RA Family

Hall Sensor/Sensorless vector control for dual permanent magnetic synchronous motor

For Motor Flexible Control Kit

Introduction

This application note describes the sample program for hall sensor/sensorless vector control of dual permanent magnetic synchronous motors, based on Renesas RA6T2 microcontroller. This application note also describes how to use the motor control development support tool, 'Renesas Motor Workbench'.

The targeted software for this application is 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.

Target Device

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

- RA6T2 (R7FA6T2BD3CFP)

Contents

1. Overview

This application note explains how to implement the software for hall sensor/sensorless vector control that drives dual permanent magnetic synchronous motor (PMSM) using the RA6T2 microcontroller and how to use the motor control development support tool, 'Renesas Motor Workbench'.

Note that this software uses the algorithm described in the application note 'Sensorless vector control for permanent magnet synchronous motor (Algorithm)' (R01AN3786), so please refer to that for the details of the algorithm.

In this document, the two motors are called Motor 1 and Motor 2

1.1 Development Environment

Table 1-1 and Table 1-2 show the development environment of the software explained in this application note,

Table 1-1 Hardware development environment

Microcontroller	Evaluation board (Note 1)	Motor (Note 2)
RA6T2 (R7FA6T2BD3CFP)	MCK-RA6T2 (Invertor board, CPU board) MCI-LV-1 (Additional inverter board)	R42BLD30L3 (2 units)

Table 1-2 Software development environment

e2studio version	FSP version	Toolchain version
V2023-04	V4.4.0	GCC ARM Embedded: V10.3.1.20210824

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

Notes: 1. The inverter board (RTK0EM0000B12020BJ) and the CPU board (RTK0EMA270C00000BJ) are included in the kit product MCK-RA6T2 (RTK0EMA270S00020BJ), and it is a product of Renesas Electronics Corporation. MCI-LV-1(RTK0EM0000S04020BJ) is additionally used to drive Motor 2.

2. R42BLD30L3 is a product of MOONS'.
MOONS' (https://www.moonsindustries.com/)

2. System Overview

Overview of this system is explained below.

2.1 Hardware Configuration

The hardware configuration is shown below.

(1) Overall configuration

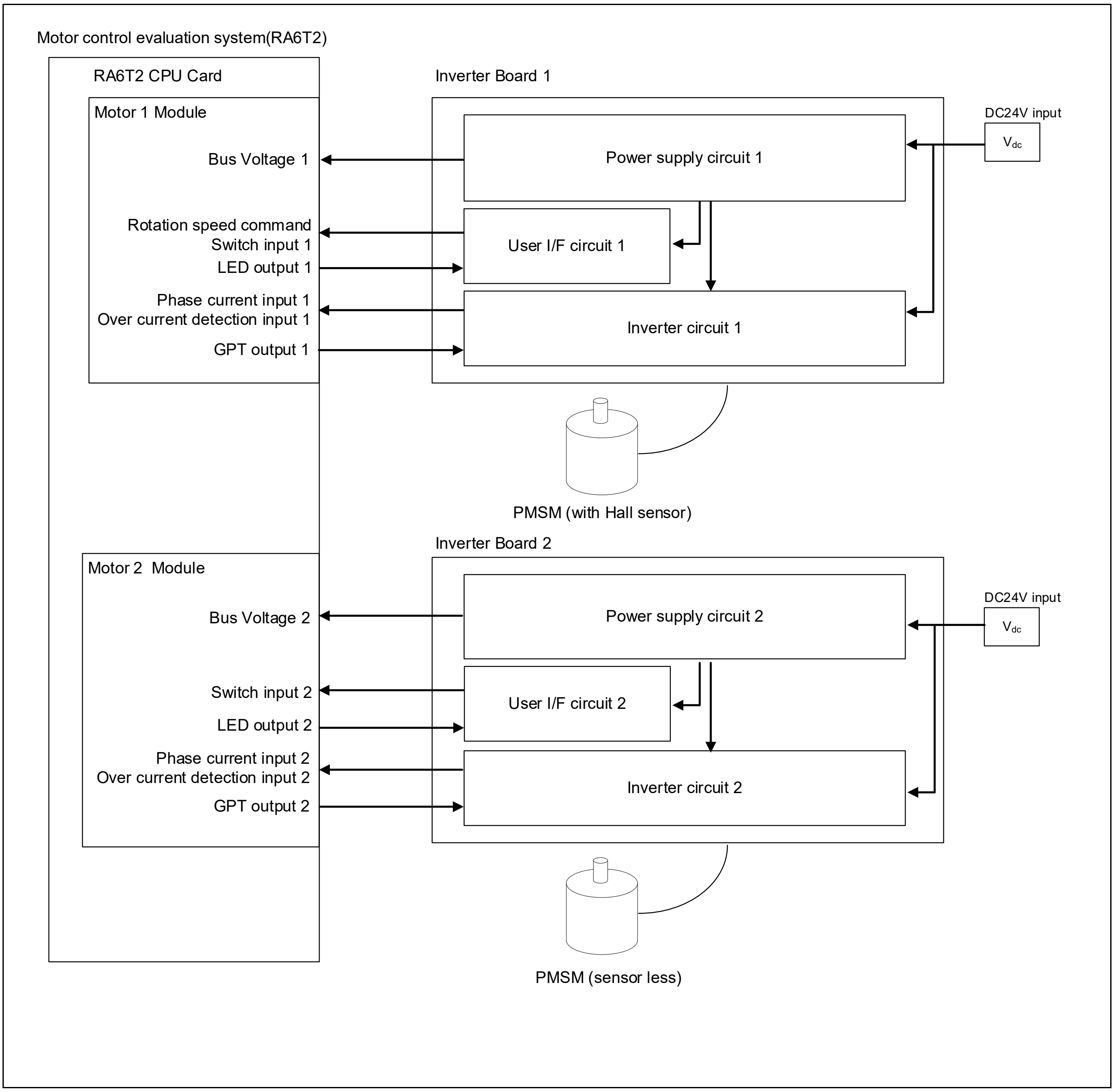


Figure 2-1 Hardware configuration diagram

(2) Motor 1 module configuration

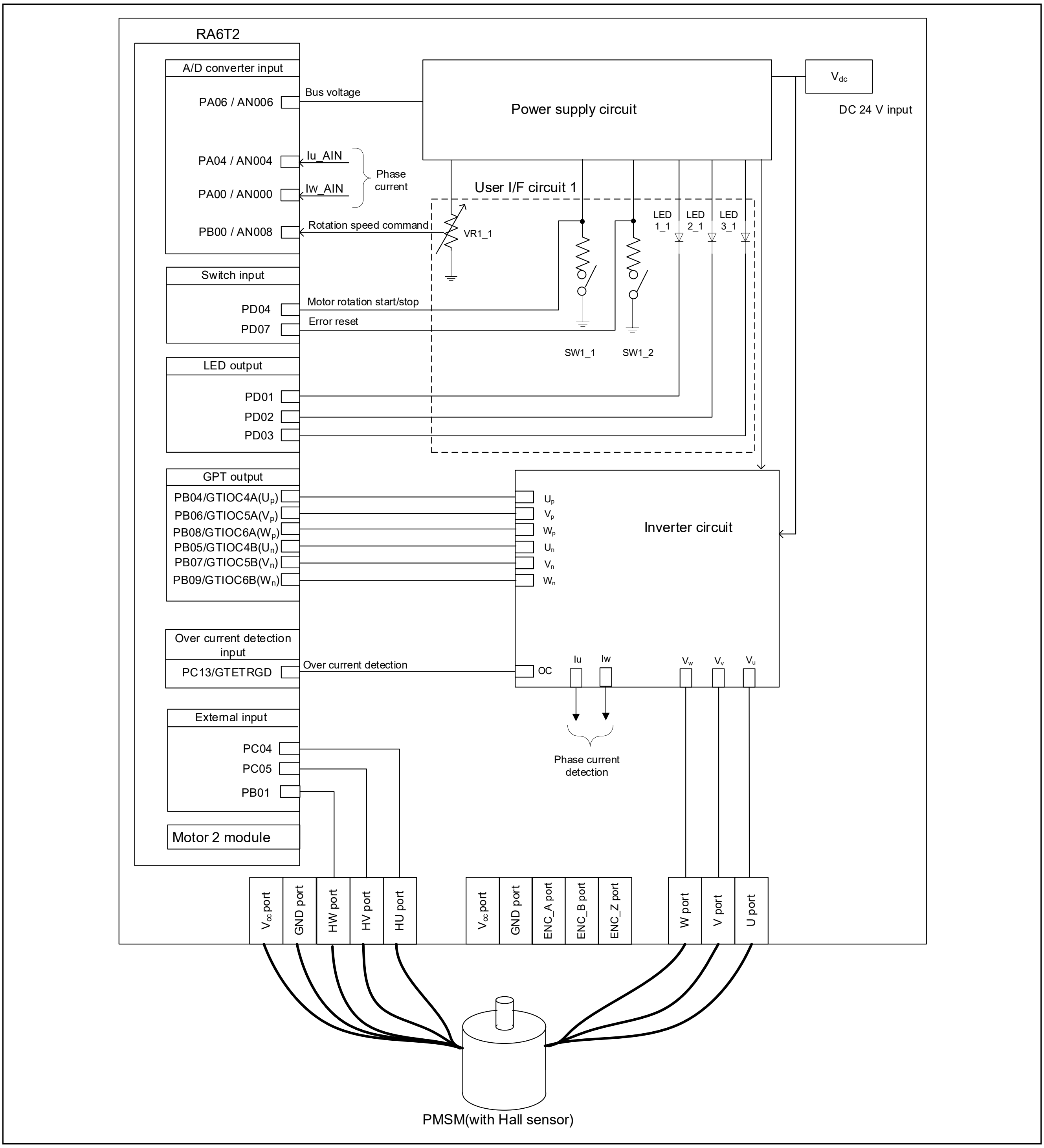


Figure 2-2 Hardware configuration diagram (Motor 1 module)

(3) Motor 2 module configuration

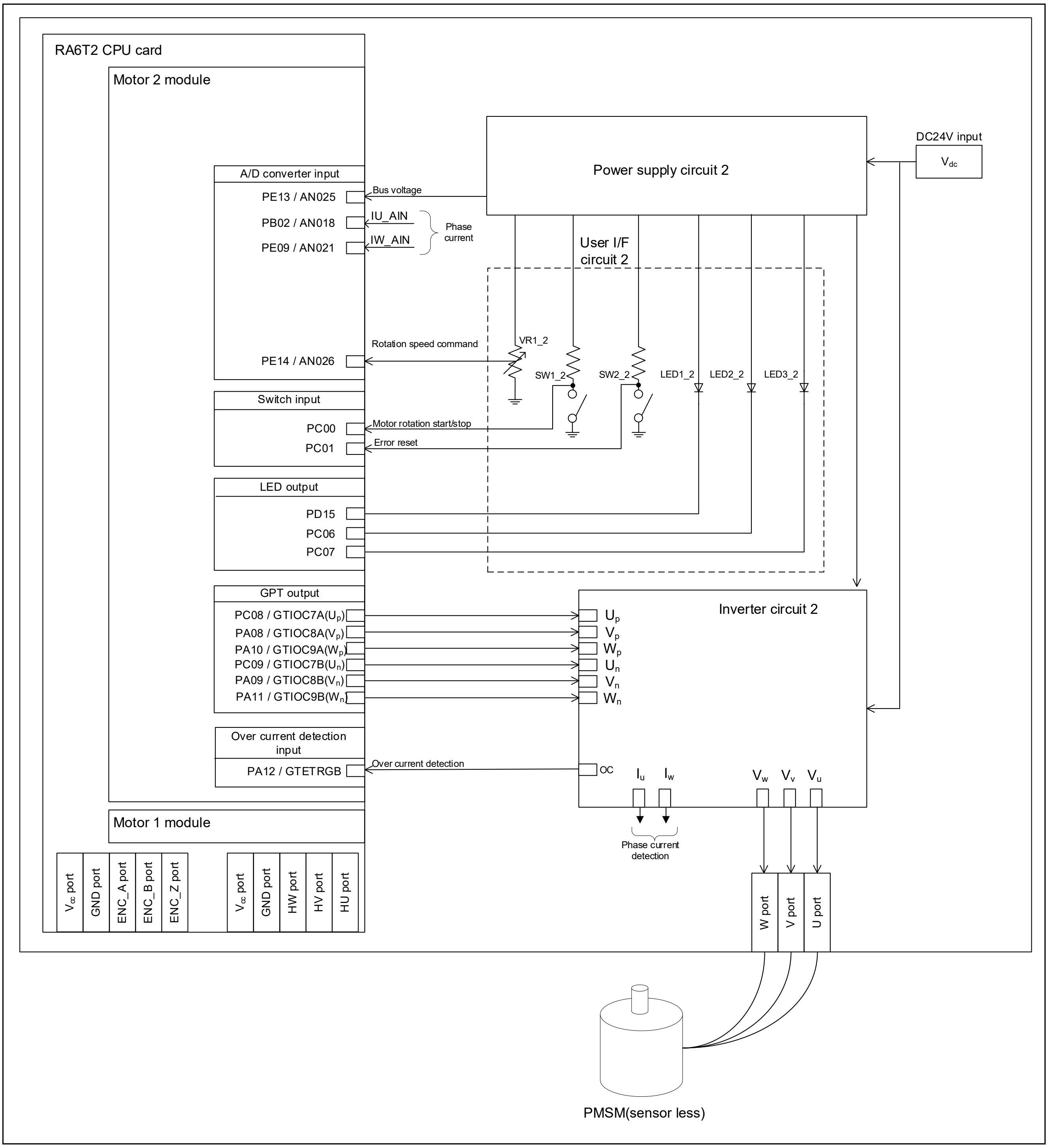


Figure 2-3 Hardware configuration diagram (Motor 2 module)

2.2 Hardware Specifications

2.2.1 Inverter board connection

When using this product for motor control evaluation, connect the CPU board and two inverter boards as shown in Figure 2-4.

For vector control with hall sensors, connect INV1 (silk-printed as “INV1” on the CPU board) to the inverter board. For sensorless vector control, connect INV2 (silk-printed as “INV2” on the CPU board) to the inverter board.

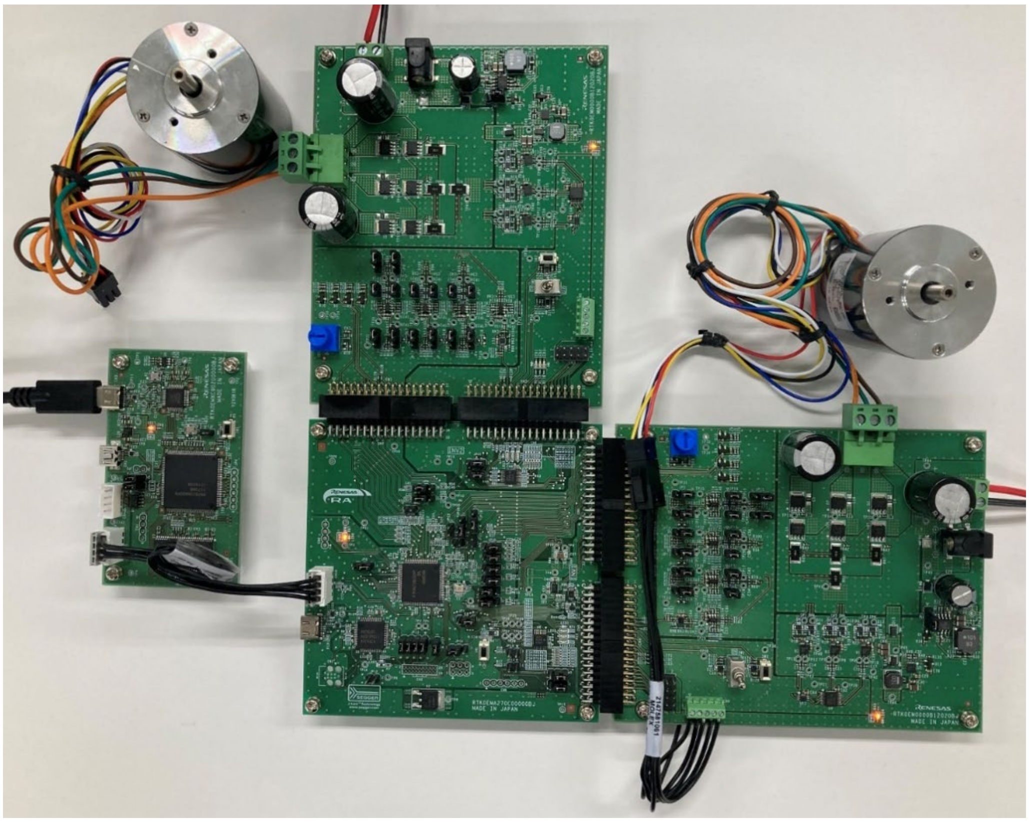


Figure 2-4 Connection for CPU board and inverter board

2.2.2 User interface

Table 2-1 is the list of user interface of this system.

Table 2-1 User interfaces

Item	Interface component	Function
Rotation speed command 1	Variable resistor of Motor 1 side (VR1_1)	Motor 1 reference value of rotation speed input (analog value)
START / STOP 1	Toggle switch of Motor 1 side (SW1_1)	Motor 1 rotation start/stop command
ERROR RESET 1	Push switch of Motor 1 side (SW2_1)	Command of recovery from error status
LED1_1	Orange LED of Motor 1 side (LED1_1)	• At the time of Motor 1 rotation: ON • At the time of Motor 1 stop: OFF
LED2_1	Orange LED of Motor 1 side (LED2_1)	• At the time of error detection: ON • At the time of normal operation: OFF
Rotation speed command 2	Variable resistor of Motor 2 side (VR1_2)	Motor 2 reference value of rotation speed input (analog value)
START / STOP 2	Toggle switch of Motor 2 side (SW1_2)	Motor 2 rotation start/stop command
ERROR RESET 2	Push switch of Motor 2 side (SW2_2)	Command of recovery from error status
LED1_2	Orange LED of Motor 2 side (LED1_2)	• At the time of Motor 2 rotation: ON • At the time of Motor 2 stop: OFF
LED2_2	Orange LED of Motor 2 side (LED2_2)	• At the time of error detection: ON • At the time of normal operation: OFF

Table 2-2 and Table 2-3 are the lists of port interface of this system.

