Renesas Solution Starter Kit
Motor Control Evaluation System
- Motor Control IC: RAJ306102 -

RAJ306102 RSSK User's Manual

Renesas Electronics
www.renesas.com

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General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

For Your Safety

Do not fail to read this manual before using the RAJ306012 Renesas Solution Starter Kit

(RTK0EML2J0S00020BJ) (this product).

- Follow the indications in this manual when using the product.
- Keep this manual near the product so you can refer to it whenever necessary.
- Transfer or sale of the product to third parties is prohibited without written approval.
- The purchaser or importer of the product is responsible for ensuring compliance with local regulations. In addition, the customer is responsible for ensuring that the product is handled correctly and safely, in accordance with the laws of the customer's country (region).
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- By purchasing the product or downloading the documents from Renesas Electronics website, the support services provided from Renesas Electronics is not guaranteed.

Meaning of Notations

In this manual items related to the safe use of the product are indicated as described below.

The degree of injury to persons or damage to property that could result if the designated content in this manual is not followed is indicated as follows.

⚠ **Danger**	Indicates content that, if not followed, could result in death or serious injury Note.1 to the user, and which is highly urgent.
⚠ **Warning**	Indicates content that, if not followed, could result in death or serious injury to the user.
⚠ **Caution**	Indicates content that, if not followed, could result in injury Note.2 to persons or physical damage. Note.3

Note.1: Serious injury refers to conditions resulting in persistent after-effects and for which treatment would necessitate hospitalization or regular hospital visits, such as loss or impairment of eyesight, burns (high- or low-temperature), electric shock, bone fracture, or poisoning.

Note.2: Injury refers to conditions for which treatment would necessitate hospitalization or regular hospital visits.

Note.3: Physical damage refers to damage affecting the wider surroundings, such as the user's home or property.

Requirements related to the handling of the product are classified into the following categories.

- Marks indicating that an action is prohibited.

🚫	General Prohibition The indicated action is prohibited.	✋	Example: Do Not Touch! Touching the specified location could result in injury.

- Marks indicating that an action is prohibited.

⚠	General Caution Indicates a general need for caution that is not specified.	♨	Example: Caution – Hot! Indicates the possibility of injury due to high temperature.

- Marks directing that the specified action is required.

❗	General Instruction The specified action is required.	🔌	Example: Turn Off (Disconnect) Power Supply! Instructs the user to turn off (disconnect) the power supply to the product.

Warnings Regarding Use of the Product

■ Danger Items

<table>
<tr>
<td colspan="2" align="center">⚠ Danger</td>
</tr>
<tr>
<td>❗
🔥
🔄</td>
<td>

The product should be used only by persons (users) having a thorough knowledge of electrical and mechanical components and systems, a full knowledge of the risks associated with handling them, and training in inverter motor control and handling motors, or equivalent skills. Users should be limited to persons who have carefully read the Caution Items contained in this manual.
Unlike typical equipment, the product has no protective case to ensure safety, and it contains moving parts and high-temperature components that could be dangerous. Do not touch the evaluation board or cables while power is being supplied.
Carefully check to make sure that there are no pieces of conductive materials or dust adhering to the board, connectors, and cables.
There are moving parts, driven by a motor. Do not touch the motor while power is being supplied.
Ensure that the motor is insulated and placed in a stable location before supplying power.

</td>
</tr>
<tr>
<td>🚫</td>
<td>
Do Not Connect Load to Motor!

This could cause fire, burns, or injury.

</td>
</tr>
</table>

■Warning Items

<table>
<tr>
<td colspan="2" align="center">⚠ Warning</td>
</tr>
<tr>
<td>🔄</td>
<td>
Caution – Rotating Parts!

The system includes a motor. Touching the rotating shaft could cause high-temperature burns or injury.

</td>
</tr>
<tr>
<td rowspan="4">❗</td>
<td>
Always insert plugs, connectors, and cables securely, and confirm that they are fully inserted.

Incomplete connections could cause fire, burns, electric shock, or injury.

</td>
</tr>
<tr>
<td>
Use the power supply apparatus specified in the manual.

Failure to do so could cause fire, burns, electric shock, injury, or malfunction.

</td>
</tr>
<tr>
<td>
Disconnect the power supply and unplug all cables when the system will not be used for a period of time or when moving the system.

Failure to do so could cause fire, burns, electric shock, or malfunction.
This will protect the system against damage due to lightning.

</td>
</tr>
<tr>
<td>
Use a mechanism (switch, outlet, etc.) located within reach to turn off (disconnect) the power supply.

In case of emergency, it may be necessary to cut off the power supply quickly.

</td>
</tr>
<tr>
<td>🔌</td>
<td>
Turn off the power supply immediately if you notice abnormal odor, smoke, abnormal sound, or overheating.

Continuing to use the system in an abnormal condition could cause fire, burns, or electric shock.

</td>
</tr>
<tr>
<td>🚫</td>
<td>
Do Not Disassemble, Modify, or Repair!

Doing so could cause fire, burns, electric shock, injury, or malfunction.
Disassembly, remodeling, repair, or modification should be done at the customer's own risk, and should be done safely after carefully checking the circuitry.

</td>
</tr>
<tr>
<td>🚫</td>
<td>
Do not use the product for any purpose other than initial evaluation of motor control in a testing room or lab. Do not integrate the product or any part of it into other equipment. Do not insert or remove cables or connectors when the product is powered on.

The product has no safety case.
Failure to observe the above could cause fire, electric shock, burns, or malfunction.
The product may not perform as expected if used for other than its intended purpose.

</td>
</tr>
</table>

■ Caution Items

	⚠ Caution
⚠	Caution – Hot! ● The motor gets hot. Touching it could cause high-temperature burns.
❗	Follow the procedure specified in the manual when powering the system on or off. ● Failure to do so could cause overheating or malfunction.
⚠	Caution – Static Electricity ● Use the antistatic band. Failure to do so could cause malfunction or unstable motion.

CONTENTS

Renesas Solution Starter Kit
Motor Control Evaluation System
- Motor Control IC: RAJ306102 -

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Chapter 1. Overview

The Renesas Solution Starter Kit Motor Control Evaluation System - Motor Control IC: RAJ306102 - [RTK0EML2J0S00020BJ] (now referred to as RAJ306102 RSSK) is an evaluation kit for the RAJ306102. The RAJ306102 is a motor control IC consisting of the RL78/G1F (R5F11BLEGFB) and a smart gate driver (RAA306012). The RAJ306102 evaluation board included in the evaluation kit enables motor control by inverter operation.

This Evaluation Board is initially equipped with a sample program for 120-degree conducting control using Hall sensors. The basic motor control evaluation is available by connecting the attached motor, changing the Evaluation Board to a configuration suitable for control use, and supplying DC 24[V]. In addition, it is possible to connect and evaluate a motor other than the attached motor and external MOSFET board prepared by the user.

Related Documents:

The related documentation and sample program for the Renesas Solution Starter Kit BLDC Motor Evaluation System for RAJ306102 (Motor Control IC) [RTK0EML2J0S00020BJ] can be downloaded from our motor solution website.

Motor Solution Website:

https://www.renesas.com/us/en/key-technologies/motor-control-robotics/motor-control-solutions

RAJ306102 Evaluation Board (Evaluation Board)

·Schematic   : R12TU0225EJ

·BOM LIST   : R12TU0231EJ

·PWB Pattern Drawing   : R12TU0251EJ

RAJ306102 Product Information Website:

https://www.renesas.com/RAJ306102

RAJ306102 RSSK Product Information Website:

https://www.renesas.com/RTK0EML2J0S00020BJ

Package Contents

Item	Renesas Solution Starter Kit Motor Control Evaluation System - Motor Control IC: RAJ306102 -	Quantity
Board	RAJ306102 Evaluation Board (RTK0EML2J0D01021BJ)	1
Motor	TG-55L-KA 24V	1
Motor Cable	Motor Cable for TG-55L-KA, 24V	1
Ferrite Core	E04SR200932	1
Paper	Motor Control Evaluation System - Motor Control IC: RAJ306102 -	1
	Caution regarding the Renesas Solution Starter Kit Motor Control Evaluation System - Motor Control IC: RAJ306102 -	1

Equipment to Prepare for

Item of the Necessary Unit	Model Name (Specification)
Power supply	Use for the bundled motor: 24[V]/2[A]
USB cable	USB micro-B cable x2 Note.1
Motor (optional)	Available connecting a motor other than the attached motor
Shunt resistors (optional)	When connecting a motor other than the attached motor, change the shunt resistance according to the characteristics of the motor
0[Ω] registers (optional)	The 0[Ω] resisters are used to change the connection, 1005[mm] or 1608[mm] size registers are available (solder shorts are available too)

Note.1 USB cable for connecting with PC is necessary to use Renesas Motor Workbench or IDE.

Abbreviations

Abbreviations	Full Name	Remarks
RAJ306102 RSSK	Renesas Solution Starter Kit Motor Control Evaluation System - Motor Control IC: RAJ306102 -	Product No.: RTK0EML2J0S00020BJ
Evaluation Board	RAJ306102 Evaluation Board	Product No.: RTK0EML2J0D01021BJ

1.1   Feature

1. **Easy to start the motor control evaluation with RAJ306102.**
    Since the reference sample program has already been written on Evaluation Board, the user can start the evaluation immediately by changing the Evaluation Board configuration suitable for control and supplying DC 24[V]. (Factory Default Setting of the Evaluation Board is 120-degree conducting control using Hall sensors.)

2. **Board with high expandability and operability (180 mm x 140 mm).**
    Since the switches, potentiometers, LEDs, and thermistors are mounted, the Evaluation Board is small and easy to operate. Their functions can be used by using the user program.

3. **Connectable to the external MOSFET board.**
    By changing the MOSFET connection selection resistors, it is possible to select mounted MOSFETs or external MOSFET board.

4. **Various sample software for the basic motor control.**
    Sample programs for the basic control required for BLDC Motor control can be downloaded from the website.
    ・120-degree conducting control using Hall sensors
    ・Sensorless 120-degree conducting control.

    RAJ306102 Sample programs download website:
    https://www.renesas.com/RTK0EML2J0S00020BJ

5. **Support Renesas Motor Workbench tool.**
    Renesas Motor Workbench is a tool for monitoring and changing global variables in operation from a PC. For details of the features and instructions on using the tool, refer to Renesas website.

Chapter 2. Product Specifications

2.1 Outline

Table 2-1 Specification List for RAJ306102 RSSK

Item	Specification
Kit name	Renesas Solution Starter Kit Motor Control Evaluation System - Motor Control IC: RAJ306102 - (RAJ306102 RSSK)
Kit product No.	RTK0EML2J0S00020BJ
Power supply	VM power supply range: DC 24[V] Use a stable power supply such as a stabilized power supply equipment or a battery. The power supply to the VM provides 3.3[V] or 5.0[V] to the Control Board from the built-in LDO of the smart gate driver.
Operation temperature	Room temperature
Operation humidity	No condensation
MOSFET	TPH12008NH (80[V], 24[A])
Sensor	Hall sensor or sensorless
Connector	・ USB for E2 Lite (E2OB) ・ USB for Renesas Motor WorkBench (Now referred to as RMWB) ・ External MOSFET connector (CN_EXT_MOS) [Note.1] ・ Hall sensor signal input connector (CN_HALL) [Note.2] ・ Analog general-purpose input/output connector (CN_ANA) [Note.1] ・ Digital general-purpose input/output connector (CN_DIGI1) [Note.1] ・ I2C communication connector (CN_I2C) [Note.1] ・ SPI communication connector (CN_SPI) [Note.1] ・ UART communication connector (CN_UART) [Note.1] ・ External volume connector (CN_VOL) [Note.1]
Switch/Potentiometer	Toggle SW x2 Potentiometer x1 Tact switch for RESET x1
LED	LED x7
Wave viewer tool	Renesas Motor Workbench tool is supported The latest tool is available from Renesas website

Note.1: The Evaluation Board has through holes for mounting the connector. When using this function, please mount the connector.
         For details on this function, refer to- Chapter 4.
Note.2: The connector is mounted on the Evaluation Board.

2.2 Evaluation Board

Table 2-2 Specification List for Evaluation Board

Item	Specification
Board name	RAJ306102 Evaluation Board (Evaluation Board)
Product No.	RTK0EML2J0D01021BJ
Power supply	VM power supply range: DC 6[V] to 48[V] Note.1 Use a stable power supply such as a stabilized power supply equipment or a battery. (Use bundled motor: DC24[V]/2[A] power supply)
Operation temperature	Room temperature
Operation humidity	No condensation
MOSFET	TPH12008NH (80[V], 24[A])
Sensor	Hall sensor or sensorless
Connector	・ USB for E2 Lite (E2OB) ・ USB for Renesas Motor WorkBench (RMWB) ・ External MOSFET connector (CN_EXT_MOS) Note.2 ・ Hall sensor signal input connector (CN_HALL) Note.3 ・ Analog general-purpose input/output connector (CN_ANA) Note.2 ・ Digital general-purpose input/output connector(CN_DIGI1) Note.2 ・ I^{2}C communication connector (CN_I2C) Note.2 ・ SPI communication connector (CN_SPI) Note.2 ・ UART communication connector (CN_UART) Note.2 ・ External volume connector (CN_VOL) Note.2
Switch/Potentiometer	Toggle switch x2 Potentiometer x1
LED	LED x7
Wave viewer tool	Renesas Motor Workbench tool is supported The latest tool can be received from Renesas website

Note.1: The maximum VM rating of the RAJ306102 is 65[V], but due to the Low Voltage Directive (LVD), this kit supports a maximum VM of 48[V].
Note.2: The Evaluation Board has through holes for mounting the connector. When using this function, please mount the connector. For details on this function, refer to Chapter 4.
Note.3: The connector is mounted on the Evaluation Board.
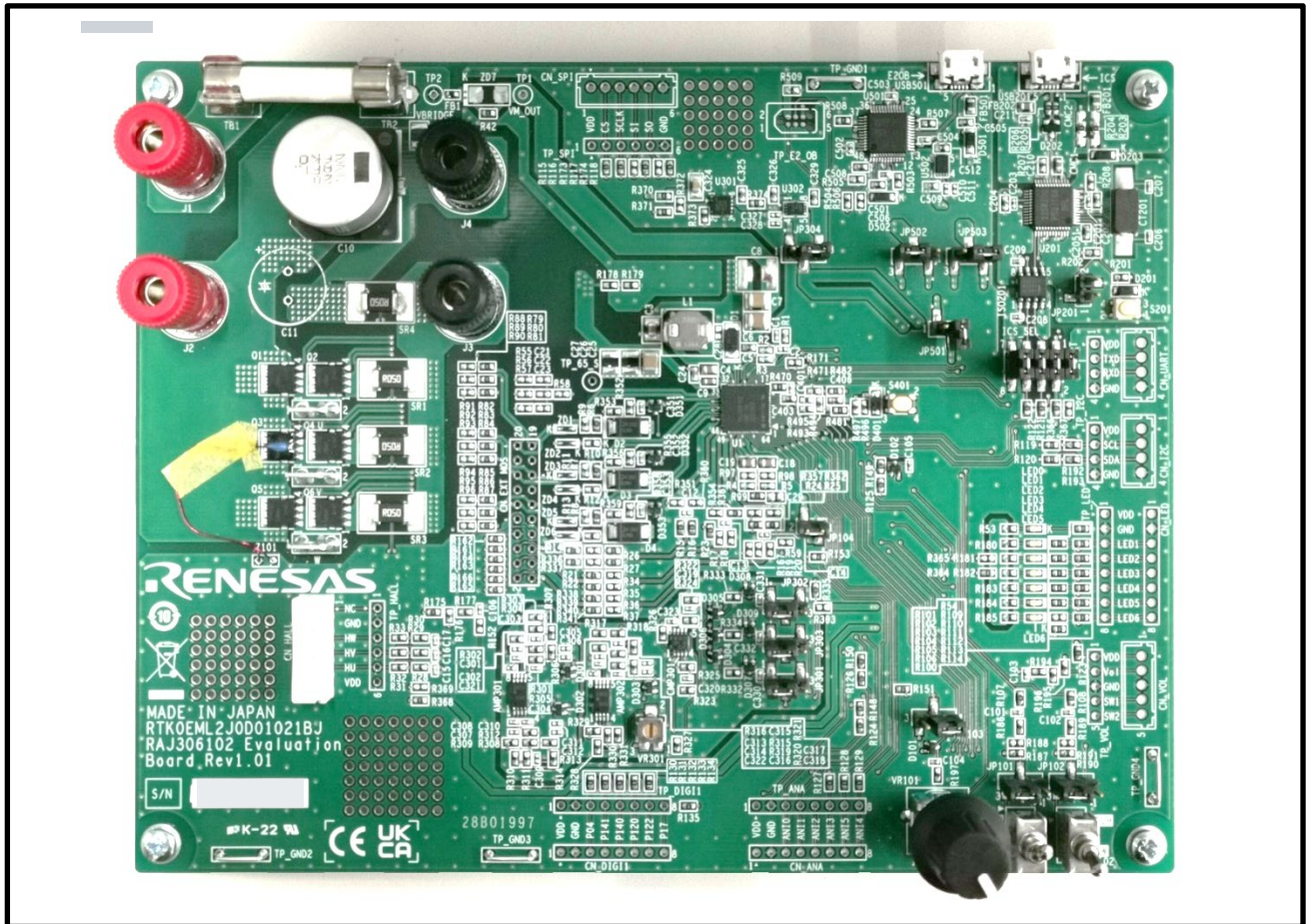
2.2.1   Appearance

Figure 2-1 Appearance

2.2.2   Block Diagram
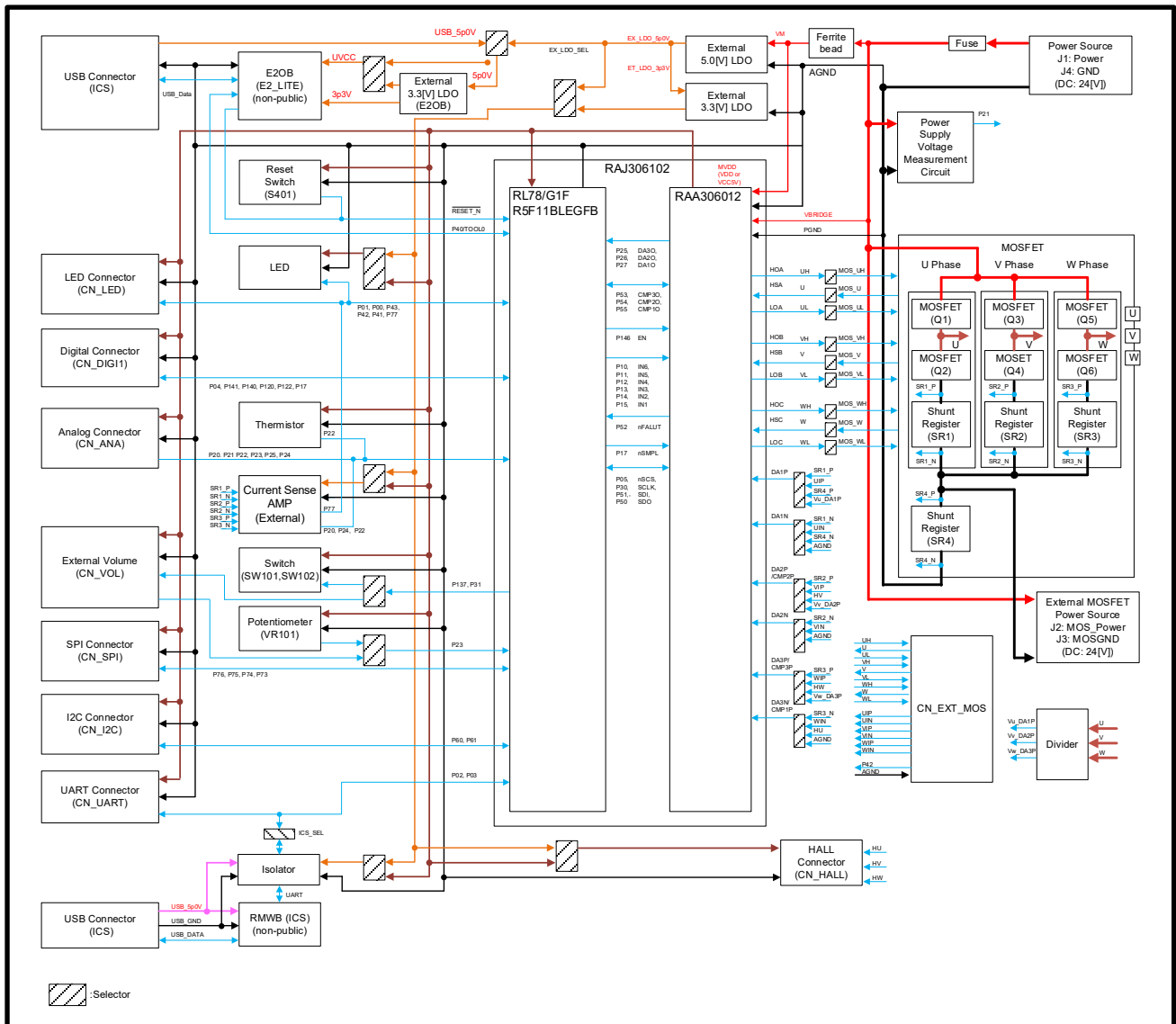
Figure 2-2 Block Diagram

2.2.3   Pin Assignment and Connection on Evaluation Board

Table 2-3 Pin Assignments and Connection on Evaluation Board

Pin No.	RAJ306102	Connection on Evaluation Board	Note
1	P02/TxD1	ICS/CN_UART_2	
2	P01	LED1/CN_LED_3	
3	P00	LED2/CN_LED_4	
4	P141	CN_DIGI1_4	
5	P140	CN_DIGI1_5	
6	P120	CN_DIGI1_6	
7	P43	LED3/CN_LED_5	
8	P42	LED4/CN_LED_6	
9	P41	LED5/CN_LED_7	
10	P40/TOOL0	E2OB	
11	RESET_N	Reset Switch (S401)/E2OB	
12	P137/INTP0	SW101/(CN_VOL_4)	
13	P122	CN_DIGI1_7	
14	REGC	—	
15	GND_MCU	MVDD	
16	VDD_MCU	AGND	
17	P60/SCLA0	CN_I2C_2	
18	P61/SDAA0	CN_I2C_3	
19	P31	SW102/(CN_VOL_5)	
20	P77/(INTP11)	OC#/(LED6)/CN_LED_8	
21	P76/INTP0	CS/CN_SPI_2	
22	P75/SCK01	SCLK/CN_SPI_3	
23	P74/SI01	SI/CN_SPI_4	
24	P73/SO01	SO/CN_SPI_5	
25	P17/nSMPL	CN_DIGI1_8	
26	PC	—	
27	FB	—	
28	VM	VM	
29	SW1	—	
30	VDRV	—	
31	CPL	—	
32	CPH	—	
33	VCP	—	
34	VBRIDGE	VBRIDGE	
35	HOA	UH/CN_EXT_MOS_19	
36	HSA	U/CN_EXT_MOS_20	
37	LOA	UL/CN_EXT_MOS_17	
38	NC	NC(Open)	
39	HOB	VH/CN_EXT_MOS_15	
40	HSB	V/CN_EXT_MOS_16	
41	LOB	VL/CN_EXT_MOS_13	
42	NC	NC(Open)	
43	HOC	WH/CN_EXT_MOS_11	
44	HSC	W/CN_EXT_MOS_12	
45	LOC	WL/CN_EXT_MOS_9	
46	PGND	PGND	
47	DA1P	SR4_P/(SR1_P)/CN_EXT_MOS_6/(Vu_DA1P)	
48	DA1N	SR4_N/(SR1_N)/(AGND)/CN_EXT_MOS_5	
49	DA2P	CN_HALL_4/(SR2_P)/CN_EXT_MOS_4/(Vv_DA2P)	
50	DA2N	ANGD/(SR2_N)/CN_EXT_MOS_3	
51	DA3P	CN_HALL_3/(SR3_P)/CN_EXT_MOS_2/(Vw_DA3P)/(DA3O)	
52	DA3N	CN_HALL_5/(SR3_N)/(AGND)/CN_EXT_MOS_1	
53	VDD	MVDD	

