

# Sensorless 120-degree conducting control of permanent magnetic synchronous motor

For Renesas Flexible Motor Control Series

## Abstract

This application note describes the sample program for a permanent magnetic synchronous motor drive with 120-degree conducting method based on Renesas microcontroller. This application note also describes how to use the motor control development support tool, 'Renesas Motor Workbench'.

The targeted software for this application note is only to be used as reference purposes only and Renesas Electronics Corporation does not guarantee the operations. Please use this after carrying out a thorough evaluation in a suitable environment.

## Operation checking device

Operations of the target software of this application note are checked by using the following device.

- RA6T2 (R7FA6T2BD3CFP)
- RA6T3 (R7FA6T3BB3CFM)
- RA4T1 (R7FA4T1BB3CFM)

## Target software

The following shows the target software for this application:

- RA6T2\_MCILV1\_SPM\_LESS\_120\_E2S\_V110
- RA6T3\_MCILV1\_SPM\_LESS\_120\_E2S\_V100
- RA4T1\_MCILV1\_SPM\_LESS\_120\_E2S\_V100

## Contents

|                                                                                      |    |
|--------------------------------------------------------------------------------------|----|
| 1. Overview .....                                                                    | 4  |
| 2. Development environment .....                                                     | 4  |
| 2.1 Operation check environment .....                                                | 4  |
| 2.2 Hardware specifications .....                                                    | 5  |
| 2.2.1 Hardware configuration diagram .....                                           | 5  |
| 2.2.2 Board user interface .....                                                     | 6  |
| 2.2.3 Peripheral functions .....                                                     | 7  |
| 2.3 Software structure .....                                                         | 24 |
| 2.3.1 Software file structure .....                                                  | 24 |
| 2.3.2 Module configuration .....                                                     | 26 |
| 2.4 Software specifications .....                                                    | 27 |
| 2.5 Interrupt priority .....                                                         | 28 |
| 3. Descriptions of the control software .....                                        | 29 |
| 3.1 Contents of control .....                                                        | 29 |
| 3.1.1 Motor start / stop .....                                                       | 29 |
| 3.1.2 A/D converter .....                                                            | 29 |
| 3.1.3 Speed control .....                                                            | 30 |
| 3.1.4 Voltage control by PWM .....                                                   | 31 |
| 3.1.5 State transition .....                                                         | 33 |
| 3.1.6 Start-up method in sensorless control .....                                    | 34 |
| 3.1.7 System protection function .....                                               | 35 |
| 3.1.8 AD triggers .....                                                              | 36 |
| 3.2 Function specifications of 120-degree conducting control software .....          | 37 |
| 3.3 Contents of control .....                                                        | 49 |
| 3.3.1 Configuration Options .....                                                    | 49 |
| 3.3.2 Configuration Options for included modules .....                               | 49 |
| 3.4 Control flows (flow charts) .....                                                | 54 |
| 3.4.1 Main process .....                                                             | 54 |
| 3.4.2 Current Control Periodic interrupt (carrier periodic interrupt) handling ..... | 55 |
| 3.4.3 Speed Control periodic interrupt handling .....                                | 56 |
| 3.4.4 Overcurrent interrupt handling .....                                           | 57 |
| 4. Evaluation environment explanation .....                                          | 58 |
| 4.1 Project import .....                                                             | 58 |
| 4.2 Build and debug .....                                                            | 59 |
| 4.3 Quick start .....                                                                | 60 |
| 4.4 Motor Control Development Support Tool, 'Renesas Motor Workbench' .....          | 61 |
| 4.4.1 Overview .....                                                                 | 61 |
| 4.4.2 Easy function operation example .....                                          | 62 |
| 4.4.3 List of variables for Analyzer function .....                                  | 64 |
| 4.4.4 Operation Example for Analyzer .....                                           | 65 |
| 4.4.5 Example of changing communication speed .....                                  | 67 |
| 4.4.6 How to use the built-in communication library .....                            | 68 |

5. Reference document .....71

## 1. Overview

This application note explains how to implement the 120-degree conducting control sample program of permanent magnetic synchronous motor (PMSM) using the RA series microcontroller and how to use the motor control development support tool, 'Renesas Motor Workbench'.

Note that this sample programs use the algorithm described in the application note '120-degree conducting control of permanent magnetic synchronous motor: algorithm' (R01AN2657).

## 2. Development environment

### 2.1 Operation check environment

Table 2-1 and

Table 2-2 show the development environment of software targeted by this application note.

**Table 2-1 Hardware development environment**

| Classification               | Product used                                                                                                                           |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Microcomputer / CPU card P/N | RA6T2 (R7FA6T2BD3CFP) / RTK0EMA270C00000BJ<br>RA4T1 (R7FA4T1BB3CFM) / RTK0EMA430C00000BJ<br>RA6T3 (R7FA6T3BB3CFM) / RTK0EMA330C00000BJ |
| Inverter board               | MCI-LV-1 / RTK0EM0000S04020BJ                                                                                                          |
| motor                        | R42BLD30L3 (manufactured by MOONS')                                                                                                    |

**Table 2-2 Software development environment**

| e <sup>2</sup> studio version   | FSP version | Toolchain version                      |
|---------------------------------|-------------|----------------------------------------|
| e <sup>2</sup> studio : 2023-04 | V4.4.0      | GCC ARM Embedded :<br>V10.3.1.20210824 |

For purchase and technical support contact, Sales representatives and dealers of Renesas Electronics Corporation.

## 2.2 Hardware specifications

### 2.2.1 Hardware configuration diagram

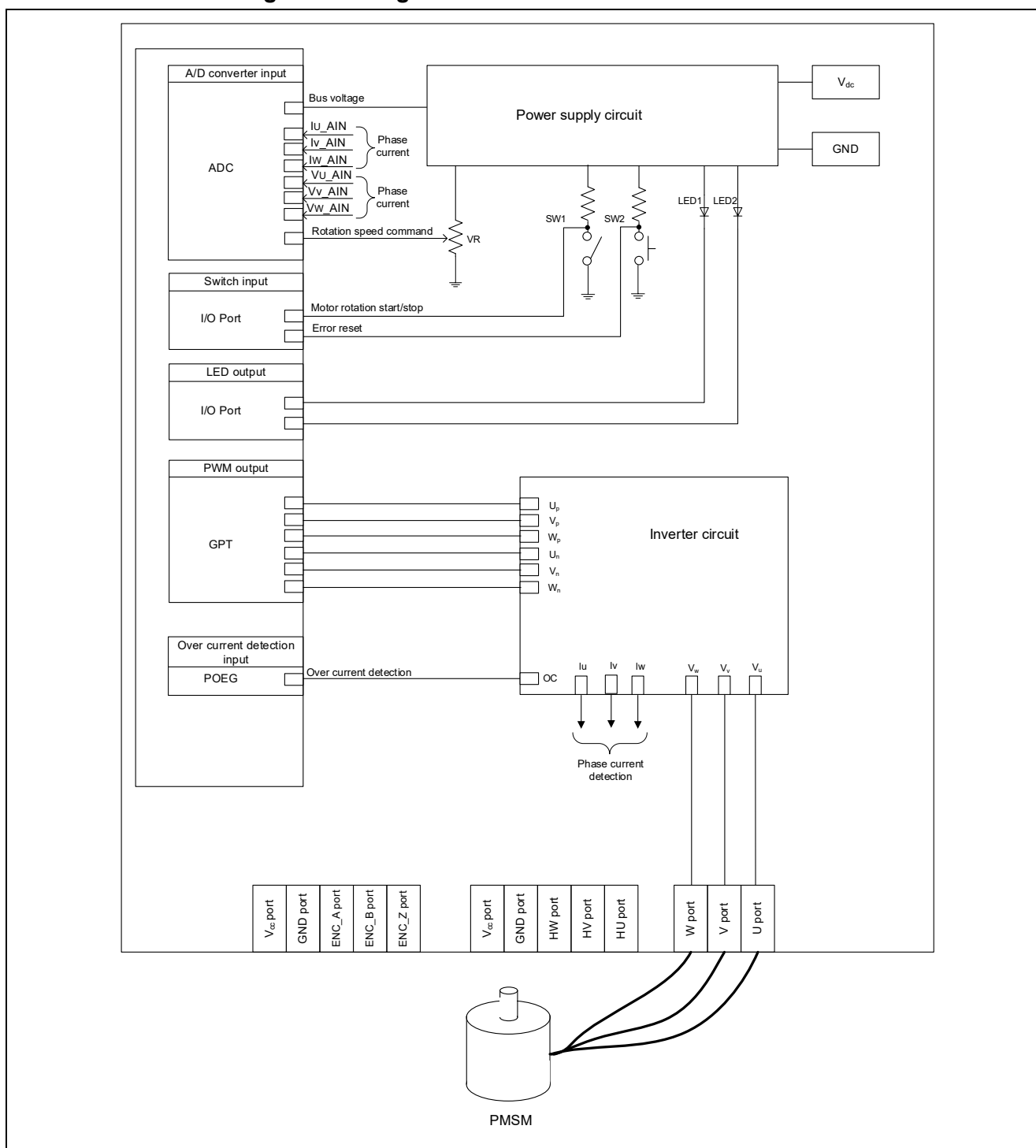


Figure 2-1 Hardware Configuration Diagram

## 2.2.2 Board user interface

Table 2-3 is lists of user interfaces of this system.

**Table 2-3 Board user interface**

| Item           | Interface component      | Function                                                                         |
|----------------|--------------------------|----------------------------------------------------------------------------------|
| Rotation speed | Variable resistance(VR1) | Rotation speed command value input(analog values)                                |
| START / STOP   | Toggle switch(SW1)       | Motor rotation start/stop command                                                |
| ERROR RESET    | Push switch (SW2)        | Command of recovery from error status                                            |
| LED1           | Yellow green LED         | - At the time of Motor rotation : ON<br>- At the time of stop : OFF              |
| LED2           | Yellow green LED         | - At the time of error detection : ON<br>- At the time of normal operation : OFF |
| LED3           | Yellow green LED         | Not used in this system                                                          |
| RESET          | Push switch(SW1)         | System reset                                                                     |

List of port interfaces of this system is given in Table 2-4.

**Table 2-4 Port Interface**

| Function                                                      | RA6T2          | RA4T1          | RA6T3          |
|---------------------------------------------------------------|----------------|----------------|----------------|
| Inverter bus voltage measurement                              | PA06 / AN006   | P004 / AN004   | P004 / AN004   |
| For rotation speed command value input (analog value)         | PB00 / AN008   | P005 / AN005   | P005 / AN005   |
| START/STOP toggle switch (SW1)                                | PD04           | P304           | P304           |
| ERROR RESET push switch (SW2)                                 | PD07           | P200           | P200           |
| LED1 ON/OFF control                                           | PD01           | P113           | P113           |
| LED2 ON/OFF control                                           | PD02           | P106           | P106           |
| U phase current measurement                                   | PA04 / AN004   | P000 / AN000   | P000 / AN000   |
| V phase current measurement                                   | PA02 / AN002   | P001 / AN001   | P001 / AN001   |
| W phase current measurement                                   | PA00 / AN000   | P002 / AN002   | P002 / AN002   |
| U phase voltage measurement                                   | PA07 / AN007   | P500 / AN016   | P500 / AN016   |
| V phase voltage measurement                                   | PA03 / AN003   | P014 / AN012   | P014 / AN012   |
| W phase voltage measurement                                   | PA01 / AN001   | P013 / AN011   | P013 / AN011   |
| PWM output ( $U_p$ )                                          | PB04 / GTIOC4A | P409 / GTIOC1A | P409 / GTIOC1A |
| PWM output ( $V_p$ )                                          | PB06 / GTIOC5A | P103 / GTIOC2A | P103 / GTIOC2A |
| PWM output ( $W_p$ )                                          | PB08 / GTIOC6A | P111 / GTIOC3A | P111 / GTIOC3A |
| PWM output ( $U_n$ )                                          | PB05 / GTIOC4B | P408 / GTIOC1B | P408 / GTIOC1B |
| PWM output ( $V_n$ )                                          | PB07 / GTIOC5B | P102 / GTIOC2B | P102 / GTIOC2B |
| PWM output ( $W_n$ )                                          | PB09 / GTIOC6B | P112 / GTIOC3B | P112 / GTIOC3B |
| PWM emergency stop input at the time of overcurrent detection | PC13 / GTETRGD | P104 / GTETRGB | P104 / GTETRGB |

### 2.2.3 Peripheral functions

Table 2-5 is a list of peripheral functions used in this system.

**Table 2-5 Peripheral Functions List**

| Peripheral           | Purpose                                                       | RA6T2   | RA4T1   | RA6T3   |
|----------------------|---------------------------------------------------------------|---------|---------|---------|
| 12-bit A/D Converter | U phase current measurement                                   | AN004   | AN000   | AN000   |
|                      | V phase current measurement                                   | AN002   | AN001   | AN001   |
|                      | W phase current measurement                                   | AN000   | AN002   | AN002   |
|                      | U phase voltage measurement                                   | AN007   | AN016   | AN016   |
|                      | V phase voltage measurement                                   | AN003   | AN012   | AN012   |
|                      | W phase voltage measurement                                   | AN001   | AN011   | AN011   |
|                      | Inverter bus voltage measurement                              | AN006   | AN004   | AN004   |
| AGT                  | For rotation speed command value input (analog value)         | AN008   | AN005   | AN005   |
|                      | Speed control interval timer                                  | AGT0    | AGT0    | AGT0    |
| GPT                  | Free run timer for rotation speed measurement                 | -       | AGT1    | AGT1    |
|                      | U phase PWM output                                            | CH4     | CN1     | CN1     |
|                      | V phase PWM output                                            | CH5     | CN2     | CN2     |
|                      | W phase PWM output                                            | CH6     | CN3     | CN3     |
| POEG                 | Free run timer for rotation speed measurement                 | CH0     | -       | -       |
|                      | PWM emergency stop input at the time of overcurrent detection | Group D | Group B | Group B |

#### 2.2.3.1 RA6T2

##### (1). 12-bit A/D converter(ADC12)

U-phase current ( $I_u$ ), V-phase current ( $I_v$ ), W-phase current ( $I_w$ ), the rotation speed command value input, Uphase voltage( $V_u$ ), V phase voltage( $V_v$ ) W phase voltage( $V_w$ ), and inverter bus voltage( $V_{dc}$ ) are measured by using the '12 bit A/D converter'.

The operation modes must be set to the 'Signle scan mode'(use a hardware trigger).

##### (2). Low power consumption asynchronous general-purpose timer(AGT)

Used as a 1ms interval taimer.

##### (3). General-purpose PWM timer(GPT)

On the channel 4, 5, and 6, output with dead time is performed by using the complementary PWM Output Operating Mode.

Channel 0 is used as a free run timer for speed measurement.

##### (4). Port output enable for GPT(POEG)

The ports executing PWM output are set to high impedance state when an overcurrent is detected(when the low level of the GTETRGD port is detected).

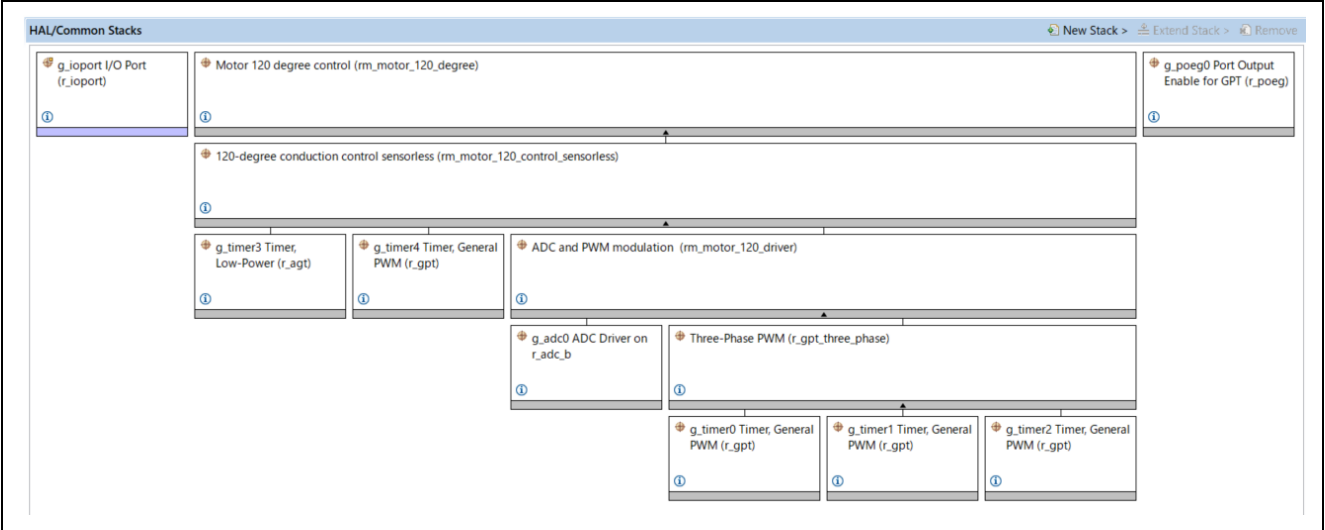


Figure 2-2 Overall FSP Stacks diagram

| g_adc0 ADC Driver on r_adc_b |                                       |                            |
|------------------------------|---------------------------------------|----------------------------|
| Settings                     | Property                              | Value                      |
| API Info                     | ▼ Common                              |                            |
|                              | Parameter Checking                    | Default (BSP)              |
|                              | ▼ Module g_adc0 ADC Driver on r_adc_b |                            |
|                              | ▼ General                             |                            |
|                              | ▼ Mode                                |                            |
|                              | ADC 0                                 | Single Scan                |
|                              | ADC 1                                 | Single Scan                |
|                              | > ADC Successive Approximation Time   |                            |
|                              | > Synchronous Operation               |                            |
|                              | > Calibration                         |                            |
|                              | > Sampling State Table                |                            |
|                              | Name                                  | g_adc0                     |
|                              | > Clock Configuration                 |                            |
|                              | ▼ Interrupts                          |                            |
|                              | > Limiter Clip Priority               |                            |
|                              | > Conversion Error Priority           |                            |
|                              | > Overflow Priority                   |                            |
|                              | > Calibration End Priority            |                            |
|                              | ▼ Scan End Priority                   |                            |
|                              | Group 0                               | Priority 5                 |
|                              | Group 1                               | Disabled                   |
|                              | Group 2                               | Disabled                   |
|                              | Group 3                               | Disabled                   |
|                              | Group 4                               | Disabled                   |
|                              | Group 5 to 8                          | Disabled                   |
|                              | > FIFO Priorities                     |                            |
|                              | Callback                              | rm_motor_120_driver_cyclic |
|                              | > Sample and Hold                     |                            |
|                              | > User Offset Table                   |                            |
|                              | > User Gain Table                     |                            |
|                              | > Limiter Clipping                    |                            |
|                              | > Virtual Channels                    |                            |
|                              | > Scan Groups                         |                            |

Figure 2-3 FSP configuration of ADC driver [1/4]

| g_adc0 ADC Driver on r_adc_b |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Settings                     | Property                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Value                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| API Info                     | <ul style="list-style-type: none"> <li>Virtual Channels           <ul style="list-style-type: none"> <li>Virtual Channel 0               <ul style="list-style-type: none"> <li>Scan Group</li> <li>Channel Select</li> <li>Sampling State Table ID</li> <li>Channel Gain Table</li> <li>Channel Offset Table</li> <li>Add/Average Mode</li> <li>Add/Average Count</li> <li>Limit Clip Table Id</li> <li>Conversion Resolution Format Select</li> </ul> </li> <li>Virtual Channel 1               <ul style="list-style-type: none"> <li>Scan Group</li> <li>Channel Select</li> <li>Sampling State Table ID</li> <li>Channel Gain Table</li> <li>Channel Offset Table</li> <li>Add/Average Mode</li> <li>Add/Average Count</li> <li>Limit Clip Table Id</li> <li>Conversion Resolution Format Select</li> </ul> </li> <li>Virtual Channel 2               <ul style="list-style-type: none"> <li>Scan Group</li> <li>Channel Select</li> <li>Sampling State Table ID</li> <li>Channel Gain Table</li> <li>Channel Offset Table</li> <li>Add/Average Mode</li> <li>Add/Average Count</li> <li>Limit Clip Table Id</li> <li>Conversion Resolution Format Select</li> </ul> </li> <li>Virtual Channel 3               <ul style="list-style-type: none"> <li>Scan Group</li> <li>Channel Select</li> <li>Sampling State Table ID</li> <li>Channel Gain Table</li> <li>Channel Offset Table</li> <li>Add/Average Mode</li> <li>Add/Average Count</li> <li>Limit Clip Table Id</li> <li>Conversion Resolution Format Select</li> </ul> </li> </ul> </li> </ul> | Scan Group 0<br>AN000<br>Sampling State Entry 0<br>Disabled<br>Disabled<br>Disabled<br>1-time conversion (Normal Conversion)<br>Disabled<br>12-bit Data Format<br>Scan Group 0<br>AN002<br>Sampling State Entry 0<br>Disabled<br>Disabled<br>Disabled<br>1-time conversion (Normal Conversion)<br>Disabled<br>12-bit Data Format<br>Scan Group 0<br>AN004<br>Sampling State Entry 0<br>Disabled<br>Disabled<br>Disabled<br>1-time conversion (Normal Conversion)<br>Disabled<br>12-bit Data Format<br>Scan Group 1<br>AN006<br>Sampling State Entry 0<br>Disabled<br>Disabled<br>Disabled<br>1-time conversion (Normal Conversion)<br>Disabled<br>12-bit Data Format |

Figure 2-4 FSP configuration of ADC driver [2/4]

| g_adc0 ADC Driver on r_adc_b |                                     |                                       |
|------------------------------|-------------------------------------|---------------------------------------|
| Settings                     | Property                            | Value                                 |
| API Info                     | Virtual Channel 4                   |                                       |
|                              | Scan Group                          | Scan Group 1                          |
|                              | Channel Select                      | AN008                                 |
|                              | Sampling State Table ID             | Sampling State Entry 0                |
|                              | Channel Gain Table                  | Disabled                              |
|                              | Channel Offset Table                | Disabled                              |
|                              | Add/Average Mode                    | Disabled                              |
|                              | Add/Average Count                   | 1-time conversion (Normal Conversion) |
|                              | Limit Clip Table Id                 | Disabled                              |
|                              | Conversion Resolution Format Select | 12-bit Data Format                    |
|                              | Virtual Channel 5                   |                                       |
|                              | Scan Group                          | Scan Group 1                          |
|                              | Channel Select                      | AN007                                 |
|                              | Sampling State Table ID             | Sampling State Entry 0                |
|                              | Channel Gain Table                  | Disabled                              |
|                              | Channel Offset Table                | Disabled                              |
|                              | Add/Average Mode                    | Disabled                              |
|                              | Add/Average Count                   | 1-time conversion (Normal Conversion) |
|                              | Limit Clip Table Id                 | Disabled                              |
|                              | Conversion Resolution Format Select | 12-bit Data Format                    |
|                              | Virtual Channel 6                   |                                       |
|                              | Scan Group                          | Scan Group 0                          |
|                              | Channel Select                      | AN003                                 |
|                              | Sampling State Table ID             | Sampling State Entry 0                |
|                              | Channel Gain Table                  | Disabled                              |
|                              | Channel Offset Table                | Disabled                              |
|                              | Add/Average Mode                    | Disabled                              |
|                              | Add/Average Count                   | 1-time conversion (Normal Conversion) |
|                              | Limit Clip Table Id                 | Disabled                              |
|                              | Conversion Resolution Format Select | 12-bit Data Format                    |
|                              | Virtual Channel 7                   |                                       |
|                              | Scan Group                          | Scan Group 0                          |
|                              | Channel Select                      | AN001                                 |
|                              | Sampling State Table ID             | Sampling State Entry 0                |
|                              | Channel Gain Table                  | Disabled                              |
|                              | Channel Offset Table                | Disabled                              |
|                              | Add/Average Mode                    | Disabled                              |
|                              | Add/Average Count                   | 1-time conversion (Normal Conversion) |
|                              | Limit Clip Table Id                 | Disabled                              |
|                              | Conversion Resolution Format Select | 12-bit Data Format                    |