Table 2-2 Port interfaces (Motor 1 side)

R7FA6T2BD3CFP port name	Function
PA06/ AN006	Inverter bus voltage measurement
PB00 / AN008	For rotation speed command value input (VR1_1)
PD04	START/STOP toggle switch (SW1_1)
PD07	ERROR RESET push switch (SW2_1)
PD01	LED1_1 ON/OFF control
PD02	LED2_1 ON/OFF control
PA04 / AN004	U1 phase current measurement
PA00 / AN000	W1 phase current measurement
PB04/GTIOC4A	PWM output (Up1)
PB06/GTIOC5A	PWM output (Vp1)
PB08/GTIOC6A	PWM output (Wp1)
PB05/GTIOC4B	PWM output (Un1)
PB07/GTIOC5B	PWM output (Vn1)
PB09/GTIOC6B	PWM output (Wn1)
PC04	U phase hall sensor input (HU)
PC05	V phase hall sensor input (HV)
PB01	W phase hall sensor input (HW)
PC13/GTETRGD	PWM emergency stop input at the time of overcurrent detection

Table 2-3 Port interfaces (Motor 2 side)

R7FA6T2BD3CFP port name	Function
PE13 / AN025	Inverter bus voltage measurement
PE14 / AN026	For rotation speed command value input (VR1_2)
PC00	START/STOP toggle switch (SW1_2)
PC01	ERROR RESET push switch (SW2_2)
PD15	LED1_2 ON/OFF control
PC06	LED2_2 ON/OFF control
PB02/ AN018	U2 phase current measurement
PE09 / AN021	W2 phase current measurement
PC08/GTIOC7A	PWM output (Up2)
PA08/GTIOC8A	PWM output (Vp2)
PA10/GTIOC9A	PWM output (Wp2)
PC09/GTIOC7B	PWM output (Un2)
PA09/GTIOC8B	PWM output (Vn2)
PA11/GTIOC9B	PWM output (Wn2)
PA12/GTETRGB	PWM emergency stop input at the time of overcurrent detection

2.2.3 Peripheral functions

List of the peripheral functions used in this system is given in Table 2-4.

Table 2-4 List of the peripheral functions

Peripheral	Resource	Purpose
12-bit A/D converter	AN000, AN002, AN004, AN006, AN008, AN018, AN020, AN021, AN025, AN026	• Rotational speed or position command input • Measure U-/W-phase current • Measure inverter bus voltage
AGT	AGT0, AGT1	500 [μs] interval timer
GPT	CH4, CH5, CH6, CH7, CH8, CH9	Complementary PWM outputs
POEG	Group B, Group D	Sets ports executing PWM output to high impedance state when an overcurrent is detected by external circuit.

(1) 12-bit A/D Converter (ADC12)

U-phase current, W-phase current, inverter bus voltage, and rotation speed command for Motor 1 and 2 are measured in "Single Scan Mode" (use a hardware trigger). A/D conversion is implemented to be synchronized with carrier synchronized interrupt.

(2) Low Power Asynchronous General-Purpose Timer (AGT)

The AGT is used as 500 [μs] interval timer.

(3) General PWM Timer (GPT)

On the channel 4,5,6,7,8 and 9, output with dead time is performed by using the complementary PWM Output Operating Mode.

(4) Port Output Enable for GPT (POEG)

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

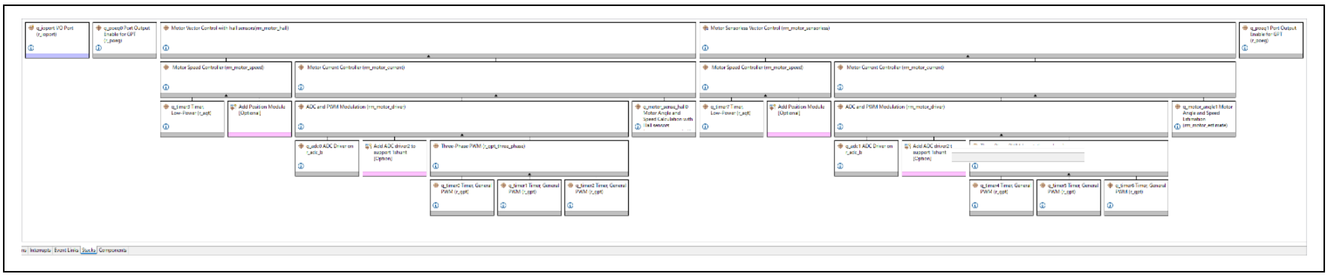


Figure 2-5 Overall FSP stacks diagram

Virtual Channel 0	
Scan Group	Scan Group 0
Channel Select	AN000
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 1	
Scan Group	Scan Group 0
Channel Select	AN002
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 2	
Scan Group	Scan Group 0
Channel Select	AN004
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 3	
Scan Group	Scan Group 1
Channel Select	AN006
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled

Motor 1

Virtual Channel 5	
Scan Group	Scan Group 2
Channel Select	AN018
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 6	
Scan Group	Scan Group 2
Channel Select	AN020
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 7	
Scan Group	Scan Group 2
Channel Select	AN021
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 8	
Scan Group	Scan Group 3
Channel Select	AN025
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled
Virtual Channel 9	
Scan Group	Scan Group 3
Channel Select	AN026
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 Data Format Select	12-bit Data Format
Digital Filter Selection	Disabled

Motor 2

Figure 2-6 FSP configuration of ADC driver [1/3]

˅ Virtual Channel 0	
Scan Group	Scan Group 0
Channel Select	AN000
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 1	
Scan Group	Scan Group 0
Channel Select	AN002
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 2	
Scan Group	Scan Group 0
Channel Select	AN004
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 3	
Scan Group	Scan Group 1
Channel Select	AN006
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 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

Motor 1

˅ Virtual Channel 5	
Scan Group	Scan Group 2
Channel Select	AN018
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 2
Channel Select	AN020
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 2
Channel Select	AN021
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 8	
Scan Group	Scan Group 3
Channel Select	AN025
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 9	
Scan Group	Scan Group 3
Channel Select	AN026
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

Motor 2

Figure 2-7 FSP configuration of ADC driver [2/3]

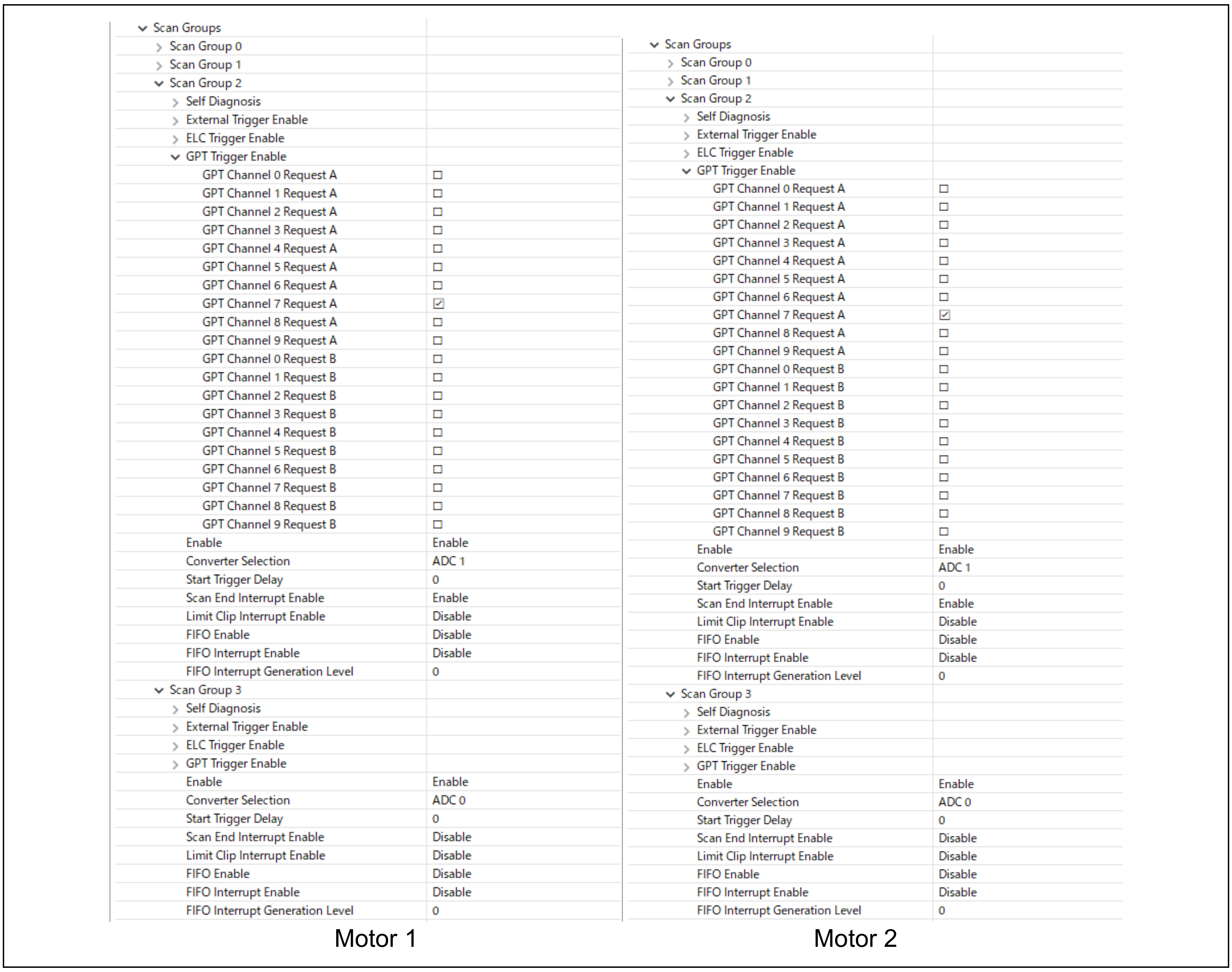


Figure 2-8 FSP configuration of ADC driver [3/3]

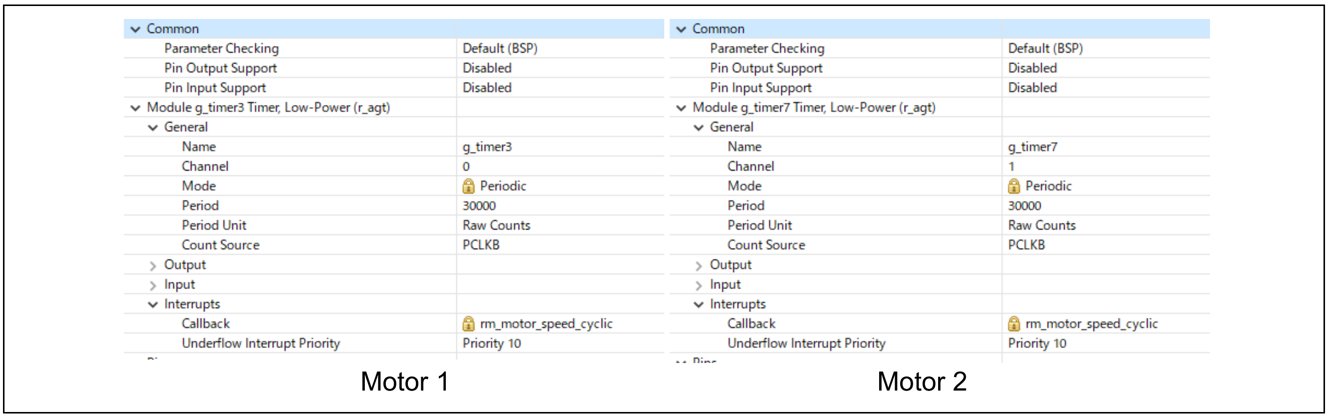


Figure 2-9 FSP configuration of AGT driver

∨ Common	
Parameter Checking	Default (BSP)
∨ Module g_poeg0 Port Output Enable for GPT (r_poeg)	
∨ General	
∨ Trigger	
GTETRG Pin	☑
GPT Output Level	☐
Oscillation Stop	☐
ACMPHS0	☐
ACMPHS1	☐
ACMPHS2	☐
ACMPHS3	☐
Name	g_poeg0
Channel	3
∨ Input	
GTETRG Polarity	Active Low
GTETRG Noise Filter	PCLKB/32
∨ Interrupts	
Callback	g_poe_overcurrent0
Interrupt Priority	Priority 0 (highest)

∨ 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 mo	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	
› Output Disable POEG Trigger	
POEG Link	POEG Channel 3
GTIOCA Disable Setting	Set Hi Z
GTIOCB Disable Setting	Set Hi Z
∨ ADC Trigger	
∨ Start Event Trigger (Channels with GTINTAD c	
Trigger Event A/D Converter Start Request	☐
Trigger Event A/D Converter Start Request	☑
Trigger Event A/D Converter Start Request	☐
Trigger Event A/D Converter Start Request	☐
∨ Dead Time (Value range varies with Channel)	
Dead Time Count Up (Raw Counts)	240
Dead Time Count Down (Raw Counts) (Chanr	240
› ADC Trigger (Channels with GTADTRA only)	
› ADC Trigger (Channels with GTADTRB only)	
› Interrupt Skipping (Channels with GTITC only)	
Extra Features	Enabled
∨ Pins	
GTIOC4A	PB04
GTIOC4B	PB05

Motor 1 and 2

Figure 2-10 FSP configuration of GPT driver

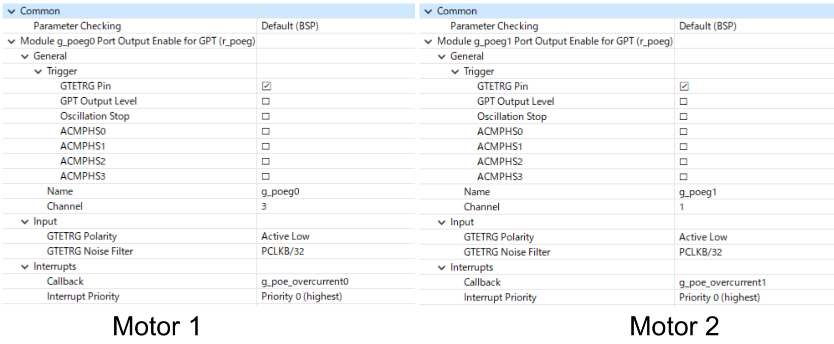
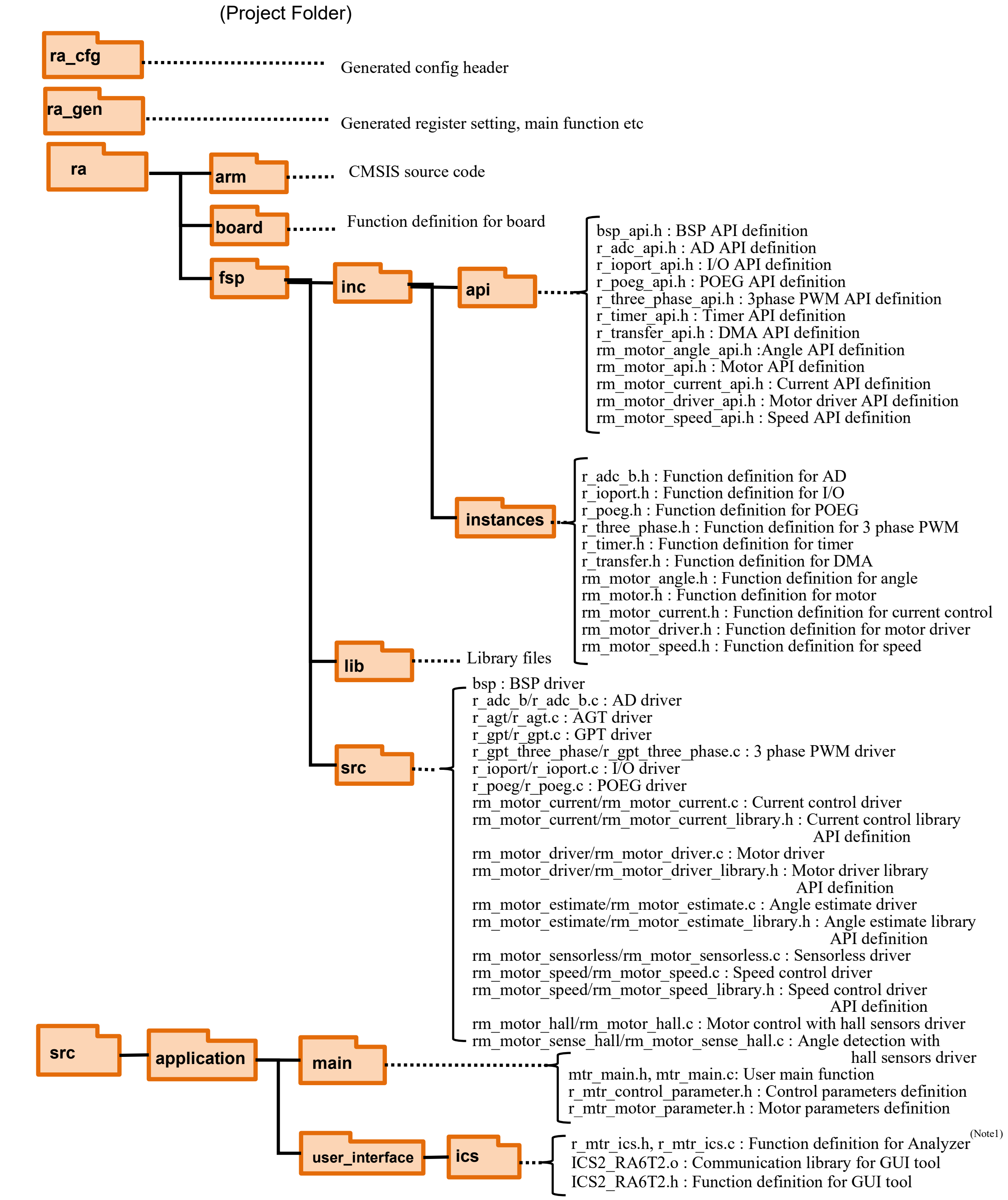


Figure 2-11 FSP Configuration of POEG driver

2.3 Software configuration

2.3.1 Software file configuration

Folder and file configuration of the software is given below.



Note 1 : Regarding the specification of Analyzer function in the motor control development support tool "Renesas Motor Workbench", please refer to the chapter 4.4. The identifier "ics/ICS (ICS is previous motor control development support tool "In Circuit Scope")" is attached to the name of folders, files, functions, variables related to "Renesas Motor Workbench".

Figure 2-12 Folder and file configuration

2.3.2 Module configuration

Module configuration of the software is described below.

