TOLL 48V POWER LINE EVALUATION BOARD

TOLL Package MOSFET Evaluation

About this document

The TOLL 48V EVB is an inverter board that utilize the Renesas's latest Power MOSFET TOLL and RL78/F14 microcontroller to drive 3-phase BLDC motor. It provides a versatile platform for testing and evaluating motor control systems, with precise speed control and efficiency. The information provided in this document serves as a guideline to use the TOLL 48V EVB with the TMS-2000W-ISG-INV-R2.0 and TMS-RL78F14-ISG-CTR-R1.0 board.

Target Device

MOSFET: REXFET-1 (RBA300N10EANS-3UA02)

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1. Introduction

1.1 Overview

The TOLL 48V Power Line Evaluation Board (TOLL 48V EVB) was developed as an inverter capable of driving up to a 48V 3-phase BLDC motor. It is able to support motor speed control up to 4000 rpm. It also features error handling for overvoltage, overspeed, motor time-out, and hall sensor errors.

The TOLL 48V EVB is a comprehensive motor control system that consists of two main components, the Power board (**TMS-2000W-ISG-INV-R2.0**) and the Controller board (**TMS-RL78F14-ISG-CTR-R1.0**). The Power board is responsible for providing the necessary power to drive the motor, while the Controller board handles the control and feedback signals. Together, these two boards create a solution for driving 3-phase BLDC motors with precision and accuracy. This board is a tool for motor control functional testing.

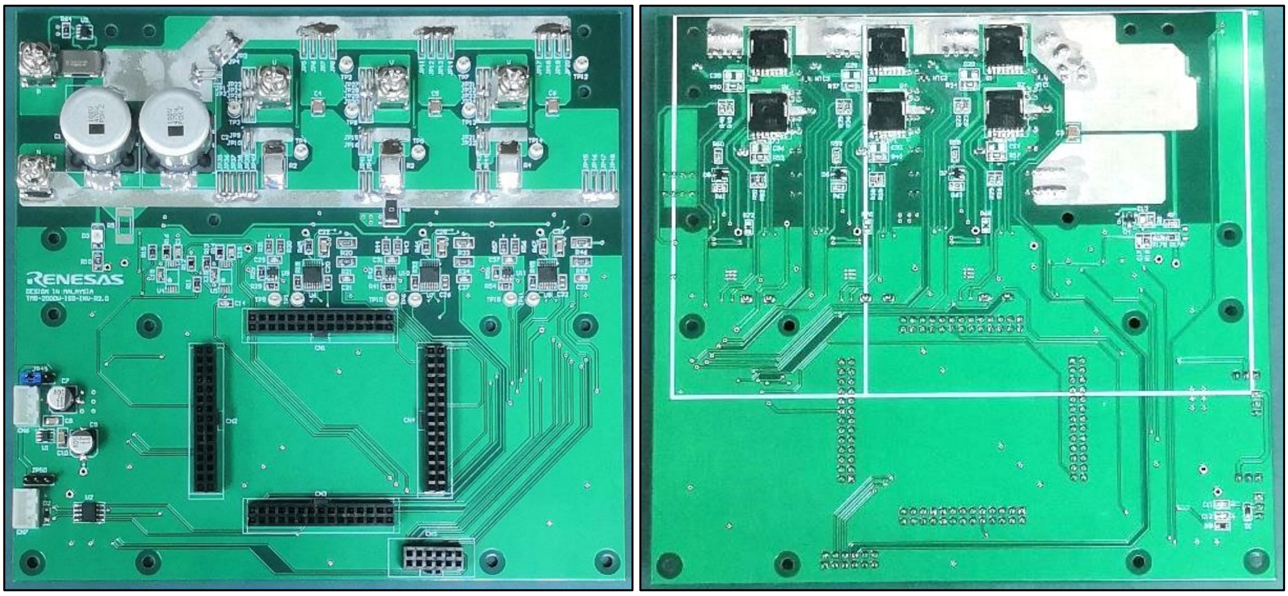


Figure 1-1 Power board: Top view (Left) and Bottom view (Right)

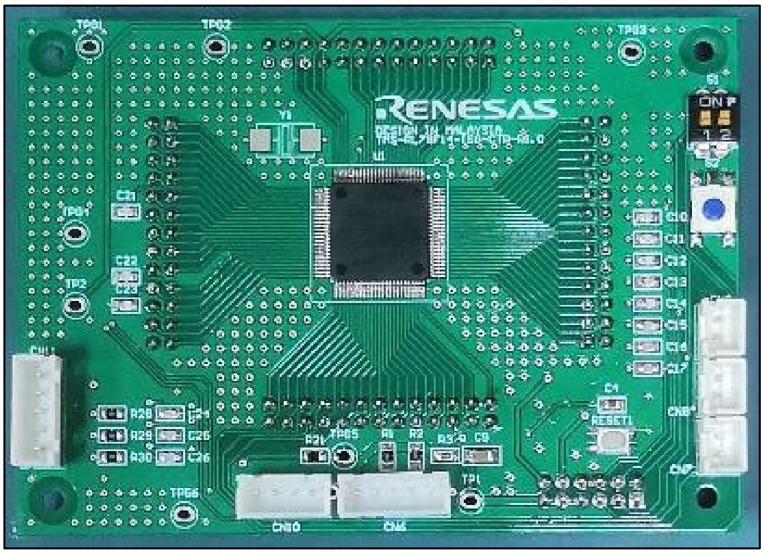


Figure 1-2 Controller board

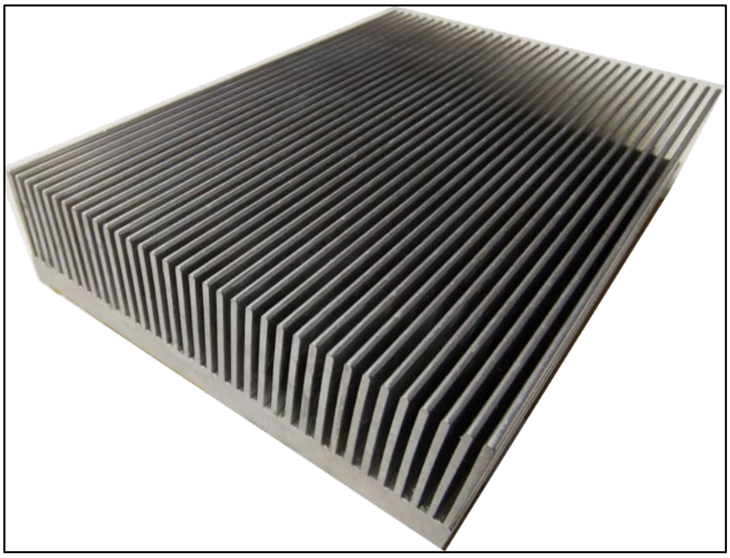


Figure 1-3 Heatsink Block

The heatsink block is installed on the bottom side of the Power Board, positioned in close proximity to the Power MOSFETs. Its purpose is to dissipate the thermal heat generated by the MOSFETs. This heatsink block measures 15cm x 10cm x 3.3cm in size.

1.2 EVB Hardware and Technical Data

Table 1-1 shows the specification of the TOLL 48V EVB. The power stage of the TOLL 48V EVB operates at DC 12V to 48V. A separate DC 12V powers both the driver circuit and the controller (the controller is powered by DC 5V converted from the DC 12V). The board can deliver a maximum of 700W at 48V. The maximum output current is 70A.

Table 1-1 Specification of the TOLL 48V EVB

Parameter	Value
Power stage voltage applicable	12VDC to 48VDC
Switching frequency	10kHz
Operating temperature	0°C ~ 95°C
Power board dimension (W x L)	160mm × 150mm
Controller board dimension (W x L)	110mm × 73mm

1.3 Main Features

The primary feature of the evaluation board is its utilization of 100V power MOSFET technology, specifically the TOLL MOSFET, designed for 3-phase BLDC motor applications.

- 48V nominal input voltage
- Input voltage range from 12V to 48V
- Overcurrent control (OCP) for each phase achieved by monitoring the current through shunt resistors.
- Realtime temperature monitoring with over temperature protection.
- Board supplied with 12V input power for the gate driver IC and controller board
- Speed control switch button

1.4 Block Diagram

The block diagram of TOLL 48V EVB as shown below. The red box is representing the hardware part and the blue box is representing the software part.

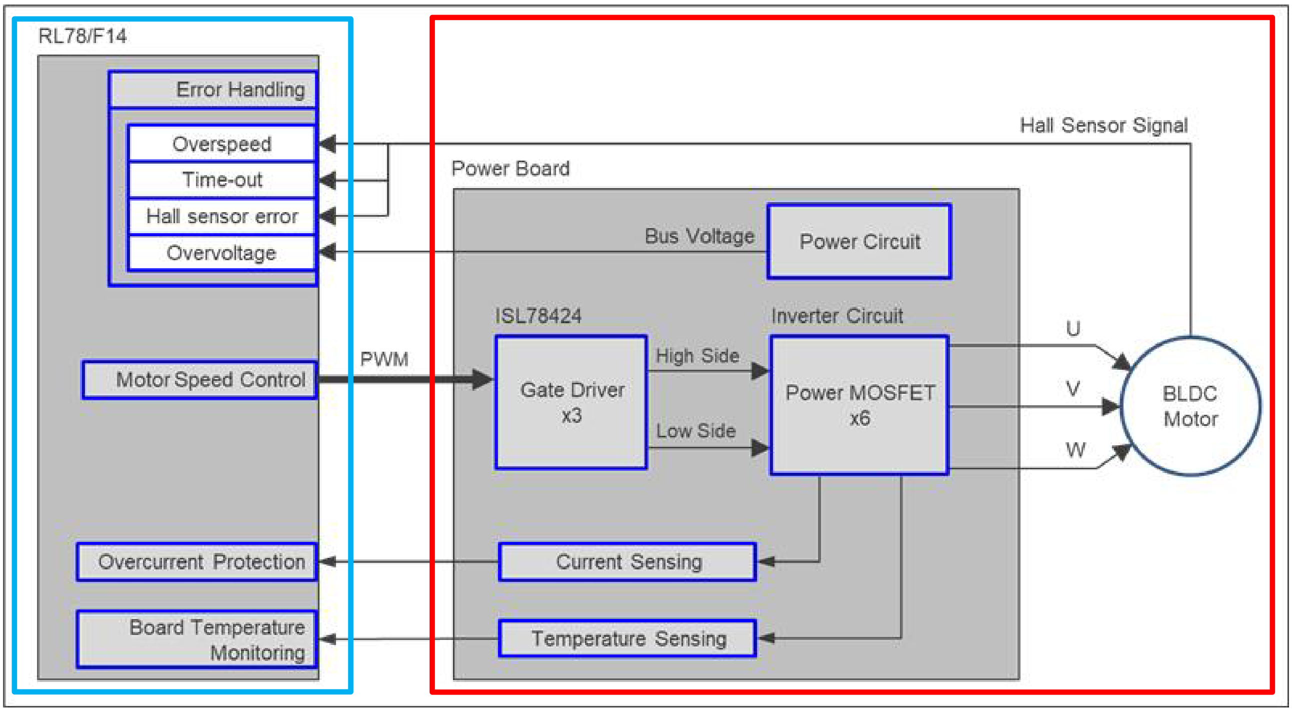


Figure 1-4 Evaluation Board Block Diagram

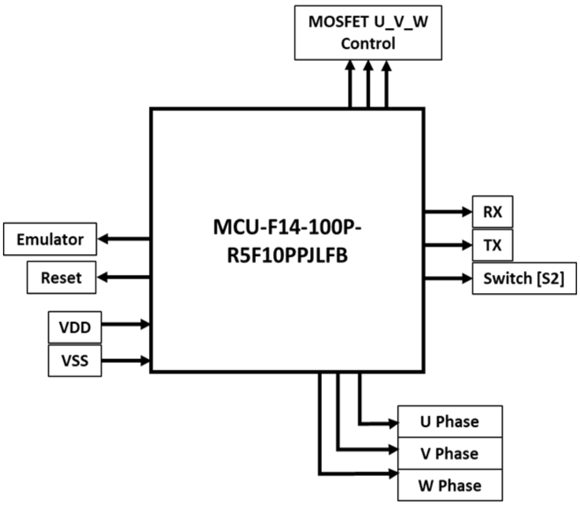


Figure 1-5 Controller Block Diagram (Critical Pin Function)

The diagram above illustrates the critical pin functions for the microcontroller to be used in motor control applications. For detailed information about specific pin assignments, please refer to the online datasheet, specifically the '**RL78/F13, F14 User's Manual: Hardware**'

2. Hardware Description

The following are the hardware components required to showcase the functionality of TOLL 48V EVB.

i. Power board - TMS-2000W-ISG-INV-R2.0
ii. Controller board - TMS-RL78F14-ISG-CTR-R1.0
iii. 3 phase Brushless DC Motor (BLDC) motor, with Hall sensors
iv. Renesas E2 emulator
v. Desk Top Lab ICS++ W2002 debugging tool (http://www.desktoplab.co.jp/)
vi. 12V DC Power Supply
vii. 48V DC Power Supply

2.1 Controller Board Installation

The controller board and power board are designed to work together and are connected via four 26-pin headers and one 12-pin header (please refer to Figure 1-1. and Figure 1-2.). The controller board is mounted on top of the power board. The figure below shows the controller board installed on the power board.

