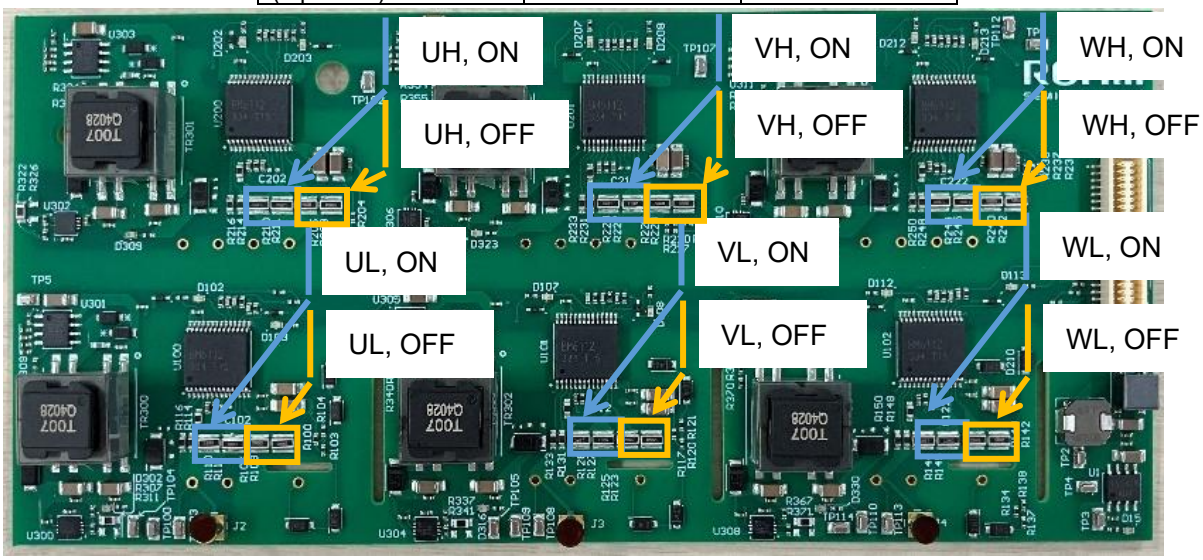


Figure 10. gate resistor location

8.2. LED

This GD Board is integrated with 19 LEDs providing status information of the board. The user can judge the board status and do troubleshooting easily. Table 10 is the list of LEDs. Figure 11 shows the location of the LED

Table 10. LED list

Category	Side	Designator	Description
Auxiliary power	Primary	D15	ON: +5V is normal OFF: +5V is abnormal
UH	Primary	D102	ON: RDY error is triggered OFF: Normal
		D103	ON: FLT error is triggered OFF: Normal
	Secondary	D302	ON: +18V is normal OFF: +18V is abnormal
UL	Primary	D202	ON: RDY error is triggered OFF: Normal
		D203	ON: FLT error is triggered OFF: Normal
	Secondary	D309	ON: +18V is normal OFF: +18V is abnormal
VH	Primary	D107	ON: RDY error is triggered OFF: Normal
		D108	ON: FLT error is triggered OFF: Normal
	Secondary	D316	ON: +18V is normal OFF: +18V is abnormal
VL	Primary	D207	ON: RDY error is triggered OFF: Normal
		D208	ON: FLT error is triggered OFF: Normal
	Secondary	D323	ON: +18V is normal OFF: +18V is abnormal
WH	Primary	D112	ON: RDY error is triggered OFF: Normal

		D113	ON: FLT error is triggered OFF: Normal
	Secondary	D330	ON: +18V is normal OFF: +18V is abnormal
WL	Primary	D212	ON: RDY error is triggered OFF: Normal
		D213	ON: FLT error is triggered OFF: Normal
	Secondary	D337	ON: +18V is normal OFF: +18V is abnormal

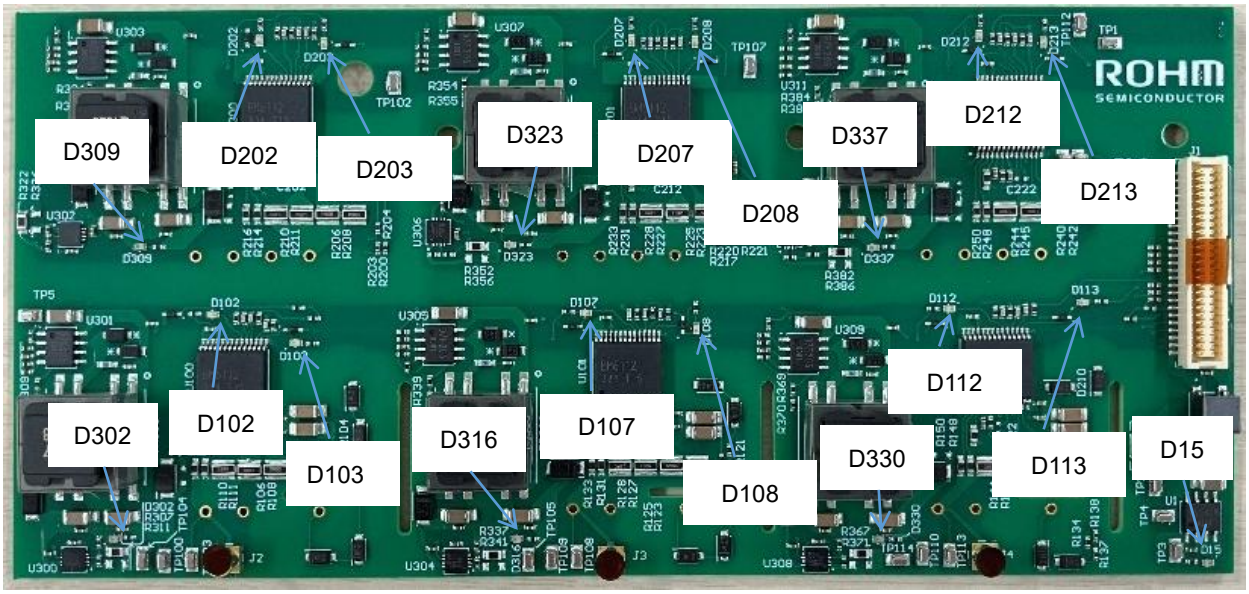


Figure 11. LED location

8.3. Test pin and MMCX connector

GD Board is integrated with 16 test pins and 3 MMCX connectors. Figure 12 shows test pin and MMCX location.

Table 11. test pin list

Category	Side	Designator	Signal Name
Input voltage and signal	Primary	TP1	ENA
		TP2	VSUP
		TP3	+5V
		TP4, TP5	GND
UH	Primary	TP102	IN_UH
	Secondary	TP100	UH VCC2
		TP103	UH Gate
		TP104	UH VEE2
		J2	UH Vgs MMCX
VH	Primary	TP107	IN_VH
	Secondary	TP105	VH VCC2
		TP108	VH Gate
		TP109	VH VEE2
		J3	VH Vgs MMCX
WH	Primary	TP112	IN_WH
	Secondary	TP110	WH VCC2
		TP113	WH Gate
		TP114	WH VEE2
		J4	WH Vgs MMCX

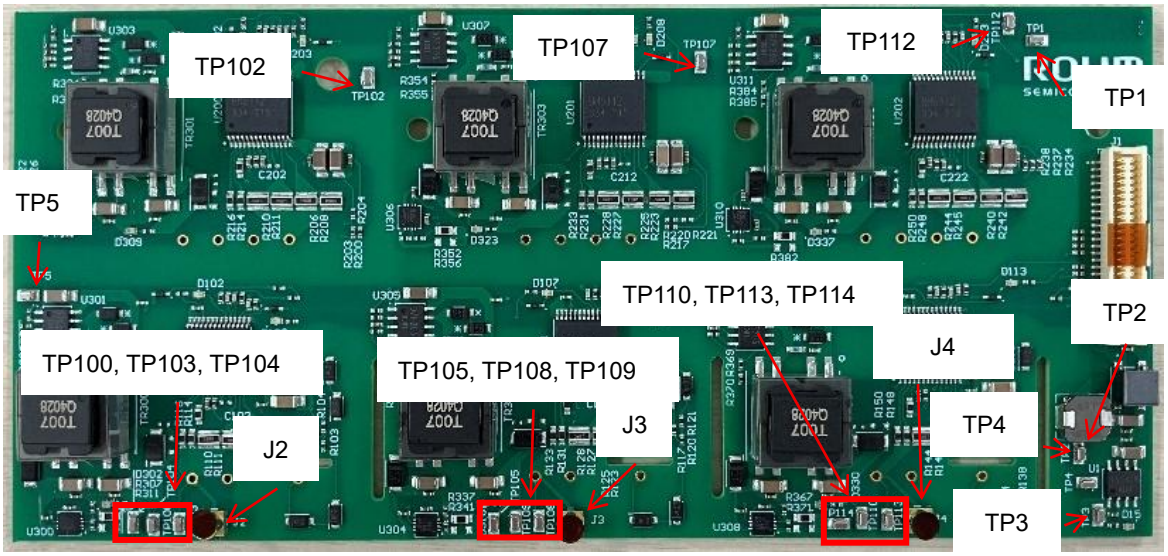


Figure 12. test Pin location

8.4. Pin assignment

Figure 13 shows GD Board pin location. The user refers to the Table13 and J1 pin assignment to design the cable, which can provide the I/O signal to the GD Board

J1 Connector P/N: BM50B-SHLDS-G-TFT

J1 Cable Housing P/N: SHLDP-50V-S-1(B)

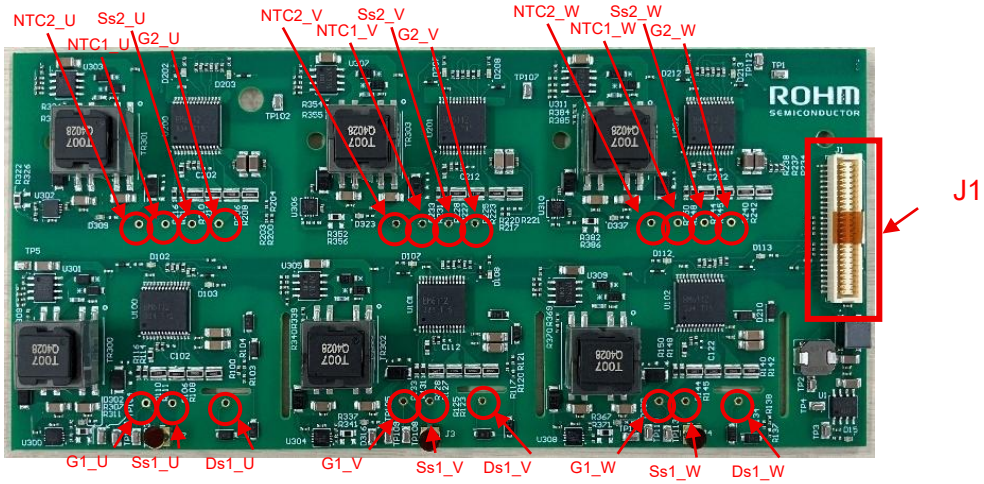


Figure 13. GD Board Pin press fit pin

8.4.1. GD Board pressfit pin assignment

Table 12 is the list of pressfit pin

Table 12. GD Board pressfit pin list

Pin Name	Details
G1_U	U High side Gate
Ss1_U	U High side Source Sense
Ds1_U	U High side Drain Sense
G2_U	U Low side Gate
Ss2_U	U Low side Source Sense
NTC1_U	U phase power device NTC

NTC2 _U	U phase power device NTC
G1_V	V High side Gate
Ss1_V	V High side Source Sense
Ds1_V	V High side Drain Sense
G2_V	V Low side Gate
Ss2_V	V Low side Source Sense
NTC1_V	V phase power device NTC
NTC2 _V	V phase power device NTC
G1_W	W High side Gate
Ss1_W	W High side Source Sense
Ds1_W	W High side Drain Sense
G2_W	W Low side Gate
Ss2_W	W Low side Source Sense
NTC1_W	W phase power device NTC
NTC2 _W	W phase power device NTC

8.4.2. Connector Assignment

Table 13 is the pin assignment list of J1.

Table 13. J1 pin assignment

Pin No.	Pin Name	I/O	details
1	N.C.	-	-
2	GND_IN	-	GND
3	N.C.	-	-
4	GND_IN	-	GND
5	N.C.	-	-
6	GND_IN	-	GND
7	N.C.	-	-
8	N.C.	-	-
9	N.C.	-	-
10	N.C.	-	-
11	TEMP_U	O	U phase Power Module contains build-in NTC, and GD Board provides temperature monitor function
12	GND_IN	-	GND
13	TEMP_V	O	V phase Power Module contains build-in NTC, and GD Board provides temperature monitor function
14	GND_IN	-	GND
15	TEMP_W	O	W phase Power Module contains build-in NTC, and GD Board provides temperature monitor function
16	GND_IN	-	GND
17	N.C.	-	-
18	N.C.	-	-
19	N.C.	-	-
20	N.C.	-	-
21	RDY_H	O	Abnormal signal pin(High side). Normal: "H", When Fault(UVLO or OSFB) : "L"
22	GND_IN	-	GND
23	RDY_L	O	Abnormal signal pin(Low side). Normal: "H", When Fault(UVLO or OSFB) : "L"
24	GND_IN	-	GND
25	FLT_H	O	Fault signal pin(High side). Normal: "Hi-Z", When fault: "L"
26	GND_IN	-	GND
27	FLT_L	O	Fault signal pin(Low side). Normal: "Hi-Z", When fault: "L"

28	GND_IN	-	GND
29	N.C.	-	-
30	N.C.	-	-
31	ENA	I	Enabling signal pin. When ENA is "H" level, output is enabled. When ENA is "L" level, output is disabled
32	GND_IN	-	GND
33	IN_WH	I	Input signal for W High side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
34	GND_IN	-	GND
35	IN_WL	I	Input signal for W Low side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
36	GND_IN	-	GND
37	IN_VH	I	Input signal for V High side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
38	GND_IN	-	GND
39	IN_VL	I	Input signal for V Low side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
40	GND_IN	-	GND
41	IN_UH	I	Input signal for U High side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
42	GND_IN	-	GND
43	IN_UL	I	Input signal for U Low side SiC-MOSFET "H" Level：output(Gate Driver Voltage) is high "L" Level：output(Gate Driver Voltage) is low
44	GND_IN	-	GND
45	+B	I	Power Supply Voltage
46	+B	I	Power Supply Voltage
47	+B	I	Power Supply Voltage
48	+B	I	Power Supply Voltage
49	+B	I	Power Supply Voltage
50	+B	I	Power Supply Voltage

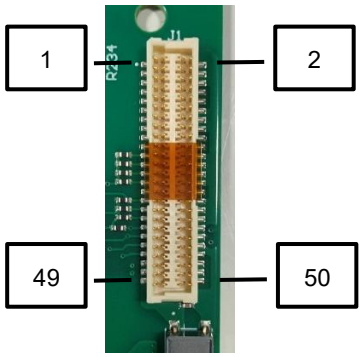


Figure 14. J1 connector photo

8.5. Power ON/OFF sequence

This GD Board has multiple inputs for power supplies and control signals. Please follow the power on/off sequence described below. Otherwise, power module is possibly damaged due to voltage overshoot

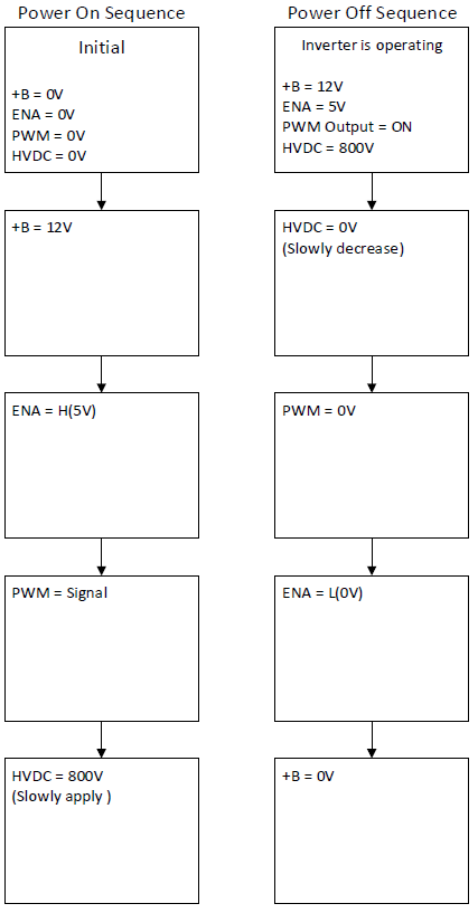


Figure 15. Power on and off sequence

9. Test Result

9.1. Double Pulse Test

Double pulse test (DPT) is carried out to evaluate the switching behavior, such as switching loss, Vds spike, etc. Figure 17 is the DPT circuit for this GD Board and Figure 16 is the switching characteristics definition of the measurement.

- Vin = 800VDC
- High Side Switching
- Inductor: 125μH

The time interval of Eon, Eoff, tr, tf is based on power device datasheet.

Table 14. Time interval definition

	Time interval T1	Time interval T2
Eon	ID(2%)	VDS(2%)
Eoff	VDS(2%)	ID(2%)
Tr	ID(10%)	ID(90%)
Tf	ID(90%)	ID(10%)

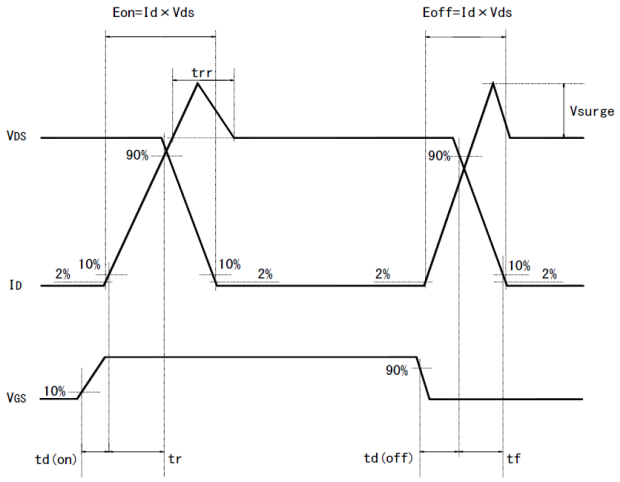


Figure 16. Switching characteristics definition

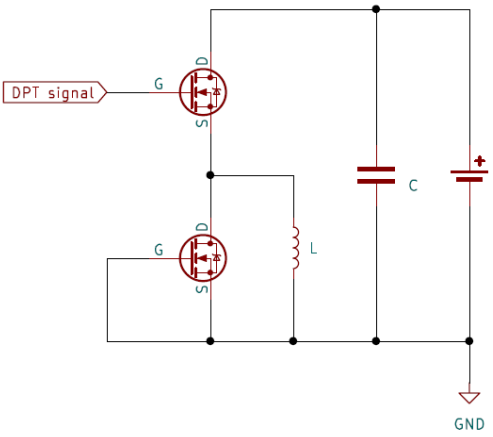


Figure 17. DPT circuit

9.1.1. Double Pulse Test Waveform

Figure 18 is an example of DPT waveform. The results may change depending on the measurement environment.

