

Renesas Solution Starter Kit 12 V Motor Control Evaluation System for RL78/F24

User's Manual

R20UT5165EJ0110
Rev.1.10
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For Your Safety




Do not fail to read this manual before using the Renesas Solution Starter Kit 12 V Motor Control Evaluation System for RL78/F24 (RTK7F124FGS00000BJ).

- 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).
- All information contained in this manual represents information on products at the time of publication of this manual. Please note that the product data, specification, sales offices, contents of website, address, etc., are subject to change by Renesas Electronics Corporation without notice due to product improvements or other reasons. Please confirm the latest information on Renesas Electronics website.
- The manual for the product, and specification (the documents) are the tool that was developed for the function and performance evaluation of Renesas Electronics semiconductor device (Renesas Electronics device) mounted on the product, and not guarantee the same quality, function and performance.
- 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 item 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} . |

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

| | | | |
|---|---|---|--|
|  | <p>General Prohibition The indicated action is prohibited.</p> |  | <p>Example: Do Not Touch! Touching the specified location could result in injury.</p> |
|---|---|---|--|

- Marks indicating that an action is prohibited.






| | | | |
|---|---|---|--|
|  | <p>General Caution Indicates a general need for caution that is not specified.</p> |  | <p>Example: Caution – Hot! Indicates the possibility of injury due to high temperature.</p> |
|---|---|---|--|

- Marks directing that the specified action is required.







| | | | |
|---|---|---|---|
|  | <p>General Instruction The specified action is required.</p> |  | <p>Example: Turn Off (Disconnect) Power Supply! Instructs the user to turn off (disconnect) the power supply to the product.</p> |
|---|---|---|---|

Warnings Regarding Use of the Product






Danger Items

| | |
|---|--|
|  <h2 style="margin: 0;">Danger</h2> | |
|    | <ul style="list-style-type: none"> 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. |
|  | <p>Do Not Connect Load to Motor!</p> <ul style="list-style-type: none"> This could cause fire, burns, or injury. |

Warning Items

|  Warning | |
|--|---|
|  | <p>Caution – Rotating Parts!</p> <ul style="list-style-type: none"> • The system includes a motor. Touching the rotating shaft could cause high-temperature burns or injury. |
|  | <p>Always insert plugs, connectors, and cables securely, and confirm that they are fully inserted.</p> <ul style="list-style-type: none"> • Incomplete connections could cause fire, burns, electric shock, or injury. |
| | <p>Use the power supply apparatus specified in the manual.</p> <ul style="list-style-type: none"> • Failure to do so could cause fire, burns, electric shock, injury, or malfunction. |
| | <p>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.</p> <ul style="list-style-type: none"> • Failure to do so could cause fire, burns, electric shock, or malfunction. • This will protect the system against damage due to lightning. |
|  | <p>Use a mechanism (switch, outlet, etc.) located within reach to turn off (disconnect) the power supply.</p> <ul style="list-style-type: none"> • In case of emergency, it may be necessary to cut off the power supply quickly. |
| | <p>Turn off the power supply immediately if you notice abnormal odor, smoke, abnormal sound, or overheating.</p> <ul style="list-style-type: none"> • Continuing to use the system in an abnormal condition could cause fire, burns, or electric shock. |
|  | <p>Do Not Disassemble, Modify, or Repair!</p> <ul style="list-style-type: none"> • Doing so could cause fire, burns, electric shock, injury, or malfunction. |
|  | <p>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.</p> <ul style="list-style-type: none"> • 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. |

Caution Items

|  Caution | |
|--|---|
|  | <p>Caution – Hot!</p> <ul style="list-style-type: none"> • The motor gets hot. Touching it could cause high-temperature burns. |
|  | <p>Follow the procedure specified in the manual when powering the system on or off.</p> <ul style="list-style-type: none"> • Failure to do so could cause overheating or malfunction. |
|  | <p>Caution – Static Electricity</p> <ul style="list-style-type: none"> • Use the antistatic band. Failure to do so could cause malfunction or unstable motion. |
|  | <p>Use the ferrite core “near this product” on cable between the power supply and this product.</p> <ul style="list-style-type: none"> • Failure to do so could cause inhibition of motion to other equipment. |

Introduction

The product is a brushless DC motor control evaluation kit designed for use in a 12 V automotive power supply environment. The product includes a inverter board with 125 °C compatible automotive grade parts, sample software that runs on the inverter board, and various evaluation data for the system. It is intended to assist customers in the development of brushless DC motor.

For this product, please prepare regulated power supply and E2/E2 Lite emulator by the customer.

This User's Manual describes about the operation method and the specification.

Target Device

- RL78/F24 (R7F124FGJ)

Related Documents

- Circuit Diagram : R20UT5166EJ0100
- Parts List : R20UT5167EJ0100
- PWB Pattern Diagram : R20UT5168EJ0100
- Application Note
 - Sensorless Trapezoidal Control of BLDC Motor by MCU : R01AN6308EJ0110
 - Three-Shunt Sensorless Vector Control for PMSM by MCU : R01AN6309EJ0110
 - Single-Shunt Sensorless Vector Control for PMSM by MCU : R01AN6310EJ0110

Included Items

Refer to the sheet "Included Items (R20UT5169XJ0100)", which is included in the product package.

Abbreviations and Acronyms

| Abbr. / Acronym | Standard Nomenclature | Note |
|-----------------|--|--|
| A/D, AD | Analog to Digital | – |
| CAN, CANFD | Controller Area Network, CAN with Flexible Data rate | One of the serial communication protocols |
| CPU | Central Processing Unit | – |
| DC | Direct Current | – |
| ECU | Electronic Control Unit | – |
| MCU | Micro-Controller Unit | – |
| MOSFET | Metal-Oxide-Semiconductor Field Effect Transistor | – |
| NC | Non-Connection | – |
| OCD | On-chip Debugging System | Refers to E2/E2 Lite emulator in this system |
| PMSM | Permanent Magnet Synchronous Motor | – |
| PWM | Pulse Width Modulation | – |
| UART | Universal Asynchronous Receiver/Transmitter | One of the serial communication protocols |

Contents

| | |
|---|----|
| For Your Safety..... | 1 |
| Introduction..... | 4 |
| 1. Features..... | 7 |
| 2. Specification Outline..... | 8 |
| 2.1 Specification..... | 8 |
| 2.2 Rules and Regulations..... | 9 |
| 2.2.1 European Union Regulatory Notices..... | 9 |
| 3. Block Diagram..... | 10 |
| 4. Layout..... | 11 |
| 5. Usage..... | 13 |
| 5.1 Quick Start..... | 13 |
| 5.1.1 Connecting the Motor and the Inverter Board Using the Included Motor Cable..... | 14 |
| 5.1.2 Connecting the Regulated Power Supply and the Inverter Board..... | 15 |
| 5.1.3 Supplying Power..... | 15 |
| 5.1.4 Checking the Change in Motor Rotation Speed..... | 15 |
| 5.1.5 Finish the Operation Check..... | 15 |
| 5.2 Software Specification..... | 16 |
| 5.3 Dealing with Errors..... | 17 |
| 5.3.1 Operation when an Error Occurs..... | 17 |
| 5.3.2 Measures for the Unusual Odor, Smoke, Unusual Noise, Overheating, etc..... | 17 |
| 5.4 Software Programming..... | 17 |
| 5.4.1 Connecting the Regulated Power Supply and the Inverter Board..... | 17 |
| 5.4.2 Connecting the Inverter Board and the OCD Conversion Board..... | 17 |
| 5.4.3 Connecting the E2/E2 Lite Emulator..... | 17 |
| 5.4.4 Supplying Power..... | 17 |
| 5.4.5 Launching the RFP..... | 17 |
| 5.4.6 Create the RFP Project..... | 18 |
| 5.4.7 Executing the Flash Memory Programming..... | 18 |
| 5.4.8 Checking the Result for the Flash Memory Programming..... | 18 |
| 5.5 How to Control the Default Software Using PWM Interface..... | 18 |
| 5.5.1 Change Software to Enable PWM Interface Function..... | 18 |
| 5.5.2 Software Specification of the PWM Interface Function..... | 20 |
| 5.5.3 Notes on the PWM Interface Function..... | 20 |
| 6. Board Specification..... | 21 |
| 6.1 Inverter Board..... | 21 |
| 6.1.1 Hardware Setting for Single-shunt Current Method..... | 21 |

| | | |
|--------|---|----|
| 6.1.2 | Voltage Generator Circuit..... | 22 |
| 6.1.3 | Connecting the E2/E2 Lite Emulator | 22 |
| 6.1.4 | Inverter Control Circuit Block..... | 23 |
| 6.1.5 | Current Detection Circuit | 24 |
| 6.1.6 | Overcurrent Detection Circuit | 24 |
| 6.1.7 | Bus Voltage Detection Circuit..... | 25 |
| 6.1.8 | Board Temperature Detection Circuit..... | 25 |
| 6.1.9 | Motor Coil-end Temperature Detection Circuit..... | 26 |
| 6.1.10 | CAN/CANFD Communication Circuit | 26 |
| 6.1.11 | PWM Rotation Speed Command Input Circuit..... | 27 |
| 6.2 | OCD Conversion Board..... | 27 |
| 6.2.1 | E2/E2 Lite Emulator Connection | 27 |
| 6.2.2 | ICS++ Connection (Option) | 27 |
| 7. | Usage Notes..... | 28 |
| | Appendix..... | 29 |
| | Revision History..... | 31 |

1. Features

The typical features of this product are shown below.

- (1) Supports the RL78/F24 microcontroller with the motor control function.
- (2) Supports permanent magnetic synchronous motors.
- (3) Supports FOC control method (three-shunt and single-shunt).
- (4) Supports trapezoidal control method.
- (5) Space-saving board layout 60mm × 56mm (dia. 60).
- (6) Equipped with overcurrent detection circuit.
- (7) Equipped with PCB temperature detection circuit.
- (8) Equipped with an external thermistor connection circuit designed for using motor coil-end temperature detection (optional).
- (9) Equipped with a CAN/CANFD transceiver and a PWM circuit as a communication interface for external ECU.
- (10) Equipped with a E2/E2 Lite emulator connector as a debug interface.
- (11) Supports ICS++^{Note 1} using UART communication (option).
- (12) Includes design data and various evaluation data^{Note 2} of the product.