Pin No.	RAJ306102	Connection on Evaluation Board	Note
54	AGND	AGND	
55	FBLDO	—	
56	VCC5V	MVDD	
57	P25/ANI5/DA3O	CN_ANA_7	
58	P24/ANI4	CN_ANA_8/IV_COM	
59	P23/ANI3	VR101/CN_ANA_6/(CN_VOL_2)	
60	P22/ANI2	CN_ANA_5/IW_COM	
61	P21/ANI1	CN_ANA_4/VBRIDGE_VOL	
62	P20/ANI0	CN_ANA_3/IU_COM	
63	P04	CN_DIGI1_3	
64	P03/RxD1	ICS/CN_UART_3	
—	EPAD	PGND	

2.2.4   Main Parts, Terminals, and Connectors

The Main Parts, Terminals, and Connectors on the Evaluation Board are in the layout as follows.
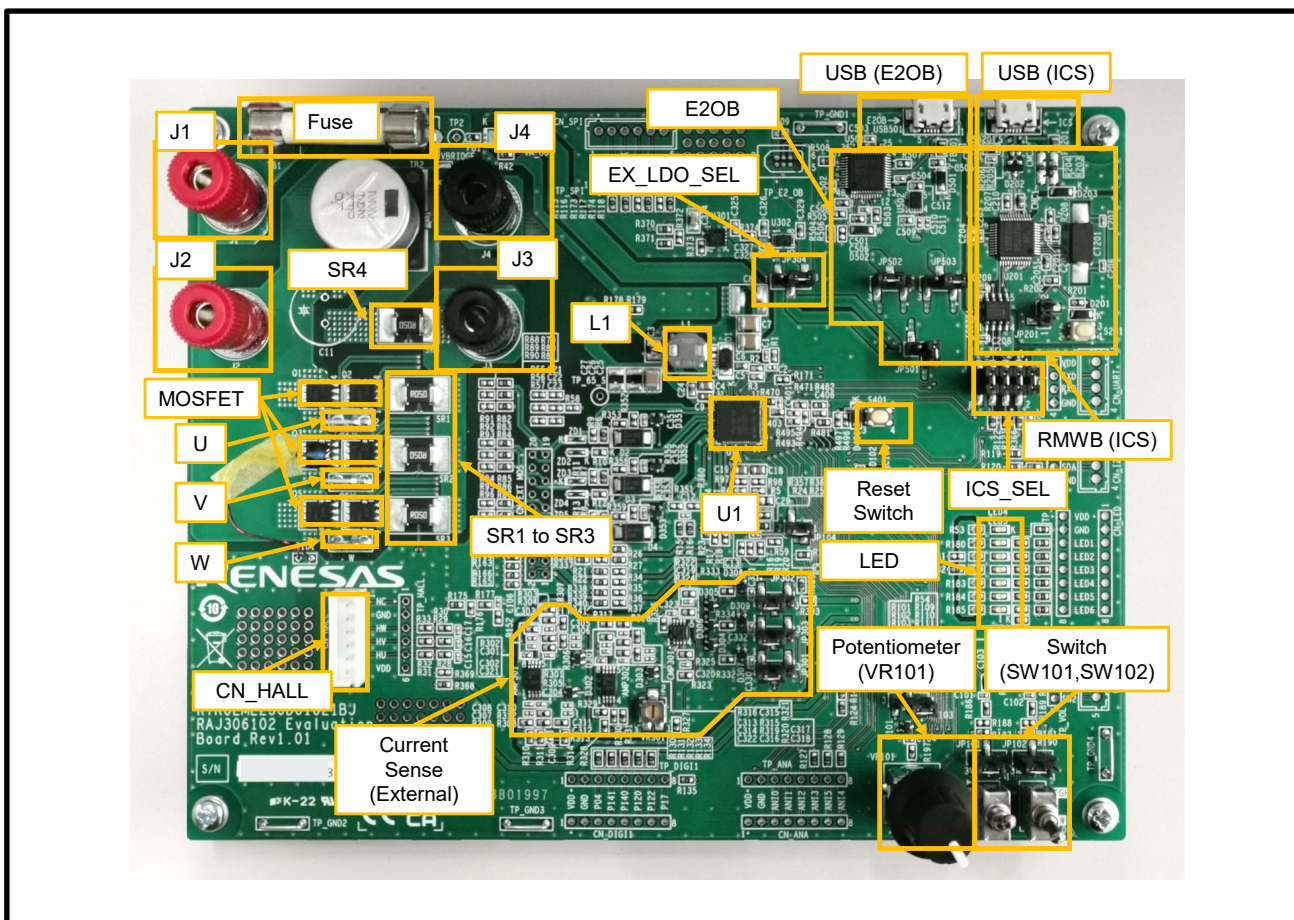
Figure 2-3 Main Parts, Terminals, and Connectors

Table 2-4 Main Parts, Terminals, and Connectors List

Parts Name	Item
U1	RAJ306102GNP (Motor Control IC)
Reset Switch (S401)	Reset for RAJ306102.
J1, J4	Power source terminal (J1: + side, J4: - side)
J2, J3	Power supply terminal for MOSFETs (J2: + side, J3: - side)
Fuse	Fuse (Fuse holder)
MOSFET	On-board MOSFET
U, V, W	Motor connection terminal
SR1 to SR3	Shunt resistors for phase current detection
SR4	Shunt resistor for power current detection
L1	Coil for VDRV
USB (E2OB)	USB terminal for E2OB (E2 Lite function)
E2OB	E2OB (E2 Lite function) circuit. This circuit is non-public
USB (ICS)	USB terminal for RMWB (ICS)
RMWB (ICS)	RMWB (ICS) circuit. This circuit is non-public
ICS_SEL	RMWB (ICS) selector. Short when using RMWB (ICS)
EX_LDO_SEL	External LDO selector
Current Sense (External)	External current sense circuit
Potentiometer (VR101)	Potentiometer for motor control
Switch (SW101, SW102)	Switch for motor control
LED	LEDs to indicate control status
CN_HALL	Connector for Hall sensor input
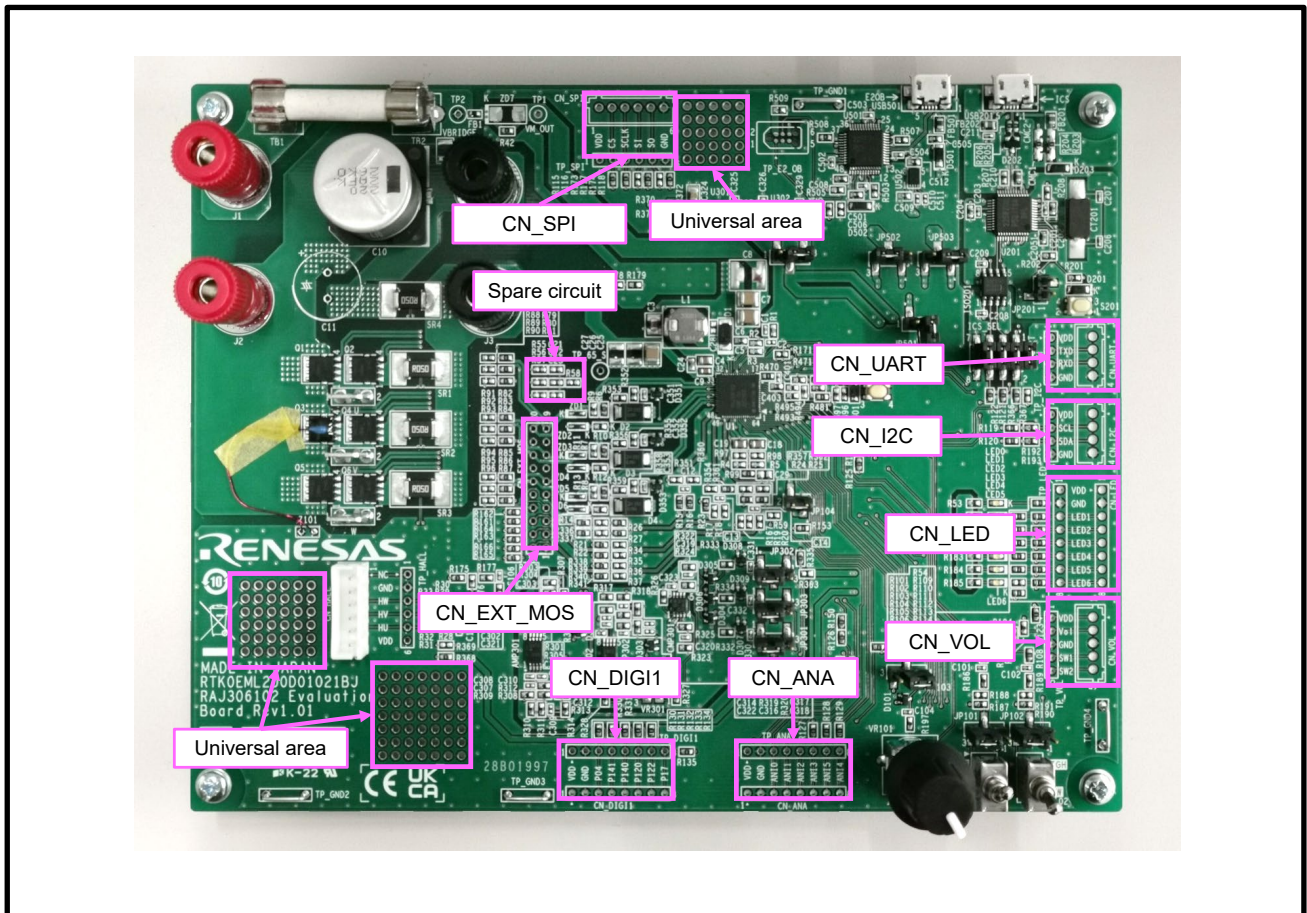
Figure 2-4 Unmounted Connectors and Other Circuits

Table 2-5 Unmounted Connectors and Other Circuits List

Parts Name	Item
CN_EXT_MOS	Connector for external MOSFET board
CN_ANA	Connector for external analog functions
CN_DIGI1	Connector for external digital functions
CN_VOL	Connector for external controller
CN_LED	Connector for external digital functions
CN_SPI	Connector for external SPI communication
CN_UART	Connector for external UART communication
CN_I2C	Connector for external I^{2}C communication
Spare circuit	Spare circuit that can be used for snubbers, etc.
Universal area	Universal area that can be used freely

2.3 Motor [TG-55L-KA 24V (TSUKASA ELECTRIC CO., LTD)]

Table 2-6 shows the specification of the attached motor. For the details of the motor specifications, refer to TSUKASA ELECTRIC website.

Table 2-6 TG-55L-KA 24V Motor Specification

Rated Voltage	24[V]
Rated Speed	2650[rpm]
No-Load Speed	3900[rpm]
Rated Current	420[mA]
No-Load Current	85[mA]
Torque	19.6[mN·m]

2.4 Cable for Motor Connection

The attached cable is used to connect the Evaluation Board and the attached motor. When using a motor other than the attached motor, connect to the motor referring to the parts list and the connection of the attached motor.

Figure 2-5 Motor Cable Connection

Table 2-7 Motor Cable Terminal Parts List

Parts Number	Product Name	Manufacturer
1	PHDR-12VS	J.S.T. MFG.
2, 3, 4	TMEDN 630809-FA	NICHIFU
5	XHP-6	J.S.T. MFG.

2.5   Ferrite Core [E04SR200932 (SEIWA ELECTRIC MFG.)]

The RAJ306102 RSSK includes a ferrite core to comply with the EMC Directive. Please use the ferrite core with 2 turns as necessary.

Figure 2-6 Ferrite Core

Chapter 3. Usage

The RAJ306102 RSSK is available for evaluation with some kinds of motor control methods by using the Evaluation Board, and Motor attached in this evaluation kit. This evaluation kit includes the following can be evaluated for two different control methods with sample programs. This chapter describes the control specifications, board settings, and operation guide when using the sample programs.

For details of the sample programs, please refer to the application notes and source files of each sample program.

- 120-degree conducting control using Hall sensors (*Application Note: R18AN0062EJ* (Factory default FW))

- Sensorless 120-degree conducting control (*Application Note: R18AN0062EJ*)

For changing the sample program, refer to *Chapter 5* Emulator Function and the manual for each development environment.

The appropriate board settings are required for each control method. Refer to the corresponding section for the board settings.

Using 0[Ω] resistors or short-circuiting with solder is required to change the board settings. [Note.1]

Note.1: This product does not include replacement 0[Ω] resistors. 0[Ω] resistors should be prepared by the user or short-circuited by soldering.

3.1 Factory Default Setting

In the factory default setting, the RAJ306102 RSSK is configured as a 120-degree Conducting Control Using Hall Sensors.

120-degree Conducting Control Using Hall Sensors evaluation is quickly available by combining the Evaluation Board, and motors that make up the kit.

Refer to *Figure 3-2 Setting of RAJ306102 RSSK for Motor Evaluation* for details on the evaluation method.

To evaluate other motor control methods, it is necessary to change the wiring of the Evaluation Board and the FW.
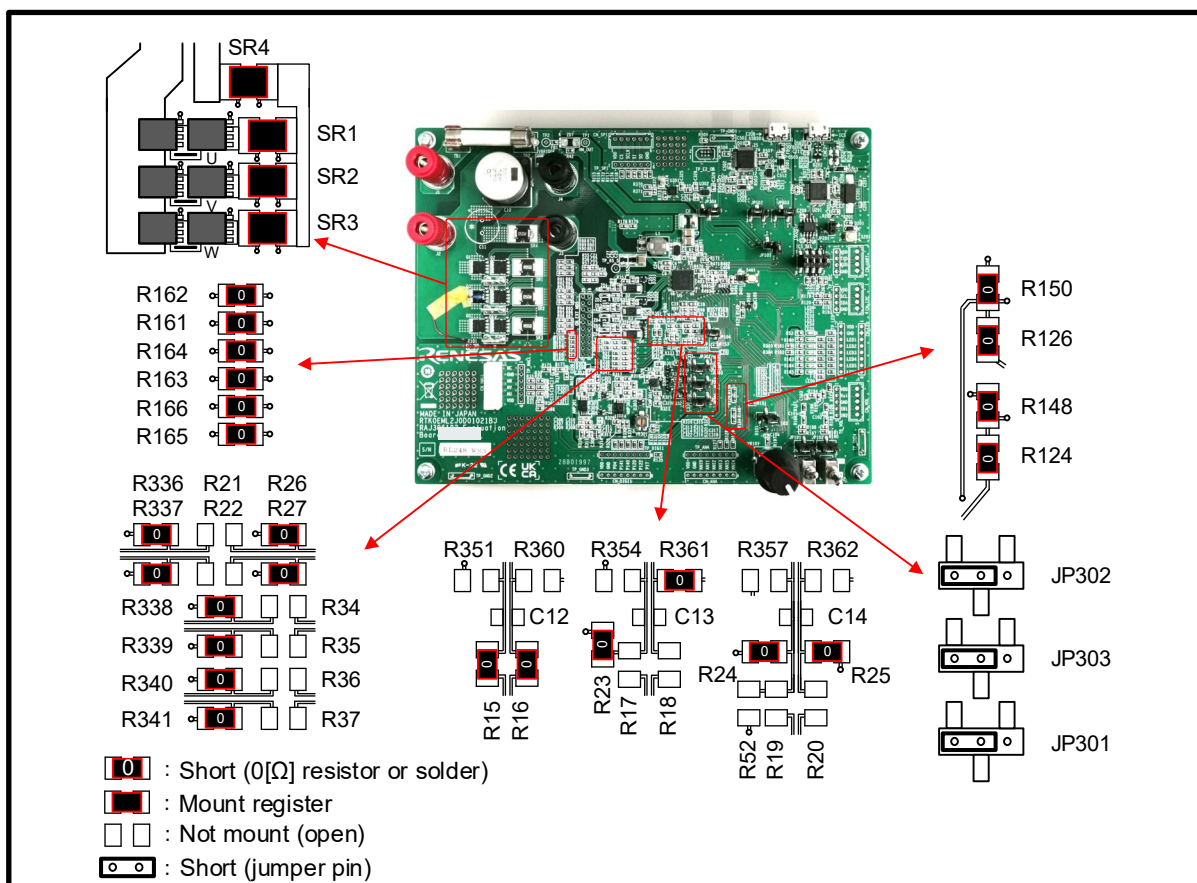

Figure 3-1 Factory Default Settings (120-degree Conducting Control Using Hall Sensors)
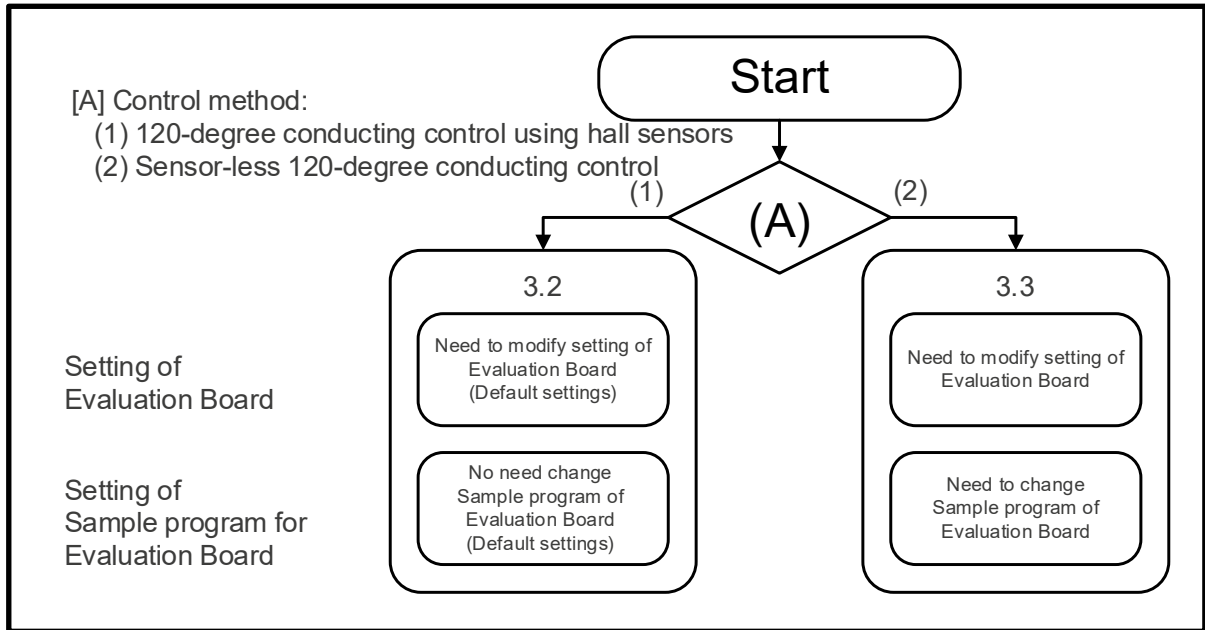
Figure 3-2 Setting of RAJ306102 RSSK for Motor Evaluation

3.2   120-degree Conducting Control Using Hall Sensors

3.2.1   Control Specifications

The 120-degree conducting control using Hall sensors is a method that controls the motor by switching the energized phase according to the Hall signal.

Table 3-1 shows the control specifications.

For details of the specifics of the program, please refer to the *Application Note "120-degree conducting control of permanent magnetic synchronous motor (Implementation) (R18AN0062EJ)" of RAJ306102.*

Table 3-1 Basic Specifications of 120-degree Conducting Control Using Hall Sensors Software

Item	Content
Control method	120-degree conducting method (chopping upper arm)
Motor rotation start/stop	Determined depending on the level of SW101 ("High": rotation start "Low": stop) or input from Renesas Motor Workbench
Position detection of rotor magnetic pole	Hall effect sensor: Position detection based on interruption of signal from Hall effect sensors (every 60 degrees) When position of rotor is detected, PWM duty and conducting pattern are set at same time.
Input voltage	DC 24[V]
Main clock frequency	CPU clock: f_{CLK} 32[MHz] TRD clock: f_{HOCO} 64[MHz]
Carrier frequency (PWM)	20[kHz]
Dead time	2[μs]
Control cycle	Speed PI control: every 1[ms]
Rotational speed control range	Hall effect sensor control mode: 530[rpm] to 3200[rpm] [(Note,1)] CW and CCW are supported
Optimization	Default
Processing stops for protection	Disables the motor control signal output (six outputs), under any of the following conditions. 1. Inverter bus voltage exceeds 28[V] (monitored per 1[ms]) 2. Inverter bus voltage is less than 15[V] (monitored per 1[ms]) 3. Rotational speed exceeds 3900[rpm] (monitored per 1[ms]) 4. Hall effect sensor interruptions are not detected for 200[ms]. 5. Detection of unexpected output voltage pattern 6. Detection of overcurrent by external circuit (low-level input) 7. Fault detection of the Smart Gate Driver

3.2.2 Board Settings

In the 120-degree conducting control using Hall sensors, the motor position is detected by the external Hall sensors and the Hall signals are input to the general-purpose comparators of the smart gate driver.