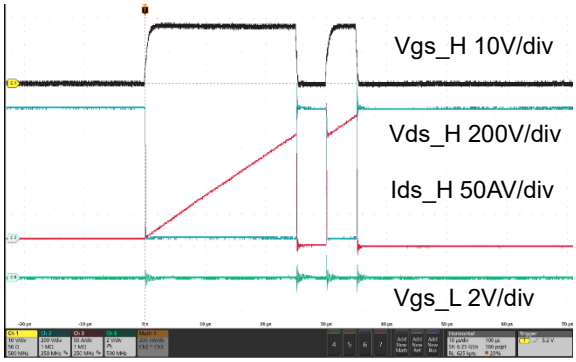


Figure 18. DPT waveform

9.1.2. Double Pulse Test Result

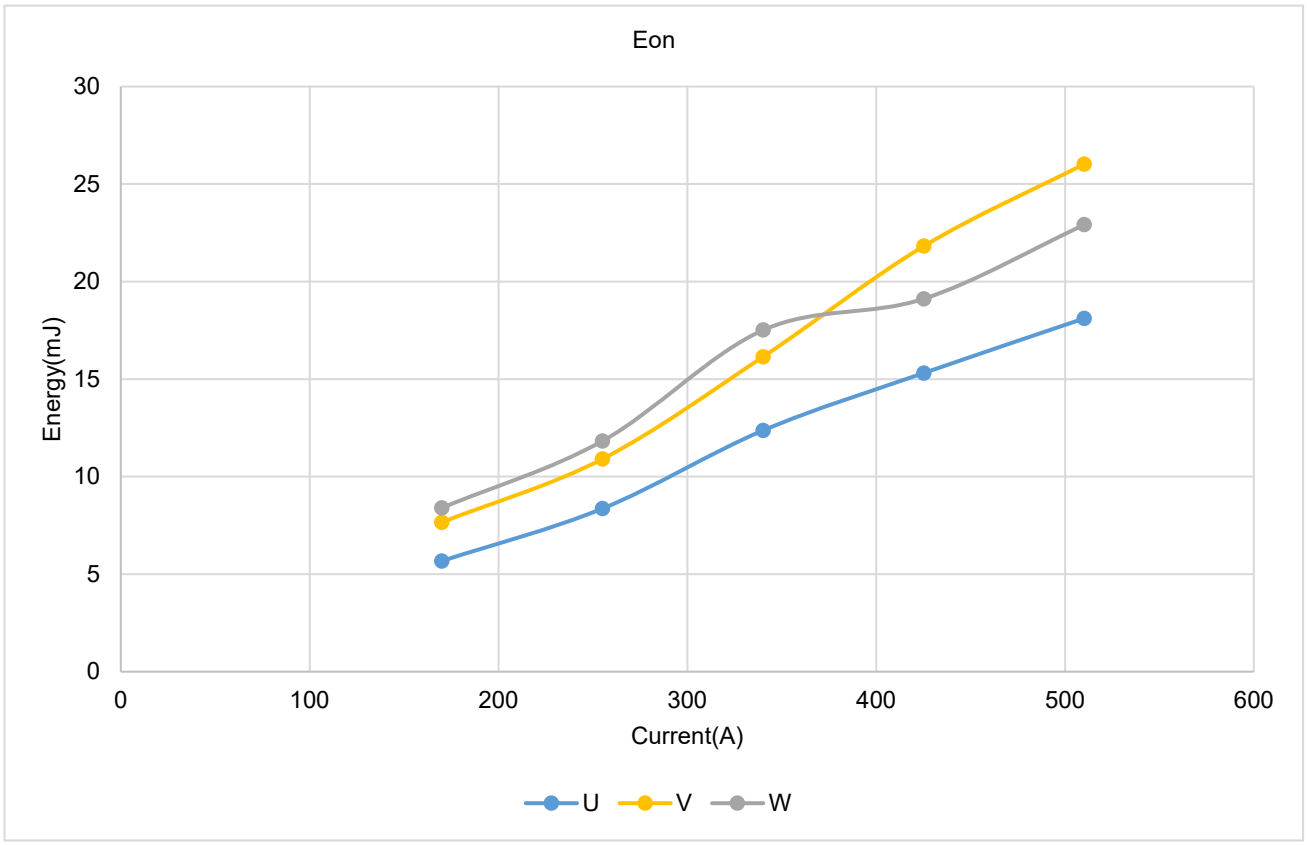


Figure 19. Turn on loss

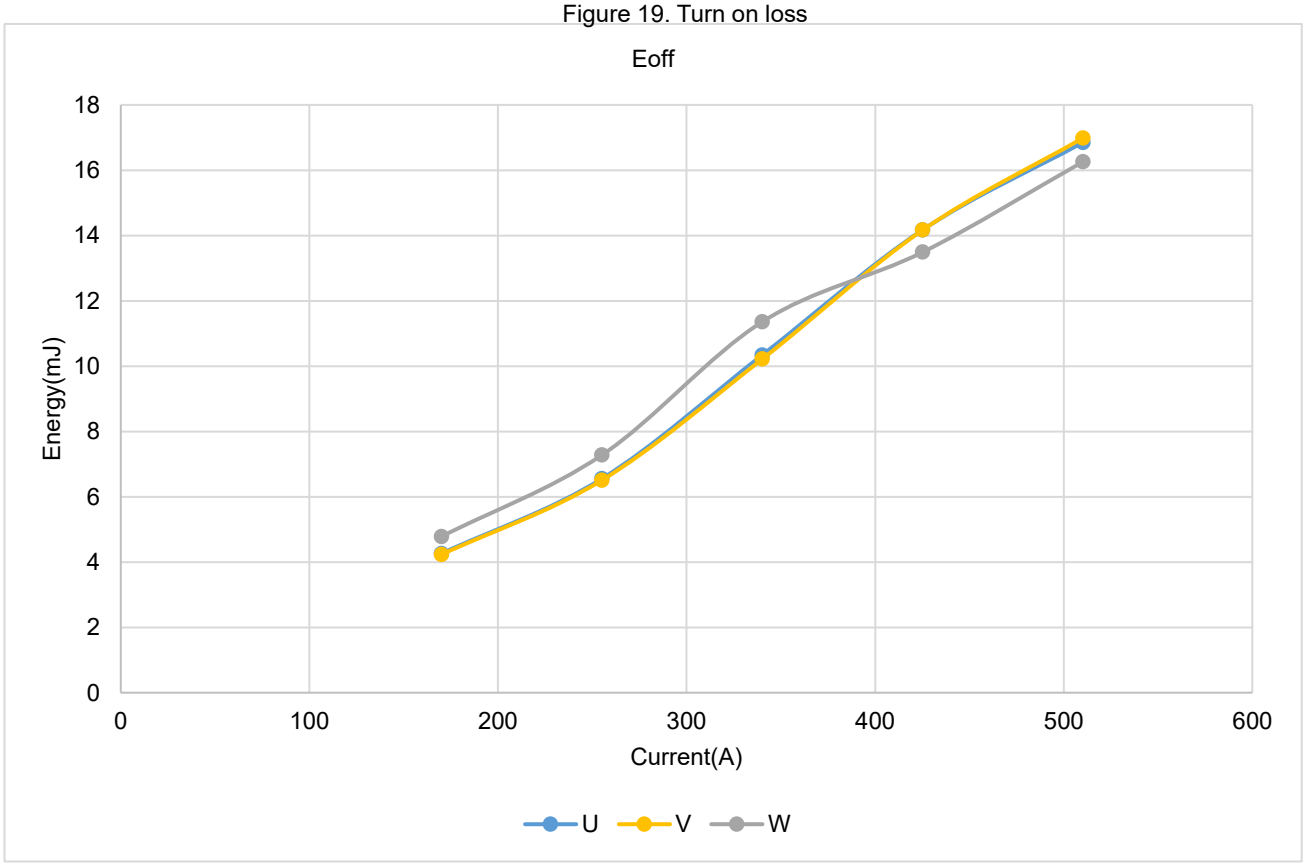


Figure 20. Turn off loss

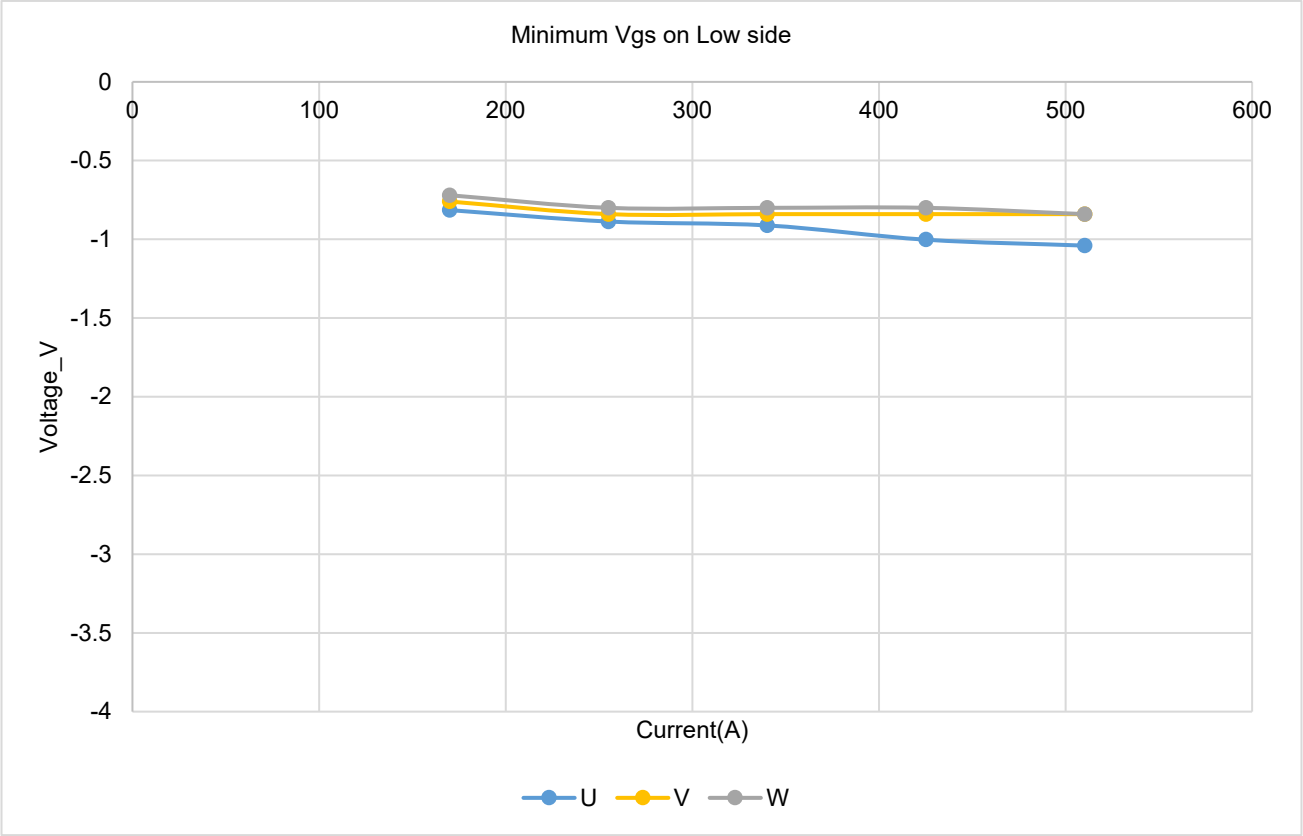


Figure 21. Minimum Vgs_L

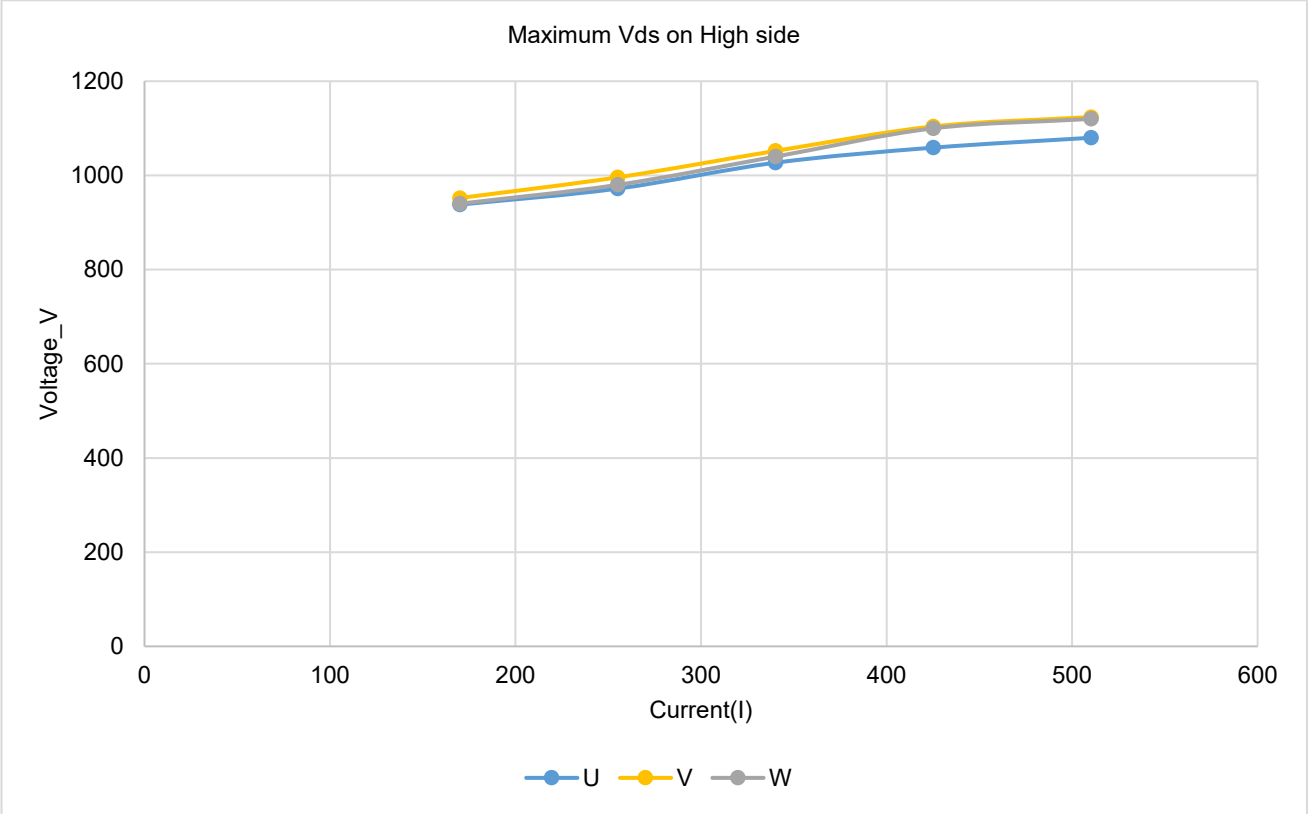


Figure 22. Maximum Vds

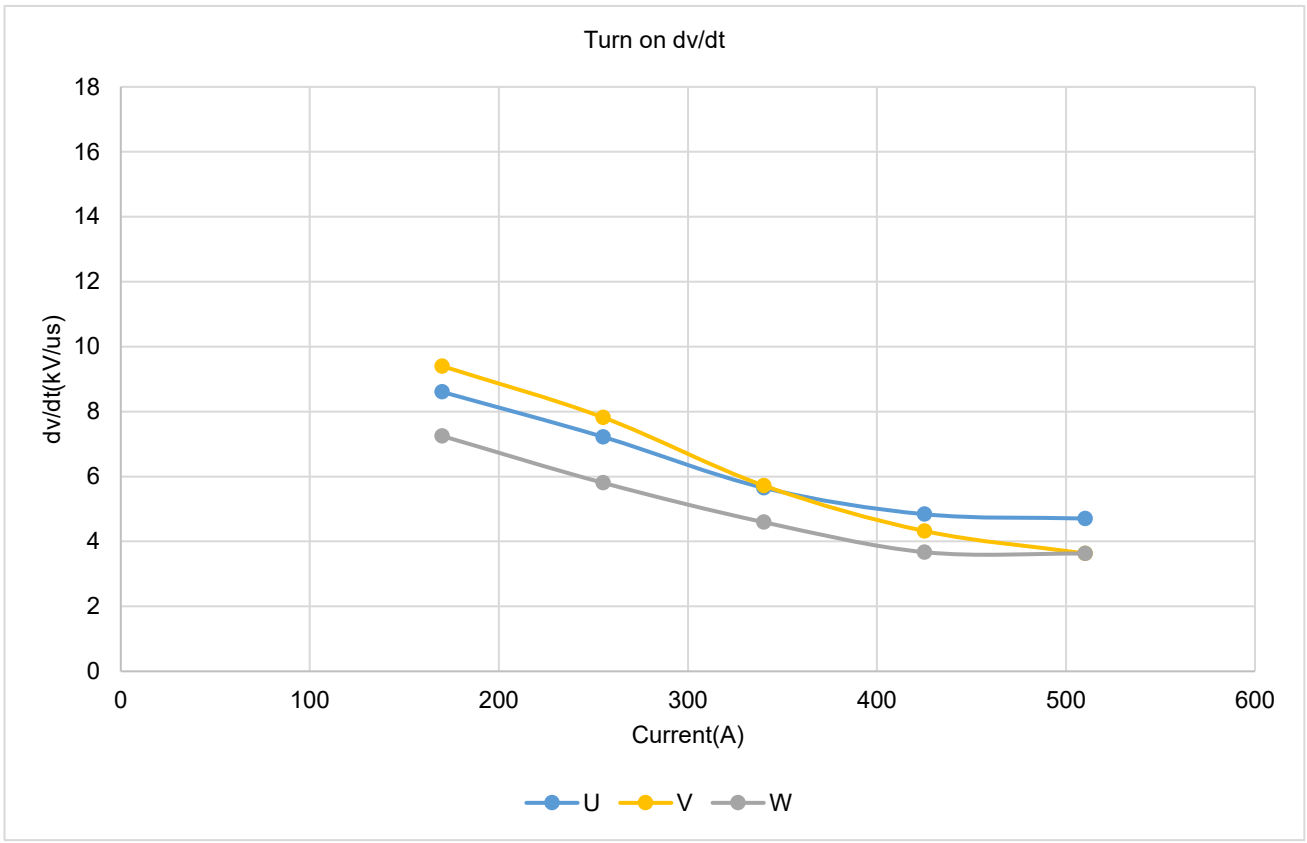


Figure 23. Turn on dv/dt

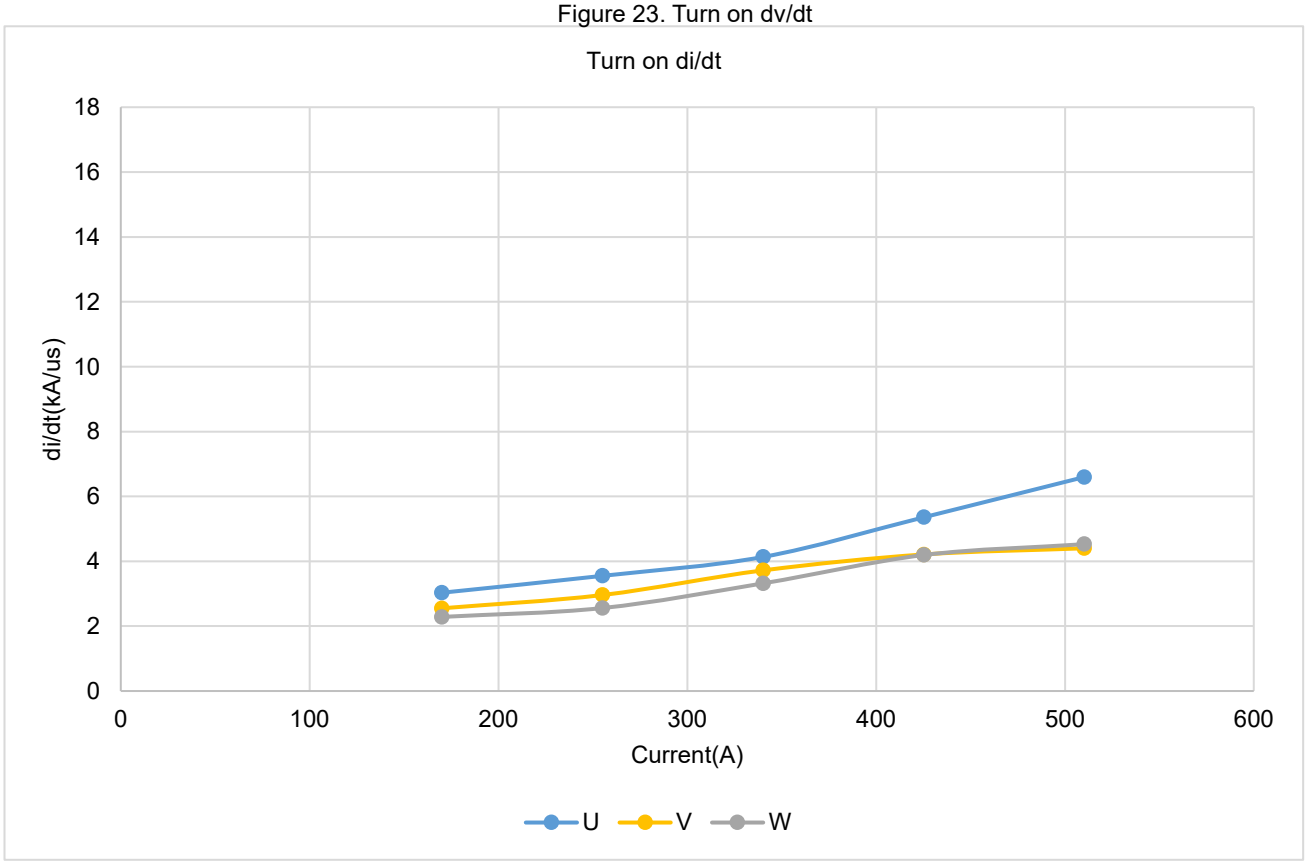


Figure 24. Turn on di/dt

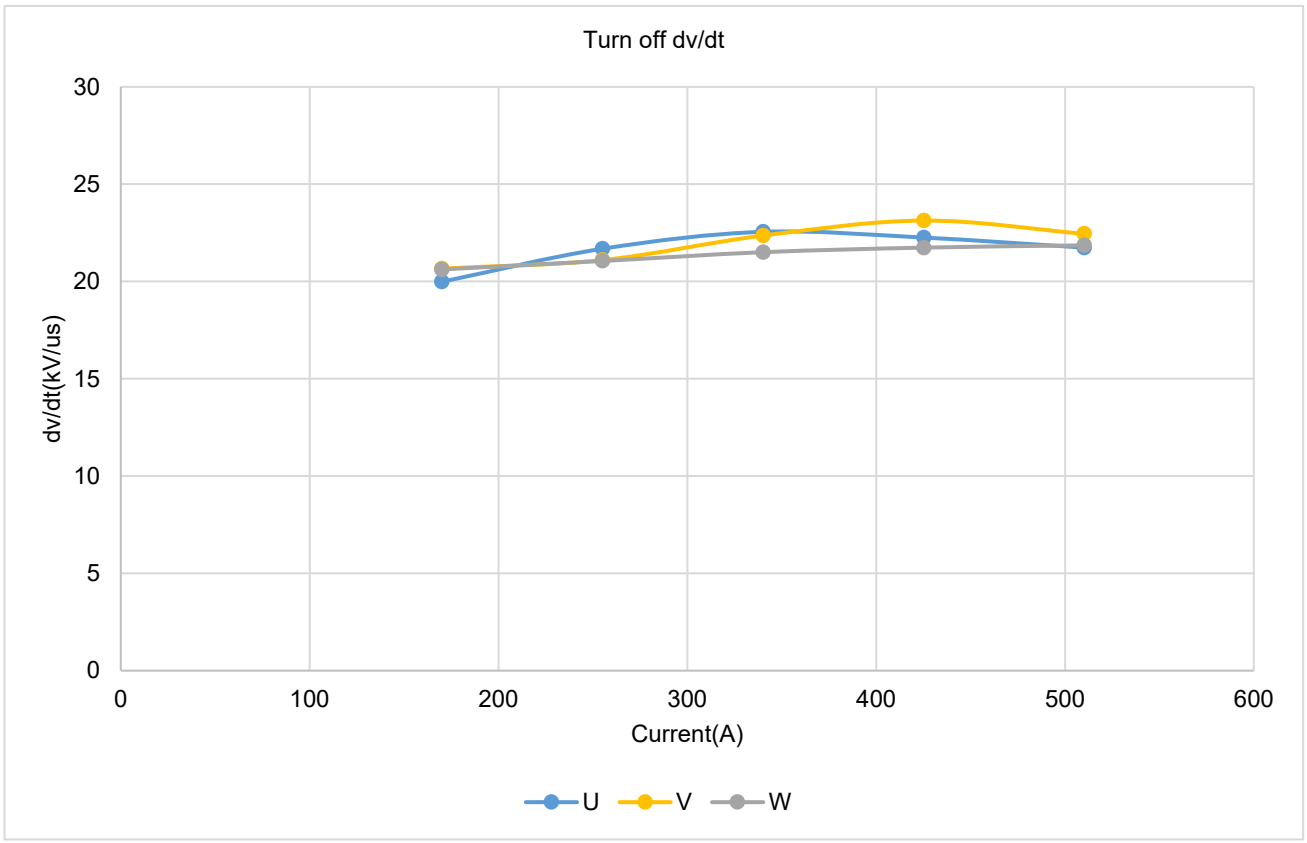


Figure 25. Turn off dv/dt

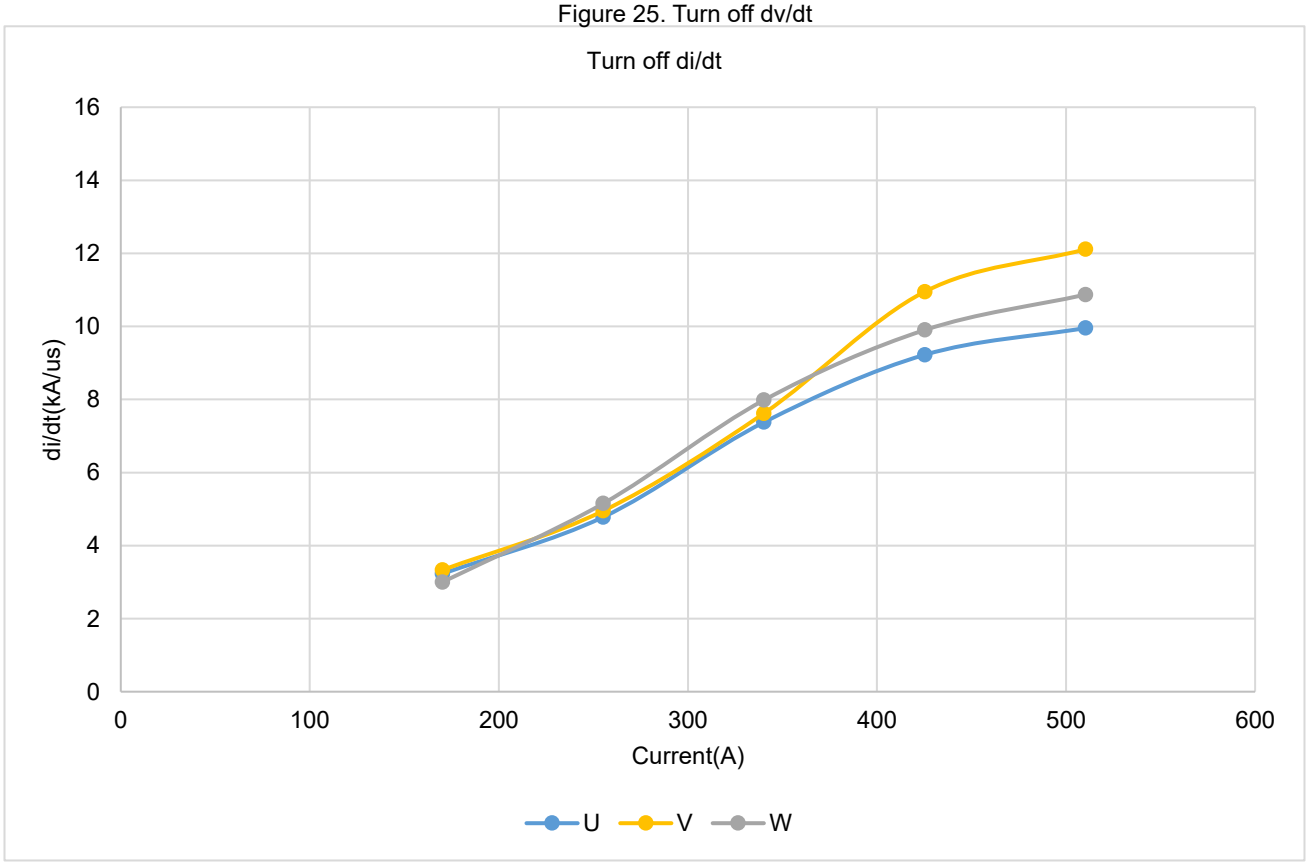


Figure 26. Turn off di/dt

9.1.3. Comparison of Various Gate Resistors

The following results show the difference between various gate resistors. In the gate driver circuit, there are 2 resistors in parallel for turn-on and turn-off, so the practical resistor value would be half of the resistor which are mounted.

Table 15. Turn on and turn off resistor values

	Gate Resistor(Ω) Default		Gate Resistor(Ω) 1 level down		Gate Resistor(Ω) 1 level up	
	Turn on	Turn off	Turn on	Turn off	Turn on	Turn off
Resistor Value(Ω)	13	5.6	3.3	4.7	18	6.8
Practical Value(Ω) (2 parallel)	6.5	2.8	1.65	2.35	9	3.4