Figure 2-5 FSP configuration of ADC driver [3/4]

| g_adc0 ADC Driver on r_adc_b |                                 |                                     |
|------------------------------|---------------------------------|-------------------------------------|
| Settings<br>API Info         | Property                        | Value                               |
|                              | ▼ Scan Group 0                  |                                     |
|                              | > Self Diagnosis                |                                     |
|                              | > External Trigger Enable       |                                     |
|                              | > ELC Trigger Enable            |                                     |
|                              | ▼ GPT Trigger Enable            |                                     |
|                              | GPT Channel 0 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 1 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 2 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 3 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 4 Request A         | <input checked="" type="checkbox"/> |
|                              | GPT Channel 5 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 6 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 7 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 8 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 9 Request A         | <input type="checkbox"/>            |
|                              | GPT Channel 0 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 1 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 2 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 3 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 4 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 5 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 6 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 7 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 8 Request B         | <input type="checkbox"/>            |
|                              | GPT Channel 9 Request B         | <input type="checkbox"/>            |
|                              | Enable                          | Enable                              |
|                              | Converter Selection             | ADC 0                               |
|                              | Start Trigger Delay             | 0                                   |
|                              | Scan End Interrupt Enable       | Enable                              |
|                              | Limit Clip Interrupt Enable     | Disable                             |
|                              | FIFO Enable                     | Disable                             |
|                              | FIFO Interrupt Enable           | Disable                             |
|                              | FIFO Interrupt Generation Level | 0                                   |
|                              | ▼ Scan Group 1                  |                                     |
|                              | > Self Diagnosis                |                                     |
|                              | > External Trigger Enable       |                                     |
|                              | > ELC Trigger Enable            |                                     |
|                              | > GPT Trigger Enable            |                                     |
|                              | Enable                          | Enable                              |
|                              | Converter Selection             | ADC 1                               |
|                              | Start Trigger Delay             | 0                                   |
|                              | Scan End Interrupt Enable       | Disable                             |
|                              | Limit Clip Interrupt Enable     | Disable                             |
|                              | FIFO Enable                     | Disable                             |
|                              | FIFO Interrupt Enable           | Disable                             |
|                              | FIFO Interrupt Generation Level | 0                                   |
|                              | > Scan Group 2                  |                                     |

Figure 2-6 FSP configuration of ADC driver [4/4]

| g_timer3 Timer, Low-Power (r_agt) |                                            |                                              |
|-----------------------------------|--------------------------------------------|----------------------------------------------|
| Settings<br>API Info              | Property                                   | Value                                        |
|                                   | ▼ Common                                   |                                              |
|                                   | Parameter Checking                         | Default (BSP)                                |
|                                   | Pin Output Support                         | Disabled                                     |
|                                   | Pin Input Support                          | Disabled                                     |
|                                   | ▼ Module g_timer3 Timer, Low-Power (r_agt) |                                              |
|                                   | ▼ General                                  |                                              |
|                                   | Name                                       | g_timer3                                     |
|                                   | Channel                                    | 0                                            |
|                                   | Mode                                       | Periodic                                     |
|                                   | Period                                     | 60000                                        |
|                                   | Period Unit                                | Raw Counts                                   |
|                                   | Count Source                               | PCLKB                                        |
|                                   | > Output                                   |                                              |
|                                   | > Input                                    |                                              |
|                                   | ▼ Interrupts                               |                                              |
|                                   | Callback                                   | rm_motor_120_control_sensorless_speed_cyclic |
|                                   | Underflow Interrupt Priority               | Priority 10                                  |

Figure 2-7 FSP configuration of AGT driver

| g_timer0 Timer, General PWM (r_gpt) |                                                   |                                     |
|-------------------------------------|---------------------------------------------------|-------------------------------------|
| Settings<br>API Info                | Property                                          | Value                               |
|                                     | ▼ Common                                          |                                     |
|                                     | Parameter Checking                                | Default (BSP)                       |
|                                     | Pin Output Support                                | Enabled with Extra Features         |
|                                     | Write Protect Enable                              | Disabled                            |
|                                     | Clock Source                                      | PCLKD                               |
|                                     | ▼ Module g_timer0 Timer, General PWM (r_gpt)      |                                     |
|                                     | ▼ General                                         |                                     |
|                                     | Name                                              | g_timer0                            |
|                                     | Channel                                           | 4                                   |
|                                     | Mode                                              | Triangle-Wave Symmetric PWM         |
|                                     | Period                                            | 50                                  |
|                                     | Period Unit                                       | Microseconds                        |
|                                     | ▼ Output                                          |                                     |
|                                     | > Custom Waveform                                 |                                     |
|                                     | Duty Cycle Percent (only applicable in PWM mode)  | 50                                  |
|                                     | GTIOCA Output Enabled                             | True                                |
|                                     | GTIOCA Stop Level                                 | Pin Level Low                       |
|                                     | GTIOCB Output Enabled                             | True                                |
|                                     | GTIOCB Stop Level                                 | Pin Level High                      |
|                                     | > Input                                           |                                     |
|                                     | > Interrupts                                      |                                     |
|                                     | ▼ Extra Features                                  |                                     |
|                                     | > Output Disable                                  |                                     |
|                                     | ▼ ADC Trigger                                     |                                     |
|                                     | ▼ Start Event Trigger (GPTE/GPTEH only)           |                                     |
|                                     | Trigger Event A/D Converter Start Request A Durin | <input type="checkbox"/>            |
|                                     | Trigger Event A/D Converter Start Request A Durin | <input checked="" type="checkbox"/> |
|                                     | Trigger Event A/D Converter Start Request B Durin | <input type="checkbox"/>            |
|                                     | Trigger Event A/D Converter Start Request B Durin | <input type="checkbox"/>            |
|                                     | > Dead Time                                       |                                     |
|                                     | > ADC Trigger (GPTE/GPTEH only)                   |                                     |
|                                     | > Interrupt Skipping (GPTE/GPTEH only)            |                                     |
|                                     | Extra Features                                    | Enabled                             |
|                                     | ▼ Pins                                            |                                     |
|                                     | GTIOC4A                                           | PB04                                |
|                                     | GTIOC4B                                           | PB05                                |

Figure 2-8 FSP configuration of GPT driver(complementary PWM output)

| g_timer4 Timer, General PWM (r_gpt) |                                              |                             |
|-------------------------------------|----------------------------------------------|-----------------------------|
| Settings<br>API Info                | Property                                     | Value                       |
|                                     | ▼ Common                                     |                             |
|                                     | Parameter Checking                           | Default (BSP)               |
|                                     | Pin Output Support                           | Enabled with Extra Features |
|                                     | Write Protect Enable                         | Disabled                    |
|                                     | Clock Source                                 | PCLKD                       |
|                                     | ▼ Module g_timer4 Timer, General PWM (r_gpt) |                             |
|                                     | ▼ General                                    |                             |
|                                     | Name                                         | g_timer4                    |
|                                     | Channel                                      | 0                           |
|                                     | Mode                                         | Periodic                    |
|                                     | Period                                       | 0x100000000                 |
|                                     | Period Unit                                  | Raw Counts                  |
|                                     | > Output                                     |                             |
|                                     | > Input                                      |                             |
|                                     | > Interrupts                                 |                             |
|                                     | > Extra Features                             |                             |
|                                     | ▼ Pins                                       |                             |
|                                     | GTIOC0A                                      | <unavailable>               |
|                                     | GTIOC0B                                      | <unavailable>               |

Figure 2-9 FSP configuration of GPT driver (free run timer for speed measurement)

| g_poeg0 Port Output Enable for GPT (r_poeg) |                                                      |                      |
|---------------------------------------------|------------------------------------------------------|----------------------|
| Settings<br>API Info                        | Property                                             | Value                |
|                                             | ▼ Common                                             |                      |
|                                             | Parameter Checking                                   | Default (BSP)        |
|                                             | ▼ Module g_poeg0 Port Output Enable for GPT (r_poeg) |                      |
|                                             | ▼ General                                            |                      |
|                                             | > Trigger                                            |                      |
|                                             | Name                                                 | g_poeg0              |
|                                             | Channel                                              | 3                    |
|                                             | ▼ Input                                              |                      |
|                                             | GTETRG Polarity                                      | Active Low           |
|                                             | GTETRG Noise Filter                                  | PCLKB/32             |
|                                             | ▼ Interrupts                                         |                      |
|                                             | Callback                                             | g_poe_overcurrent    |
|                                             | Interrupt Priority                                   | Priority 0 (highest) |

Figure 2-10 FSP configuration of POEG driver

### 2.2.3.2 RA4T1

#### (1). 12-bit A/D converter(ADC12)

U-phase current ( $I_u$ ), V-phase current ( $I_v$ ), W-phase current ( $I_w$ ), the rotation speed command value input, Uphase voltage( $V_u$ ), V phase voltage( $V_v$ ) W phase voltage( $V_w$ ), and inverter bus voltage( $V_{dc}$ ) are measured by using the '12 bit A/D converter'.

The operation modes must be set to the 'Single scan mode'(use a hardware trigger).

#### (2). Low power consumption asynchronous general-purpose timer(AGT)

Used as a 1ms interval taimer.

Channel 1 is used as a free run timer for speed measurement.

#### (3). General-purpose PWM timer(GPT)

On the channel 1, 2, and 3, output with dead time is performed by using the complementary PWM Output Operating Mode.

#### (4). Port output enable for GPT(POEG)

The ports executing PWM output are set to high impedance state when an overcurrent is detected(when the low level of the GTETRGB port is detected).

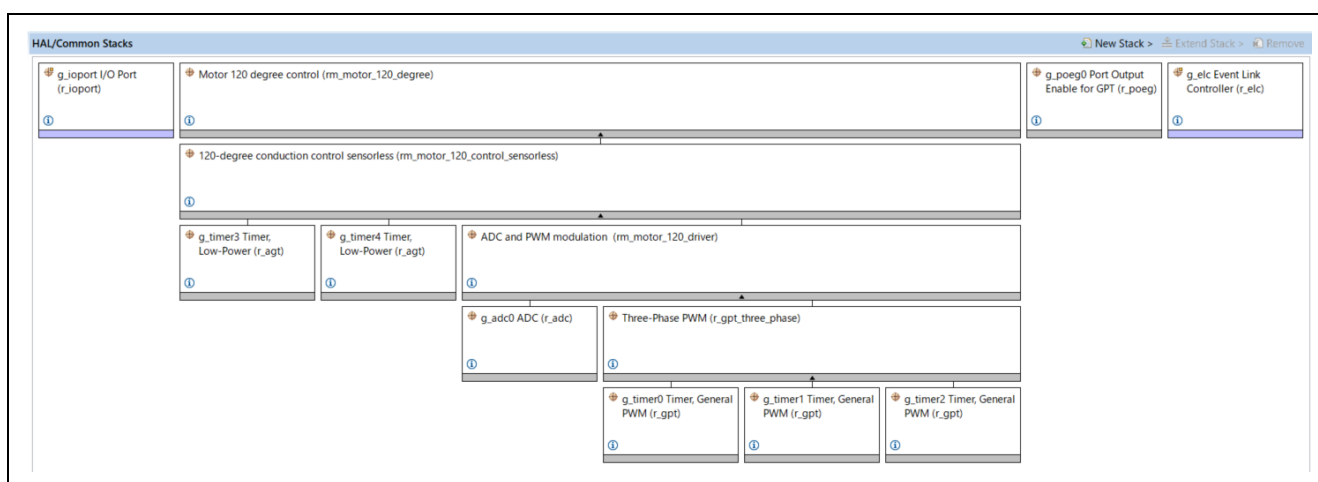


Figure 2-11 Overall FSP Stacks diagram

| g_adc0 ADC (r_adc) |                                                |                                    |
|--------------------|------------------------------------------------|------------------------------------|
| Settings           | Property                                       | Value                              |
| API Info           | ▼ Common                                       |                                    |
|                    | Parameter Checking                             | Default (BSP)                      |
|                    | ▼ Module g_adc0 ADC (r_adc)                    |                                    |
|                    | ▼ General                                      |                                    |
|                    | Name                                           | g_adc0                             |
|                    | Unit                                           | 0                                  |
|                    | Resolution                                     | 🔒 12-Bit                           |
|                    | Alignment                                      | 🔒 Right                            |
|                    | Clear after read                               | 🔒 Off                              |
|                    | Mode                                           | 🔒 Single Scan                      |
|                    | Double-trigger                                 | Disabled                           |
|                    | > Input                                        |                                    |
|                    | ▼ Interrupts                                   |                                    |
|                    | Normal/Group A Trigger                         | GPT1 COUNTER UNDERFLOW (Underflow) |
|                    | Group B Trigger                                | Disabled                           |
|                    | Group Priority (Valid only in Group Scan Mode) | Group A cannot interrupt Group B   |
|                    | Callback                                       | 🔒 rm_motor_120_driver_cyclic       |
|                    | Scan End Interrupt Priority                    | Priority 5                         |
|                    | Scan End Group B Interrupt Priority            | Disabled                           |
|                    | Window Compare A Interrupt Priority            | Disabled                           |
|                    | Window Compare B Interrupt Priority            | Disabled                           |
|                    | > Extra                                        |                                    |

Figure 2-12 FSP configuration of ADC driver [1/2]

| g_adc0 ADC (r_adc)                                    |                                                                         |                                     |
|-------------------------------------------------------|-------------------------------------------------------------------------|-------------------------------------|
| Settings                                              | Property                                                                | Value                               |
| API Info                                              | ▼ Module g_adc0 ADC (r_adc)                                             |                                     |
|                                                       | > General                                                               |                                     |
|                                                       | ▼ Input                                                                 |                                     |
|                                                       | ▼ Channel Scan Mask (channel availability varies by MCU)                |                                     |
|                                                       | Channel 0                                                               | <input checked="" type="checkbox"/> |
|                                                       | Channel 1                                                               | <input checked="" type="checkbox"/> |
|                                                       | Channel 2                                                               | <input checked="" type="checkbox"/> |
|                                                       | Channel 3                                                               | <input type="checkbox"/>            |
|                                                       | Channel 4                                                               | <input checked="" type="checkbox"/> |
|                                                       | Channel 5                                                               | <input checked="" type="checkbox"/> |
|                                                       | Channel 6                                                               | <input type="checkbox"/>            |
|                                                       | Channel 7                                                               | <input type="checkbox"/>            |
|                                                       | Channel 8                                                               | <input type="checkbox"/>            |
|                                                       | Channel 9                                                               | <input type="checkbox"/>            |
|                                                       | Channel 10                                                              | <input type="checkbox"/>            |
|                                                       | Channel 11                                                              | <input checked="" type="checkbox"/> |
|                                                       | Channel 12                                                              | <input checked="" type="checkbox"/> |
|                                                       | Channel 13                                                              | <input type="checkbox"/>            |
|                                                       | Channel 14                                                              | <input type="checkbox"/>            |
|                                                       | Channel 15                                                              | <input type="checkbox"/>            |
|                                                       | Channel 16                                                              | <input checked="" type="checkbox"/> |
|                                                       | Channel 17                                                              | <input type="checkbox"/>            |
|                                                       | Channel 18                                                              | <input type="checkbox"/>            |
|                                                       | Channel 19                                                              | <input type="checkbox"/>            |
|                                                       | Channel 20                                                              | <input type="checkbox"/>            |
|                                                       | Channel 21                                                              | <input type="checkbox"/>            |
|                                                       | Channel 22                                                              | <input type="checkbox"/>            |
|                                                       | Channel 23                                                              | <input type="checkbox"/>            |
|                                                       | Channel 24                                                              | <input type="checkbox"/>            |
|                                                       | Channel 25                                                              | <input type="checkbox"/>            |
|                                                       | Channel 26                                                              | <input type="checkbox"/>            |
|                                                       | Channel 27                                                              | <input type="checkbox"/>            |
|                                                       | Temperature Sensor                                                      | <input type="checkbox"/>            |
|                                                       | Voltage Sensor                                                          | <input type="checkbox"/>            |
|                                                       | > Group B Scan Mask (channel availability varies by MCU)                |                                     |
|                                                       | > Addition/Averaging Mask (channel availability varies by MCU and unit) |                                     |
|                                                       | ▼ Sample and Hold                                                       |                                     |
|                                                       | ▼ Sample and Hold Channels (Available only on selected MCUs)            |                                     |
|                                                       | Channel 0                                                               | <input checked="" type="checkbox"/> |
|                                                       | Channel 1                                                               | <input checked="" type="checkbox"/> |
| Channel 2                                             | <input checked="" type="checkbox"/>                                     |                                     |
| Sample Hold States (Applies only to channels 0, 1, 2) | 24                                                                      |                                     |
| > Window Compare                                      |                                                                         |                                     |
| Add/Average Count                                     | Disabled                                                                |                                     |
| Reference Voltage control                             | VREFH0/VREFH                                                            |                                     |
| > Interrupts                                          |                                                                         |                                     |
| > Extra                                               |                                                                         |                                     |

Figure 2-13 FSP configuration of ADC driver [2/2]

| g_timer3 Timer, Low-Power (r_agt) |                                            |                                                |
|-----------------------------------|--------------------------------------------|------------------------------------------------|
| Settings<br>API Info              | Property                                   | Value                                          |
|                                   | ▼ Common                                   |                                                |
|                                   | Parameter Checking                         | Default (BSP)                                  |
|                                   | Pin Output Support                         | Disabled                                       |
|                                   | Pin Input Support                          | Disabled                                       |
|                                   | ▼ Module g_timer3 Timer, Low-Power (r_agt) |                                                |
|                                   | ▼ General                                  |                                                |
|                                   | Name                                       | g_timer3                                       |
|                                   | Channel                                    | 0                                              |
|                                   | Mode                                       | 🔒 Periodic                                     |
|                                   | Period                                     | 1                                              |
|                                   | Period Unit                                | Milliseconds                                   |
|                                   | Count Source                               | PCLKB                                          |
|                                   | > Output                                   |                                                |
|                                   | > Input                                    |                                                |
|                                   | ▼ Interrupts                               |                                                |
|                                   | Callback                                   | 🔒 rm_motor_120_control_sensorless_speed_cyclic |
|                                   | Underflow Interrupt Priority               | Priority 10                                    |

Figure 2-14 FSP configuration of AGT driver

| g_timer4 Timer, Low-Power (r_agt) |                                            |               |
|-----------------------------------|--------------------------------------------|---------------|
| Settings<br>API Info              | Property                                   | Value         |
|                                   | ▼ Common                                   |               |
|                                   | Parameter Checking                         | Default (BSP) |
|                                   | Pin Output Support                         | Disabled      |
|                                   | Pin Input Support                          | Disabled      |
|                                   | ▼ Module g_timer4 Timer, Low-Power (r_agt) |               |
|                                   | ▼ General                                  |               |
|                                   | Name                                       | g_timer4      |
|                                   | Channel                                    | 1             |
|                                   | Mode                                       | 🔒 Periodic    |
|                                   | Period                                     | 0xFFFFFFFF    |
|                                   | Period Unit                                | Raw Counts    |
|                                   | Count Source                               | PCLKB         |
|                                   | > Output                                   |               |
|                                   | > Input                                    |               |
|                                   | > Interrupts                               |               |

Figure 2-15 FSP Configuration of AGT Driver (free run timer for speed measurement)

| g_timer0 Timer, General PWM (r_gpt) |                                                                  |                             |
|-------------------------------------|------------------------------------------------------------------|-----------------------------|
| Settings                            | Property                                                         | Value                       |
| API Info                            | ▼ Common                                                         |                             |
|                                     | Parameter Checking                                               | Default (BSP)               |
|                                     | Pin Output Support                                               | Enabled with Extra Features |
|                                     | Write Protect Enable                                             | Disabled                    |
|                                     | Clock Source                                                     | PCLKD                       |
|                                     | ▼ Module g_timer0 Timer, General PWM (r_gpt)                     |                             |
|                                     | ▼ General                                                        |                             |
|                                     | Name                                                             | g_timer0                    |
|                                     | Channel                                                          | 1                           |
|                                     | Mode                                                             | Triangle-Wave Symmetric PWM |
|                                     | Period                                                           | 50                          |
|                                     | Period Unit                                                      | Microseconds                |
|                                     | ▼ Output                                                         |                             |
|                                     | > Custom Waveform                                                |                             |
|                                     | Duty Cycle Percent (only applicable in PWM mode)                 | 50                          |
|                                     | GTIOCA Output Enabled                                            | True                        |
|                                     | GTIOCA Stop Level                                                | Pin Level Low               |
|                                     | GTIOCB Output Enabled                                            | True                        |
|                                     | GTIOCB Stop Level                                                | Pin Level High              |
|                                     | > Input                                                          |                             |
|                                     | > Interrupts                                                     |                             |
|                                     | ▼ Extra Features                                                 |                             |
|                                     | > Output Disable                                                 |                             |
|                                     | ▼ ADC Trigger                                                    |                             |
|                                     | ▼ Start Event Trigger (Channels with GTINTAD only)               |                             |
|                                     | Trigger Event A/D Converter Start Request A During Up Counting   | <input type="checkbox"/>    |
|                                     | Trigger Event A/D Converter Start Request A During Down Counting | <input type="checkbox"/>    |
|                                     | Trigger Event A/D Converter Start Request B During Up Counting   | <input type="checkbox"/>    |
|                                     | Trigger Event A/D Converter Start Request B During Down Counting | <input type="checkbox"/>    |
|                                     | > Dead Time                                                      |                             |
|                                     | > ADC Trigger (Channels with GTADTRA only)                       |                             |
|                                     | > ADC Trigger (Channels with GTADTRB only)                       |                             |
|                                     | > Interrupt Skipping (Channels with GTITC only)                  |                             |
|                                     | Extra Features                                                   | Enabled                     |

Figure 2-16 FSP Configuration of GPT Driver

| g_poeg0 Port Output Enable for GPT (r_poeg) |                                                      |                                     |
|---------------------------------------------|------------------------------------------------------|-------------------------------------|
| Settings                                    | Property                                             | Value                               |
| API Info                                    | ▼ Common                                             |                                     |
|                                             | Parameter Checking                                   | Default (BSP)                       |
|                                             | ▼ Module g_poeg0 Port Output Enable for GPT (r_poeg) |                                     |
|                                             | ▼ General                                            |                                     |
|                                             | ▼ Trigger                                            |                                     |
|                                             | GTETRG Pin                                           | <input checked="" type="checkbox"/> |
|                                             | GPT Output Level                                     | <input type="checkbox"/>            |
|                                             | Oscillation Stop                                     | <input type="checkbox"/>            |
|                                             | Name                                                 | g_poeg0                             |
|                                             | Channel                                              | 1                                   |
|                                             | ▼ Input                                              |                                     |
|                                             | GTETRG Polarity                                      | Active Low                          |
|                                             | GTETRG Noise Filter                                  | PCLKB/32                            |
|                                             | ▼ Interrupts                                         |                                     |
|                                             | Callback                                             | g_poe_overcurrent                   |
|                                             | Interrupt Priority                                   | Priority 0 (highest)                |

Figure 2-17 FSP configuration of POEG driver

### 2.2.3.3 RA6T3

#### (1). 12-bit A/D converter(ADC12)

U-phase current ( $I_u$ ), V-phase current ( $I_v$ ), W-phase current ( $I_w$ ), the rotation speed command value input, Uphase voltage( $V_u$ ), V phase voltage( $V_v$ ) W phase voltage( $V_w$ ), and inverter bus voltage( $V_{dc}$ ) are measured by using the '12 bit A/D converter'.