Align the board connection settings on the Evaluation Board with **Figure 3-3**. [Note.1]
For details on the circuit diagram of the Evaluation Board, refer to the **Schematic (R12TU0225EJ).**

Note.1: This setting is factory default setting. The 120-degree conducting control using Hall sensors can be evaluated without changing the board connection setting from factory default setting.
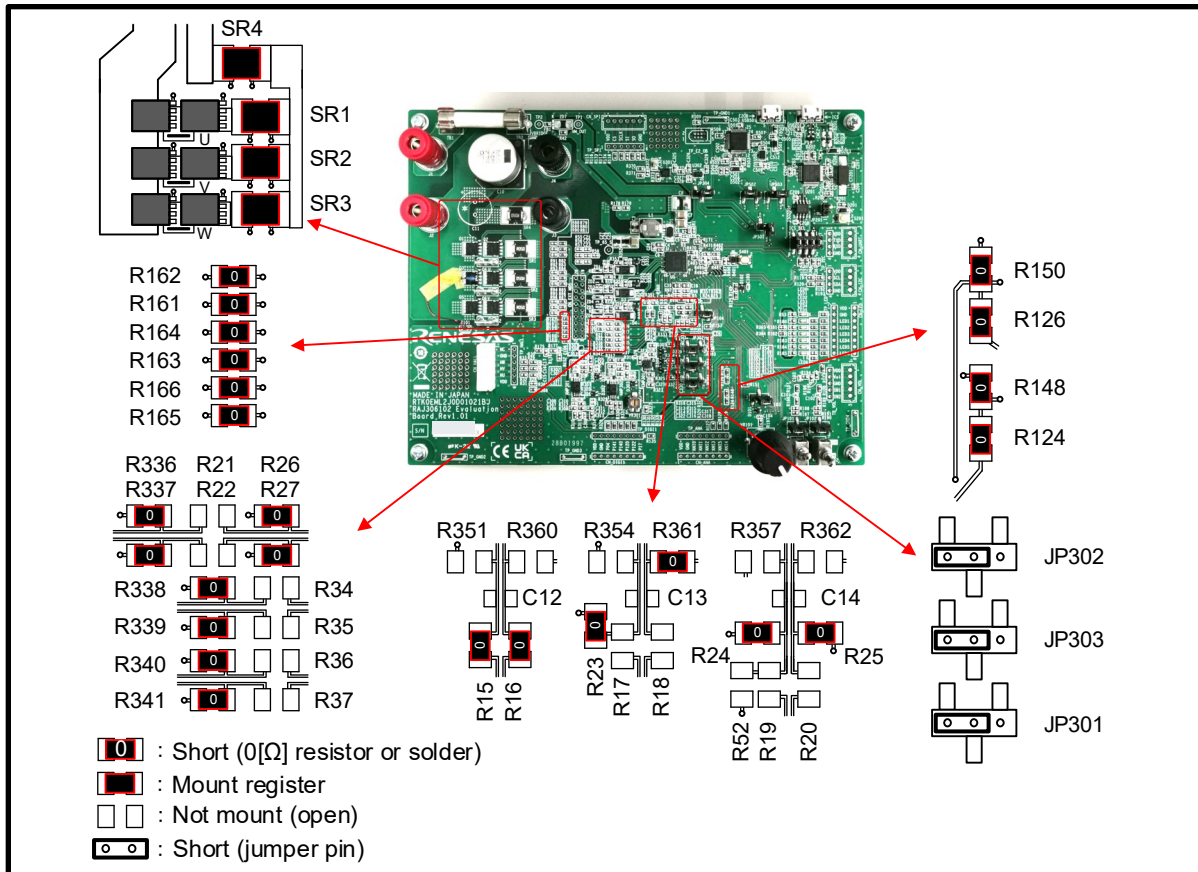
Figure 3-3 Board Connection Settings (120-degree Conducting Control Using Hall Sensors)

3.2.3   Operation Guide

3.2.3.1   Connections

Follow the procedures below to build the evaluation environment.

a. Write 120-degree conducting control using Hall sensors FW to the Evaluation Board.

b. Connect the Evaluation Board and the motor U, V, W, and Hall by the attached cable. (120-degree conducting control using Hall sensors control requires the connections of Hall signals.)

c. Connect the power source and the Evaluation Board. (Do not supply power at this time.)

The RAJ306102 RSSK includes a ferrite core to comply with the EMC Directive. Please use the ferrite core with 2 turns as necessary.

Power Source (Output: Off)
DC 24[V]／2[A] limit.

Ferrite Core (2 turns)

Evaluation Board

Motor Cable
(U: Orange line, V: White line, W: Blue line, Hall)

Motor (TG-55L-KA,24V)
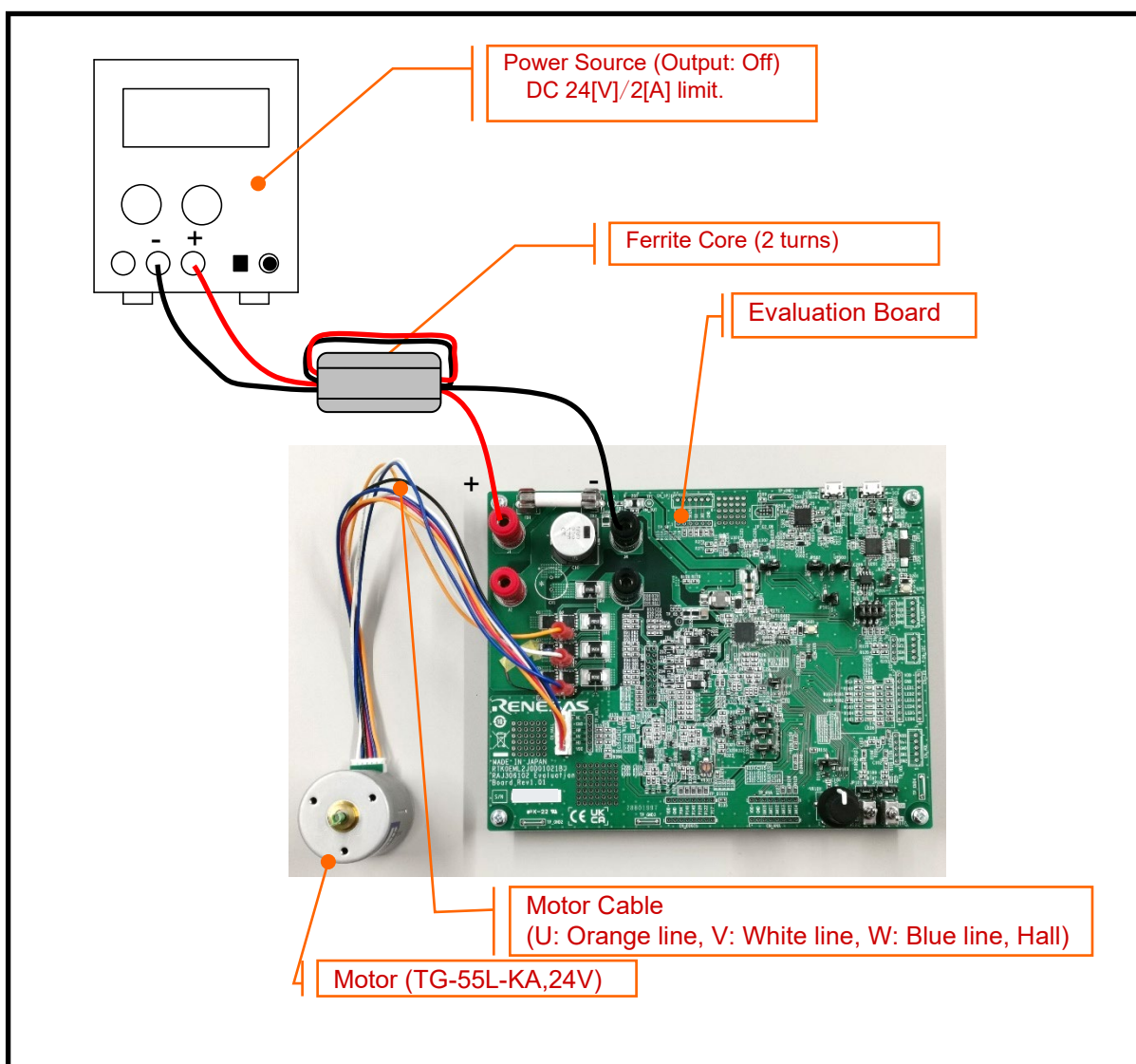
Figure 3-4 Connections for Evaluation Environment

3.2.3.2   Initial Setting

Set the toggle switches (SW101, SW102) to Low and set the potentiometer (VR101) to center.
(The state in which the knob mark is directly above the knob is called center. The potentiometer used on this board has a pivot point in the center position.)

Power Source (Output: Off)
DC 24[V]／2[A] limit

Evaluation Board

LED0
LED1
LED2
LED3
LED4
LED5
LED6

High
Low

SW101 SW102

VR101
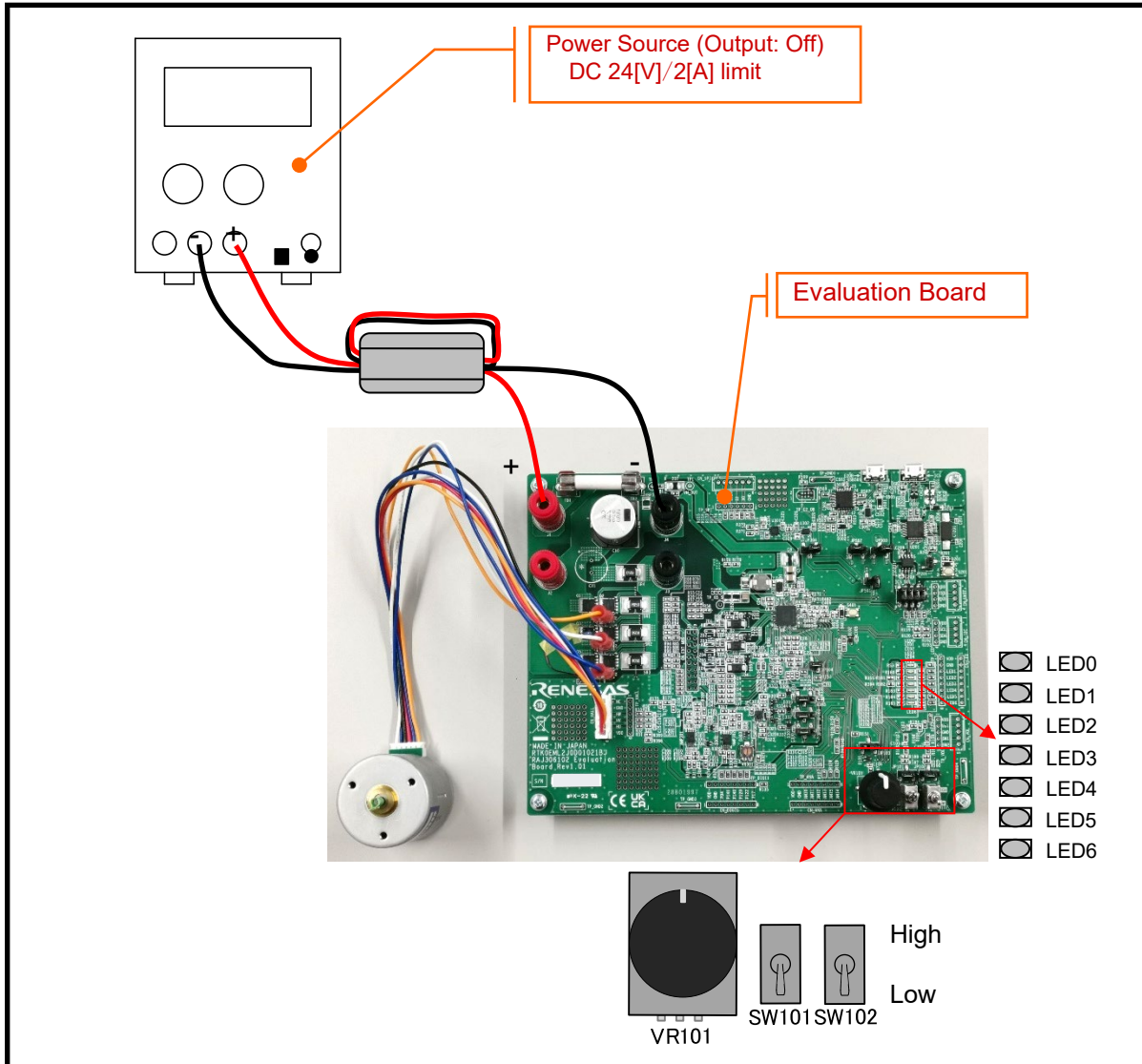
Figure 3-5 Initial Settings for Evaluation Board

3.2.3.3   Power Supply

Supply DC 24[V] to Evaluation Board.

The LED0 lights up when power is supplied.
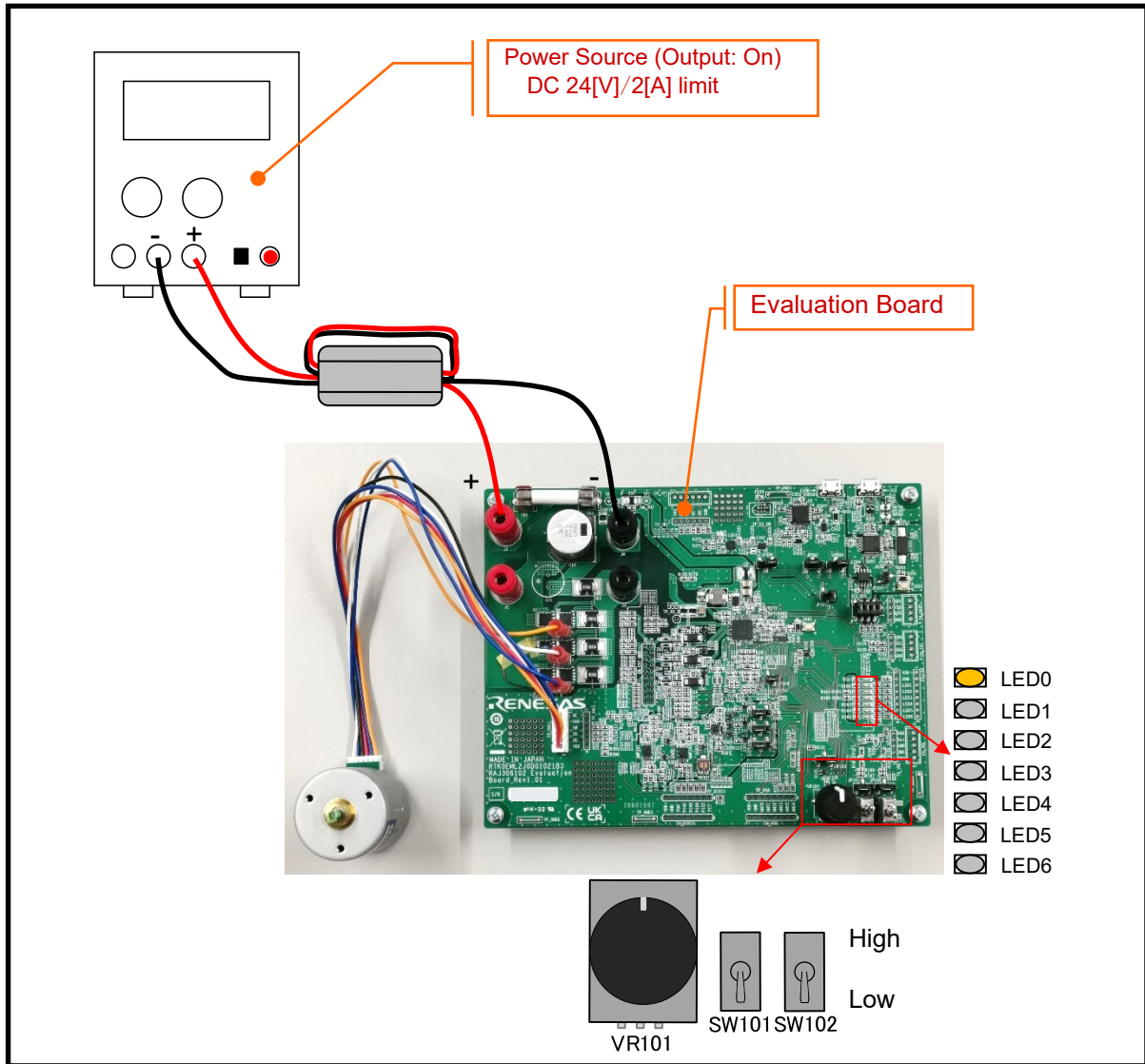
Figure 3-6 Power Supply for Evaluation Board

3.2.3.4   Motor Operation

Set SW101 to High and turn the potentiometer (VR101).

The motor rotates in the direction in which the potentiometer (VR101) is turned, according to the amount of turning. The LEDs lights up according to the control.

Figure 3-7 Motor Operation

3.2.3.5   Stop Motor Operation

To stop the motor, return the potentiometer (VR101) to the center and set SW101 to Low.

Figure 3-8 Stop Motor Operation

3.2.3.6   Stop Power Supply

Stop the power supply.

Power Source (Output: Off)
DC 24[V]／2[A] limit

Evaluation Board

LED0
LED1
LED2
LED3
LED4
LED5
LED6

High
Low

VR101   SW101 SW102

+

Figure 3-9 Stop Power Supply

3.3 Sensorless 120-degree Conducting Control

3.3.1 Control Specifications

The sensorless 120-degree conducting control is a method that controls the motor by switching the energized phase based on the inductive voltage (BEMF) generated by the motor rotation.

Table 3-2 show the control specifications.

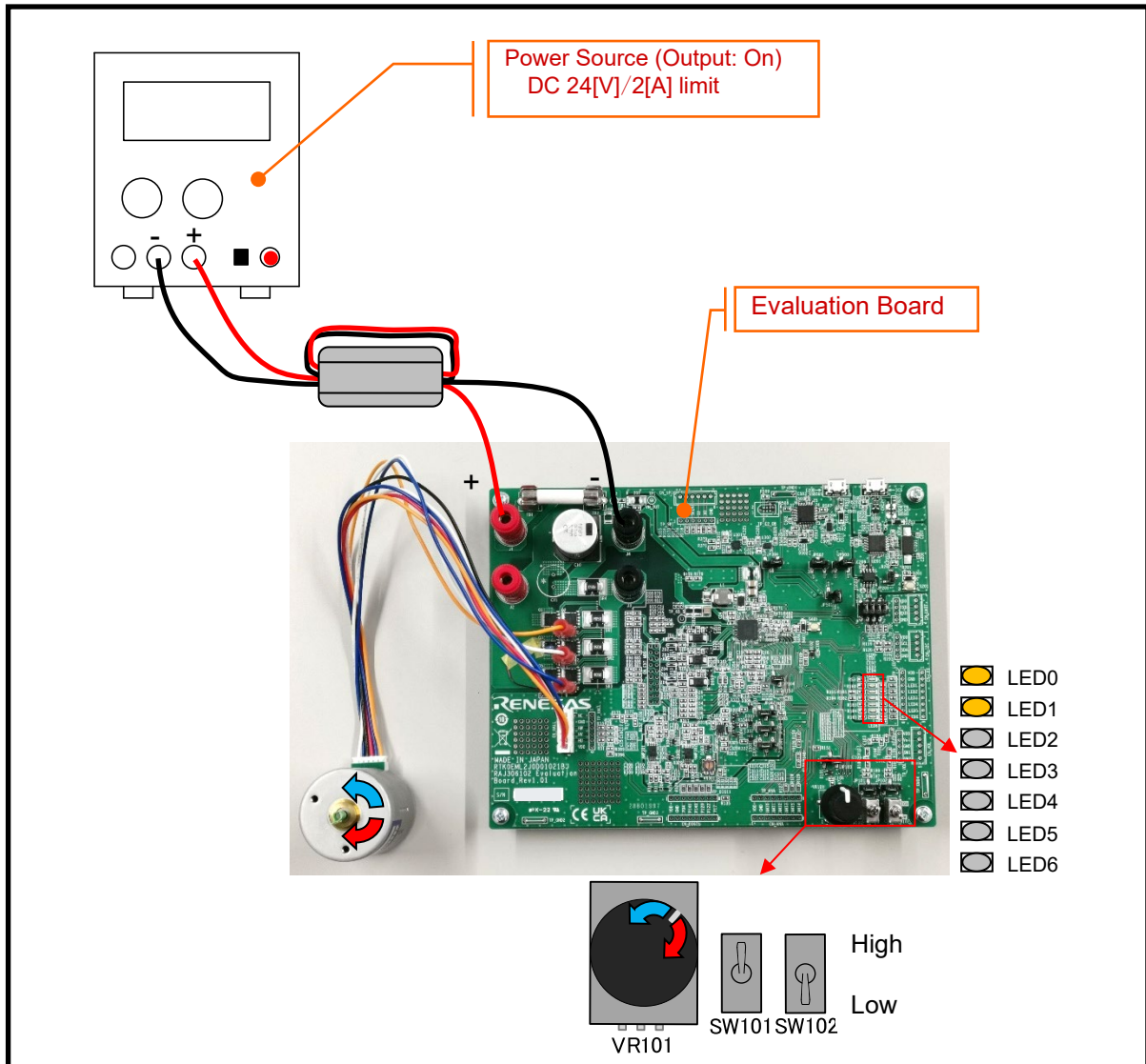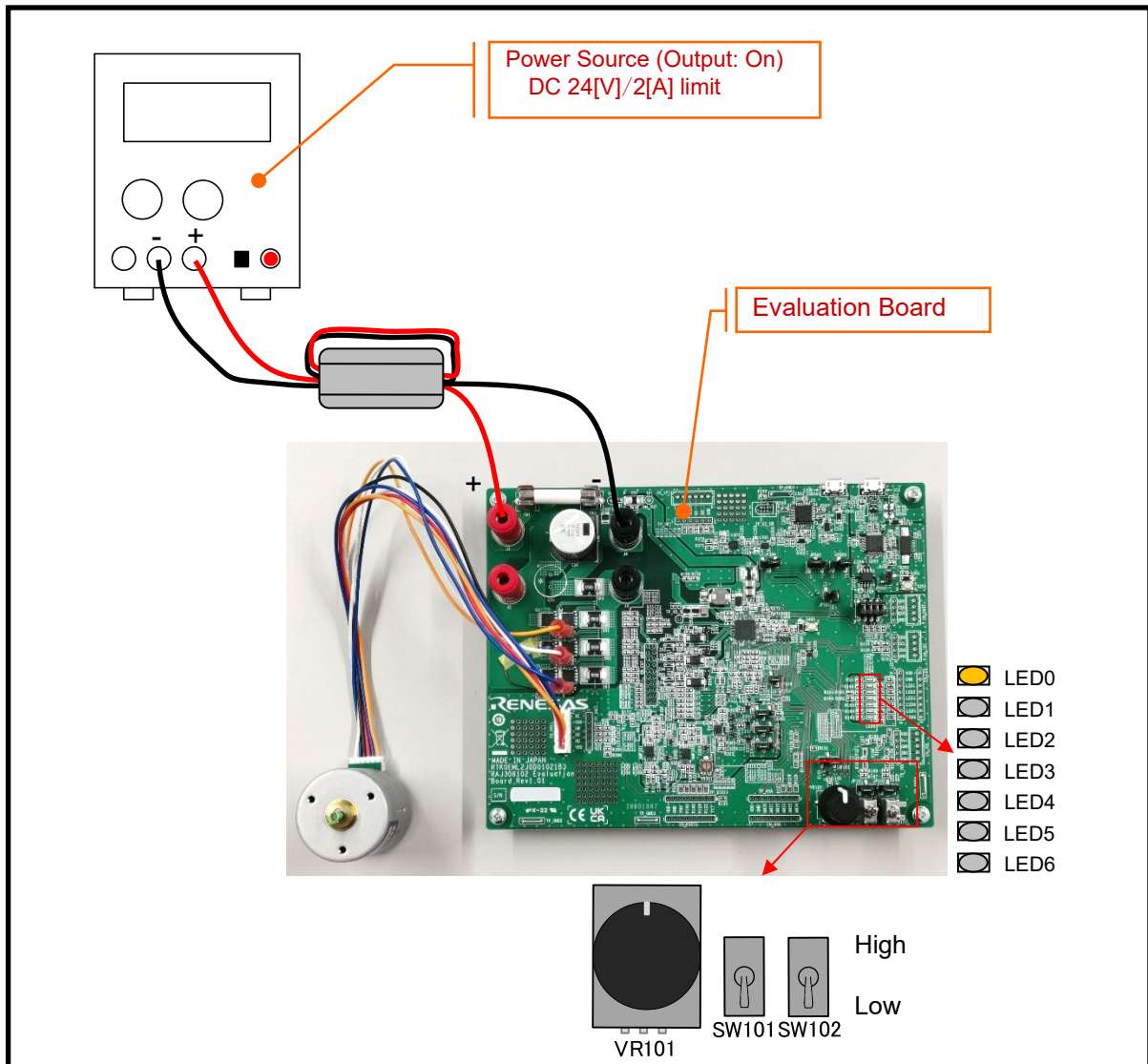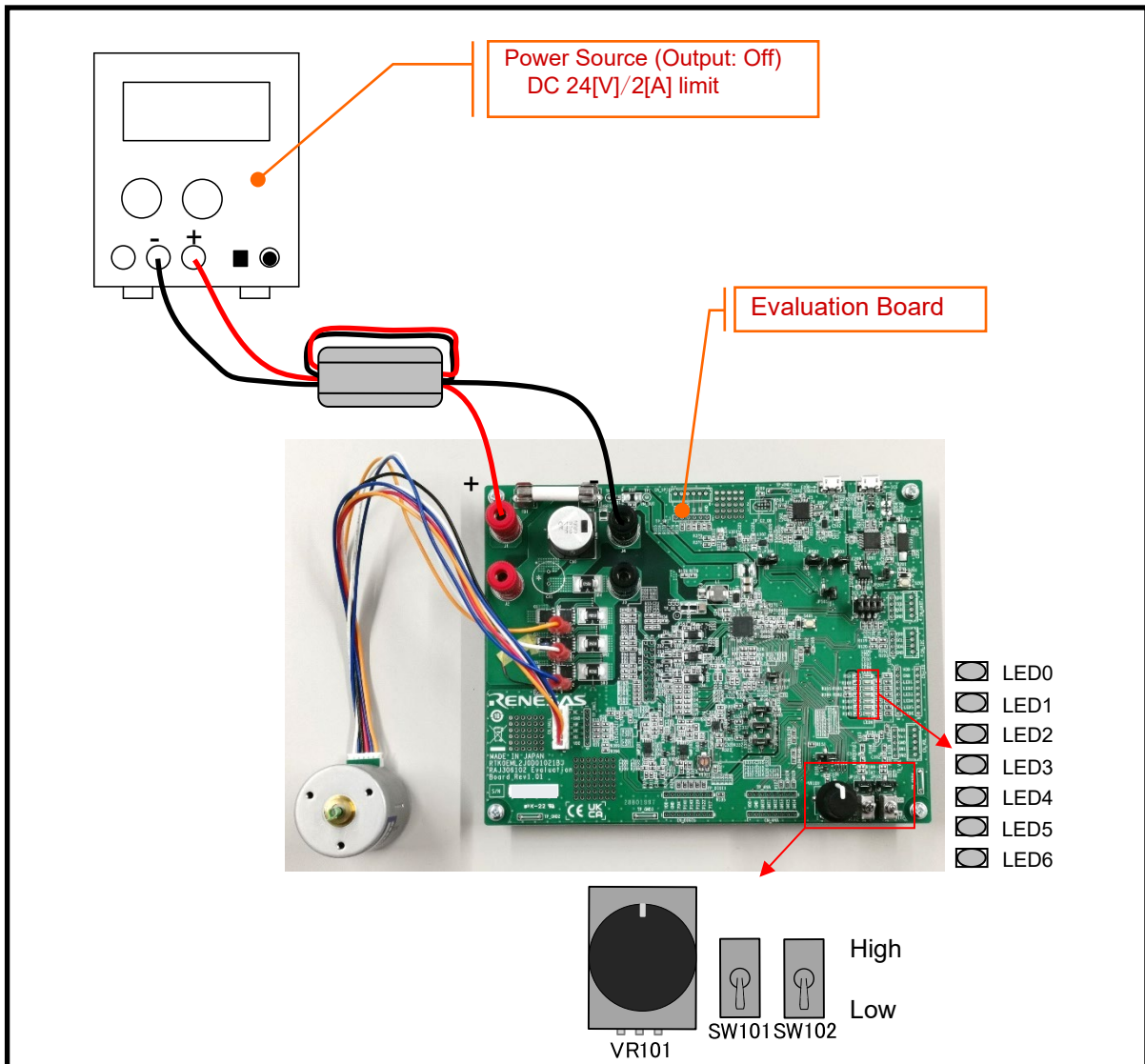For details of the specifics of the program, please refer to the *Application Note "120-degree conducting control of permanent magnetic synchronous motor (Implementation) (R18AN0062EJ)" of RAJ306102.*