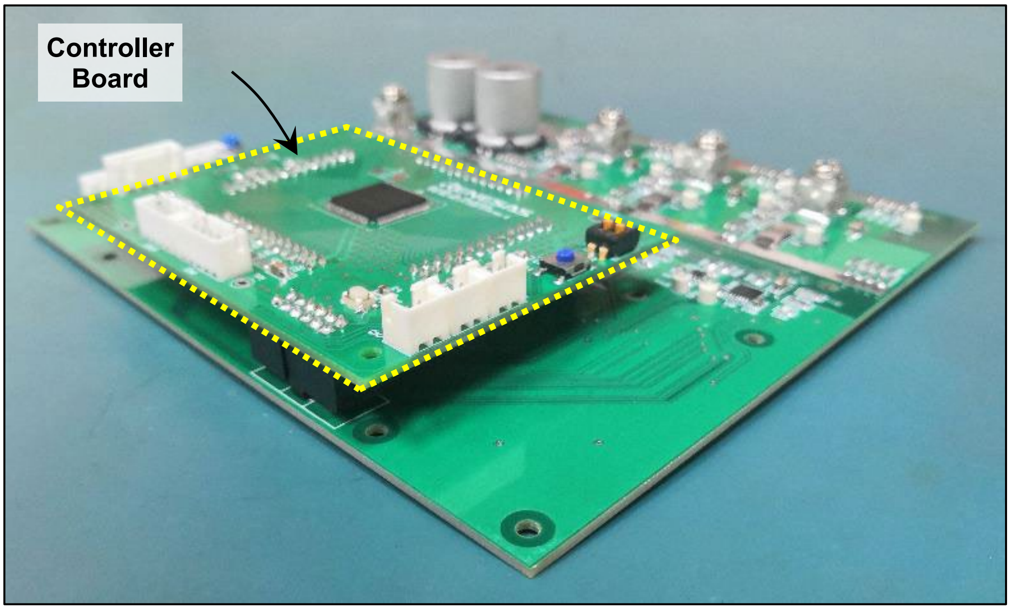


Figure 2-1 Controller Board Installed on Power Board

2.2 Board Connections Overview

The following figure provides an overview of the TOLL 48V EVB connections required for operation and functional testing.

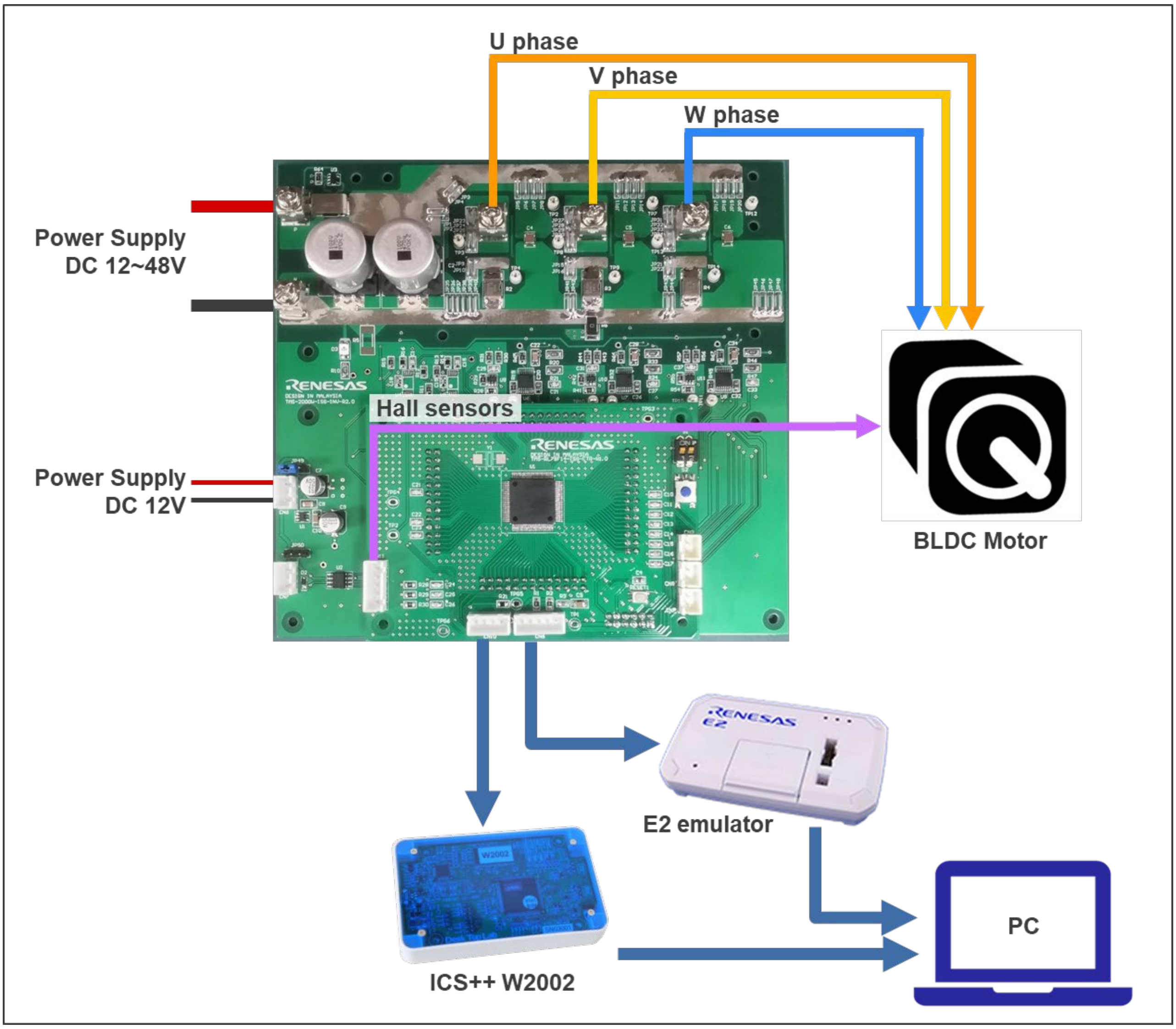


Figure 2-2 Overview of TOLL 48V EVB Connections

The power stage of EVB can be connected to voltages ranging from DC 12V to 48V, and it requires a separate DC 12V to power the driver circuit and the controller board. The output of the inverter is connected to a 3-phase BLDC motor, and the E2 emulator is connected to the controller board to download firmware to the MCU and for source code debugging. In addition, the ICS++ is used to monitor the values of the variables used in the firmware during operation. Furthermore, the Hall sensors from the BLDC motor are connected to the controller board, which allows for accurate detection of the rotor magnetic pole position and speed of the motor. This information can then be used to control the motor's speed and direction of rotation.

Next will display each connector used on the evaluation board along with the pin description. Please note that the wire colors displayed below are based on this specific setup only. Actual wire colors may vary by manufacturer.