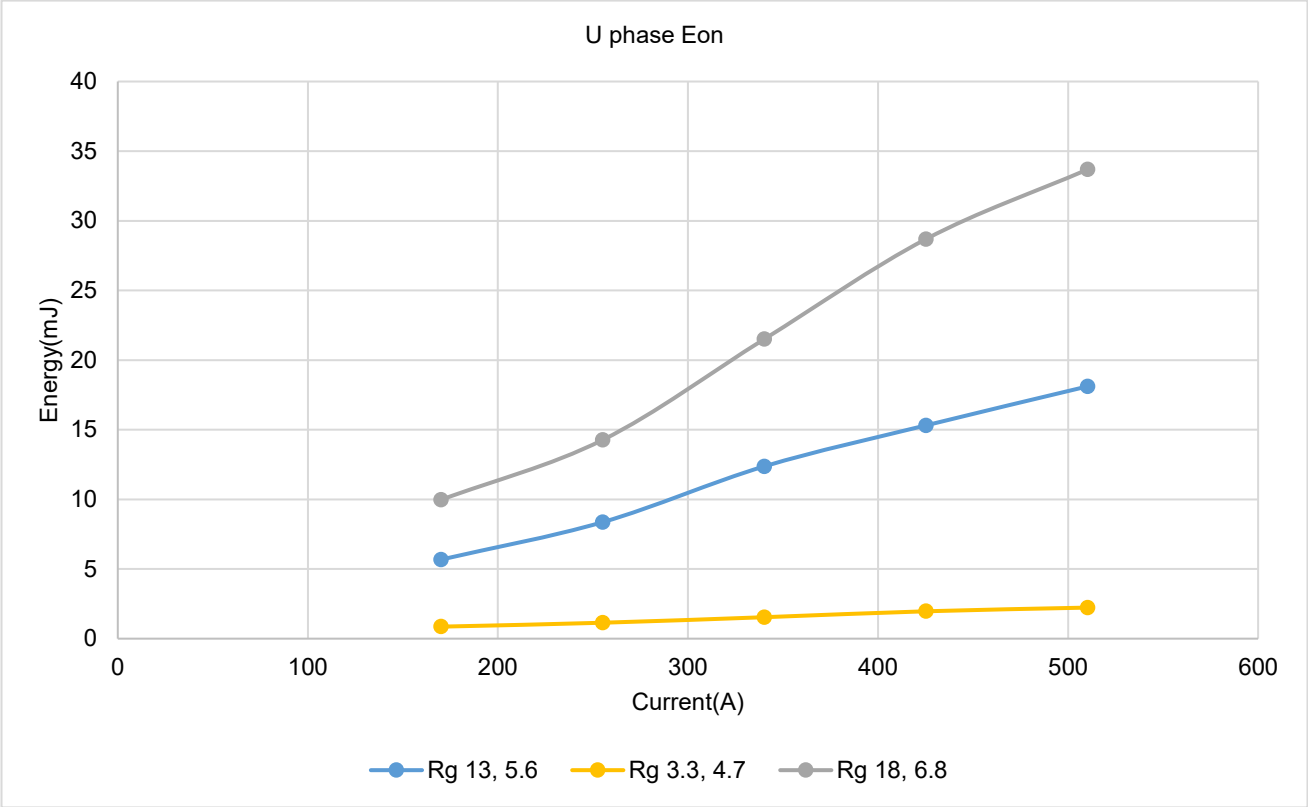


Figure 27. U phase turn on loss

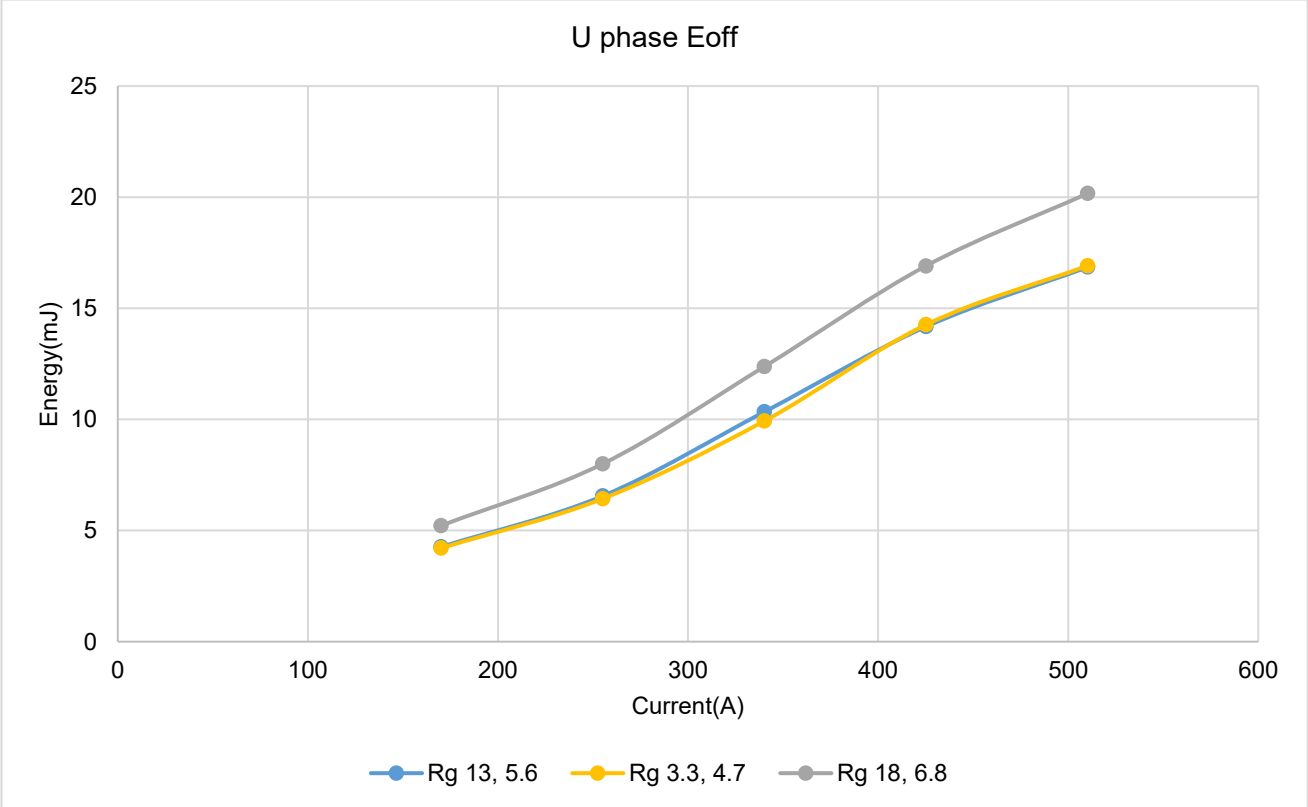


Figure 28. U phase turn off loss

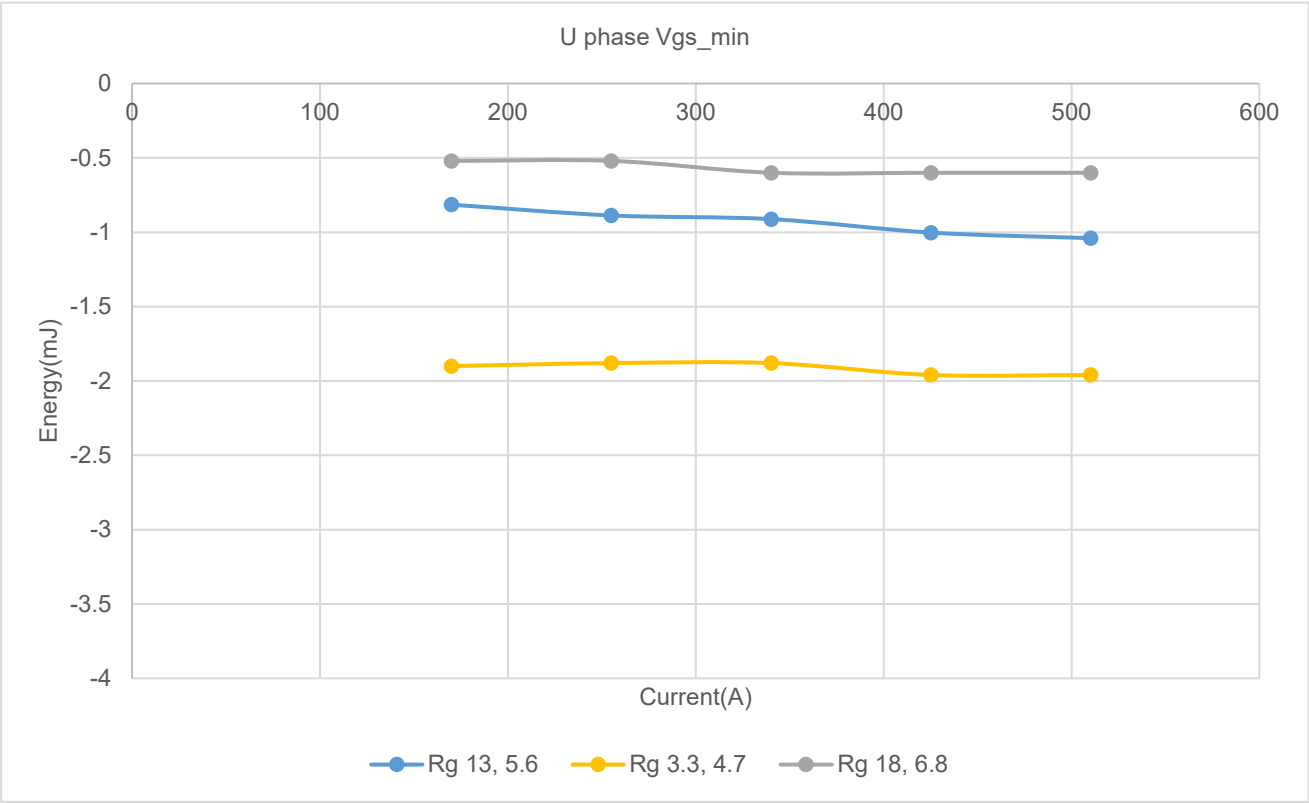


Figure 29. U phase Minimum Vgs_L

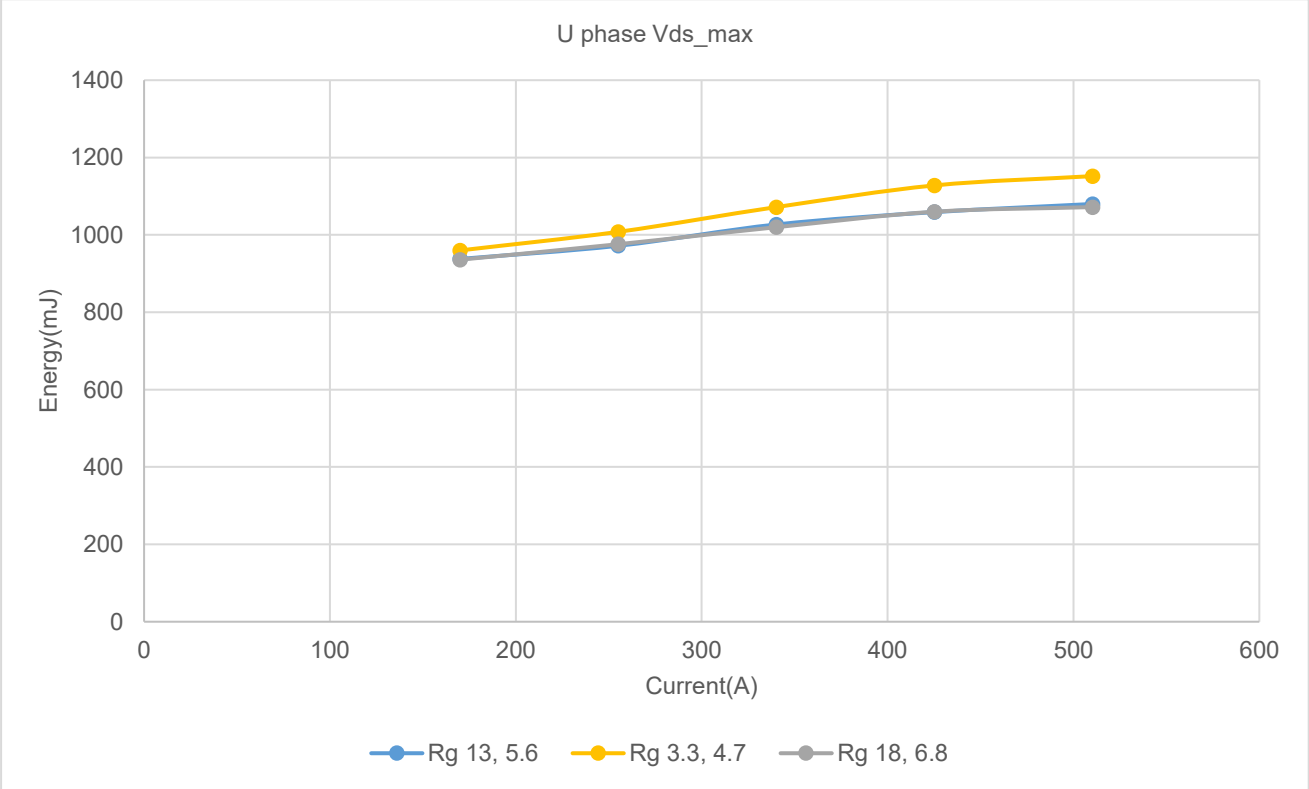


Figure 30. U phase Maximum Vds

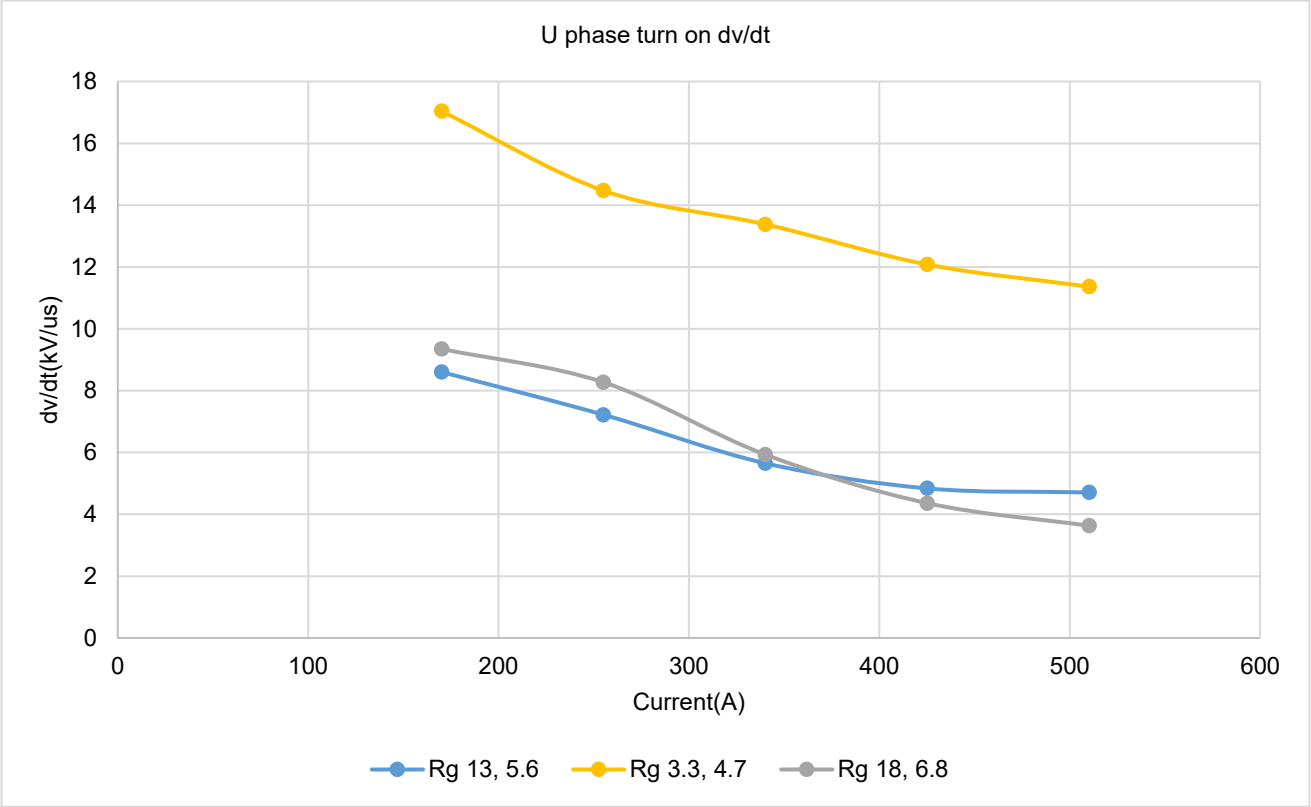


Figure 31. U phase turn on dv/dt

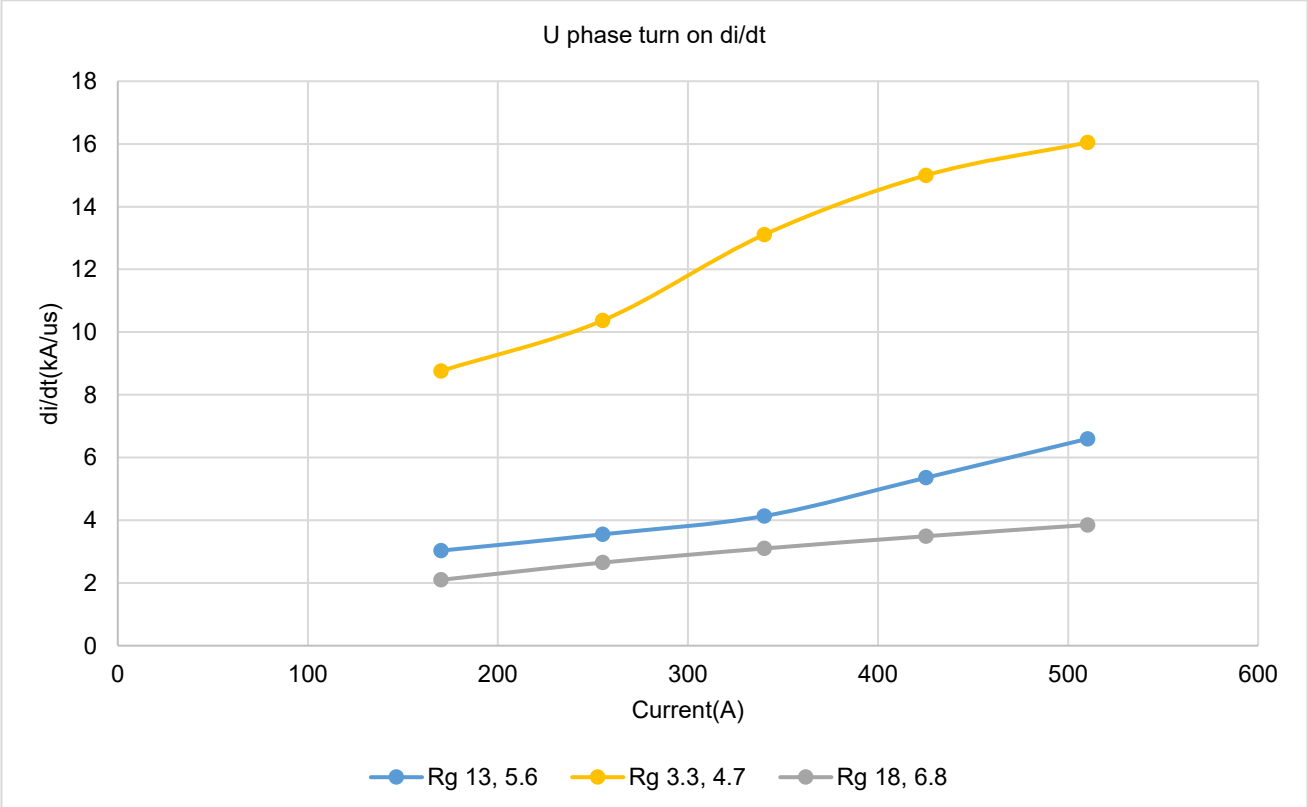


Figure 32. U phase turn on di/dt

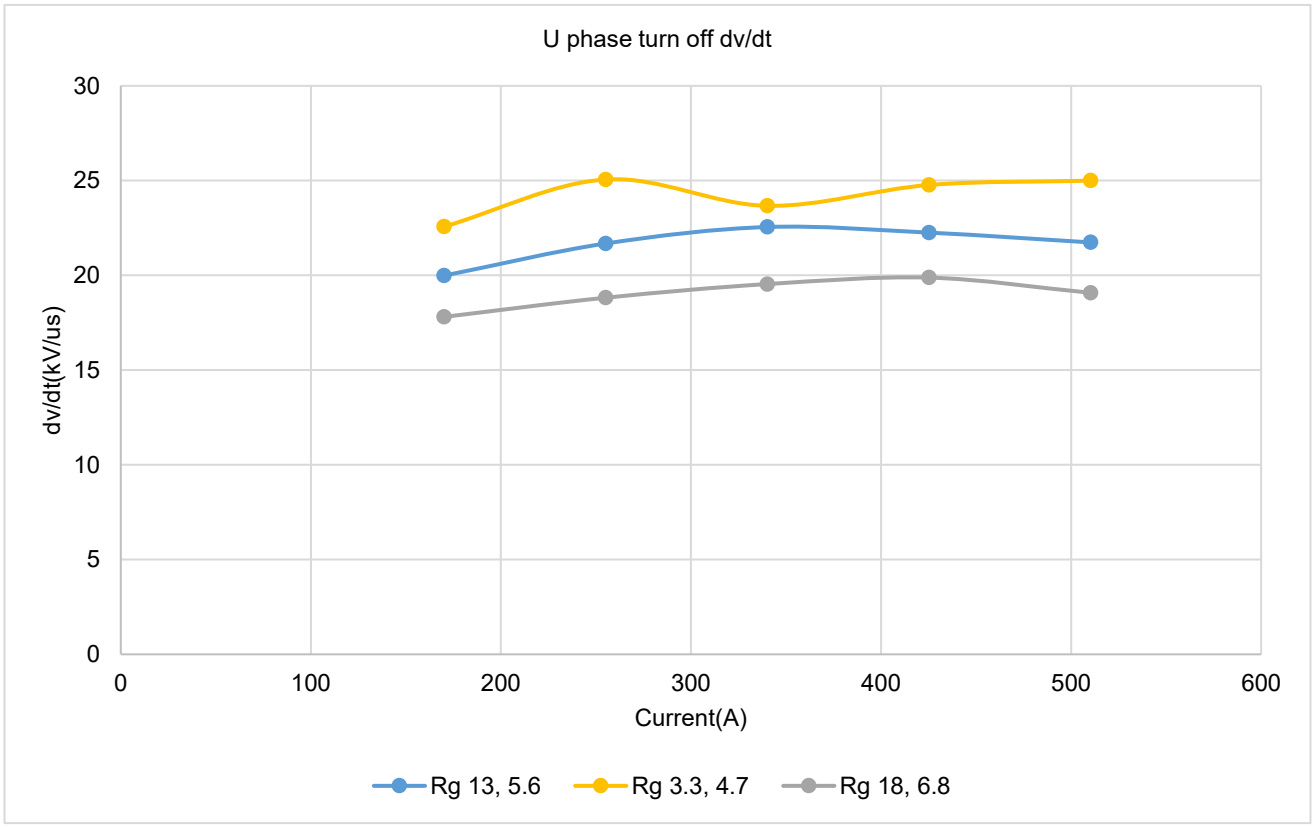


Figure 33. U phase turn off dv/dt

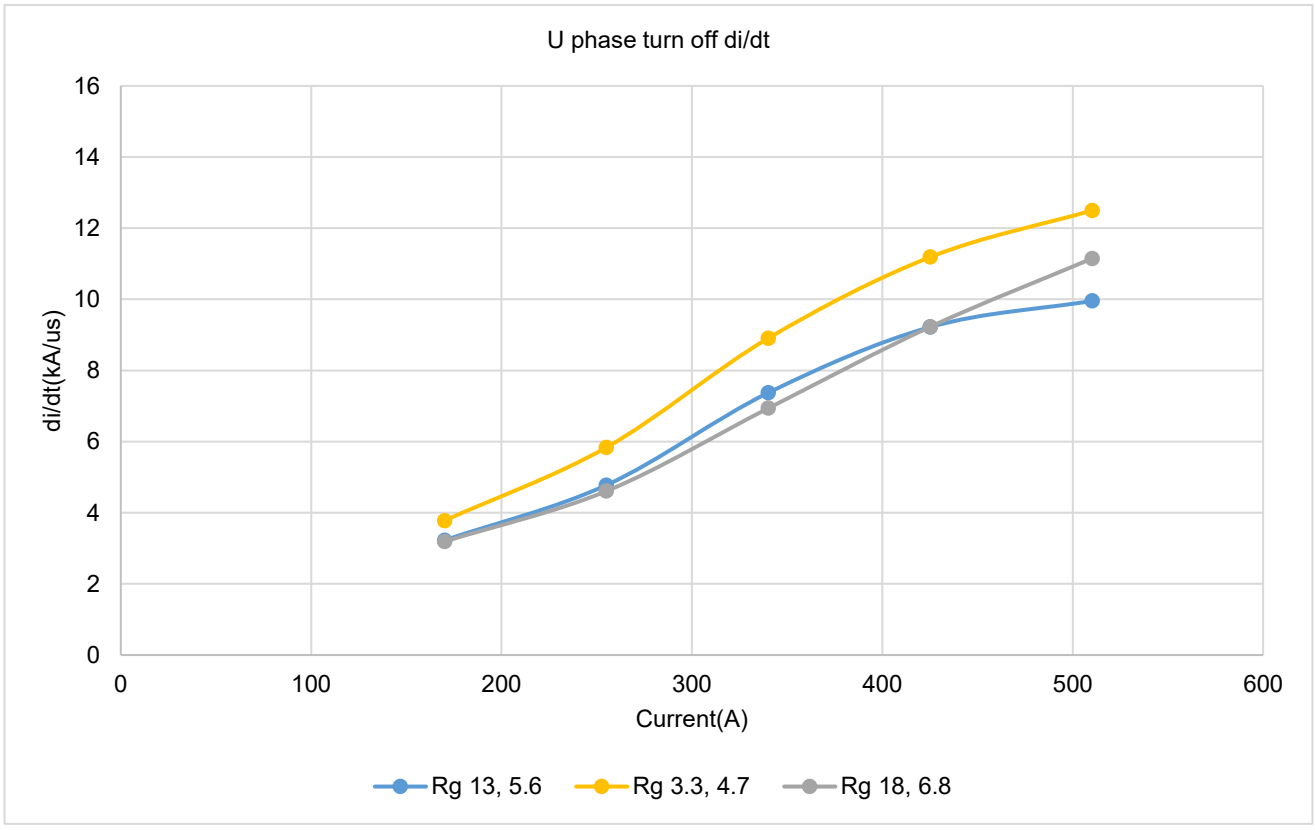


Figure 34. U phase turn off di/dt

9.2. Motor Bench Test

The EVK is evaluated with IPMSM (Interior permanent magnet synchronous motor) as a traction inverter. The test specification is shown in Table 15. Figure 35 shows the wiring of the motor bench test. Figure 36 is the connection of the motor bench test.

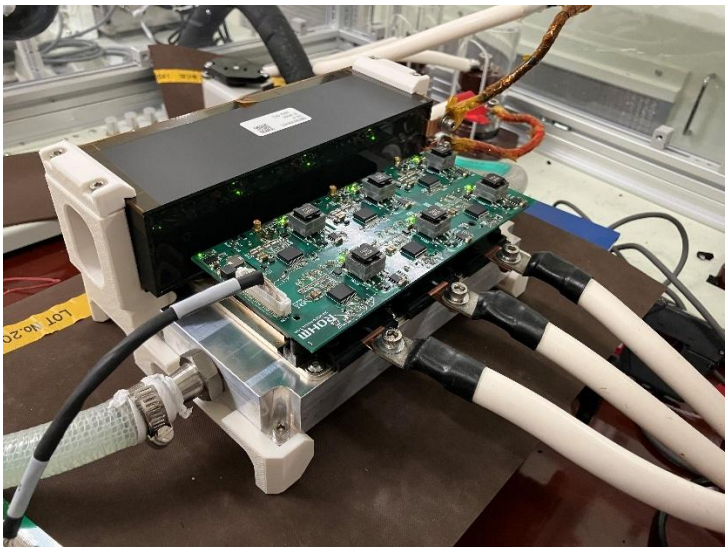