The operation modes must be set to the 'Single scan mode'(use a hardware trigger).

#### (2). Low power consumption asynchronous general-purpose timer(AGT)

Used as a 1ms interval taimer.

Channel 1 is used as a free run timer for speed measurement.

#### (3). General-purpose PWM timer(GPT)

On the channel 1, 2, and 3, output with dead time is performed by using the complementary PWM Output Operating Mode.

#### (4). Port output enable for GPT(POEG)

The ports executing PWM output are set to high impedance state when an overcurrent is detected(when the low level of the GTETRGB port is detected).

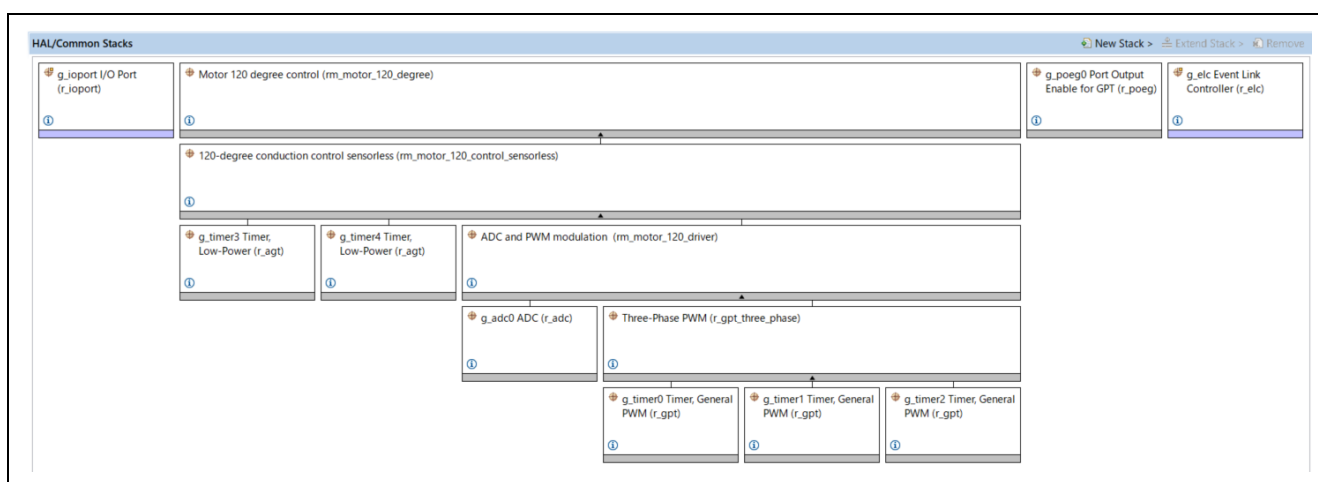


Figure 2-18 Overall FSP Stacks diagram

| g_adc0 ADC (r_adc) |                                                |                                    |
|--------------------|------------------------------------------------|------------------------------------|
| Settings           | Property                                       | Value                              |
| API Info           | ▼ Common                                       |                                    |
|                    | Parameter Checking                             | Default (BSP)                      |
|                    | ▼ Module g_adc0 ADC (r_adc)                    |                                    |
|                    | ▼ General                                      |                                    |
|                    | Name                                           | g_adc0                             |
|                    | Unit                                           | 0                                  |
|                    | Resolution                                     | 🔒 12-Bit                           |
|                    | Alignment                                      | 🔒 Right                            |
|                    | Clear after read                               | 🔒 Off                              |
|                    | Mode                                           | 🔒 Single Scan                      |
|                    | Double-trigger                                 | Disabled                           |
|                    | > Input                                        |                                    |
|                    | ▼ Interrupts                                   |                                    |
|                    | Normal/Group A Trigger                         | GPT1 COUNTER UNDERFLOW (Underflow) |
|                    | Group B Trigger                                | Disabled                           |
|                    | Group Priority (Valid only in Group Scan Mode) | Group A cannot interrupt Group B   |
|                    | Callback                                       | 🔒 rm_motor_120_driver_cyclic       |
|                    | Scan End Interrupt Priority                    | Priority 5                         |
|                    | Scan End Group B Interrupt Priority            | Disabled                           |
|                    | Window Compare A Interrupt Priority            | Disabled                           |
|                    | Window Compare B Interrupt Priority            | Disabled                           |
|                    | > Extra                                        |                                    |

Figure 2-19 FSP configuration of ADC driver [1/2]

| g_adc0 ADC (r_adc) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Settings           | Property                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Value |
| API Info           | <ul style="list-style-type: none"> <li>Module g_adc0 ADC (r_adc) <ul style="list-style-type: none"> <li>General</li> <li>Input <ul style="list-style-type: none"> <li>Channel Scan Mask (channel availability varies by MCU) <ul style="list-style-type: none"> <li>Channel 0 <input checked="" type="checkbox"/></li> <li>Channel 1 <input checked="" type="checkbox"/></li> <li>Channel 2 <input checked="" type="checkbox"/></li> <li>Channel 3 <input type="checkbox"/></li> <li>Channel 4 <input checked="" type="checkbox"/></li> <li>Channel 5 <input checked="" type="checkbox"/></li> <li>Channel 6 <input type="checkbox"/></li> <li>Channel 7 <input type="checkbox"/></li> <li>Channel 8 <input type="checkbox"/></li> <li>Channel 9 <input type="checkbox"/></li> <li>Channel 10 <input type="checkbox"/></li> <li>Channel 11 <input checked="" type="checkbox"/></li> <li>Channel 12 <input checked="" type="checkbox"/></li> <li>Channel 13 <input type="checkbox"/></li> <li>Channel 14 <input type="checkbox"/></li> <li>Channel 15 <input type="checkbox"/></li> <li>Channel 16 <input checked="" type="checkbox"/></li> <li>Channel 17 <input type="checkbox"/></li> <li>Channel 18 <input type="checkbox"/></li> <li>Channel 19 <input type="checkbox"/></li> <li>Channel 20 <input type="checkbox"/></li> <li>Channel 21 <input type="checkbox"/></li> <li>Channel 22 <input type="checkbox"/></li> <li>Channel 23 <input type="checkbox"/></li> <li>Channel 24 <input type="checkbox"/></li> <li>Channel 25 <input type="checkbox"/></li> <li>Channel 26 <input type="checkbox"/></li> <li>Channel 27 <input type="checkbox"/></li> <li>Temperature Sensor <input type="checkbox"/></li> <li>Voltage Sensor <input type="checkbox"/></li> </ul> </li> <li>Group B Scan Mask (channel availability varies by MCU)</li> <li>Addition/Averaging Mask (channel availability varies by MCU and unit)</li> <li>Sample and Hold <ul style="list-style-type: none"> <li>Sample and Hold Channels (Available only on selected MCUs) <ul style="list-style-type: none"> <li>Channel 0 <input checked="" type="checkbox"/></li> <li>Channel 1 <input checked="" type="checkbox"/></li> <li>Channel 2 <input checked="" type="checkbox"/></li> </ul> </li> <li>Sample Hold States (Applies only to channels 0, 1, 2) 24</li> </ul> </li> <li>Window Compare <ul style="list-style-type: none"> <li>Add/Average Count  Disabled</li> <li>Reference Voltage control  VREFH0/VREFH</li> </ul> </li> <li>Interrupts</li> <li>Extra</li> </ul> </li> </ul> </li></ul> |       |

Figure 2-20 FSP configuration of ADC driver [2/2]

| g_timer3 Timer, Low-Power (r_agt)       |                                            |                                                |
|-----------------------------------------|--------------------------------------------|------------------------------------------------|
| <div>Settings</div> <div>API Info</div> | Property                                   | Value                                          |
|                                         | ▼ Common                                   |                                                |
|                                         | Parameter Checking                         | Default (BSP)                                  |
|                                         | Pin Output Support                         | Disabled                                       |
|                                         | Pin Input Support                          | Disabled                                       |
|                                         | ▼ Module g_timer3 Timer, Low-Power (r_agt) |                                                |
|                                         | ▼ General                                  |                                                |
|                                         | Name                                       | g_timer3                                       |
|                                         | Channel                                    | 0                                              |
|                                         | Mode                                       | 🔒 Periodic                                     |
|                                         | Period                                     | 1                                              |
|                                         | Period Unit                                | Milliseconds                                   |
|                                         | Count Source                               | PCLKB                                          |
|                                         | > Output                                   |                                                |
|                                         | > Input                                    |                                                |
|                                         | ▼ Interrupts                               |                                                |
|                                         | Callback                                   | 🔒 rm_motor_120_control_sensorless_speed_cyclic |
|                                         | Underflow Interrupt Priority               | Priority 10                                    |

Figure 2-21 FSP configuration of AGT driver

| g_timer4 Timer, Low-Power (r_agt)       |                                            |               |
|-----------------------------------------|--------------------------------------------|---------------|
| <div>Settings</div> <div>API Info</div> | Property                                   | Value         |
|                                         | ▼ Common                                   |               |
|                                         | Parameter Checking                         | Default (BSP) |
|                                         | Pin Output Support                         | Disabled      |
|                                         | Pin Input Support                          | Disabled      |
|                                         | ▼ Module g_timer4 Timer, Low-Power (r_agt) |               |
|                                         | ▼ General                                  |               |
|                                         | Name                                       | g_timer4      |
|                                         | Channel                                    | 1             |
|                                         | Mode                                       | 🔒 Periodic    |
|                                         | Period                                     | 0xFFFFFFFF    |
|                                         | Period Unit                                | Raw Counts    |
|                                         | Count Source                               | PCLKB         |
|                                         | > Output                                   |               |
|                                         | > Input                                    |               |
|                                         | > Interrupts                               |               |

Figure 2-22 FSP Configuration of AGT Driver (free run timer for speed measurement)

| g_timer0 Timer, General PWM (r_gpt) |                                                                  |                             |
|-------------------------------------|------------------------------------------------------------------|-----------------------------|
| Settings                            | Property                                                         | Value                       |
| API Info                            | ▼ Common                                                         |                             |
|                                     | Parameter Checking                                               | Default (BSP)               |
|                                     | Pin Output Support                                               | Enabled with Extra Features |
|                                     | Write Protect Enable                                             | Disabled                    |
|                                     | Clock Source                                                     | PCLKD                       |
|                                     | ▼ Module g_timer0 Timer, General PWM (r_gpt)                     |                             |
|                                     | ▼ General                                                        |                             |
|                                     | Name                                                             | g_timer0                    |
|                                     | Channel                                                          | 1                           |
|                                     | Mode                                                             | Triangle-Wave Symmetric PWM |
|                                     | Period                                                           | 50                          |
|                                     | Period Unit                                                      | Microseconds                |
|                                     | ▼ Output                                                         |                             |
|                                     | > Custom Waveform                                                |                             |
|                                     | Duty Cycle Percent (only applicable in PWM mode)                 | 50                          |
|                                     | GTIOCA Output Enabled                                            | True                        |
|                                     | GTIOCA Stop Level                                                | Pin Level Low               |
|                                     | GTIOCB Output Enabled                                            | True                        |
|                                     | GTIOCB Stop Level                                                | Pin Level High              |
|                                     | > Input                                                          |                             |
|                                     | > Interrupts                                                     |                             |
|                                     | ▼ Extra Features                                                 |                             |
|                                     | > Output Disable                                                 |                             |
|                                     | ▼ ADC Trigger                                                    |                             |
|                                     | ▼ Start Event Trigger (Channels with GTINTAD only)               |                             |
|                                     | Trigger Event A/D Converter Start Request A During Up Counting   | <input type="checkbox"/>    |
|                                     | Trigger Event A/D Converter Start Request A During Down Counting | <input type="checkbox"/>    |
|                                     | Trigger Event A/D Converter Start Request B During Up Counting   | <input type="checkbox"/>    |
|                                     | Trigger Event A/D Converter Start Request B During Down Counting | <input type="checkbox"/>    |
|                                     | > Dead Time                                                      |                             |
|                                     | > ADC Trigger (Channels with GTADTRA only)                       |                             |
|                                     | > ADC Trigger (Channels with GTADTRB only)                       |                             |
|                                     | > Interrupt Skipping (Channels with GTITC only)                  |                             |
|                                     | Extra Features                                                   | Enabled                     |

Figure 2-23 FSP Configuration of GPT Driver

| g_poeg0 Port Output Enable for GPT (r_poeg) |                                                      |                                     |
|---------------------------------------------|------------------------------------------------------|-------------------------------------|
| Settings                                    | Property                                             | Value                               |
| API Info                                    | ▼ Common                                             |                                     |
|                                             | Parameter Checking                                   | Default (BSP)                       |
|                                             | ▼ Module g_poeg0 Port Output Enable for GPT (r_poeg) |                                     |
|                                             | ▼ General                                            |                                     |
|                                             | ▼ Trigger                                            |                                     |
|                                             | GTETRГ Pin                                           | <input checked="" type="checkbox"/> |
|                                             | GPT Output Level                                     | <input type="checkbox"/>            |
|                                             | Oscillation Stop                                     | <input type="checkbox"/>            |
|                                             | Name                                                 | g_poeg0                             |
|                                             | Channel                                              | 1                                   |
|                                             | ▼ Input                                              |                                     |
|                                             | GTETRГ Polarity                                      | Active Low                          |
|                                             | GTETRГ Noise Filter                                  | PCLKB/32                            |
|                                             | ▼ Interrupts                                         |                                     |
|                                             | Callback                                             | g_poe_overcurrent                   |
|                                             | Interrupt Priority                                   | Priority 0 (highest)                |

Figure 2-24 FSP configuration of POEG driver

## 2.3 Software structure

### 2.3.1 Software file structure

The folder and file configurations of the sample programs are given below.

**Table 2-6 File and folder configuration[1/2]**

| Folder | Subfolder         | File                                  | Remarks                                             |
|--------|-------------------|---------------------------------------|-----------------------------------------------------|
| ra_cfg |                   |                                       | Generated config header                             |
| ra_gen |                   |                                       | Generated register setting, main function etc       |
| ra     | arm               |                                       | CMSIS source code                                   |
|        | board             |                                       | Function definition for board                       |
|        | fsp/inc/api       | bsp_api.h                             | BSP API definition                                  |
|        |                   | r_adc_api.h                           | AD API definition                                   |
|        |                   | r_elc_api.h                           | ELC API definition                                  |
|        |                   | r_ioport_api.h                        | I/O API definition                                  |
|        |                   | r_poeg_api.h                          | POEG API definition                                 |
|        |                   | r_three_phase_api.h                   | 3phase PWM API definition                           |
|        |                   | r_timer_api.h                         | Timer API definition                                |
|        |                   | r_transfer_api.h                      | Transfer API definition                             |
|        |                   | rm_motor_120_control_api.h            | 120-degree conduction control API definition        |
|        |                   | rm_motor_120_driver_api.h             | 120-degree conduction control driver API definition |
|        |                   | rm_motor_angle_api.h                  | Angle API definition                                |
|        |                   | rm_motor_api.h                        | Motor API definition                                |
|        |                   | rm_motor_current_api.h                | Current API definition                              |
|        |                   | rm_motor_driver_api.h                 | Motor driver API definition                         |
|        |                   | rm_motor_position_api.h               | Position API definition                             |
|        |                   | rm_motor_speed_api.h                  | Speed API definition                                |
|        | fsp/inc/instances | r_adc_b.h(RA6T2) r_adc.h(RA4T1,RA6T3) | Function definition for AD                          |
|        |                   | r_agt.h                               | Function definition for AGT                         |
|        |                   | r_elc.h(Only RA4T1 and RA6T3)         | Function definition for ELC                         |
|        |                   | r_gpt_three_phase.h                   | Function definition for 3 Phase PWM                 |
|        |                   | r_gpt.h                               | Function definition for GPT                         |

Table 2-7 File and folder configuration[2/2]

| Folder | Subfolder                      | File                                                               | Remarks                                                     |
|--------|--------------------------------|--------------------------------------------------------------------|-------------------------------------------------------------|
| ra     | fsp/inc/instances              | r_ioport.h                                                         | Function definition for I/O                                 |
|        |                                | r_poeg.h                                                           | Function definition for POEG                                |
|        |                                | rm_motor_120_control_sensorless.h                                  | Sensorless 120-degree conduction control related definition |
|        |                                | rm_motor_120_degree.h                                              | 120-degree conduction control related definition            |
|        |                                | rm_motor_120_driver.h                                              | 120-degree conduction control driver related definition     |
|        | fsp/src                        | bsp                                                                | BSP driver                                                  |
|        |                                | r_adc_b/r_adc_b.c(RA6T2)                                           | AD driver                                                   |
|        |                                | r_adc/r_adc.c(RA4T1,RA6T3)                                         |                                                             |
|        |                                | r_agt/r_agt.c                                                      | AGT driver                                                  |
|        |                                | r_elc/r_elc.c(Only RA4T1 and RA6T3)                                | ELC driver                                                  |
|        |                                | r_gpt/r_gpt.c                                                      | GPT driver                                                  |
|        |                                | r_gpt_three_phase/ r_gpt_three_phase.c                             | 3 phase PWM driver                                          |
|        |                                | r_ioport/r_ioport.c                                                | I/O driver                                                  |
|        |                                | r_poeg/r_poeg.c                                                    | POEG driver                                                 |
|        |                                | rm_motor_120_control_sensorless/ rm_motor_120_control_sensorless.c | Sensorless 120-degree conduction control                    |
|        |                                | rm_motor_120_degree/ rm_motor_120_degree.c                         | 120-degree conduction control                               |
|        |                                | rm_motor_120_driver/ rm_motor_120_driver.c                         | 120-degree conduction control driver                        |
| src    | application/main               | mtr_main.h , mtr_main.c                                            | User main function                                          |
|        |                                | r_mtr_control_parameter.h<br>(Only RA4T1 and RA6T3)                | Control parameters definition                               |
|        |                                | r_mtr_motor_parameter.h<br>(Only RA4T1 and RA6T3)                  | Motor parameters definition                                 |
|        | application/user_interface/ics | r_mtr_ics.h , r_mtr_ics.c                                          | Function definition for Analyzer                            |
|        |                                | ICS2_RA6T2.h , ICS2_RA4T1.h , ICS2_RA6T3.h                         | Function definition for GUI tool                            |
|        |                                | ICS2_RA6T2.o , ICS2_RA4T1.o , ICS2_RA6T3.o                         | Communication library for GUI tool                          |

### 2.3.2 Module configuration

Figure 2-25 show module configuration of software.

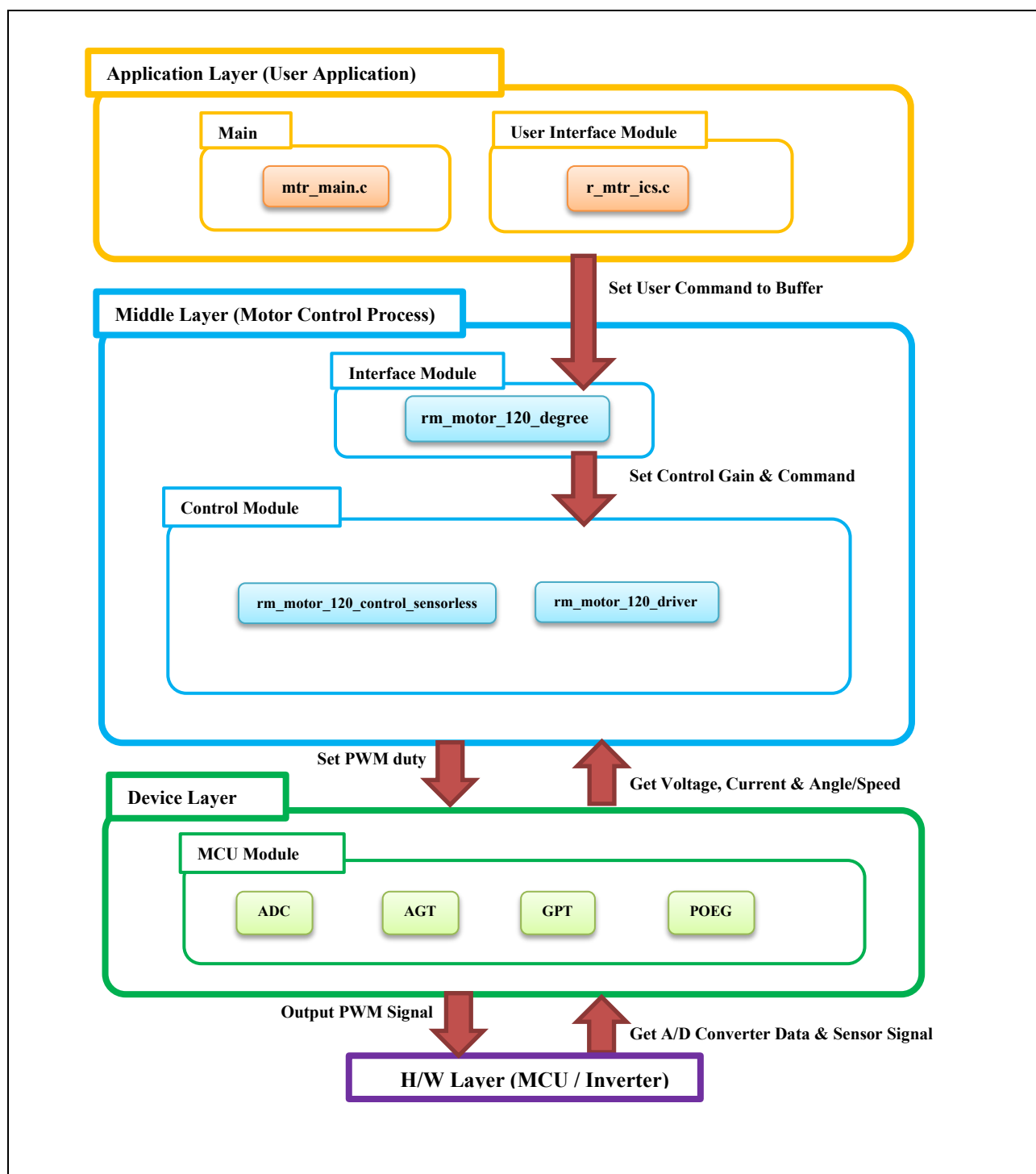


Figure 2-25 Module Configuration

## 2.4 Software specifications

**Table 2-8** shows the basic specifications of target software of this application note. For details of 120-degree conducting control, refer to the application note '120-degree conducting control of permanent magnetic synchronous motor: algorithm' (R01AN2657).