Table 3-2 Basic Specifications of Sensorless 120-degree Conducting Control Software

Item	Content
Control method	120-degree conducting method (chopping upper arm)
Motor rotation start/stop	Determined depending on the level of SW101 ("High": rotation start "Low": stop) or input from Renesas Motor Workbench
Position detection of rotor magnetic pole	Sensorless: Position detection based on induced voltage measured by A/D converters (every 60 degrees) When position of rotor is detected, PWM duty and conducting pattern are set at same time.
Input voltage	DC24[V]
Main clock frequency	CPU clock: f_{CLK} 32[MHz] TRD clock: f_{HOCO} 64[MHz]
Carrier frequency (PWM)	20 [kHz]
Dead time	2[μs]
Control cycle	Speed PI control: every 1[ms]
Rotational speed control range	Sensorless control mode: 265[rpm] to 3200[rpm] [Note.1] CW and CCW are supported
Optimization	Default
Processing stop for protection	Disables the motor control signal output (six outputs), under any of the following conditions. 1. Inverter bus voltage exceeds 28[V] (monitored per 1[ms]) 2. Inverter bus voltage is less than 15[V] (monitored per 1[ms]) 3. Rotational speed exceeds 3900[rpm] (monitored per 1[ms]) 4. Zero-crossing are not detected for 200[ms]. 5. Detection of unexpected output voltage pattern 6. Detection of overcurrent by external circuit (low-level input) 7. Fault detection of the Smart Gate Driver

Note.1: Please refrain from driving motor overrated speed for a long period.

3.3.2   Board Settings

In the sensorless 120-degree conducting control, the motor position is detected by zero-crossing of the inductive voltage (BEMF).

The inductive voltage (BEMF) can be sensed by input the phase voltages to the differential amplifiers or BEMF sense amplifier of the smart gate driver. In the sample program, the BEMF sense amplifier is disabled and the differential amplifiers are used for BEMF sensing.
Align the board connection settings on the Evaluation Board with *Figure 3-10*.
For details on the circuit diagram of the Evaluation Board, refer to the *Schematic (R12TU0225EJ)*.
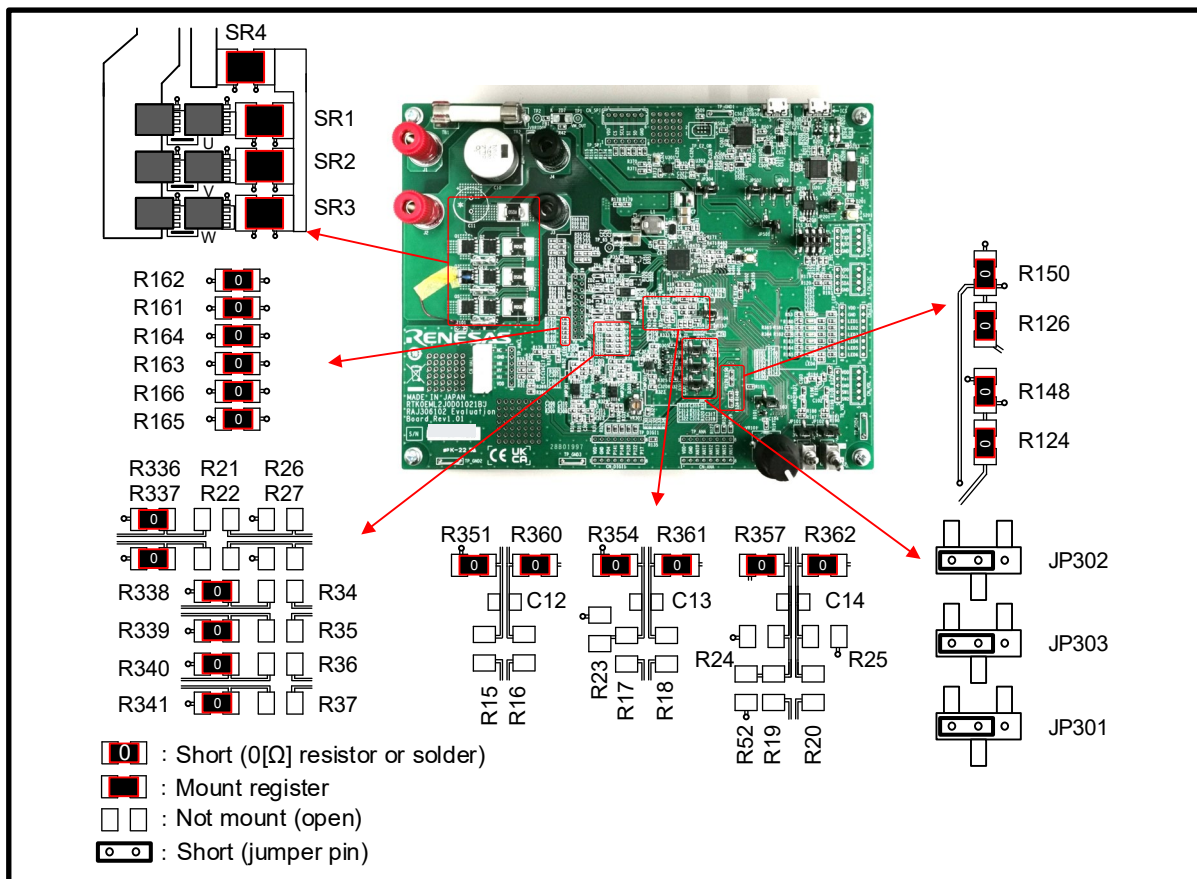
Figure 3-10 Board Connection Settings (Sensorless 120-degree Conducting Control)

3.3.3   Operation Guide

3.3.3.1   Connections

Follow the procedures below to build the evaluation environment.

a. Write Sensorless 120-degree conducting control FW to the Evaluation Board.

b. Connect the Evaluation Board and the motor U, V, and W by the attached cable. (Sensorless 120-degree conducting control does not require the connections of Hall signals.)

c. Connect the power source and the Evaluation Board. (Do not supply power at this time.)

The RAJ306102 RSSK includes a ferrite core to comply with the EMC Directive. Please use the ferrite core with 2 turns as necessary.
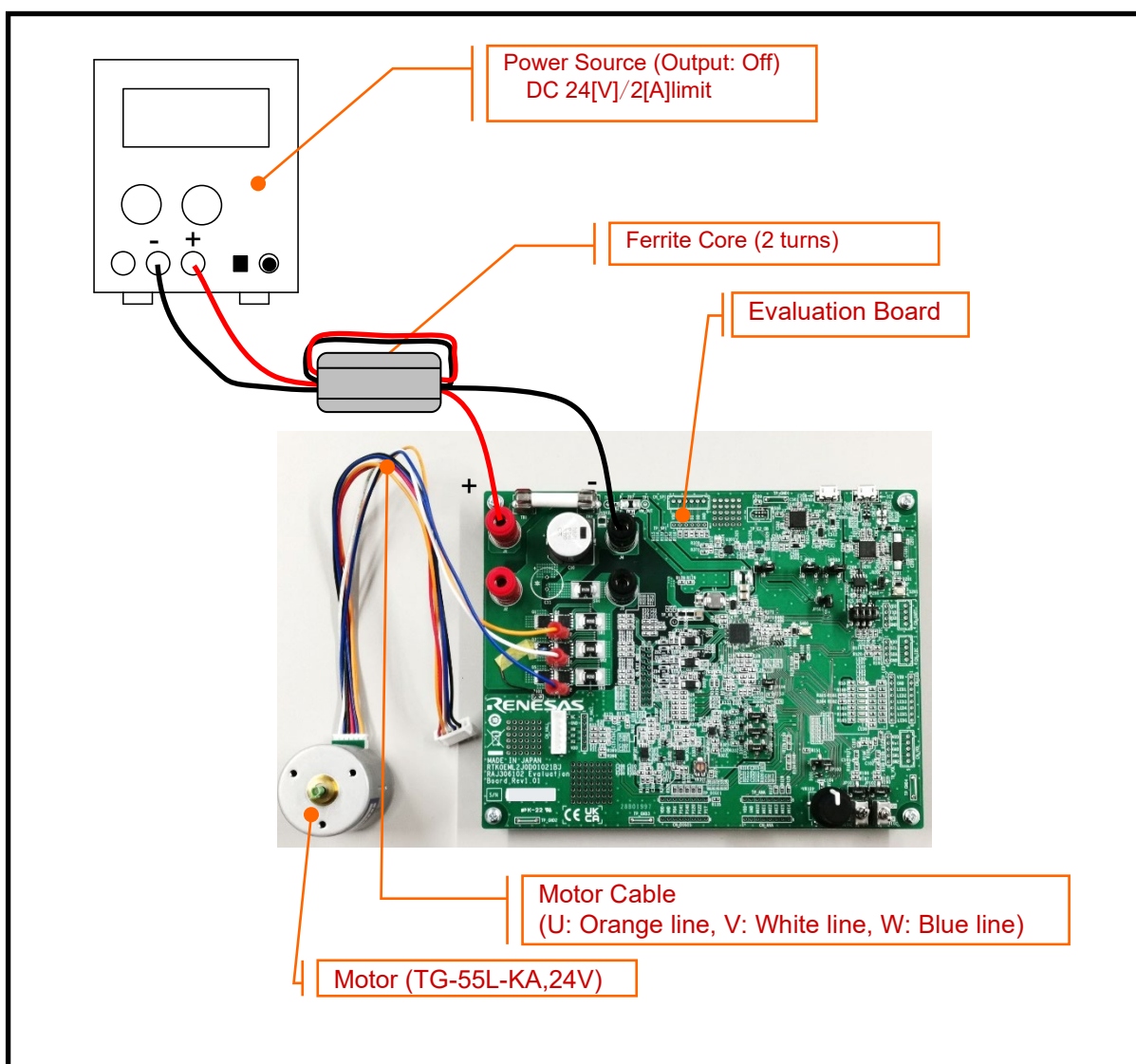
Figure 3-11 Connections for Evaluation Environment

3.3.3.2 Initial Setting

Set the toggle switches (SW101, SW102) to Low and set the potentiometer (VR101) to center.
(The state in which the knob mark is directly above the knob is called center. The potentiometer used on this board has a pivot point in the center position.)

Power Source (Output: Off)
DC 24[V] ／ 2[A] limit

Evaluation Board

LED0
LED1
LED2
LED3
LED4
LED5
LED6

High

Low

VR101   SW101 SW102
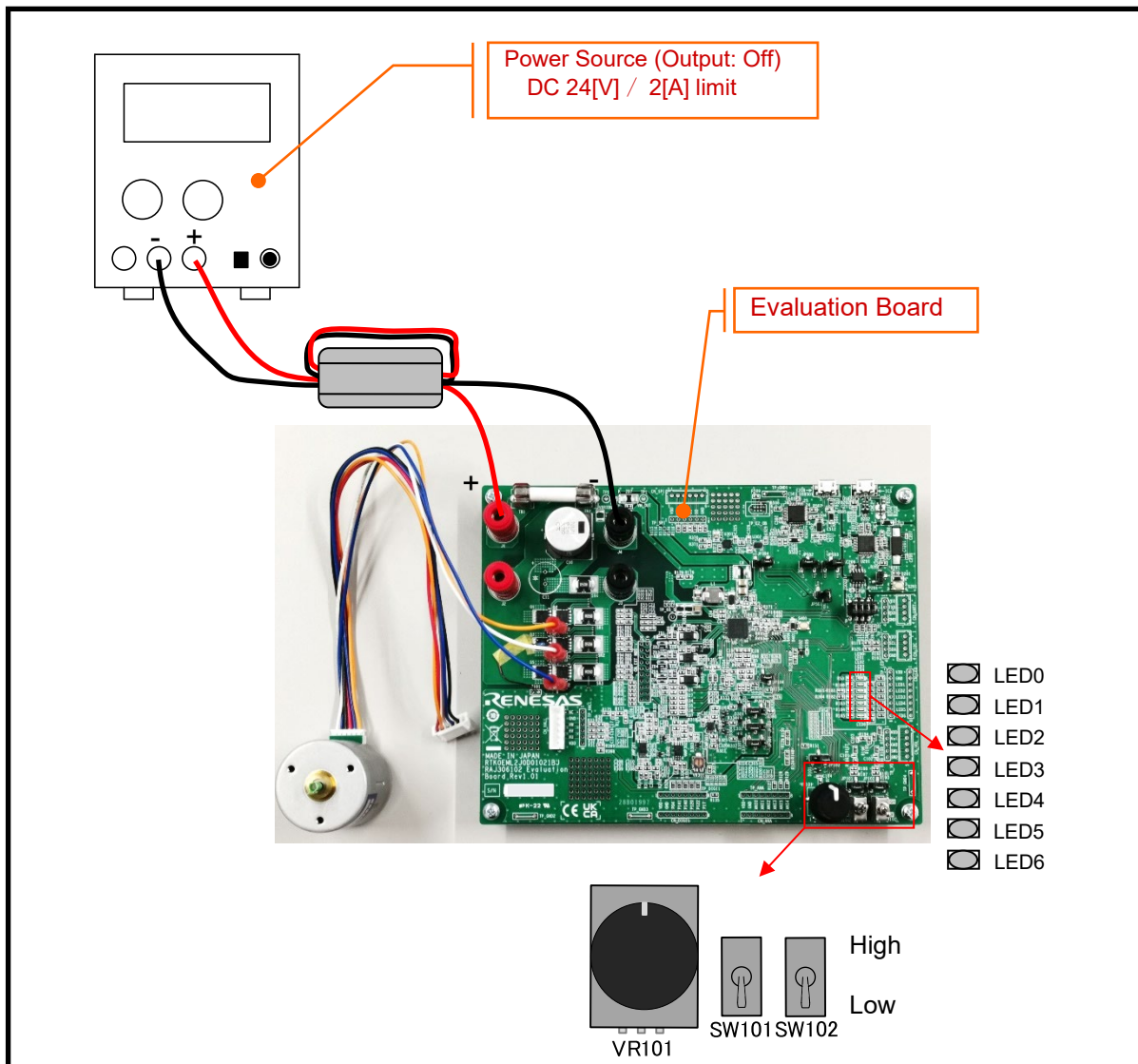
Figure 3-12 Initial Settings for Evaluation Board

3.3.3.3   Power Supply

Supply DC 24[V] to Evaluation Board by connecting the power source.

The LED0 lights up when power is supplied.
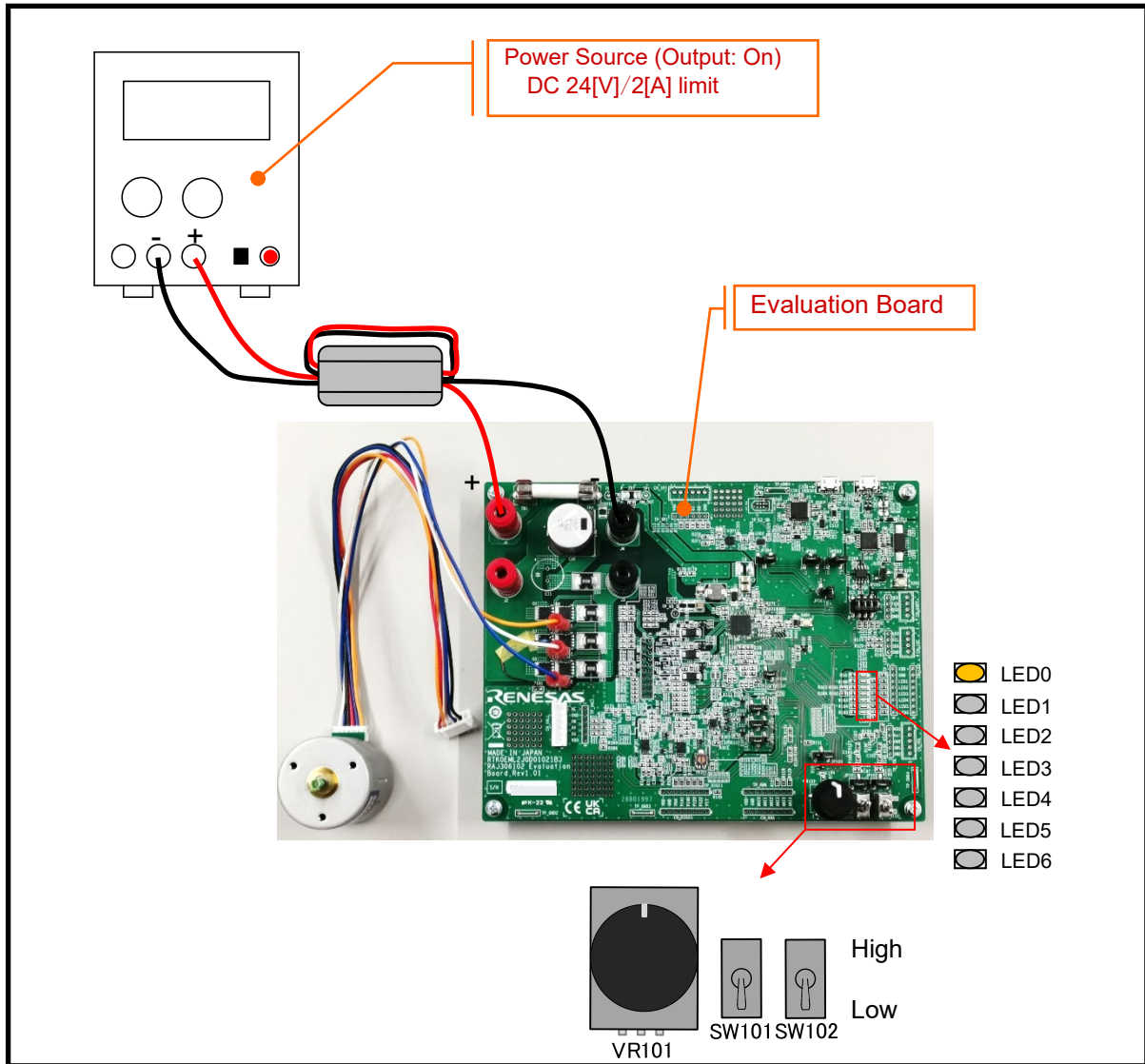
Figure 3-13 Power Supply for Evaluation Board

3.3.3.4   Motor Operation

Set SW101 to High and turn the potentiometer (VR101).