Notes 1. ICS++ (In Circuit Scope Plus) is a real-time RAM monitor is manufactured by Desk Top Laboratories Inc. <http://www.desktoplab.co.jp/>

2. Refer to the sheet "Included Items" which is included in the product package.

2. Specification Outline

2.1 Specification

Table 2-1 12 V Motor Control Evaluation System for RL78/F24 Specifications (1/3)

| Item | Specification |
|-----------------------|---|
| Series | Renesas Solution Starter Kit 12V Motor Control Evaluation System for RL78/F24 |
| Kit Type | RTK7F124FGS00000BJ |
| Kit Contents | Inverter Board with RL78/F24 (RTK7F124FGS00000BJ) |
| | OCD Conversion Board |
| | Permanent Magnet Synchronous Motor |
| Operating Temperature | At normal temperature |
| Operating Humidity | No condensation |

Table 2-1 12 V Motor Control Evaluation System for RL78/F24 Specifications (2/3)

| Item | Specification | |
|-------------------------------------|---|----------------------|
| Inverter Board with RL78/F24 | | |
| MCU | Product Name | RL78/F24 (R7F124FGJ) |
| | CPU Maximum Operating Frequency | 40 MHz |
| | Package | 48 pins LQFP |
| | ROM | 256 KB |
| | RAM | 24 KB |
| | Data Flash | 16 KB |
| | Operating Temperature | -40 °C to 125 °C |
| MCU Input Clock | Crystal resonator 16 MHz | |
| Supported Emulators | E2/E2 Lite emulator | |
| Connection Terminals | <ul style="list-style-type: none"> DC 12 V input terminal (VBAT / GND) Motor 3-phase output (U/ V/ W) | |
| Connector | OCD conversion board connector | |
| Through-holes as Connector | <ul style="list-style-type: none"> External thermistor (Motor coil-end temperature measurement) (optional) CAN/CANFD communication interface PWM command input interface | |
| Operating Input Voltage | Rated DC 12 V (Operating voltage range: 8 V to 19 V) | |
| Max. Input Power | 120 W | |
| Rated Output Capacity | 42.4 VA | |
| Rated Output Current | 5 Arms | |
| Switching Frequency | 20 kHz | |
| Dead-time | 1.0 μs and more | |
| Current Detection Method | Three-shunt / Single-shunt method | |
| Shunt Resistor | 5 mΩ | |
| PWM Logic | Positive logic with upper and lower arms | |
| DC Bus Voltage Detection | Detection by resistance division (5.5 V to 25 V) | |
| Three-phase Current Detection | Voltage detection using shunt resistor (-25 A to +25 A) | |
| Overcurrent Detection Function | Detect by comparing shunt voltage with a comparator built into the RL78/F24 microcontroller | |
| PCB Temperature Detection | Temperature measurement using a thermistor (-40 °C to 150 °C) | |

Table 2-1 12 V Motor Control Evaluation System for RL78/F24 Specifications (3/3)

| Item | Specification |
|-----------------------------|--|
| <u>OCD Conversion Board</u> | |
| Connectors | <ul style="list-style-type: none"> • For E2/E2 Lite emulator connection • For ICS++ connection (optional) • For inverter board connection |

2.2 Rules and Regulations

2.2.1 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:

- Authorised representative
Name: Renesas Electronics Corporation
Address: Toyosu Foresia, 3-2-24, Toyosu, Koto-ku, Tokyo 135-0061, Japan
- Manufacture
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: 12V Motor Control Evaluation System for RL78/F24
Type name: RTK7F124FGS00000BJ

Environmental Compliance and Certifications:

- Waste Electrical and Electronic Equipment (WEEE) directive (2012/19/EU)

3. Block Diagram

Figure 3-1 shows a block diagram of inverter board with RL78/F24.

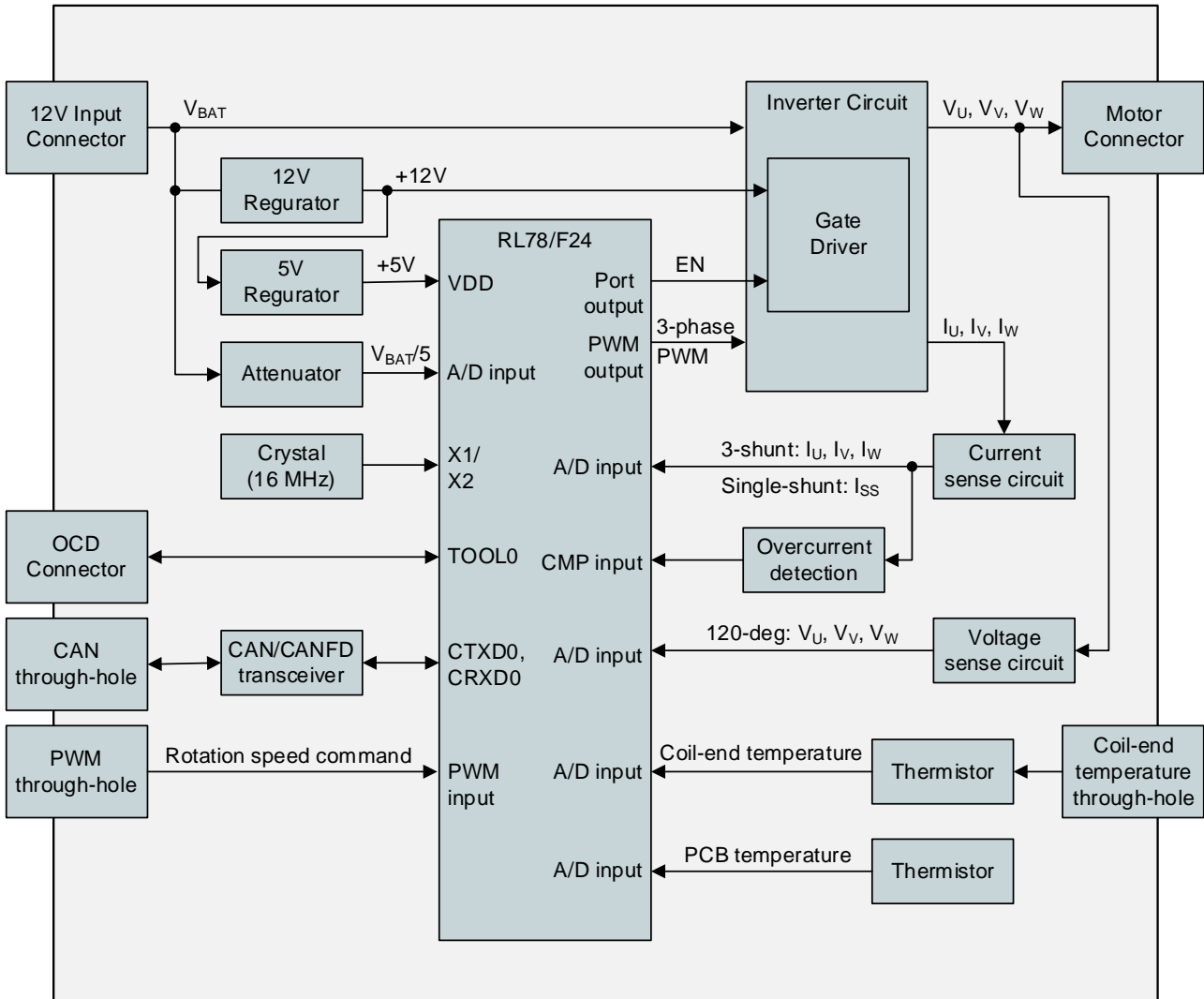
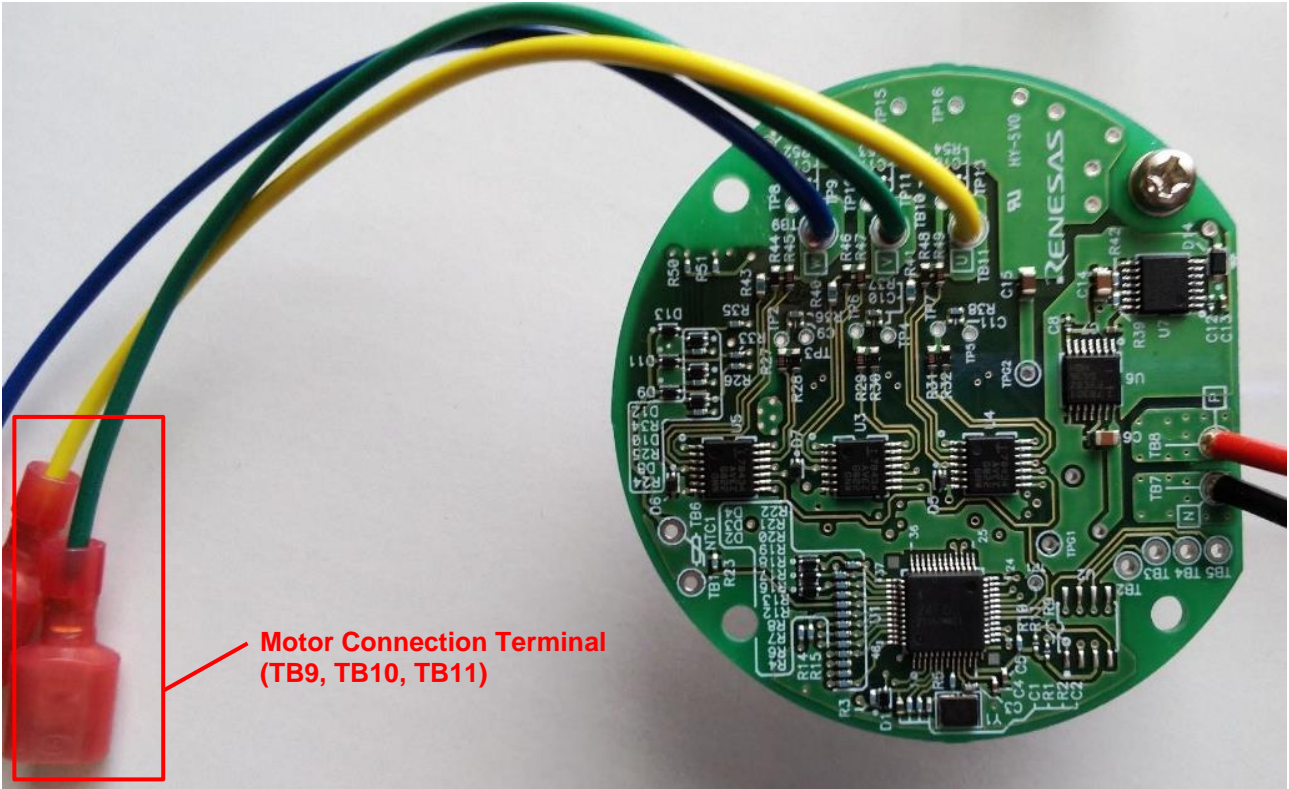