2.2.1 Board Connector Overview

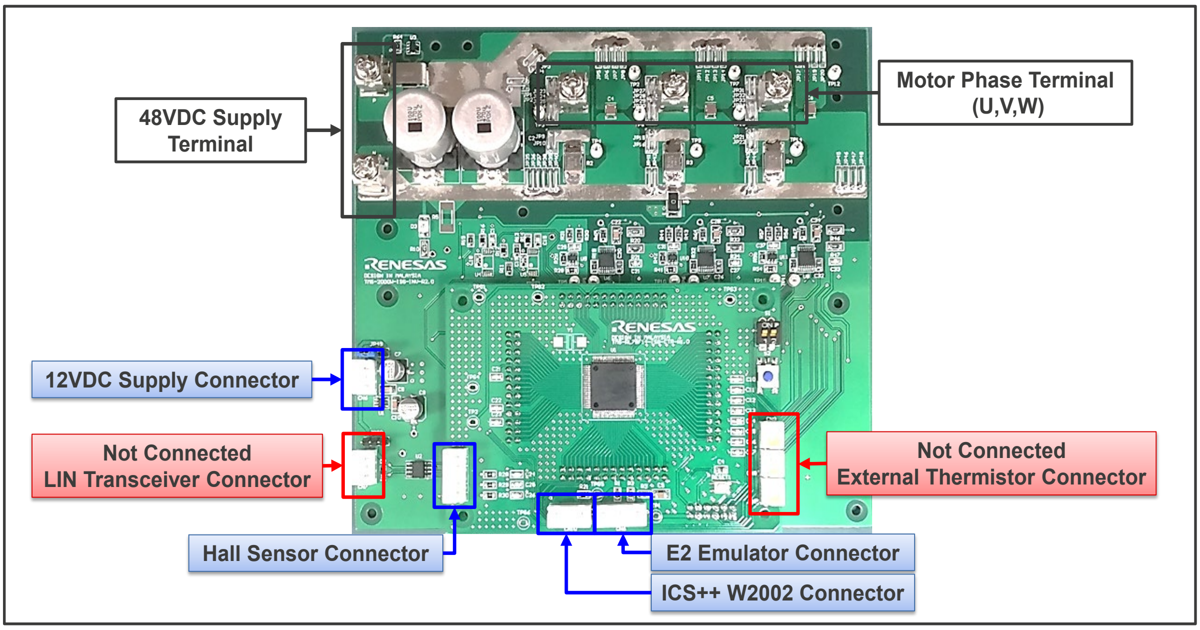


Figure 2-3 Overview of TOLL 48V EVB Connector

2.2.2 12VDC Supply Connector

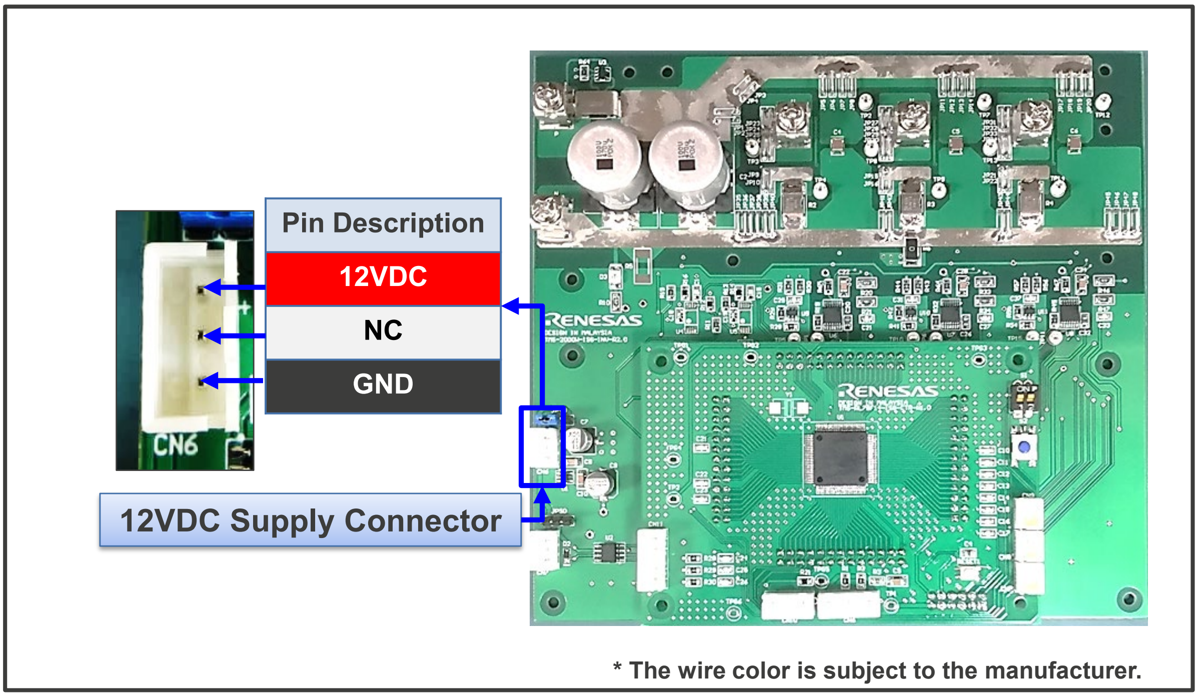


Figure 2-4 12VDC Supply Connector Pin Description

2.2.3 Hall Sensor Connector

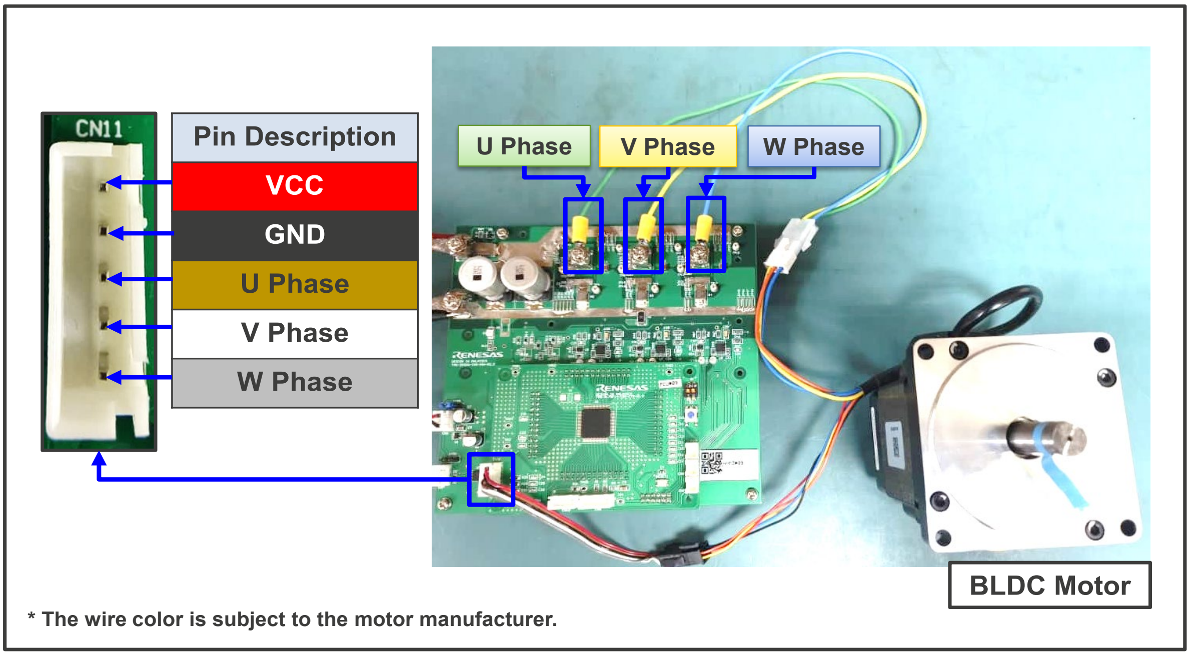


Figure 2-5 Hall Sensor Connector Pin Description

2.2.4 E2 Emulator Connector

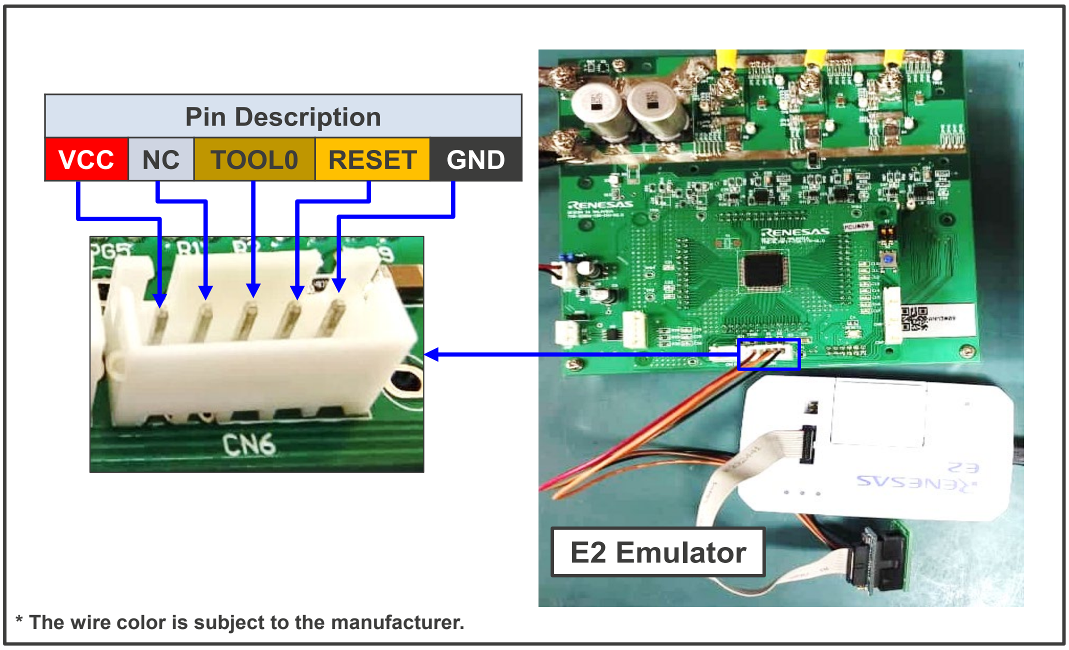


Figure 2-6 E2 Emulator Connector Pin Description

2.2.5 ICS++ W2002 Connector

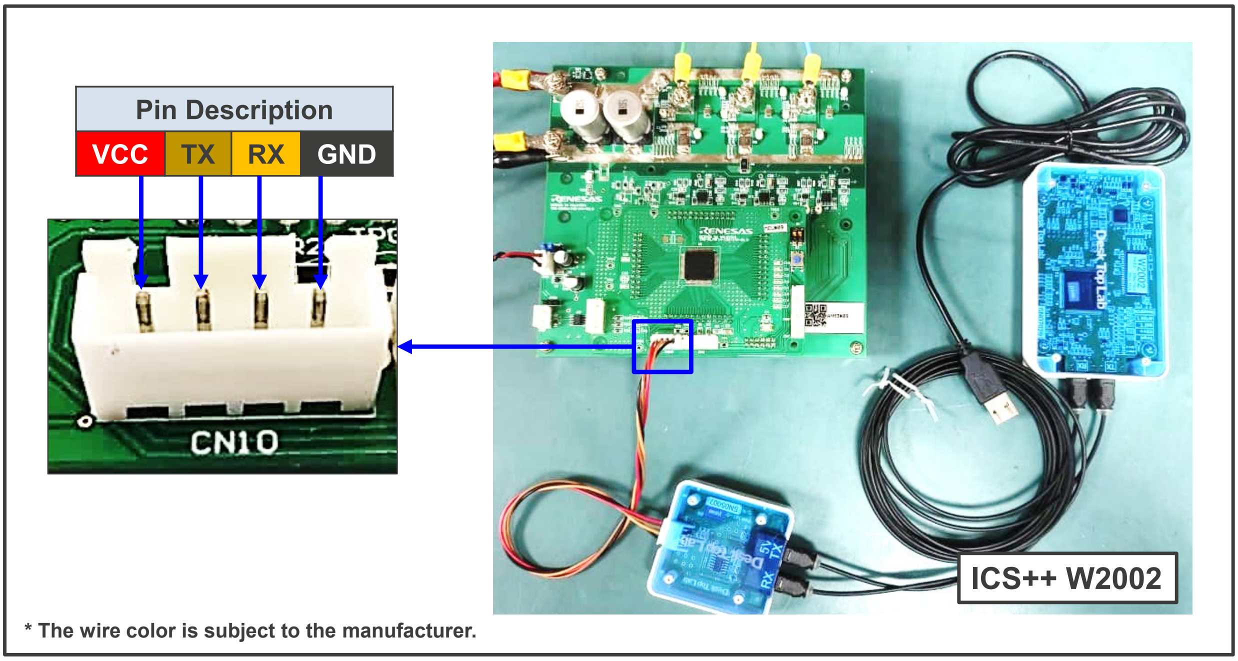


Figure 2-7 ICS++ W2002 Connector Pin Description

2.3 MOSFET Introduction

The TOLL (TO-Leadless) MOSFET is an innovative packaging type for MOSFETs that offers several advantages over traditional packages. It utilizes surface-mount technology, enabling fast and automated pick-and-place assembly, thereby making it highly cost-effective. Renesas has improved the wafer process technology to enhance the MOSFET's RDS(ON) characteristic. This improvement includes enhancing the deeper p-column in the super junction structure, which helps reduce the electric field strength in the device. This allows for a more uniform channel and enables it to support higher voltage ratings.

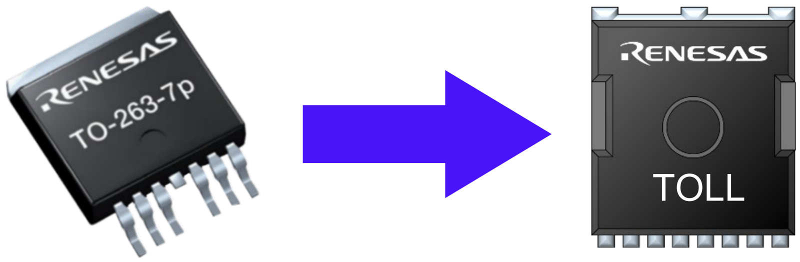


Figure 2-8 TOLL vs TO-263-7P Package

2.3.1 Key Features and Application Target

The TOLL MOSFET is specifically designed for high-power density, fast switching times, and excellent thermal performance, making it an ideal choice for applications such as DC motors, BLDC motors, power steering, and battery management. This MOSFET features a drain-down package with a large metal pad on the bottom, designed for efficient heat dissipation. Additionally, its slim profile allows for the attachment of a heatsink to the bottom of the PCB, enabling high-power demand applications without incurring extra costs for the system and hardware size increasing.

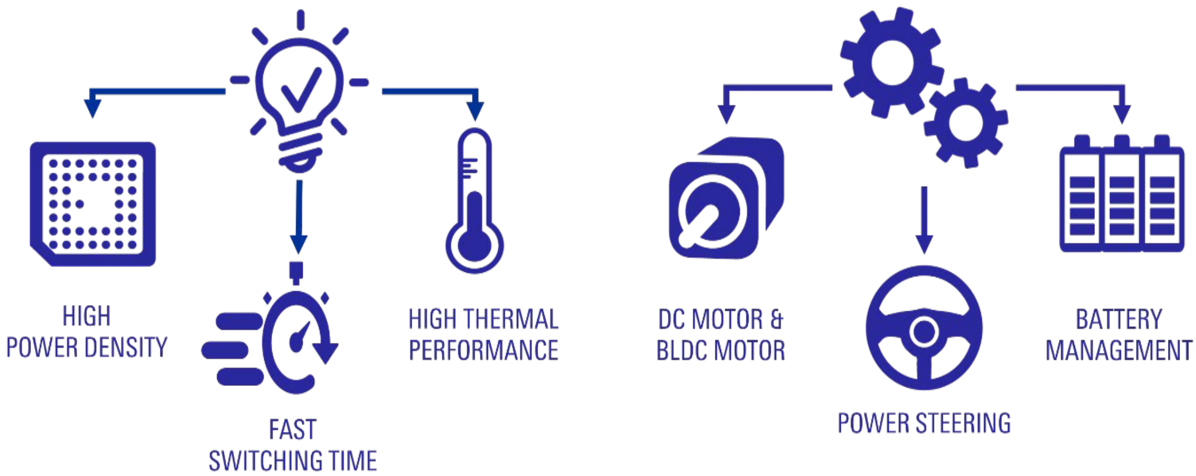


Figure 2-9 Key Features and the target application

2.4 ISL78424 Gate driver

The RL78/F14 (MCU) outputs PWM signals to the ISL78424 gate driver, one for each phase. The ISL78424 automatically converts the PWM signals into high-side and low-side drives. These drive signals then go to the MOSFETs in the inverter circuit, where they are applied to the motor's three phases to generate the required rotation. The high-side drive signals are applied to the upper MOSFETs, while the low-side drive signals are applied to the lower MOSFETs. This allows the MOSFETs to switch on and off in the required sequence, producing a rotating magnetic field that drives the motor.

ISL78424 gate driver circuit connection (U phase as example) as shown in figure below.

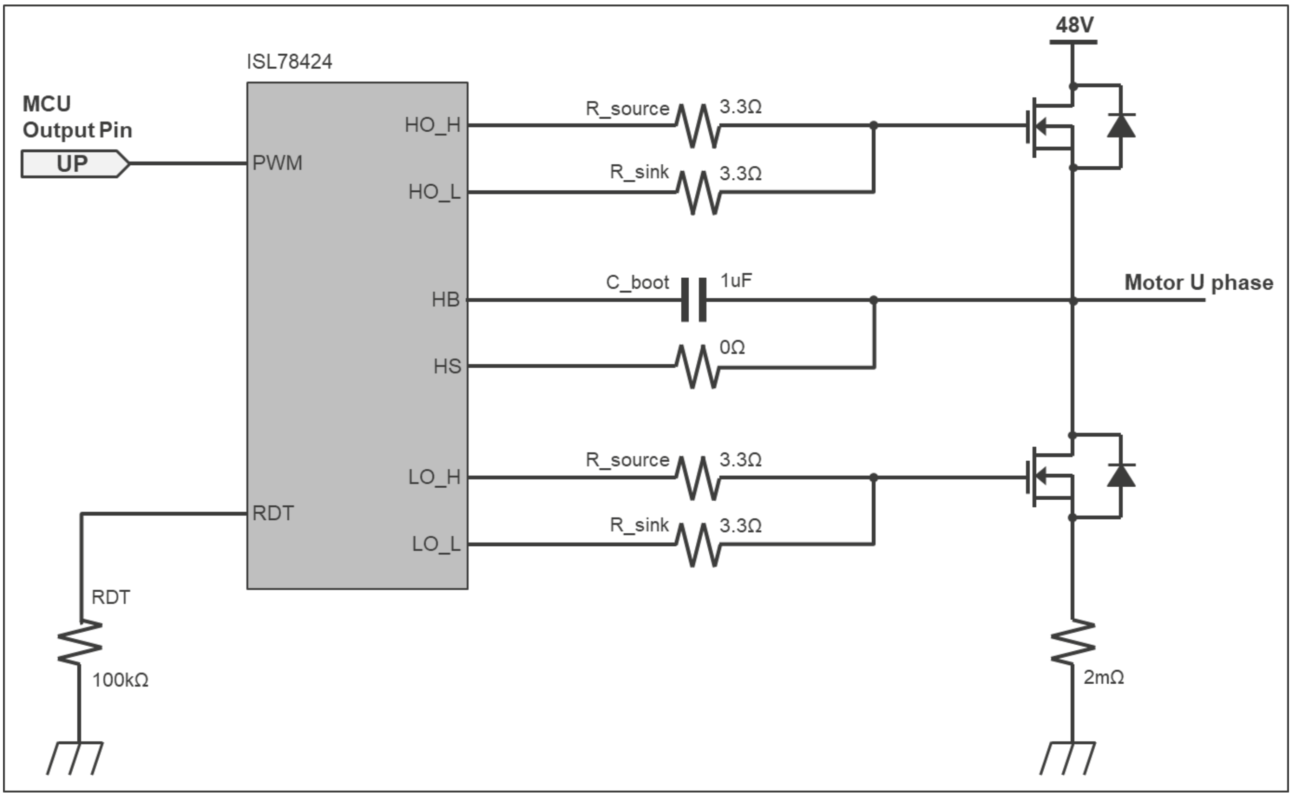


Figure 2-10 ISL78424 Gate Driver Connection

The gate driver features adaptive dead time control, which prevents shoot-through in a half bridge by ensuring that the MOSFET does not turn on before the other one completely turns off. The turn-on and turn-off of a MOSFET is detected through the source and sink outputs of the ISL78424 (pin HO_H, HO_L, LO_H, LO_L). The typical dead time for switching is around 70ns. The RDT pin of ISL78424 can be used to increase the dead time by 30ns to 240ns by adding a 10kΩ to 100kΩ resistor at RDT.