The motor rotates in the direction in which the potentiometer (VR101) is turned, according to the amount of turning. The LEDs lights up according to the control.
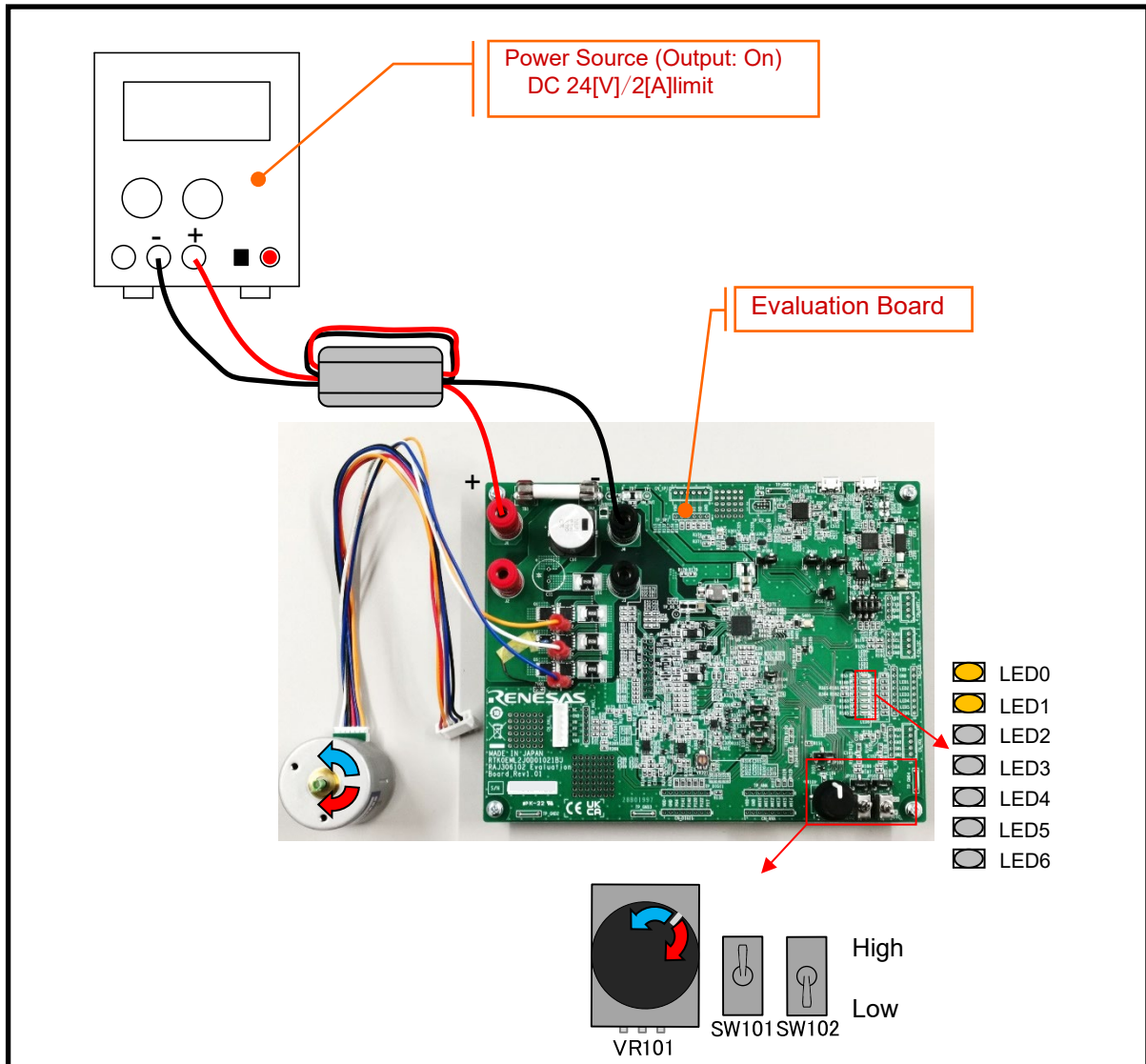
Figure 3-14 Motor Operation

3.3.3.5   Stop Motor Operation

To stop the motor, return the potentiometer (VR101) to the center and set SW101 to Low.
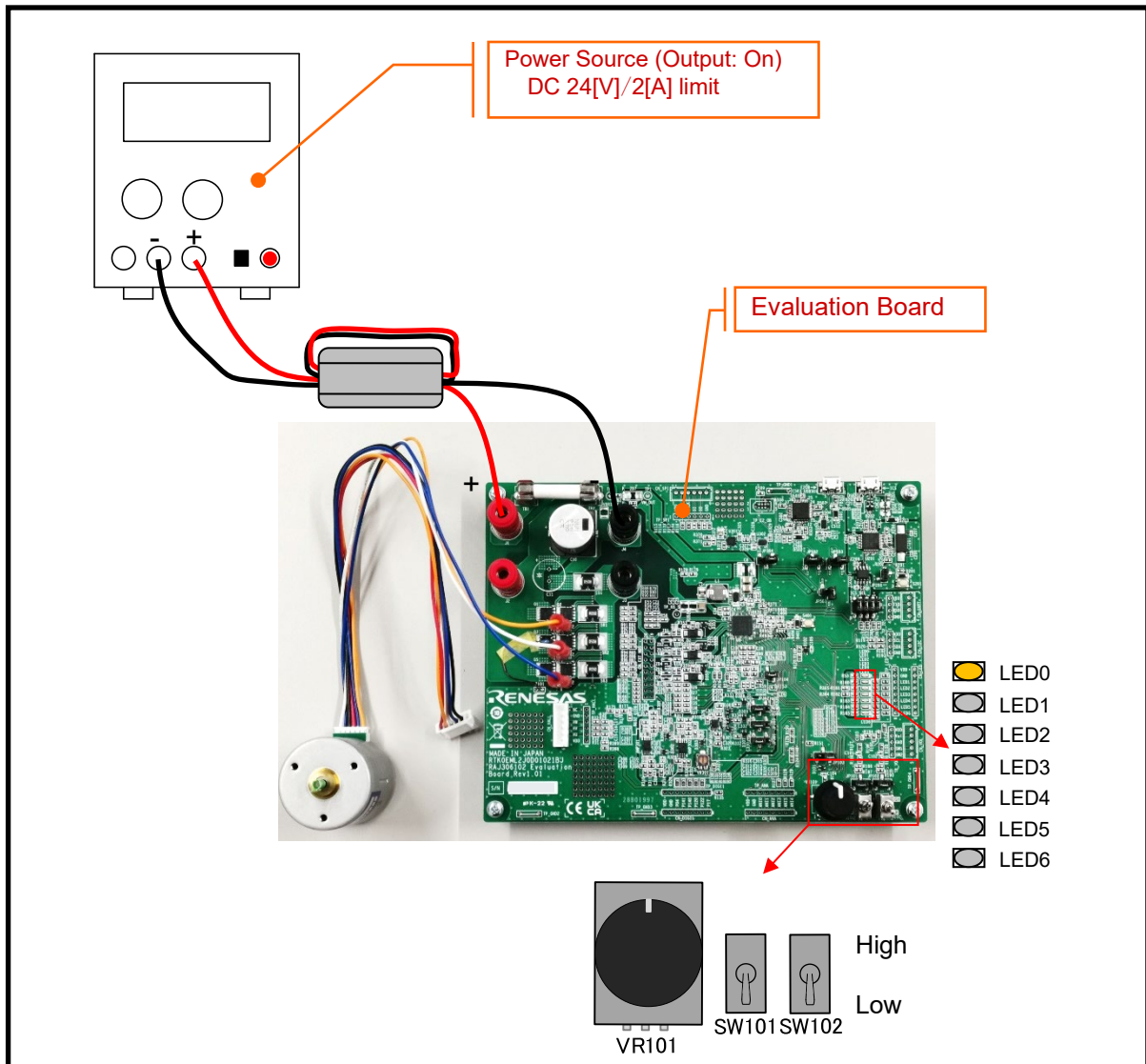
Figure 3-15 Stop Motor Operation

3.3.3.6   Stop Power Supply

Stop the power supply.
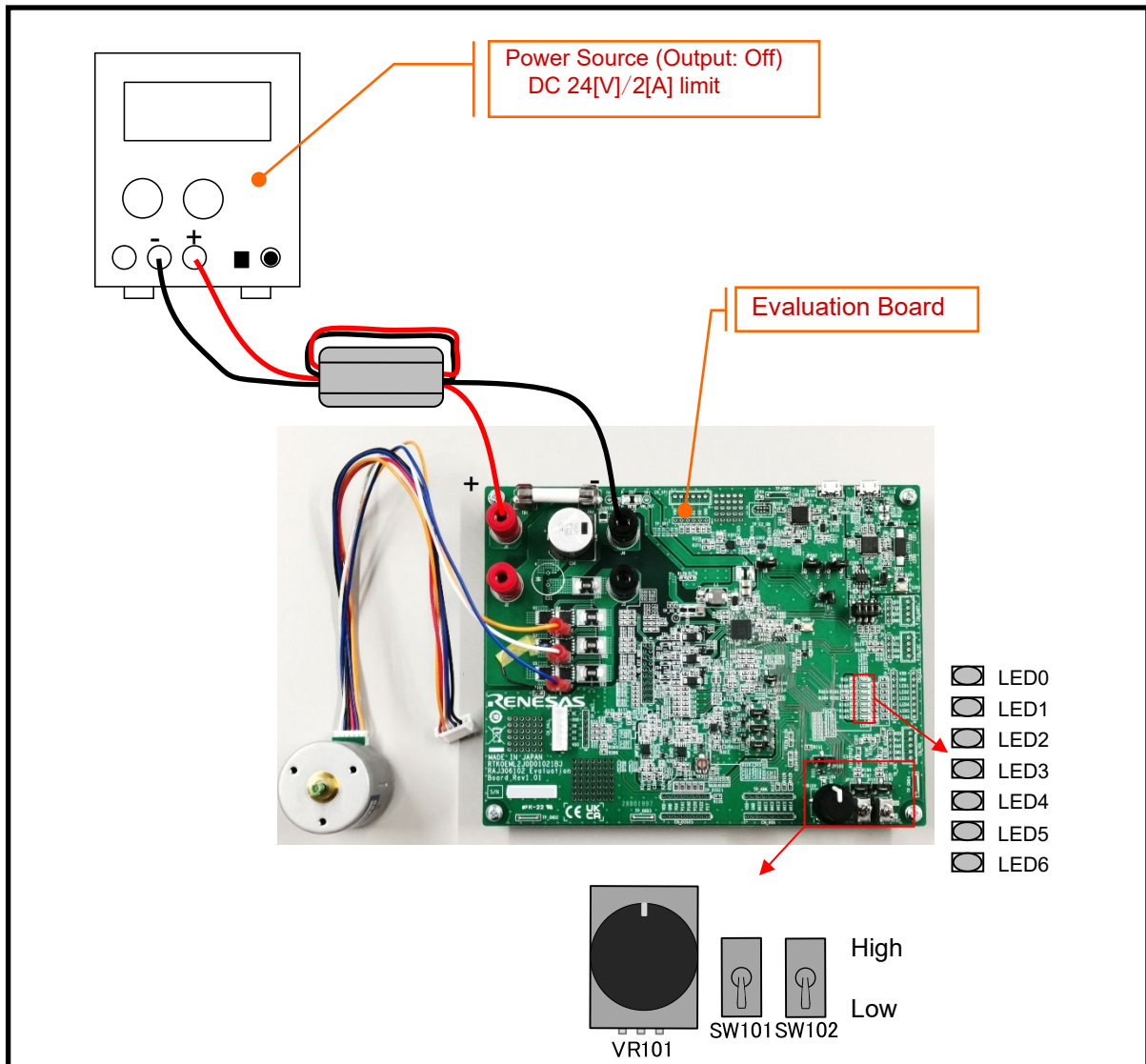
Figure 3-16 Stop Power Supply

Chapter 4. Peripheral Circuits

4.1   Power Supply Circuit

4.1.1   Main Power Supply (VM, VBRIDGE)

The Evaluation Board operates by supplying a single power supply of 6 to 48[V] between the J1 (VM, VBRIDGE connection terminal) and J4 (GND connection terminal). [Note.1] When using a motor other than the attached motor, refer to **4.3.4 Motor** and supply the voltage according to the motor within the operating range of RAJ306102. In addition, a fuse is mounted between TB1 and TB2 of Evaluation Board. Replace the fuse capacity according to the motor drive current. When using external MOSFET board and shunt resistor mounted on the Evaluation Board, refer to **4.3.1.1 MOSFET** and connect the external MOSFET board power and GND to J2 and J3 respectively.

Note.1: When using the attached motor, 24[V] ± 10[%] should be supplied.

4.1.2   Gate Drive Power Supply (VDRV, VCP)

The gate drive power supply (VDRV, VCP) of Evaluation Board is generated by the buck switching regulator and charge pump of the smart gate driver.
The output voltage of the low-side gate drive power supply (VDRV) can be adjusted from 5[V] to 15[V] by the bleeder ratio (R2 / R3) of the external feedback resistors shown in **Figure 4-1**. These resistances on the Evaluation Board are R2 = 48.7[kΩ] and R3 = 3.48[kΩ], so the VDRV output voltage is 12[V]. For details of the components for buck switching regulator, refer to **5.1.3** in the **"RAJ306102 User's Manual: Hardware (R18UZ0082EJ)"**.
The output voltage of the high-side gate drive power supply (VCP) is main power supply (VBRIDGE) + VDRV [V]. For details on the components for charge pump output capacitor (C9), pumping capacitor (C4), refer to **5.1.4** in the **"RAJ306102 User's Manual: Hardware (R18UZ0082EJ)"**.
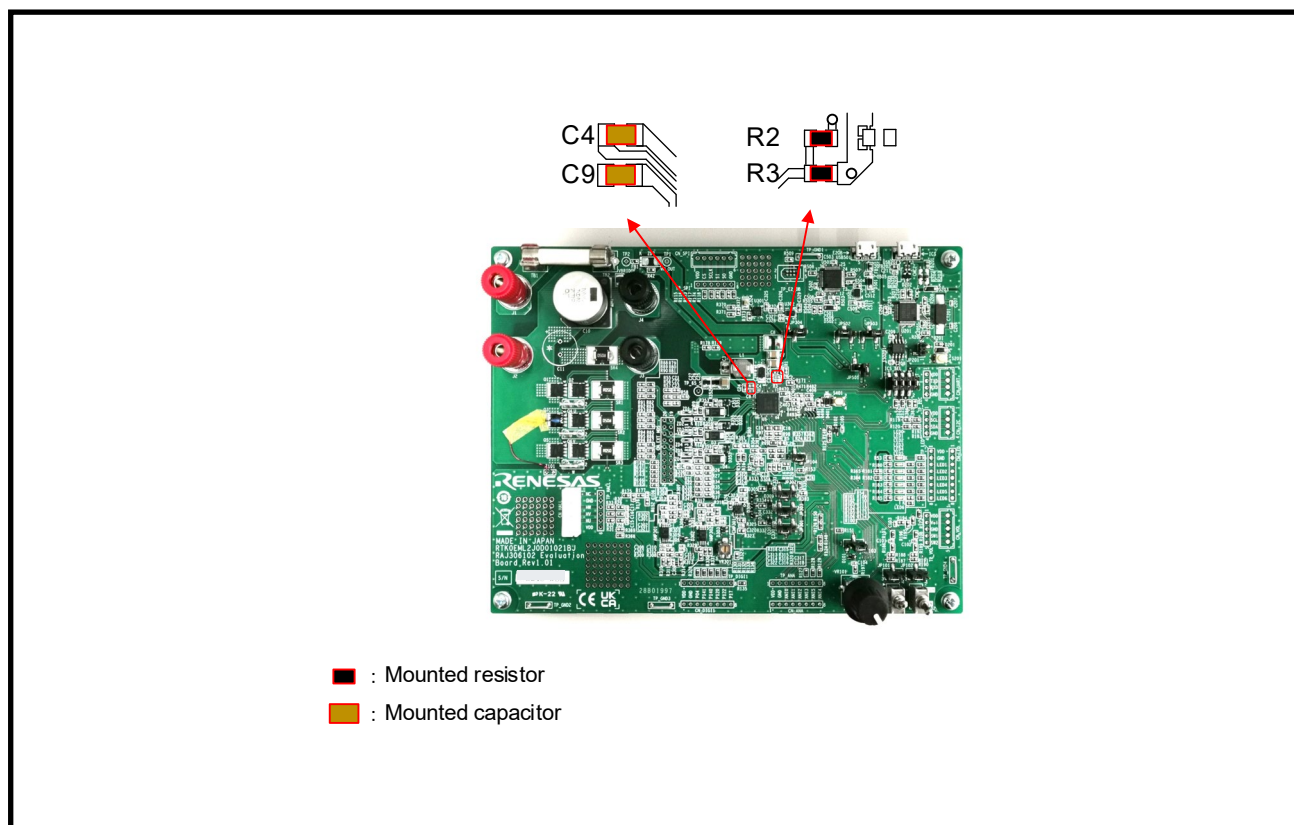

Figure 4-1 Gate Drive Power Supply Components

4.1.3   Peripheral Circuit Power Supply (VDD(3.3[V]) or VCC5V(5.0[V]))

The power supply for the peripheral circuits on the Evaluation Board can be selected from VDD pin (3.3[V]) or VCC5V pin (5.0[V]) of the smart gate driver by the 0[Ω] resistors connection. The power supply for some peripheral circuits (Current Sense (External), Halls, LEDs, RMWB(ICS)) can be also selected from U301 (5.0[V]) or U302 (3.3[V]) by JP304 and 0[Ω] resistors (R335, R363, R364, R365, R366, R367, R368, R369). In the default settings of the Evaluation Board, R97 and R98 are not mounted, so the VDD pin (3.3[V]) is selected, and 2-3 of JP304 are shorted to select U302 (3.3[V]). When selecting the VCC5V pin (5.0[V]) as the power supply for the peripheral circuits, mount 0[Ω] resistors to R97 and R98 shown in **Figure 4-2**. Also, connect 1-2 of JP304 to select U301 (5.0[V]).

The output voltage (V_{DD}) can be fine-tuned within the recommended operating conditions by adjusting the bleeder ratio (R4 / R5) of the external feedback resistors shown in **Figure 4-2**. These resistances on the Evaluation Board are R4 = 160[kΩ] and R5 = 91[kΩ], so the output voltage of the VDD pin is 3.310[V]. For details of VDD pin and VCC5V pin, refer to **5.1.2** in the **"RAJ306102 User's Manual: Hardware (R18UZ0082EJ)"**.

When changing the Peripheral Circuit Power Supply on the Evaluation Board, it is necessary to change the operating voltage of the E2OB circuit on the Evaluation Board as well. The voltage settings of the E2OB circuit on the Evaluation Board can be changed by changing the JP502 settings. To use 5.0[V], connect 1-2 of JP502 and to use 3.3[V], connect 2-3 of JP502. The power supply settings for the E2OB circuit on the Evaluation Board with JP502 are shown in **Figure 4-2**.
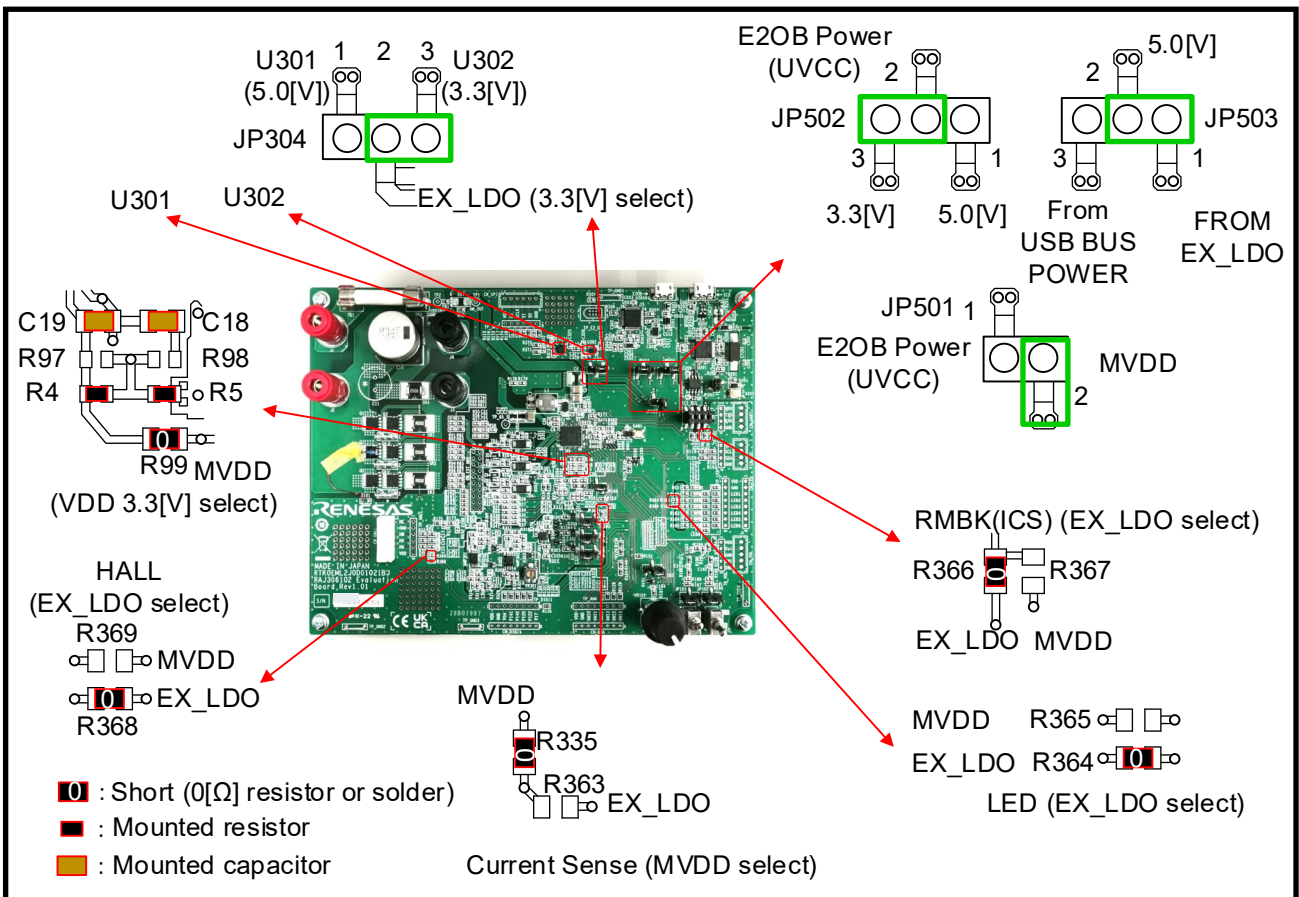

Figure 4-2 Peripheral Circuit Power Supply Components for Evaluation Board (VDD(3.3[V]) or VCC5V(5.0[V]))

4.2   Reset Circuit

The Evaluation Board has a reset circuit for power-on reset and external reset of the MCU. To apply an external reset to the MCU, press the reset switch (S401).

4.3   Motor Drive Circuit

The Evaluation Board has MOSFETs, shunt resistors, and a thermistor for the MOSFET as a motor drive circuit. Also, it is possible to connect the external MOSFET board to CN_EXT_MOS (external MOSFET connector). In order to switch the motor drive circuit, it is necessary to change the mount setting of 0[Ω] resistors. *Table 4-1* shows the mount setting of 0[Ω] resistors to switch the motor drive circuit and the information of CN_EXT_MOS connector.

Table 4-1 The Motor Drive Function According to The Mount Setting of 0[Ω] Resistors

Function Selection	Mount Setting	Function
Phase current sense	R161~R166 mount (default setting)	Shunt resistors (SR1, SR2, SR3) on the Evaluation Board are selected.
	R161~R166 unmount	CN_EXT_MOS Shunt resistors (UIP, UIN, VIP, VIN, WIP, WIN) are selected.
Thermistor for MOSFET Note.1	R150 mount, R152 unmount, R175 mount (default setting)	Thermistor on the Evaluation Board is unselected. (IW current sense is selected.)
	R150 unmount, R152 mount, R175 mount	Thermistor on the Evaluation Board is selected.
	R150 unmount, R152 mount, R175 unmount	CN_EXT_MOS terminal (TH) is selected.
MOSFET	R79~R87 mount, R88~R96 unmount (default setting)	MOSFETs on the Evaluation Board are selected. Note.2
	R79~R87 unmount, R88~R96 mount	External MOSFETs are selected (MOSFETs on the Evaluation Board are unselected.)

Note.1: The MOSFET temperature measurement function by the thermistor is not supported by the sample program. When using the thermistor, please change the program by user.