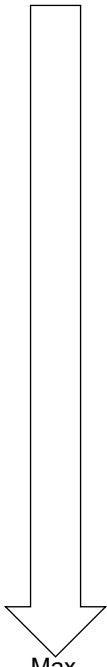
**Table 2-8 Basic Specifications of Software**

| Item                                   | Content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Control method                         | 120-degree conducting control                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Rotor magnetic pole position detection | Position detection by inductive voltage (by 60 degrees)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Motor rotation start/stop              | SW1 input or input from 'Renesas Motor Workbench'                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Input voltage                          | DC 24V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Main clock frequency                   | RA6T2: 240 [MHz]<br>RA6T3: 200 [MHz]<br>RA4T1: 100 [MHz]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Carrier frequency (PWM)                | 20 [kHz] (Carrier cycle : 50 [μs])                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| dead time                              | 2 [μs]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Control frequency(Speed)               | RA6T2: 1 [ms]<br>RA6T3: 1 [ms]<br>RA4T1: 1 [ms]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Rotation speed control range           | CW : 0 [rpm] ~ 2400 [rpm]<br>CCW : 0 [rpm] ~ 2400 [rpm]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Compiler optimization settings         | Optimization level      Optimize more(-O2) (default setting)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Processing stop for protection         | Disables the motor control signal output (six outputs), under any of the following conditions. <ol style="list-style-type: none"> <li>1.Current of any phase exceeds <math>3.54(=1.67 \times \sqrt{2}) \times 1.5</math> [A]( monitored every current control cycle)</li> <li>2.Inverter bus voltage exceeds 60 [V] (monitored in current control period)</li> <li>3.Inverter bus voltage is less than 8 [V] (monitored in current control period)</li> <li>4.Rotation speed exceeds 4500 [rpm] (monitored in current control period)</li> <li>5.At the time of sensorless drive, zero-crossing is not detected for current control period</li> <li>6.Fault detection of virtual hall sensor pattern(position information)</li> </ol> <p>When an external over current signal is detected (when a low level is detected), the PWM output ports are set to high impedance state.</p> |

## 2.5 Interrupt priority

The interrupts and priorities used in this system are shown below.

**Table 2-9 Interrupt priority**

| Interrupt level | Priority                                                                           | function                                                                            |
|-----------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| 15              |  |                                                                                     |
| 14              |                                                                                    |                                                                                     |
| 13              |                                                                                    |                                                                                     |
| 12              |                                                                                    |                                                                                     |
| 11              |                                                                                    |                                                                                     |
| 10              |                                                                                    | AGT0 INT<br>Speed control Interrupt                                                 |
| 9               |                                                                                    |                                                                                     |
| 8               |                                                                                    |                                                                                     |
| 7               |                                                                                    |                                                                                     |
| 6               |                                                                                    |                                                                                     |
| 5               |                                                                                    | ADC0 ADI0(RA6T2)<br>ADC0 SCAN END(RA4T1,RA6T3)<br>A/D conversion complete interrupt |
| 4               |                                                                                    |                                                                                     |
| 3               |                                                                                    |                                                                                     |
| 2               |                                                                                    |                                                                                     |
| 1               |                                                                                    |                                                                                     |
| 0               |                                                                                    | POEG3 EVENT(RA6T2)<br>POEG1 EVENT(RA4T1,RA6T3)<br>Over current error interrupt      |

### Allocations

| Interrupt | Event                                           | ISR            |
|-----------|-------------------------------------------------|----------------|
| 0         | AGT0 INT (AGT interrupt)                        | agt_int_isr    |
| 1         | ADC0 ADI0 (End of A/D scanning operation(Gr.0)) | adc_b_adi0_isr |
| 2         | POEG3 EVENT (Port Output disable interrupt D)   | poeg_event_isr |

Figure 2-26 FSP configuration of interrupt

### Allocations

| Interru... | Event                                         | ISR              |
|------------|-----------------------------------------------|------------------|
| 0          | AGT0 INT (AGT interrupt)                      | agt_int_isr      |
| 1          | ADC0 SCAN END (A/D scan end interrupt)        | adc_scan_end_isr |
| 2          | POEG1 EVENT (Port Output disable interrupt B) | poeg_event_isr   |

Figure 2-27 RA4T1/RA6T3 FSP Interrupts Configuration

### 3. Descriptions of the control software

The target sample software of this application note is explained here.

#### 3.1 Contents of control

##### 3.1.1 Motor start / stop

Starting and stopping of the motor are controlled by input from 'Renesas Motor Workbench' or SW1.

A general-purpose port is assigned to SW1 and based upon its level the motor operation is controlled.

"High" level → Motor Start

"Low" level → Motor Stop

##### 3.1.2 A/D converter

###### (1). Motor rotation speed command value

The rotation speed command value of the motor is determined from the input from 'Renesas Motor Workbench' or the output value (analog value) of VR1. Rotation speed command value from VR1 is measured as shown in the table below.

**Table 3-1 Conversion Ratio of the Rotation Speed Command Value**

| Item                         | Conversion ratio(Command value: A/D conversion value) |                                  |
|------------------------------|-------------------------------------------------------|----------------------------------|
| Rotation speed command value | CW                                                    | 0 [rpm]~2400[rpm] : 0800H~0FFFFH |
|                              | CCW                                                   | 0 [rpm]~2400[rpm] : 07FFH~0000H  |

###### (2). Inverter bus voltage

Inverter bus voltage is measured as shown in the table below. It is used for calculation of modulation rate and detection of overvoltage and undervoltage (PWM stops in case of abnormality).

**Table 3-2 Inverter Bus Voltage Conversion Ratio**

| Item                 | Conversion ratio(Inverter bus voltage : A/D conversion value) |
|----------------------|---------------------------------------------------------------|
| Inverter bus voltage | 0 [V]~73.26 [V] : 0000H~0FFFFH                                |

###### (3). U, V, and W phase voltage

The U, V, and W phase voltages are measured as shown in **Table 3-3** and used for determining zero-crossing.

**Table 3-3 Conversion Ratio of U, V, and W Phase Voltage**

| Item                      | Conversion ratio(U, V, and W phase voltage : A/D conversion value) |
|---------------------------|--------------------------------------------------------------------|
| U, V, and W phase voltage | 0 [V]~73.26 [V] : 0000H~0FFFFH                                     |

###### (4). U, V, and W phase current

The U, V and W phase currents are measured as shown in **Table 3-4**.

**Table 3-4 Conversion Ratio U, V, and W Phase Current**

| Item                      | Conversion ratio(U, V, and W phase current : A/D conversion value) |
|---------------------------|--------------------------------------------------------------------|
| U, V, and W phase current | -8.25 [A] to 8.25 [A]: 0000H to 0FFFFH <sup>(Note)</sup>           |
|                           | Current = (3.3V-1.65V)/(0.01Ohm * 20) =8.25A                       |

### 3.1.3 Speed control

In this system, the motor rotation speed is calculated from a difference of the current timer value and the timer value  $2\pi$  [rad] before. The timer values are obtained from compare match value of GPT0 (free running timer) at every external interrupt due to zero cross occurs.

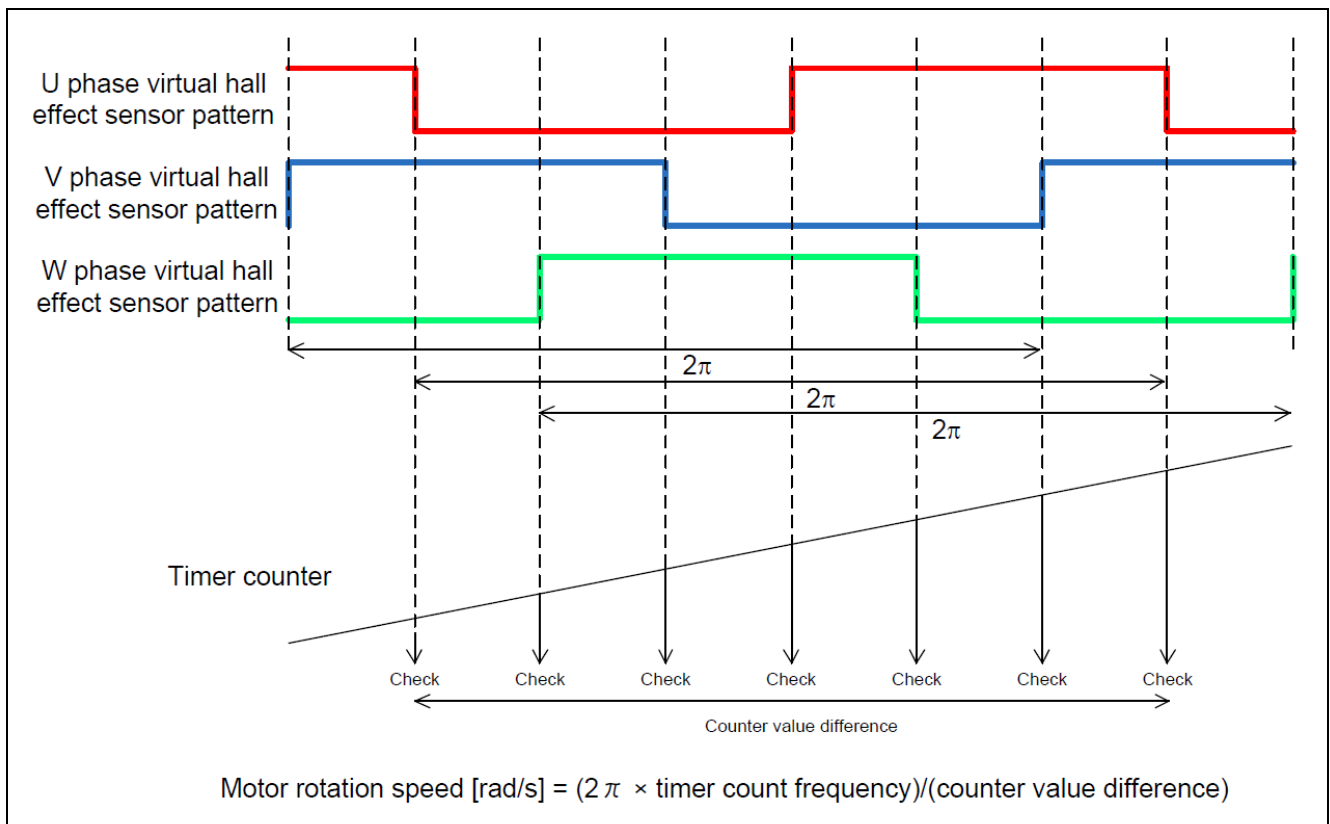


Figure 3-1 Motor Rotation Speed Calculation Method

Speed control in the software targeted by this application note is performed by PI control. Obtain the voltage command value by the following speed control PI control.

$$v^* = (K_{P\omega} + \frac{K_{I\omega}}{s})(\omega^* - \omega)$$

$v^*$ : Voltage command value,  $\omega^*$ : Speed command value,  $\omega$ : Rotation speed

$K_{P\omega}$ : Speed PI proportional gain,  $K_{I\omega}$ : Speed PI integral gain,  $s$ : Laplace operator

### 3.1.4 Voltage control by PWM

PWM control is used for controlling output voltage. The PWM control is a control method that continuously adjusts the average voltage by varying the duty of pulse, as shown in Figure 3-2.

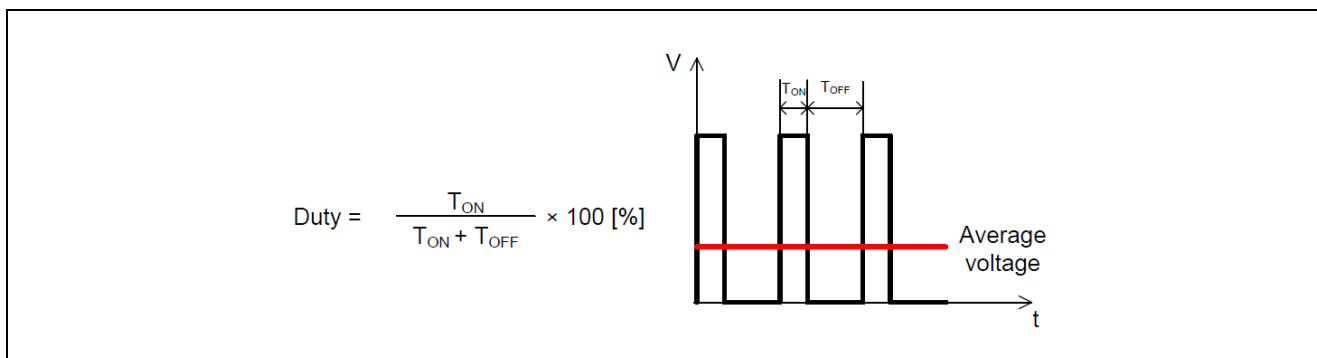


Figure 3-2 PWM Control

Here, modulation factor  $m$  is defined as follows.

$$m = \frac{V}{E}$$

$m$ : Modulation factor     $V$ : Command value voltage     $E$ : Inverter bus voltage

This modulation factor is reflected in the setting value of the register that determines the PWM duty.

In the target software of this application note, first-60-degree chopping is used to control the output voltage and speed. Figure 3-3 shows an example of motor control signal output waveforms at non-complimentary first-60-degree Chopping. Figure 3-4 shows an example of motor control signal output waveforms at Complimentary first 60-degree Chopping.

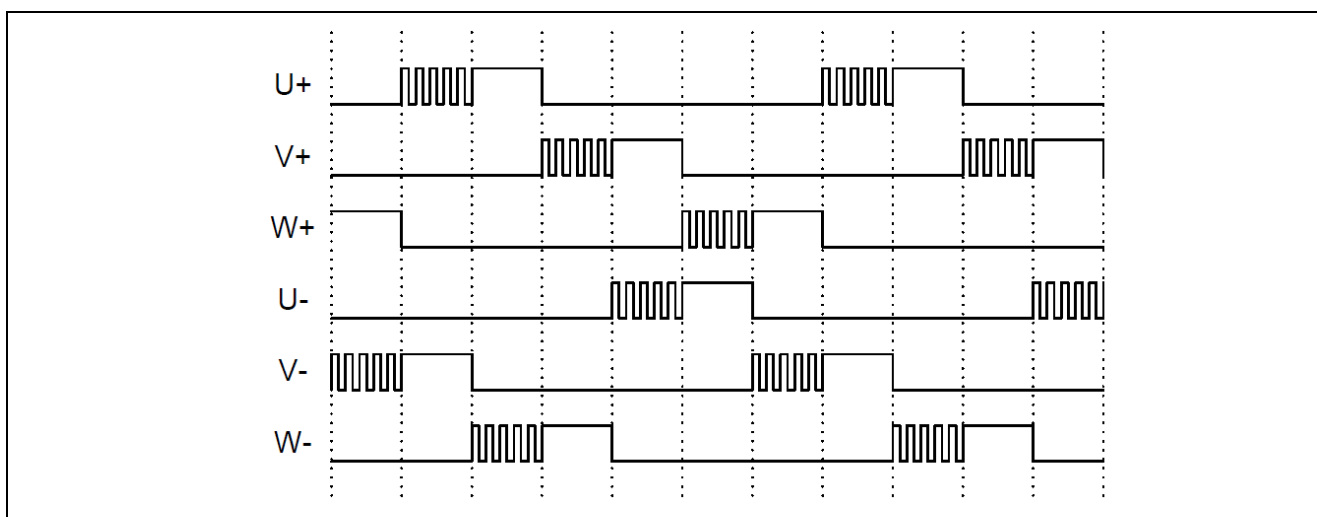


Figure 3-3 non-complimentary first 60-degree Chopping

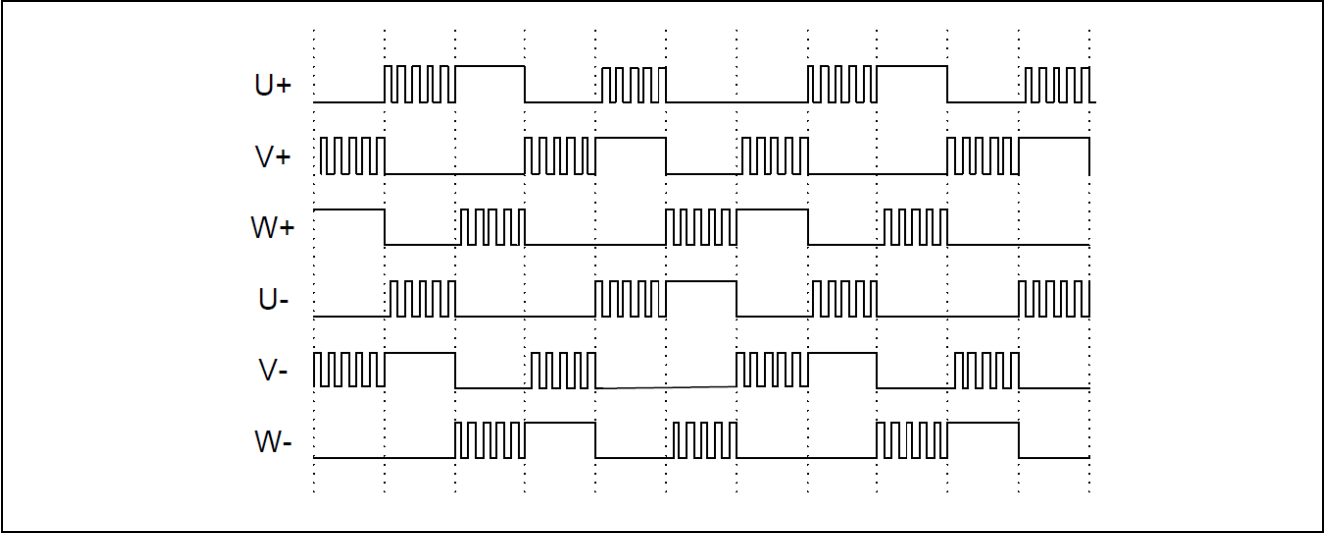


Figure 3-4 Complimentary first 60-degree Chopping

3.1.5 State transition

Figure 3-5 show state transition diagrams of 120-degree conducting control software. In this application note target software, the status is managed by "SYSTEM MODE".

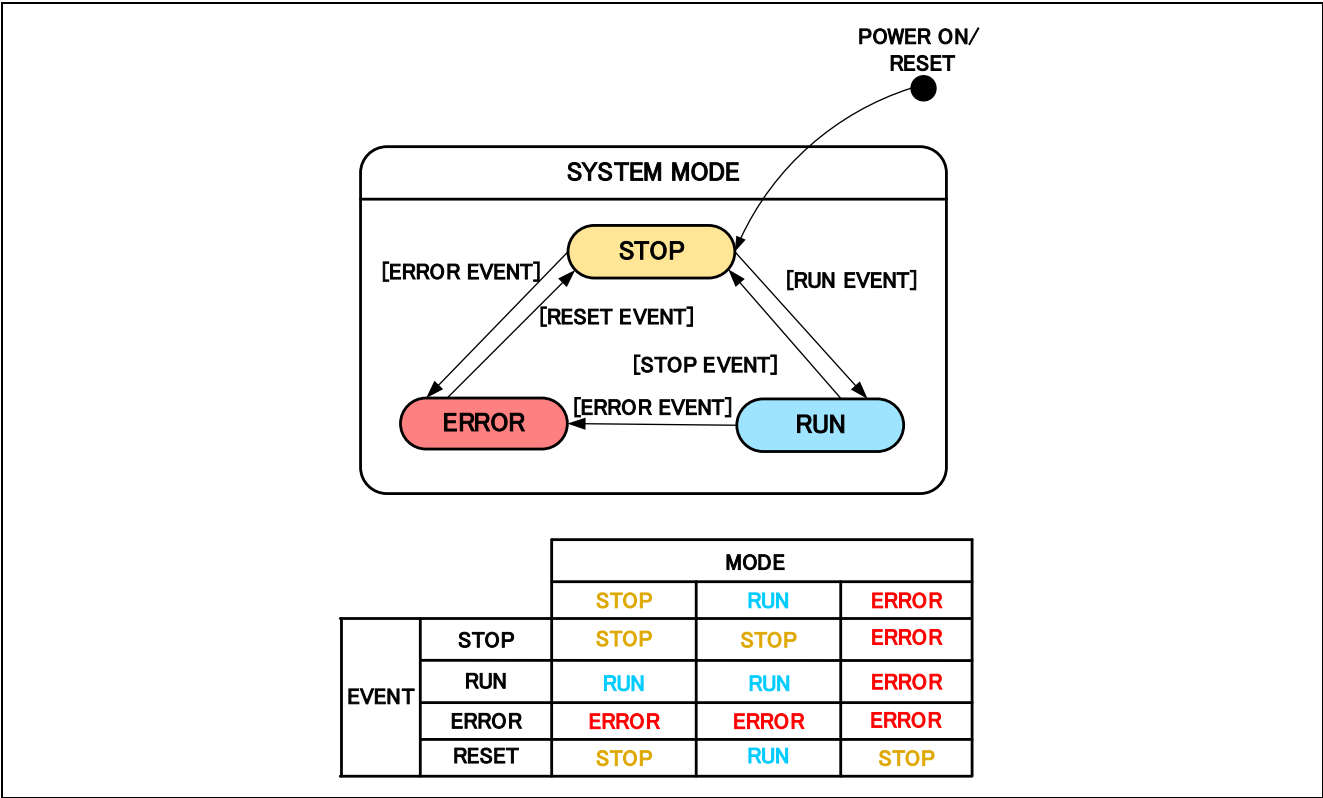


Figure 3-5 State Transition Diagram of Sensorless 120-degree Conducting Control Software

(1) SYSTEM MODE

Represents the operating status of the system. The state changes when each event (EVENT) occurs. The operating status of the system includes motor drive stop (INACTIVE), motor drive (ACTIVE), and abnormal status (ERROR).

(2) EVENT

When an EVENT occurs during each SYSTEM MODE, the system operating status changes as shown in the table in Fig. 35 according to the EVENT. The causes of each EVENT are as follows.

Table 3-5 EVENT List

| Event | Occurrence factor                          |
|-------|--------------------------------------------|
| STOP  | Caused by user operation.                  |
| RUN   | Caused by user operation.                  |
| ERROR | Occurs when the system detects an anomaly. |
| RESET | Caused by user operation.                  |

Sensorless 120-degree conducting control, to estimate the position of the magnetic poles of every 60 degrees in the induced voltage due to the change in the magnetic flux of the permanent magnet (rotor).

Figure 3-6 shows the start-up method in the sample software.



### 3.1.7 System protection function

This system has the following six types of error status and enables emergency stop functions in case of occurrence of respective error. Refer to Table 3-6 for settings.

- Overcurrent error

There are two kind of overcurrent protection.

Hardware OCP: When emergency stop signal from the hardware is detected, PWM output ports are automatically set to high impedance output (without software intervention).

Software OCP: U, V, and W phase currents are monitored in over current monitoring cycle. When an over current is detected, the CPU executes emergency stop.

- Overvoltage error

The inverter bus voltage is monitored at the overvoltage monitoring cycle. When an over voltage is detected (when the voltage exceeds the limit value), CPU performs an emergency stop. The threshold value of the overvoltage is set in consideration of the error of resistance value of the detection circuit.

- Undervoltage error

The inverter bus voltage is monitored at the undervoltage monitoring cycle. When an under voltage is detected (when the voltage lowers the limit value), CPU performs an emergency stop. The threshold value of the overvoltage is set in consideration of the error of resistance value of the detection circuit.

- Rotation speed abnormality error

The rotation speed is monitored at the rotation speed monitoring cycle. When the speed exceeds the limit value, CPU performs an emergency stop.