For more information about ISL78424, please refer to the datasheet.

2.5 ISL28006 Current Sense Amplifier

The ISL28006 is a micropower, uni-directional current sense amplifier designed for both high-side and low-side current sensing. It incorporates a proprietary rail-to-rail input current sensing amplifier. Remarkably, the micropower ISL28006 consumes a mere 50µA of supply current when operating from a 2.7V to 28V supply voltage. This device boasts a common-mode input voltage range spanning from 0V to 28V. Its unique architecture further extends the input voltage sensing range down to 0V, making it an outstanding choice for low-side ground sensing applications. For more information about ISL28006, please refer to the datasheet.

The ISL28006 gate driver circuit connection, illustrated in Figure 2-11, is exemplified for the U-phase.

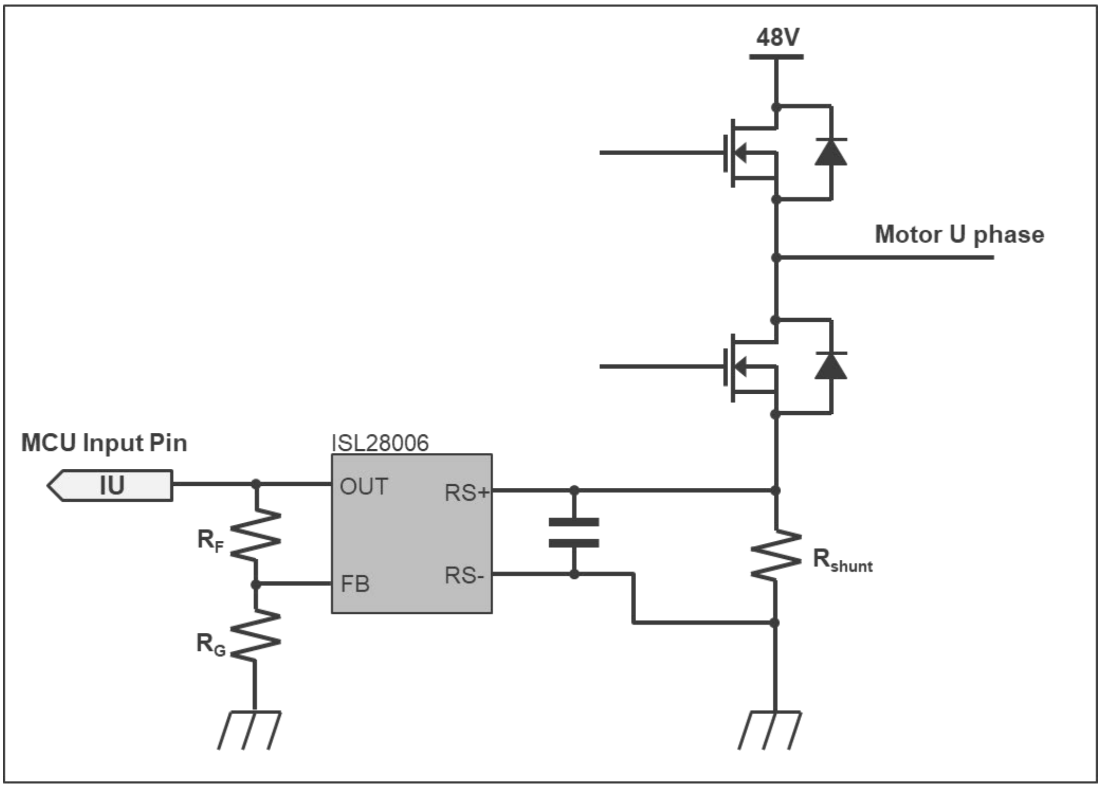


Figure 2-11 ISL28006 Current Sense Amplifier Connection

2.5.1 Over Current Protection (OCP)

Overcurrent Protection (OCP) mechanisms have been devised to protect the motor and MOSFETs from abrupt increases in current that could lead to damage. This feature enables real-time monitoring of the output current signal. In the event of a sudden spike in the output current, the system will trigger a motor shutdown to prevent potential damage.

2.6 Temperature Monitoring

There are 3 thermistors located at Power MOSFET area to sense the board temperature surrounding of the Power MOSFET during operation. Real-time temperature changes being monitored during the operation of EVB. In the event the board temperature over the pre-set temperature limit, the system able to perform thermal shutdown immediately to protect the EVB from damaged due to over temperature condition. The over temperature protection has the hysteresis recovery features where the operating of the EVB shall recover once the over temperature condition resolved.

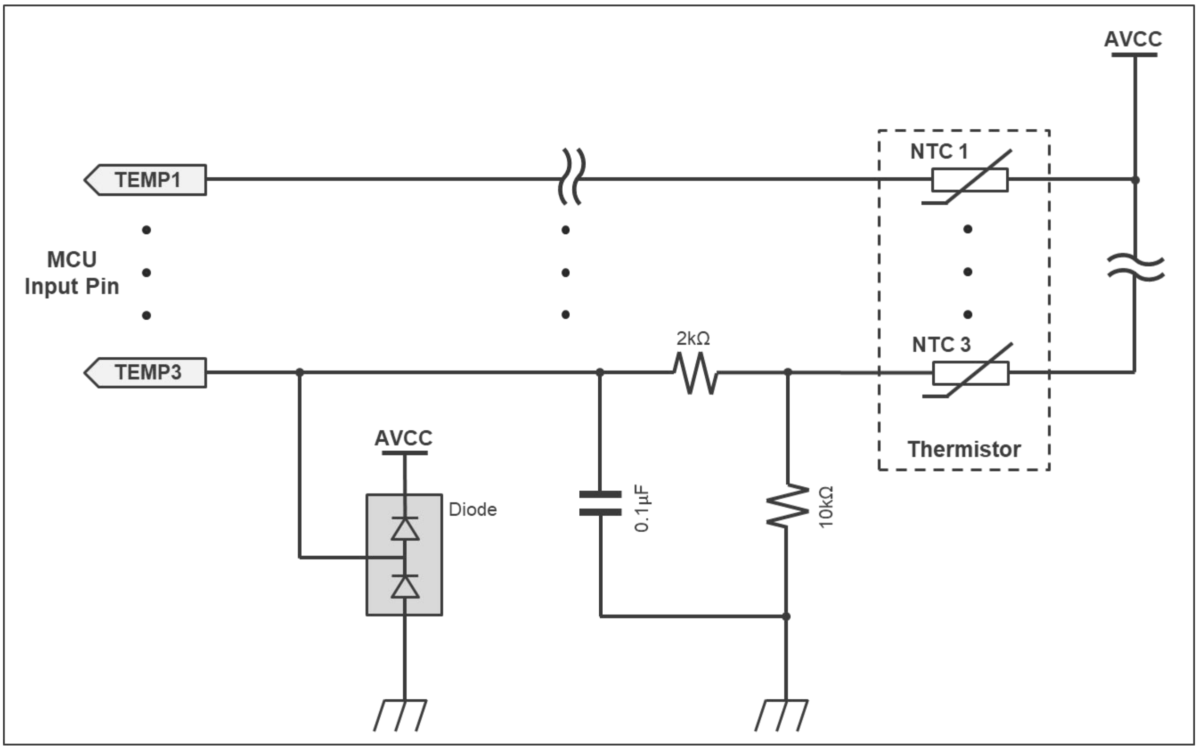


Figure 2-12 Temperature Monitoring Circuit

3. Firmware and Control

We've selected the RL78/F14 microcontrollers for our controller board evaluation. These microcontrollers are renowned for their low power consumption and high efficiency. It comes with integrated CAN and LIN modules for seamless automotive communication and provide support for BLDC motor control, capitalizing on the RL78/F14's functional safety features, timer RD, comparator, and D/A converter. Their exceptional reliability makes them well-suited for both industrial and automotive applications.

With this RL78/F14, the firmware able to perform as below features and control. This will help to

- Motor speed control with range 0 RPM to 4000 RPM
- Motor speed change per step (programable)
- Direction of motor rotation in CW or CCW
- Motor switch [S2] control in different mode (Stepping up/down and force stop)
- Error handling (protection) on Voltage, Current, Speed, Motor control.

3.1 Motor Speed Control

The TOLL 48V EVB features speed control through an on-board switch [S2], which allows for incremental changes in motor speed. Each short press of the switch increases the motor speed by 500 rpm, starting from 0 and reaching a maximum speed of 4000 rpm. Once the maximum speed is reached, subsequent short presses of the switch will decrease the speed by 500 rpm. A long press of the switch will stop the motor at any speed.

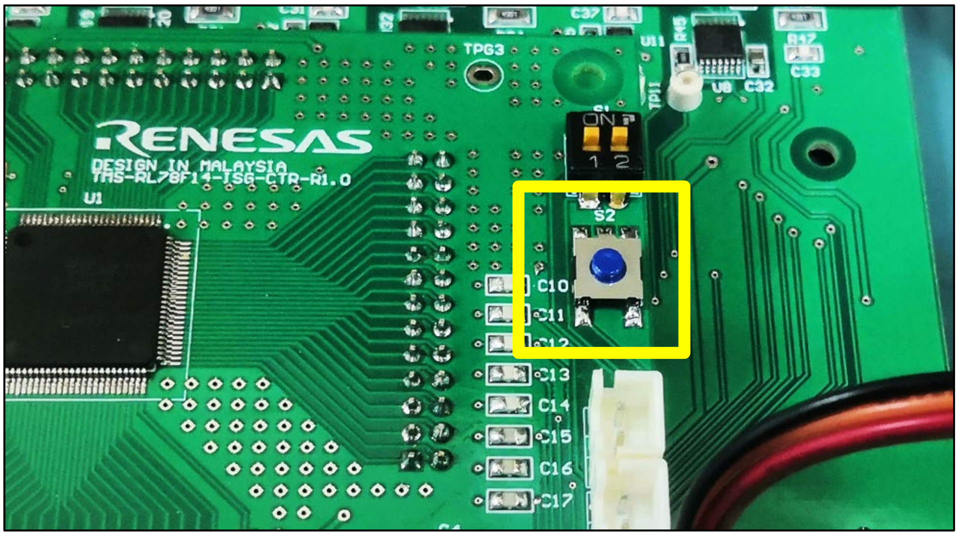


Figure 3-1 On-board Switch [S2] of Controller board

3.2 System Error Handling

The TOLL 48V EVB is capable of performing an emergency stop of operations to protect both the users and the device in case of errors or unexpected events. The TOLL 48V EVB control program can recognize the following four types of error statuses:

i. Overvoltage error

ii. Motor overspeed error

iii. Motor time-out error

iv. Motor hall sensor error

3.3 Overvoltage error

The TOLL 48V EVB is designed with the safety of the BLDC motor in mind. As the motor voltage is set at 48V, the board includes a critical error handling feature that prevents the MOSFETs from switching on if the supply voltage exceeds this limit. The voltage detection function utilizes the ANI08 pin (Pin 81) of the RL78/F14, which continuously monitors the voltage level. If the voltage is detected to be higher than the maximum allowable limit of 48V, the firmware will immediately raise an error status and prevent the MOSFETs from turning on, ensuring that the motor and other connected devices are protected from any possible damage.

3.3.1 Voltage Scale Down for MCU Signal Processing

Due to the high-power supply voltage, it is necessary to scale down the voltage level before it is inputted to the MCU for signal processing. The voltage divider circuit, as shown in the figure below, is used for this purpose. Additionally, a diode is included to clamp the voltage at AVCC, thereby protecting the MCU from receiving direct voltage from the power supply.