Note.2: Even if the MOSFETs on the Evaluation Board are selected, the connection of the MOSFET pin of CN_EXT_MOS is valid. DO NOT connect external MOSFETs to the CN_EXT_MOS connector on this mount setting.
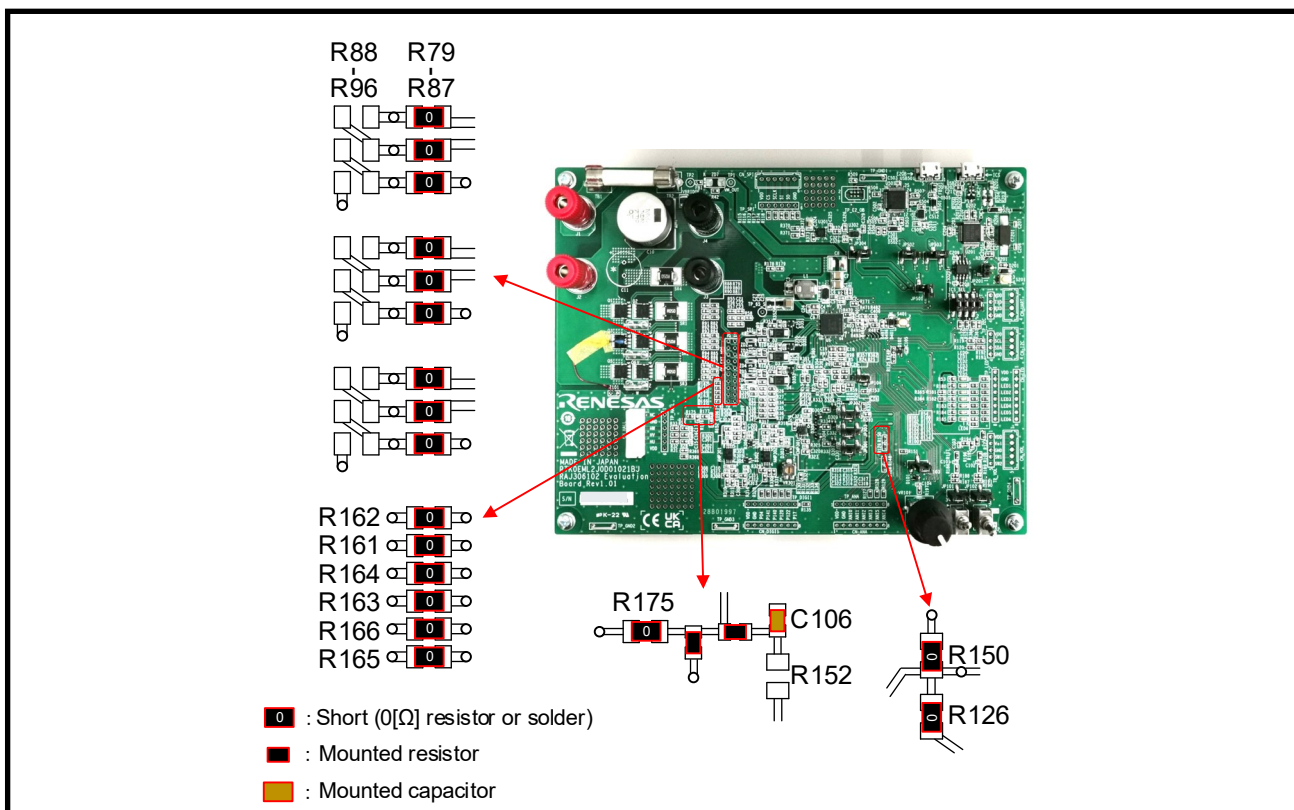
Figure 4-3 Motor Drive Circuit Function Selection Resistors (Factory Default)

Table 4-2 External MOSFET Connector (CN_EXT_MOS) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_EXT_MOS	1	WIN (DA3N)	P23/ANI3 (IW), P25/ANI5 (DA3O)
	2	WIP (DA3P)	P23/ANI3 (IW), P25/ANI5 (DA3O)
	3	VIN (DA2N)	P24/ANI4 (IV), P26/ANI6 (DA2O)
	4	VIP (DA2P)	P24/ANI4 (IV), P26/ANI6 (DA2O)
	5	UIN (DA1N)	P20/ANI0 (IU), P27/ANI7 (DA1O)
	6	UIP (DA1P)	P20/ANI0 (IU), P27/ANI7 (DA1O)
	7	TH	P22/ANI2
	8	AGND	GND_MCU(VSS)
	9	WL (LOC)	P10/TRDIOD1 (Selectable by GDSELC register)
	10	NC	NC
	11	WH (HOC)	P12/TRDIOB1 (Selectable by GDSELC register)
	12	W (HSC)	NC
	13	VL (LOB)	P11/TRDIOC1 (Selectable by GDSELB register)
	14	NC	NC
	15	VH (HOB)	P13/TRDIOA1 (Selectable by GDSELB register)
	16	V (HSB)	NC
	17	UL (LOA)	P14/TRDIOD0 (Selectable by GDSELA register)
	18	NC	NC
	19	UH (HOA)	P15/TRDIOB0 (Selectable by GDSELA register)
	20	U (HSA)	NC

4.3.1　Half-Bridges

The Evaluation Board has inverter control circuit consisting of six MOSFETs for motor control. The MCU controls the MOSFETs through the smart gate driver by using six timer output functions. In addition, the bus voltage signals, the U, V, and W phase voltage signals, and the shunt current signals can be input from the inverter control circuit to the A/D converter input port of the MCU on the Evaluation Board to measure these signals. For details of the current sense and voltage detection, refer to *4.3.2.2 Current Sense (External)*, *4.3.2.4 Bus Voltage Detection*, and *4.3.2.5 Phase Voltage Detection*.

The Evaluation Board also has a protection circuit for the shunt overcurrent. For details, refer to *4.3.1.2 Protection Circuits*. *Figure 4-4* shows the inverter control circuit. In the actual circuit, the signals to the A/D converter input ports are input through voltage dividers, or amplifiers, etc. For details, refer to the circuit diagram of the Evaluation Board.
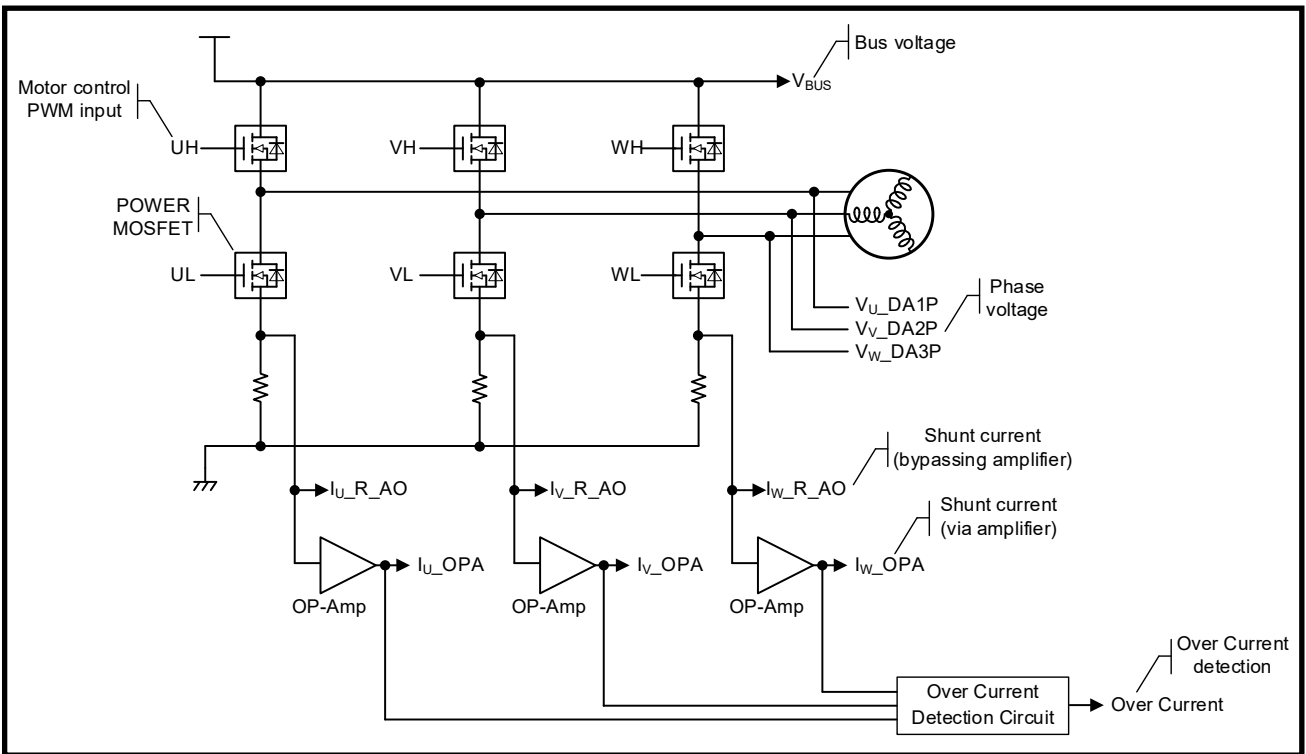
Figure 4-4 Inverter Control Circuit

4.3.1.1   MOSFET

The Evaluation Board has MOSFETs for the motor drive. It is also possible to connect external MOSFET board to CN_EXT_MOS (external MOSFET connector). The default setting of Evaluation Board has a 0[Ω] resistors mounted on the MOSFET connection selection resistors (R79-R87), so the MOSFET mounted on the Evaluation Board is enabled. In this configuration, the connection of external MOSFET board to CN_EXT_MOS is prohibited. When connecting external MOSFET board, remove the MOSFET connection selection resistors (R79-R87) and mount 0[Ω] resistors to the MOSFET connection selection resistors (R88-R96). By mounting 0[Ω] resistors in the MOSFET connection selection resistors (R88-R96), the gate and source of the MOSFET mounted on the Evaluation Board are connected to the PGND to prevent the penetration breakdown.

Note: Depending on the motor, control method and main power supply voltage, the MOSFETs mounted on the Evaluation Board may be damaged by exceeding the absolute maximum rating. In this case, consider replacing the MOSFETs or using an external MOSFET board.
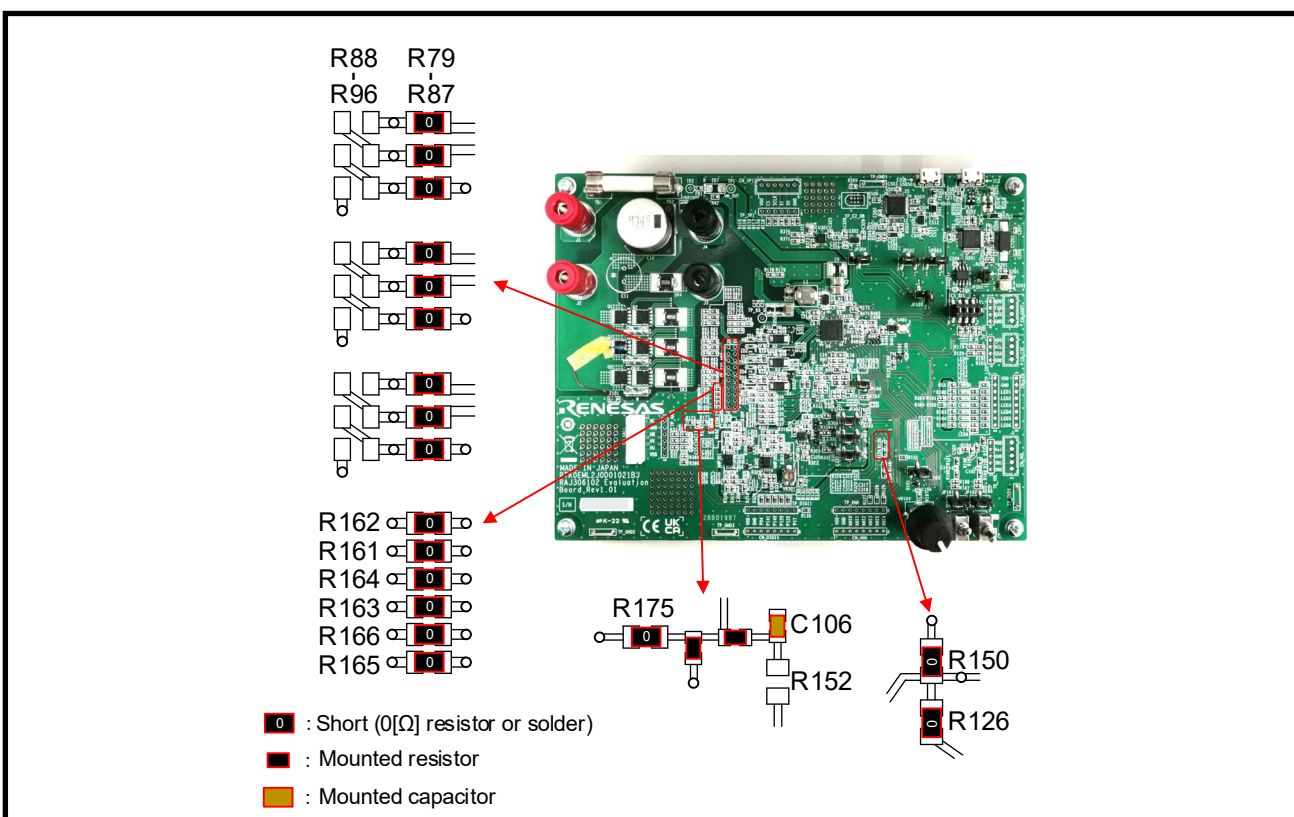
Figure 4-5 Motor Drive Circuit Function Selection Resistors (Factory Default)

4.3.1.2 Protection Circuits

The Evaluation Board has a protection circuit that detects overcurrent from the U, V, and W phase shunt currents. The overcurrent detection circuit judges that an overcurrent state has occurred when any among the U, V, and W phase currents exceeds the threshold. The threshold can be adjusted by variable resistor VR301. The overcurrent detection signal OC# is High when the shunt current value is within the threshold range and Low when an overcurrent is detected. Therefore, as long as the MOSFETs and RAJ306102 are not broken, the Evaluation Board and the motor are protectable by monitoring the overcurrent detection signal OC# and forcing the timer output port into Low to make the MOSFET turn off. The overcurrent detection circuit does not provide direct protection of the Evaluation Board and the motor. It is necessary to perform appropriate processing on the MCU and/or use the protection function of the smart gate driver, to provide protection.
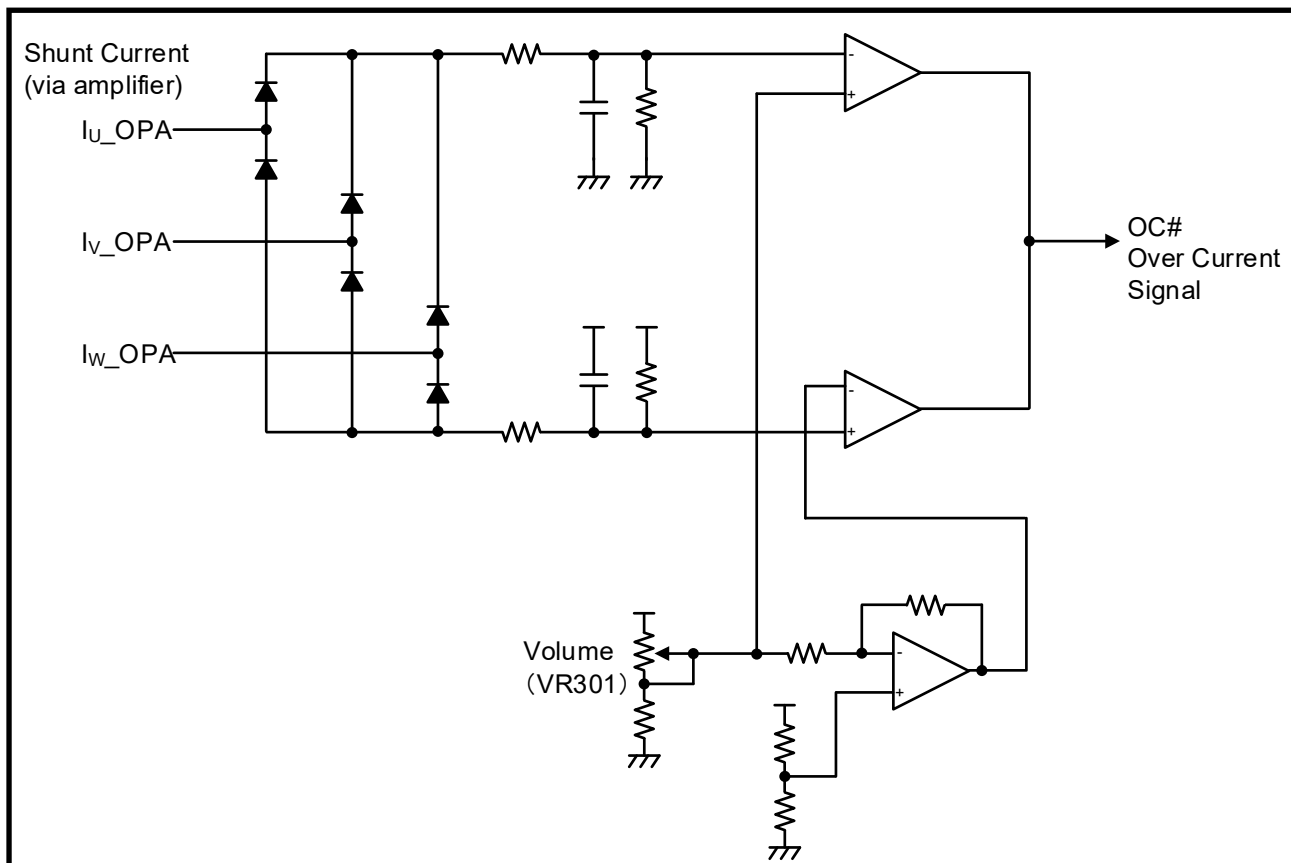
Figure 4-6 Overcurrent Detection Circuit

4.3.2   Sense Circuits

4.3.2.1   Current Sense (Internal)

This Evaluation Board is also available to detect U, V, and W phase currents by connecting U, V, and W phase shunt resistors to the built-in differential amplifier of the smart gate driver. The differential amplifiers are disabled in the sample program. When using the built-in differential amplifier for the motor current sense, refer to *Figure 4-7* to mount and remove 0[Ω] resistors, and change the smart gate driver register settings. The relation between the phase current (Iin) flow to the shunt resistor (Rs) and the voltage input to the MCU (Vout) is expressed by *EQ 4-1*. For details of the shunt resistors and differential amplifier gain, refer to *5.1.6* in the "*RAJ306102 User's Manual: Hardware (R18UZ0082EJ)*".

EQ 4-1
$$Vout[V] = Iin[A] \times Rs[\Omega] \times Gain[V/V] + \left(\frac{VDD[V]}{2}\right)$$

Iin : Current flow to shunt resistor
Rs : Shunt resistor (0.05[Ω])
Gain: Differential amplifier gain
VDD : Smart Gate Driver VDD pin voltage
Vout : Voltage applied to A/D converter input port of the MCU
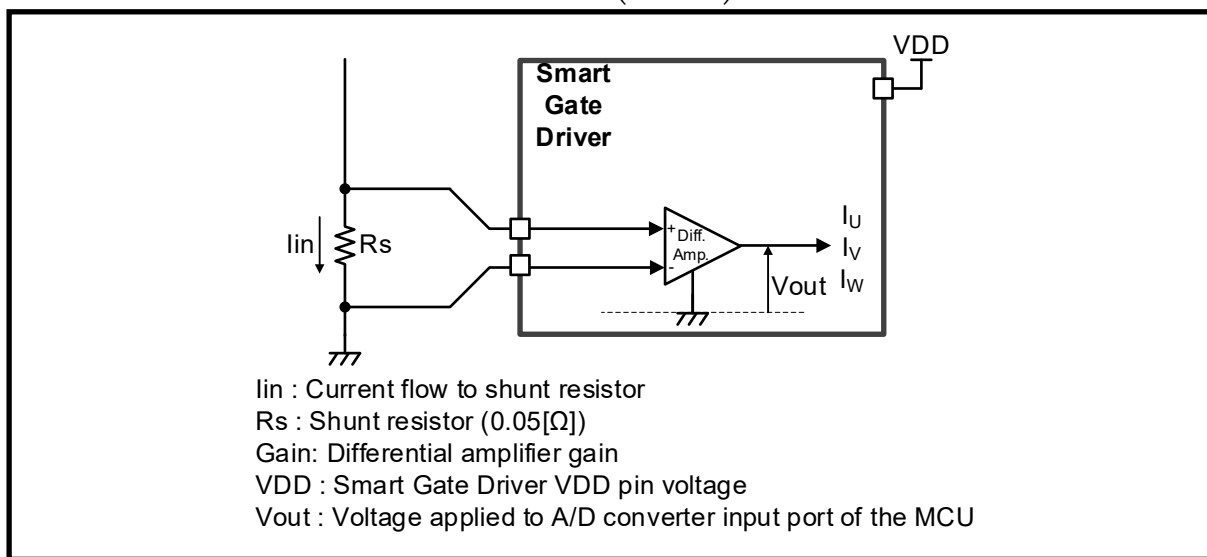
Figure 4-7 Current Sense Circuits (Internal)

4.3.2.2   Current Sense (External)

The Evaluation Board has current sense circuits including shunt resistors to detect the U, V, and W phase currents. The current sense circuits the voltage drop resulting from the current flow to the shunt resistor, and the result is input to the MCU. The relation between the phase current (Iin) flow to the shunt resistor (Rs) and the voltage input to the MCU (Vout) is expressed by *EQ 4-2.*

EQ 4-2

$$Vout[V] = Iin[A] \times Rs[\Omega] \times 5 + \left(\frac{AMP\_VCC[V]}{2}\right)$$

Iin : Current flow to shunt resistor
Rs : Shunt resistor (0.05[Ω])
AMP_VCC : Amplifier VCC pin voltage
Vout : Voltage applied to A/D converter input port of the MCU

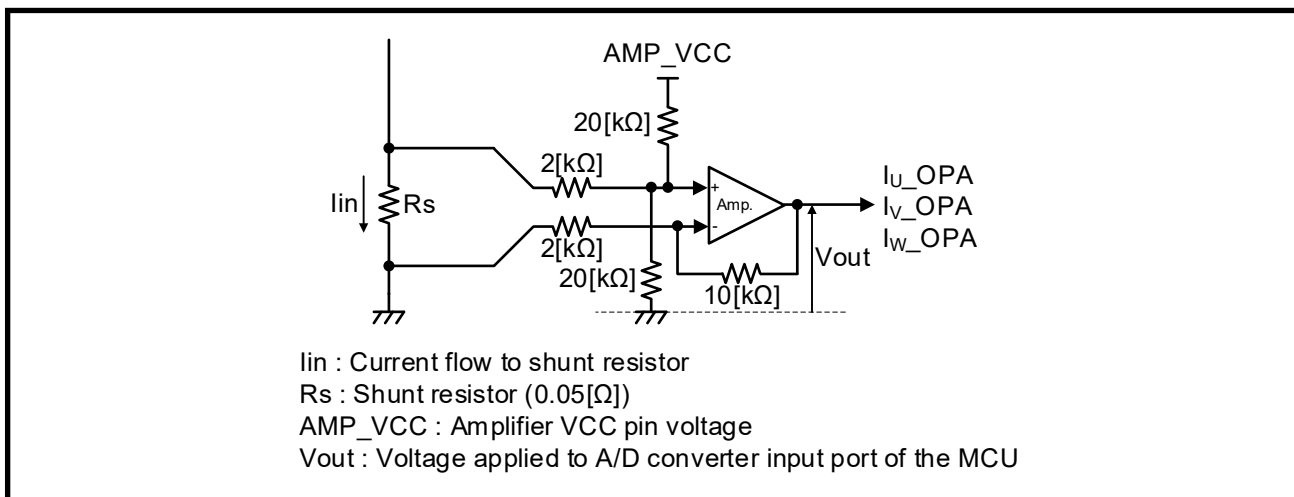**Figure 4-8 Current Sense Circuits (External)**