- Timeout error of zero-cross detection

When no pattern switching by detecting a timeout zero-crossing occurs, CPU performs an emergency stop.

- Virtual hall sensor pattern (position information) error

When an error is detected in virtual hall sensor patterns (position information) generated from each of U, V, and W phase voltage, CPU performs an emergency stop.

**Table 3-6 Setting Value of Each System Protection Function**

| Error name                            | Threshold              |      | Monitoring cycle       |
|---------------------------------------|------------------------|------|------------------------|
| Overcurrent error                     | Over current limit [A] | 3.54 | Current control period |
| Overvoltage error                     | Over voltage limit [V] | 60   | Current control period |
| Undervoltage error                    | Low voltage limit [V]  | 8    | Current control period |
| Over speed error                      | Speed limit [rpm]      | 4500 | Current control period |
| Timeout error of zero-cross detection | Timeout value [ms]     | 100  |                        |

3.1.8 AD triggers

Shows the timing of AD triggers and scan groups.

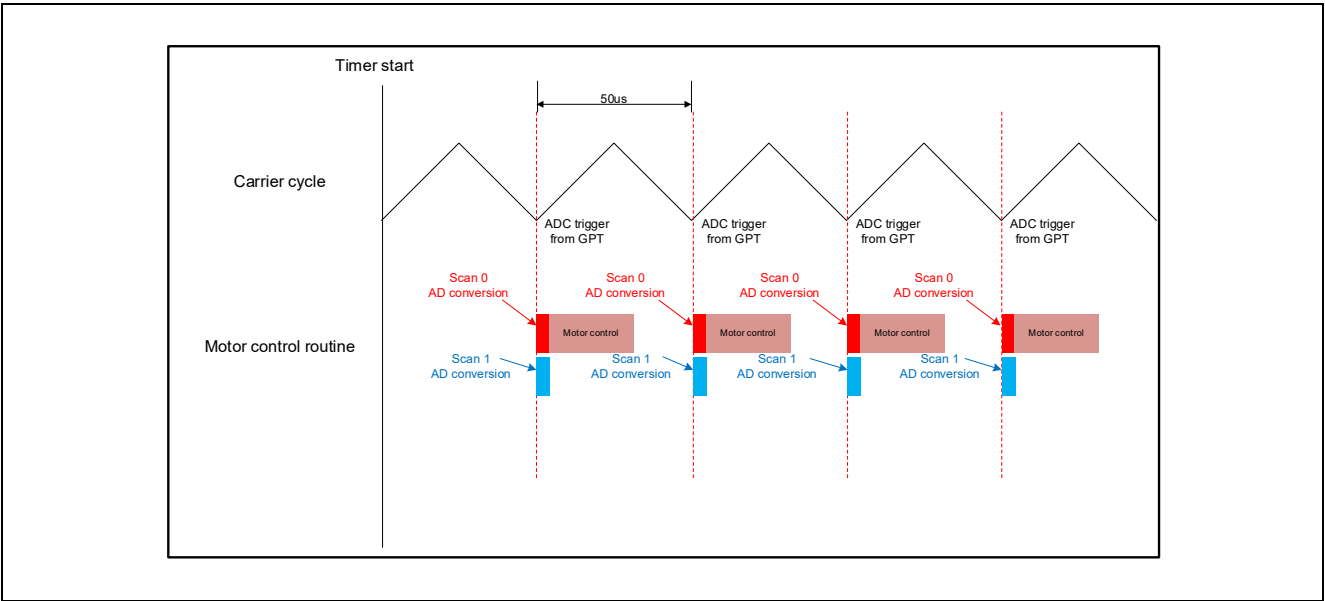


Figure 3-1 AD trigger timing

### 3.2 Function specifications of 120-degree conducting control software

Multiple control functions are used in this control program.

**Table 3-7 List of Functions “mtr\_main.c” [1/2]**

| File name  | Function name                                                                                                            | Process overview                                     |
|------------|--------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|
| mtr_main.c | mtr_init<br>Input : None<br>Output : None                                                                                | Initialization process                               |
|            | mtr_main<br>Input : None<br>Output : None                                                                                | Main processing                                      |
|            | board_ui<br>Input : None<br>Output : None                                                                                | Board user interface use                             |
|            | ics_ui<br>Input : None<br>Output : None                                                                                  | GUI tool user interface use                          |
|            | software_init<br>Input : None<br>Output : None                                                                           | Initialization of variables used in the main process |
|            | g_poe_overcurrent<br>Input : (poeg_callback_args_t *) p_args / callback function parameter<br>Output : None              | POEG interrupt processing                            |
|            | motor_fsp_init<br>Input : None<br>Output : None                                                                          | FSP module initialization process                    |
|            | mtr_callback_120_degree<br>Input : (motor_callback_args_t *) p_args / callback function parameter<br>Output : None       | 120 degree control callback function                 |
|            | mtr_board_led_control<br>Input : (uint8_t) u1_motor_status / motor status<br>Output : None                               | LED pattern setting process                          |
|            | mtr_remove_sw_chattering<br>Input : (uint8_t) u1_sw / switch type<br>(uint8_t) u1_on_off / ON/OFF state<br>Output : None | Switch chattering removal process                    |
|            | get_vr1<br>Input : None<br>Output : None                                                                                 | Get the state of VR1                                 |

**Table 3-8 List of Functions “mtr\_main.c” [2/2]**

| File name  | Function name                             | Process overview      |
|------------|-------------------------------------------|-----------------------|
| mtr_main.c | get_sw1<br>Input : None<br>Output : None  | Get the status of SW1 |
|            | get_sw2<br>Input : None<br>Output : None  | Get the status of SW2 |
|            | led1_on<br>Input : None<br>Output : None  | LED1 on               |
|            | led2_on<br>Input : None<br>Output : None  | LED2 on               |
|            | led3_on<br>Input : None<br>Output : None  | LED3 on               |
|            | led1_off<br>Input : None<br>Output : None | LED1 off              |
|            | led2_off<br>Input : None<br>Output : None | LED2 off              |
|            | led3_off<br>Input : None<br>Output : None | LED3 off              |

**Table 3-9 List of Functions “r\_mtr\_ics.c”**

| File name   | Function name                                              | Process overview                                |
|-------------|------------------------------------------------------------|-------------------------------------------------|
| r_mtr_ics.c | mtr_set_com_variables<br>Input : None<br>Output : None     | Set value from GUI tool                         |
|             | mtr_ics_variables_init<br>Input : None<br>Output : None    | Initialization of variables used<br>by GUI tool |
|             | mtr_ics_interrupt_process<br>Input : None<br>Output : None | Reflect the set value in motor<br>control       |

**Table 3-10 List of Functions “rm\_motor\_120\_degree.c” [1/3]**

| File name             | Function name                                                                                                                                                                                       | Process overview                             |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| rm_motor_120_degree.c | RM_MOTOR_120_DEGREE_Open<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_cfg_t const * const) p_cfg / configuration parameter<br>Output : (fsp_err_t) err / Result          | 120 degree control start process             |
|                       | RM_MOTOR_120_DEGREE_Close<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                        | 120 degree control end process               |
|                       | RM_MOTOR_120_DEGREE_Reset<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                        | Error state reset process                    |
|                       | RM_MOTOR_120_DEGREE_Run<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                          | Motor rotation start process                 |
|                       | RM_MOTOR_120_DEGREE_Stop<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                         | Motor rotation stop process                  |
|                       | RM_MOTOR_120_DEGREE_ErrorSet<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_error_t const) error / error parameter<br>Output : (fsp_err_t) err / Result                    | Error status setting process                 |
|                       | RM_MOTOR_120_DEGREE_SpeedSet<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>(float const) speed_rpm / Rotation speed command value [RPM]<br>Output : (fsp_err_t) err / Result     | Motor rotation command value setting process |
|                       | RM_MOTOR_120_DEGREE_StatusGet<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>(uint8_t * const) p_status / Motor control status<br>Output : (fsp_err_t) err / Result               | Acquisition of motor control status          |
|                       | RM_MOTOR_120_DEGREE_SpeedGet<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>(float * const) p_speed_rpm / Rotation speed command value [RPM]<br>Output : (fsp_err_t) err / Result | Motor rotation speed acquisition process     |
|                       | RM_MOTOR_120_DEGREE_WaitStopFlagGet<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>(uint8_t * const) p_flg_wait_stop / Motor stopped state<br>Output : (fsp_err_t) err / Result   | Acquisition of motor stop state              |
|                       | RM_MOTOR_120_DEGREE_ErrorCheck<br>Input : (motor_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result<br>(uint16_t * const) p_error / Error status                      | Error check process                          |

Table 3-11 List of Functions “rm\_motor\_120\_degree.c” [2/3]

| File name             | Function name                                                                                                                                                                                 | Process overview                     |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| rm_motor_120_degree.c | rm_motor_120_degree_active<br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : (uint8_t) err / Result                                                     | Motor rotation start process         |
|                       | rm_motor_120_degree_inactive<br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : (uint8_t) err / Result                                                   | Motor rotation stop process          |
|                       | rm_motor_120_degree_nowork<br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : (uint8_t) err / Result                                                     | Blank process                        |
|                       | rm_motor_120_degree_reset<br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : (uint8_t) err / Result                                                      | Error state reset process            |
|                       | rm_motor_120_degree_error<br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : (uint8_t) err / Result                                                      | Post-processing in case of error     |
|                       | rm_motor_120_degree_statemachine_init<br>Input : (motor_120_degree_statemachine_t *) p_state_machine / State machine<br>Output : None                                                         | State machine initialization process |
|                       | rm_motor_120_degree_statemachine_reset<br>Input : (motor_120_degree_statemachine_t *) p_state_machine / State machine<br>Output : None                                                        | State machine reset process          |
|                       | rm_motor_120_degree_statemachine_event<br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>(motor_120_degree_ctrl_event_t) u1_event / event<br>Output : None       | State transition process             |
|                       | rm_motor_check_over_speed_error<br>Input : (float) f4_speed / Rotation speed [RPM]<br>(float) f4_speed_limit / Rotation speed upper limit [RPM]<br>Output : (uint16_t) u2_temp0 / Error flag  | Overspeed error detection processing |
|                       | rm_motor_check_over_voltage_error<br>Input : (float) f4_vdc / Inverter bus voltage [V]<br>(float) f4_overvoltage_limit / voltage upper limit [V]<br>Output : (uint16_t) u2_temp0 / Error flag | Overvoltage error detection process  |
|                       | rm_motor_check_low_voltage_error<br>Input : (float) f4_vdc / Inverter bus voltage [V]<br>(float) f4_lowvoltage_limit / voltage lower limit [V]<br>Output : (uint16_t) u2_temp0 / Error flag   | Low voltage error detection process  |

**Table 3-12 List of Functions “rm\_motor\_120\_degree.c” [3/3]**

| File name             | Function name                                                                                                                                                                                                                                                                                                                                                                | Process overview                    |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| rm_motor_120_degree.c | <b>rm_motor_check_over_current_error</b><br>Input : (float) f4_iu / U phase current [A]<br>(float) f4_iv / V phase current [A]<br>(float) f4_iw / W phase current [A]<br>(float) f4_oc_limit / Current upper limit [A]<br>Output : (uint16_t) u2_temp0 / Error flag                                                                                                          | Overcurrent error detection process |
|                       | <b>rm_motor_120_degree_error_check</b><br>Input : (motor_120_degree_instance_ctrl_t *) p_ctrl / Instance parameter<br>(float) f_iu / U phase current [A]<br>(float) f_iv / V phase current [A]<br>(float) f_iw / W phase current [A]<br>(float) f_vdc / Inverter bus voltage[V]<br>(float) f_speed / Rotation speed [RPM]<br>Output : (uint16_t) u2_error_flags / Error flag | Error detection process             |
|                       | <b>rm_motor_120_degree_120_control_callback</b><br>Input : (motor_120_control_callback_args_t *) p_args / Callback function parameter<br>Output : None                                                                                                                                                                                                                       | 120control module callback process  |

**Table 3-13 List of Functions “rm\_motor\_120\_control\_sensorless.c” [1/4]**

| File name                         | Function name                                                                                                                                                                                                                                                                           | Process overview                                              |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| rm_motor_120_control_sensorless.c | RM_MOTOR_120_CONTROL_SENSORLESS_Open<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_control_cfg_t const * const) p_cfg / Configuration parameter<br>Output : (fsp_err_t) err / Result                                                          | Sensorless control start process                              |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_Close<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                    | Sensorless control end process                                |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_Run<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                      | Motor rotation start process (sensorless control)             |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_Stop<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                     | Motor rotation stop process (sensorless control)              |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_Reset<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                    | Error state reset process                                     |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_SpeedSet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(float * const) p_speed_rpm / Rotation command value [RPM]<br>Output : (fsp_err_t) err / Result                                                                   | Motor rotation command value setting process                  |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_SpeedGet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(float * const) p_speed_rpm / Rotation speed value [RPM]<br>Output : (fsp_err_t) err / Result                                                                     | Motor rotation speed acquisition process                      |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_CurrentGet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_driver_current_status_t * const) p_current_status / current status<br>Output : (fsp_err_t) err / Result                                              | Current and voltage data acquisition process                  |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_WaitStopFlagGet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_control_wait_stop_flag_t * const) p_flag / Motor stopped state<br>Output : (fsp_err_t) err / Result                                             | Motor stop state acquisition process                          |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_TimeoutErrorFlagGet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_control_timeout_error_flag_t * const) p_timeout_error_flag / Zero-cross detection timeout error status<br>Output : (fsp_err_t) err / Result | Zero-cross detection timeout error status acquisition process |

**Table 3-14 List of Functions “rm\_motor\_120\_control\_sensorless.c” [2/4]**

| File name                         | Function name                                                                                                                                                                                                                                                                      | Process overview                                             |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| rm_motor_120_control_sensorless.c | RM_MOTOR_120_CONTROL_SENSORLESS_PatternErrorFlagGet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_control_pattern_error_flag_t * const)<br>p_pattern_error_flag / Virtual hall pattern error status<br>Output : (fsp_err_t) err / Result | Virtual Hall sensor pattern error status acquisition process |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_VoltageRefGet<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_control_voltage_ref_t * const) p_voltage_ref /<br>Voltage setting status<br>Output : (fsp_err_t) err / Result                                | Obtain voltage setting status                                |
|                                   | RM_MOTOR_120_CONTROL_SENSORLESS_ParameterUpdate<br>Input : (motor_120_control_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_control_cfg_t const * const) p_cfg / Configuration parameter<br>Output : (fsp_err_t) err / Result                                          | Parameter update process                                     |
|                                   | rm_motor_120_control_sensorless_speed_cyclic<br>Input : (timer_callback_args_t *) p_args / Callback function parameter<br>Output : None                                                                                                                                            | Callback function for speed control                          |
|                                   | rm_motor_120_control_sensorless_driver_callback<br>Input : (motor_120_driver_callback_args_t *) p_args / Callback function parameter<br>Output : None                                                                                                                              | A/D conversion complete callback function                    |
|                                   | rm_motor_120_control_sensorless_reset<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                                     | Instance parameter reset process                             |
|                                   | rm_motor_120_control_sensorless_start_openloop<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                            | Open loop start processing                                   |
|                                   | rm_motor_120_control_sensorless_ol_signal_set<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                             | Voltage pattern setting process during open loop             |
|                                   | rm_motor_120_control_sensorless_speed_calc<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                                | Rotation speed calculation process                           |
|                                   | rm_motor_120_control_sensorless_generate_pattern<br>Input : (float) vu_ad / U phase voltage<br>(float) vv_ad / V phase voltage<br>(float) vw_ad / W phase voltage<br>(float) vn_ad / Midpoint voltage<br>Output : (uint8_t) u1_temp / Voltage pattern                              | Voltage pattern generation process                           |

**Table 3-15 List of Functions “rm\_motor\_120\_control\_sensorless.c” [3/4]**

| File name                         | Function name                                                                                                                                                                                             | Process overview                                      |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| rm_motor_120_control_sensorless.c | rm_motor_120_control_sensorless_set_angle_shift<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                               | Calculation of phase shift amount                     |
|                                   | rm_motor_120_control_sensorless_check_pattern<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                                 | Zero-cross judgment process                           |
|                                   | rm_motor_120_control_sensorless_shift_angle<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                                   | Phase shift process                                   |
|                                   | rm_motor_120_control_sensorless_wait_motorstop<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                                | Rotation stop check process                           |
|                                   | rm_motor_120_control_sensorless_pattern_set<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                                   | Voltage pattern setting process                       |
|                                   | rm_motor_120_control_sensorless_pattern_first60<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>(uint8_t) u1_signal / Voltage pattern<br>Output : None      | Non-complementary first 60 degree chopping process    |
|                                   | rm_motor_120_control_sensorless_pattern_first60_comp<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>(uint8_t) u1_signal / Voltage pattern<br>Output : None | Complementary first 60 degree chopping process        |
|                                   | rm_motor_120_control_sensorless_speed_ref_set<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                                 | Speed control command value setting process           |
|                                   | rm_motor_120_control_sensorless_voltage_ref_set<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                               | Voltage command value setting process                 |
|                                   | rm_motor_120_control_sensorless_pi_ctrl<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                                       | PI control processing                                 |
|                                   | rm_motor_120_control_sensorless_check_timeout_error<br>Input : (motor_120_control_sensorless_instance_ctrl_t *) p_ctrl /<br>Instance parameter<br>Output : None                                           | Virtual Hall sensor pattern error judgment processing |

**Table 3-16 List of Functions “rm\_motor\_120\_control\_sensorless.c” [4/4]**

| File name                         | Function name                                                                                                                                                                                                                    | Process overview              |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| rm_motor_120_control_sensorless.c | rm_motor_120_control_sensorless_lpff<br>Input : (float) f4_lpff_input / LPF input value<br>(float) f4_pre_lpff_output / Previous LPF output value<br>(float) f4_lpff_k / LPF gain<br>Output : (float) f4_temp / LPF output value | LPF process                   |
|                                   | rm_motor_120_control_sensorless_limitf<br>Input : (float) f4_value / Input value<br>(float) f4_max / Upper limit<br>(float) f4_min / Lower limit<br>Output : (float) f4_temp / Output value                                      | Upper and lower limit process |
|                                   | rm_motor_120_control_sensorless_limitf_h<br>Input : (float) f4_value / Input value<br>(float) f4_max / Upper limit<br>Output : (float) f4_temp / Output value                                                                    | Upper limit process           |
|                                   | rm_motor_120_control_sensorless_limitf_l<br>Input : (float) f4_value / Input value<br>(float) f4_min / Lower limit<br>Output : (float) f4_temp / Output value                                                                    | Lower limit process           |
|                                   | rm_motor_120_control_sensorless_limitf_abs<br>Input : (float) f4_value / Input value<br>(float) f4_limit_value / Limit value<br>Output : (float) f4_temp / Output value                                                          | Absolute value limit process  |

**Table 3-17 List of Functions “rm\_motor\_120\_driver.c” [1/2]**

| File name             | Function name                                                                                                                                                                                                                                                                               | Process overview                                        |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| rm_motor_120_driver.c | RM_MOTOR_120_DRIVER_Open<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_driver_cfg_t const * const) p_cfg / Configuration parameter<br>Output : (fsp_err_t) err / Result                                                                            | Driver start processing for 120 degree control          |
|                       | RM_MOTOR_120_DRIVER_Close<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                                     | 120 degree control driver termination process           |
|                       | RM_MOTOR_120_DRIVER_Run<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                                       | Motor rotation start process                            |
|                       | RM_MOTOR_120_DRIVER_Stop<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                                      | Motor rotation stop process                             |
|                       | RM_MOTOR_120_DRIVER_Reset<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                                     | Error state reset process                               |
|                       | RM_MOTOR_120_DRIVER_PhaseVoltageSet<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>(float const) u_voltage / U phase PWM duty<br>(float const) v_voltage / V phase PWM duty<br>(float const) w_voltage / W phase PWM duty<br>Output : (fsp_err_t) err / Result | PWM duty setting process                                |
|                       | RM_MOTOR_120_DRIVER_PhasePatternSet<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_driver_phase_pattern_t const) pattern / Voltage pattern<br>Output : (fsp_err_t) err / Result                                                                     | PWM output state switching process                      |
|                       | RM_MOTOR_120_DRIVER_CurrentGet<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_driver_current_status_t * const) p_current_status / Current status<br>Output : (fsp_err_t) err / Result                                                               | Current and voltage data acquisition process            |
|                       | RM_MOTOR_120_DRIVER_CurrentOffsetCalc<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>Output : (fsp_err_t) err / Result                                                                                                                                         | A/D value offset calculation process                    |
|                       | RM_MOTOR_120_DRIVER_FlagCurrentOffsetGet<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_driver_flag_offset_calc_t * const) p_flag_offset / offset computation state<br>Output : (fsp_err_t) err / Result                                            | A/D value offset calculation status acquisition process |

**Table 3-18 List of Functions “rm\_motor\_120\_driver.c” [2/2]**

| File name             | Function name                                                                                                                                                                                                                                      | Process overview                              |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| rm_motor_120_driver.c | RM_MOTOR_120_DRIVER_ParameterUpdate<br>Input : (motor_120_driver_ctrl_t * const) p_ctrl / Instance parameter<br>(motor_120_driver_cfg_t const * const) p_cfg / Configuration parameter<br>Output : (fsp_err_t) err / Result                        | Parameter update process                      |
|                       | rm_motor_120_driver_reset<br>Input : (motor_120_driver_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                             | Instance parameter reset process              |
|                       | rm_motor_120_driver_output_pwm<br>Input : (motor_120_driver_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                        | PWM output start process                      |
|                       | rm_motor_120_driver_ctrl_start<br>Input : (motor_120_driver_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                        | PWM output start processing for motor control |
|                       | rm_motor_120_driver_ctrl_stop<br>Input : (motor_120_driver_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                         | PWM output stop process                       |
|                       | rm_motor_120_driver_set_uvw_duty<br>Input : (motor_120_driver_instance_ctrl_t *) p_ctrl / Instance parameter<br>(float) f_duty_u / U phase PWM duty<br>(float) f_duty_v / V phase PWM duty<br>(float) f_duty_w / W phase PWM duty<br>Output : None | PWM duty setting process                      |
|                       | rm_motor_120_driver_current_get<br>Input : (motor_120_driver_instance_ctrl_t *) p_ctrl / Instance parameter<br>Output : None                                                                                                                       | A/D value acquisition process                 |
|                       | rm_motor_120_driver_mod_set_max_duty<br>Input : (motor_120_driver_modulation_t *) p_mod/ PWM setting<br>(float) f4_max_duty / Maximum duty<br>Output : None                                                                                        | Maximum duty setting process                  |
|                       | rm_motor_120_driver_mod_set_min_duty<br>Input : (motor_120_driver_modulation_t *) p_mod/ PWM setting<br>(float) f4_max_duty / Minimum duty<br>Output : None                                                                                        | Minimum duty setting process                  |
|                       | rm_motor_120_driver_pin_cfg<br>Input : (bsp_io_port_pin_t) pin / Pin number<br>(uint32_t) cfg / Set value<br>Output : None                                                                                                                         | Pin configuration setting process             |
|                       | rm_motor_120_driver_cyclic<br>Input : (adc_callback_args_t *) p_args / Callback function parameter<br>Output : None                                                                                                                                | A/D conversion complete callback function     |

### 3.3 Contents of control

#### 3.3.1 Configuration Options

The configuration options for the sensorless 120 degree control module for the motor can be configured using the RA Configurator. The changed options are automatically reflected in `hal_data.c` when the code is generated. Option names and settings are listed in **Table 3-19** Configuration Options below.