Figure 3-1 Block Diagram of Inverter Board with RL78/F24

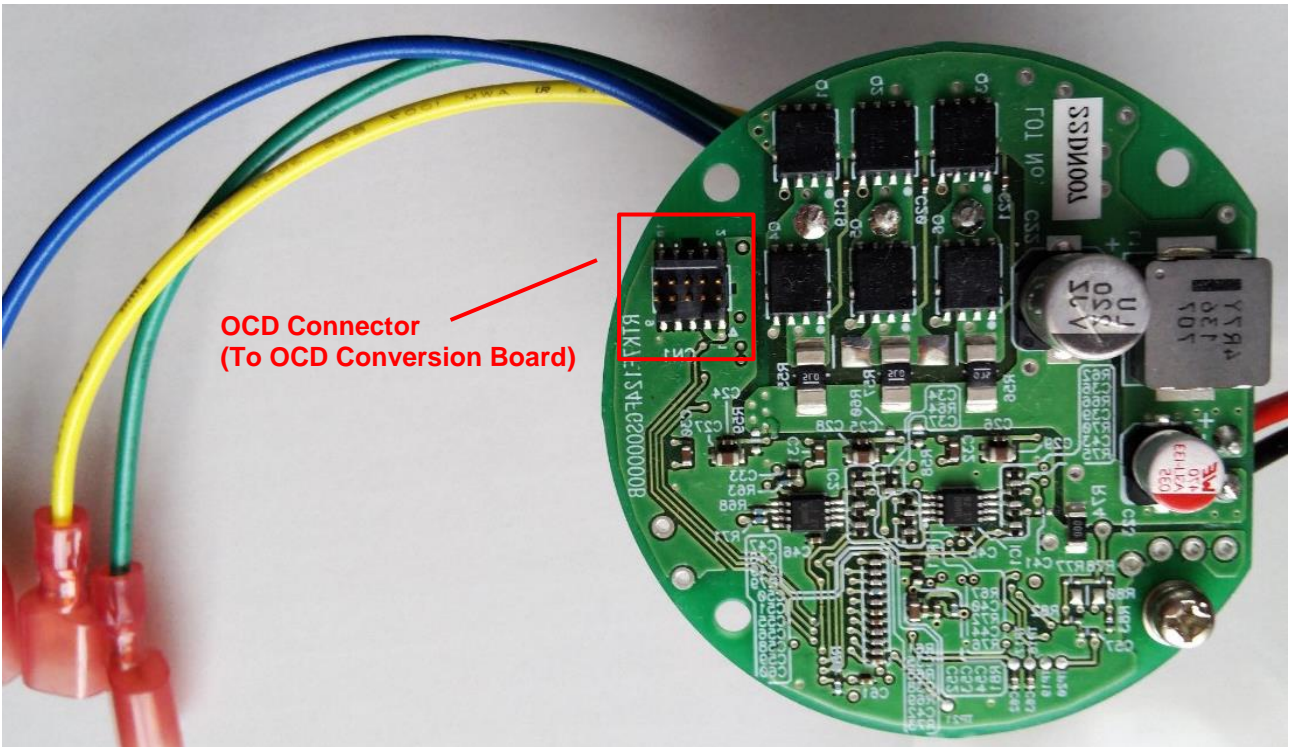
4. Layout

Inverter Board:

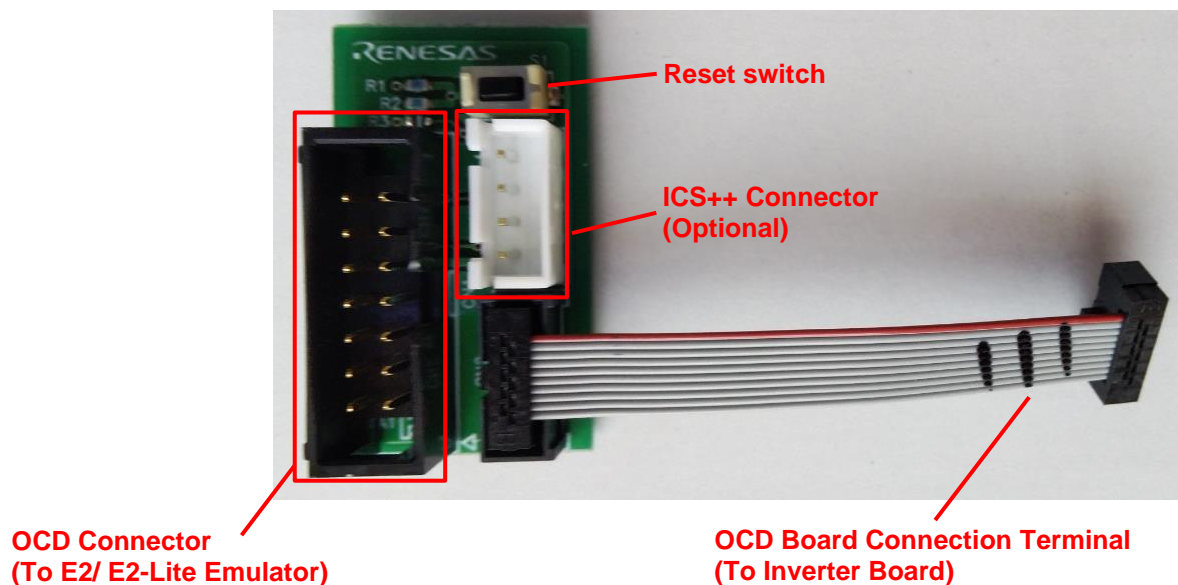
Surface



Back



OCD Conversion Board:



5. Usage

This chapter describes how to use the 12 V Inverter Board with RL78/F24.

5.1 Quick Start

This section describes the quick start procedure for the product. Perform steps (1) to (5) in this order.

The product includes a TG-55N-KA permanent magnet synchronous motor manufactured by Tsukasa Electric Co., Ltd (<https://www.tsukasa-d.co.jp/>). Use the supplied motor when performing the steps described in this section.

Please use anti-static wristbands for the use of this product. Touching this product while static charged may cause equipment failure or unstable operation.

Preparation for Quick Start

Please prepare the following:

- Regulated Power Supply: Output voltage is DC 12 [V], Output current limit is 3 [A]

Quick Start Procedure

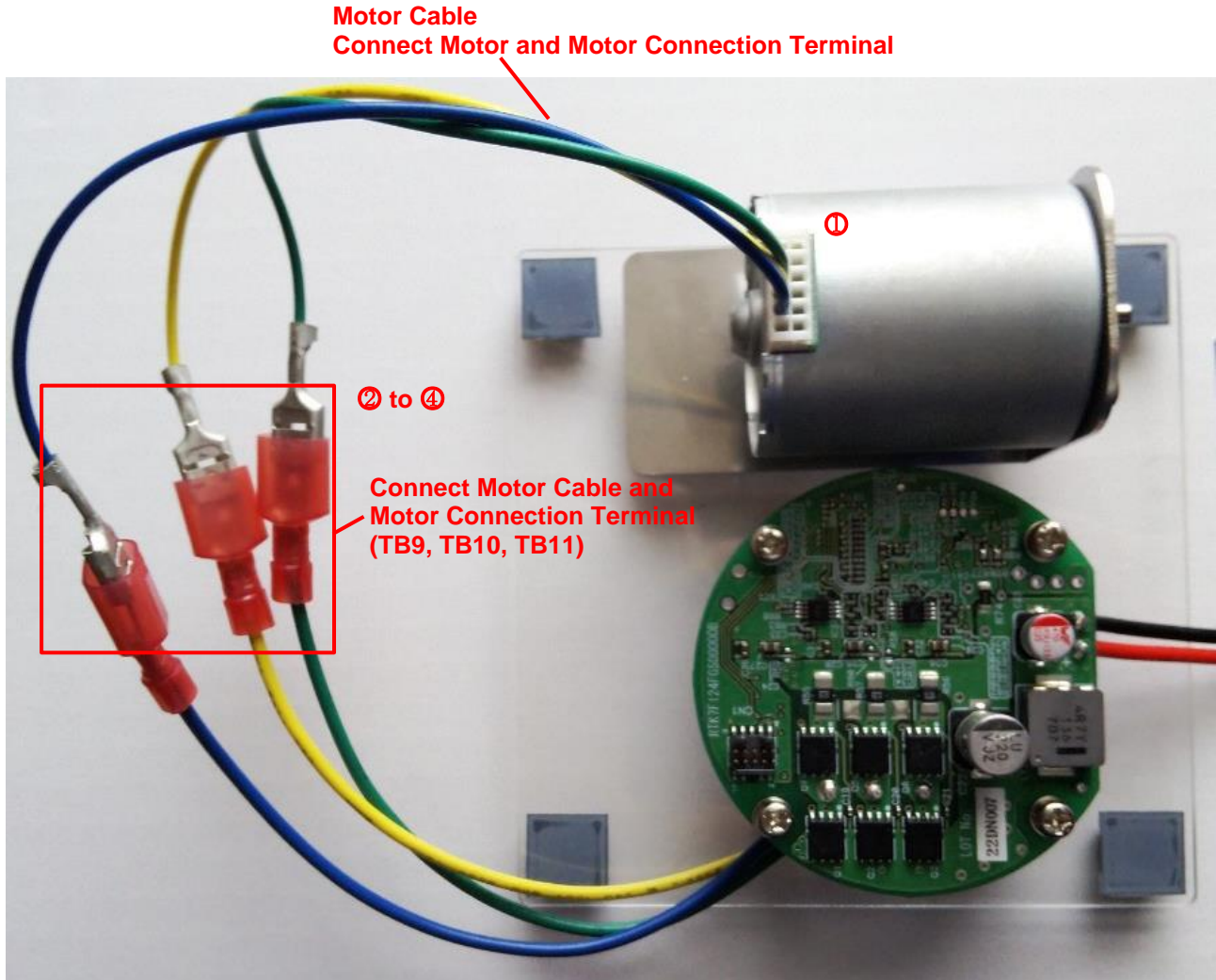
| Step | Item |
|------|---|
| (1) | Connect the motor and the inverter board using the included motor cable |
| (2) | Connect the regulated power supply and the inverter board |
| (3) | Supply power (and start the motor) |
| (4) | Check the change in motor rotation speed |
| (5) | Finish the operation check |

If Any Errors Occur

The motor stops rotating. The default software does not perform automatic recovery processing. To recover, stop the power supply, wait 5 seconds or more, and then resupply power.