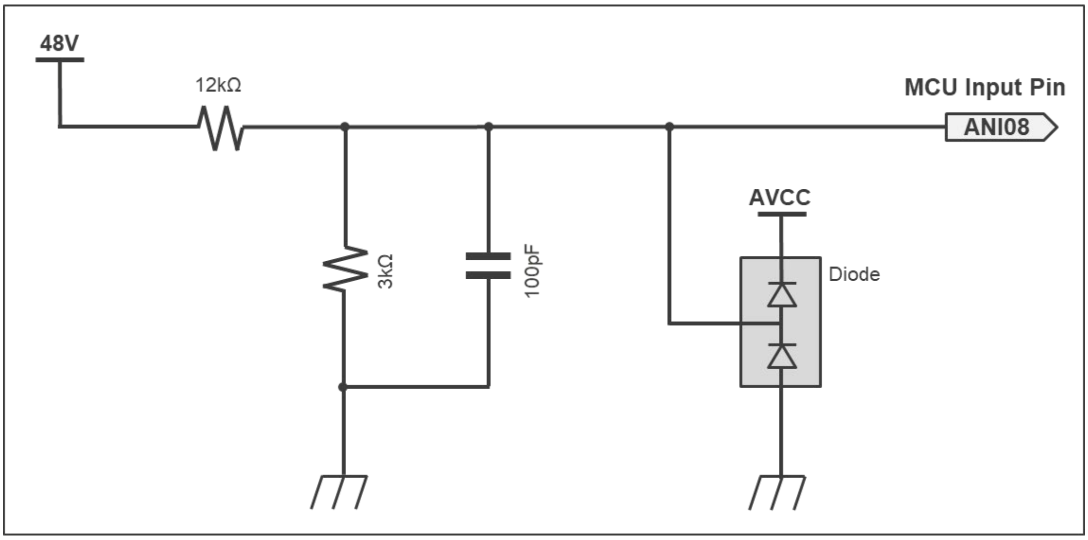


Figure 3-2 Voltage Divider Circuit

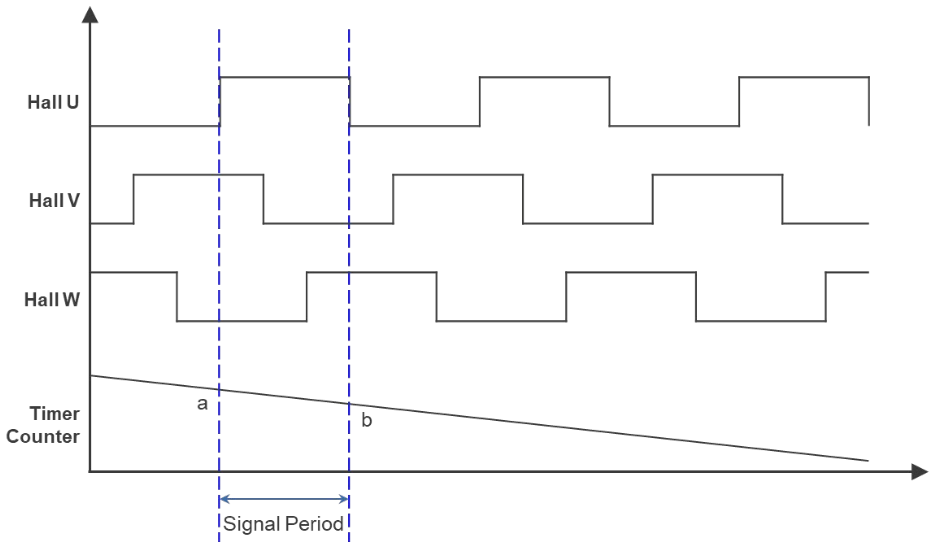
3.4 Motor Overspeed Error

The system utilizes the hall sensors that is mounted in the BLDC motor to detect its rotation speed. As the rotor's magnetic pole passes the hall sensor, a signal is generated, and the timer value is recorded. By analyzing the period between each signal generated by the hall sensor, together with the frequency of the timer, the firmware can accurately calculate the speed of the motor. This process is repeated multiple times per second to provide a continuous reading of the motor's speed. By using this calculation method, the EVB can ensure that the motor operates at a controlled speed.

The firmware will monitor the motor speed with 1ms interval. If the motor speed is over the target speed, an error status will be triggered and the system will perform emergency stop.

3.4.1 Motor Speed Calculation

Method of motor speed calculation as shown in figure below.



$$\text{Motor Rotation Speed (rpm)} = \frac{60 \times \text{Timer Frequency}}{2 \times (a - b)}$$

Figure 3-3 Method of Motor Speed Calculation

3.5 Motor Time-out error

To detect the motor time-out error, the system still monitors on the interrupt signals generated from hall sensors during the operation of BLDC motor. The interrupt signals will generate at regular intervals when the rotor is rotating. However, if the rotor turns slower than expected due to an overload or obstruction, the system will generate a timeout error. This error occurs when the sensor does not detect a pulse signal from the rotor within a specified time period.

When the timeout error occurs, the system acts to protect the motor and other components in the system. It turns off the PWM output, which controls the power delivered to the motor. Additionally, the MOSFET, which is responsible for switching the PWM signal on and off, is also turned off to prevent any further damage.

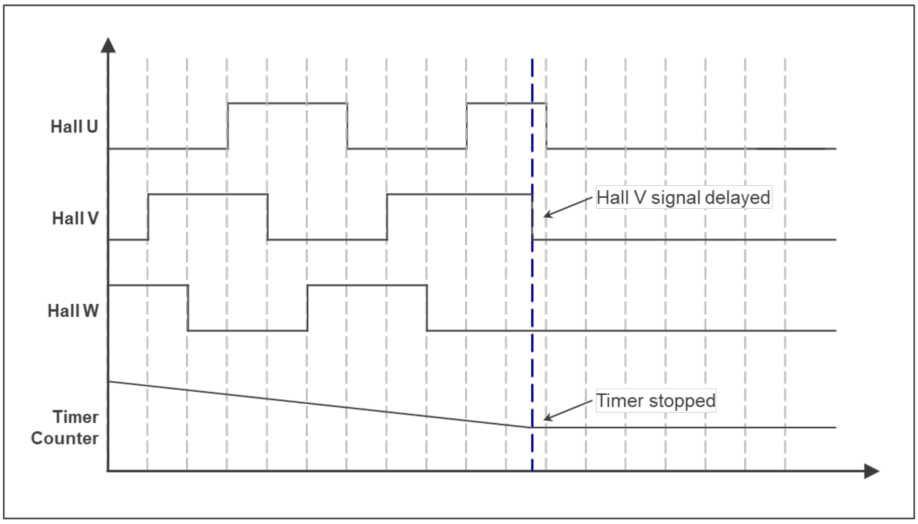


Figure 3-4 Example of Hall Sensor Signal Delayed

3.6 Motor Hall Sensor error

The motor hall sensor generates an interrupt at regular intervals when the rotor is rotating, but if the signal is lost during operation, a hall error will occur. When this happens, the PWM output, which controls the power delivered to the motor, will be turned off. Additionally, the MOSFET will also stop switching follow by the PWM output is turned off. This prompt response to the hall error helps prevent any further damage to the motor or other components, ensuring the safe and efficient operation of the system.

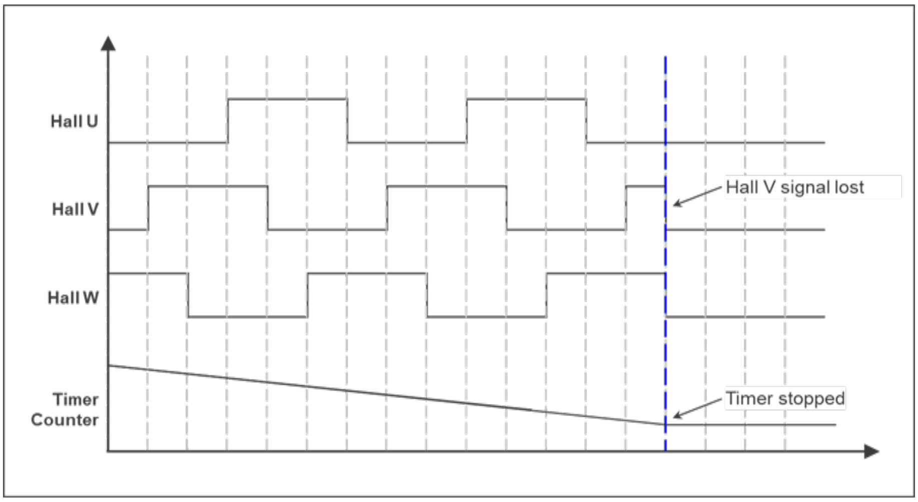


Figure 3-5 Example of Hall Sensor Signal Lost

4. Measurement Result

4.1 Test Setup for the Evaluation

Below is the schematic diagram of the test setup that was used for data measurement and to generate the operation waveform.

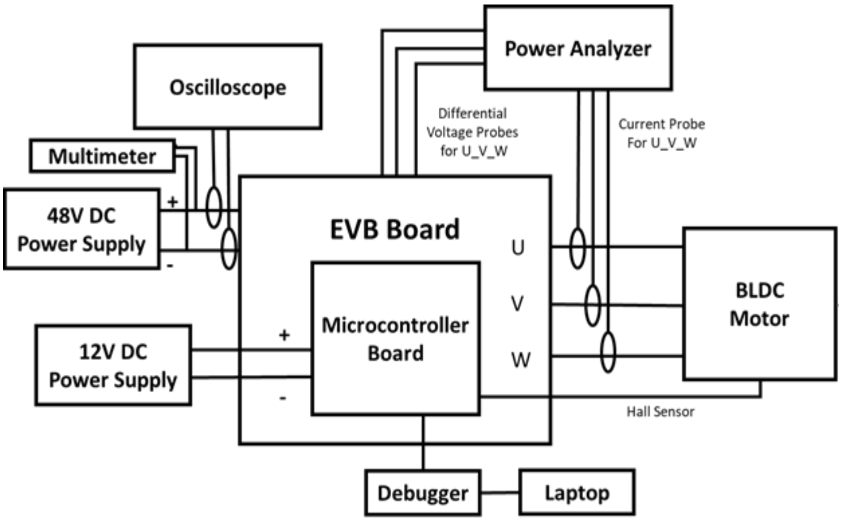


Figure 4-1 Schematic diagram of the test setup

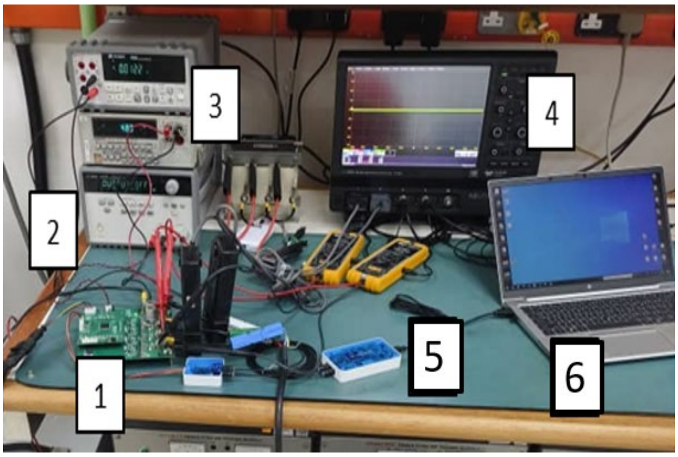


Figure 4-2 Test Setup

Table 4-1 Test Setup equipment

Unit	Description
1	Power Board & Controller Board
2	12V & 48V DC power Supply
3	Digital Multimeter
4	Power Analyzer (Four-Channel)
5	Debugger
6	Laptop

4.2 Operation Waveform

Measurements were carried out on several parameters of MOSFETs during operation, including turn off surge voltage, turn on switching time, turn off switching time and reverse recovery current. The following operation waveforms display the measurements on both low-side and high-side MOSFET at conditions of V_{DS} = 48V, I_{PHASE} = 60A.