**Table 3-19 Configuration Options**

| Configuration Options (rm_motor_120_degree.h) |                                                                                     |
|-----------------------------------------------|-------------------------------------------------------------------------------------|
| Option name                                   | Contents                                                                            |
| Limit of over current (A)                     | When a phase current exceeds this value, PWM output ports are set to off.           |
| Limit of over voltage (V)                     | When an inverter voltage exceeds this value, PWM output ports are set to off.       |
| Limit of over speed (rpm)                     | When a rotation speed exceeds this value, PWM output ports are set to off.          |
| Limit of low voltage (V)                      | When an inverter voltage becomes below this value, PWM output ports are set to off. |

**Table 3-20 Configuration Options Initial Value(rm\_motor\_120\_degree.h)**

| Options                   | RA6T2  | RA4T1  | RA6T3  |
|---------------------------|--------|--------|--------|
| Limit of over current (A) | 1.67   | 1.67   | 1.67   |
| Limit of over voltage (V) | 60.0   | 60.0   | 60.0   |
| Limit of over speed (rpm) | 4500.0 | 4500.0 | 4500.0 |
| Limit of low voltage (V)  | 8.0    | 8.0    | 8.0    |

#### 3.3.2 Configuration Options for included modules

The sensorless 120-degree conducting control module for motors includes the following modules.

- 120 control sensorless module
- 120 driver module

In addition, these modules have the same configuration parameters as the sensorless 120-degree conducting control module. The option names and setting values are shown in the table below.

**Table 3-21 Configuration Options**

| <b>Configuration Options (rm_motor_120_control_api.h)</b> |                                                |
|-----------------------------------------------------------|------------------------------------------------|
| <b>Option name</b>                                        | <b>Contents</b>                                |
| Conduction type                                           | Switching of first 60 degree chopping control  |
| Timeout counts (msec)                                     | Stop judgement counter [ms]                    |
| Maximum voltage (V)                                       | Maximum command voltage [V]                    |
| Minimum voltage (V)                                       | Minimum command voltage [V]                    |
| Speed PI decimation                                       | Interrupt thinning number for speed PI control |
| Free run timer frequency (MHz)                            | Free run timer frequency [MHz]                 |
| Speed LPF K                                               | Speed LPF parameter                            |
| Step of speed change                                      | Speed command maximum increase limit           |
| PI control KP                                             | Speed PI proportional gain                     |
| PI control KI                                             | Speed PI Integral gain                         |
| PI control limit                                          | Voltage PI control output limit value [V]      |
| Motor Parameter   Pole pairs                              | Number of pole pairs                           |

**Table 3-22 Configuration Options Initial Value(rm\_motor\_120\_control\_api.h)**

| <b>Options</b>                 | <b>RA6T2</b>        | <b>RA4T1</b>        | <b>RA6T3</b>        |
|--------------------------------|---------------------|---------------------|---------------------|
| Conduction type                | First 60 degree PWM | First 60 degree PWM | First 60 degree PWM |
| Timeout counts (msec)          | 2000                | 2000                | 2000                |
| Maximum voltage (V)            | 20.0                | 20.0                | 20.0                |
| Minimum voltage (V)            | 3.0                 | 3.0                 | 3.0                 |
| Speed PI decimation            | 1                   | 1                   | 1                   |
| Free run timer frequency (MHz) | 120                 | 50                  | 50                  |
| Speed LPF K                    | 1.0                 | 1.0                 | 1.0                 |
| Step of speed reference change | 0.2                 | 0.2                 | 0.2                 |
| PI control KP                  | 0.02                | 0.02                | 0.02                |
| PI control KI                  | 0.004               | 0.004               | 0.004               |
| PI control limit               | 24.0                | 24.0                | 24.0                |
| Motor Parameter   Pole pairs   | 4                   | 4                   | 4                   |

**Table 3-23 Configuration Options**

| Configuration Options (rm_motor_120_control_sensorless.h) |                                                              |
|-----------------------------------------------------------|--------------------------------------------------------------|
| Option name                                               | Contents                                                     |
| Stop BEMF                                                 | Value of stop motor BEMF                                     |
| Maximum voltage for BOOT (V)                              | Maximum command voltage for BOOT MODE [V]                    |
| Carrier frequency (kHz)                                   | Carrier frequency [khz]                                      |
| Adjusting angle                                           | Pattern switching timing adjustment value                    |
| Boot reference voltage (V)                                | Voltage command value [V]                                    |
| Voltage lamping time                                      | Voltage command value addition time                          |
| Voltage constant adjust time                              | Voltage command value constant time                          |
| Open loop start speed (rpm)                               | Open loop starting rpm [rpm]                                 |
| Open loop mode2 speed (rpm)                               | Open loop mode1 change speed [rpm]                           |
| Open loop mode3 speed (rpm)                               | Open loop mode2 change speed [rpm]                           |
| Open loop start voltage (V)                               | Open loop start reference voltage [V]                        |
| Open loop mode1 speed rate                                | Open loop mode1 rate of reference speed [rpm/control period] |
| Open loop mode2 voltage rate                              | Open loop mode2 rate of reference voltage [V/control period] |
| Open loop mode2 speed rate                                | Open loop mode2 rate of reference speed [rpm/control period] |
| Open loop mode3 voltage rate                              | Open loop mode3 rate of reference voltage [V/control period] |
| Open loop maximum voltage (V)                             | Open loop mode3 Maximum voltage [V]                          |

**Table 3-24 Configuration Options Initial Value(rm\_motor\_120\_control\_sensorless.h)**

| Options                       | RA6T2   | RA4T1   | RA6T3   |
|-------------------------------|---------|---------|---------|
| Stop BEMF                     | 0.5     | 0.5     | 0.5     |
| Maximum voltage for BOOT (V)  | 8.0     | 8.0     | 8.0     |
| Carrier frequency (kHz)       | 20.0    | 20.0    | 20.0    |
| Adjusting angle               | 0       | 0       | 0       |
| Boot reference voltage (V)    | 3.0     | 3.0     | 3.0     |
| Voltage lamping time          | 128     | 128     | 128     |
| Voltage constant adjust time  | 64      | 64      | 64      |
| Open loop start speed (rpm)   | 150     | 150     | 150     |
| Open loop mode2 speed (rpm)   | 185     | 185     | 185     |
| Open loop mode3 speed (rpm)   | 1000    | 1000    | 1000    |
| Open loop start voltage (V)   | 3.0     | 3.0     | 3.0     |
| Open loop mode1 speed rate    | 0.25    | 0.25    | 0.25    |
| Open loop mode2 voltage rate  | 0.00285 | 0.00285 | 0.00285 |
| Open loop mode2 speed rate    | 0.71    | 0.71    | 0.71    |
| Open loop mode3 voltage rate  | 0.002   | 0.002   | 0.002   |
| Open loop maximum voltage (V) | 6.5     | 6.5     | 6.5     |

**Table 3-25 Configuration Options [1/2]**

| <b>Configuration Options (rm_motor_120_driver.h)</b> |                                             |
|------------------------------------------------------|---------------------------------------------|
| <b>Option name</b>                                   | <b>Contents</b>                             |
| 120 degree control type                              | 120 degree energization control sensor type |
| PWM output port UP                                   | PWM output (Up) port                        |
| PWM output port UN                                   | PWM output (Un) port                        |
| PWM output port VP                                   | PWM output (Vp) port                        |
| PWM output port VN                                   | PWM output (Vn) port                        |
| PWM output port WP                                   | PWM output (Wp) port                        |
| PWM output port WN                                   | PWM output (Wn) port                        |
| PWM timer frequency (MHz)                            | PWM timer frequency [MHz]                   |
| PWM carrier period (Microseconds)                    | PWM carrier frequency [Micro seconds]       |
| Dead time (Raw counts)                               | Dead time count [Raw counts]                |
| Current range (A)                                    | Current detection range [A]                 |
| Voltage range (V)                                    | Voltage detection range [V]                 |
| Resolution of A/D conversion                         | A/D conversion value                        |
| Offset of A/D conversion for current                 | A/D conversion offset                       |
| Conversion level of A/D conversion for voltage       | Voltage A/D conversion rate                 |
| Counts for current offset measurement                | Offset value calculation count              |
| Input voltage                                        | Bus voltage                                 |
| A/D conversion channel for U phase current           | U phase current detection channel           |
| A/D conversion channel for W phase current           | W phase current detection channel           |
| A/D conversion channel for main line voltage         | Inverter bus voltage detection channel      |
| A/D conversion channel for U phase voltage           | U phase voltage detection channel           |
| A/D conversion channel for V phase voltage           | V phase voltage detection channel           |
| A/D conversion channel for W phase voltage           | W phase voltage detection channel           |
| GTIOCA stop level                                    | Level when the upper arm is stopped         |
| GTIOCB stop level                                    | Level when lower arm is stopped             |
| Modulation   Maximum duty                            | PWM maximum duty                            |

**Table 3-26 Configuration Options Initial Value(rm\_motor\_120\_driver.h)**

| Options                                        | RA6T2                 | RA4T1                 | RA6T3                 |
|------------------------------------------------|-----------------------|-----------------------|-----------------------|
| 120 degree control type                        | Sensorless            | Sensorless            | Sensorless            |
| PWM output port UP                             | BSP_IO_PORT_11_PIN_04 | BSP_IO_PORT_04_PIN_09 | BSP_IO_PORT_04_PIN_09 |
| PWM output port UN                             | BSP_IO_PORT_11_PIN_05 | BSP_IO_PORT_04_PIN_08 | BSP_IO_PORT_04_PIN_08 |
| PWM output port VP                             | BSP_IO_PORT_11_PIN_06 | BSP_IO_PORT_01_PIN_03 | BSP_IO_PORT_01_PIN_03 |
| PWM output port VN                             | BSP_IO_PORT_11_PIN_07 | BSP_IO_PORT_01_PIN_02 | BSP_IO_PORT_01_PIN_02 |
| PWM output port WP                             | BSP_IO_PORT_11_PIN_08 | BSP_IO_PORT_01_PIN_11 | BSP_IO_PORT_01_PIN_11 |
| PWM output port WN                             | BSP_IO_PORT_11_PIN_09 | BSP_IO_PORT_01_PIN_12 | BSP_IO_PORT_01_PIN_12 |
| PWM timer frequency (MHz)                      | 120                   | 100                   | 100                   |
| PWM carrier period (Microseconds)              | 50                    | 50                    | 50                    |
| Dead time (Raw counts)                         | 240                   | 200                   | 200                   |
| Current range (A)                              | 16.5                  | 16.5                  | 16.5                  |
| Voltage range (V)                              | 73.26                 | 73.26                 | 73.26                 |
| Resolution of A/D conversion                   | 0xFFFF                | 0xFFFF                | 0xFFFF                |
| Offset of A/D conversion for current           | 0x7FF                 | 0x7FF                 | 0x7FF                 |
| Conversion level of A/D conversion for voltage | 1.0                   | 1.0                   | 1.0                   |
| Counts for current offset measurement          | 500                   | 500                   | 500                   |
| Input voltage                                  | 24.0                  | 24.0                  | 24.0                  |
| A/D conversion channel for U phase current     | ADC_CHANNEL_4         | ADC_CHANNEL_0         | ADC_CHANNEL_0         |
| A/D conversion channel for W phase current     | ADC_CHANNEL_0         | ADC_CHANNEL_2         | ADC_CHANNEL_2         |
| A/D conversion channel for main line voltage   | ADC_CHANNEL_6         | ADC_CHANNEL_4         | ADC_CHANNEL_4         |
| A/D conversion channel for U phase voltage     | ADC_CHANNEL_7         | ADC_CHANNEL_16        | ADC_CHANNEL_16        |
| A/D conversion channel for V phase voltage     | ADC_CHANNEL_3         | ADC_CHANNEL_12        | ADC_CHANNEL_12        |
| A/D conversion channel for W phase voltage     | ADC_CHANNEL_1         | ADC_CHANNEL_11        | ADC_CHANNEL_11        |
| GTIOCA stop level                              | Pin Level Low         | Pin Level Low         | Pin Level Low         |
| GTIOCB stop level                              | Pin Level High        | Pin Level High        | Pin Level High        |
| Modulation   Maximum duty                      | 0.9375                | 0.9375                | 0.9375                |

### 3.4 Control flows (flow charts)

#### 3.4.1 Main process

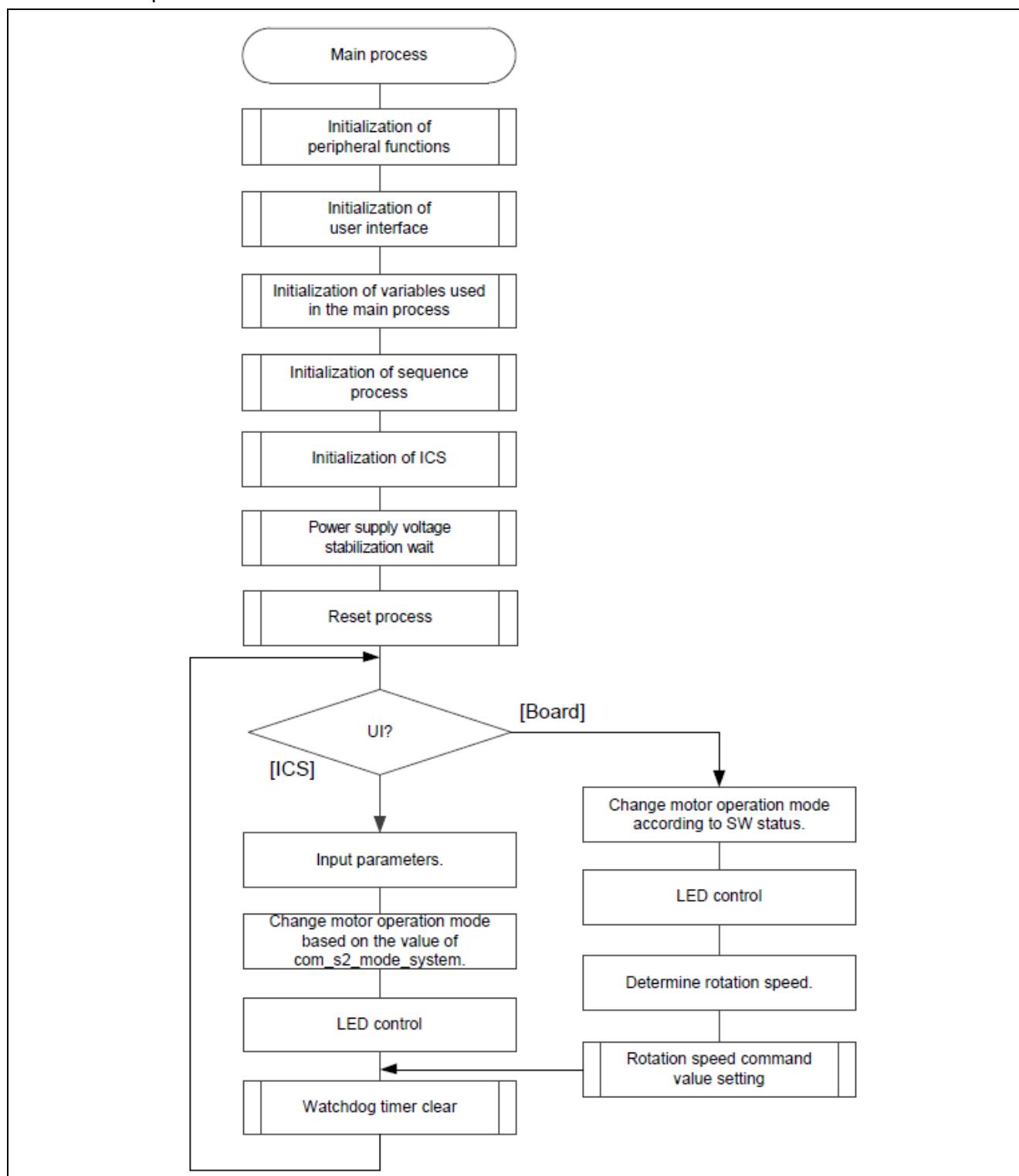


Figure 3-7 Main Process Flowchart

### 3.4.2 Current Control Periodic interrupt (carrier periodic interrupt) handling

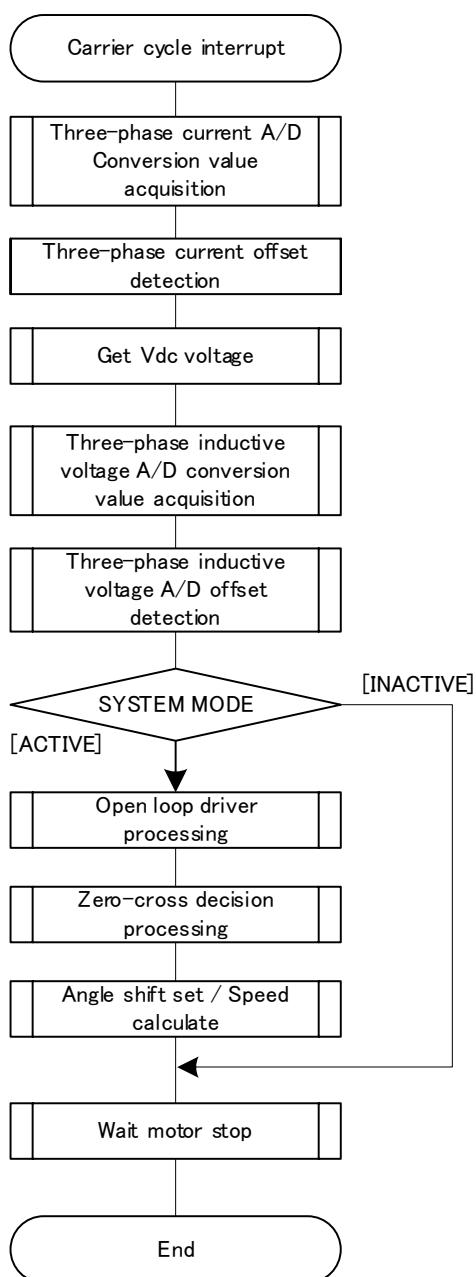


Figure 3-8 Current Control Periodic Interrupt Handling

3.4.3 Speed Control periodic interrupt handling

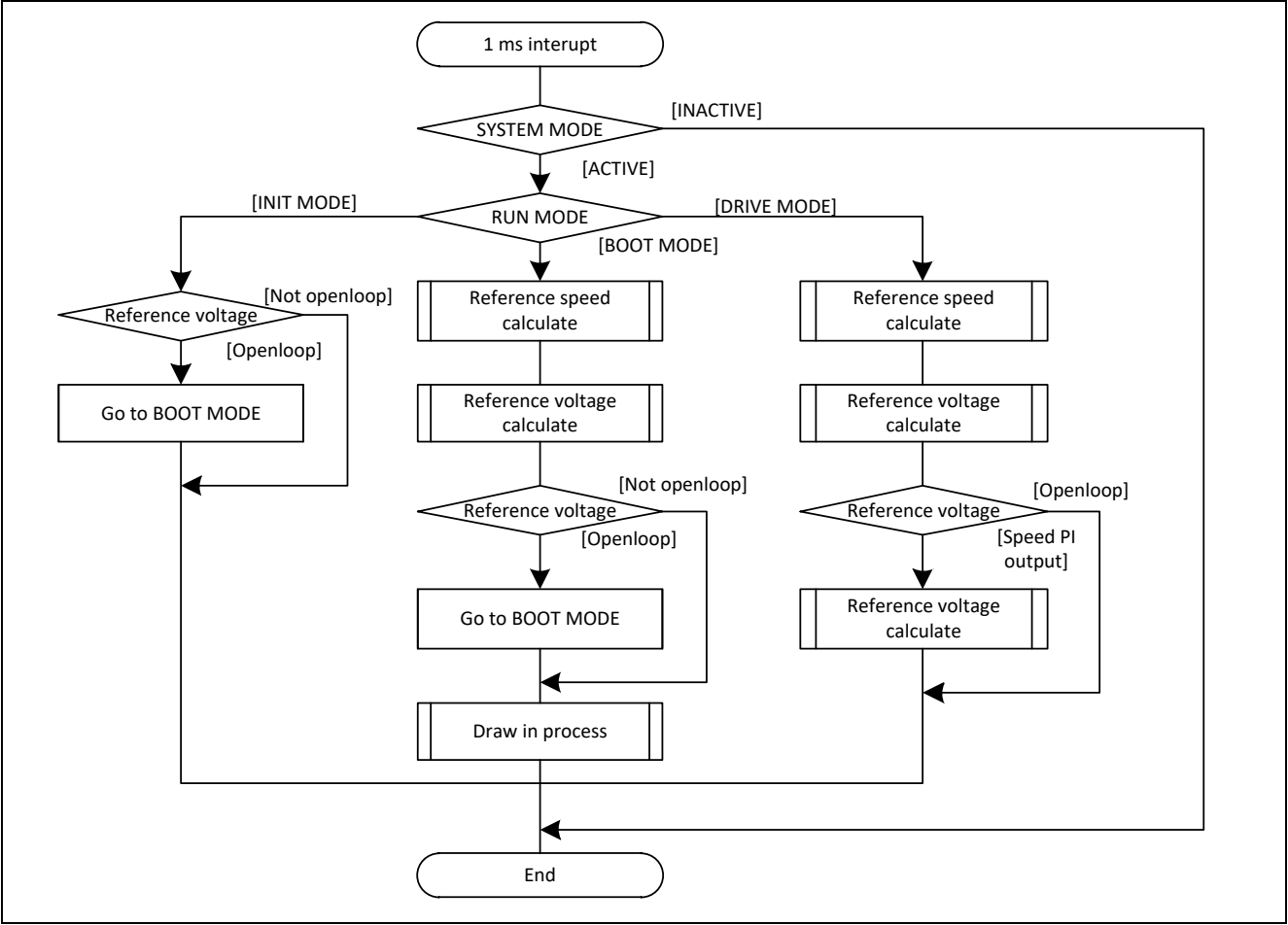


Figure 3-9 Speed Control Periodic Interrupt Handling

### 3.4.4 Overcurrent interrupt handling

The overcurrent detection interrupt is an interrupt that occurs when an external overcurrent detection signal is input. The PWM output terminal are put in the high impedance state. Therefore, at the start of execution of this interrupt processing, the PWM output terminal is already in the high impedance state and the output to the motor had been stopped.