The Evaluation Board has jumpers to input from the shunt resistors to the MCU directly by bypassing amplifiers. When using these inputs, change the jumper JP301, JP302, and JP303 on the Evaluation Board to the appropriate connections.
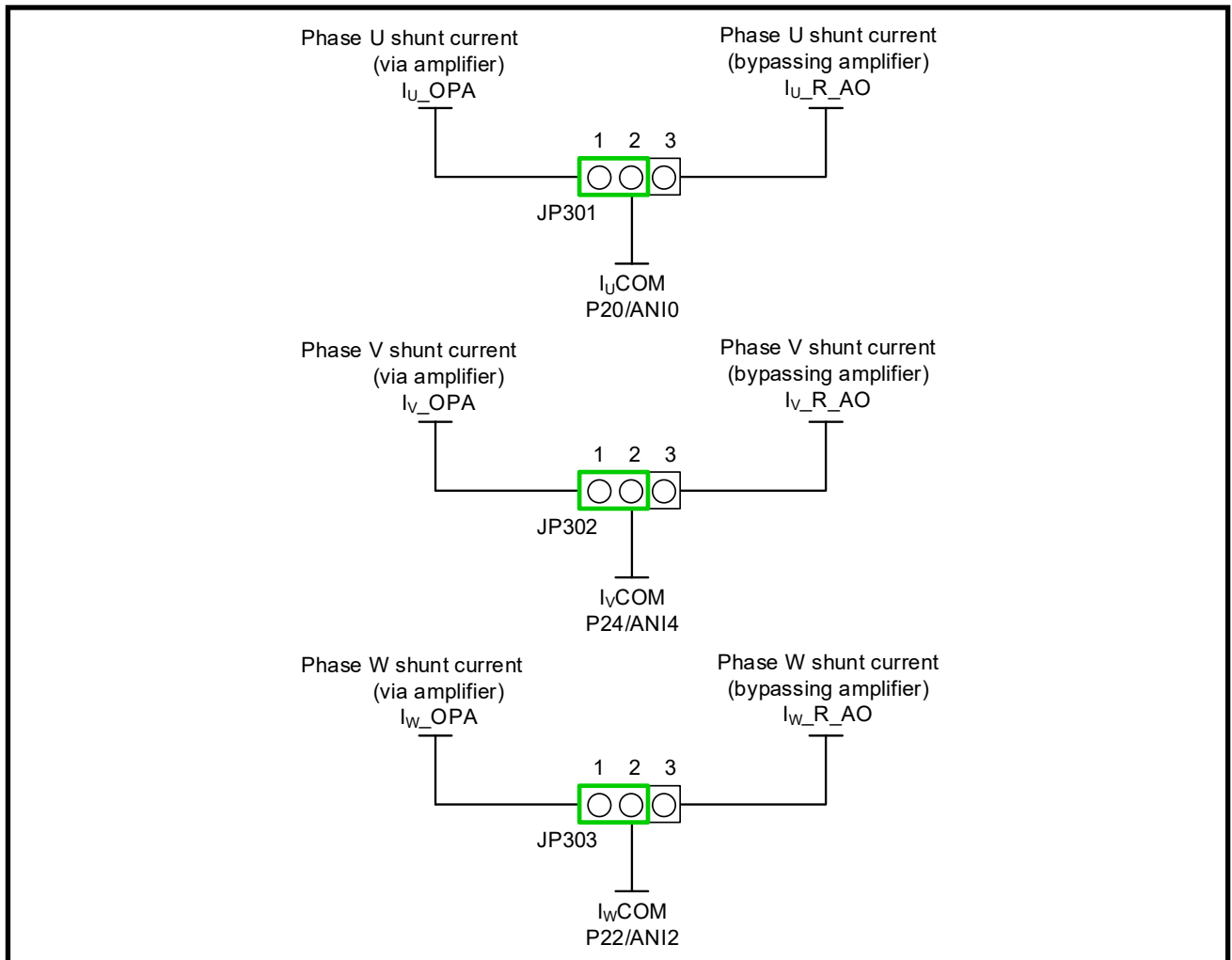
Figure 4-9 Current Sense Circuits (External) Function Selection Jumper

4.3.2.3   Hall Input

The Evaluation Board has a Hall sensor signal input connector (CN_HALL) with 3.3[V] or 5[V] pull-up resistors. The Hall sensor of the attached motor can be connected to the Hall sensor signal input connector (CN_HALL). Hall sensor signals are input to the MCU through RC filters and the smart gate driver.

Table 4-3 Hall Sensor Connector (CN_HALL) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_HALL	1	NC	NC
	2	GND	GND_MCU(VSS)
	3	HW (DA3P)	P53/INTP2
	4	HV (DA2P)	P54/INTP3
	5	HU (DA3N)	P55/INTP4
	6	VDD	VCC_MCU(VDD)

4.3.2.4   Bus Voltage Detection

The Evaluation Board has a voltage divider circuit to input the bus voltage to the A/D converter input port of the MCU. The relation between the bus voltage and detection voltage is expressed by *EQ 4-3*.

EQ 4-3

$$Vout[V] = \frac{20 \times 10^3}{(470 \times 10^3 + 20 \times 10^3)} \times Vin[V]$$

Vin : Bus voltage
Vout : Voltage applied to A/D converter input port of the MCU

Figure 4-10 Bus Voltage Detection Circuit

4.3.2.5   Phase Voltage Detection

The Evaluation Board has a voltage divider circuit to input the phase voltages (U, V, and W phase) to the A/D converter input port of the MCU through the built-in differential amplifier of the smart gate driver. The relation between the phase voltages and detection voltage is expressed by *EQ 4-4*.
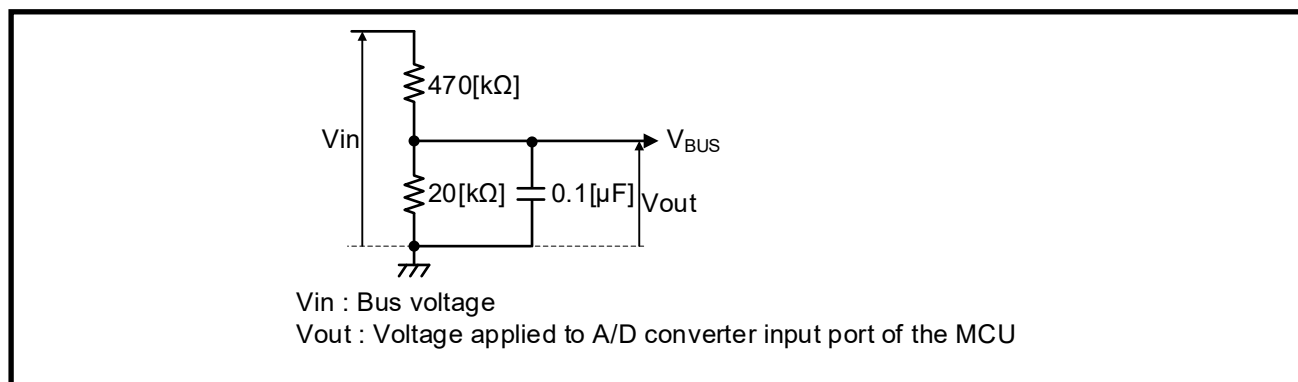
EQ 4-4

$$\text{Vout}[V] = (0.5803 * VDD[V]) + 0.0205 \times Vin[V]$$

Vin : Phase voltage
VDD : Smart Gate Driver VDD pin voltage
Vout : Voltage applied to A/D converter input port of the MCU
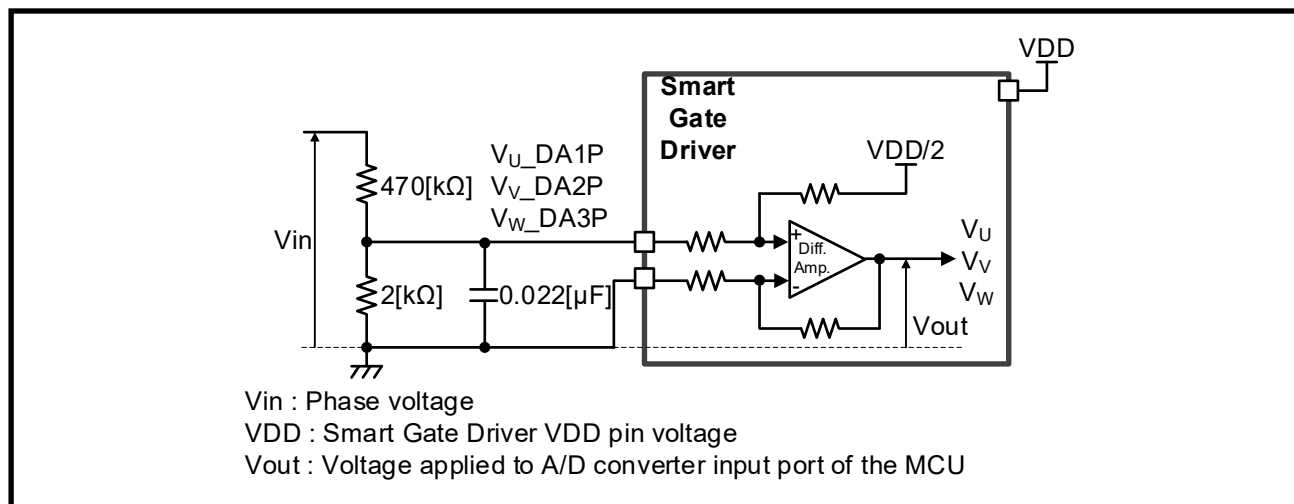
Figure 4-11 Phase Voltage Detection Circuit

4.3.2.6   Thermistor for MOSFET

The Evaluation Board has a thermistor (Z101) for MOSFET temperature measurement. However, R150 and R175 are mounted and R152 is not mounted in the Evaluation Board default settings, so a MOSFET thermistor (Z101) or an external thermistor cannot be used. When using a thermistor for MOSFET, remove R150 and mount a 0[Ω] resistor to R152 to connect the thermistor (Z101) on the board to P22/ANI2. [Note.1] When using an external thermistor, remove R150 and R175 and mount a 0[Ω] resistor to R152 to allow the external thermistor connected to TH (Pin 7) of CN_EXT_MOS to be connected to P22/ANI2.

Note.1: The MOSFET temperature measurement function by the thermistor is not supported by the sample program. When using a thermistor, please change the program by user.

4.3.3   Spare Circuit

The Evaluation Board has a PAD on which parts can be mounted as a spare circuit. If strong ringing occurs in the BEMF waveform, it is recommended to implement a snubber circuit if necessary.
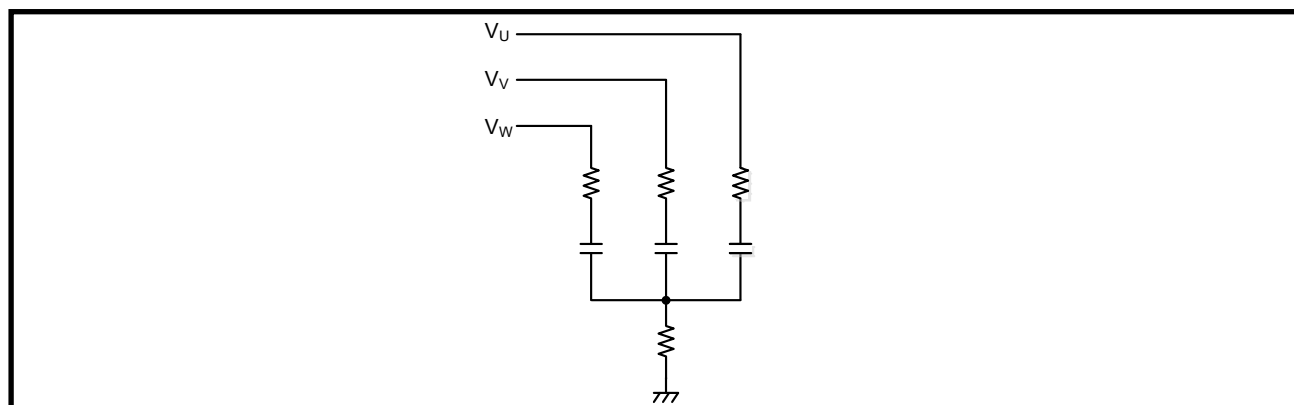
Figure 4-12 Spare Circuit

4.3.4   Motor

The Evaluation Board and sample program are set according to the attached motor. When using a motor other than the attached motor, it may be necessary to change the setting parameters such as drive current settings and change the hardware.
The followings are the components that may need to be changed.

・　Shunt resistors (SR1, SR2, SR3, SR4) -- Modified to fit the amount of motor phase current.
　　Factory default: CRA2512-FZ-R050ELF (50[mΩ], 3[W])
・　MOSFETs (Q1, Q2, Q3, Q4, Q5, Q6) -- Modified to fit the amount of motor phase current.
　　Factory default: TPH12008NH (VDSS = 80[V], ID = 24[A], RDS(ON) = 10.1[mΩ])
・　FUSE (FU1) -- change according to the amount of power supply current.
　　Factory default: 486-7270-ND (30[A])
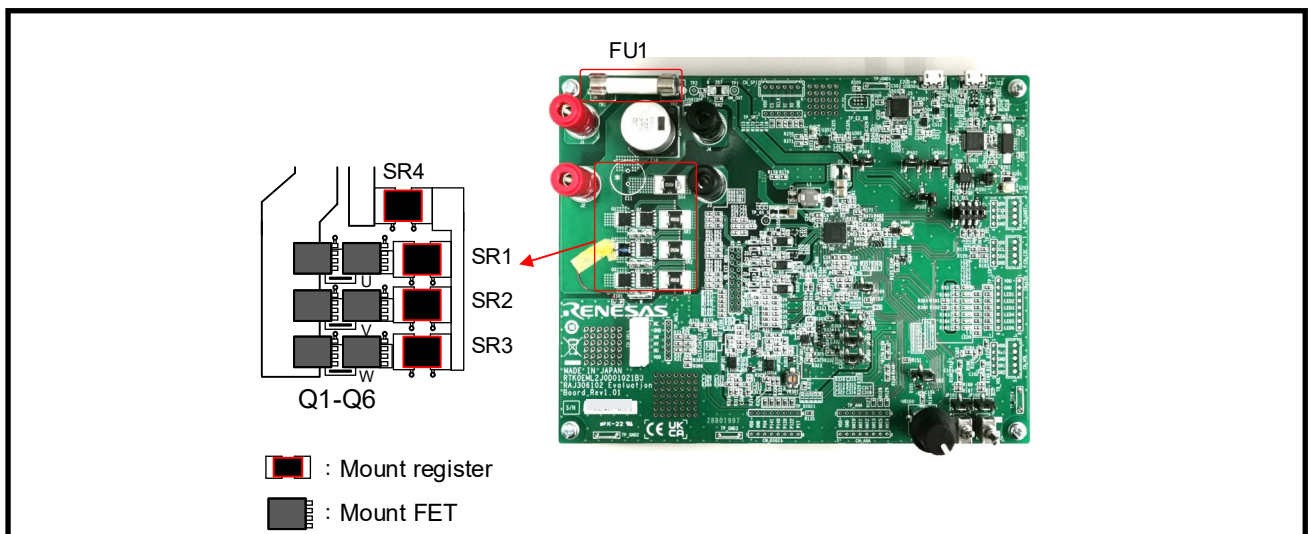
Figure 4-13 Components Change Location (Using Other Motor)

4.4   User Interface

4.4.1   Potentiometer (VR101) & Toggle Switches (SW101, SW102)

The Evaluation Board has a potentiometer (VR101) and toggle switches (SW101 and SW102). The potentiometer (VR101) is connected to P23/ANI3 and uses it to indicate the amount of rotation and direction of rotation. The toggle switch (SW101) is connected to the P137 and uses it to indicate the start/stop of rotation. Toggle switch (SW102) is connected to P31 and used it to reset errors.

The evaluation board also has a through-hole for external controller connector (CN_VOL) and the test points for verification (TP_VOL), allowing connection of trigger switches and other devices.

The jumper pins (JP103, JP101, JP102) allow you to select whether to use the potentiometer (VR101) and toggle switches (SW101, SW102) on the board or CN_VOL.

If 1-2 of JP103 are shorted, the potentiometer (VR101) side is valid, and if 2-3 are shorted, the CN_VOL side is valid.

If 2-3 of JP101 and JP102 are shorted, the toggle switch (SW101 and SW102) side is valid, and if 1-2 are shorted, the CN_VOL side is valid.

Table 4-4 Connector for CN_VOL Connection (CN_VOL) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_VOL	1	VDD	VCC_MCU(VDD)
	2	Vol	P23/ANI3
	3	GND	GND_MCU(VSS)
	4	SW1	P137
	5	SW2	P31

4.4.2   LED

The Evaluation Board has 7 LEDs, 6 of which can be used as the program debugging and system display. Each LED turns on when the output on the corresponding port is low-level and turns off when the output is high-level. The Evaluation Board also has through-holes for the CN_LED connector and test points (TP_LED) to confirm the MCU output.

Table 4-5 LED Connector (CN_LED) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_LED	1	VDD	VCC_MCU(VDD)
	2	GND	GND_MCU(VSS)
	3	LED1	P01
	4	LED2	P00
	5	LED3	P43
	6	LED4	P42
	7	LED5	P41
	8	LED6	P77

4.4.3   SPI Connector

The Evaluation Board has through holes for CN_SPI connector and test points (TP_SPI) to confirm the SPI signals. The CN_SPI connector is not used in the sample program.

Table 4-6 SPI Connector (CN_SPI) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_SPI	1	VDD	VCC_MCU(VDD)
	2	CS	P76/(INTP6)
	3	SCLK	P75/SCK01
	4	SO	P74/SI01
	5	SI	P73/SO01
	6	GND	GND_MCU(VSS)

4.4.4   I²C Connector

The Evaluation Board has through holes for CN_I2C connector and test points (TP_I2C) to confirm the I²C signals. The CN_I2C connector is not used in the sample program.

Table 4-7 I²C Connector (CN_I2C) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_I2C	1	VDD	VCC_MCU(VDD)
	2	SCL	P60/SCLA0
	3	SDA	P61/SDAA0
	4	GND	GND_MCU(VSS)

4.4.5   UART Connector

The Evaluation Board has through holes for CN_UART connector and test points (TP_UART) to confirm the UART signals. The UART is also used for the connection circuit with the motor control development support tool Renesas Motor Workbench through ICS_SEL jumpers, so when using the CN_UART connector, change all ICS_SEL jumpers to open. The CN_UART connector is not used in the sample program.

Table 4-8 UART Connector (CN_UART) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_UART	1	VDD	VCC_MCU(VDD)
	2	TXD	P02/TxD1/SO10
	3	RXD	P03/RxD1/SI10
	4	GND	GND_MCU(VSS)

4.4.6   General-purpose Digital Input/Output Connectors

The Evaluation Board has through holes for CN_DIGI1 connectors and test points (TP_DIGI1) to confirm the input/output signals of the MCU. The CN_DIGI1 connectors are not used in the sample program.

Table 4-9 General-purpose Digital Input/Output Connector (CN_DIGI1) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_DIGI1	1	VDD	VCC_MCU(VDD)
	2	GND	GND_MCU(VSS)
	3	NC	P04
	4	NC	P141
	5	NC	P140
	6	NC	P120
	7	NC	P122
	8	GPIO (nSMPL)	P17

4.4.7   General-purpose Analog Input/Output Connector

The Evaluation Board has through holes for CN_ANA connector and test points (TP_ANA) to confirm the analog input/output signals of the MCU. The CN_ANA connector is not used in the sample program.

Table 4-10 General-purpose Analog Input/Output Connector (CN_ANA) Pin Assignment

Connector	Terminal No.	Terminal Function	RAJ306102 Port
CN_ANA	1	VDD	VCC_MCU(VDD)
	2	GND	GND_MCU(VSS)
	3	IU	P20/ANI0
	4	VM detection	P21/ANI1
	5	IW/Thermistor	P22/ANI2
	6	Potentiometer	P23/ANI3
	7	(DA3O)	P25/ANI5
	8	NC	P24/ANI4

Chapter 5. Emulator Function

5.1   Program Write

The Evaluation Board is equipped with an on-board emulator for flash write. Connect your PC to the USB501 connector on the Evaluation Board with a USB micro-B cable for the firmware write. Use applications such as e^2 studio, CS+, or Renesas Flash Programmer to write firmware. The on-board emulator circuit connected to the PC is recognized as E2 Lite, please set the connection accordingly. Refer to the document of e^2 studio, CS+, Renesas Flash Programmer in detail.

Reference

- •   e^2 studio User's Manual: Quick Start Guide (R20UT5293EJ)
- •   CS+ User's Manual: Project Operation (R20UT5299EJ)
- •   Renesas Flash Programmer User's Manual (R20UT5312EJ)

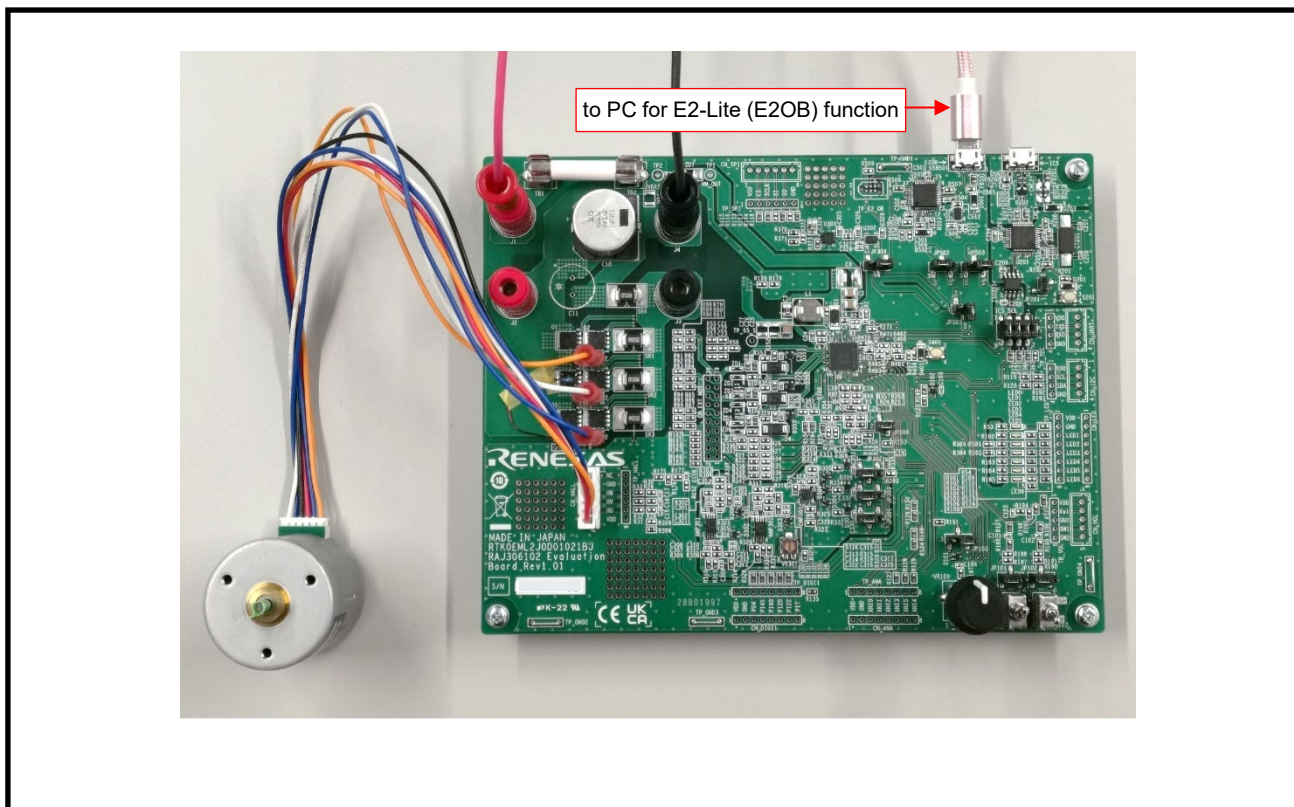to PC for E2-Lite (E2OB) function

Figure 5-1 Connect with PC (E2 Lite Function)

By using the on-board emulator function, it is possible to debug while executing the firmware. However, when driving a motor, debugging using this function is not recommended for the following reasons.
When driving a motor, it is recommended to use the RMWB function. For details about RMWB, refer to **Chapter 6**.