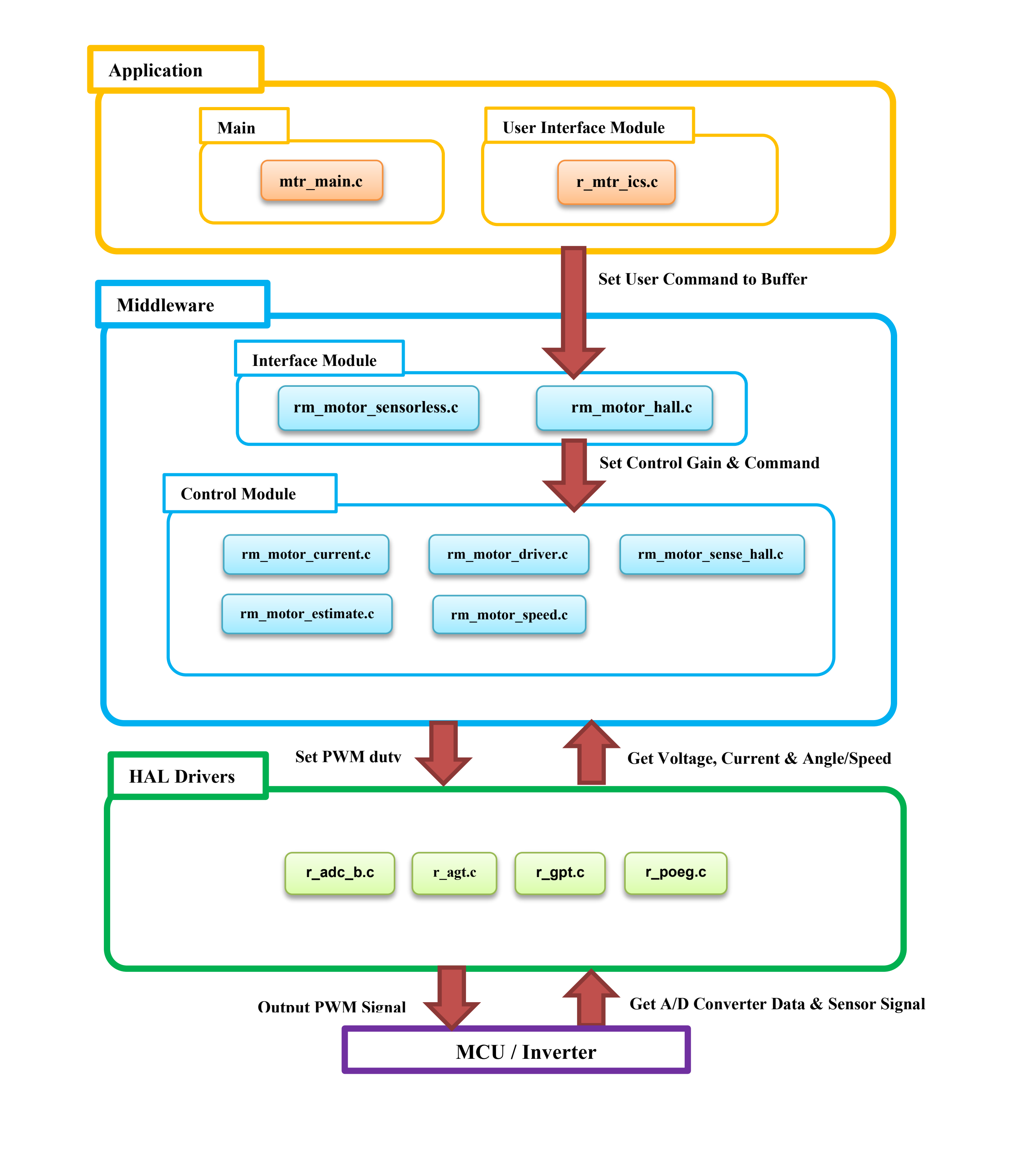


Figure 2-13 Module configuration

2.4 Software Specifications

Table 2-5 shows basic software specification of this system. For details of the sensorless vector control, refer to the application note 'Sensorless vector control for permanent magnet synchronous motor (Algorithm)' (R01AN3786).

Specifications are the same for Motor 1 and 2, except for hardware interface.

Table 2-5 Basic specifications of hall sensor/sensorless vector control software

<table>
<tr><th>Item</th><th colspan="2">Content</th></tr>
<tr><td>Control method</td><td colspan="2">Vector control</td></tr>
<tr><td>Position detection method</td><td colspan="2">Motor 1: Hall sensor, Motor 2: Sensorless</td></tr>
<tr><td>Motor rotation start/stop</td><td colspan="2">Determined depending on the level of SW1_1 for Motor 1 and SW1_2 for Motor 2, or input from Renesas Motor Workbench</td></tr>
<tr><td>Input voltage</td><td colspan="2">DC 24V</td></tr>
<tr><td>Main clock frequency</td><td colspan="2">240 [MHz]</td></tr>
<tr><td>Carrier frequency (PWM)</td><td colspan="2">20 [kHz] (Carrier period: 50 [μs])</td></tr>
<tr><td>Dead time</td><td colspan="2">2 [μs]</td></tr>
<tr><td>Control period</td><td colspan="2">Current control / Position and speed estimation: 50 [μs] (the carrier period)
Speed control: 500 [μs]</td></tr>
<tr><td>Rotation speed control range</td><td colspan="2">CW : 0 [rpm] to 2400 [rpm]
CCW : 0 [rpm] to 2400 [rpm]
However, 500 [rpm] or less is driven by a speed open loop.</td></tr>
<tr><td>Natural frequency of each control system</td><td colspan="2">Current control system : 300 [Hz]
Speed control system : 5 [Hz]
BEMF estimation system : 1000 [Hz]
Position estimation system : 50 [Hz]</td></tr>
<tr><td>Optimization setting of compiler</td><td>Optimization level</td><td>2(-optimize=2) (default setting)</td></tr>
<tr><td>ROM/RAM size</td><td colspan="2">ROM : 40.5KB
RAM : 5.8KB</td></tr>
<tr><td>Processing stop for protection</td><td>[Motor 1]
Disables the Motor 1 control signal output (six outputs), under any of the following conditions.
1. Instantaneous value of current of any phase exceeds 3.54(=1.67*sqrt (2)*1.5) [A] (monitored every 50 [μs])
2. Inverter bus voltage exceeds 60 [V] (monitored every 50 [μs])
3. Inverter bus voltage is less than 8 [V] (monitored every 50 [μs])
4. Rotation speed exceeds 4500 [rpm] (monitored every 50 [μs])

When an external over current signal is detected (when a low level of the GTETRGD port is detected), the PWM output ports are set to high impedance state.</td><td>[Motor 2]
Disables the Motor 2 control signal output (six outputs), under any of the following conditions.
1. Instantaneous value of current of any phase exceeds 3.54(=1.67*sqrt (2)*1.5) [A] (monitored every 50 [μs])
2. Inverter bus voltage exceeds 60 [V] (monitored every 50 [μs])
3. Inverter bus voltage is less than 8 [V] (monitored every 50 [μs])
4. Rotation speed exceeds 4500 [rpm] (monitored every 50 [μs])

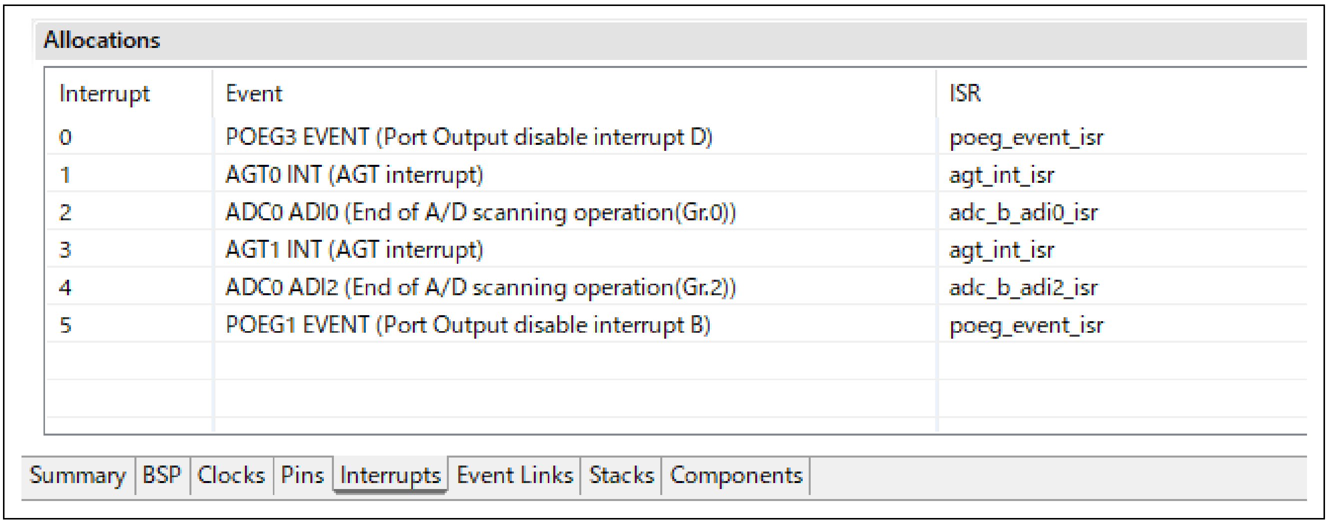
When an external over current signal is detected (when a low level of the GTETRGB port is detected), the PWM output ports are set to high impedance state.</td></tr>
</table>

2.5 Interrupt Priority

Table 2-6 shows the interrupt and priorities used in this system.

Table 2-6 Interrupt priority

Interrupt level	Priority	Function
15	Min	
14	↓	
13		
12		
11		
10		AGT0/1 INT 500 [usec] Interrupt handling (Motor 1, 2 are same priority)
9		
8		
7		
6		
5		ADC0 ADI0/2 A/D complete interrupt (Motor 1, 2 are same priority)
4		
3		
2		
1		
0	Max	POEG1/3 EVENT Over current error interrupt (Motor 1, 2 are same priority)


Allocations

Interrupt	Event	ISR
0	POEG3 EVENT (Port Output disable interrupt D)	poeg_event_isr
1	AGT0 INT (AGT interrupt)	agt_int_isr
2	ADC0 ADI0 (End of A/D scanning operation(Gr.0))	adc_b_adi0_isr
3	AGT1 INT (AGT interrupt)	agt_int_isr
4	ADC0 ADI2 (End of A/D scanning operation(Gr.2))	adc_b_adi2_isr
5	POEG1 EVENT (Port Output disable interrupt B)	poeg_event_isr

Summary | BSP | Clocks | Pins | Interrupts | Event Links | Stacks | Components

Figure 2-14 FSP Interrupts configuration

3. Descriptions of Control Program

3.1 Contents of Control

3.1.1 Motor start/stop

The start and stop of the motor are controlled by input from Renesas Motor Workbench or SW1_1, SW1_2.

SW1_1 and SW1_2 are assigned to a general-purpose port. When the port is at a "Low" level, it is determined that the start switch is being pressed. Conversely, when the level is switched to "High", the software determines that the motor should be stopped.

3.1.2 A/D converter

(1) Motor rotation speed reference

The motor rotation speed reference can be set by Renesas Motor Workbench input or A/D conversion of the VR1_1 and VR1_2 output value (analog value). The A/D converted value is used as rotation speed command value, as shown below.

Table 3-1 Conversion ratio of rotation speed reference

Item	Conversion ratio (Reference : A/D conversion value)		Channel
Rotation speed reference	CW	0 [rpm] to 2400[rpm] : 0800H to 0FFFH	[Motor 1] AN008 [Motor 2] AN026
	CCW	0 [rpm] to 2400[rpm] : 07FFH to 0000H	

(2) Inverter bus voltage

Inverter bus voltage is measured as given in Table 3-2.
It is used for modulation factor calculation and over-/low-voltage detection. (When an abnormality is detected, PWM is stopped.)

Table 3-2 Inverter bus voltage conversion ratio

Item	Conversion ratio (Inverter bus voltage : A/D conversion value)	Channel
Inverter bus voltage	0 [V] to 73.26 [V] : 0000H to 0FFFH	[Motor 1] AN006 [Motor 2] AN025

(3) U, W phase current

The U and W phase currents are measured as shown in Table 3-3 and used for vector control.

Table 3-3 Conversion ratio of U and W phase current

Item	Conversion ratio (U, W phase curren t: A/D conversion value)	Channel
U, W phase current	-8.25 [A] to 8.25 [A] : 0000H to 0FFFH (Note) Current = (3.3V-1.65V)/(0.01Ohm*20) =8.25A	[Motor 1] Iu1: AN004 Iw1: AN000 [Motor 2] Iu2: AN018 Iw2: AN021

Note: For more details of A/D conversion characteristics, refer to "RA6T2 Group User's Manual: Hardware".

3.1.3 Modulation

The target software of this application note uses pulse width modulation (hereinafter called PWM) to generate the input voltage to the motor. And the PWM waveform is generated by the triangular wave comparison method.

- Triangular wave comparison method
  The triangular wave comparison method is used to output the voltage command value. By this method, the pulse width of the output voltage can be determined by comparing the carrier waveform (triangular wave) and voltage command value waveform. The voltage command value of the pseudo sinusoidal wave can be output by turning the switch on or off when the voltage command value is larger or smaller than the carrier wave respectively.

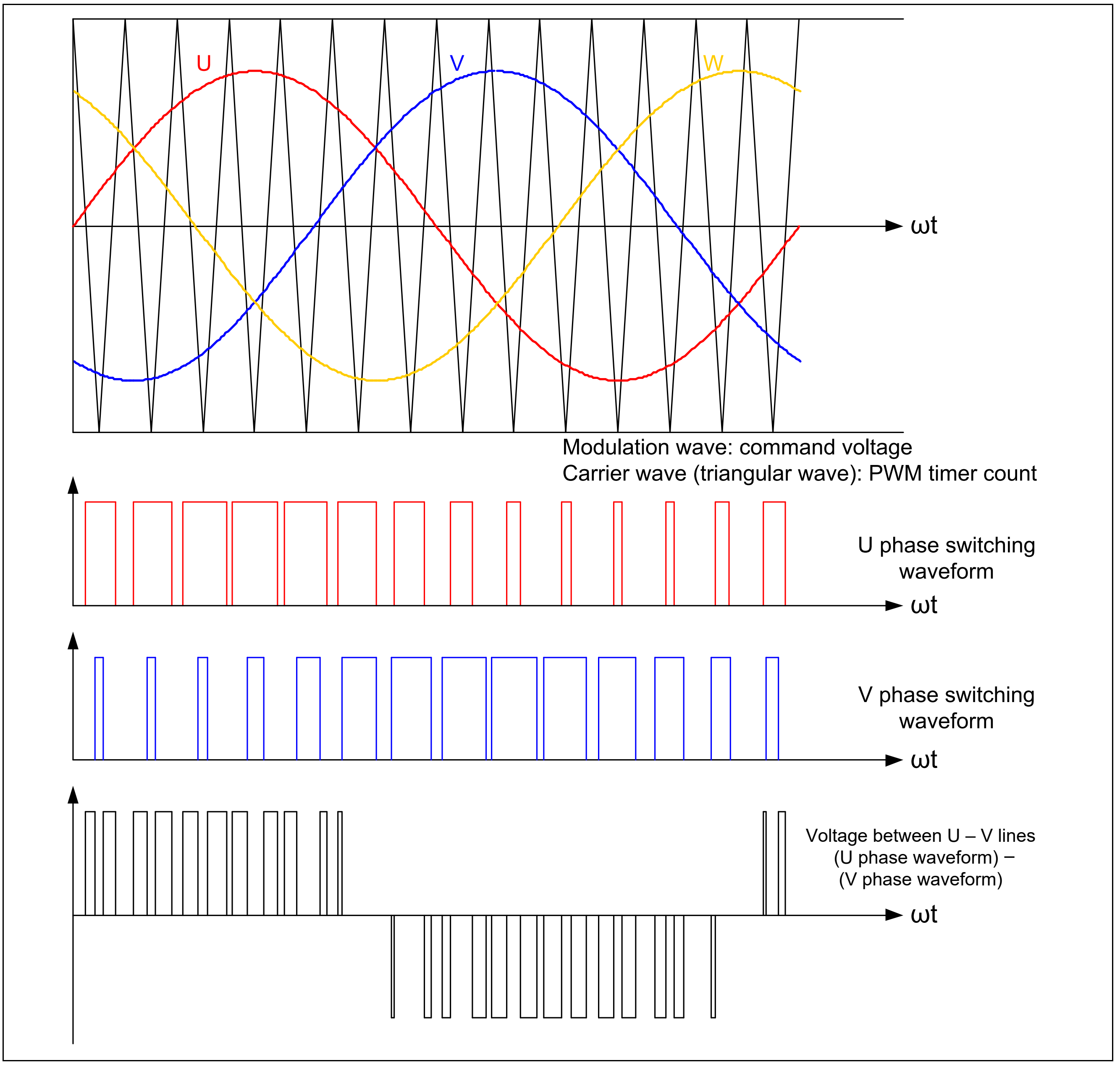


Figure 3-1 Conceptual diagram of triangular wave comparison method

As shown in the Figure 3-2, ratio of the output voltage pulse to the carrier wave is called duty.

$$\text{Duty} = \frac{T_{ON}}{T_{ON} + T_{OFF}} \times 100\ [\%]$$

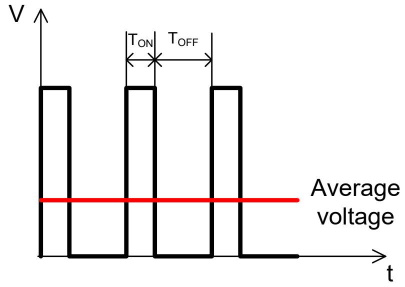


Figure 3-2 Definition of duty

Modulation factor “m” is defined as follows.

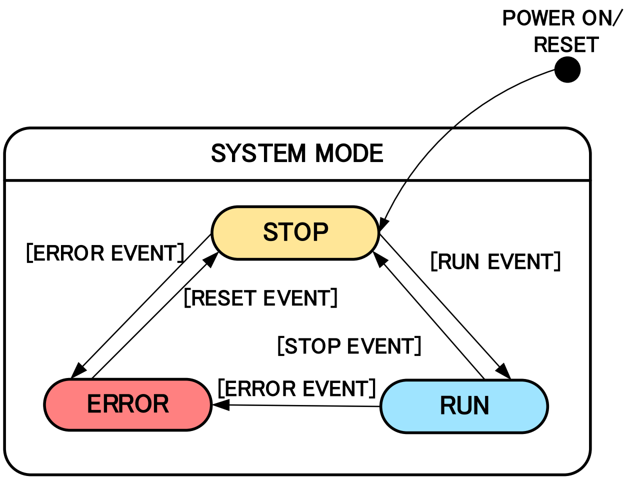
$$m = \frac{V}{E}$$

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

A requested control can be performed by setting this modulation factor to the register which determines PWM duty.

3.1.4 State transition

Figure 3-3 is a state transition diagram of the sample software. In the target software of this application note, the software state is managed by “SYSTEM MODE”. Motor 1 and 2 are controlled in the same method.



		MODE		
		STOP	RUN	ERROR
EVENT	STOP	STOP	STOP	ERROR
	RUN	RUN	RUN	ERROR
	ERROR	ERROR	ERROR	ERROR
	RESET	STOP	RUN	STOP

Figure 3-3 State transition diagram of hall sensor/sensorless vector control software

(1) SYSTEM MODE
“SYSTEM MODE” indicates the operating states of the system. The state transits on occurrence of each event (EVENT). “SYSTEM MODE” has 3 states that are motor drive stop (INACTIVE), motor drive (ACTIVE), and abnormal condition (ERROR).