Figure 35. EVK in motor bench

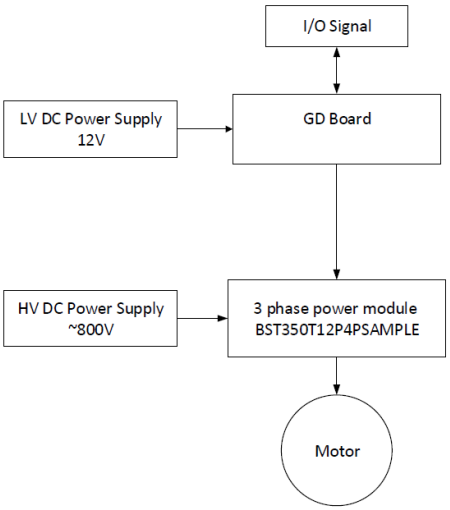


Figure 36 Motor bench Connection

9.2.1. Test Specification

The test condition is as below in table 16

Table 16. test conditions

	Value and unit	Remarks
Input DC Voltage	800V	
Input Capacitor	500μF	
Phase current	200Arms	
Output frequency	200Hz	
Carrier frequency	20kHz	
Current phase degree	20 degree	Fixed value
Dead time	3 μs	
Motor type	IPMSM	Motion System Tech
Motor Pole	4	
Motor Maximum output power	100kW	
Power module	BST350T12P4PSAMPLE	TRCDRIVE pack™ BSTP
Practical gate resistor value	Ron: 6.5 Ω Roff: 2.8 Ω	The component is Ron 13 Ω, Roff is 5.6 Ω.
Inverter liquid cooling speed	12 L/min	

9.2.2. Test waveform and result

The result is shown in the table 19, figure 37 and figure 38.

Table 17. Input and output power

	Power
Inverter input power	81kW
Inverter output power	80kW
Motor output power	74kW