5.1.1 Connecting the Motor and the Inverter Board Using the Included Motor Cable

Connect the motor and the motor cable included the product package. Then connect the motor 3-phase wire terminals U, V, and W to the inverter board.



| | Motor Cable | Connection |
|---|------------------|---|
| ① | 12 pin Connector | Motor |
| ② | Yellow Cable | The yellow cable connected to the TB11 terminal on the inverter board |
| ③ | Green Cable | The green cable connected to the TB10 terminal on the inverter board |
| ④ | Blue Cable | The blue cable connected to the TB9 terminal on the inverter board |

5.1.2 Connecting the Regulated Power Supply and the Inverter Board

The power supply for the inverter board is supplied from the regulated power supply. Connect the black cable of the inverter board to the regulated power supply "GND" and the red cable to "DC 12 [V]".



The inverter board of the product does not support reverse connection protection circuit.

Please note that a large current may flow through the board and damage the inverter board, if the power supply connector connection is reversed.

5.1.3 Supplying Power

Using the prepared regulated power supply, set the output voltage to DC 12 [V] and the limit current to 3 [A], and then turn it on. If the voltage drops even momentarily, the drop in the microcontroller (RL78/F24) power supply will cause a reset to be generated, and program execution becomes undefined.

5.1.4 Checking the Change in Motor Rotation Speed

When power is supplied from the regulated power supply, the program starts the motor rotation control.

The default software controls motor action with elapsed time from hardware initialization for MCU.

The operation after turning on the power is as shown in Table 5-1.

Table 5-1 Default Software Operation

| | Elapsed Time after the Initialization Processing | Operation |
|-----|--|---|
| (1) | 3 [s] | Start the motor at a rotation speed of 1000 [rpm] |
| (2) | After 10 [s] have passed from (1) | Accelerate the motor to 2000 [rpm] |
| (3) | After 10 [s] have passed from (2) | Accelerate the motor to 3000 [rpm] |
| (4) | After 10 [s] have passed from (3) | Stop the motor |
| (5) | After 1 [s] have passed from (4) | Repeat the operation from (1) |

5.1.5 Finish the Operation Check

The default software cannot stop by external operation.

When finishing the operation check, make sure that the rotation of motor has stopped and turn off the output of the regulated power supply.

5.2 Software Specification

As for the state of the product after unpacking, 180-degree energization method three-shunt sensorless vector control software has been written into RL78/F24 microcontroller. The factory-written software specifications are as follows.

Table 5-2 Default Software Specification

| Item | Specification |
|--------------------------------------|---|
| Control method | Sensorless vector control (Using three-shunt current method) |
| Motor rotation start/stop | Operates by selecting one of the following two condition. <ul style="list-style-type: none"> • After MCU reset released, the control rotation state is changed at the following timing. <ul style="list-style-type: none"> – After 3 [s], starts operation targeted on 1000 [rpm] as speed command value. – After 10 [s] from above condition, speed command changes to 2000 [rpm]. – After 10 [s] from above condition, speed command changes to 3000 [rpm]. – After 10 [s] from above condition, stops the motor rotation. – After 1 [s] from above condition, resume operation from the reset state. • After MCU reset released, controls rotation speed command value by PWM signal input. <ul style="list-style-type: none"> – Applicable PWM signal input range is from 10 [Hz] to 1000 [Hz]. – If duty ratio is 100%, rotation speed command value is 3000 [rpm], – If duty ration is 0%, rotation speed command value is 0 [rpm]. |
| Rotor pole position detection method | Sensorless control based on current estimation error method |
| Carrier frequency (PWM) | 20 [kHz] |
| Dead-time | 1 [μs] |
| Control cycle | 100 [μs] (50 [μs] × 2 for decimation once) |
| Rotating speed control range | Bothe CW/CCW are supported from 500 [rpm] to 3000 [rpm]. |
| Protection procedure | Deactivates the motor control signal outputs (6 ch), if any of the following conditions are met. <ul style="list-style-type: none"> – In case of exceeding +/- 16.97 [A] (10Arms + 20%) in any one of the three-phase current values. (Monitored in every 100 [μs].) – In case of the inverter power supply voltage (Vdc) exceeds 28.0 [V]. (Monitored in every 100 [μs].) – In case of the inverter power supply voltage is lower than 8.0 [V]. (Monitored in every 100 [μs].) – In case of the rotation speed exceed 5000 [rpm]. (Monitored in every 1 [ms].) – When low level signal input to INTPO. (Signal stop operation is real time. Error detection is monitored in every 100 [μs].) – In case of the PCB temperature exceeds 120 [°C]. (Monitored in every 1 [ms].) – In case of the motor coil-end temperature exceeds 180 [°C]. (Monitored in every 1 [ms].) |

5.3 Dealing with Errors

5.3.1 Operation when an Error Occurs

The default software stops the rotation when an overcurrent, power failure or any abnormality is detected. The software does not automatically recover. To recover, stop the power supply and forcibly reset system. Refer to the application note for detectable errors in the default software.

5.3.2 Measures for the Unusual Odor, Smoke, Unusual Noise, Overheating, etc.

If any abnormality (e.g., unusual odor, smoke, unusual noise, overheating, etc.) occurs, please turn off the power supply unit immediately.

5.4 Software Programming

This section describes the procedure for rewriting the software of the RL78/F24 mounted on the inverter board. As an example in this section, that describes the procedure for rewriting the default software. If the default software is modified, please build using software development environment.

Preparation for Software Programming

Please prepare the following:

- Connect inverter board and OCD conversion board with the attached cable.
- Regulated Power Supply: Output voltage is DC 12 [V], Output current limit is 0.5 [A].
- PC (with RFP (Renesas Flash Programmer) installed)
- Connect E2/E2 Lite emulator and OCD conversion board.

For details on the functions of E2/E2 Lite emulator and RFP, refer to the target manual.

Flash Memory Programming Procedure

| Step | Item |
|------|--|
| (1) | Connect the regulated power supply and the inverter board |
| (2) | Connect the inverter board and the OCD conversion board |
| (3) | Connect E2/E2 Lite emulator to OCD conversion board and PC |
| (4) | Supply power |
| (5) | Launch the RFP |
| (6) | (First time only) Create an RFP project |
| (7) | Select a writing file and execute program writing |
| (8) | Check the result for the program writing |

5.4.1 Connecting the Regulated Power Supply and the Inverter Board

The power supply for the inverter board is supplied from the regulated power supply. Connect the black cable of the inverter board to the regulated power supply "GND" and the red cable to "DC 12 [V]".



The inverter board of the product does not support reverse connection protection circuit. Please note that a large current may flow through the board and damage the inverter board, if the power supply connector connection is reversed.

5.4.2 Connecting the Inverter Board and the OCD Conversion Board

Connect the inverter board and the OCD conversion board with the attached cable.

5.4.3 Connecting the E2/E2 Lite Emulator

Connect the E2/E2 Lite emulator to the OCD conversion board and the prepared PC.

5.4.4 Supplying Power

Using the prepared regulated power supply, set the output voltage to DC 12 [V] and the limit current to 0.5 [A], and then turn it on. If the voltage drops even momentarily, the drop in the microcontroller (RL78/F24) power supply will cause a reset to be generated, and program execution becomes undefined.

5.4.5 Launching the RFP

Launch the RFP on the prepared PC.

5.4.6 Create the RFP Project

Select “New project...” in the “File” menu of the RFP. Then set the microcontroller to “RL78/F24”. In this procedure, set the power to “None”. Specify the project name and the project folder. Click “Connect” when the settings are complete.

This step is required only once at the first time in the environment. The next launch will load the already created project.

5.4.7 Executing the Flash Memory Programming

Specify the file path to write to the program file on the “Operation” tab.

In this example, select the “RL78F24_SSL_FOC180.mot”.

Then click to “Start”. If “Operation completed.” is displayed in the message window at the bottom, the flash memory programming is completed.

5.4.8 Checking the Result for the Flash Memory Programming

Check the operation according to the procedure shown in “5.1 Quick Start”.

5.5 How to Control the Default Software Using PWM Interface

The sample operation of the default software includes a function that can change the command rotational speed value by inputting PWM.

This section describes the how to edit the source code, and the software specifications.

5.5.1 Change Software to Enable PWM Interface Function

The PWM interface function is disabled in the default software. To enable the function, edit the source code for the software according to (1) and (2) below.

After editing the software, run the build using the development environment.

(1) Disabling the counter operation

File Name : user_control.c (for three-shunt control)

Function Name : userControlTimer ()

```

0161 /*****
0162 * Function Name: userControlTimer↓
0163 * Description : This function is user control task of interval timer↓
0164 * Arguments : None↓
0165 * Return Value : None↓
0166 *****/
0167 void userControlTimer(void)↓
0168 {↓
0169     userThOnBoard = invGetBoardTemp();↓
0170     userThCoilEnd = invGetCoilendTemp();↓
0171     ↓
0172     #if 1 * Sample: Operates with 1ms counter timer */↓
0173     #define IT_TIMEtoCOUNT(f_time_s) ((uint32_t)((float)CP_FREQ_SPEED_Hz * (f_time_s)))↓
0174     #define TIME1 (3.0f)↓
0175     #define TIME2 (TIME1 + 10.0f)↓
0176     #define TIME3 (TIME2 + 10.0f)↓
0177     #define TIME4 (TIME3 + 10.0f)↓
0178     #define TIME5 (TIME4 + 1.0f)↓
0179     {↓

```

Edit “#if 1” to “#if 0”.