(2) EVENT
When “EVENT” occurs in each “SYSTEM MODE”, “SYSTEM MODE” changes as shown the table in Figure 3-3, according to that “EVENT”. The occurrence factors of each event are shown below.

Table 3-4 List of EVENT

EVENT name	Occurrence factor
STOP	by user operation
RUN	by user operation
ERROR	when the system detects an error
RESET	by user operation

3.1.5 Rotor angle and rotational speed estimation with hall sensors

3.1.5.1 Estimation of rotational speed

The rotational speed is estimated by below algorithm.

At every carrier interrupt (50μsec), hall sensors input signal are read, and the change in hall signal pattern is detected. Time for rotation by 60-degree electrical angle (period between each hall signal pattern change) is measured by counting the number of carrier interrupt.

Period of 60 degree (electrical) = Number of carrier interrupt * Period of carrier interrupt [50μsec]

From this equation, rotational speed (electrical) can be calculated.

Rotational speed (electrical) [rad/sec] = (2π * 60/360) / Period of 60-degree (electrical) [μsec]

However, if only one period of hall sensor signal change is used, there is a possibility of an error due to the tolerance of hall signal. Therefore, in this implementation, summation of last 6 periods of hall sensor signal changes is used to estimate the rotational speed.

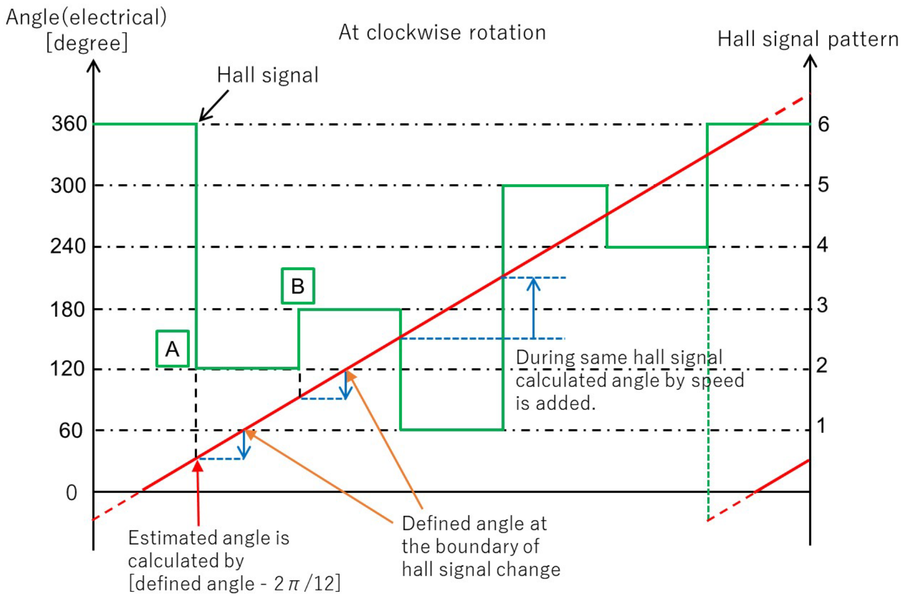
Rotational speed (electrical) [rad/sec] = 2π / Period of 360-degree (6 * 60-degree) (electrical) [μsec]

3.1.5.2 Estimation of rotor angle

The rotor angle is estimated by below information.

A) The direction of rotation
B) The estimated rotational speed

The direction of rotation is detected by the hall sensor signal pattern. The hall sensor signal pattern is unique in each rotation direction, therefore, the direction of rotation can be detected by comparison between current and last hall signal pattern.



	CW	CCW
Hall signal pattern	6 -> 2 -> 3 -> 1 -> 5 -> 4	6 -> 4 -> 5 -> 1 -> 3 -> 2

Figure 3-4 Estimation of rotor angle (at clockwise rotation)

At the point A in Figure 3-4, the hall signal changes 6 to 2. Therefore, the direction of rotation can be detected as clockwise. At this point A, the rotor angle is set as below.

Rotor angle [rad] = 2π * (60*1)/360 + internal angle [rad] + offset [rad]

Internal angle means fixed angle at the boundary of hall signal change. It is defined as “-2π/12” at clockwise rotation, as “2π/12” at counterclockwise rotation. At each carrier interrupt, the difference of angle calculated with the rotational speed is added at clockwise, decreased at counterclockwise.
The difference is limited -2π/12 to 2π/12 with consideration about an error and speed change.

— At clockwise rotation
  Internal angle in same hall signal [rad]
  = Defined value (-2π/12) + estimated speed [rad/sec] * carrier interrupt period(50μsec) * Number of carrier interrupt

— At counterclockwise rotation
  Internal angle in same hall signal [rad]
  = Defined value (2π/12) – estimated speed [rad/sec] * carrier interrupt period(50μsec) * Number of carrier interrupt

At each case, calculated angle is limited from -2π/12 to 2π/12.

At the point B in Figure 3-4, the rotor angle is set as below.

Rotor angle [rad] = 2π * (60*2)/360 + internal angle [rad] + offset [rad]

At the boundary of hall signal change, the rotor angle is estimated with 60-degree definition angle. (At next boundary, 120 is changed to 180.)

Offset value is set by user with an evaluation of each motor characteristics. (mainly the tolerance of hall signal sensor.)

3.1.6 Start-up method

Figure 3-5 shows startup control of vector control software. Each mode is controlled by flags managing each reference of the d-axis current, q-axis current, and speed. Motor 1 and 2 are controlled in the same method.

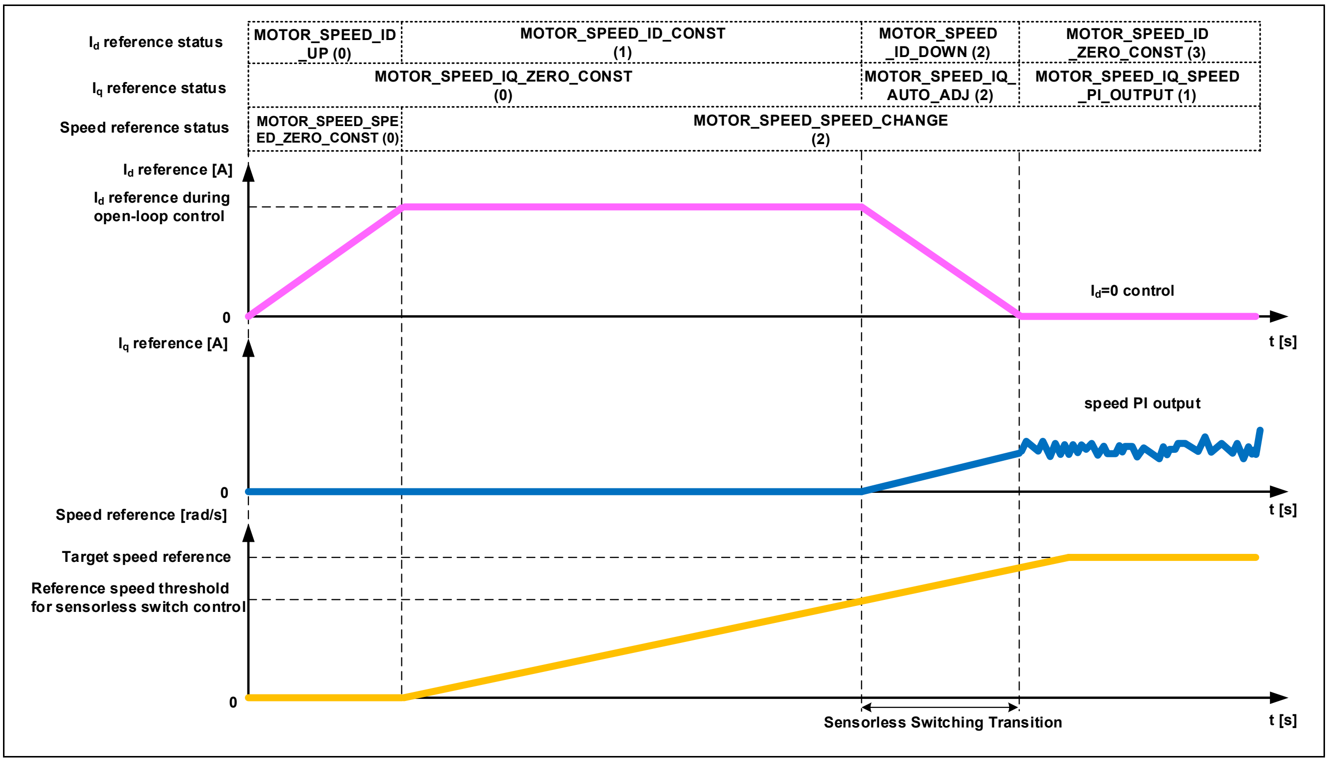


Figure 3-5 Startup control of vector control software

3.1.7 System protection function

This control software has the following error status and executes emergency stop functions in case of occurrence of respective errors. Table 3-5 shows each software threshold for the system protection function.

- Over current error
  The PWM output ports are set to high impedance state in response to an emergency stop signal (over current detection) from the hardware.
  In addition, U, V, and W phase currents are monitored in over current monitoring cycle. When an over current (when the current exceeds the over current limit) is detected, the CPU executes emergency stop (software detection).

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

- Low voltage error
  The inverter bus voltage is monitored in low-voltage monitoring cycle. The CPU performs emergency stop when low voltage (when voltage falls below the limit) is detected. Here, the low voltage limit is set in consideration of the error of resistance value of the detect circuit.

- Over speed error
  The rotation speed is monitored in rotation speed monitoring cycle. The CPU performs emergency stop when the speed is over the limit.

Table 3-5 Setting values of the system protection function

Error name	Threshold	
Over current error	Over current limit [A]	3.54
	Monitoring cycle [μs]	50
Over voltage error	Over voltage limit [V]	60
	Monitoring cycle [μs]	50
Low voltage error	Low voltage limit [V]	8
	Monitoring cycle [μs]	50
Over speed error	Speed limit [rpm]	4500
	Monitoring cycle [μs]	50

3.1.8 Carrier synchronized interrupt

In the case of 2-motor control, if each timer is started at the same time, the interrupt timings will overlap, so the two motors should work in turn to make sure they enter the PWM interrupt at different time.

In this control program, it is implemented by adjusting the carrier cycle of Motor 2 side.

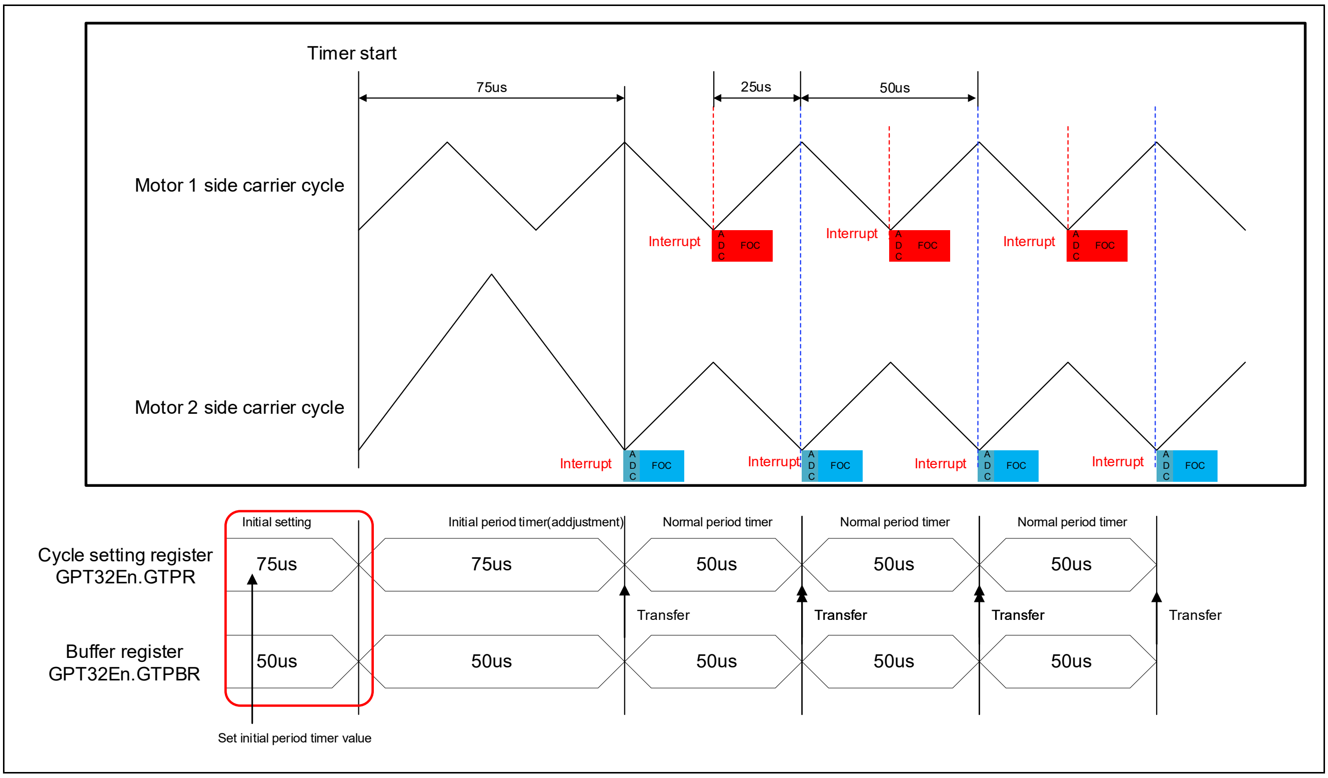


Figure 3-6 Start carrier output

By this setting, the two motors all have 50us carrier period. And, carrier synchronized interrupt will not occur at the same time. Carrier synchronous interrupts of Motor 1 and Motor 2 occur alternately at periods of 25 [μs]. Therefore, it is necessary to implement the processing time of interrupt (including processing time at error occurrence) within 25[μs].

3.2 Function Specifications of Hall Sensor Vector Control Software

The control process of the target software of this application note is mainly consisted of 50[μs] period interrupt (carrier interrupt) and 500[μs] period interrupt. As following Figure 3-7, the control process in the red broken line part is executed every 50[μs] cycle, and the control process in the blue broken line part is executed every 500[μs] cycle.

In this system, the control cycle of Motor 1 and Motor 2 is set to 50[μs]. The PWM frequency and the control cycle frequency of Motor 1 and Motor 2 should be same due to interrupt timing.

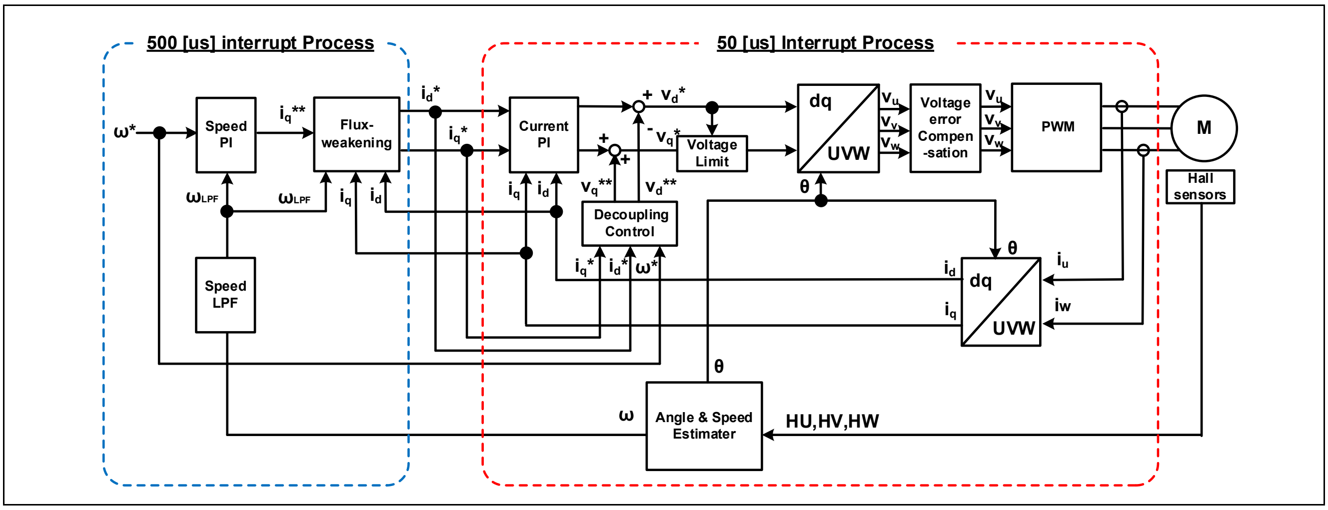


Figure 3-7 Block diagram of vector control with hall sensors

This chapter shows the specification of 2 interrupt functions and functions executed in each interrupt cycle. In 3.4 List of functions, only primary functions of the hall sensor/sensorless vector control are listed. Regarding the specification of functions not listed in following tables, refer to source codes.

3.3 Function Specifications of Sensorless Vector Control Software

The control process of the target software of this application note is mainly consisted of 50[μs] period interrupt (carrier interrupt) and 500[μs] period interrupt. As following Figure 3-8 and Figure 3-9, the control process in the red broken line part is executed every 50[μs] cycle, and the control process in the blue broken line part is executed every 500[μs] cycle.

In this system, the control cycle of Motor 1 and Motor 2 is set to 50[μs]. The PWM frequency and the control cycle frequency of Motor 1 and Motor 2 should be same due to interrupt timing.