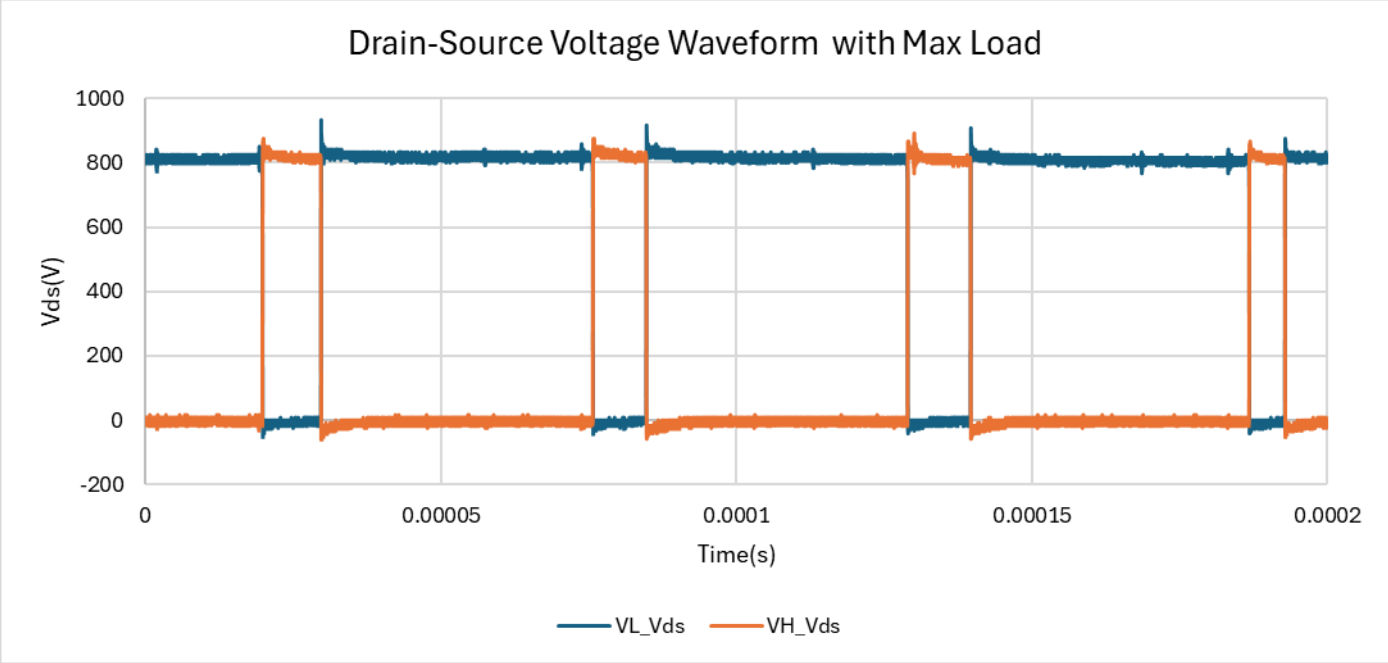


Figure 37. V side Vds

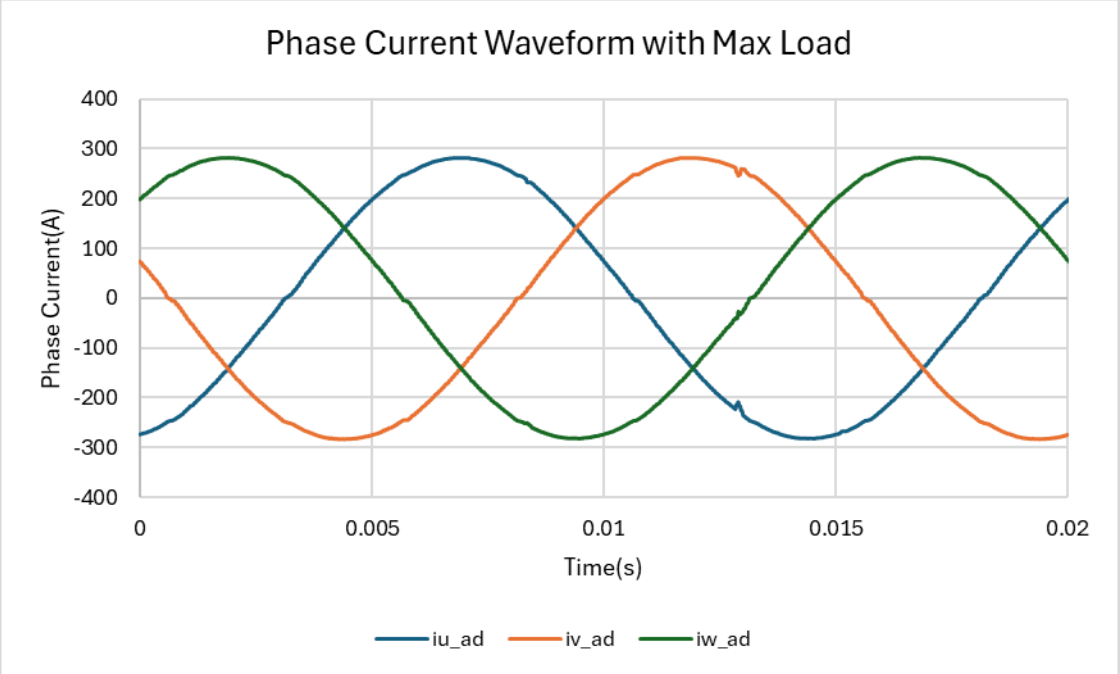


Figure 38. phase current

10. Circuit

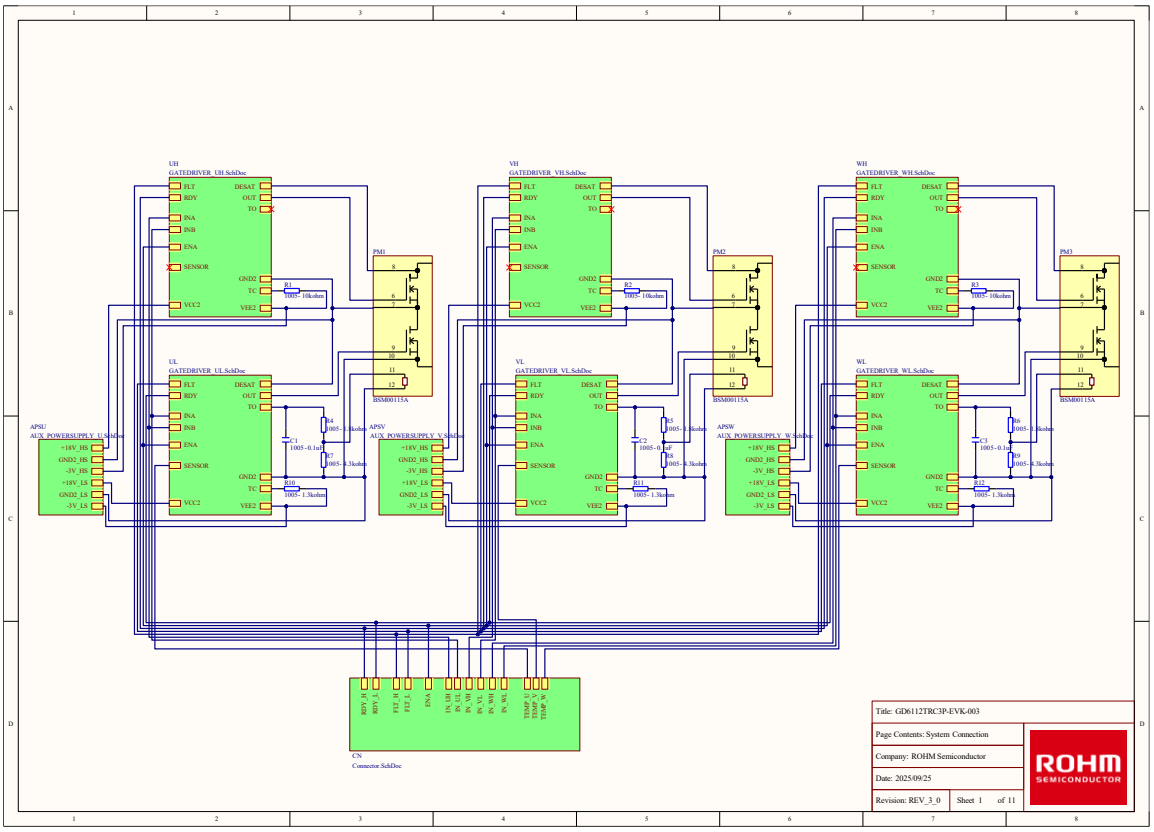


Figure 39. Page1, system connection

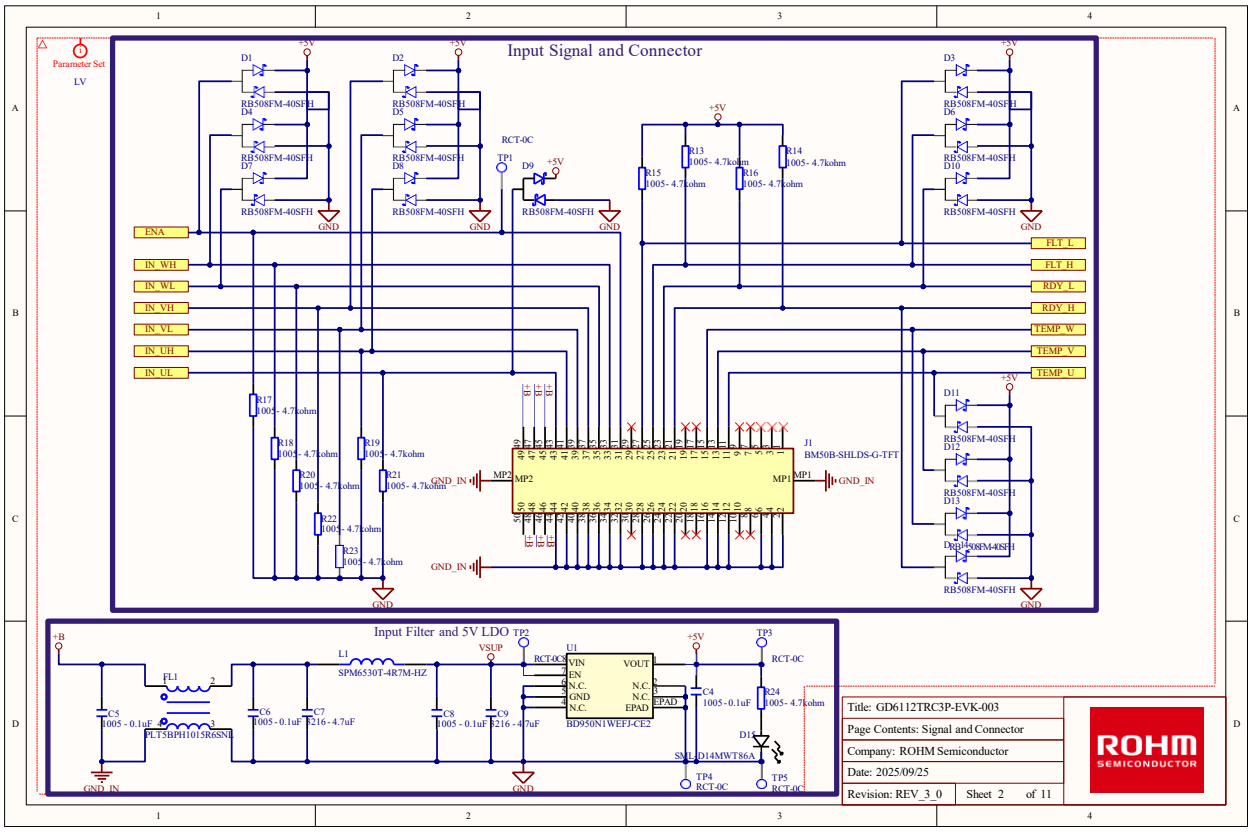


Figure 40. Page2, Signal and Connector

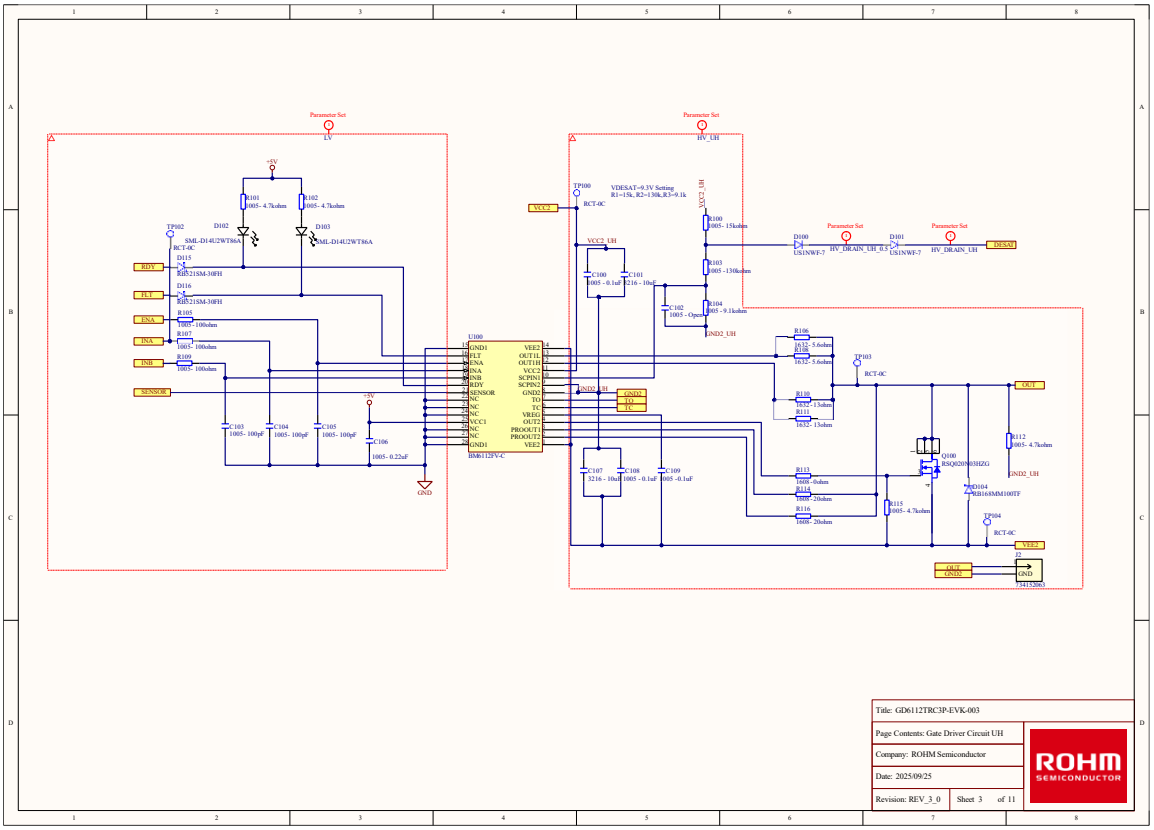


Figure 41. Page3, Gate Driver Circuit UH

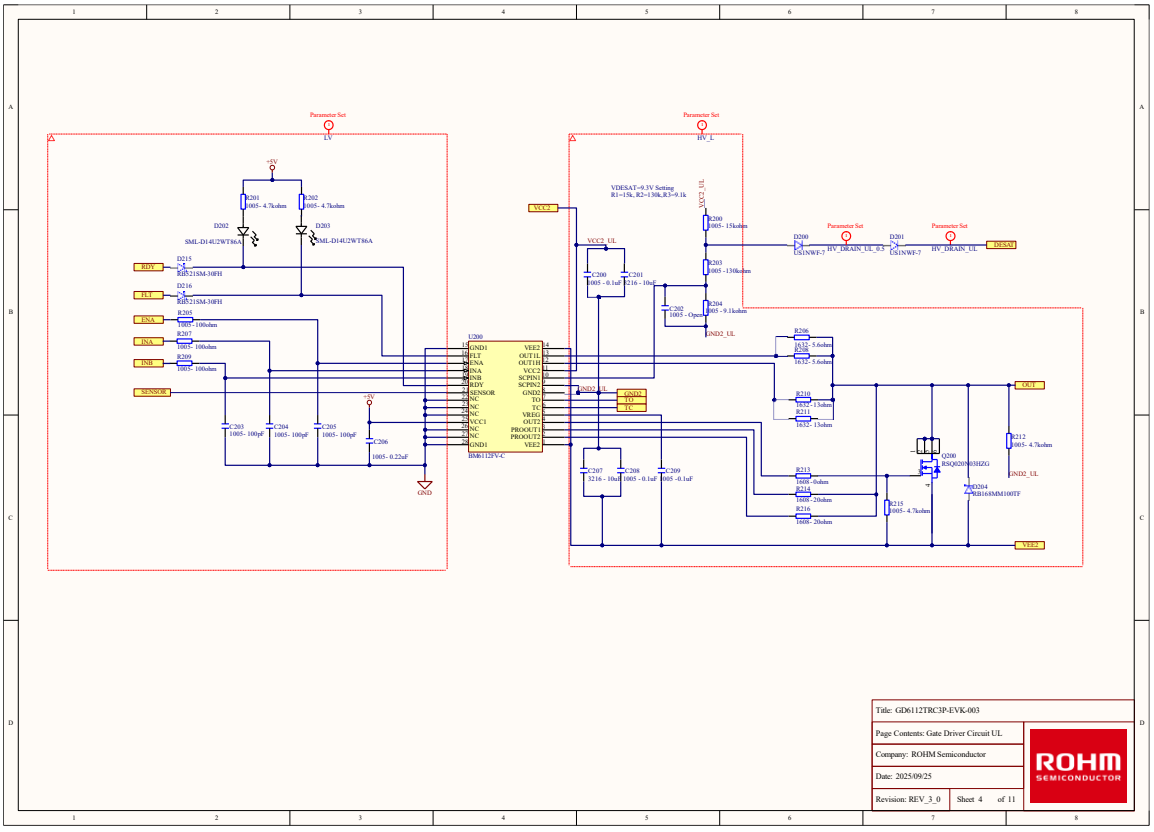