- •   If the MCU is STOPPED from the emulator while the motor is driving, the output of the timer stops at a fixed output, and the current continues to flow to a fixed phase, possibly causing burnout.
- •   When using the on-board emulator function, the PC and the Evaluation Board share the same GND. If the GND is shaken by motor drive, the PC may be damaged. (The circuit (ICS) used in the RMWB contains an isolator, so the GND of the PC and the Evaluation Board is not shared, allowing safe evaluation.)

5.1.1   e² studio

1. Supply power to the Evaluation Board, then connect to PC by USB cable.

2. Execute e² studio, click "Build All" from "Project" tab of e² studio. Note.1

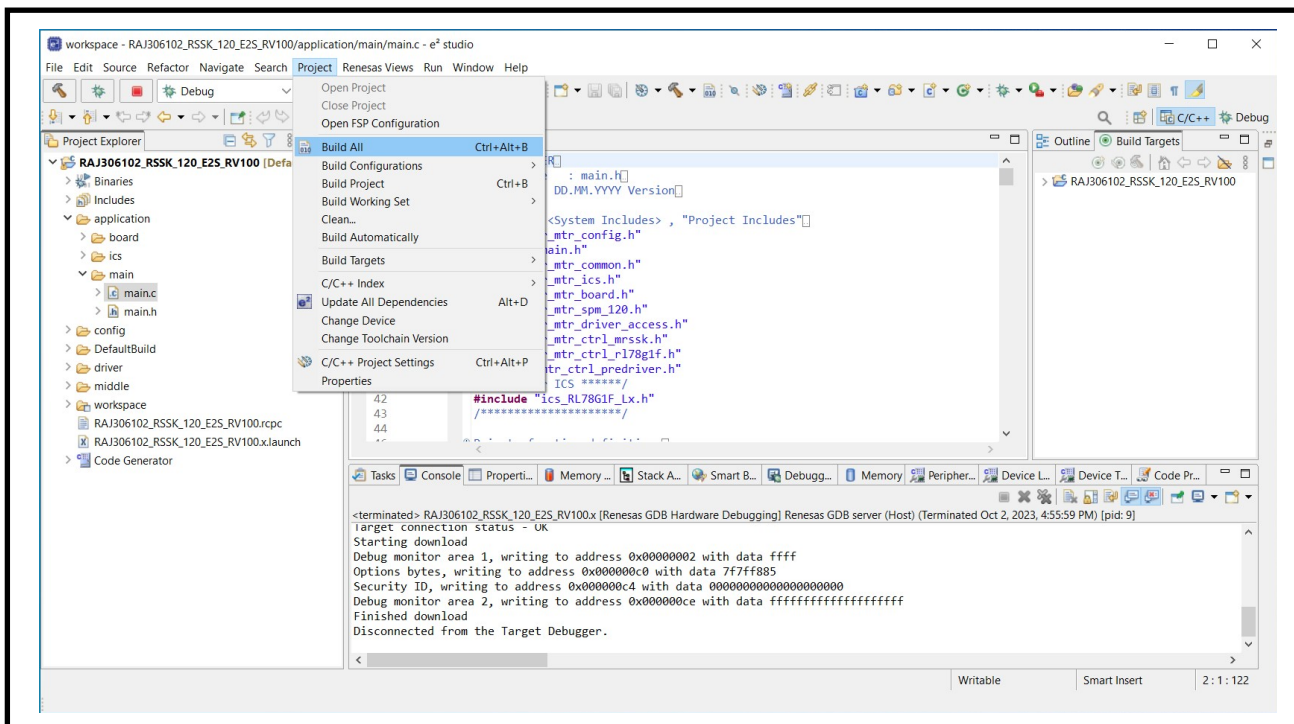3. Click "Debug" from "Run" tab of e² studio to write firmware.
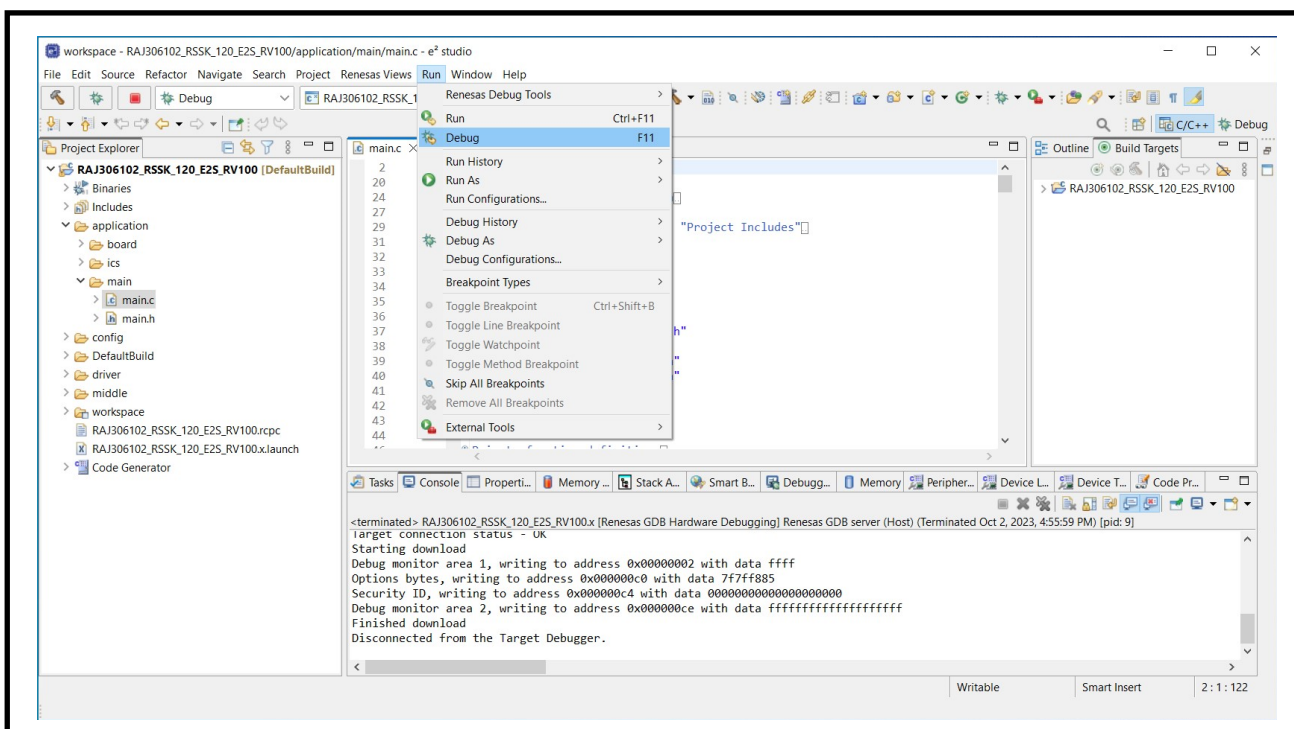

Figure 5-2 Firmware Build

Figure 5-3 Firmware Write

Note.1: This document is confirmed using e2 studio 2023-01.

5.1.2   CS+

1. Supply power to Evaluation Board, then connect to PC by USB cable.

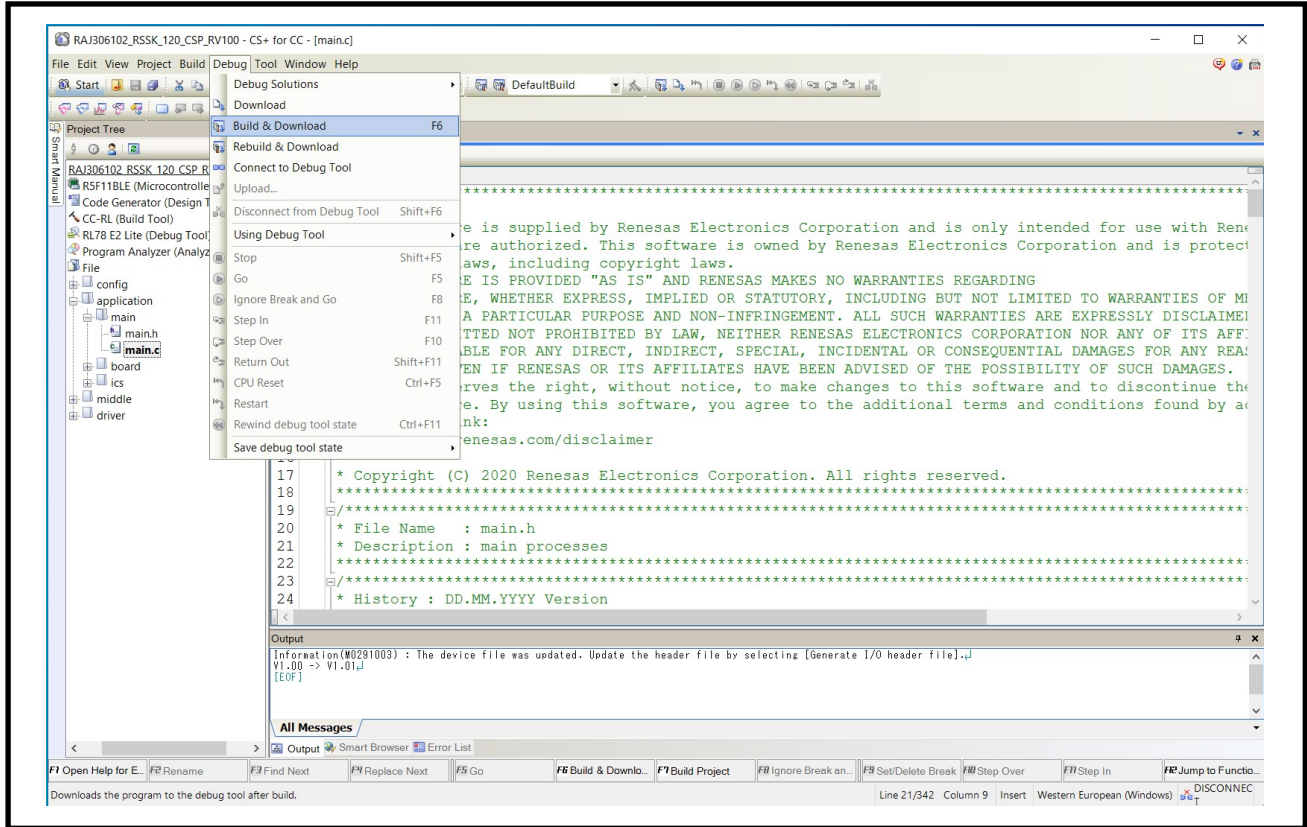2. Execute CS+, click "Build & Download" from "Debug" tab of CS+ to write firmware. Note.1

Figure 5-4 Firmware Write

Note.1: This document is confirmed using CS+ for CC V8.09.0.

5.1.3 Renesas Flash Programmer

1. Supply power to Evaluation Board, then connect to PC by USB cable.

2. Execute Renesas Flash Programmer, then connect from menu "File" > "New Project…" in reference to
   Figure 5-5. Note.1

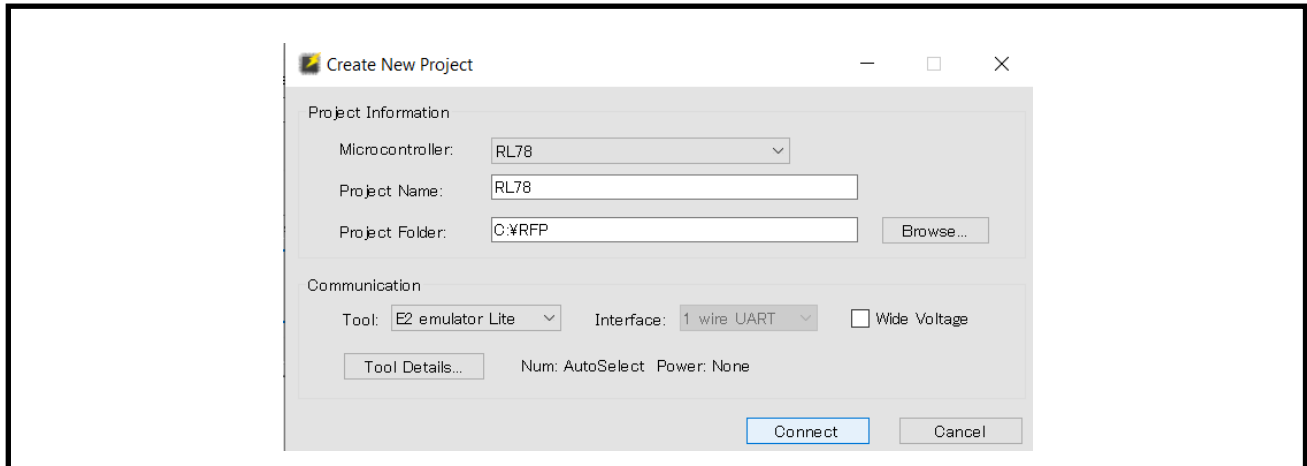3. Select HEX file, then click "Start" in reference to *Figure 5-6* to write firmware.
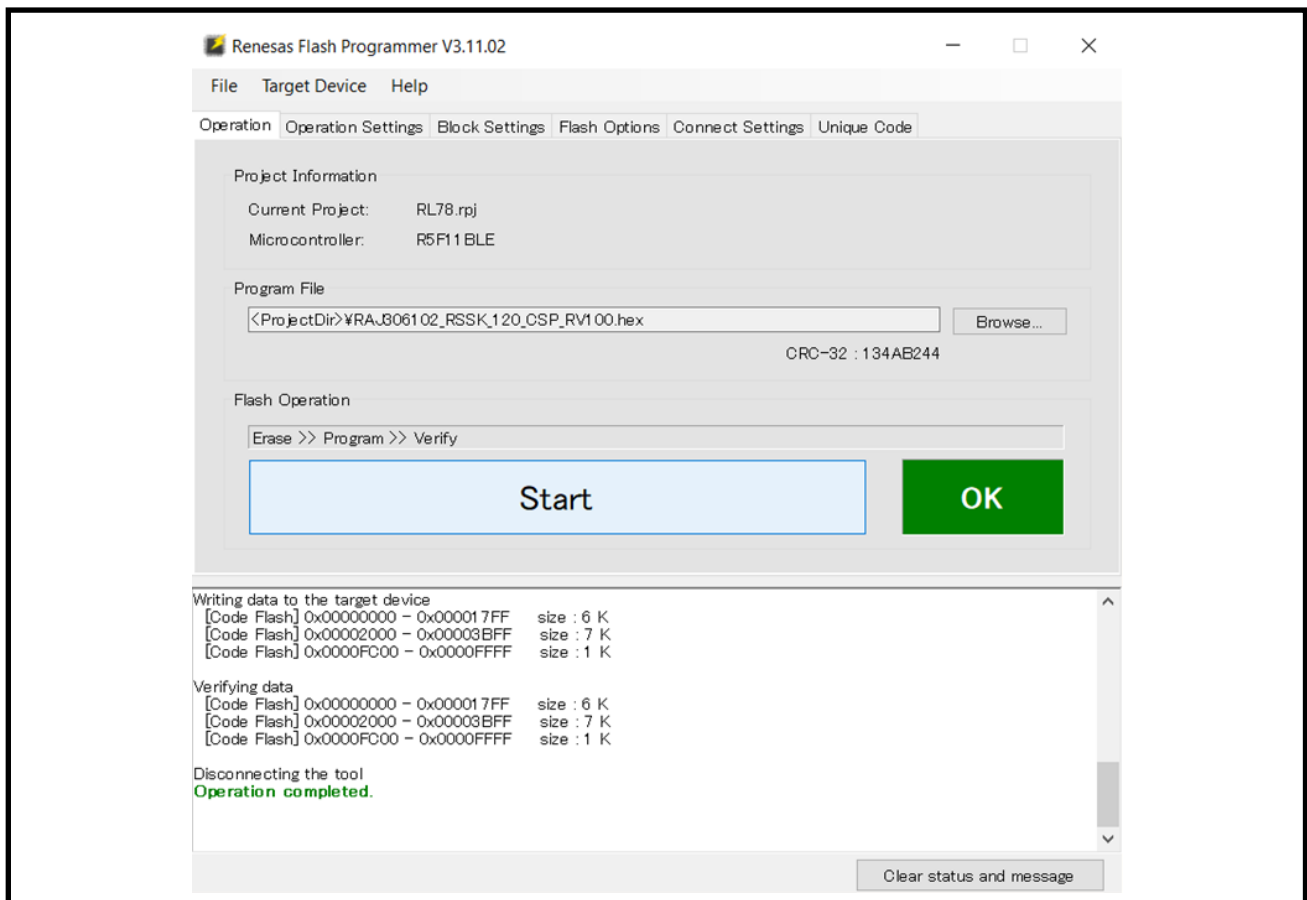

Figure 5-5 Create New Project (RAJ306102)

Figure 5-6 Firmware Write (RAJ306102)

Note.1: This document is confirmed using Renesas Flash Programmer V3.11.02.

Chapter 6. Renesas Motor Workbench

The board is equipped with an evaluation version of the Renesas Motor Workbench (RMWB) and ICS host function. The sample program for this IC uses RMBK. Install RMWB on a Windows PC and connect the PC and Evaluation Board with a USB micro-B cable, monitor and change global variables from the PC, and display the graphs.

When using RMWB (ICS), it is necessary to set a jumper pin in ICS_SEL. ICS uses the UART function. Therefore, UART cannot be used as a general-purpose function at the same time.

This tool and library are sample and Renesas does not provide technical support. In addition, Renesas cannot be held responsible for any problems such as damage caused by incorporating or using this tool.
For instructions on using the tool, refer to the user's manual of the Motor Control Development Support Tool Renesas Motor Workbench.
Reference:
Renesas Motor Workbench URL: https://www.renesas.com/us/en/software-tool/renesas-motor-workbench.

If you wish to use RMWB in your user system, please consider purchasing the ICS / ICS ++ product version. The product version of ICS/ICS++ is sold by Desktop Lab Co., Ltd.

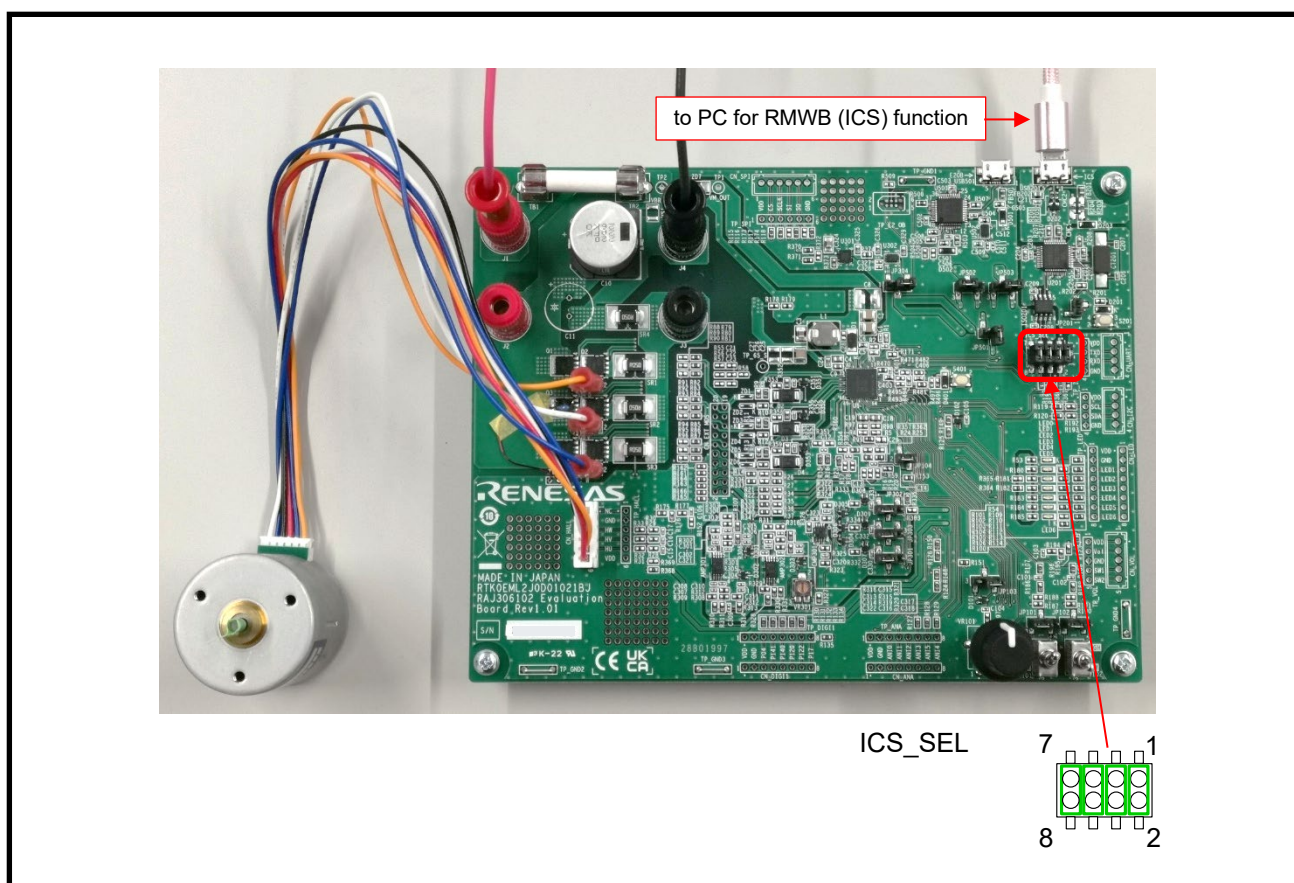Reference:
Desktop Lab Co., Ltd. URL: http://www.desktoplab.co.jp/download.html

Figure 6-1 Connect with PC (RMWB (ICS) Function)

Chapter 7. Information

7.1   European Union Regulatory Notices

This product complies with the following EU Directives. (These directives are only valid in the European Union.)

CE Certifications:

・Electromagnetic Compatibility (EMC) Directive 2014/30/EU

EN61326-1: 2013 Class A

WARNING: This is a Class A product. This equipment can cause radio frequency noise when used in the residential area. In such cases, the user/operator of the equipment may be required to take appropriate countermeasures under his responsibility.

・Information for traceability

　　・Authorized representative

　　　　Name: Renesas Electronics Corporation

　　　　Address: Toyosu Foresia, 3-2-24, Toyosu, Koto-ku, Tokyo 135-0061, Japan

　　・Manufacturer

　　　　Name: Renesas Electronics Corporation

　　　　Address:Toyosu Foresia, 3-2-24, Toyosu, Koto-ku, Tokyo 135-0061, Japan

　　・Person responsible for placing on the market

　　　　Name: Renesas Electronics Corporation

　　　　Address:Toyosu Foresia, 3-2-24, Toyosu, Koto-ku, Tokyo 135-0061, Japan

　　・Trademark and Type name

　　　　Trademark: Renesas

　　　　Product name: Renesas Solution Starter Kit
　　　　 Motor Control Evaluation System
　　　　 - Motor Control IC: RAJ306102 -

　　　　Type name: RTK0EML2J0S00020BJ

Environmental Compliance and Certifications:

・Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU

Revision History

Revision	Date	Description	Object Page
1.00	Nov 1, 2023	· Initial release.	· All

RAJ306102

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