(2) Enabling the PWM Interface Function

Edit the following two places to enabling the PWM interface function.

File Name : user_control.c (for three-shunt control)

Function Name : userControlInit ()

```
0154 | #if 0 /* Sample: Operates with pulse input to PWM port(P00) 1/2 */
0155 |     R_TAUD_Channel5_Start(); /* start pulse width measurement counter */
0156 |     R_TAUD_Channel6_Start(); /* start time out counter */
0157 | #endif
```

Edit "#if 0" to "#if 1".

File Name : user_control.c (for three-shunt control)

Function Name : userControlTimer ()

```
0213 | #elif 0 /* Sample: Operates with pulse input to PWM port(P00) 2/2 */
0214 | #define DELAY_CNT (1000)
0215 | {
```

Edit "#elif 0" to "#elif 1".

PWM interface function can also be enabled for single-shunt method and trapezoidal control by making the changes shown in the table below.

Table 5-3 Enable Setting of PWM Interface Function

| Control Method | File Name | Line | Contents |
|----------------------------|--------------------------|-------------------|--|
| Three-shunt method | user_control.c | 154 172 213 | Edit "#if 0" to "#if 1". Edit "#if 1" to "#if 0". Edit "#elif 0" to "#elif 1". |
| Single-shunt method | user_control.c | 154 172 213 | Edit "#if 0" to "#if 1". Edit "#if 1" to "#if 0". Edit "#elif 0" to "#elif 1". |
| Trapezoidal control method | r_mtr_user_control_cfg.h | 103 | Removed definition of "#define USER_CFG_TIME_CONTROL". |

5.5.2 Software Specification of the PWM Interface Function

The default software specifications of the PWM interface function (three-shunt) are as follows.

Table 5-4 Default Software Specification of the PWM Interface Function

| Item | Specification |
|--------------------------------------|---|
| Control method | Sensorless vector control (Using three-shunt current method) |
| Motor rotation start/stop | Monitor the TI05 input and start/stop under the following conditions. <ul style="list-style-type: none"> • Duty<100%, Start operation if low level is detected. <ul style="list-style-type: none"> – Duty=100% : 0 [rpm] (Stopping) – Duty= 50% : 1500 [rpm] – Duty= 0% : 3000 [rpm] The motor operates by calculating the rotation speed command value from the input PWM Duty. <ul style="list-style-type: none"> • Duty=100% (High level is 100 [ms] or more), Stop operation if 100% duty is detected. |
| Input PWM frequency | 10 to 1,000 [Hz] |
| Detectable PWM duty ratio | 0 to 100 [%] (Negative logic) |
| Rotor pole position detection method | Sensorless control based on current estimation error method |
| Carrier frequency (PWM) | 20 [kHz] |
| Dead-time | 1 [μs] |
| Control cycle | 100 [μs] (50 [μs] × 2 for decimation once) |
| Rotating speed control range | Both CW/CCW are supported from 500 [rpm] to 3000 [rpm]. |
| Protection procedure | Deactivates the motor control signal outputs (6 ch), if any of the following conditions are met. <ul style="list-style-type: none"> – In case of exceeding +/- 16.97 [A] (10Arms + 20%) in any one of the three-phase current values. (Monitored in every 100 [μs].) – In case of the inverter power supply voltage (Vdc) exceeds 28.0 [V]. (Monitored in every 100 [μs].) – In case of the inverter power supply voltage is lower than 8.0 [V]. (Monitored in every 100 [μs].) – In case of the rotation speed exceed 5000 [rpm]. (Monitored in every 1 [ms].) – When low level signal input to INTPO. (Signal stop operation is real time. Error detection is monitored in every 100 [μs].) – In case of the PCB temperature exceeds 120 [°C]. (Monitored in every 1 [ms].) – In case of the motor coil-end temperature exceeds 180 [°C]. (Monitored in every 1 [ms].) |

5.5.3 Notes on the PWM Interface Function

The input voltage to the PWM signal is 0 to 5 V with reference to GND. The PWM signal input to the microcontroller (RL78/F24) should not exceed 5 V.

If the PWM input frequency exceeds the range, the expected system operation will not be achieved.

6. Board Specification

This chapter describes the functions of the inverter board and the OCD conversion board.

6.1 Inverter Board

The inverter board included with this product can be equipped with RL78/F24 to operate the permanent magnetic synchronous motor (PMSM).

This section describes the functions of the inverter board circuit. For details of the circuit, refer to the included circuit diagram.

6.1.1 Hardware Setting for Single-shunt Current Method

As for the state of the product after unpacking, the inverter board is for three-shunt current method. The following inverter board settings are required to support single-shunt current method.

- Removal of the shunt resistors R55 and R56.
- Connecting “1 to 3” between R55 and R56 with 0 Ω resistors.

Single-shunt current can be detected using the shunt resistor R57 by the above hardware settings.

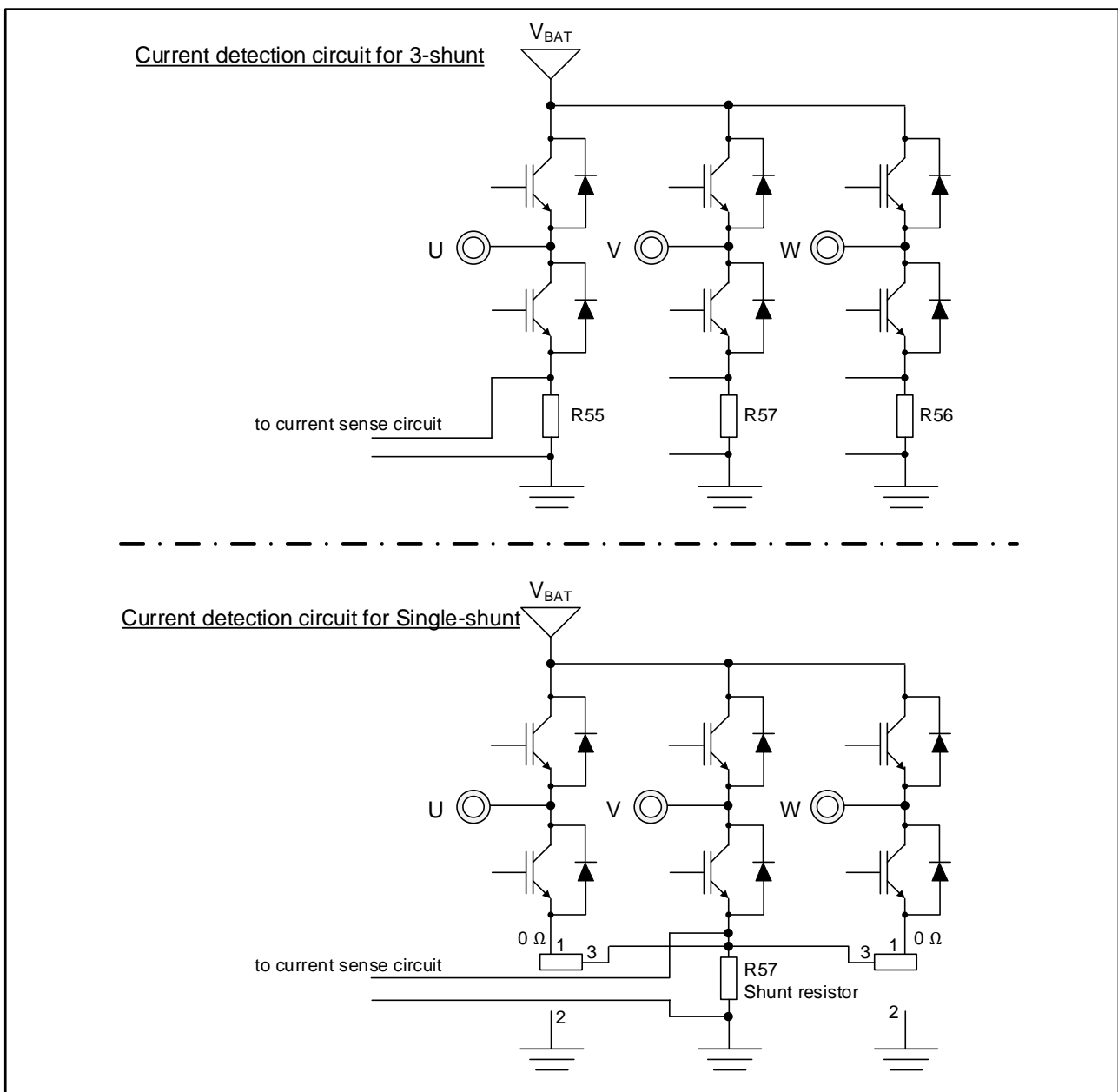


Figure 6-1 Inverter Board Setting for Single-shunt Current Detection

6.1.2 Voltage Generator Circuit

The inverter board generates voltages 12 V, 5 V, and 2.5 V from main power supply (from 8 V to 19 V).

Table 6-1 Voltage Generator Circuit

| Item | Input voltage (TYP.) | Output voltage (TYP.) | Output current (MAX.) | Application |
|-------|----------------------|-----------------------|-----------------------|---|
| 12 V | 12 [V] | 12 [V] | 0.15 [A] | Gate driver IC power supply protection |
| 5 V | 12 [V] | 5 [V] | 0.15 [A] | <ul style="list-style-type: none"> • MCU power supply • AMP IC power supply • CAN/CANFD transceiver power supply • 5 V reference voltage generation |
| 2.5 V | 5 [V] | 2.5 [V] | 0.015 [A] | Current detection circuit bias voltage generation |

6.1.3 Connecting the E2/E2 Lite Emulator

The E2/E2 Lite emulator is used to rewrite the program of the RL78/F24 microcontroller mounted on the inverter board. Connect the inverter board connector (CN1) and OCD conversion board with the included cable, and connect OCD conversion board and the emulator. Table 6-2 and Table 6-3 show the connector specifications for connecting to the E2/E2 Lite emulator and ICS++.

For details on the functions of E2/E2 Lite emulator and RFP, refer to the target manual.