Figure 42. Page4, Gate Driver Circuit UL

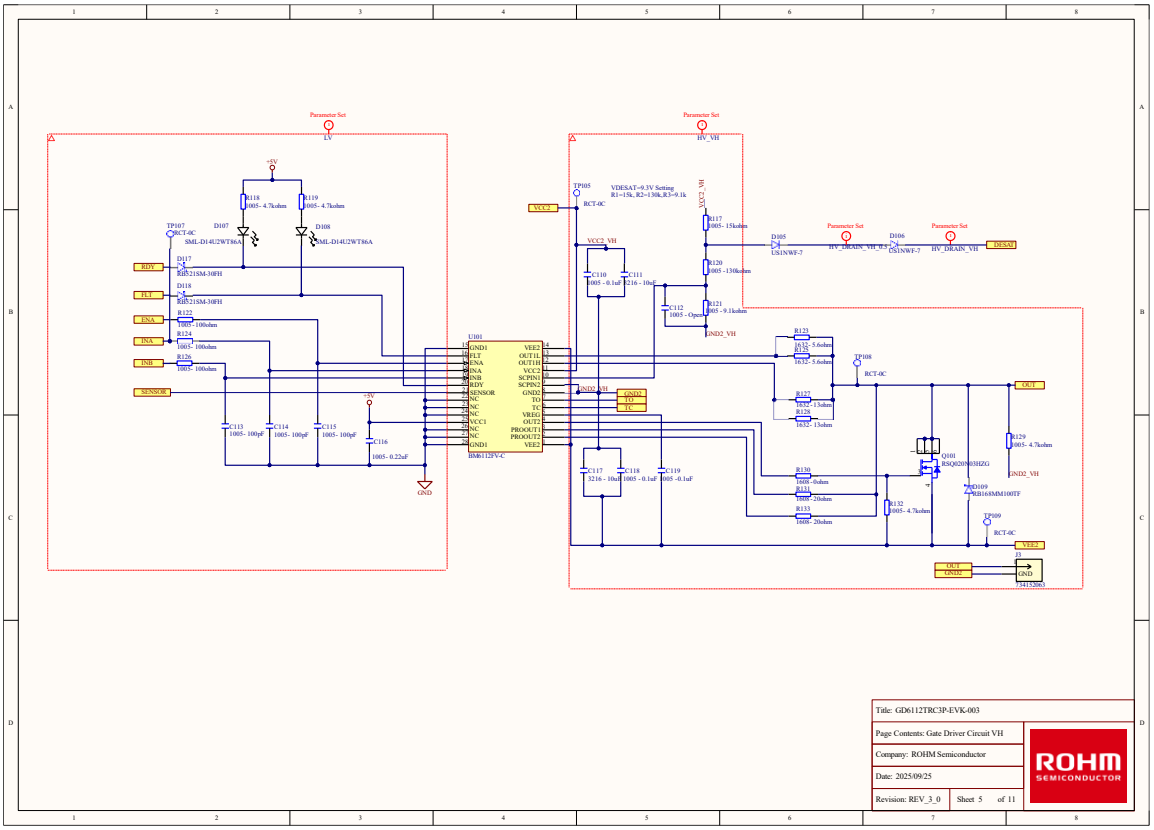


Figure 43. Page5, Gate Driver Circuit VH

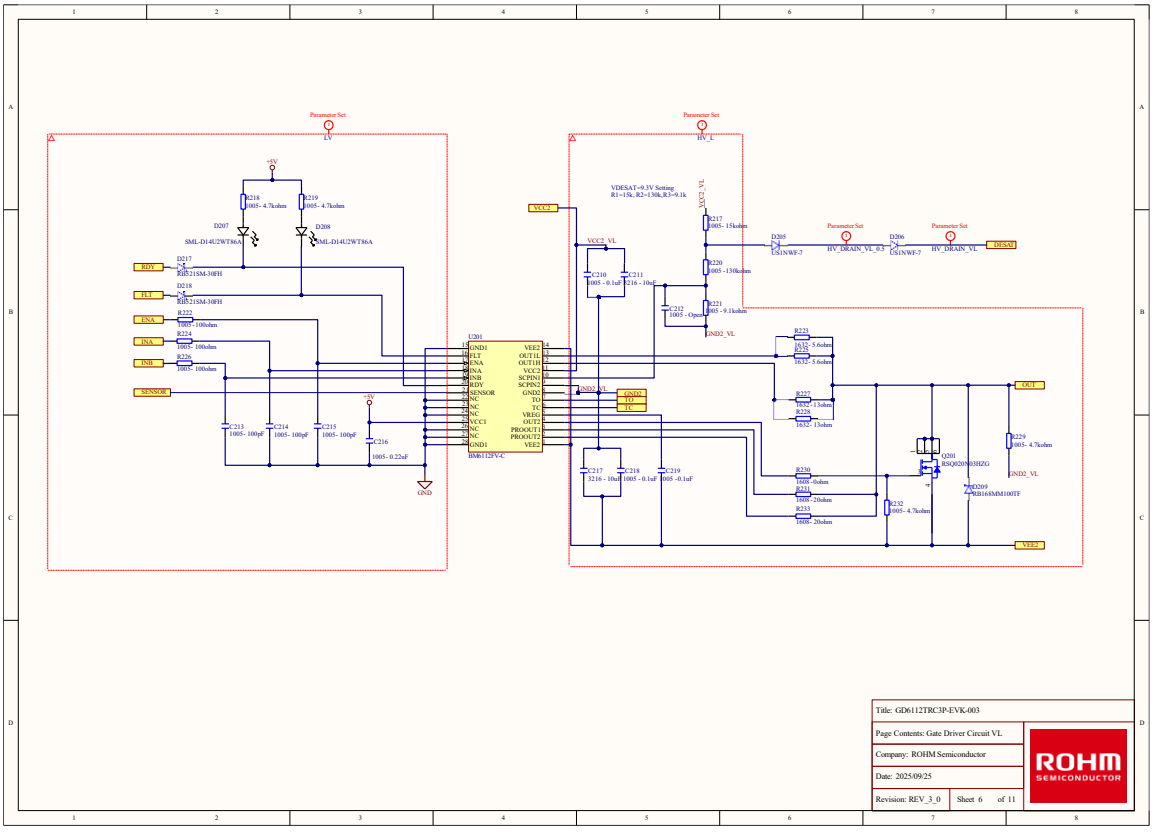


Figure 44. Page6, Gate Driver Circuit VL

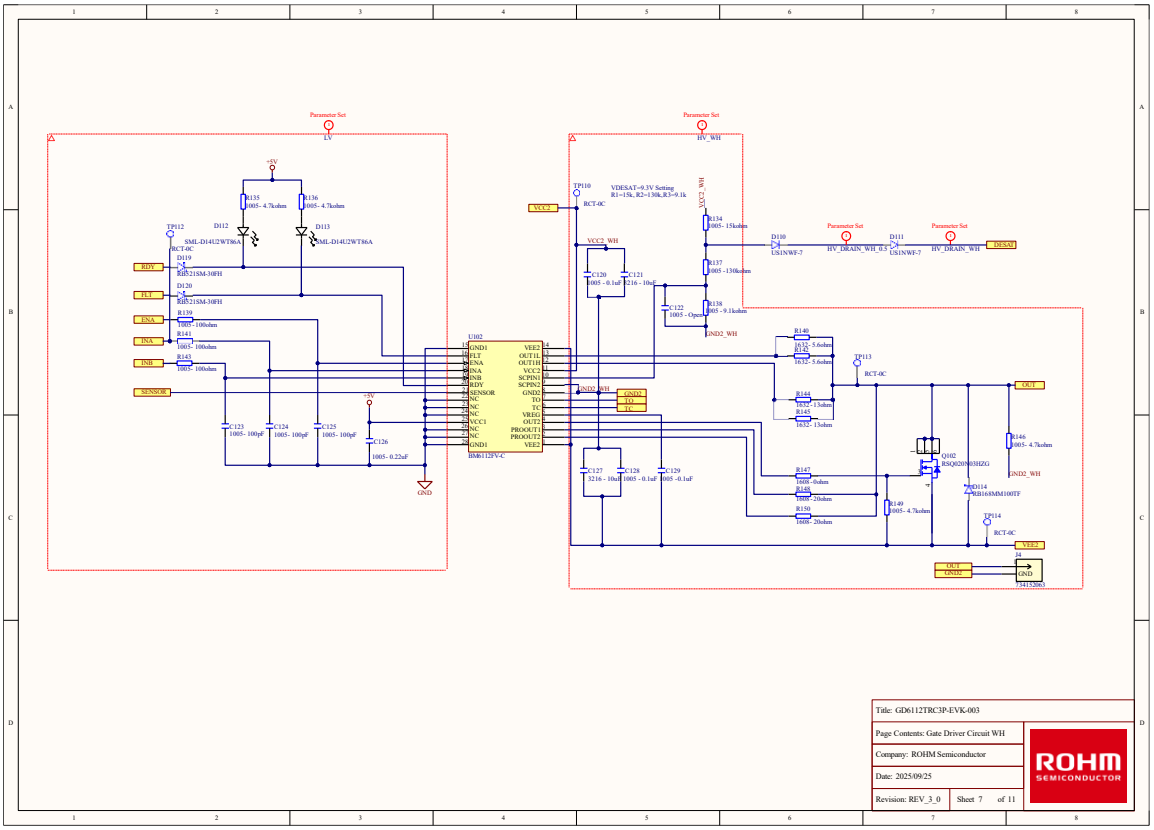


Figure 45. Page7, Gate Driver Circuit WH

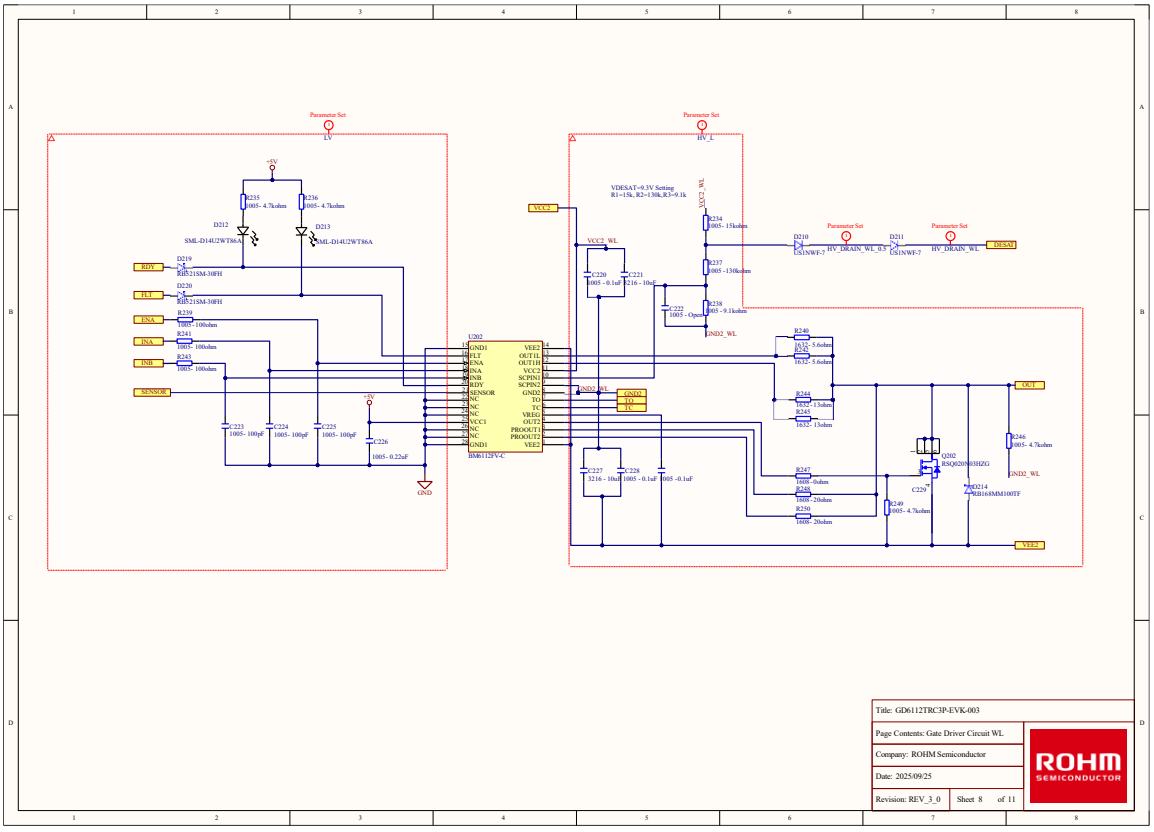


Figure 46. Page8, Gate Driver Circuit WL