4.2.1 Turn off Surge Voltage

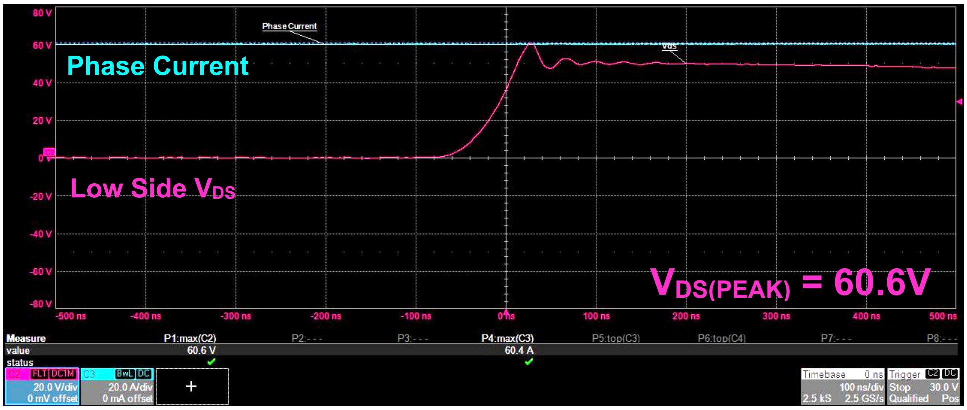


Figure 4-3 Low Side Turn Off Surge Waveform

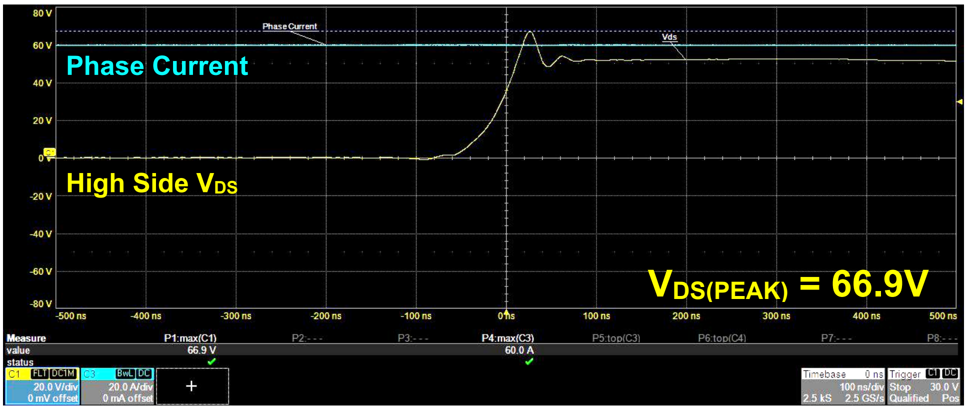


Figure 4-4 High Side Turn Off Surge Waveform

4.2.2 Turn on & off Switching Time

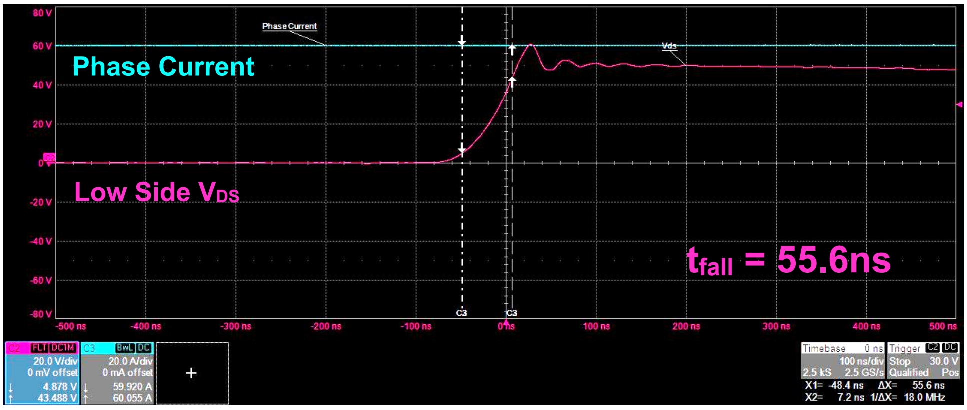


Figure 4-5 Low Side Turn off Switching Waveform

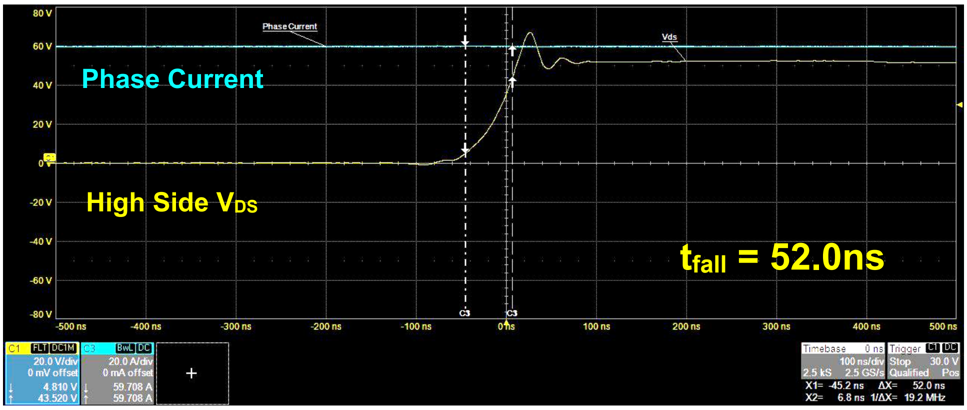


Figure 4-6 High Side Turn off Switching Waveform

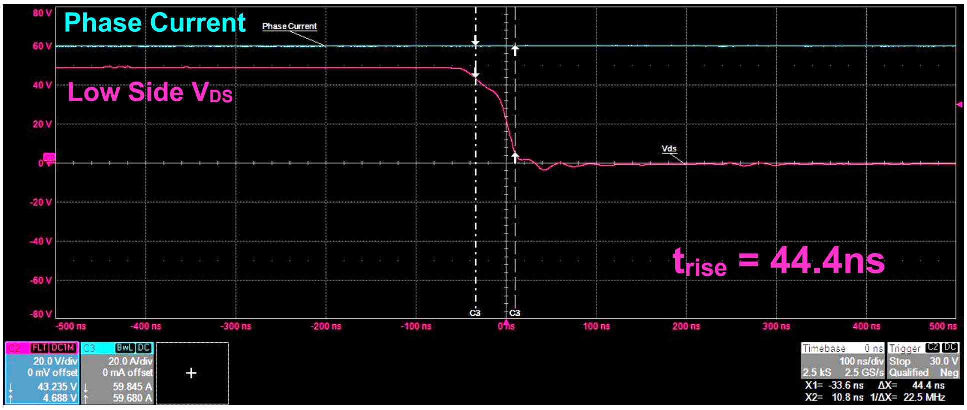


Figure 4-7 Low Side Turn on Switching Waveform

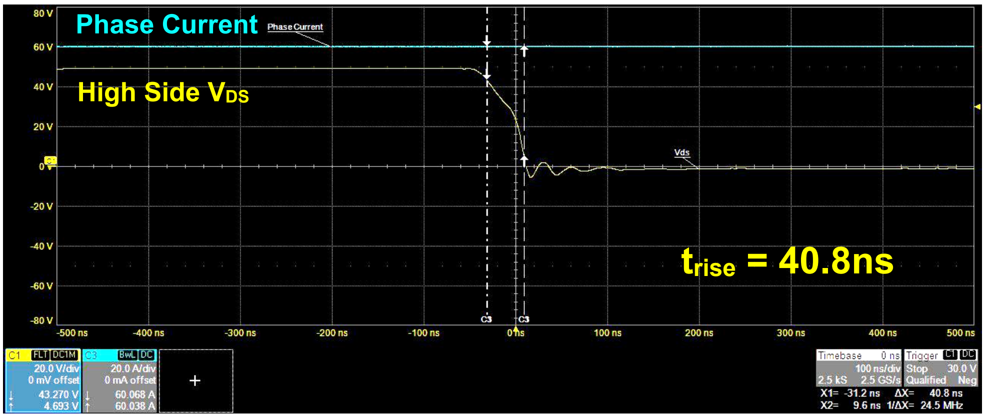


Figure 4-8 High Side Turn on Switching Waveform

4.2.3 Reverse Recovery Current

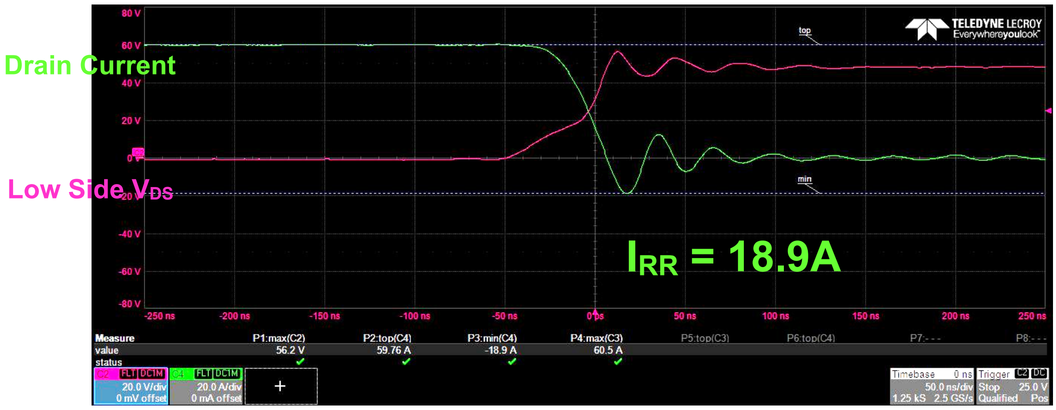


Figure 4-9 Low Side Turn Off Reverse Recovery Current Waveform

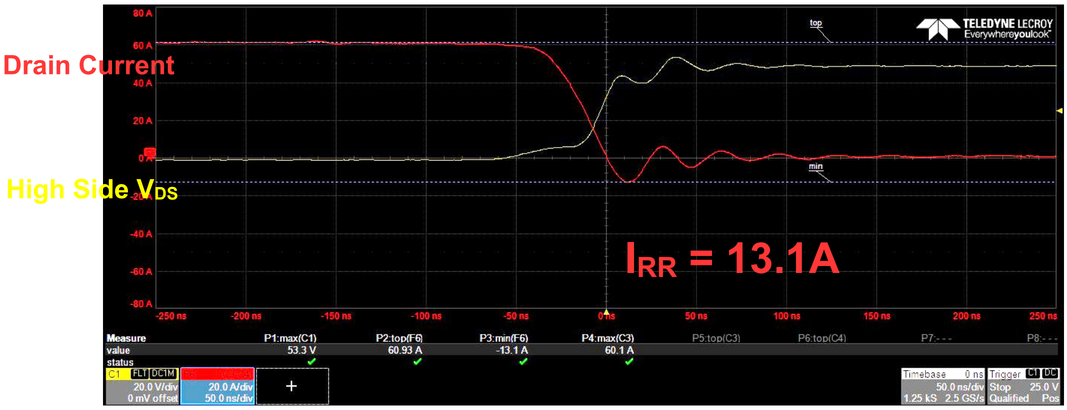


Figure 4-10 High Side Turn Off Reverse Recovery Current Waveform

4.3 Power Efficiency

Power efficiency measurements were carried out with BLDC motor at motor speed varies from 300RPM to 2100RPM under load condition. From the measurement, the efficiency achieves the highest at motor speed of 600RPM and consistently maintained an efficiency of over 60% up to 2100 RPM.