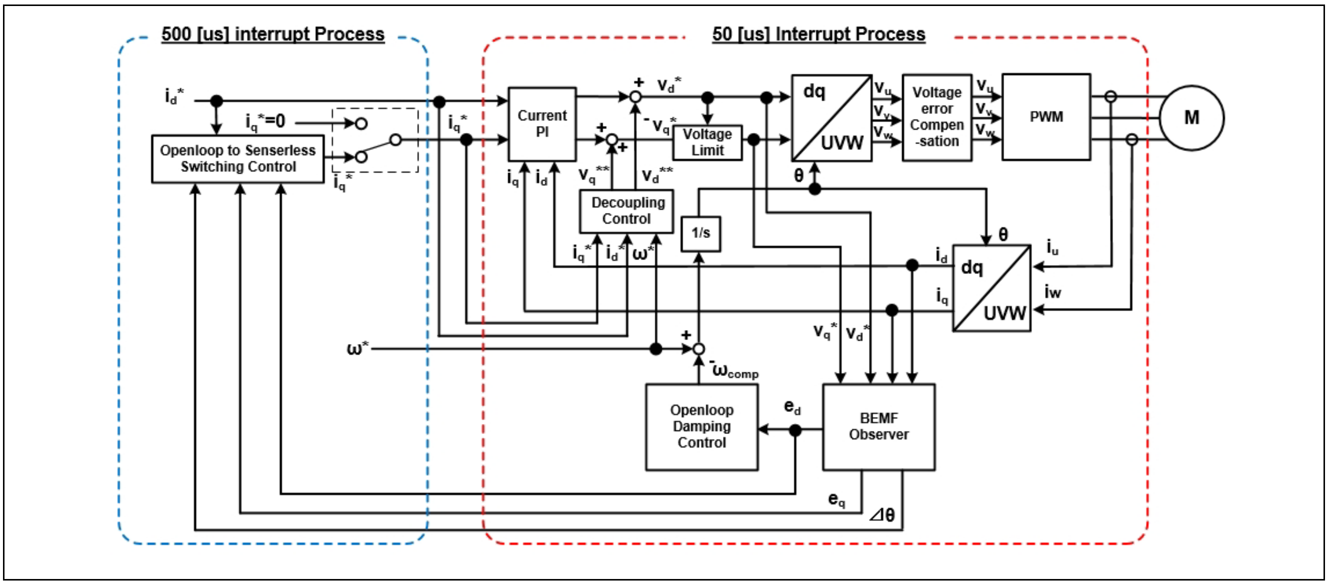


Figure 3-8 Block diagram of sensorless vector control (open-loop control)

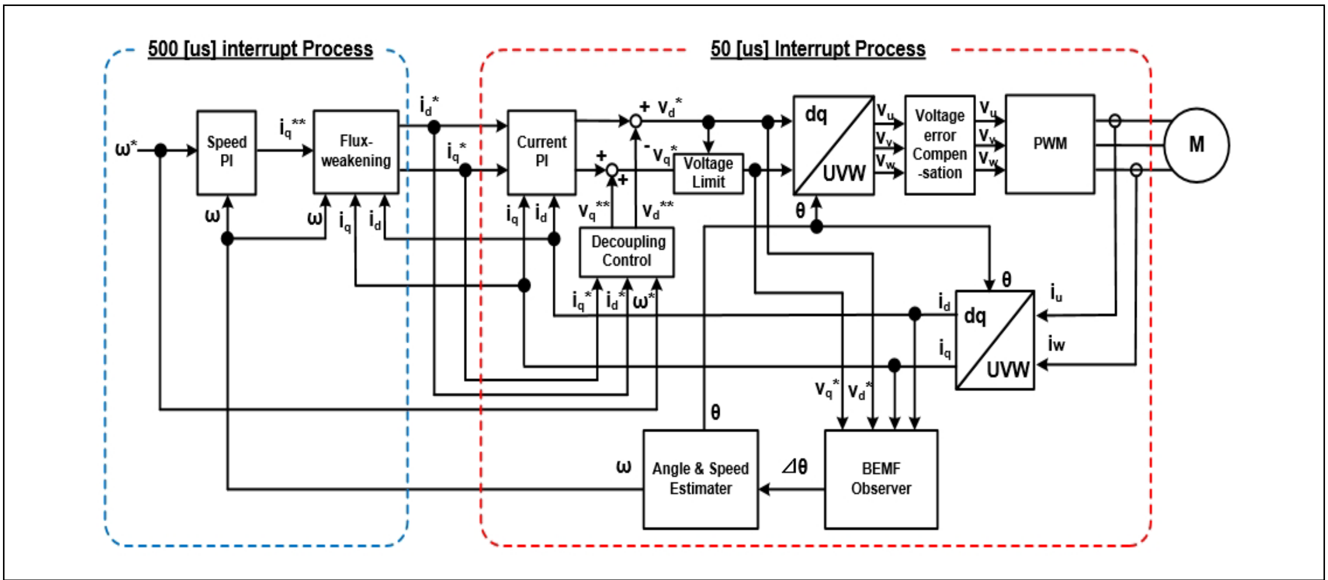


Figure 3-9 Block diagram of sensorless vector control (sensorless control)

This chapter shows the specification of 2 interrupt functions and functions executed in each interrupt cycle. In 3.4 List of functions, only primary functions of the hall sensor/sensorless vector control are listed. Regarding the specification of functions not listed in following tables, refer to source codes.

3.4 List of functions

Table 3-6 List of functions executed in 50[μs] period interrupt (1/6)

File name	Function name	Process overview
mtr_main.c	mtr_callback_event0 Input : (motor_sensorless_callback_args_t *) p_args / Callback argument Output : None	Vector control with hall sensors callback function
	mtr_callback_event1 Input : (motor_sensorless_callback_args_t *) p_args / Callback argument Output : None	Sensorless vector control callback function
rm_motor_hall.c	rm_motor_hall_current_callback Input : (motor_current_callback_args_t *) p_args / Callback argument Output : None	Set the speed control output to the current control input
	RM_MOTOR_HALL_ErrorCheck Input :(motor_ctrl_t * const) p_ctrl / Pointer to control structure (uint16_t * const) p_error / Pointer to get occurred error Output : fsp_err_t / Execution result	Check the occurrence of error
	rm_motor_hall_copy_speed_current Input :(motor_speed_output_t *) st_output / Speed control output (motor_current_input_t *) st_input / Current control input Output : None	Copy speed output data to current input data
rm_motor_sensorless.c	rm_motor_sensorless_current_callback Input :(motor_current_callback_args_t *) p_args / Callback argument Output : None	Set the speed control output to the current control input
	RM_MOTOR_SENSORLESS_ErrorCheck Input :(motor_ctrl_t * const) p_ctrl / Pointer to control structure (uint16_t * const) p_error / Pointer to get occurred error Output : fsp_err_t / Execution result	Check the occurrence of error
	rm_motor_sensorless_copy_speed_current Input :(motor_speed_output_t *) st_output / Speed control output (motor_current_input_t *) st_input / Current control input Output : None	Copy speed output data to current input data

Table 3-7 List of functions executed in 50[μs] period interrupt (2/6)

File name	Function name	Process overview
rm_motor_driver.c	rm_motor_driver_cyclic Input :(adc_callback_args_t *) p_args / Callback argument Output : None	Motor driver callback function
	rm_motor_driver_current_get Input :(motor_driver_instance_ctrl_t *) p_ctrl / Pointer to motor driver instance Output : None	Get A/D converted data (phase current & main line voltage)
	RM_MOTOR_DRIVER_FlagCurrentOffsetGet Input :(motor_driver_ctrl_t * const) p_ctrl / Pointer to control structure (uint8_t * const) p_flag_offset / Flag of finish current offset detection Output : fsp_err_t / Execution result	Measure current offset values
	RM_MOTOR_DRIVER_PhaseVoltageSet Input : (motor_driver_ctrl_t * const) p_ctrl / Pointer to control structure (float const) u_voltage / U phase voltage (float const) v_voltage / V phase voltage (float const) w_voltage / W phase voltage Output : fsp_err_t / Execution result	Set phase voltage data to calculate PWM duty.
	rm_motor_driver_modulation Input : (motor_driver_instance_ctrl_t *) p_ctrl / Pointer to motor driver instance Output : None	Perform PWM modulation
	rm_motor_driver_mod_run Input : (motor_driver_modulation_t *) p_mod / Pointer to modulation data structure (const float *) p_f4_v_in / Pointer to 3-phase input voltage (float *) p_f4_duty_out / Where to store the 3-phase output duty cycle Output : None	Calculates duty cycle from input 3-phase voltage (bipolar)
	rm_motor_driver_set_uvw_duty Input : (motor_driver_instance_ctrl_t *) p_ctrl / Pointer to motor driver instance (float) f_duty_u / Duty cycle of phase-U (float) f_duty_v / Duty cycle of phase-V (float) f_duty_w / Duty cycle of phase-W Output : fsp_err_t / Execution result	PWM duty setting
	RM_MOTOR_DRIVER_CurrentGet Input : (motor_driver_ctrl_t * const) p_ctrl / Pointer to control structure (motor_driver_current_get_t * const) p_current_get / Pointer to get data structure Output : fsp_err_t / Execution result	Get calculated phase current, Vdc & Va_max data

Table 3-8 List of functions executed in 50[μs] period interrupt (3/6)

File name	Function name	Process overview
rm_motor_current.c	rm_motor_current_cyclic Input : (motor_driver_callback_args_t *) p_args / Callback argument Output : None	Current control cycle operation
	RM_MOTOR_CURRENT_ParameterSet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (motor_current_input_current_t const * const) p_st_input / Pointer to input current structure Output : fsp_err_t / Execution result	Set (input) parameter data.
	RM_MOTOR_CURRENT_CurrentSet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (motor_current_input_current_t const * const) p_st_current / Pointer to input current structure (motor_current_input_voltage_t const * const) p_st_voltage / Pointer to input voltage structure Output : fsp_err_t / Execution result	Set d/q-axis current & voltage data.
	RM_MOTOR_CURRENT_CurrentGet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (float * const) p_id / Pointer to get d-axis current (float * const) p_iq / Pointer to get q-axis current Output : fsp_err_t / Execution result	Get d/q-axis current
	motor_current_transform_uvw_dq_abs Input : (const float) f_angle / Rotor angle (const float *) f_uvw / Pointer to UVW-phase array in [U,V,W] format (float *) f_dq / Where to store [d,q] formated array on dq coordinates Output : None	Coordinate transform UVW to dq (absolute transform)

Table 3-9 List of functions executed in 50[μs] period interrupt (4/6)

File name	Function name	Process overview
rm_motor_current.c	motor_current_angle_cyclic Input : (motor_current_instance_t *) p_instance / Pointer to current control module control instance Output : None	Angle/speed process in cyclic process of current control
	RM_MOTOR_CURRENT_SpeedPhaseSet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (float const) speed_rad / Rotational speed (float const) phase_rad / Rotor phase Output : fsp_err_t / Execution result	Set current speed & rotor phase data
	RM_MOTOR_CURRENT_CurrentReferenceSet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (float const) speed_rad / D-axis current Reference (float const) phase_rad / Q-axis current Reference Output : fsp_err_t / Execution result	Set current reference data
	RM_MOTOR_CURRENT_PhaseVoltageGet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (motor_current_get_voltage_t * const) p_voltage / Pointer to get voltages Output : fsp_err_t / Execution result	Gets the set phase voltage
	motor_current_pi_calculation Input : (motor_current_instance_ctrl_t *) p_instance / Pointer to FOC current control structure Output : None	Calculates output voltage vector from current vector command and actual current vector
	motor_current_pi_control Input : (motor_current_pi_params_t *) pi_ctrl / Pointer to PI control structure Output : float / PI control output value	PI control
	motor_current_limit_abs Input : (float) f4_value / Target value (float) f4_limit_value / Limit Output : float / Limited value	Limit with absolute value
	motor_current_decoupling Input : (motor_current_instance_ctrl_t *) p_ctrl / `Pointer to FOC current control instance (float) f_speed_rad / Electrical speed (const motor_current_motor_parameter_t *) p_mtr / Pointer to motor parameter data structure Output : None	Decoupling control
	motor_current_voltage_limit Input : (motor_current_instance_ctrl_t *) p_ctrl / Pointer to FOC current control structure Output : None	Limit voltage vector

Table 3-10 List of functions executed in 50[μs] period interrupt (5/6)

File name	Function name	Process overview
rm_motor_current.c	motor_current_transform_dq_uvw_abs Input : (const float) f_angle / Rotor angle (const float *) f_dq / Pointer to dq-axis value array in [D,Q] format (float *) f_uvw / Where to store [U,V,W] formatted 3-phase quantities array Output : None	Coordinate transform dq to UVW 3-phase (absolute transform)
librm_motor_current.a	rm_motor_voltage_error_compensation_main Input : (motor_currnt_voltage_compensation_t *) st_volt_comp / Voltage error compensation data (float *) p_f4_v_array / Reference voltage (float *) p_f4_i_array / Reference current (float) f4_vdc / Bus voltage Output : None	Voltage error compensation
rm_motor_sense_hall.c	RM_MOTOR_SENSE_HALL_FlagPiCtrlSet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (uint32_t const) flag_pi / Flag of PI control runs Output : fsp_err_t / Execution result	Set the flag of PI Control runs
	RM_MOTOR_SENSE_HALL_AngleSpeedGet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (float * const) p_angle / Memory address to get rotor angle data (float * const) p_speed / Memory address to get rotational speed data (float * const) p_phase_err / Memory address to get phase (angle) error data Output : fsp_err_t / Execution result	Gets the current rotor's angle and rotation speed. (phase error data is invalid.)
rm_motor_estimate.c	RM_MOTOR_ESTIMATE_FlagPiCtrlSet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (uint32_t const) flag_pi / Flag of PI control runs Output : fsp_err_t / Execution result	Set the flag of PI Control runs
	RM_MOTOR_ESTIMATE_SpeedSet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (float const) speed_ctrl / Control reference of rotational speed (float const) damp_speed / Damping rotational speed Output : fsp_err_t / Execution result	Set speed Information
	RM_MOTOR_ESTIMATE_CurrentSet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (motor_angle_current_t * const) p_st_current / Pointer to current structure (motor_angle_voltage_reference_t * const) p_st_voltage / Pointer to voltage reference structure Output : fsp_err_t / Execution result	Set d/q-axis current data & voltage reference
	RM_MOTOR_ESTIMATE_AngleSpeedGet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (float * const) p_angle / Memory address to get rotor angle data (float * const) p_speed / Memory address to get rotational speed data (float * const) p_phase_err / Memory address to get phase (angle) error data Output : fsp_err_t / Execution result	Gets the current rotor's angle and rotation speed
	RM_MOTOR_ESTIMATE_EstimatedComponentGet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (float * const) p_ed / Memory address to get estimated d-axis component (float * const) p_eq / Memory address to get estimated q-axis component Output : fsp_err_t / Execution result	Gets estimated d/q-axis component

Table 3-11 List of functions executed in 50[μs] period interrupt (6/6)

File name	Function name	Process overview
r_gpt_three_phase.c	R_GPT_THREE_PHASE_DutyCycleSet Input : (three_phase_ctrl_t * const) p_ctrl / Control block set in @ref three_phase_api_t::open call for this timer (three_phase_duty_cycle_t * const) p_duty_cycle / Duty cycle values for all three timer channels Output : fsp_err_t / Execution result	Sets duty cycle for all three timers

Table 3-12 List of functions executed in 500[μs] period interrupt (1/3)

File name	Function name	Process overview
mtr_main.c	mtr_callback_event0 Input : motor_callback_args_t * p_args / Callback argument Output : None	Vector control with hall sensors callback function
	mtr_callback_event1 Input : motor_callback_args_t * p_args / Callback argument Output : None	Sensorless control callback function
	get_vr1 Input : None Output : uint16_t / Conversion value	Get VR1 A/D conversion value
rm_motor_current.c	RM_MOTOR_CURRENT_ParameterGet Input : (motor_current_ctrl_t * const) p_ctrl / Pointer to control structure (motor_current_input_current_t const * const) p_st_input / Pointer to input current data Output : fsp_err_t / Execution result	Set (input) parameter data
rm_motor_hall.c	rm_motor_hall_speed_callback Input : (motor_speed_callback_args_t *) p_args / Callback argument Output : None	Speed control callback function
	rm_motor_hall_copy_current_speed Input : (motor_current_output_t *) st_output / Pointer to structure of current control output (motor_speed_input_t *) st_input / Pointer to structure of speed control input Output : None	Copy current output data to speed input data
rm_motor_sensorless.c	rm_motor_sensorless_speed_callback Input : (motor_speed_callback_args_t *) p_args / Callback argument Output : None	Speed control callback function
	rm_motor_sensorless_copy_current_speed Input : (motor_current_output_t *) st_output / Pointer to structure of current control output (motor_speed_input_t *) st_input / Pointer to structure of speed control input Output : None	Copy current output data to speed input data

Table 3-13 List of functions executed in 500[μs] period interrupt (2/3)

File name	Function name	Process overview
rm_motor_speed.c	rm_motor_speed_cyclic Input : (timer_callback_args_t *) p_args / Callback argument Output : None	Cyclic process of speed control (Call at timer interrupt)
	RM_MOTOR_SPEED_ParameterSet Input : (motor_speed_ctrl_t * const) p_ctrl / Pointer to control structure (motor_speed_input_t const * const) p_st_input / Pointer to structure of speed input parameters Output : fsp_err_t / Execution result	Set speed Input parameters
	RM_MOTOR_SPEED_SpeedControl Input : (motor_speed_ctrl_t * const) p_ctrl / Pointer to control structure Output : fsp_err_t / Execution result	Calculates the d/q-axis current reference. (Main process of Speed Control)
	rm_motor_speed_set_speed_ref Input : (motor_speed_instance_ctrl_t *) p_ctrl / Pointer to FOC data instance Output : float / Reference speed	Updates the speed reference
	rm_motor_speed_set_iq_ref Input : (motor_speed_instance_ctrl_t *) p_ctrl / Pointer to control instance Output : float / Iq reference	Updates the q-axis current reference
	rm_motor_speed_set_id_ref Input : (motor_speed_instance_ctrl_t *) p_ctrl / Pointer to control instance Output : float / Id reference	Updates the d-axis current reference
	RM_MOTOR_SPEED_ParameterGet Input : (motor_speed_ctrl_t * const) p_ctrl / Pointer to motor speed control block (motor_speed_output_t * const) p_st_output / Pointer to get speed control parameters Output : fsp_err_t / Execution result	Get speed control output parameters

Table 3-14 List of functions executed in 500[μs] period interrupt (3/3)

File name	Function name	Process overview
librm_motor_speed.a	rm_motor_speed_first_order_lpf Input : (motor_speed_lpf_t *) p_lpf / Pointer to first order LPF structure (float) f_input / Input data Output : float / Filtered data	First order LPF
	rm_motor_speed_fluxwkn_set_vamax Input : (motor_speed_flux_weakening_t *) p_fluxwkn / Pointer to flux weakening structure (float) f4_va_max / maximum magnitude of voltage vector Output : None	Sets the maximum magnitude of voltage vector
	rm_motor_speed_fluxwkn_run Input : (motor_speed_flux_weakening_t *) p_fluxwkn / Pointer to flux weakening structure (float) f4_speed_rad / Electrical speed of motor (const float *) p_f4_idq / Pointer to the measured current vector in format d/q (float *) p_f4_idq_ref / Pointer to reference current vector in format d/q Output : None	Executes the flux-weakening module

3.5 Contents of Control

3.5.1 Configuration options

The configuration options of the hall sensor/sensorless vector control module for motor can be configured using the RA Configurator. The changed options are automatically reflected to the hal_data.h and rm_motor_sensorless.h when generating code. The option names and setting values are listed in the shown as follows.

Table 3-15 Configuration options

Configuration Options (rm_motor_hall.h / rm_motor_sensorless.h)	
Options	**Description**
Limit of over current (A) Initial : 1.67	When a phase current exceeds this value, PWM output ports are set to off.
Limit of over voltage (V) Initial : 60.0	When an inverter voltage exceeds this value, PWM output ports are set to off.
Limit of over speed (rpm) Initial : 4500.0	When a rotation speed exceeds this value, PWM output ports are set to off.
Limit of over speed (rpm) Initial : 8.0	When an inverter voltage becomes below this value, PWM output ports are set to off.