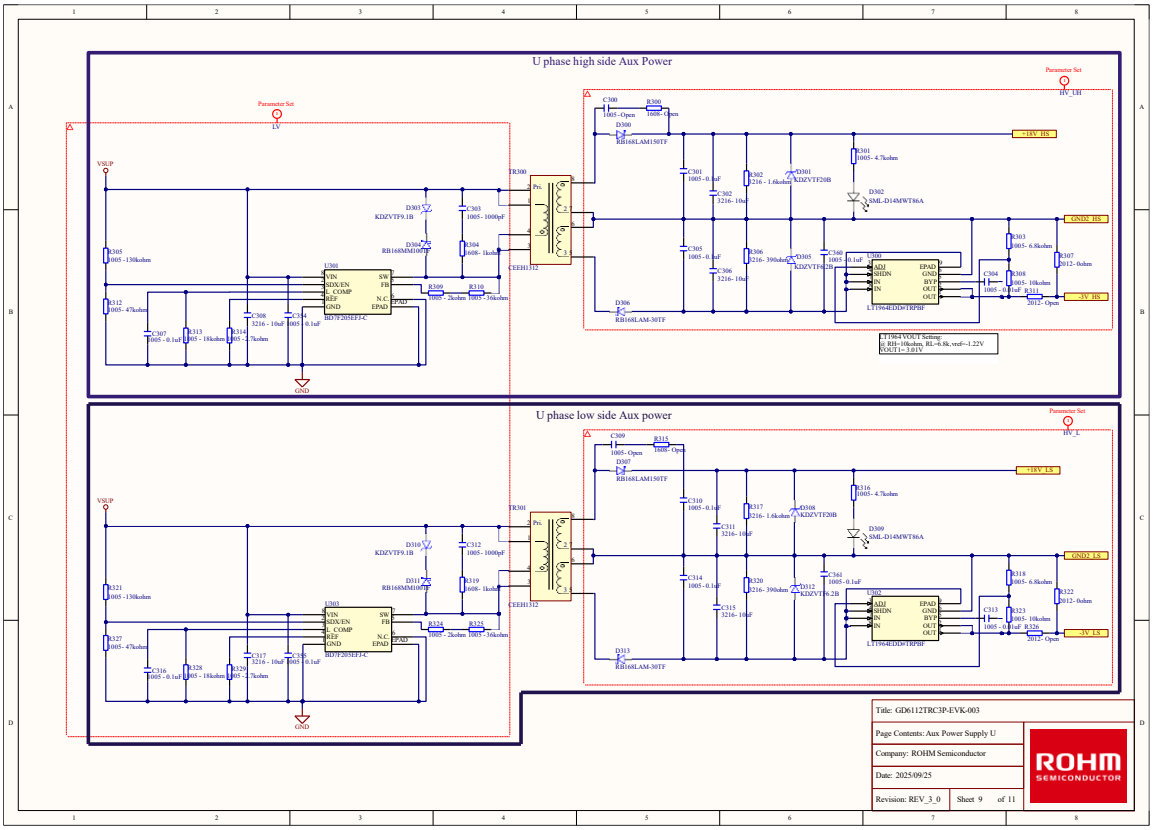


Figure 47. Aux power U

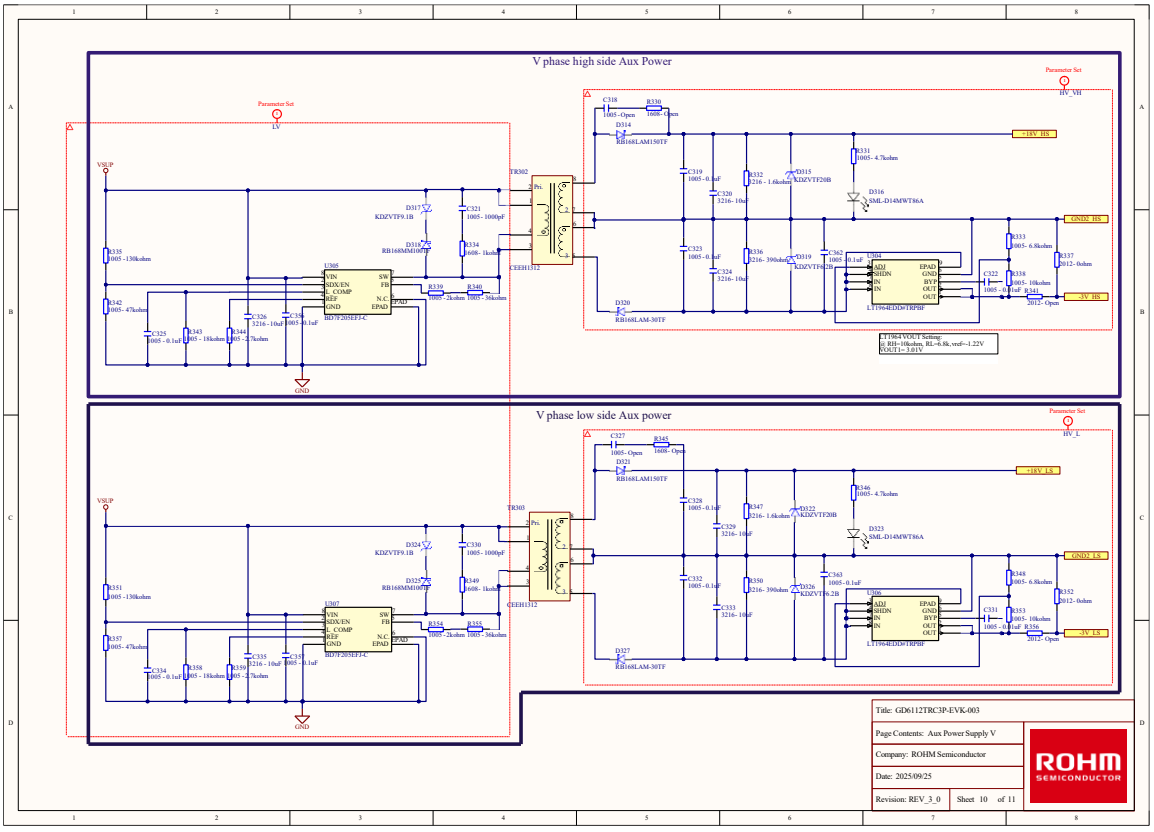


Figure 48. Aux power V

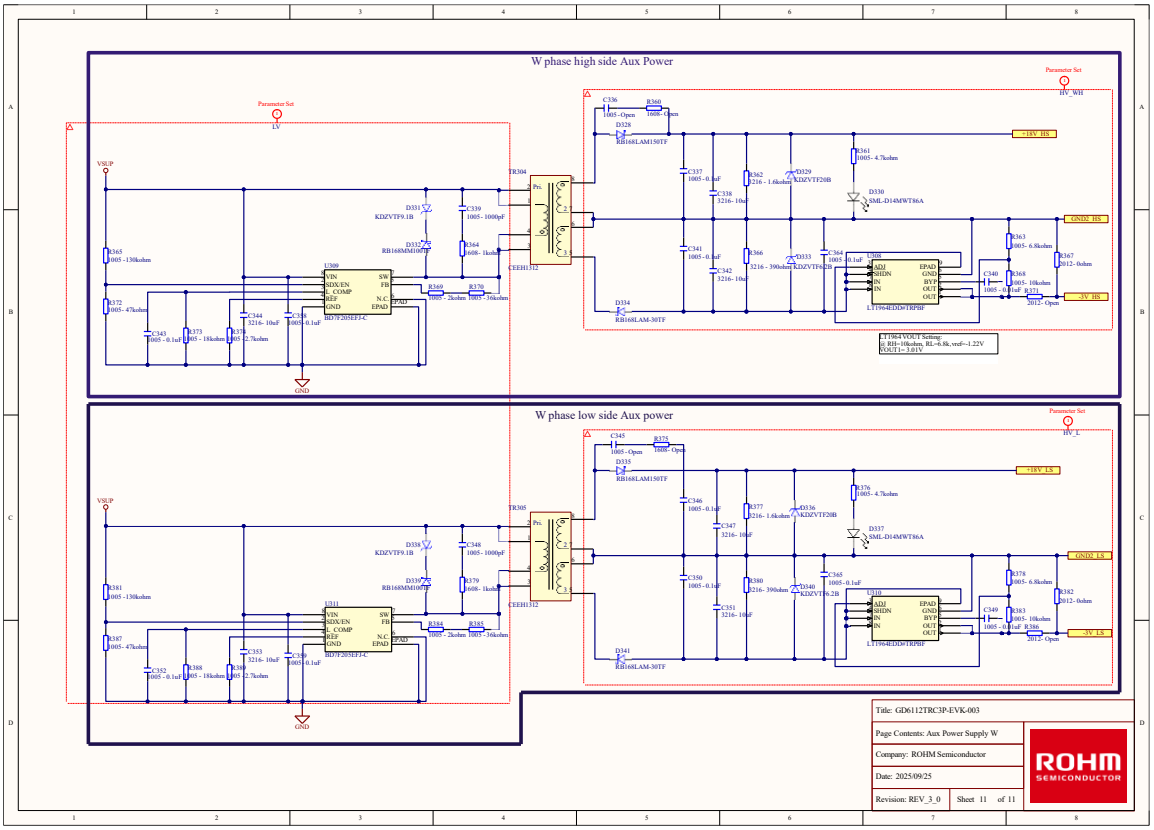


Figure 49. Aux power W

11. Layout

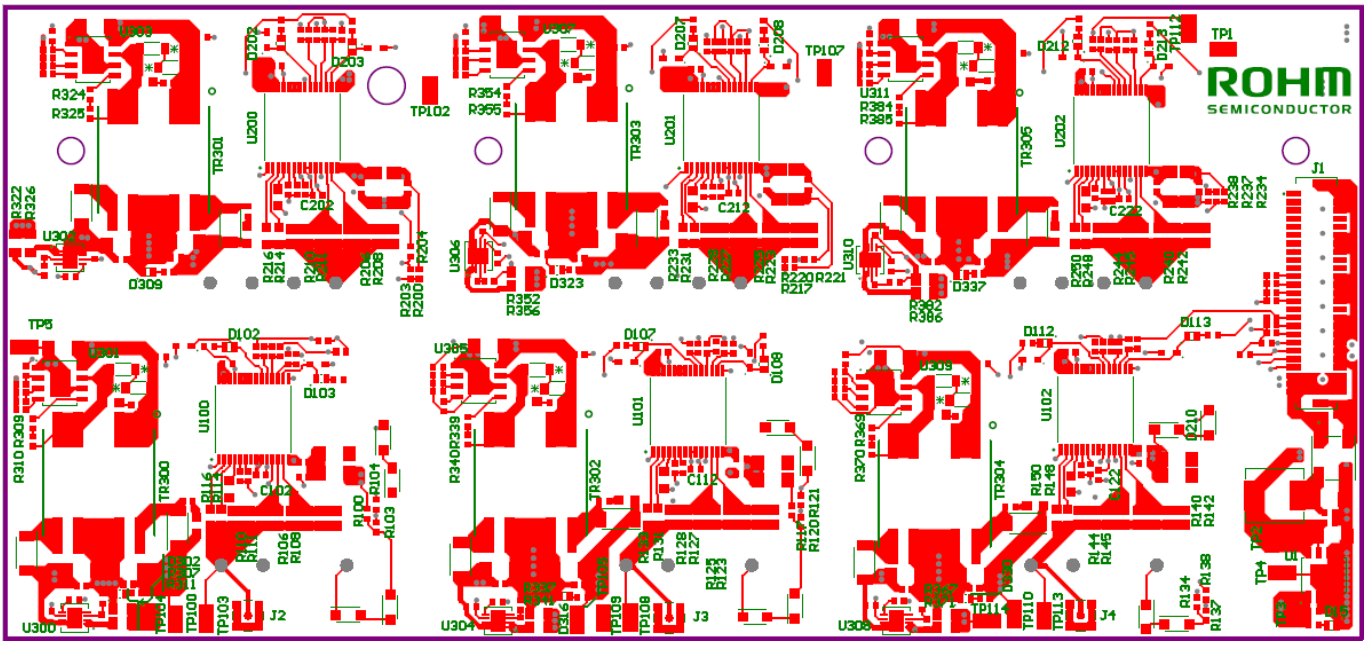


Figure 50. Top Layer (top view)

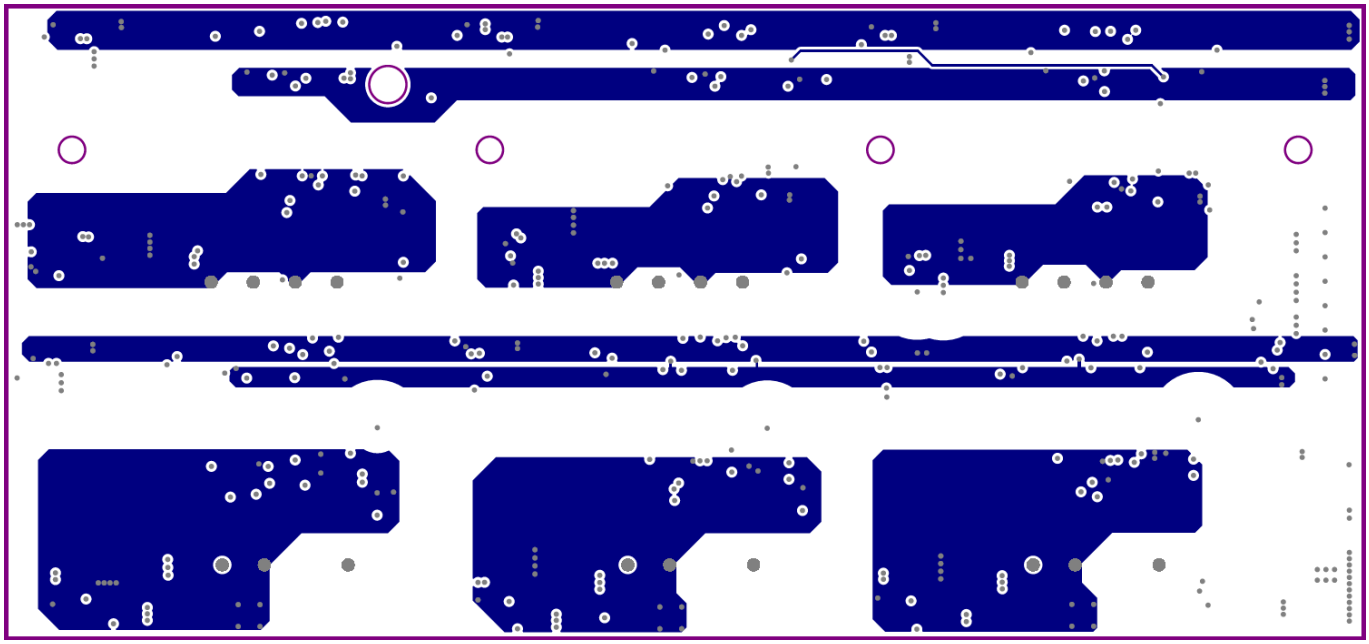


Figure 51. 2nd Layer (top view)

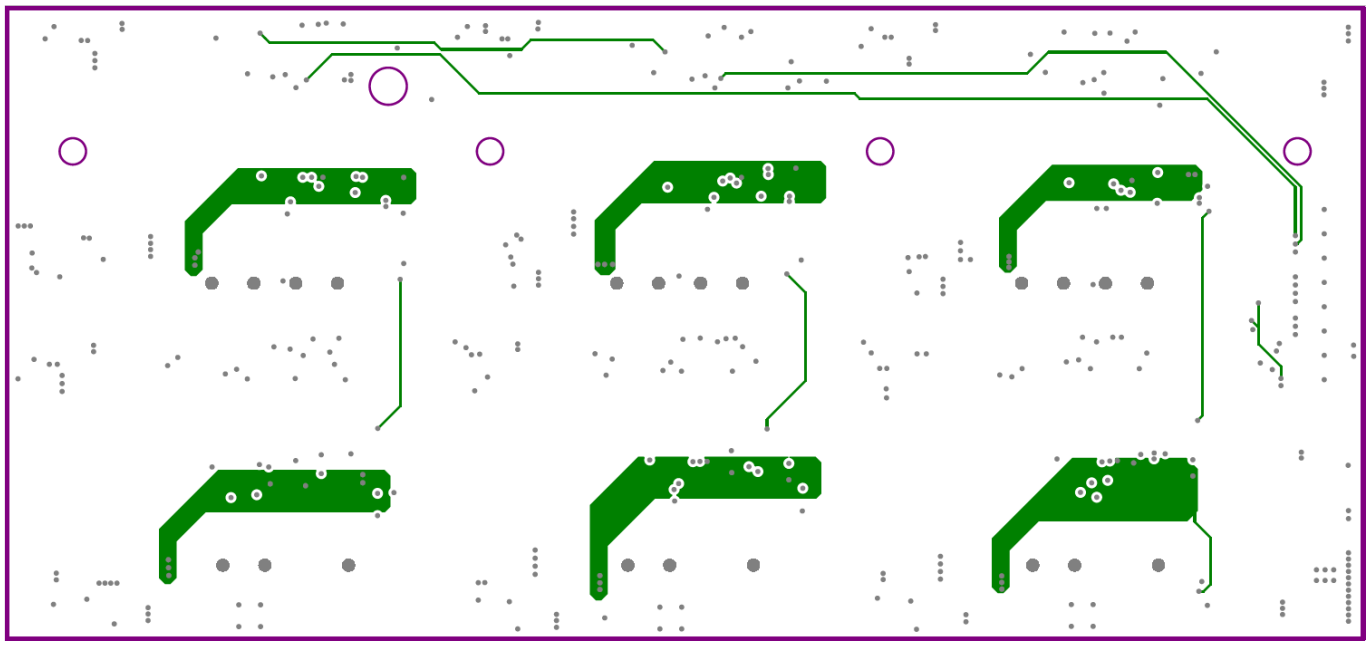


Figure 52. 3rd Layer (top view)