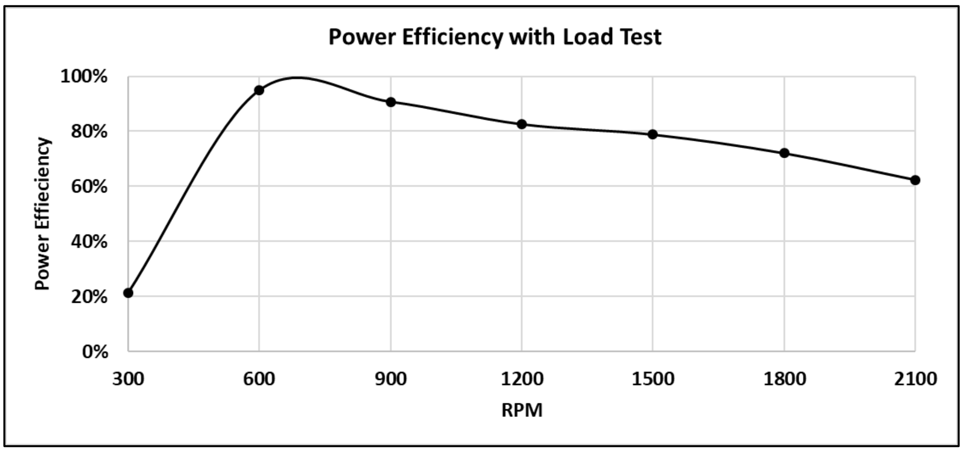


Figure 4-11 Power Efficiency Measurement Result

5. Schematic and PCB Layout

5.1 Schematic Layout

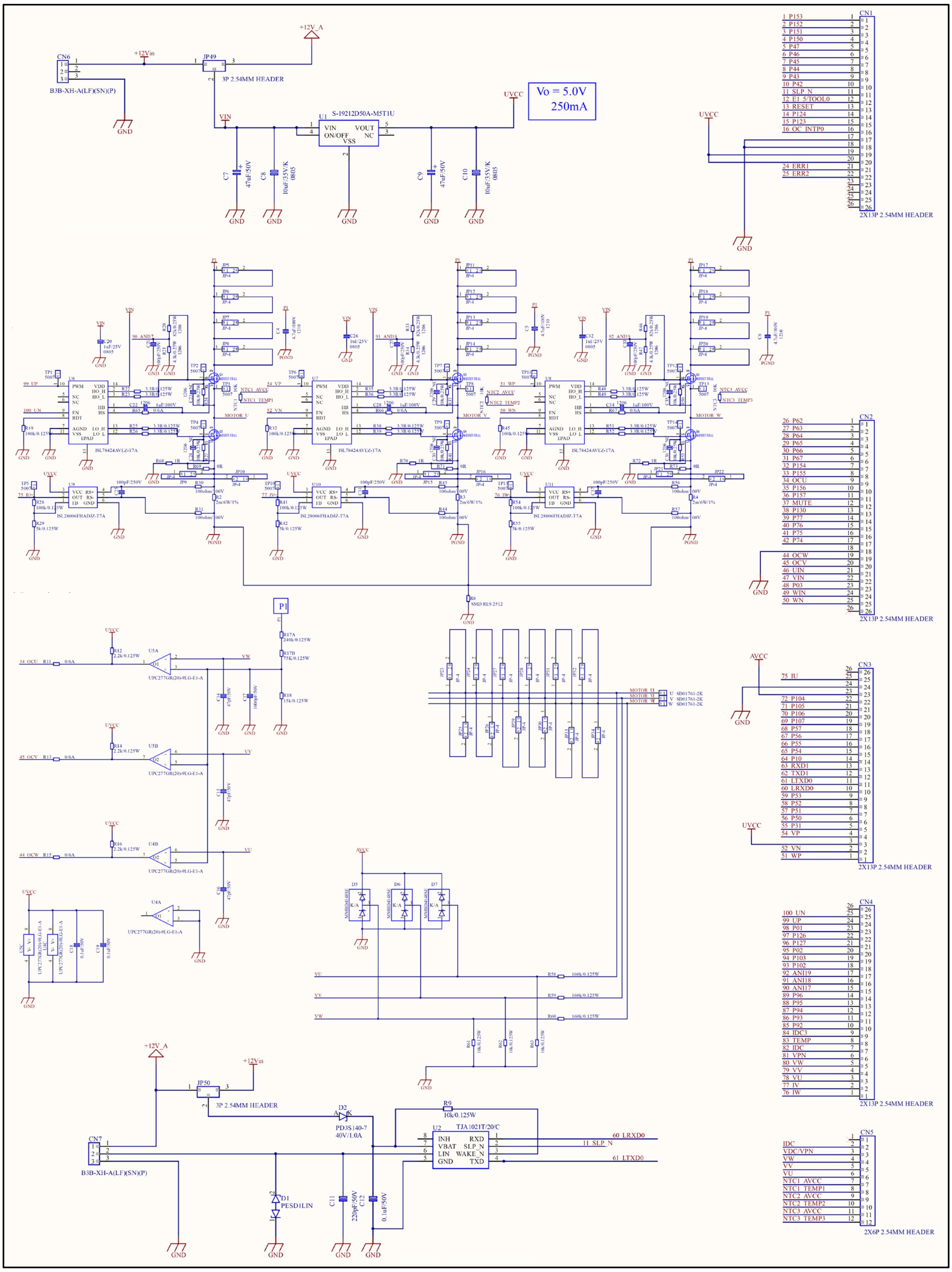


Figure 5-1 Power Board Schematic Diagram

5.2 PCB Layout

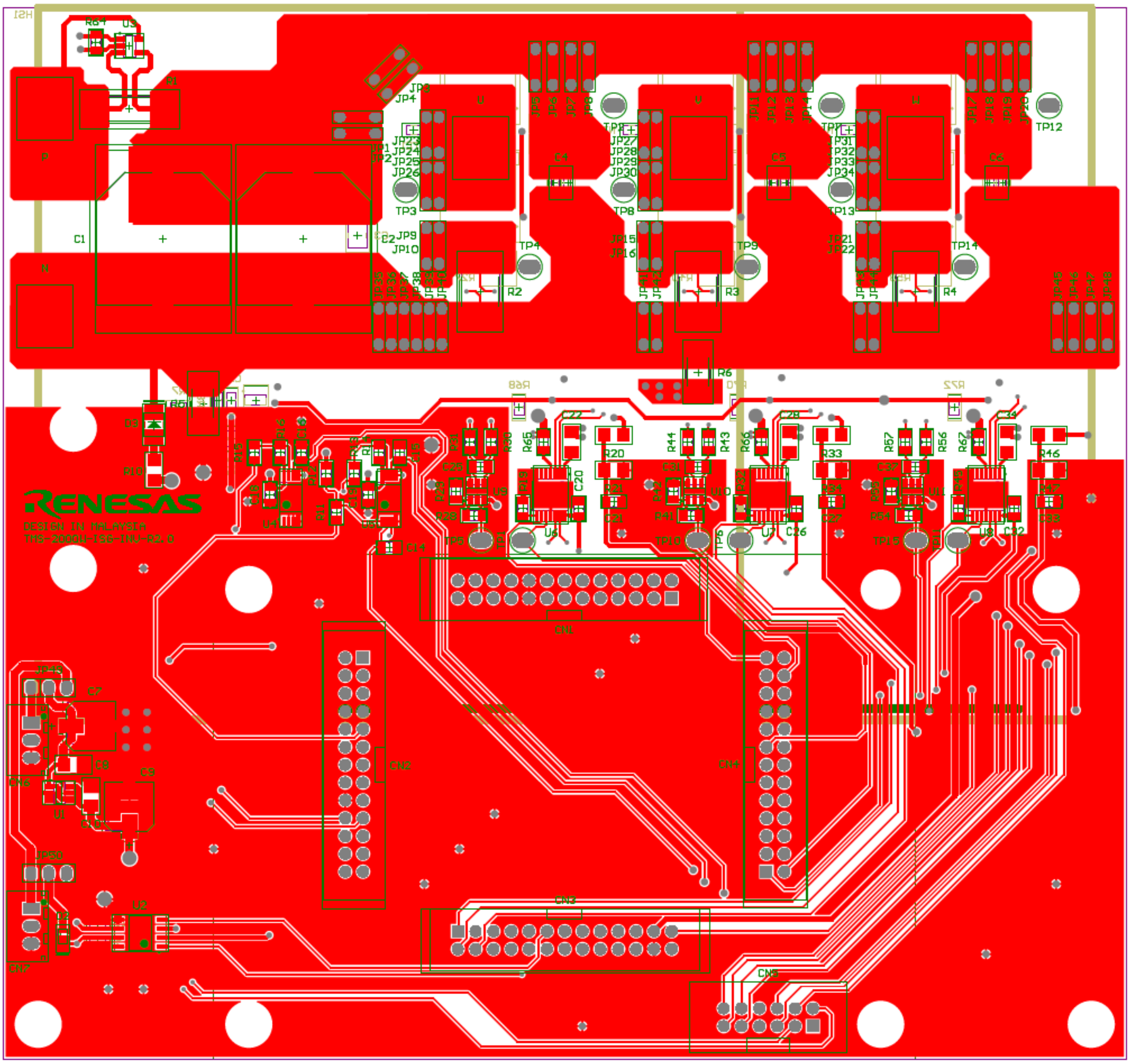


Figure 5-2 Top layer of Power Board PCB Layout

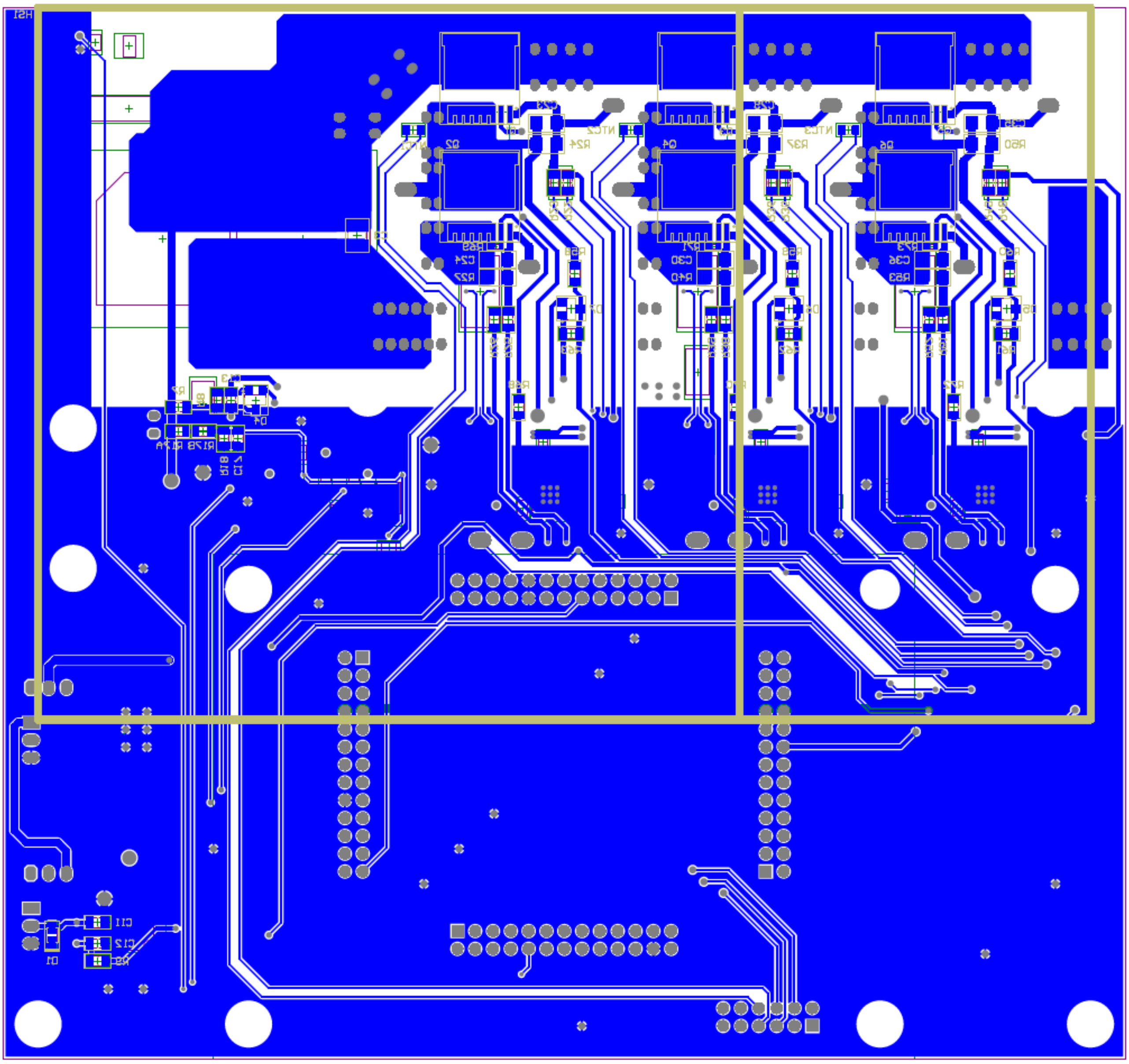


Figure 5-3 Bottom layer of Power Board PCB Layout

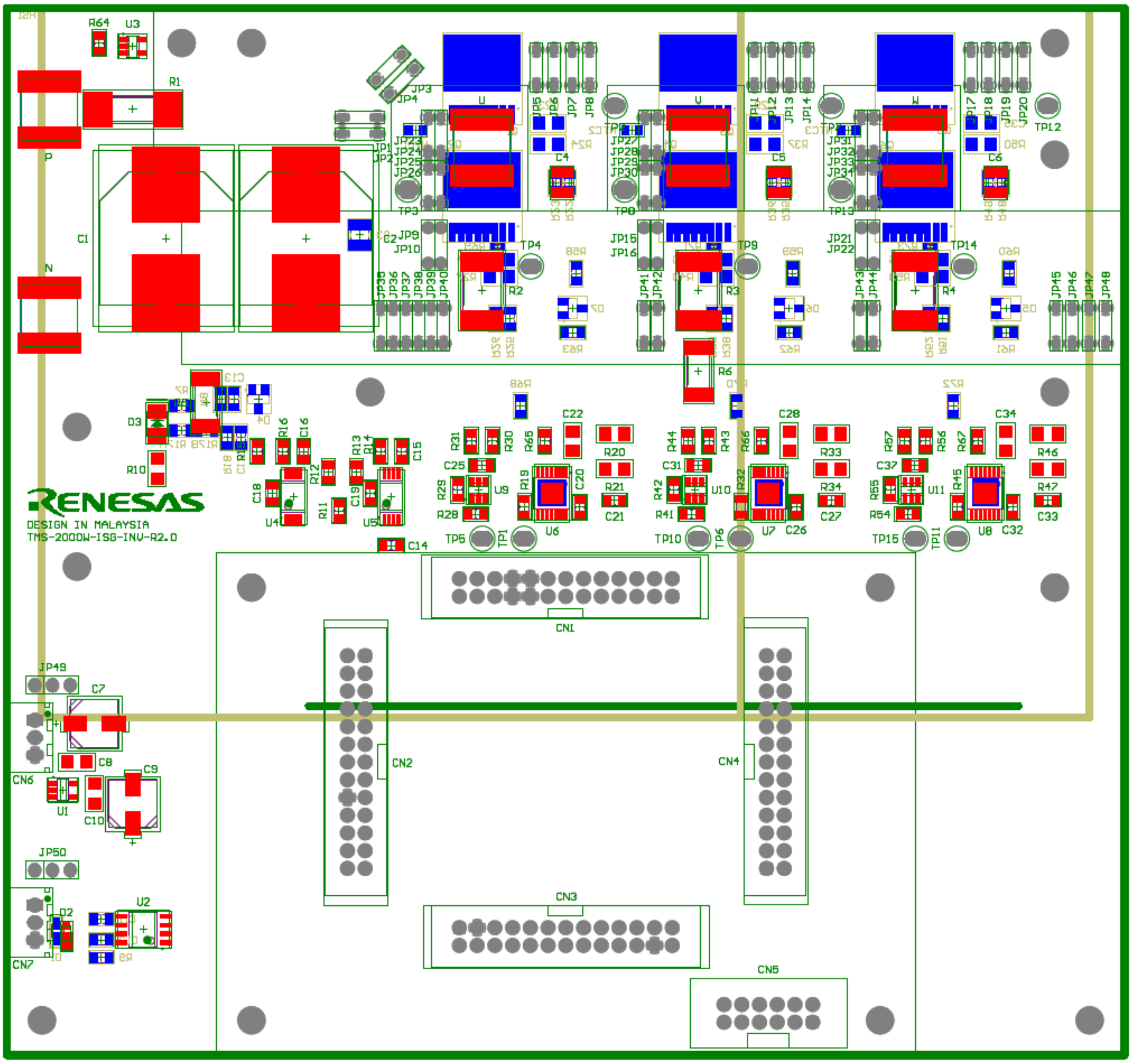


Figure 5-4 Silkscreen layer of Power Board PCB Layout

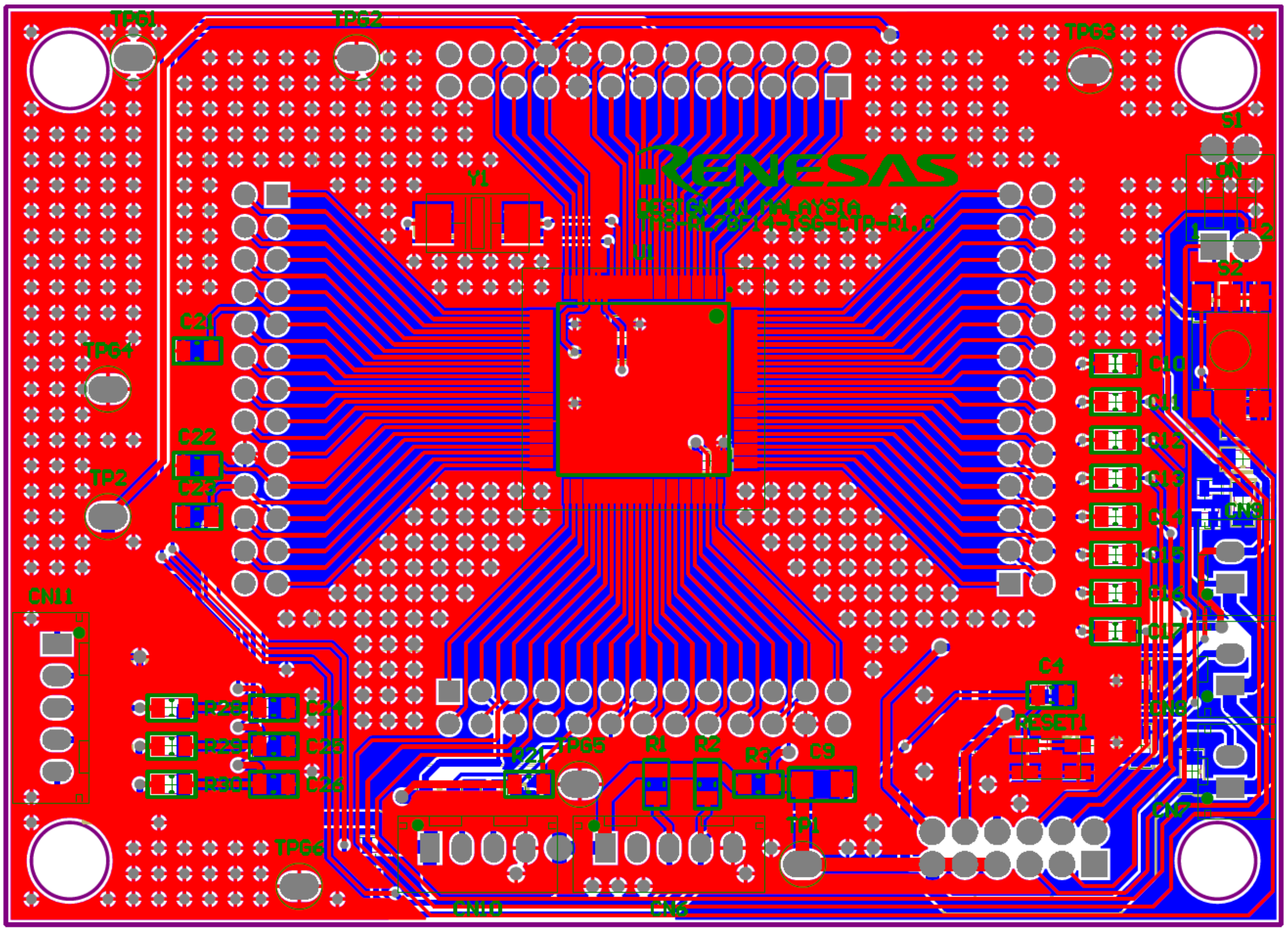


Figure 5-5 Controller Board PCB Layout

6. Bill of Material List

6.1 Power Board (TMS-2000W-ISG-INV-R2.0)

Designator	Component	Description / Package / Other	Value / Rating	Quantity
C1, C2	Capacitor	Aluminum Electrolytic / SMD	470uF / 100V	2
C3, C4, C5, C6	Capacitor	Multilayer Ceramic / SMD 1210	4.7uF / 100V	4
C7, C9	Capacitor	Aluminum Electrolytic / SMD	47uF / 50V	2
C8, C10	Capacitor	Multilayer Ceramic / SMD 1206	10uF / 50V	2
C11	Capacitor	Multilayer Ceramic / SMD 0805	220pF / 50V	1
C12, C18, C19	Capacitor	Multilayer Ceramic / SMD 0805	0.1uF / 50V	3
C13, C21, C25, C27, C31, C33, C37	Capacitor	Multilayer Ceramic / SMD 0805	100pF / 250V	7
C14, C15, C16	Capacitor	Ceramic / SMD 0805	47pF / 50V	3
C17	Capacitor	Multilayer Ceramic / SMD 0805	1000pF / 50V	1
C20, C26, C32	Capacitor	Multilayer Ceramic / SMD 0805	1uF / 25V	3
C22, C28, C34	Capacitor	Multilayer Ceramic / SMD 1206	1uF / 100V	3
C23, C24, C29, C30, C35, C36	Capacitor	Ceramic / SMD 1206	NC (not connected)	6
CN1, CN2, CN3, CN4	Board to Board connector	2X13P 2.54 MM Through Hole Mount	SSW-113-01-T-D	4
CN5	Board to Board connector	2X6P 2.54 MM Through Hole Mount	SSW-106-01-G-D	1
CN6, CN7	Conn Header	Connector [3]	B3B-XH-A(LF)(SN)(P)	2
D1	Diode	ESD Protection Device/ SOD-323/ PESD1LIN / 115	70V	1
D2	Diode	Schottky Rectifier / PD3S140-7	40V / 1.0A	1
D3	LED	RPL-LED 2 WAY-GREEN	AL1411A-YG-2mA	1
D4, D5, D6, D7	Diode	Small Signal/ Dual Series / MMBD4148SE	100V / 1200mA / 4ns	4
HS1	Heatsink	890 SP 01500-A-100	W-101.6mm/ L-150 mm/ H-32mm	1
JP1, JP2, JP3, JP4, JP5, JP6, JP7, JP8, JP9, JP10, JP11, JP12, JP13, JP14, JP15, JP16, JP17, JP18, JP19, JP20, JP21, JP22, JP23, JP24, JP25, JP26, JP27, JP28, JP29, JP30, JP31, JP32, JP33, JP34, JP35, JP36, JP37, JP38, JP39, JP40, JP41, JP42, JP43, JP44, JP45, JP46, JP47, JP48	Jumper wire	Mac 8 JP-4	5.08MM Through Hole	48
JP49, JP50	Conn Header	Vert SGL 3P Gold 2.54MM Header	961103-6404-AR	2
N, P, U, V, W	Screw Terminal	SD01761-2K SMT Surface Mount	SMD Screw terminal (M4)	5
NTC1, NTC2, NTC3	Thermistor	NTC SMD / NTCS0805E3103JMT	10K	3
Q1, Q2, Q3, Q4, Q5, Q6	MOSFET	RBA300N10EANS-3UA02 / TOLL	100V, 300A	6
R1	Resistor	SMD Current sense Resistor / OARSXPR002FLF	2m / 5W	1
R2, R3, R4	Resistor	SMD Moisture Resistant / CSS2H-3920K-2L00FE	2m / 6W / 1%	3
R5, R6	Resistor	SMD 2512 / MP001078	0 Ohm	1
R7	Resistor	Ceramic / SMD 0805	20k / 0.125W	1
R8	Resistor	Sulfur Resistant / SMD 0805	1.1k / 0.125W	1
R9	Resistor	Precision / SMD 0805	10k	1

Designator	Component	Description / Package / Other	Value / Rating	Quantity
R10	Resistor	Precision / SMD 1206	4.7k / 0.25W	1
R11, R13, R15, R65, R66, R67	Resistor	SMD 0805 / RCW08050000ZSTA	0 ohm	6
R12, R14, R16	Resistor	General Purpose / SMD 0805	2.2k / 0.125W	3
R17A, R64	Resistor	Thick Film / SMD 0805	240k / 0.125W	2