Table 6-2 Inverter Board Connector (CN1) Specifications

| CN1 PIN No. | Inverter board connection | Contents |
|-------------|---------------------------|------------------------------------|
| 1, 3 | UVCC (5V) | – |
| 2 | RL78/F24: P62/(TXD0) | for ICS++ connection (option) |
| 4 | RL78/F24: P61/(RXD0) | for ICS++ connection (option) |
| 5, 7, 9 | GND | – |
| 6 | NC | – |
| 8 | RL78/F24: P40/TOOL0 | for E2/E2 Lite emulator connection |
| 10 | RL78/F24: RESET | for E2/E2 Lite emulator connection |

Table 6-3 OCD Conversion Board Specifications

| OCD conversion board connector | Specification |
|--------------------------------|------------------------------------|
| 10-pin connector | for inverter board connection |
| 14-pin connector | for E2/E2 Lite emulator connection |
| 4-pin connector | for ICS++ connection (option) |

6.1.4 Inverter Control Circuit Block

The inverter board has a motor driver circuit block consisting of six N-channel MOS-FETs for motor control. This circuit is equipped with three gate drivers because it is necessary to boost voltage from MCU port outputs for driving N-channel MOS-FETs.

The inverter control circuit of this system is shown in Figure 6-2 and Figure 6-3.

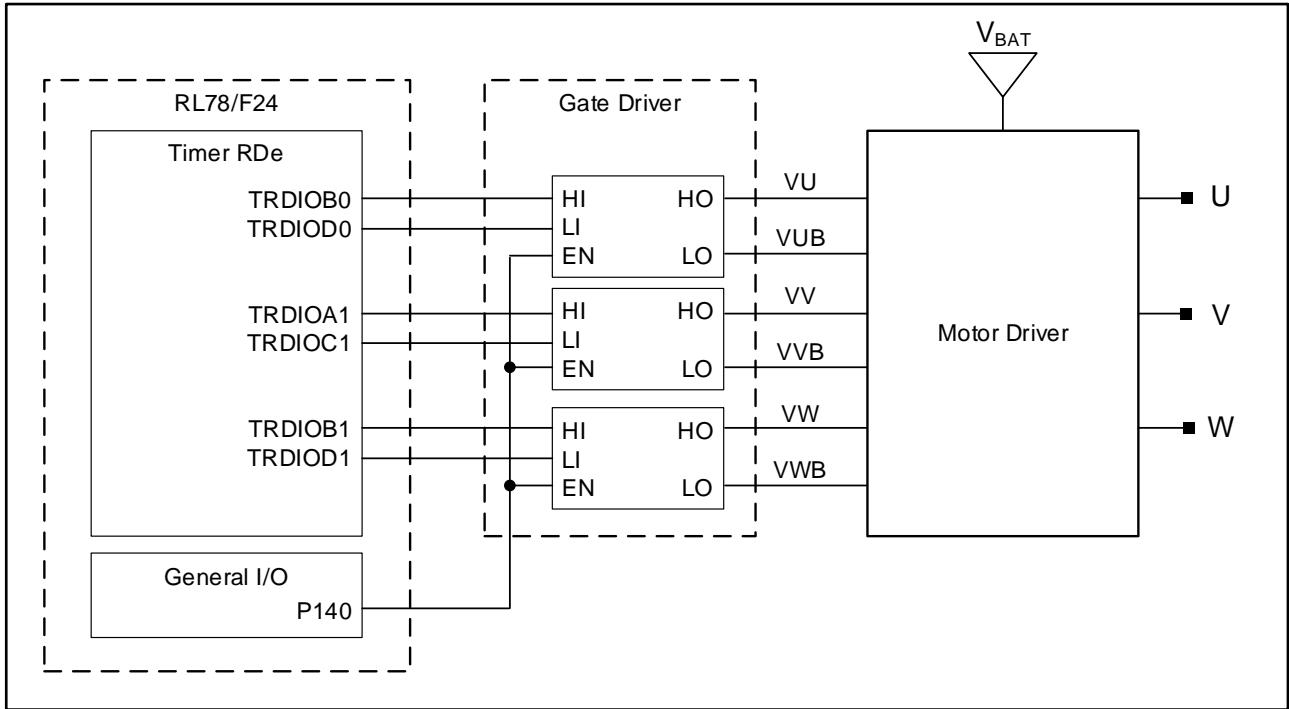


Figure 6-2 Inverter Control Circuit Block Diagram

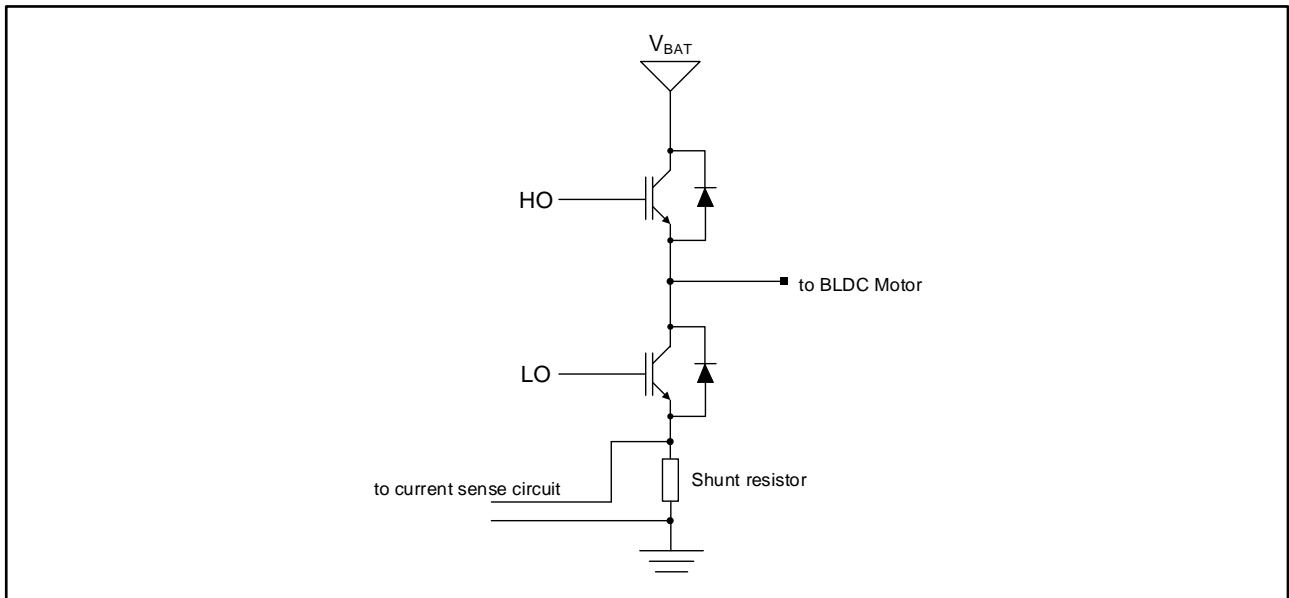


Figure 6-3 Motor Driver Circuit (1 phase)

6.1.5 Current Detection Circuit

The inverter board has current detection circuits to measure the U, V, and W-phase currents (for single-shunt method single-shunt current detection circuit). The U-phase, V-phase, and W-phase are equipped with a shunt resistor forming part of a current detection circuit. The current flowing through the shunt resistor is amplified by an OP-amp and input to the A/D input pin of RL78/F24. Figure 1 shows the circuit of current detection circuit.

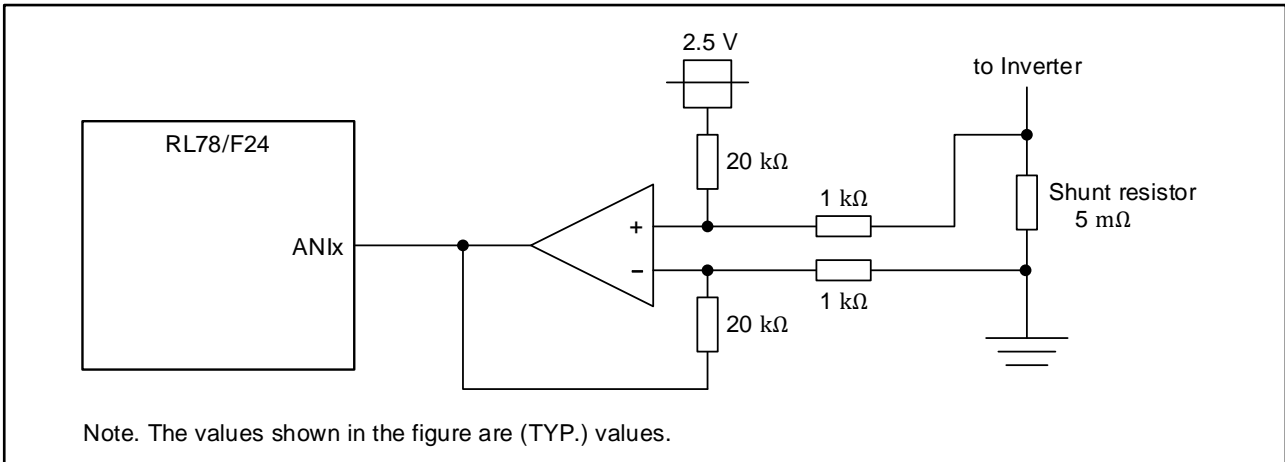


Figure 6-4 Current Detection Circuit (1 phase)

From the above current detection circuit, the relationship between the current flowing through the shunt resistor and the voltage input to the microcomputer can be calculated by the following formula.

$$\text{A/D input voltage (ANIx) [V]} = \text{“Current flowing through the shunt resistor”} \times 0.005 [\Omega] \times 20 + 2.5 [\text{V}]$$

Table 6-4 Relationship between Current Flow to Shunt Resistor and Voltage Input to MCU ^{Note}

| Current flowing through the shunt resistor | Output voltage of OP-Amp |
|--|--------------------------|
| + 25 [A] | 5 [V] |
| + 5 [A] | 3 [V] |
| 0 [A] | 2.5 [V] |
| - 5 [A] | 2 [V] |
| - 25 [A] | 0 [V] |

Note The values shown in this table are theoretical values. Errors in each element such as resistance used in this system are not taken into consideration.

6.1.6 Overcurrent Detection Circuit

The current detection circuit is used to detect the current flowing through the shunt resistor. The shunt current is input to comparator of RL78/F24, and when the threshold value is exceeded, an overcurrent is detected. The reference voltage of comparator uses D/A converter of RL78/F24 product.