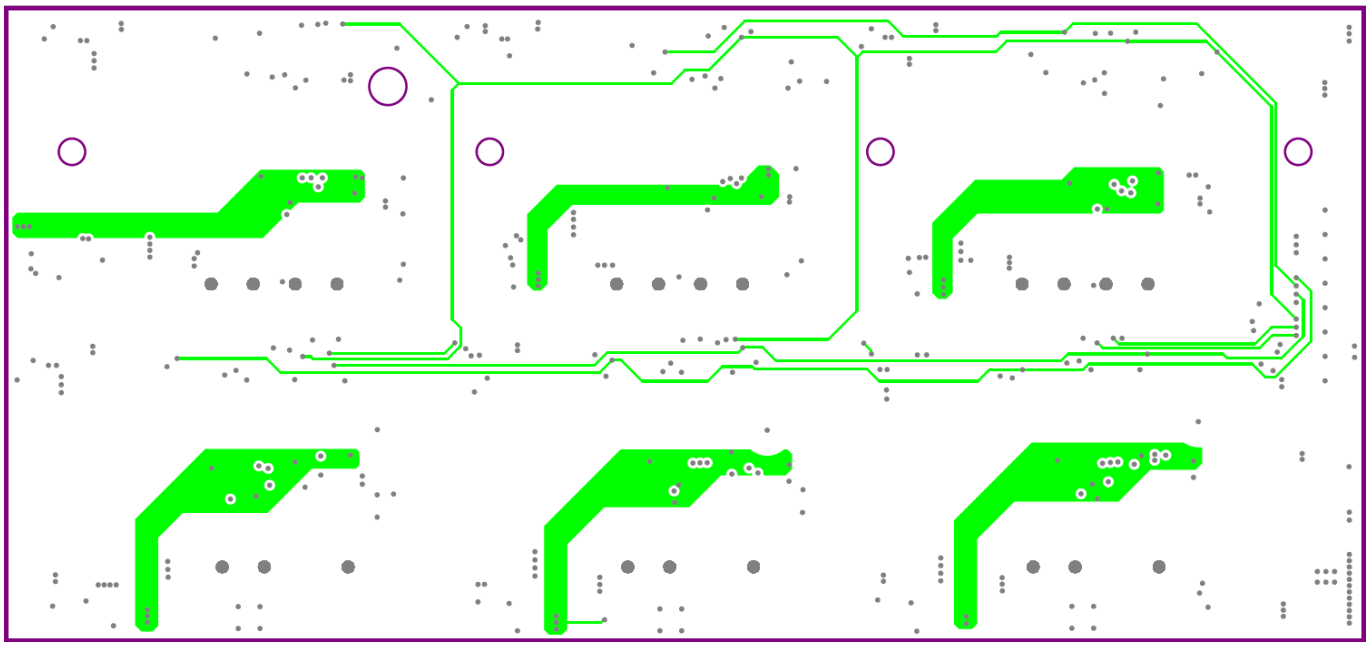


Figure 53. 4th Layer (top view)

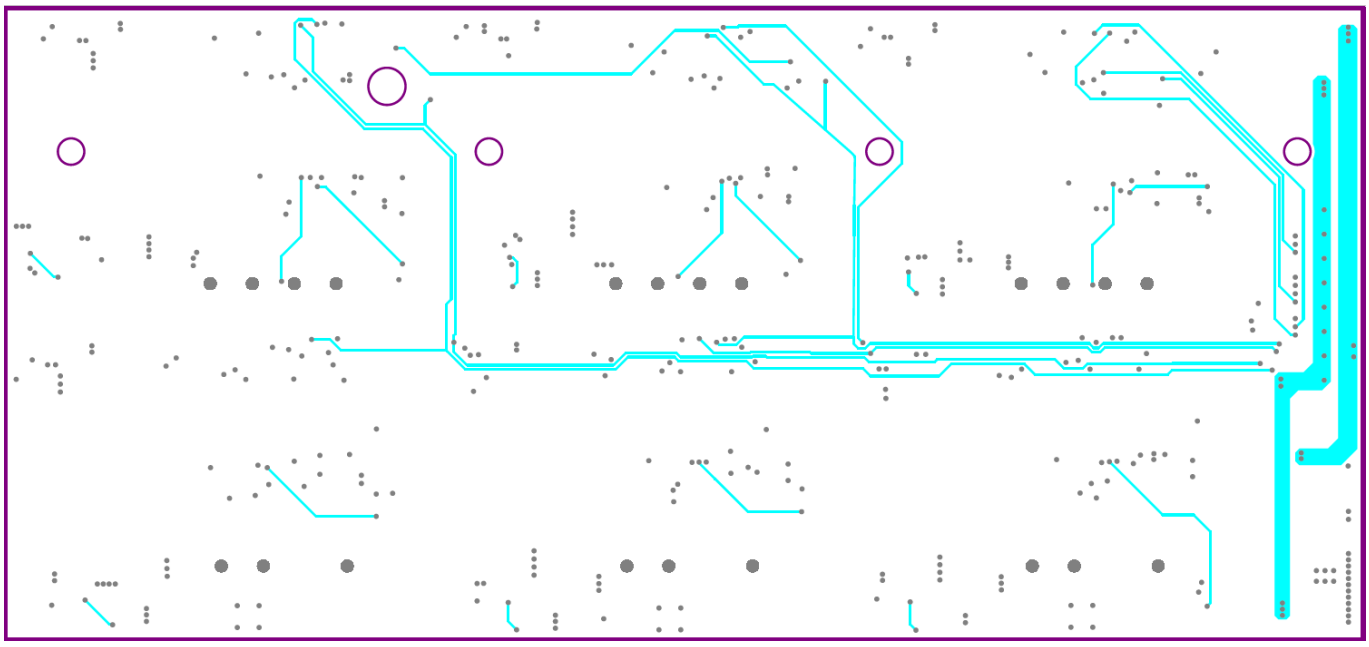


Figure 54. 5th Layer (top view)

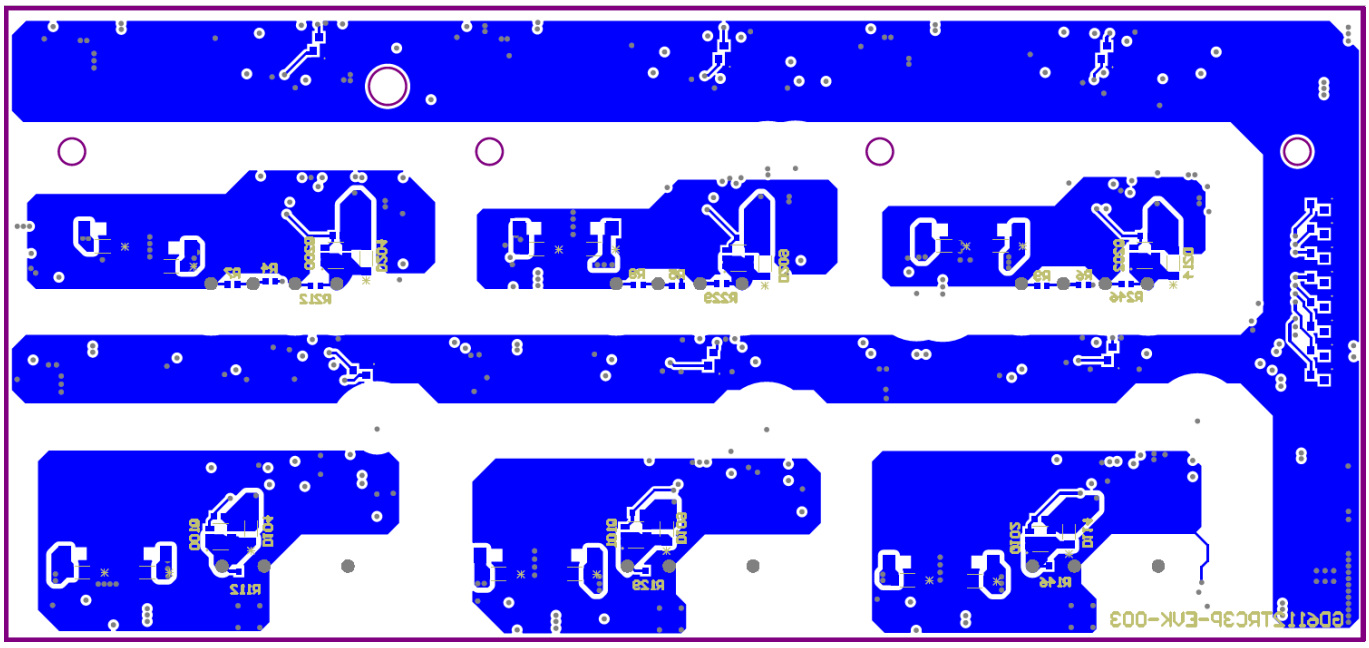


Figure 55. Bottom Layer (top view)

12. Bill of Materials

Device	Designator	Part Name	Values	Manufacture	Quantity
Capacitor	C1, C2, C3, C4, C5, C6, C8, C100, C108, C109, C110, C118, C119, C120, C128, C129, C200, C208, C209, C210, C218, C219, C220, C228, C229, C301, C305, C307, C310, C314, C316, C319, C323, C325, C328, C332, C334, C337, C341, C343, C346, C350, C352, C354, C355, C356, C357, C358, C359, C360, C361, C362, C363, C364, C365	GCM155R71H104KE02	CAP CER 0.1µF 50V X7R 0402	Murata	55
Capacitor	C7, C9	GCM31CC71H475KA03	CAP CER 4.7µF 50V X7S 1206	Murata	2
Capacitor	C101, C107, C111, C117, C121, C127, C201, C207, C211, C217, C221, C227, C302, C306, C308, C311, C315, C317, C320, C324, C326, C329, C333, C335, C338, C342, C344, C347, C351, C353	GCM31CD7YA106KE36	CAP CER 10µF 35V X7T 1206	Murata	30
Capacitor	C102, C112, C122, C202, C212, C222, C300, C309, C318, C327, C336, C345	-	No mounted	-	12
Capacitor	C103, C104, C105, C113, C114, C115, C123, C124, C125, C203, C204, C205, C213, C214, C215, C223, C224, C225	GCM1555C1H101JA16	CAP CER 100pF 50V C0G/NP0 0402	Murata	18
Capacitor	C106, C116, C126, C206, C216, C226	GCM155R71C224KE02	CAP CER 0.22µF 16V X7R 0402	Murata	6
Capacitor	C303, C312, C321, C330, C339, C348	GCM1555C1H102JA16	CAP CER 1000pF 50V C0G/NP0 0402	Murata	6
Capacitor	C304, C313, C322, C331, C340, C349	GCM1885C1H103GA16	CAP CER 10000pF 50V C0G/NP0 0603	Murata	6
Diode	D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14	RB508FM-40SFH	DIODE ARR SCHOTT 40V 80MA SOT323	ROHM	14
Diode	D100, D101, D105, D106, D110, D111, D200, D201, D205, D206, D210, D211	US1NWF-7	DIODE STANDARD 1200V 1A SOD123F	Diodes	12
Diode	D104, D109, D114, D204, D209, D214, D304, D311, D318, D325, D332, D339	RB168MM100TF	DIODE SCHOTTKY 100V 1A PMDU	ROHM	12
Diode	D115, D116, D117, D118, D119, D120, D215, D216, D217, D218, D219, D220	RB521SM-30FH	DIODE SCHOTTKY 30V 200mA EMD2	ROHM	12
Diode	D300, D307, D314, D321, D328, D335	RB168LAM150TF	DIODE SCHOTTKY 150V 1A PMDTM	ROHM	6
Diode	D301, D308, D315, D322, D329, D336	KDZVTF20B	DIODE ZENER 21.2V 1W PMDU	ROHM	6
Diode	D303, D310, D317, D324, D331, D338	KDZVTF9.1B	DIODE ZENER 9.65V 1W PMDU	ROHM	6

Diode	D305, D312, D319, D326, D333, D340	KDZVTF6.2B	DIODE ZENER 6.6V 1W PMDU	ROHM	6
Diode	D306, D313, D320, D327, D334, D341	RB168LAM-30TF	DIODE SCHOTTKY 30V 1A PMDTM	ROHM	6
LED	D15, D302, D309, D316, D323, D330, D337	SML-D14MWT86A (Use as an indicator, not automative component)	LED YLW-GRN CLEAR 1608 SMD	ROHM	7
LED	D102, D103, D107, D108, D112, D113, D202, D203, D207, D208, D212, D213	SML-D14U2WT86A (Use as an indicator, not automative component)	LED RED CLEAR 1608 SMD	ROHM	12
Filter	FL1	PLT5BPH1015R4SNL	-	Murata	1
Connector	J1	BM50B-SHLDS-G-TFT	CONN SMD	JST	1
Connector	J2, J3, J4	734152063	CONN MMCX JACK STR 50 OHM SMD	Molex	3
Inductor	L1	SPM6530T-4R7M-HZ	FIXED IND 4.7µH 5.6A 39.38 MOHM	TDK	1
MOSFET	Q100, Q101, Q102, Q200, Q201, Q202	RSQ020N03HZG	MOSFET N-CH 30V 2A TSMT6	ROHM	6
Test Point	TP1, TP2, TP3, TP4, TP5, TP100, TP102, TP103, TP104, TP105, TP107, TP108, TP109, TP110, TP112, TP113, TP114	RCT-0C	PC TEST POINT NATURAL	TE Connectivity AMP Connectors	17
Transformer	TR300, TR301, TR302, TR303, TR304, TR305	CEEH1312	-	SUMIDA	6
IC	U1	BD950N1WEFJ-CE2	IC REG LINEAR 5V 150mA 8-HTSOP-J	ROHM	1
IC	U100, U101, U102, U200, U201, U202	BM6112FV-C	IC ISO 3750VRMS 1CH GD	ROHM	6
IC	U300, U302, U304, U306, U308, U310	LT1964EDD#TRPBF	IC REG LIN NEG ADJ 200mA 8-DFN	Analog devices	6
IC	U301, U303, U305, U307, U309, U311	BD7F205EFJ-C	IC REG FLYBACK ADJ 8HTSOP-J	ROHM	6
Resistor	R1, R2, R3, R308, R323, R338, R353, R368, R383	MCR01SMQPF1002	RES SMD 10k OHM 1% 1/16W 0402	ROHM	9
Resistor	R4, R5, R6	MCR01SMQPF1801	RES SMD 1.8k OHM 1% 1/16W 0402	ROHM	3
Resistor	R7, R8, R9	MCR01SMQPF4301	RES SMD 4.3k OHM 1% 1/16W 0402	ROHM	3
Resistor	R10, R11, R12	MCR01SMQPF1301	RES SMD 1.3k OHM 1% 1/16W 0402	ROHM	3
Resistor	R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R101, R102, R112, R115, R118, R119, R129, R132, R135, R136, R146, R149, R201, R202, R212, R215, R218, R219, R229, R232, R235, R236, R246, R249, R301, R316, R331, R346, R361, R376	MCR01SMQPF4701	RES SMD 4.7k OHM 1% 1/16W 0402	ROHM	42
Resistor	R100, R117, R134, R200, R217, R234	MCR01SMQPF1502	RES SMD 15k OHM 1% 1/16W 0402	ROHM	6

Resistor	R103, R120, R137, R203, R220, R237, R305, R321, R335, R351, R365, R381	MCR01SMQPF1303	RES SMD 130k OHM 1% 1/16W 0402	ROHM	12
Resistor	R104, R121, R138, R204, R221, R238	MCR01SMQPF9101	RES SMD 9.1k OHM 1% 1/16W 0402	ROHM	6
Resistor	R105, R107, R109, R122, R124, R126, R139, R141, R143, R205, R207, R209, R222, R224, R226, R239, R241, R243	MCR01SMQPF1000	RES SMD 100 OHM 1% 1/16W 0402	ROHM	18
Resistor	R106, R108, R123, R125, R140, R142, R206, R208, R223, R225, R240, R242	LTR18EZPF5R60	RES 5.6 OHM 1% 1.5W 1206 WIDE	ROHM	12
Resistor	R110, R111, R127, R128, R144, R145, R210, R211, R227, R228, R244, R245	LTR18EZPF13R0	RES 13 OHM 1% 1.5W 1206 WIDE	ROHM	12
Resistor	R113, R130, R147, R213, R230, R247	MCR03SEQPJ000	RES SMD 0 OHM JUMPER 1/10W 0603	ROHM	6
Resistor	R114, R116, R131, R133, R148, R150, R214, R216, R231, R233, R248, R250	MCR03SEQPF20R0	RES SMD 20 OHM JUMPER 1/10W 0603	ROHM	12
Resistor	R300, R315, R330, R345, R360, R375	-	No mounted	-	6
Resistor	R302, R317, R332, R347, R362, R377	MCR18SEQPJ162	RES SMD 1.6k OHM 5% 1/4W 1206	ROHM	6
Resistor	R303, R318, R333, R348, R363, R378	MCR01SMQPF6801	RES SMD 6.8k OHM 1% 1/16W 0402	ROHM	6
Resistor	R304, R319, R334, R349, R364, R379	MCR03SEQPF1001	RES SMD 1k OHM JUMPER 1/10W 0603	ROHM	6
Resistor	R306, R320, R336, R350, R366, R380	MCR18SEQPJ391	RES SMD 390 OHM 5% 1/4W 1206	ROHM	6
Resistor	R307, R322, R337, R352, R367, R382	MCR10SEQPJ000	RES SMD 0 OHM JUMPER 1/8W 0805	ROHM	6
Resistor	R309, R324, R339, R354, R369, R384	MCR01SMQPF2001	RES SMD 2k OHM 1% 1/16W 0402	ROHM	6
Resistor	R310, R325, R340, R355, R370, R385	MCR01SMQPF3602	RES SMD 36k OHM 1% 1/16W 0402	ROHM	6
Resistor	R311, R326, R341, R356, R371, R386	-	Not Mounted	-	6
Resistor	R312, R327, R342, R357, R372, R387	MCR01SMQPF4702	RES SMD 47k OHM 1% 1/16W 0402	ROHM	6
Resistor	R313, R328, R343, R358, R373, R388	MCR01SMQPJ183	RES SMD 18k OHM 1% 1/16W 0402	ROHM	6
Resistor	R314, R329, R344, R359, R374, R389	MCR01SMQPF2701	RES SMD 2.7k OHM 1% 1/16W 0402	ROHM	6

13. Revision History

Table 18. Revision History

Revision	Date	Description of change
1	September 2025	Initial version

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