R17B	Resistor	General Purpose / SMD 0805	75K / 0.125W	1
R18	Resistor	General Purpose / SMD 0805	15k / 0.125W	1
R19, R28, R32, R41, R45, R54	Resistor	General Purpose / SMD 0805	100k / 0.125W	6
R20, R33, R46	Resistor	General Purpose / SMD 1206	82k / 0.25W	3
R21, R34, R47	Resistor	Sulfur Resistant / SMD 1206	4.3k / 0.25W	3
R22, R23, R25, 26, R35, R36, R38, R39, R48, R49, R51, R52	Resistor	General Purpose / SMD 0805	3.3R / 0.125W	12
R24, R27, R37, R40, R50, R53	Resistor	Precision / SMD 1206	10k / 0.25W	6
R29, R42, R55	Resistor	General Purpose / SMD 0805	5k / 0.125W	3
R30, R31, R43, R44, R56, R57	Resistor	General Purpose / SMD 0805	100ohm / 100V	6
R58, R59, R60	Resistor	General Purpose / SMD 0805	160k / 0.125W	3
R61, R62, R63	Resistor	General Purpose / SMD 0805	16k / 0.125W	3
R68, R70, R72	Resistor	General Purpose / SMD 0805	1R	3
R69, R71, R73	Resistor	General Purpose / SMD 0402	0 ohm	3
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15	Test Point	Through Hole / 5007	WHITE	15
U1	Voltage Regulator	SOT23-5 / S-19212D50A-M5T1U	5V / 250mA	1
U2	LIN transceiver	SOP8_225 / TJA1021T/20/C	8-SOIC	1
U3	Current Sense Amplifier	INA168NA	1Amplifier / 2uA	1
U4, U5	Dual Comparator	UPC277GR (20)-9LG-E1-A	8-Pin TSSOP	2
U6, U7, U8	Gate Driver	ISL78424_full_1	HTSSOP-14	3
U9, U10, U11	Current Sense Amplifier	ISL28006-ADJ	6 LD SOT-23	3

6.2 Controller Board (TMS-RL78F14-ISG-CTR-R1.0)

Designator	Component	Description / Package / Other	Value / Rating	Quantity
C1, C4	Capacitor	Multilayer Ceramic / SMD 2012	1.0uF / 25V	2
C2, C3	Capacitor	Multilayer Ceramic / SMD 0805	22pF / 100V	2
C5, C6, C7, C8, C18, C19, C20, C27	Capacitor	Multilayer Ceramic / SMD 0603	0.1uF / 50V	8
C9	Capacitor	Multilayer Ceramic / SMD 1206	10uF / 50V	1
C10, C11, C12, C13, C14, C21, C22, C23	Capacitor	Multilayer Ceramic / SMD 0805	100pF / 50V	8
C15, C16, C17	Capacitor	Ceramic CAP	47pF / 50V	3
C24, C25, C26	Capacitor	Multilayer Ceramic / SMD 0805	1000pF / 50V	3
CN1, CN2, CN3, CN4	Pin Header	T821 Series / Wire-to-Board	2X13P 2.54MM Socket	4
CN5	Pin Header	T821 Series / Wire-to-Board	2X6P 2.54MM Socket	1
CN6, CN11	Conn Header	B5B-XH-A(LF)(SN)	5POS 2.54MM	2
CN7, CN8, CN9	Conn Header	B2B-XH-A(LF)(SN)	2POS 2.54MM	3
CN10	Conn Header	B4B-XH-A(LF)(SN)	4POS 2.54MM	1
D1, D2, D3, D4	Diode	Small Signal Diode / Dual Series	100V / 200mA / 4ns	4
L1, L2, L3, L4, L5	Ferrite Chip	Chip / HF30ACB201209-T	7 Ohm 600mA 0805	5
R1, R2, R28 , R29, R30	Resistor	General Purpose / SMD 0805	1.0k / 0.125W	5
R3	Resistor	General Purpose / SMD 0805	4.70 / 0.125W	1
R4, R6, R8, R24, R25, R26	Resistor	General Purpose / SMD 0805	2.0k / 0.125W	6
R5, R7, R9, R10, R11, R12, R21, R22, R23	Resistor	Precision / SMD 0805	10k / 0.125W	9
R13, R14, R15, R16, R17, R18, R19, R20	Resistor	Automotive AEC-Q200 / SMD 0603	100 / 0.1W	8
R27	Resistor	Thick Film / SMD 0805	0 ohm / 6A	1
RESET1	Tactile Switch	SKRPABE010	50mA at 16VDC	1
S1	DIP Switch	SSGM120100	0.1A / 50V	1
S2	Tactile Switch	SKHM Series / Top push	6.2×6.5mm Type (Surface Mount)	1
TP1, TP2	Test Point	Through Hole / 5006	White	2
TPG1, TPG2, TPG3, TPG4, TPG5, TPG6	Test Point	Through Hole / 5007	Black	6
U1	Micro Controller	RL78F14 MCU	LQFP P-LFQFP100-14x14-0.50	1
Y1	Crystal oscillators	KYOCERA / CX8045GA04000D0PTWCC	4Mhz	1

Revision History

Rev.	Date	Description	
		Page	Summary
1.0	2024.11.13	-	First edition

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