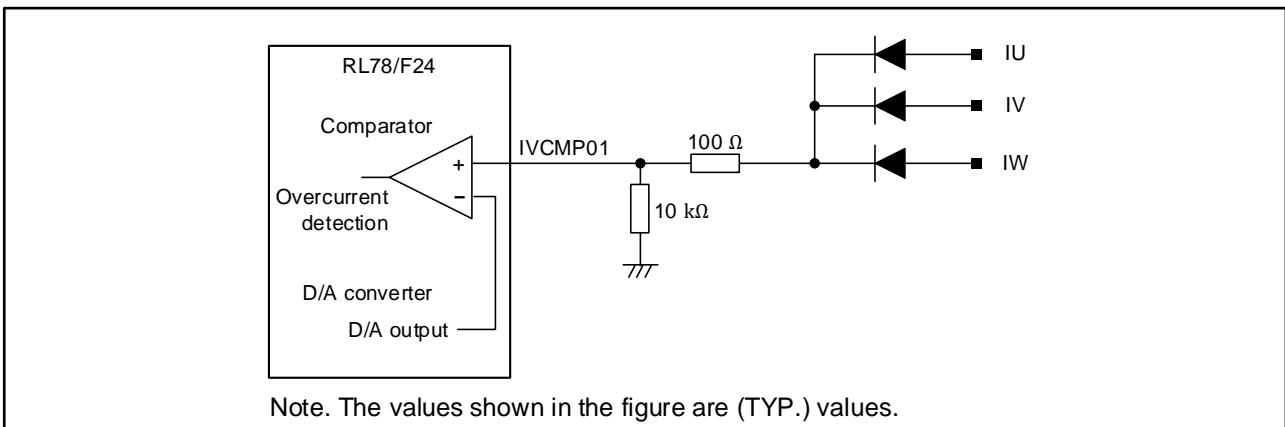


Figure 6-5 Overcurrent Detection Circuit

6.1.7 Bus Voltage Detection Circuit

The inverter board has a circuit intended for bus voltage (VBAT) detection. Input the VBAT to the analog input pin of RL78/F24 via resistive voltage divider.

$$\text{Detection voltage [V]} = \frac{1 \times 10^3}{12 \times 10^3 + 1 \times 10^3} + \text{VBAT [V]}$$

The values shown in the above formula are theoretical values. Errors in each element such as resistance used in this system are not taken into consideration.

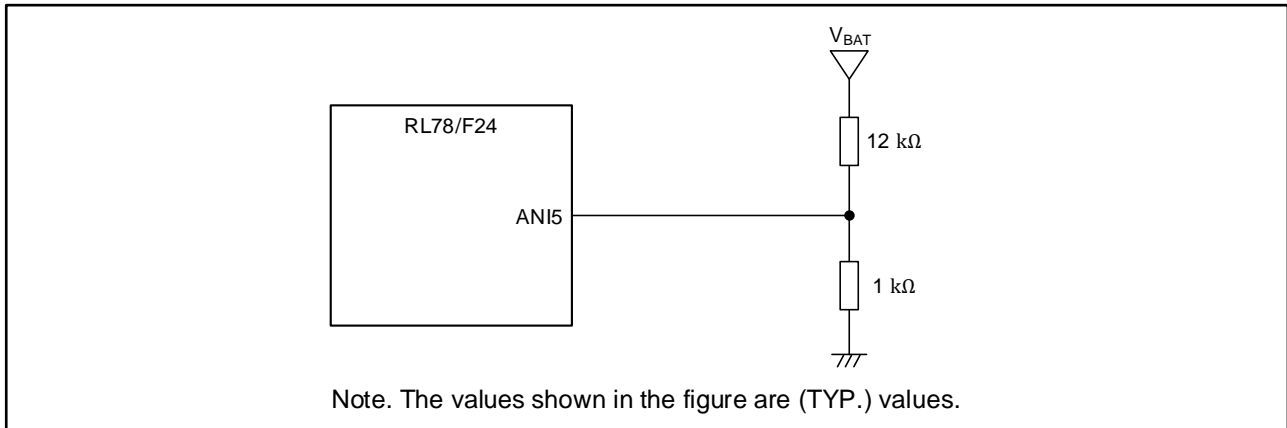


Figure 6-6 Bus Voltage Detection Circuit

6.1.8 Board Temperature Detection Circuit

The inverter board has a circuit intended for PCB temperature detection. Input to A/D input pin of RL78/F24 using a thermistor.

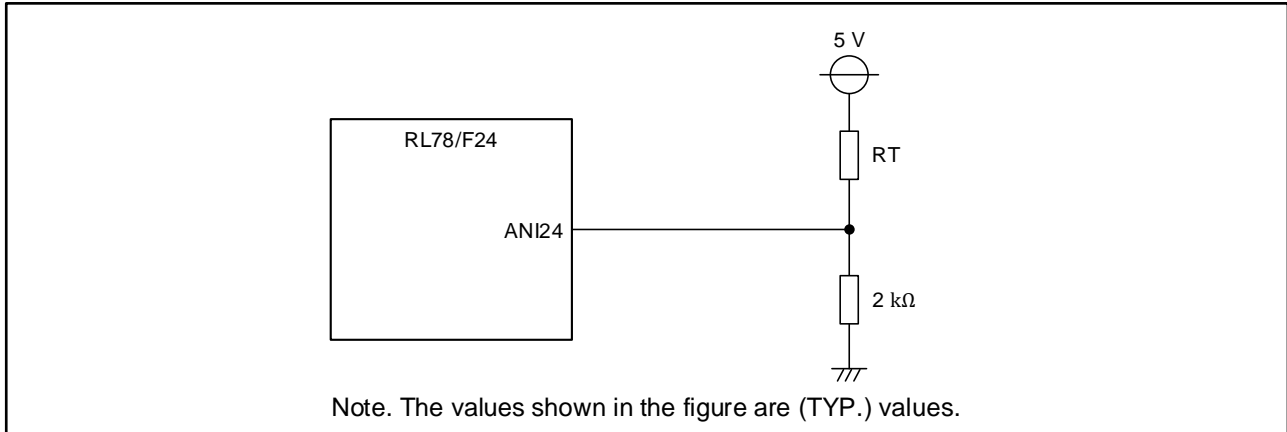


Figure 6-7 Inverter Board Temperature Detection Circuit

6.1.9 Motor Coil-end Temperature Detection Circuit

The inverter board has a circuit intended for motor coil-end temperature detection. Input to A/D input pin of RL78/F24 using a thermistor externally.

This function is optional, and this circuit is not implemented in this product. The default software is designed to support the thermistor (103NT-4-R025H41G).

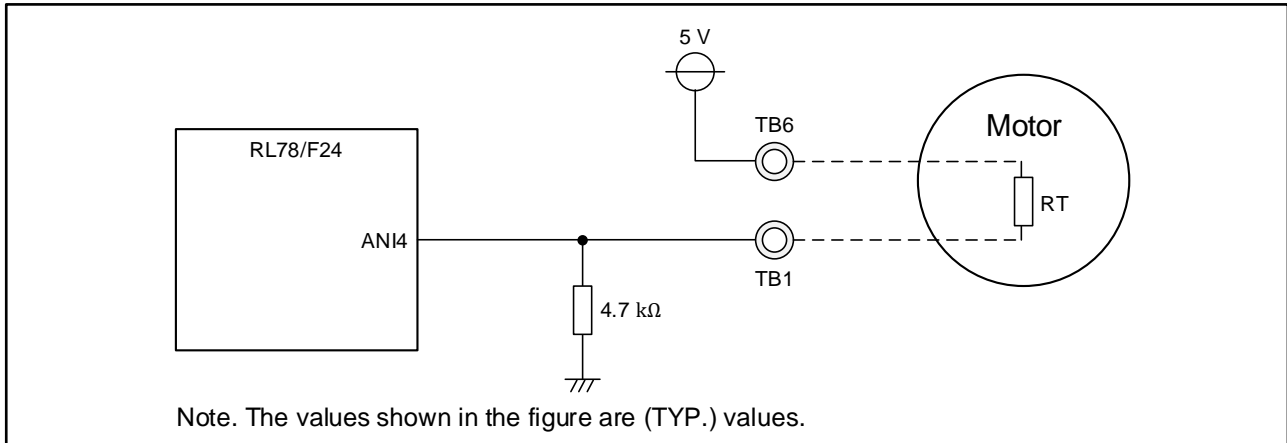


Figure 6-8 Motor Coil-end Temperature Detection Circuit

Note: The default software included in the package (sensorless trapezoidal control) disables the motor coil-end temperature detection function. To enable this function, change the description of conditional compilation in the `err_check_over_temp()` function in the `mtr_function.c` file and the `interval_timer_isr()` function in the `mtr_interrupt_bemf.c` file (change “#if 0” to “#if 1” to enable it).

6.1.10 CAN/CANFD Communication Circuit

The inverter board has a CAN/CANFD communication circuit pattern as an external interface. This function is optional, and this circuit is not implemented in this product.

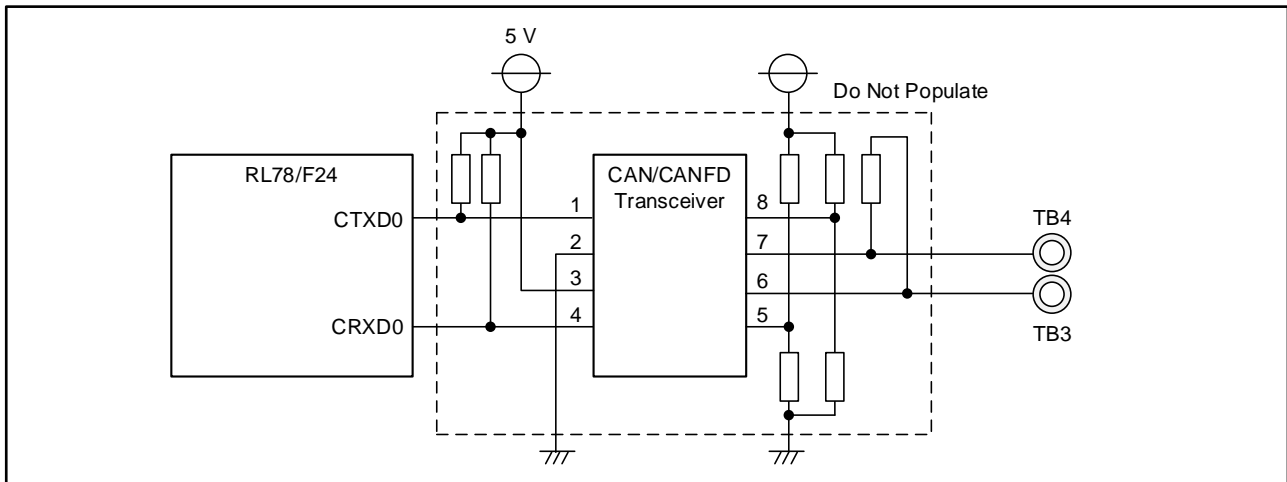


Figure 6-9 CAN/CANFD Communication Circuit

6.1.11 PWM Rotation Speed Command Input Circuit

The inverter board provides this feature as an external interface.