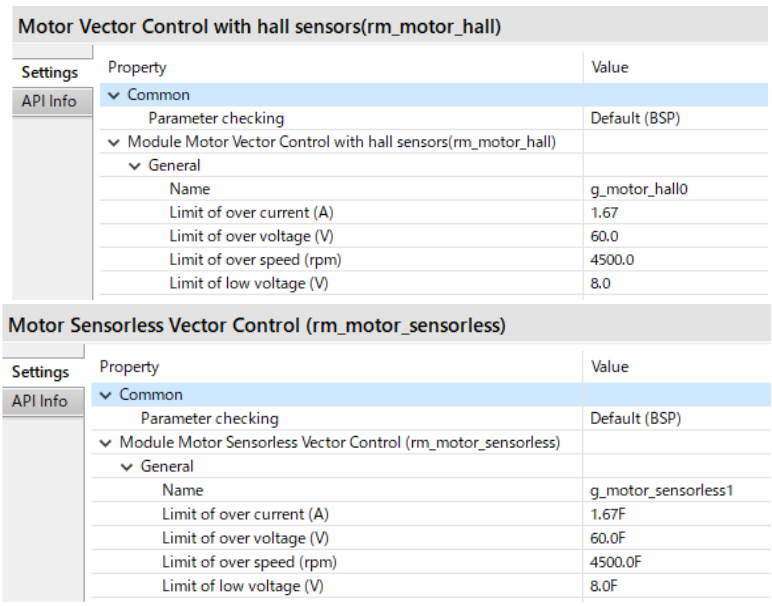


Figure 3-10 FSP configuration of hall sensor/sensorless motor vector control

3.5.2 Configuration Options for included modules

The hall sensor/sensorless vector control module for motor includes below modules.

- Current Module
- Speed Module
- Angle Module
- Driver Module

And also these included modules have each configuration parameters as same as the hall sensor/sensorless vector control module. The option names and setting values are listed in the tables shown as follows.

Table 3-16 Configuration options for current control

Configuration Options (rm_motor_current.h)	
Options	**Description**
Shunt type Initial : 2shunt	Selects how many shunt resistances to use current detection.
Input voltage (V) Initial : 24.0	Input voltage [V]
Voltage error compensation Initial : Enable	Selects whether to “enable” or “disable” voltage error compensation.
Design Parameter | Current PI loop omega Initial : 300.0	Current PI control omega parameter [Hz].
Design Parameter | Current PI loop zeta Initial : 1.0	Current PI control zeta parameter.
Motor Parameter | Pole pairs Initial : 4	Pole pairs of target motor.
Motor Parameter | Resistance (ohm) Initial : 1.3	Resistance of motor [ohm].
Motor Parameter | Inductance of d-axis (H) Initial : 0.0013	D-axis inductance [H].
Motor Parameter | Inductance of q-axis (H) Initial : 0.0013	Q-axis inductance [H].
Motor Parameter | Permanent magnetic flux (Wb) Initial : 0.01119	Magnetic flux [Wb].
Motor Parameter | Rotor inertia (kgm^2) Initial : 0.000003666	Rotor inertia [kgm^2].

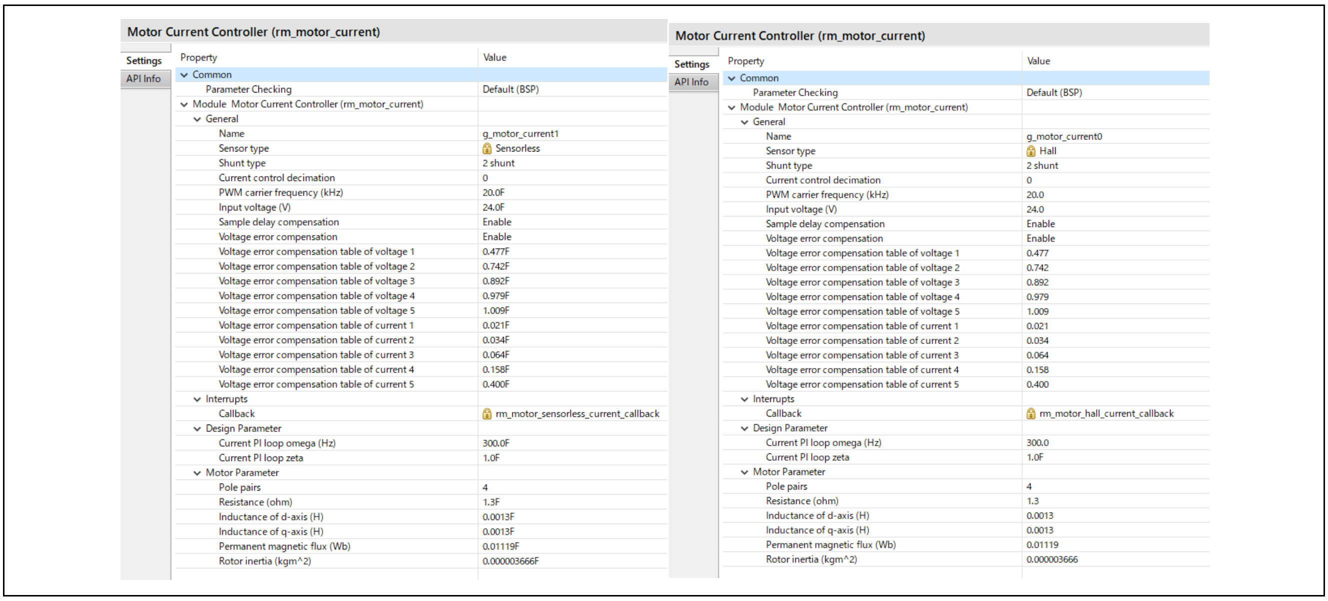


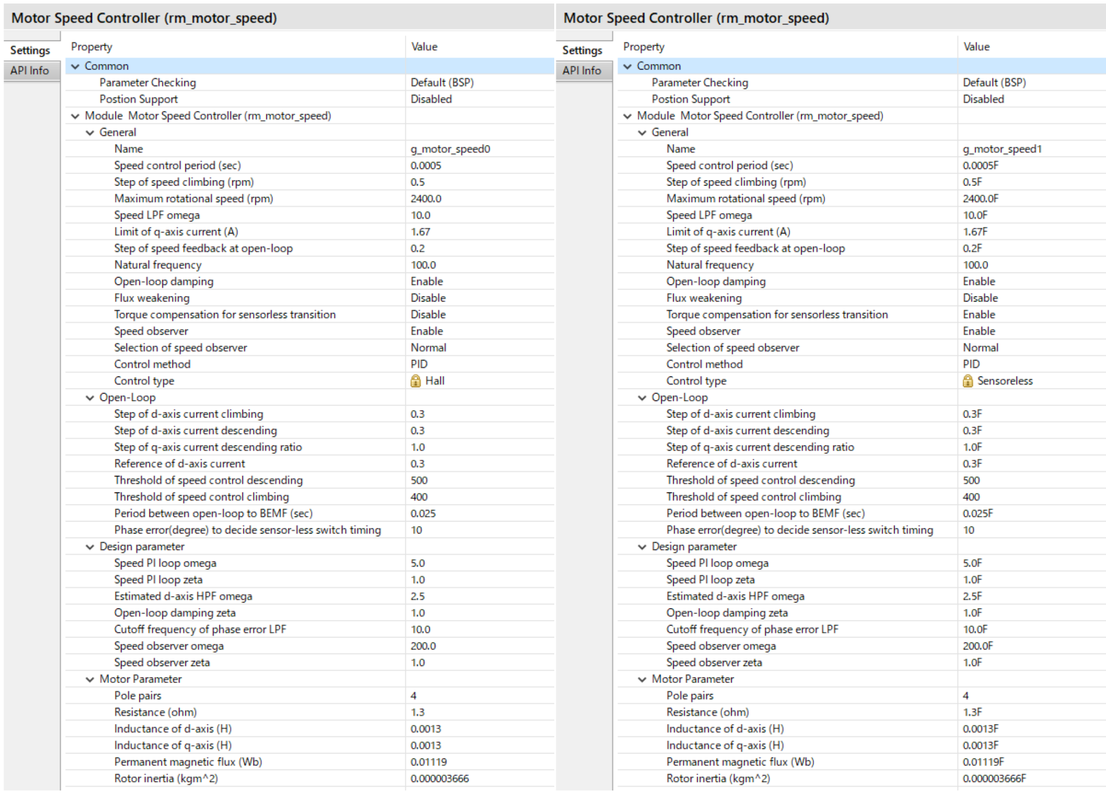
Figure 3-11 FSP Configuration of motor current controller

Table 3-17 Configuration options for speed control (1/2)

Configuration Options (rm_motor_speed.h)	
Options	**Description**
Speed control period (sec) Initial : 0.0005	The period of speed control process [sec].
Step of speed climbing (rpm) Initial : 0.5	The step of speed fluctuation [rpm]. Program controls speed by this step at acceleration and deceleration.
Maximum rotational speed (rpm) Initial : 2400.0	Maximum rotational speed [rpm]
Speed LPF omega Initial : 10.0	Speed LPF parameter omega [Hz].
Speed at Id climbing (rpm) Initial : 400.0	The threshold speed to control d-axis current increase [rad/s]. Program increases d-axis current at start up the motor rotation until the speed reaches this value.
Limit of q-axis current (A) Initial : 1.67	Limit of q-axis current [A].
Step of speed feedback at open-loop Initial : 0.2	Rate of reference speed for feedback speed limiter at Open-Loop.
Open-loop damping Initial : Enable	Select enable/disable of damping control at Open-Loop.
Flux weakening Initial : Disable	Select enable/disable of flux weakening control at high speed.
Torque compensation for sensorless transition Initial : Enable	Select enable/disable of soft switching at the transition from Open-Loop to PI control.

Table 3-18 Configuration options for speed control (2/2)

Configuration Options (rm_motor_speed.h)	
Options	**Description**
Open-Loop | Step of d-axis current climbing Initial : 0.3	The d-axis current reference ramping up rate [A/msec].
Open-Loop | Step of d-axis current descending Initial : 0.3	The d-axis current reference ramping down rate [A/msec].
Open-Loop | Step of q-axis current descending ratio Initial : 1.0	The q-axis current reference ramping down proportion to reference before open-loop [A/msec].
Open-Loop | Reference of d-axis current Initial : 0.3	The d-axis current reference in open-loop drive [A].
Open-Loop | Threshold of speed control descending Initial : 500.0	The speed threshold [rad/s] to ramp down the d-axis current [rpm].
Open-Loop | Threshold of speed control climbing Initial : 400.0	The speed threshold [rad/s] to ramp up the d-axis current [rpm].
Open-Loop | Period between open-loop to BEMF (sec) Initial : 0.025	Time to switch open-loop to sensor-less [sec].
Open-Loop | Phase error(degree) to decide sensor-less switch timing Initial : 10.0	Phase error to decide sensor-less switch timing (electrical angle) [degree].
Design parameter | Speed PI loop omega Initial : 5.0	Speed PI Control parameter omega.
Design parameter | Speed PI loop zeta Initial : 1.0	Speed PI Control parameter zeta.
Design parameter | Estimated d-axis HPF omega Initial : 2.5	Natural frequency [Hz] for HPF in open-loop damping gain design.
Design parameter | Open-loop damping zeta Initial : 1.0	Damping ratio for open-loop damping gain design.
Design parameter | Cutoff frequency of phase error LPF Initial : 10.0	The cut-off frequency [Hz] of phase error LPF gain design.
Design parameter | Speed observer omega Initial : 200.0	Speed observer omega.
Design parameter | Speed observer zeta Initial : 1.0	Speed observer zeta.
Motor Parameter | Pole pairs Initial : 4	Pole pairs of target motor.
Motor Parameter | Resistance (ohm) Initial : 1.3	Resistance of motor [ohm].
Motor Parameter | Inductance of d-axis (H) Initial : 0.0013	D-axis inductance [H].
Motor Parameter | Inductance of q-axis (H) Initial : 0.0013	Q-axis inductance [H].
Motor Parameter | Permanent magnetic flux (Wb) Initial : 0.01119	Magnetic flux [Wb].
Motor Parameter | Rotor inertia (kgm^2) Initial : 0.000003666	Rotor inertia [kgm^2].



Motor Speed Controller (rm_motor_speed)

Property	Value
Common	
Parameter Checking	Default (BSP)
Postion Support	Disabled
Module Motor Speed Controller (rm_motor_speed)	
General	
Name	g_motor_speed0
Speed control period (sec)	0.0005
Step of speed climbing (rpm)	0.5
Maximum rotational speed (rpm)	2400.0
Speed LPF omega	10.0
Limit of q-axis current (A)	1.67
Step of speed feedback at open-loop	0.2
Natural frequency	100.0
Open-loop damping	Enable
Flux weakening	Disable
Torque compensation for sensorless transition	Disable
Speed observer	Enable
Selection of speed observer	Normal
Control method	PID
Control type	Hall
Open-Loop	
Step of d-axis current climbing	0.3
Step of d-axis current descending	0.3
Step of q-axis current descending ratio	1.0
Reference of d-axis current	0.3
Threshold of speed control descending	500
Threshold of speed control climbing	400
Period between open-loop to BEMF (sec)	0.025
Phase error(degree) to decide sensor-less switch timing	10
Design parameter	
Speed PI loop omega	5.0
Speed PI loop zeta	1.0
Estimated d-axis HPF omega	2.5
Open-loop damping zeta	1.0
Cutoff frequency of phase error LPF	10.0
Speed observer omega	200.0
Speed observer zeta	1.0
Motor Parameter	
Pole pairs	4
Resistance (ohm)	1.3
Inductance of d-axis (H)	0.0013
Inductance of q-axis (H)	0.0013
Permanent magnetic flux (Wb)	0.01119
Rotor inertia (kgm^2)	0.000003666

Motor Speed Controller (rm_motor_speed)

Property	Value
Common	
Parameter Checking	Default (BSP)
Postion Support	Disabled
Module Motor Speed Controller (rm_motor_speed)	
General	
Name	g_motor_speed1
Speed control period (sec)	0.0005F
Step of speed climbing (rpm)	0.5F
Maximum rotational speed (rpm)	2400.0F
Speed LPF omega	10.0F
Limit of q-axis current (A)	1.67F
Step of speed feedback at open-loop	0.2F
Natural frequency	100.0
Open-loop damping	Enable
Flux weakening	Disable
Torque compensation for sensorless transition	Enable
Speed observer	Enable
Selection of speed observer	Normal
Control method	PID
Control type	Sensoreless
Open-Loop	
Step of d-axis current climbing	0.3F
Step of d-axis current descending	0.3F
Step of q-axis current descending ratio	1.0F
Reference of d-axis current	0.3F
Threshold of speed control descending	500
Threshold of speed control climbing	400
Period between open-loop to BEMF (sec)	0.025F
Phase error(degree) to decide sensor-less switch timing	10
Design parameter	
Speed PI loop omega	5.0F
Speed PI loop zeta	1.0F
Estimated d-axis HPF omega	2.5F
Open-loop damping zeta	1.0F
Cutoff frequency of phase error LPF	10.0F
Speed observer omega	200.0F
Speed observer zeta	1.0F
Motor Parameter	
Pole pairs	4
Resistance (ohm)	1.3F
Inductance of d-axis (H)	0.0013F
Inductance of q-axis (H)	0.0013F
Permanent magnetic flux (Wb)	0.01119F
Rotor inertia (kgm^2)	0.000003666F

Figure 3-12 FSP configuration of motor speed controller

Table 3-19 Configuration options for angle and speed calculation with hall sensors

Configuration Options (rm_motor_sense_hall.h)	
Options	**Description**
PMW Carrier Frequency (kHz) Initial : 20.0	Carrier Frequency [kHz]
Correction parameter of rotor angle Initial : 0.4	Angle correction value
Default counts of carrier interrupt Initial : 1000	Number of carrier interrupt measurements
Maximum counts of one rotation Initial : 5000	Maximum number of measurements between Hall sensor signals

Table 3-20 Configuration options for angle and speed estimation

Configuration Options (rm_motor_ estimate.h)	
Options	**Description**
Motor Parameter | Pole pairs Initial : 4	Pole pairs of target motor.
Motor Parameter | Resistance (ohm) Initial : 1.3	Resistance of motor [ohm].
Motor Parameter | Inductance of d-axis (H) Initial : 0.0013	D-axis inductance [H].
Motor Parameter | Inductance of q-axis (H) Initial : 0.0013	Q-axis inductance [H].
Motor Parameter | Permanent magnetic flux (Wb) Initial : 0.01119	Magnetic flux [Wb].
Motor Parameter | Rotor inertia (kgm^2) Initial : 0.000003666	Rotor inertia [kgm^2].
Openloop damping Initial : Enable	Select enable/disable of Open-Loop Damping Control
Natural frequency of BEMF observer Initial : 1000.0	Natural frequency for BEMF observer [Hz].
Damping ratio of BEMF observer Initial : 1.0	Damping ratio for BEMF observer.
Natural frequency of PLL Speed estimate loop Initial : 20.0	Natural frequency for rotor position Phase-Locked Loop [Hz].
Damping ratio of PLL Speed estimate loop Initial : 1.0	Damping ratio for rotor position Phase-Locked Loop.
Control period Initial : 0.0005	Period of Speed Control [sec]