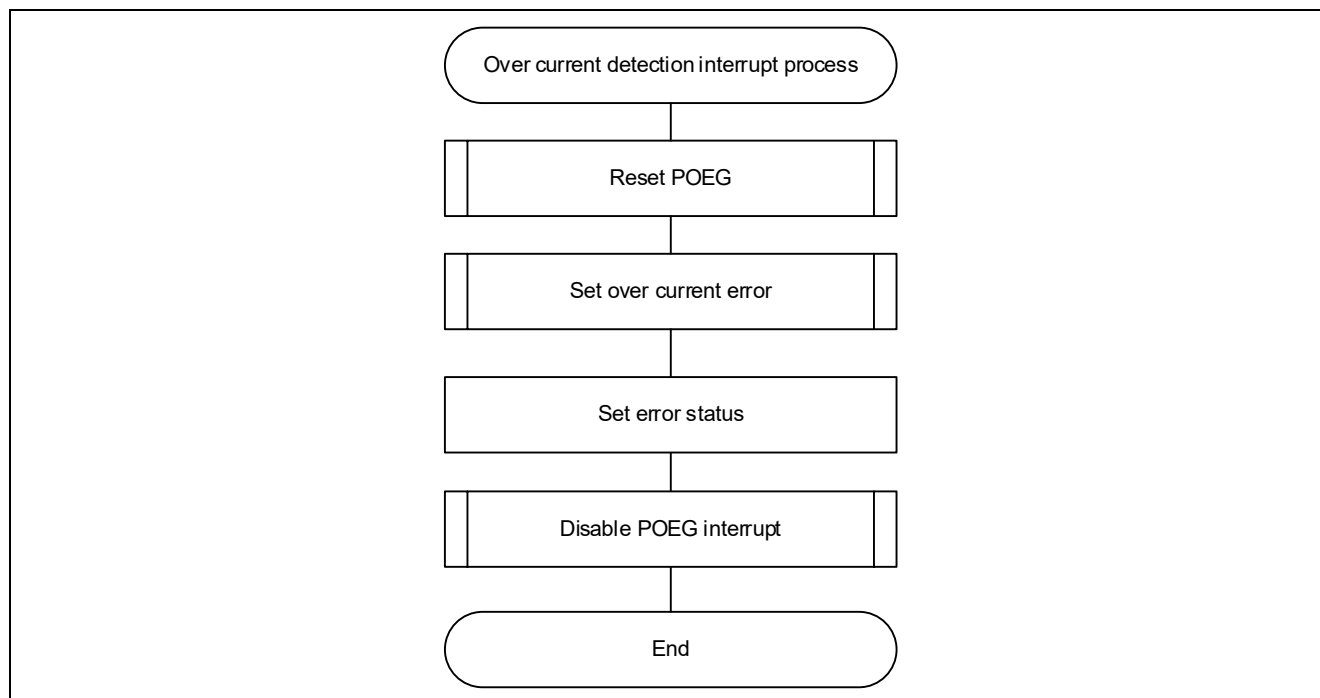


Figure 3-10 Overcurrent Detection Interrupt Handling

## 4. Evaluation environment explanation

This application note describes the target software.

### 4.1 Project import

The sample software can be imported into e2 studio by following the steps below.

#### 1. File → Import

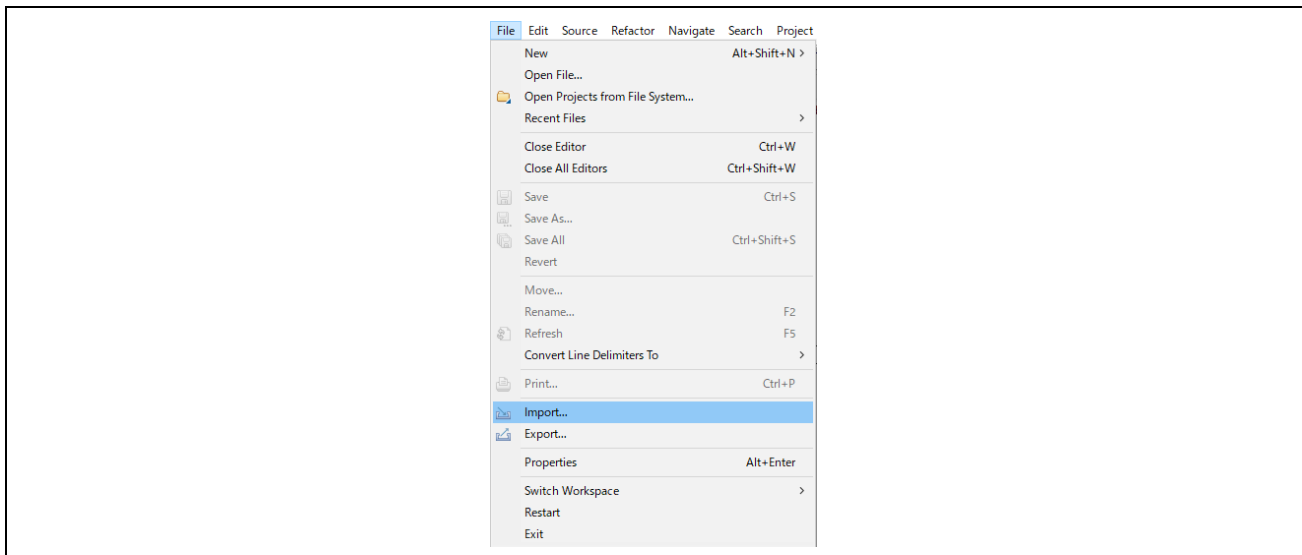


Figure 4-1 File Menu

#### 2. Select "Existing Projects into Workspace" and click the [Next] button.

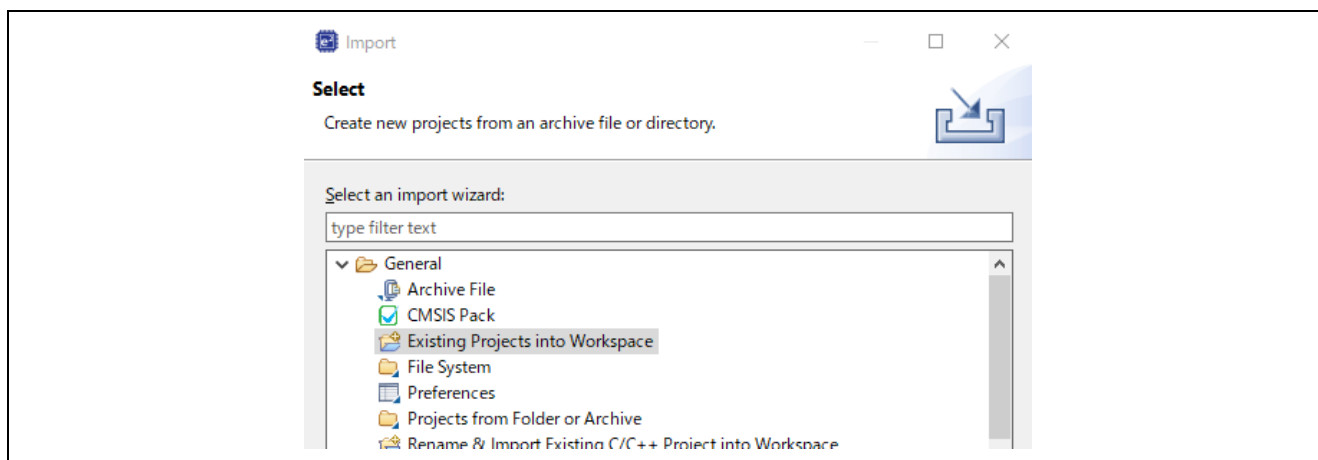


Figure 4-2 Import Menu

3. Select a project file. Click the Finish button to import the project.

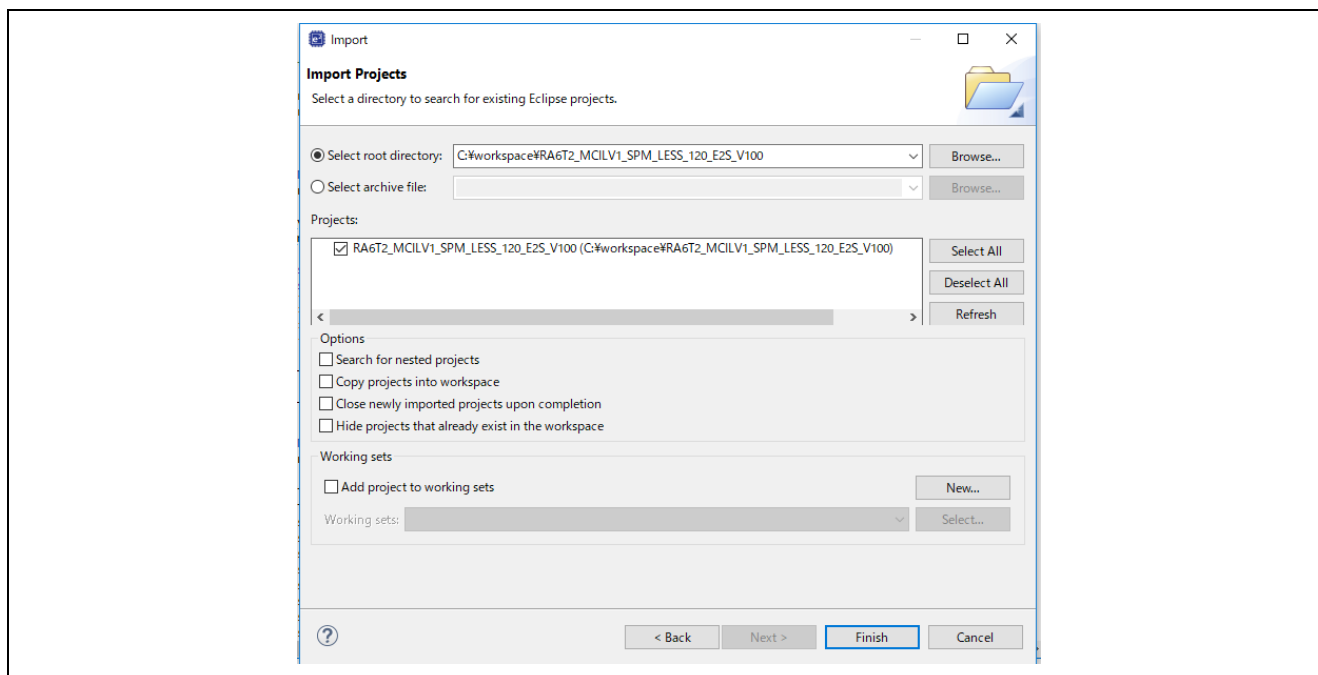


Figure 4-3 Project Import

## 4.2 Build and debug

Please refer to “e2 studio User’s Manual Starting Guide (R20UT4204)”.

### 4.3 Quick start

To operate the sample code without using the motor control development support tool "Renesas Motor Workbench", execute the quick start sample project according to the following procedure.

- (1) After the regulated power is turned on or reset, all LEDs 1 and 2 on the inverter board are off and the motor is stopped.
- (2) Turn on the toggle switch (SW1) on the inverter board to rotate the motor. Every time the toggle switch (SW1) is switched, the motor starts / stops rotating repeatedly. When the motor is rotating normally, LED1 on the inverter board lights up. At this time, if LED2 on the inverter board is lit, an error has occurred.
- (3) When changing the rotation direction of the motor, adjust it with the volume resistor (VR1) on the inverter board.
  - Turn volume resistor (VR1) clockwise : Motor rotates clockwise
  - Turn the volume resistor (VR1) counterclockwise : The motor rotates counterclockwise
- (4) If an error occurs, LED2 on the inverter board lights up and rotation stops. To recover, turn off the toggle switch (SW1) on the inverter board and then press the push switch (SW2).
- (5) When you finish the operation check, check that the rotation of the motor is stopped, and turn off the output of the regulated power supply.

## 4.4 Motor Control Development Support Tool, 'Renesas Motor Workbench'

### 4.4.1 Overview

In the target sample programs described in this application note, user interfaces (rotating/stop command, rotation speed command, etc.) based on the motor control development support tool, 'Renesas Motor Workbench' can be used. Please refer to 'Renesas Motor Workbench User's Manual' for usage and more details. You can find 'Renesas Motor Workbench' on Renesas Electronics Corporation website.

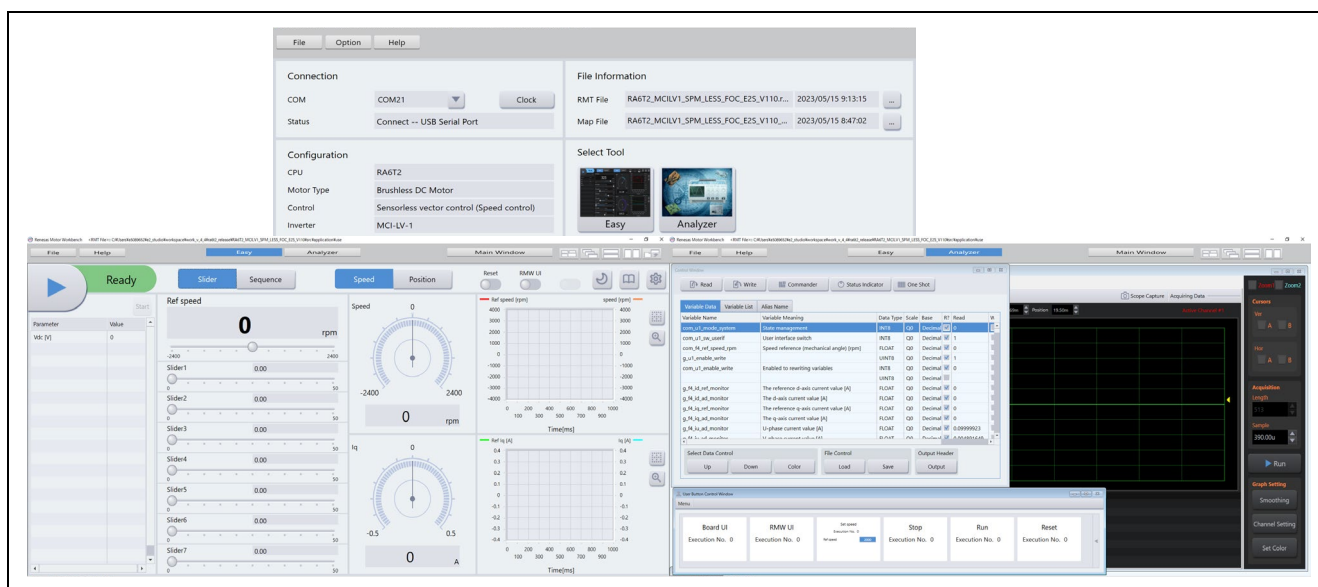
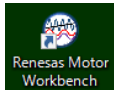


Figure 4-4 Renesas Motor Workbench - Appearance

### Set up for Renesas Motor Workbench

- ① Start 'Motor RSSK Support Tool' by clicking this icon. 
- ② Drop down menu [File] → [Open RMT File(O)].  
And select RMT file in "src/application/user\_interface/ics".
- ③ Use the 'Connection' COM select menu to choose the COM port for Motor RSSK.
- ④ Click on the 'Analyzer' icon of Select Tool panel to open Analyzer function window.
- ⑤ Please refer to '4.5.2 Easy function operation example' or '4.5.4 Operation Example for Analyzer' for motor driving operation.

#### 4.4.2 Easy function operation example

The following is an example of operating the motor using the Easy function.

- Change the user interface to use Renesas Motor Workbench
  - (1) Turn on "RMW UI".

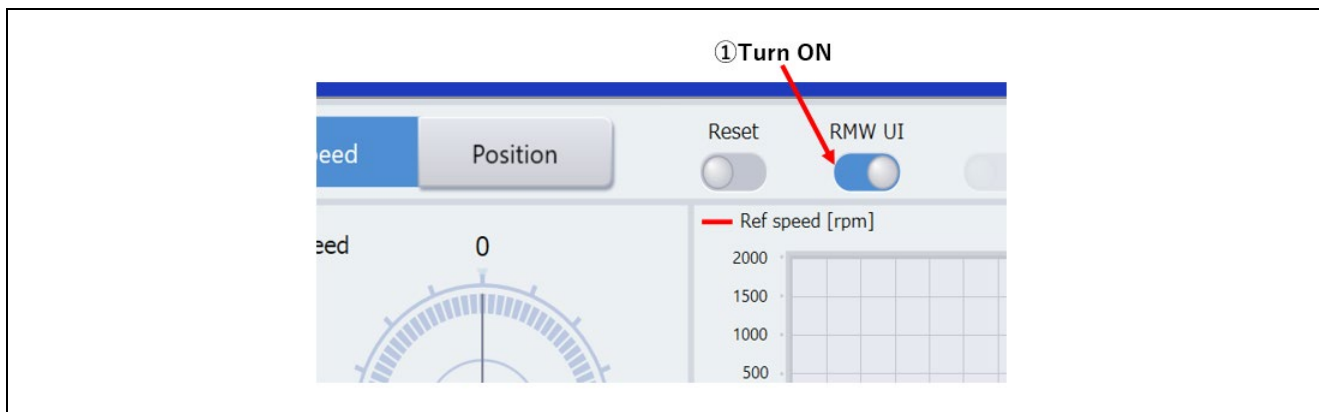


Figure 4-1 Procedure for changing to use Renesas Motor Workbench

- Change the user interface to use Renesas Motor Workbench
  - (1) Press the "Run" button

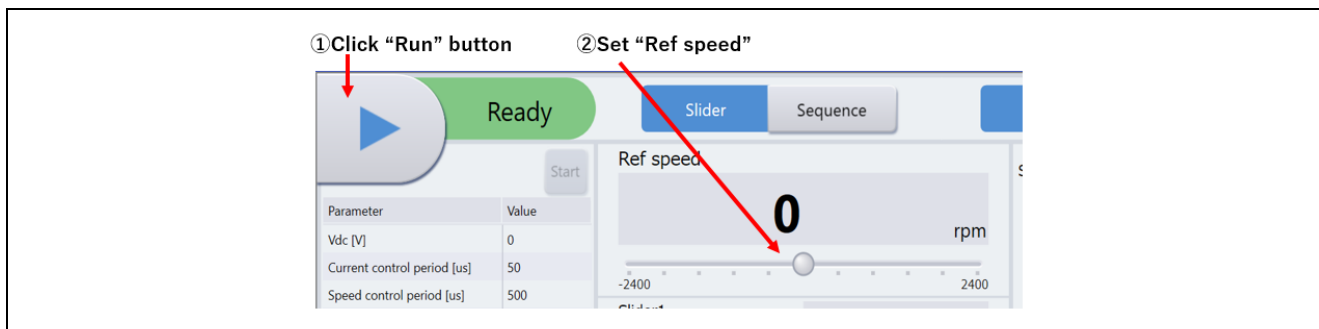


Figure 4-2 Motor rotation procedure

- Stop the motor
  - (1) Press the "Stop" button

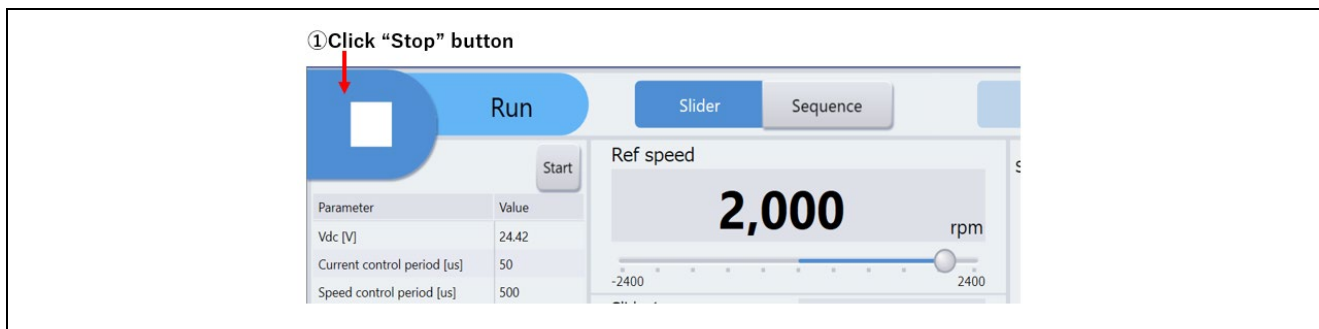


Figure 4-3 Motor rotation procedure

- Processing when it stops (error)
  - (1) Turn on "Reset" button.
  - (2) Turn off "Reset" button

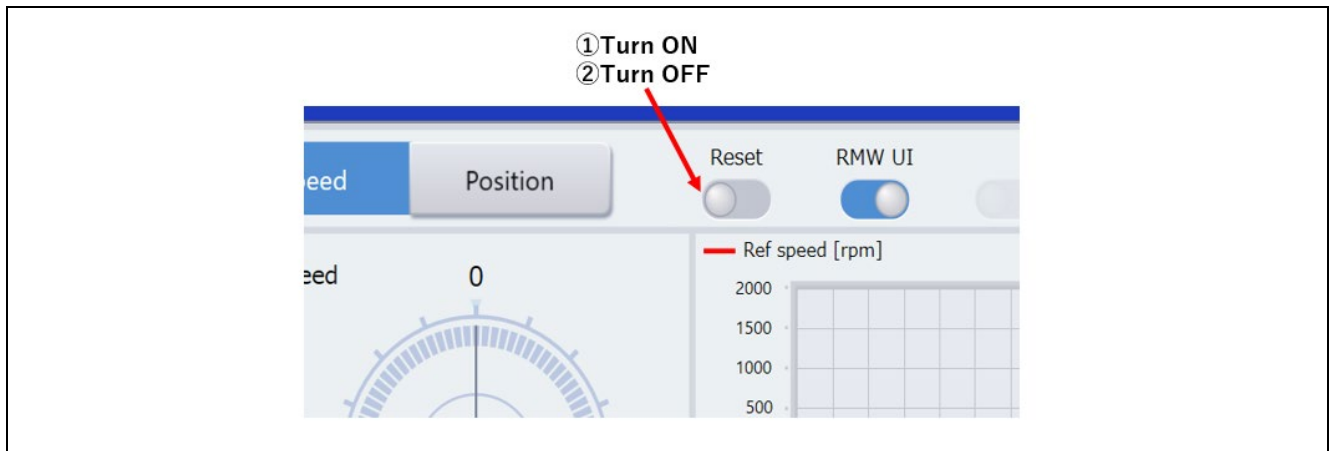


Figure 4-4 Error clearing procedure

#### 4.4.3 List of variables for Analyzer function

Table 4-1 shows a list of input variables when using the Analyzer user interface. The input values to these variables will be reflected in the corresponding variables when the same values as `g_u1_enable_write` are written to `com_u1_enable_write`. However, variables marked with (\*) do not depend on `com_u1_enable_write`.