Table 6-5 PWM Communication Circuit Connection

| Inverter board connection terminal | Specification | RL78/F24 connection pin |
|------------------------------------|-------------------------------------|-------------------------|
| TB5 | Rotation speed command input by PWM | P00/(TI05) |

Note: The PWM signal input to the microcontroller (RL78/F24) should not exceed 5 V.

The default software disables PWM interface function. To enable it, refer to “5.5.1 Change Software to Enable PWM Interface Function”.

6.2 OCD Conversion Board

This section describes the functions of the OCD conversion board circuit. For details of the circuit, refer to the included circuit diagram.

6.2.1 E2/E2 Lite Emulator Connection

The OCD conversion board is used to connect inverter board and E2/E2 Lite emulator. Connect OCD conversion board and inverter board with the cable included with this product, and connect OCD conversion board and E2/E2 Lite emulator for use.

For details on the functions of E2/E2 Lite emulator and RFP, refer to the target manual.

Table 6-6 E2/E2 Lite Emulator Connection of the OCD Conversion Board

| E2/E2 Lite emulator connection Pin No. | Specification | Connection |
|--|---------------|-------------------------------------|
| 1, 3, 4, 7, 11 | R.F.U | NC |
| 2, 12, 14 | GND | Inverter board: GND |
| 5 | TOOL0 | Inverter board RL78/F24: TOOL0 pin |
| 6 | RESET_IN | OCD conversion board: Reset circuit |
| 8 | VDD | Inverter board: UVCC (5V) |
| 9 | EMVDD | Inverter board: UVCC (5V) |
| 10, 13 | RESET_OUT | Inverter board RL78/F24: RESET pin |

6.2.2 ICS++ Connection (Option)

The OCD conversion board can be connected to ICS++ (optional). ICS++ (In Circuit Scope Plus) is a real-time RAM monitor is manufactured by Desk Top Laboratories Inc.

Table 6-7 ICS++ Connection of the OCD Conversion Board

| ICS++ Connection Pin No. | Specification | Connection |
|--------------------------|---------------|-------------------------------------|
| 1 | VCC | Inverter board: UVCC (5V) |
| 2 | TXD | Inverter board RL78/F24: P62/(TXD0) |
| 3 | RXD | Inverter board RL78/F24: P61/(RXD0) |
| 4 | GND | Inverter board: GND |

7. Usage Notes

Important points to observe when using this product are listed below:

- Some of the unused pins the productive not been processed in any way. Make sure to process these pins as appropriate for the application.
- For the board used in this product and each part including microcontroller (RL78/F24), refer to the user's manual of the target product and use it within the specifications of the target product.

Appendix

The pin assignment table for RL78/F24 product used in this product is shown below.

Table A-1 List of RL78/F24 (48 pins) Pin Functions (1/2)

| Pin No. | Pin Function | Functions Used in the Product |
|---------|--|--------------------------------------|
| 1 | P120/ANI25/TI07/TO07/TRDIOD0/SO01/(SCK10)/(LTXD1)/INTP4 | NC |
| 2 | P41/TI10/TO10/TRJIO0/TRD0RES/(SI10)/(RXD1)/VCOUT0/SNZOUT2 | VCOUT0 (connect to INTP0) |
| 3 | P40/TOOL0 | TOOL0 (for emulator) |
| 4 | RESET | RESET |
| 5 | P124/XT2/EXCLKS | Pull-down (10 kΩ) |
| 6 | P123/XT1 | Pull-down (10 kΩ) |
| 7 | P137/INTP0 | INTP0 (connect to VCOUT0) |
| 8 | P122/X2/EXCLK | Crystal oscillation circuit (16 MHz) |
| 9 | P121/X1 | Crystal oscillation circuit (16 MHz) |
| 10 | REGC | 0.47 μF |
| 11 | VSS | GND |
| 12 | VDD | UVCC (5 V) |
| 13 | P60/(TO01)/(SCK00)/(SCL00) | NC |
| 14 | P61/(TO02)/(SI00)/(SDA00)/(RXD0) | RXD0 (for ICS++ (optional)) |
| 15 | P62/(TO03)/(SO00)/(TXD0)/SCLA0 | TXD0 (for ICS++ (optional)) |
| 16 | P63/(TO07)/(SSI00)/SDAA0 | NC |
| 17 | P00/(TI05)/(TO05)/INTP9 | TI05 (PWM command input) |
| 18 | P140/TRD1RES/PCLBUZ0 | P140 (Gate driver EN control) |
| 19 | P130/RESOUT | P130/RESOUT |
| 20 | P73/ANI29/SSI11/(CRXD0)/KR3/SNZOUT7 | CRXD0 (CAN/CANFD) |
| 21 | P72/ANI28/SO11/(CTXD0)/KR2/SNZOUT6 | CTXD0 (CAN/CANFD) |
| 22 | P71/ANI27/TI17/TO17/SCK11/SCL11/INTP6/KR1/SNZOUT5 | NC |
| 23 | P70/ANI26/TI15/TO15/SI11/SDA11/INTP8/KR0/SNZOUT4 | NC |
| 24 | P32/TI16/TO16/(SO11)/INTP7 | NC |
| 25 | P30/TI01/TO01/TRDIOD1/SSI00/INTP2/SNZOUT0 | TRDIOD1 (WN-phase) |
| 26 | P17/TI00/TO00/TRDIOB1/SCK00/SCL00/INTP3 | TRDIOB1 (WP-phase) |
| 27 | P16/TI02/TO02/TRDIOC1/SI00/SDA00/RXD0 | TRDIOC1 (VN-phase) |
| 28 | P15/TI05/TO05/TRDIOA1/(TRDIOA0)/(TRDCLK0)/SO00/TXD0/RTC1HZ | TRDIOA1 (VP-phase) |
| 29 | P31/TI14/TO14/(INTP2)/STOPST | NC |
| 30 | P14/TI06/TO06/TRDIOC0/SCK01/SCL01/LRXD0 | NC |

Table A-1 List of RL78/F24 (48 pins) Pin Functions (2/2)

| Pin No. | Pin Function | Functions Used in the Product |
|---------|--|--|
| 31 | P13/TI04/TO04/TRDIOA0/TRDCLK0/SI01/SDA01/LTXD0 | NC |
| 32 | P12/TI11/TO11/(TRDIOD0)/SO10/TXD1/INTP5/SNZOUT3 | TRDIOD0 (UN-phase) |
| 33 | P11/TI12/TO12/(TRDIOB0)/SI10/SDA10/RXD1/CRXD0/LRXD1 | TRDIOB0 (UP-phase) |
| 34 | P10/TI13/TO13/TRJO0/SCK10/SCL10/CTXD0/LTXD1 | NC |
| 35 | P33/AVREFP/ANI6 | AVREFP (connect to UVCC) |
| 36 | P34/AVREFM/ANI7 | AVREFM (connect to GND) |
| 37 | P80/ANI0/ANO0 | ANI0 (Iv or Isingle-shunt) |
| 38 | P81/ANI1 | ANI1 (Iu) |
| 39 | P82/ANI2/IVCMP00 | ANI2 (Iw) |
| 40 | P83/ANI3/IVCMP01/(KR0) | IVCMP01 (Overcurrent detection) |
| 41 | P84/ANI4/IVCMP02/(KR1) | ANI4 (Motor coil-end temperature (optional)) |
| 42 | P85/ANI5/IVREF0/IVCMP03/(KR2) | ANI5 (VBAT) |
| 43 | P86/ANI8/(KR3) | ANI8 (Vu) |
| 44 | P87/ANI9/(KR4) | ANI9 (Vv) |
| 45 | P90/ANI10/(KR5) | ANI10 (Vw) |
| 46 | P91/ANI11/(KR6) | ANI11 (Idc for trapezoidal control) |
| 47 | P92/ANI12/(KR7) | NC |
| 48 | P125/ANI24/TI03/TO03/TRDIOB0/SSI01/(LRXD1)/INTP1/SNZOUT1 | ANI24 (PCB temperature) |

Revision History

| Rev. | Date | Description | |
|------|------------|-------------|---|
| | | Page | Summary |
| 1.00 | 2022. 9.30 | – | 1st edition issued |
| 1.10 | 2023. 6.30 | P.4 | Updated the version of each application note in Related Documents. |
| | | P.15, 17 | 5.1.2 Connecting the Regulated Power Supply and the Inverter Board 5.4.1 Connecting the Regulated Power Supply and the Inverter Board The description has been corrected because this board does not have Faston terminals. |
| | | P.18 | Changed the title of Chapter 5.5.1. Before: Checking the Result for the Program Writing After: Change Software to Enable PWM Interface Function |
| | | P.19 | Corrected typo in function name. Before: Function Name: userControlTimer () After: Function Name: userControlInit () |
| | | P.19 | Changed the title of Table 5-3. Before: Enable Setting of PWM Operation After: Enable Setting of PWM Interface Function |
| | | P.20 | Changed the title of Chapter 5.5.2. Before: Software Specifications of the PWM Operation After: Software Specifications of the PWM Interface Function |
| | | P.20 | Changed the title of Chapter 5.5.3. Before: Notes on the PWM Operation Mode After: Notes on the PWM Interface Function |
| | | P.26 | 6.1.9 Motor Coil-end Temperature Detection Circuit Added a note (when using sensorless trapezoidal control). |
| | | P.27 | 6.1.11 PWM Rotation Speed Command Input Circuit Added the default software description to note. |

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.

Notice

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