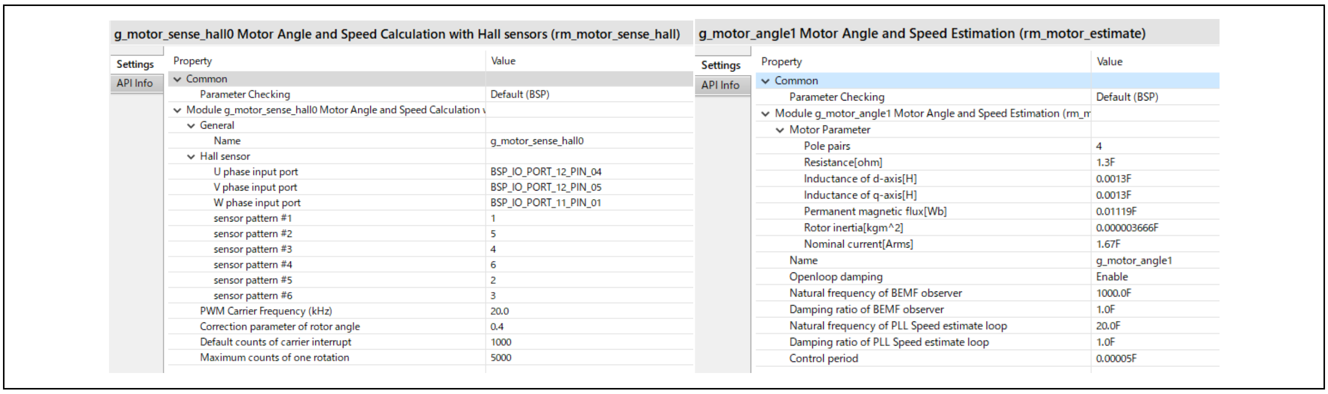
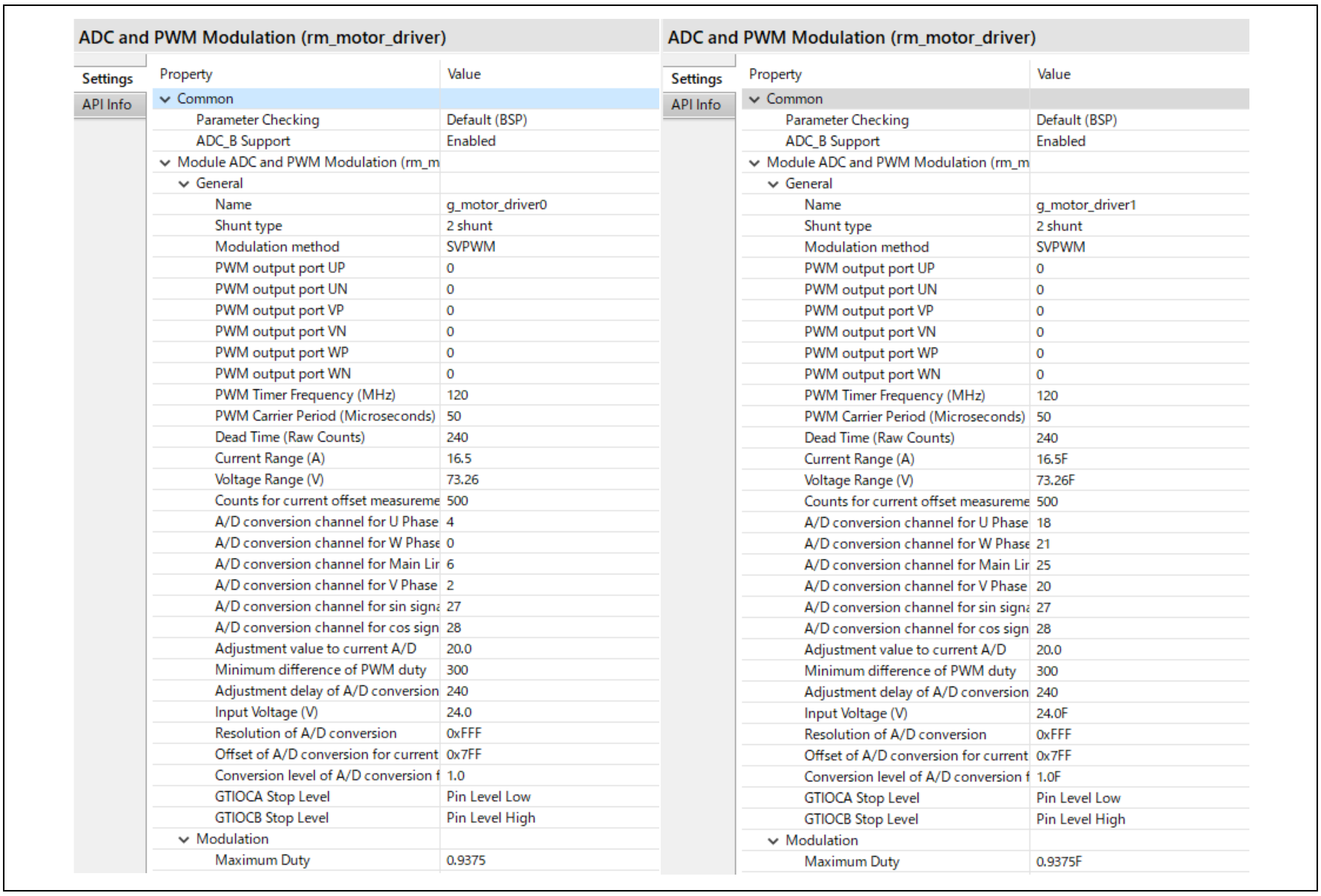


Figure 3-13 FSP configuration of motor angle driver

Table 3-21 Configuration options for ADC and PWM modulation driver

Configuration Options (rm_motor_driver.h)	
Options	**Description**
Shunt type Initial : 2shunt	Current detection method selection
PWM timer frequency (MHz) Initial : 120	PWM Timer Clock Frequency [MHz]
PWM carrier period (Micro seconds) Initial : 50	PWM Carrier Period [Micro seconds]
Dead time (raw counts) Initial : 240	PWM Dead time [raw counts]
Current range (A) Initial : 16.5	Measurement Range of Electric current [A]
Voltage range (V) Initial : 73.26	Measurement Range of Inverter Voltage [V]
Counts for current offset measurement Initial : 500	Counts of measurement the offset of A/D Conversion at electric current input.
A/D conversion channel for U phase current Initial : 4	A/D channel for U-phase current
A/D conversion channel for W phase current Initial : 0	A/D channel for W-phase current
A/D conversion channel for main line voltage Initial : 6	A/D channel for main line voltage
A/D conversion channel for V phase current Initial : 2	A/D channel for V-phase current It is invalid at 2shunt detection.
Input voltage Initial : 24.0	Range of input for main line voltage
Resolution of A/D conversion Initial : 0xFFF	Resolution of A/D conversion Please set same value with ADC module setting.
Offset of A/D conversion for current Initial : 0x7FF	Offset level of A/D conversion input for current Please set according to the circuit.
Conversion level of A/D conversion for voltage Initial : 1.0	Conversion level of A/D conversion for voltage Please set when the CPU main voltage is different.
GTIOCA stop level Initial : Pin level Low	Output level of upper arm at stop status
GTIOCB stop level Initial : Pin level High	Output level of lower arm at stop status
Maximum duty Initial : 0.9375	Maximum duty of PWM Maximum duty except dead time.



ADC and PWM Modulation (rm_motor_driver)

Settings | API Info

Property	Value
Common	
Parameter Checking	Default (BSP)
ADC_B Support	Enabled
Module ADC and PWM Modulation (rm_m	
General	
Name	g_motor_driver0
Shunt type	2 shunt
Modulation method	SVPWM
PWM output port UP	0
PWM output port UN	0
PWM output port VP	0
PWM output port VN	0
PWM output port WP	0
PWM output port WN	0
PWM Timer Frequency (MHz)	120
PWM Carrier Period (Microseconds)	50
Dead Time (Raw Counts)	240
Current Range (A)	16.5
Voltage Range (V)	73.26
Counts for current offset measureme	500
A/D conversion channel for U Phase	4
A/D conversion channel for W Phase	0
A/D conversion channel for Main Lir	6
A/D conversion channel for V Phase	2
A/D conversion channel for sin signa	27
A/D conversion channel for cos sign	28
Adjustment value to current A/D	20.0
Minimum difference of PWM duty	300
Adjustment delay of A/D conversion	240
Input Voltage (V)	24.0
Resolution of A/D conversion	0xFFF
Offset of A/D conversion for current	0x7FF
Conversion level of A/D conversion f	1.0
GTIOCA Stop Level	Pin Level Low
GTIOCB Stop Level	Pin Level High
Modulation	
Maximum Duty	0.9375

ADC and PWM Modulation (rm_motor_driver)

Settings | API Info

Property	Value
Common	
Parameter Checking	Default (BSP)
ADC_B Support	Enabled
Module ADC and PWM Modulation (rm_m	
General	
Name	g_motor_driver1
Shunt type	2 shunt
Modulation method	SVPWM
PWM output port UP	0
PWM output port UN	0
PWM output port VP	0
PWM output port VN	0
PWM output port WP	0
PWM output port WN	0
PWM Timer Frequency (MHz)	120
PWM Carrier Period (Microseconds)	50
Dead Time (Raw Counts)	240
Current Range (A)	16.5F
Voltage Range (V)	73.26F
Counts for current offset measureme	500
A/D conversion channel for U Phase	18
A/D conversion channel for W Phase	21
A/D conversion channel for Main Lir	25
A/D conversion channel for V Phase	20
A/D conversion channel for sin signa	27
A/D conversion channel for cos sign	28
Adjustment value to current A/D	20.0
Minimum difference of PWM duty	300
Adjustment delay of A/D conversion	240
Input Voltage (V)	24.0F
Resolution of A/D conversion	0xFFF
Offset of A/D conversion for current	0x7FF
Conversion level of A/D conversion f	1.0F
GTIOCA Stop Level	Pin Level Low
GTIOCB Stop Level	Pin Level High
Modulation	
Maximum Duty	0.9375F

Figure 3-14 FSP configuration of ADC and PWM modulation driver

3.6 Control flowcharts

3.6.1 Main process

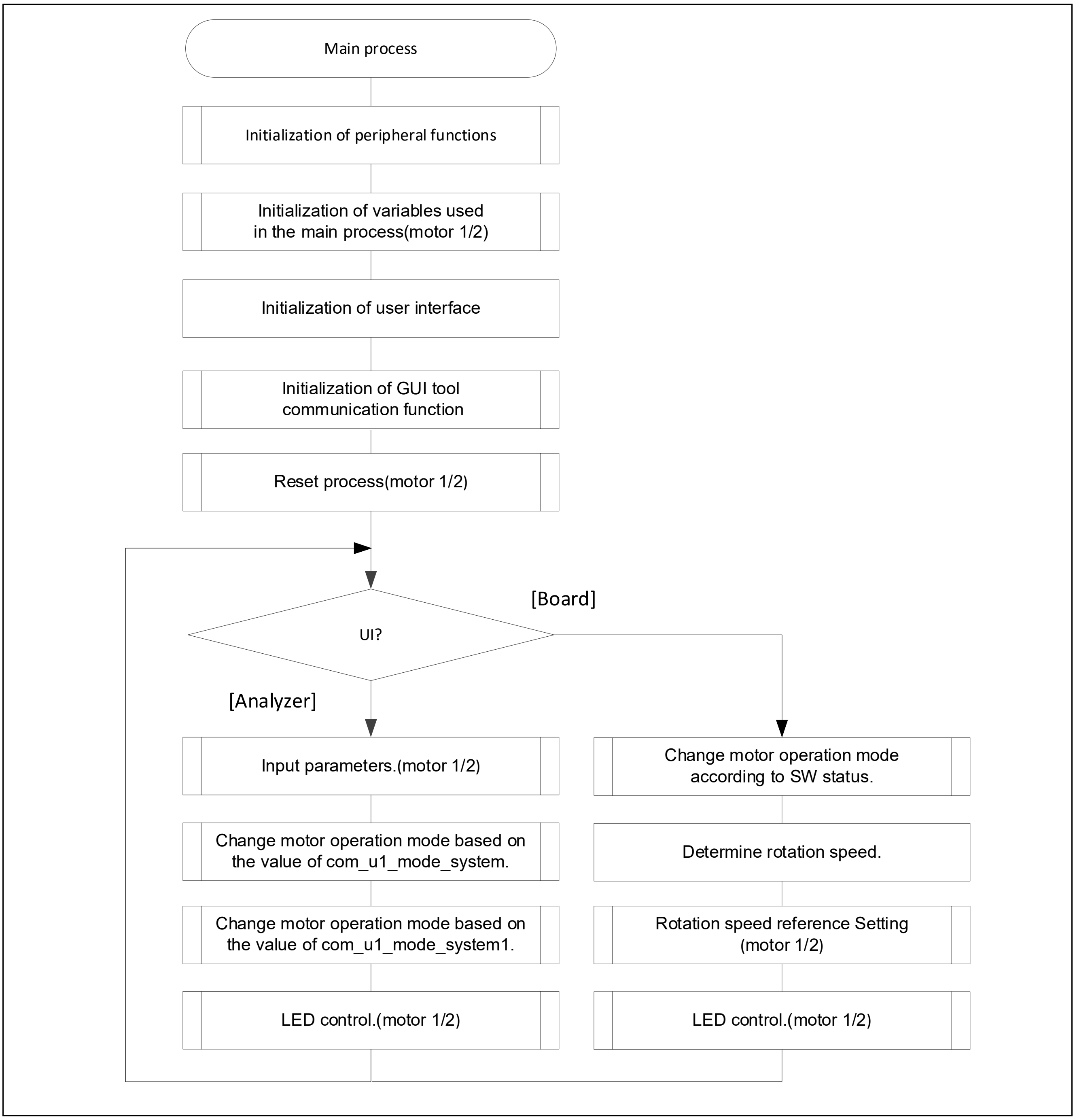


Figure 3-15 Main process flowchart

3.6.2 50[μs] period interrupt (carrier synchronized interrupt) process

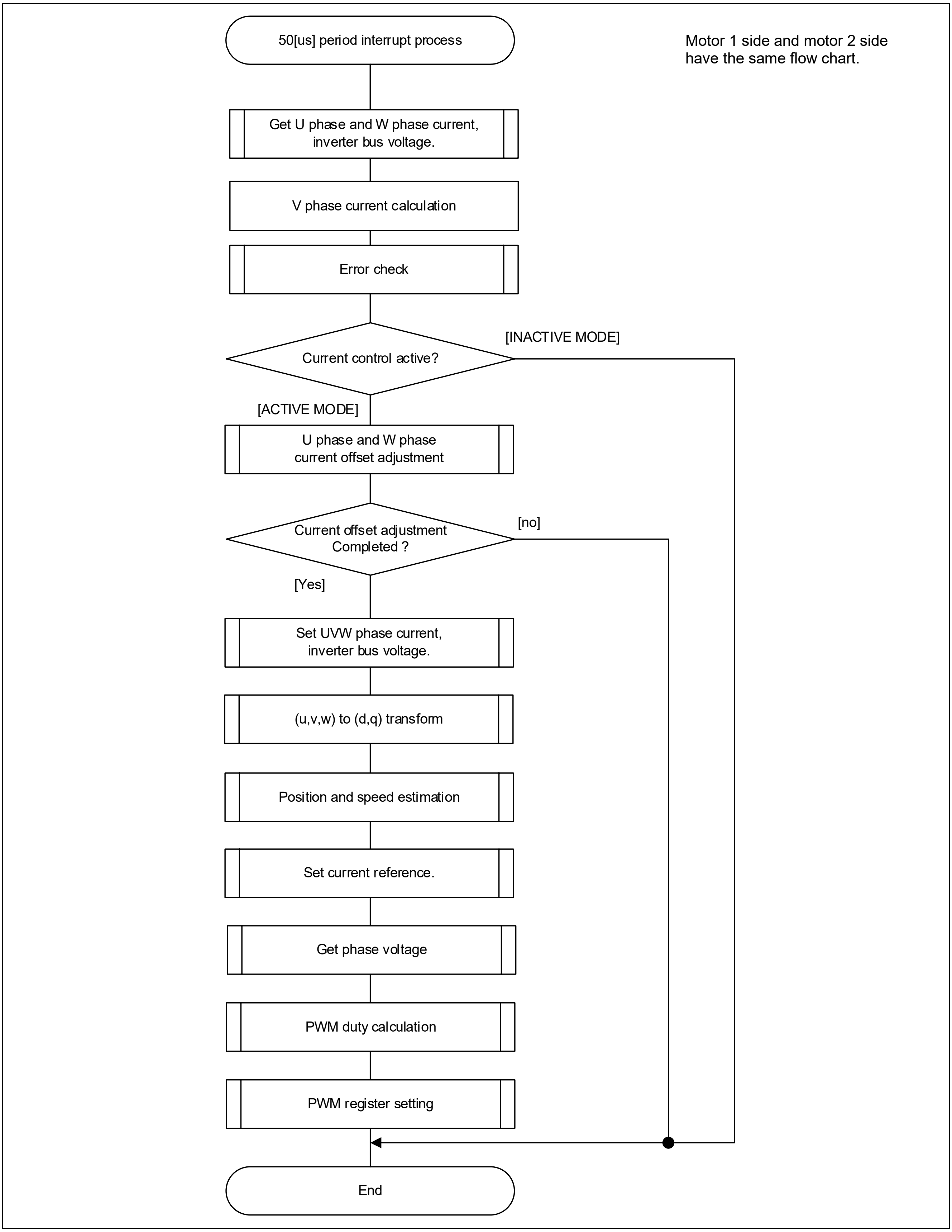


Figure 3-16 50[μs] period interrupt (carrier interrupt) process flowchart

3.6.3 500 [μs] period interrupt process

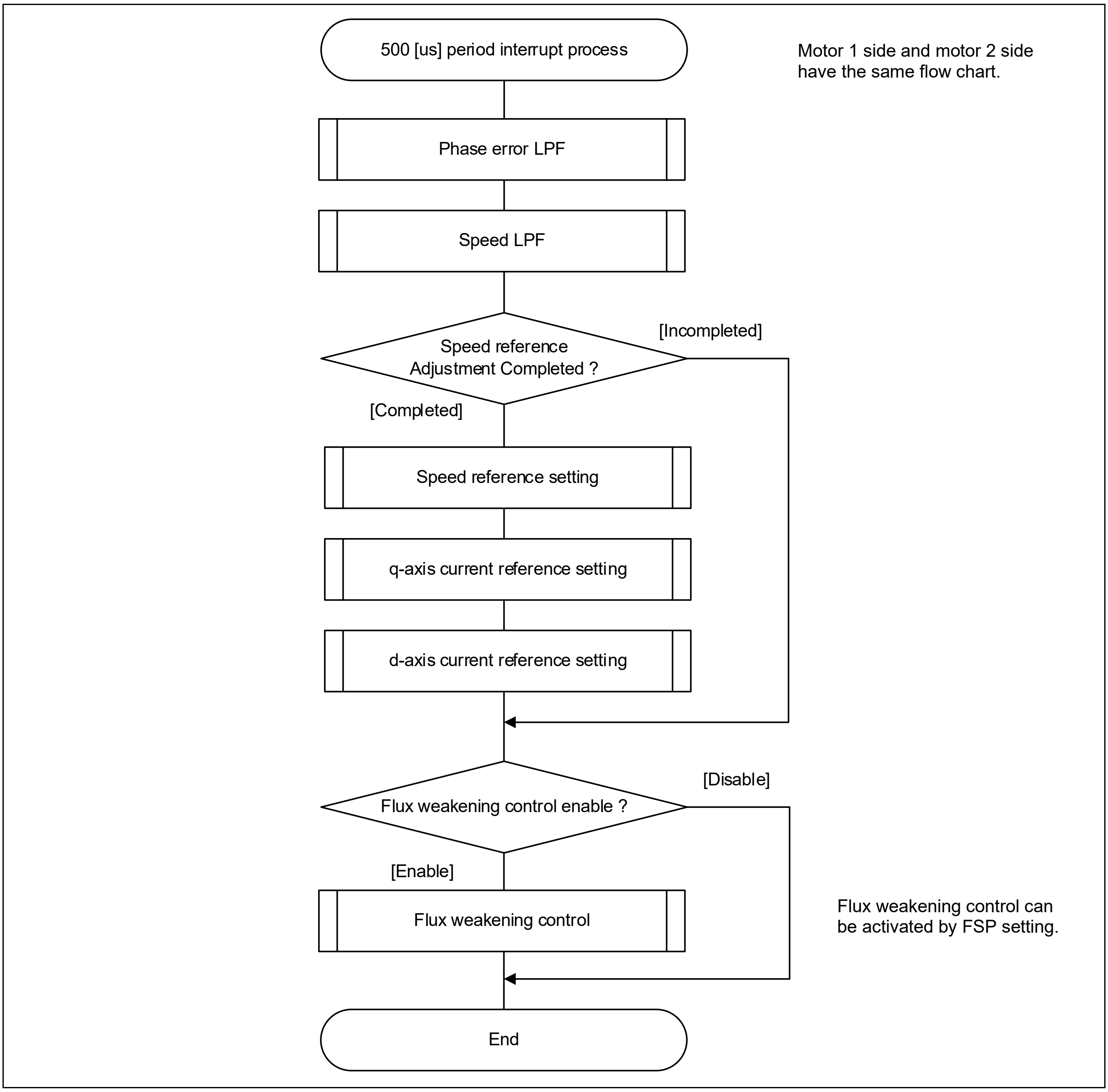


Figure 3-17 500[μs] period interrupt process flowchart

3.6.4 Over current detection interrupt process

The over current detection interrupt occurs when GTETRGD and GTETRGB pin detects an output short circuit. Therefore, when this interrupt process is executed, PWM output pins are already in high-impedance state and the output to the motor is stopped.