Table 4-1 List of variables for analyzer function input [1/2]

| Variable name                           | Type                  | Contents                                                                                                             |
|-----------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------|
| <code>com_u1_mode_system(*)</code>      | <code>uint8_t</code>  | State management<br>0 : Stop mode, 1 : Run mode, 3 : Reset                                                           |
| <code>com_f4_ref_speed_rpm</code>       | <code>float</code>    | Speed command value (mechanical angle) [rpm]                                                                         |
| <code>com_f4_overcurrent_limit</code>   | <code>float</code>    | High current limit value [A]                                                                                         |
| <code>com_f4_overspeed_limit</code>     | <code>float</code>    | High voltage limit value [V]                                                                                         |
| <code>com_f4_overspeed_limit_rpm</code> | <code>float</code>    | Speed limit value (mechanical angle) [rpm]                                                                           |
| <code>com_f4_lowvoltage_limit</code>    | <code>float</code>    | Low voltage limit value [V]                                                                                          |
| <code>com_u4_timeout_cnt</code>         | <code>uint32_t</code> | Timeout count limit                                                                                                  |
| <code>com_f4_max_drive_v</code>         | <code>float</code>    | Maximum command voltage [V]                                                                                          |
| <code>com_f4_min_drive_v</code>         | <code>float</code>    | Minimum command voltage [V]                                                                                          |
| <code>com_s4_angle_shift_adjust</code>  | <code>int32_t</code>  | Pattern switching timing adjustment value                                                                            |
| <code>com_f4_speed_lpf_k</code>         | <code>float</code>    | Speed LPF parameter                                                                                                  |
| <code>com_f4_limit_speed_change</code>  | <code>float</code>    | Command speed changing limit                                                                                         |
| <code>com_f4_boot_ref_v</code>          | <code>float</code>    | Voltage command value                                                                                                |
| <code>com_u4_v_up_time</code>           | <code>uint32_t</code> | Voltage command value addition time                                                                                  |
| <code>com_u4_v_const_time</code>        | <code>uint32_t</code> | Voltage command value constant time                                                                                  |
| <code>com_s4_ol_start_rpm</code>        | <code>int32_t</code>  | Speed at startup                                                                                                     |
| <code>com_s4_ol_mode1_change_rpm</code> | <code>int32_t</code>  | Mode1 changing speed                                                                                                 |
| <code>com_s4_ol_mode2_change_rpm</code> | <code>int32_t</code>  | Mode2 changing speed                                                                                                 |
| <code>com_f4_ol_start_refv</code>       | <code>float</code>    | Command voltage at startup                                                                                           |
| <code>com_f4_ol_mode1_rate_rpm</code>   | <code>float</code>    | Command speed adding value                                                                                           |
| <code>com_f4_ol_mode2_rate_refv</code>  | <code>float</code>    | Command voltage adding value                                                                                         |
| <code>com_f4_ol_mode2_rate_rpm</code>   | <code>float</code>    | Command speed adding value                                                                                           |
| <code>com_f4_ol_mode3_rate_refv</code>  | <code>float</code>    | Command voltage adding value                                                                                         |
| <code>com_f4_ol_mode3_max_refv</code>   | <code>float</code>    | Maximum command voltage in open loop mode                                                                            |
| <code>com_f4_pi_ctrl_kp</code>          | <code>float</code>    | Speed PI proportional gain                                                                                           |
| <code>com_f4_pi_ctrl_ki</code>          | <code>float</code>    | Speed PI Integral gain                                                                                               |
| <code>com_f4_pi_ctrl_ilimit</code>      | <code>float</code>    | Voltage PI control output limit value [V]                                                                            |
| <code>com_u4_mtr_pp</code>              | <code>uint32_t</code> | Motor Pole pairs                                                                                                     |
| <code>com_u1_enable_write</code>        | <code>uint8_t</code>  | Enable to rewriting variables<br>(Write permission when the same value as <code>g_u1_enable_write</code> is written) |

#### 4.4.4 Operation Example for Analyzer

Following example shows motor driving operation using Analyzer. Operation is using “Control Window” as shown in Figure 4-4. Regarding specification of “Control Window”, refer to ‘Renesas Motor Workbench User’s Manual’.

- Change the user interface to use Analyzer
  - ① Make sure that “check” is entered in the [W?] box of “com\_u1\_sw\_userif”.
  - ② Enter 0 in the [Write] box.
  - ③ Click the “Write” button.
- Driving the motor
  - ① The [W?] check boxes contain checkmarks for “com\_u1\_mode\_system”, “com\_f4\_ref\_speed\_rpm”, “com\_u1\_enable\_write”.
  - ② Type a reference speed value in the [Write] box of “com\_f4\_ref\_speed\_rpm”.
  - ③ Click the “Write” button.
  - ④ Click the “Read” button. Confirm the [Read] box of “com\_f4\_ref\_speed\_rpm”, “g\_u1\_enable\_write”.
  - ⑤ Enter the value of “g\_u1\_enable\_write” in the [Write] box of “com\_u1\_enable\_write”.
  - ⑥ Enter “1” in the [Write] box of “com\_u1\_mode\_system”.
  - ⑦ Click the “Write” button.

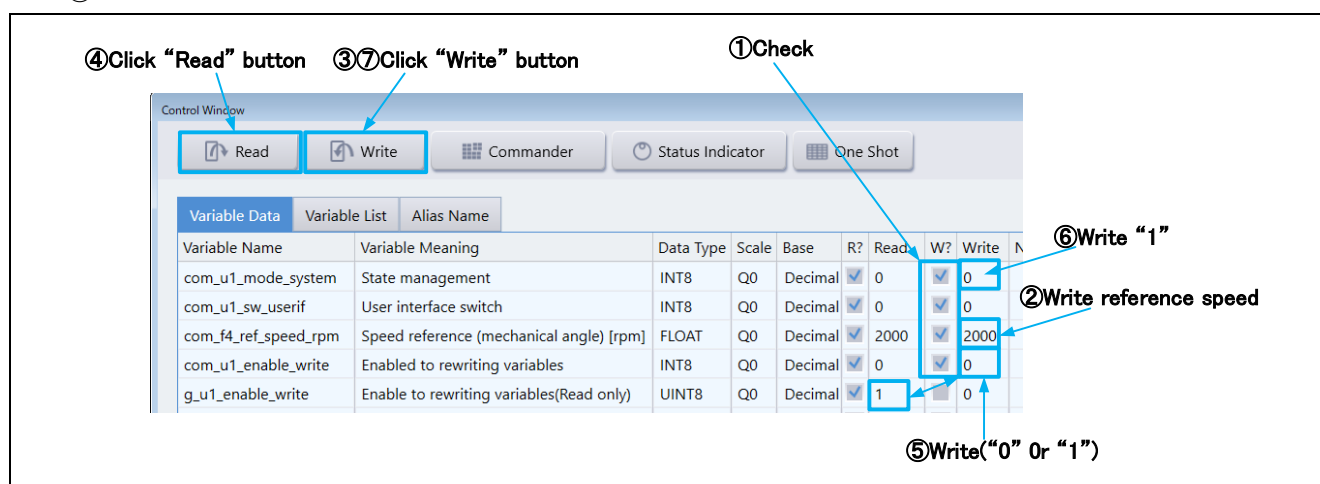


Figure 4-5 Procedure – Driving the motor

- Stop the motor
  - ① Enter “0” in the [Write] box of “com\_u1\_mode\_system”.
  - ② Click the “Write” button.

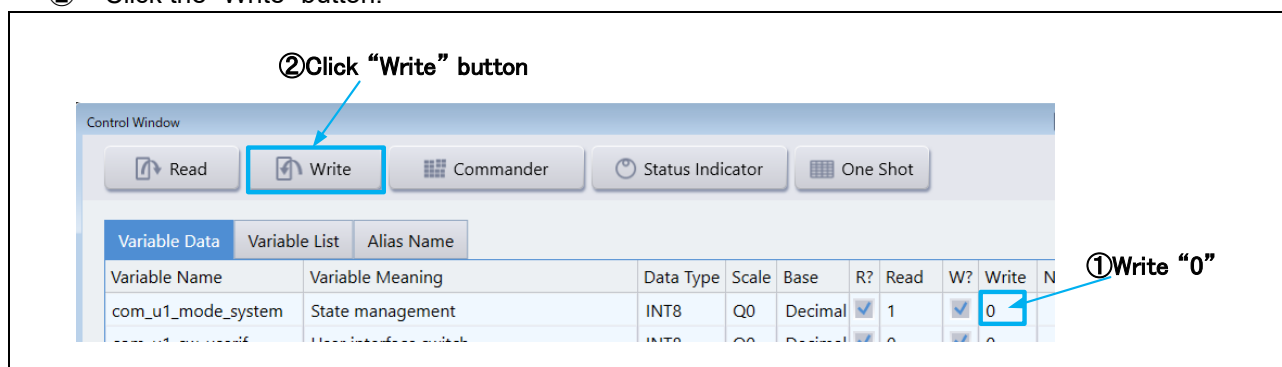


Figure 4-6 Procedure – Stop the motor

- Error cancel operation
  - ① Enter “3” in the [Write] box of “com\_u1\_mode\_system”.
  - ② Click the “Write” button.

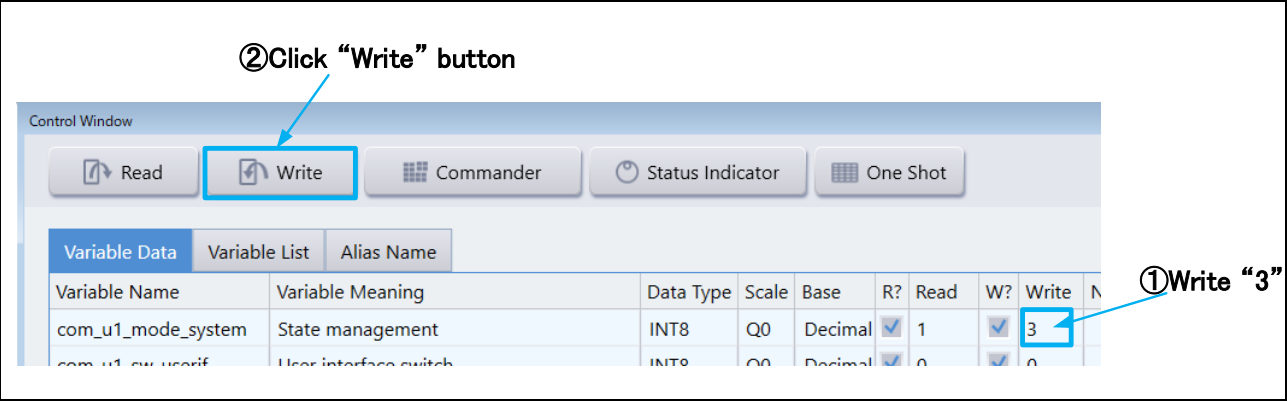
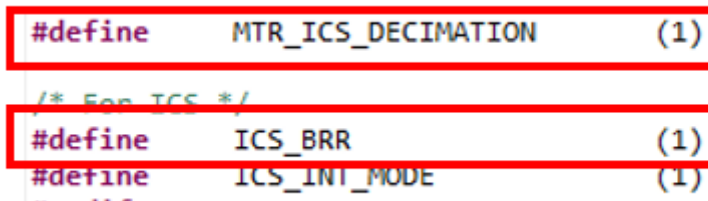


Figure 4-7 Procedure – Error cancel operation

#### 4.4.5 Example of changing communication speed

The procedure for changing the communication speed of Renesas Motor Workbench with the sample software is shown below. See the Renesas Motor Workbench User's Manual for the values to change.

- Change the communication speed setting of the sample software (when the required communication rate is 10 Mbps)
  - (1) Change the value of ICS\_BRR in r\_mtr\_ics.h to 1.
  - (2) Change the value of MTR\_ICS\_DECIMATION in r\_mtr\_ics.h to 1.



```
#define MTR_ICS_DECIMATION (1)

/* For ICS */
#define ICS_BRR (1)
#define ICS_INT_MODE (1)
```

Figure 4-5 Modification of r\_mtr\_ics.h

- Change the communication speed setting of Renesas Motor Workbench to connect
  - (1) Press the Clock button on the Main Window to change the value to 80,000,000  
This value was calculated by multiplying the default 8,000,000 by 10  
because the UART communication baud rate was changed from 1Mbps to 10Mbps.
  - (2) Select the COM of the connected kit in the COM of Connection

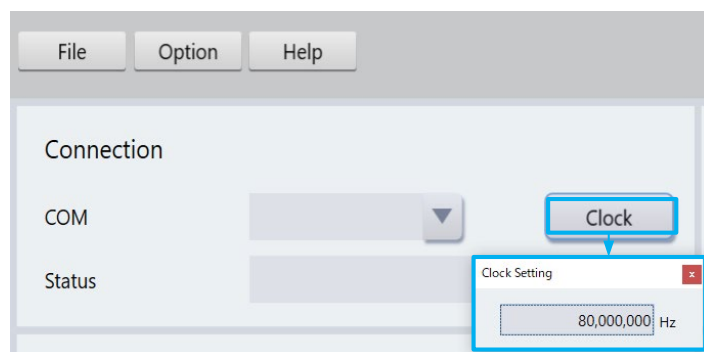


Figure 4-6 Clock frequency setting

If the connection fails, repeat the procedure for reconnecting after resetting the communication board.

#### 4.4.6 How to use the built-in communication library

The procedure for connecting to Renesas Motor Workbench using the built-in communication library without using the communication board with the sample software is shown below.

- Connection between PC and CPU board
  - (1) Connect the CPU board and PC via a USB / serial conversion board, etc.
- Preparing a project for built-in communication (example of RA6T2 921600bps)
  - (1) Cancel the registration of ICS2\_RA6T2.o

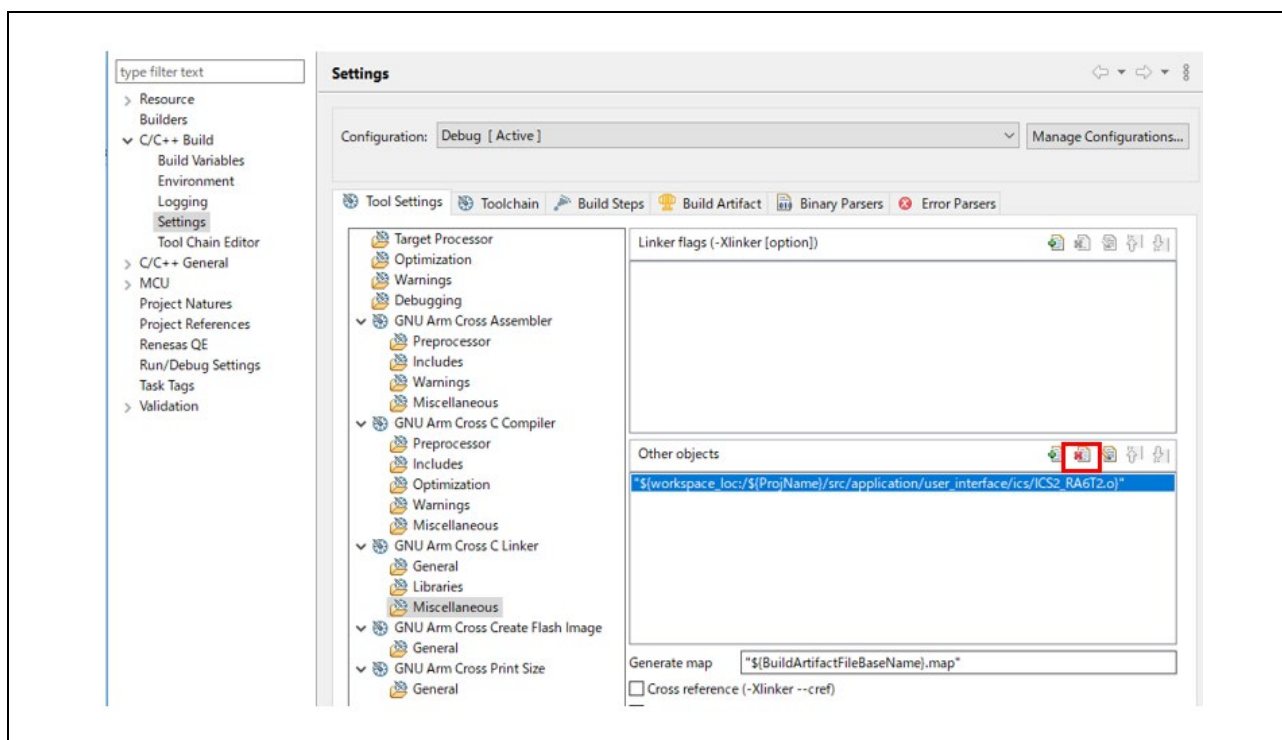


Figure 4-7 Unregister ICS2\_RA6T2.o

## (2) Register ICS2\_RA6T2\_Built\_in.o

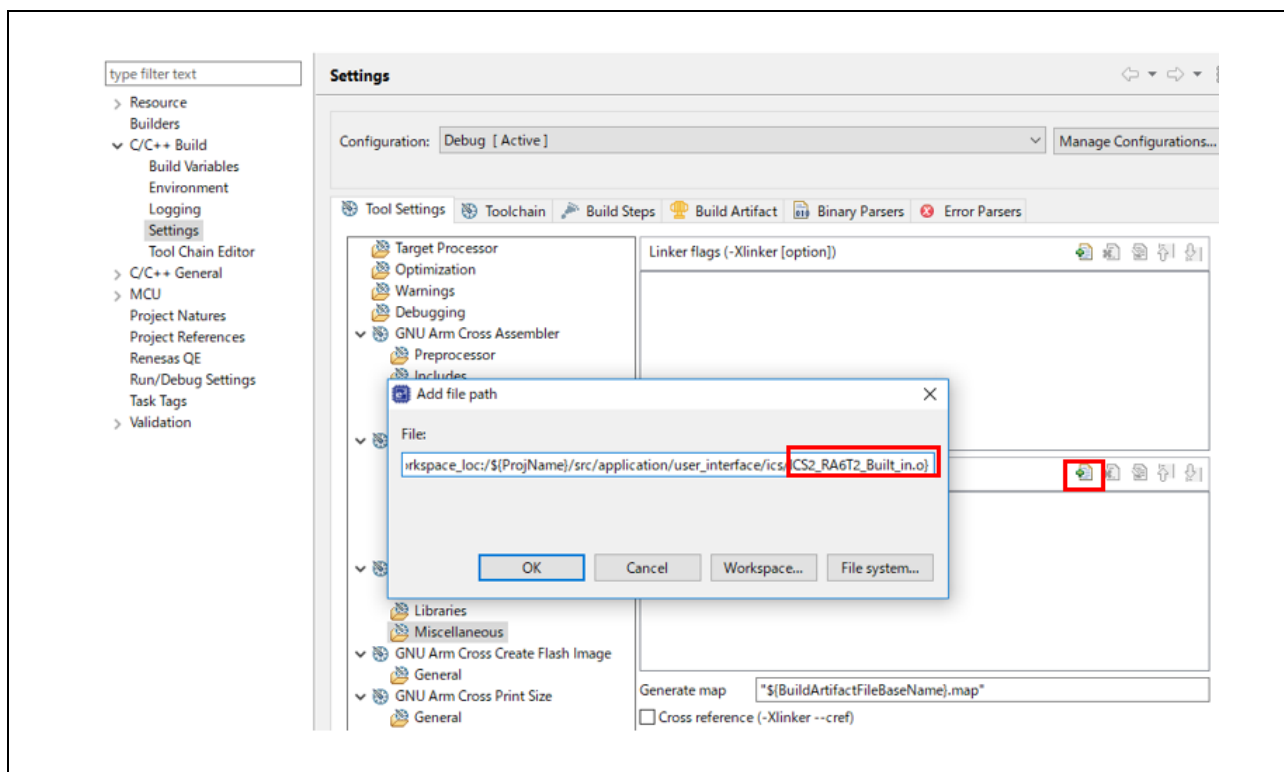


Figure 4-8 Register ICS2\_RA6T2.o

## (3) Change the value of USE\_BUILT\_IN in r\_mtr\_ics.h to 1.

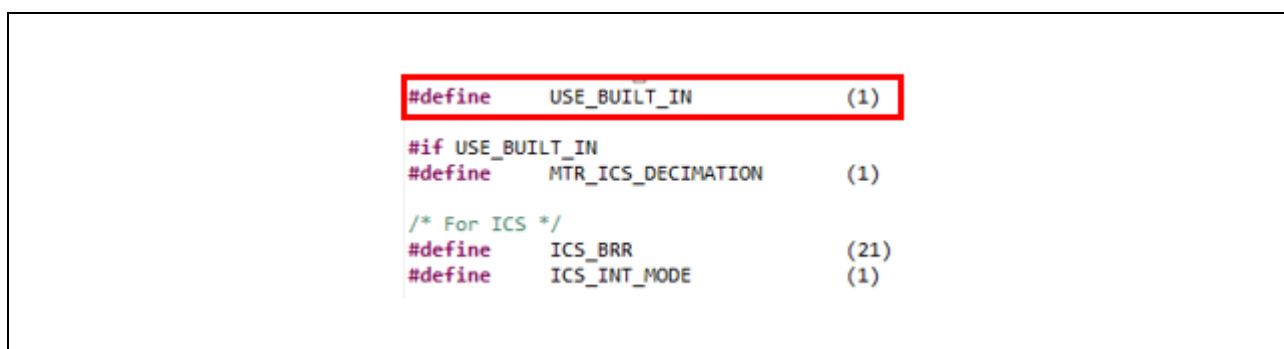


Figure 4-9 Modification of r\_mtr\_ics.h

- Change the communication baud rate setting of Renesas Motor Workbench to connect
  - (1) Change the value to 921,600 with Baud rate Dialog from the Option menu of the Main Window.
  - (2) Select the COM port of the connected kit in the COM of Connection.

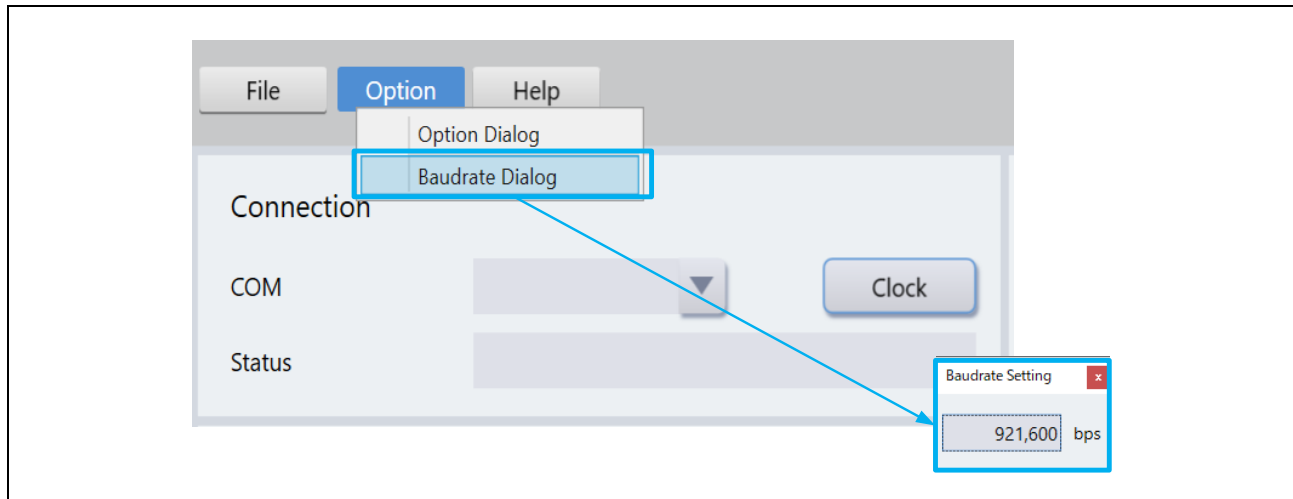


Figure 4-10 Baud rate setting

## 5. Reference document

RA6T2 Group User's Manual: Hardware (R01UH0951)

RA4T1 Group User's Manual: Hardware (R01UH0998)

RA6T3 Group User's Manual: Hardware (R01UH0999)

RA Flexible Software Package Documentation

120-degree conducting control of permanent magnetic synchronous motor (Algorithm) (R01AN2657)

Renesas Motor Workbench User's Manual (R21UZ0004)

Renesas Motor Workbench Quick start guide (R21QS0011)

MCK-RA6T2 User's Manual (R12UZ0091)

MCK-RA4T1 User's Manual (R12UZ0114)

MCK-RA6T3 User's Manual (R12UZ0115)

## Revision History

| Rev. | Data of issue | Descriptions |                       |
|------|---------------|--------------|-----------------------|
|      |               | Page         | Summary               |
| 1.00 | May 23, 2023  | —            | First edition issued. |
|      |               |              |                       |

# 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

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.

"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

## Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

## Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:  
[www.renesas.com/contact/](http://www.renesas.com/contact/).