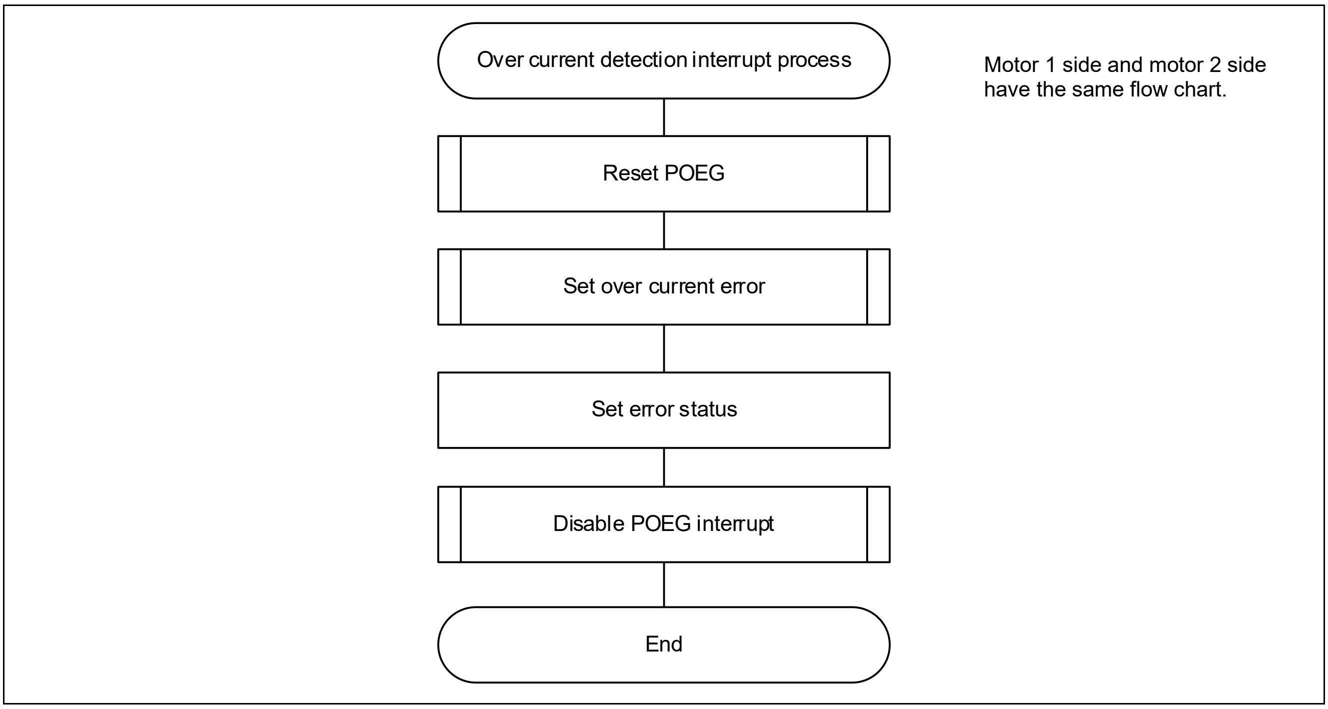


Figure 3-18 Over current detection interrupt process flowchart

4. Project Operation Overview

This section explains the operation of the sample program.

4.1 Importing Demo Project

The sample application provided with this document may be imported into e[2] studio using the steps in this section.

(1) Select File → Import

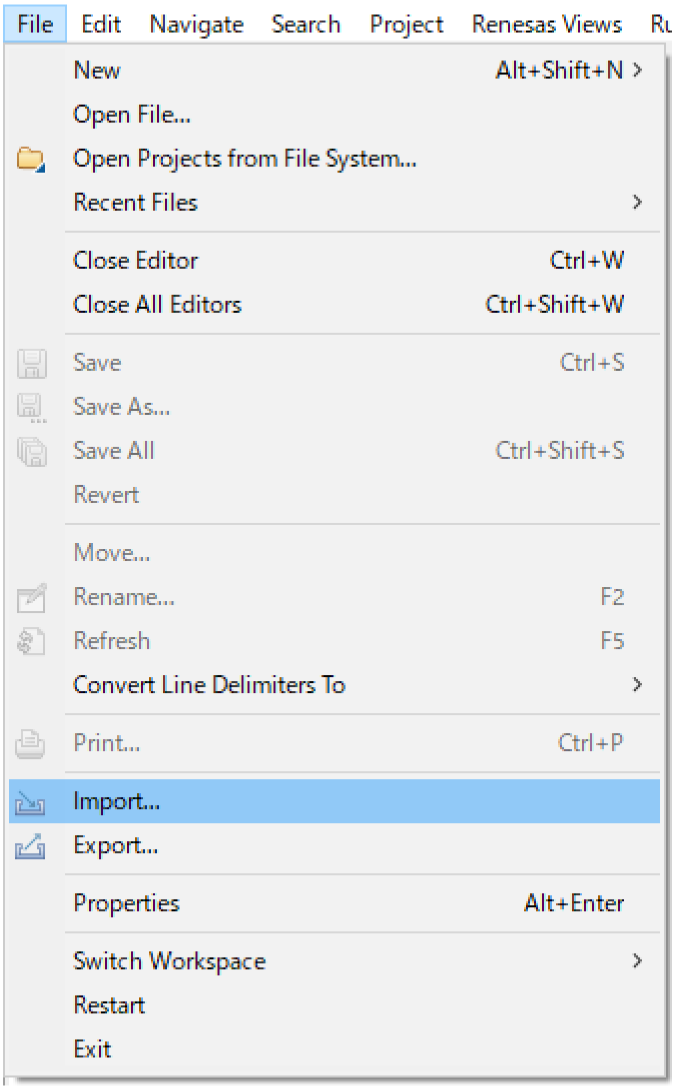


Figure 4-1 File menu

(2) Select "Existing Projects into Workspace".

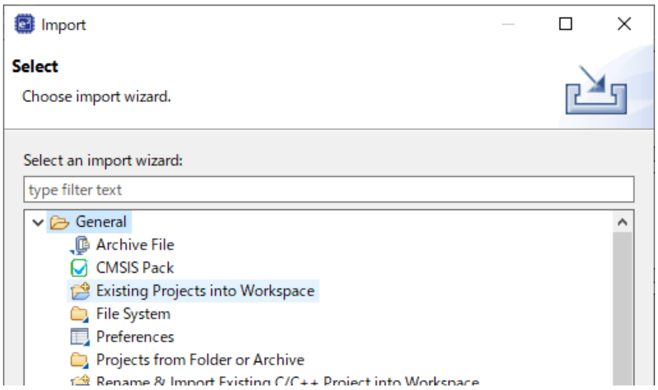


Figure 4-2 Import wizard selection

(3) Click "Browse…" button and select the demo project. Click 'Finish' button and the demo project is imported.

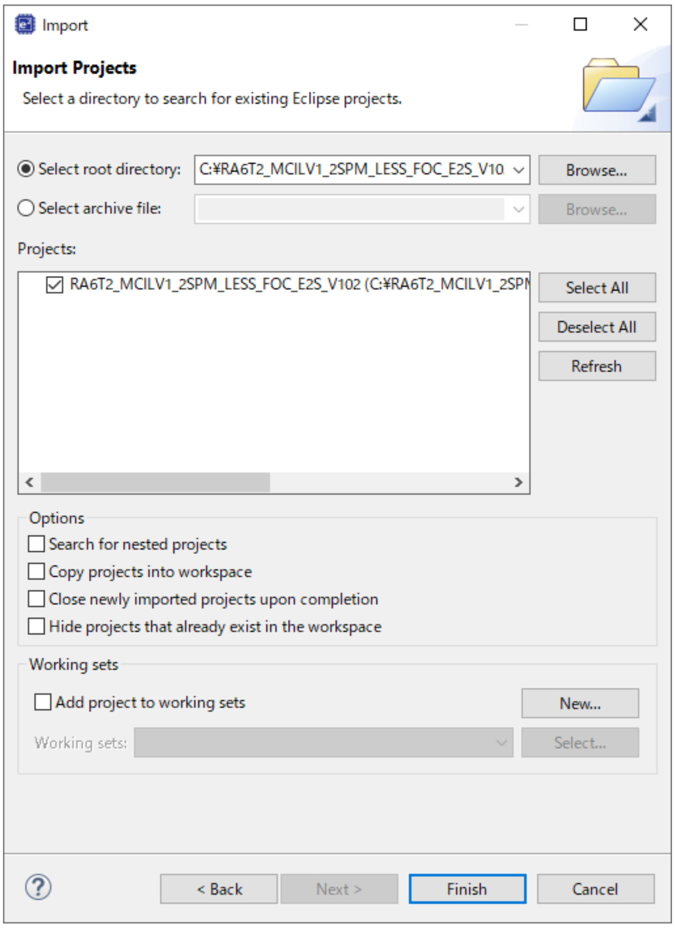


Figure 4-3 Import projects

4.2 Building and Debugging

Refer to the "e2studio User's Manual : Quick Start Guide (R20UT5210)".

4.3 Quick Start

When executing the sample code only in the evaluation environment without using Renesas motor workbench, the following procedure can be executed

(1) After turning on stabilized power supply or executing reset, LED1_1, LED1_2, LED2_1, and LED2_2 on the inverter board are both off and the motor stops.
(2) IF the toggle switch (SW1_1, SW1_2) on the inverter board is turned on, the motor starts to rotate. Every time the toggle switch (SW1_1, SW1_2) is changed, motor rotation starts/stops alternately. If the motor rotates normally, LED1_1, LED1_2 on the inverter board is on. However, if LED2_1, LED2_2 on the inverter board is also on, error is occurring.
(3) In order to change the direction of the motor rotation, adjust it with the variable resistor (VR1) on the inverter board.
  — Turn the variable resistor (VR1) right: Both motor 1 and motor 2 rotate clockwise
  — Turn the variable resistor (VR1) left: Both motor 1 and motor 2 rotate counterclockwise
(4) If error occurs, LED2_1 or LED2_2 on the inverter board lighten, and the motor rotation stops. To restore, the toggle switch (SW1_1, SW1_2) on the inverter board needs to be turned off, the push switch (SW2_1, SW2_2) to be pushed and released,
(5) In order to stop the operation check, turn off the output of the stabilized power supply after making sure that the motor rotation has already stopped.

4.4 Motor Control Development Support Tool 'Renesas Motor Workbench'

4.4.1 Overview

In the target software of this application note, the motor control development support tool "Renesas Motor Workbench" is used as a user interface (rotating/stop motor, set rotation speed reference, etc). 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.

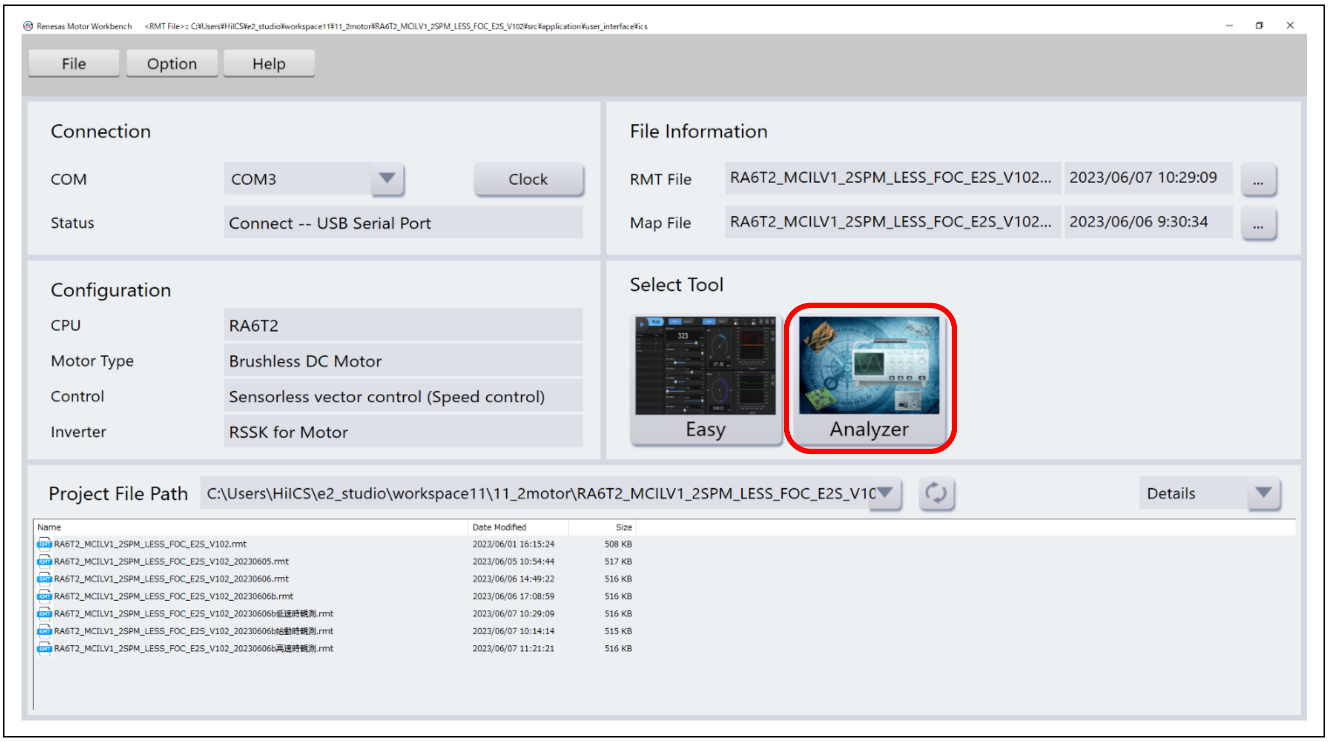
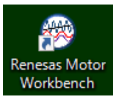


Figure 4-4 Renesas Motor Workbench – Appearance

- Set up for 'Renesas Motor Workbench'

(1) Start 'Renesas Motor Workbench' by clicking this icon. 

(2) Drop down menu [File] → [Open RMT File(O)].
    And select RMT file in '[Project Folder]/src/application/user_interface/ics/'.
(3) Use the 'Connection' [COM] select menu to choose the COM port.
(4) Click the Analyzer button of Select Tool to activate Analyzer function.
(5) Please refer to '4.4.3 Operation Example for Analyzer' for motor driving operation.

4.4.2 List of variables for Analyzer function

Table 4-1 is a list of variables for Analyzer. These variables are reflected to the corresponding variables when the same values as g_u1_enable_write are written to com_u1_enable_write. However, note that variables with (*) do not depend on com_u1_enable_write.

In Table 4-1, only variables for Motor 1 control are shown. When controlling Motor 2, use variables with “1” in variable name.

Table 4-1 List of Variables for Analyzer

Variable name	Type	Content
com_u1_sw_userif (*)	uint8_t	User interface switch 0: Analyzer use 1: Board user interface use (default)
com_u1_mode_system(*)	uint8_t	State management 0: Stop mode 1: Run mode 3: Reset
com_f4_ref_speed_rpm	float	Speed reference (mechanical angle) [rpm]
com_u2_mtr_pp	uint16_t	Number of pole pairs
com_f4_mtr_r	float	Resistance [Ω]
com_f4_mtr_ld	float	d-axis Inductance [H]
com_f4_mtr_lq	float	q-axis Inductance [H]
com_f4_mtr_m	float	Magnetic Flux [Wb]
com_f4_mtr_j	float	Inertia [kgm^2]
com_f4_current_omega	float	Natural frequency of current control system [Hz]
com_f4_current_zeta	float	Damping ratio of current control system
com_f4_speed_omega	float	Natural frequency of speed control system [Hz]
com_f4_speed_zeta	float	Damping ratio of speed control system
com_f4_e_obs_omega	float	Natural frequency of BEMF estimation system [Hz]
com_f4_e_obs_zeta	float	Damping ratio of BEMF estimation system
com_f4_pll_est_omega	float	Natural frequency of position estimation system [Hz]
com_f4_pll_est_zeta	float	Damping ratio of position estimation system
com_f4_ref_id	float	d-axis current reference in open loop mode [A]
com_f4_ol_id_up_step	float	d-axis current reference ramping up rate
com_f4_ol_id_down_step	float	d-axis current reference ramping down rate
com_f4_id_down_speed_rpm	float	Speed when start to subtract d-axis current reference (mechanical angle) [rpm]
com_f4_id_up_speed_rpm	float	Speed when start to add d-axis current reference (mechanical angle) [rpm]
com_f4_max_speed_rpm	float	Maximum speed value (mechanical angle) [rpm]
com_f4_overspeed_limit_rpm	float	Speed limit (mechanical angle) [rpm]
com_f4_overcurrent_limit	float	Over current limit [A]
com_f4_iq_limit	float	q-axis current limit [A]
com_f4_limit_speed_change	float	Change speed limit (electrical angle) [rad/s]
com_u1_enable_write	uint8_t	Enabled to rewriting variables (rewritten when the same values as g_u1_enable_write are written)

4.4.3 Operation example for Analyzer

This section shows an example of motor driving operation using the Analyzer. Please refer to Figure 4-5 for operation "Control Window". Regarding the specification of "Control Window", refer to 'Renesas Motor Workbench User's Manual'.

Variables in variable name are for Motor 1 control. When controlling Motor 2, use variables with "1" in variable name. The following operation example is described by the Motor 1 control variables only.

- Change the user interface to Analyzer
  (1) Confirm the checkboxes of column [W?] for 'com_u1_sw_userif' marks.
  (2) Input '0' in the [Write] box of 'com_u1_sw_userif'.
  (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) Type a same value of "g_u1_enable_write" in the [Write] box of "com_u1_enable_write".
  (6) Type a value of "1" in the [Write] box of "com_u1_mode_system".
  (7) Click the "Write" button.

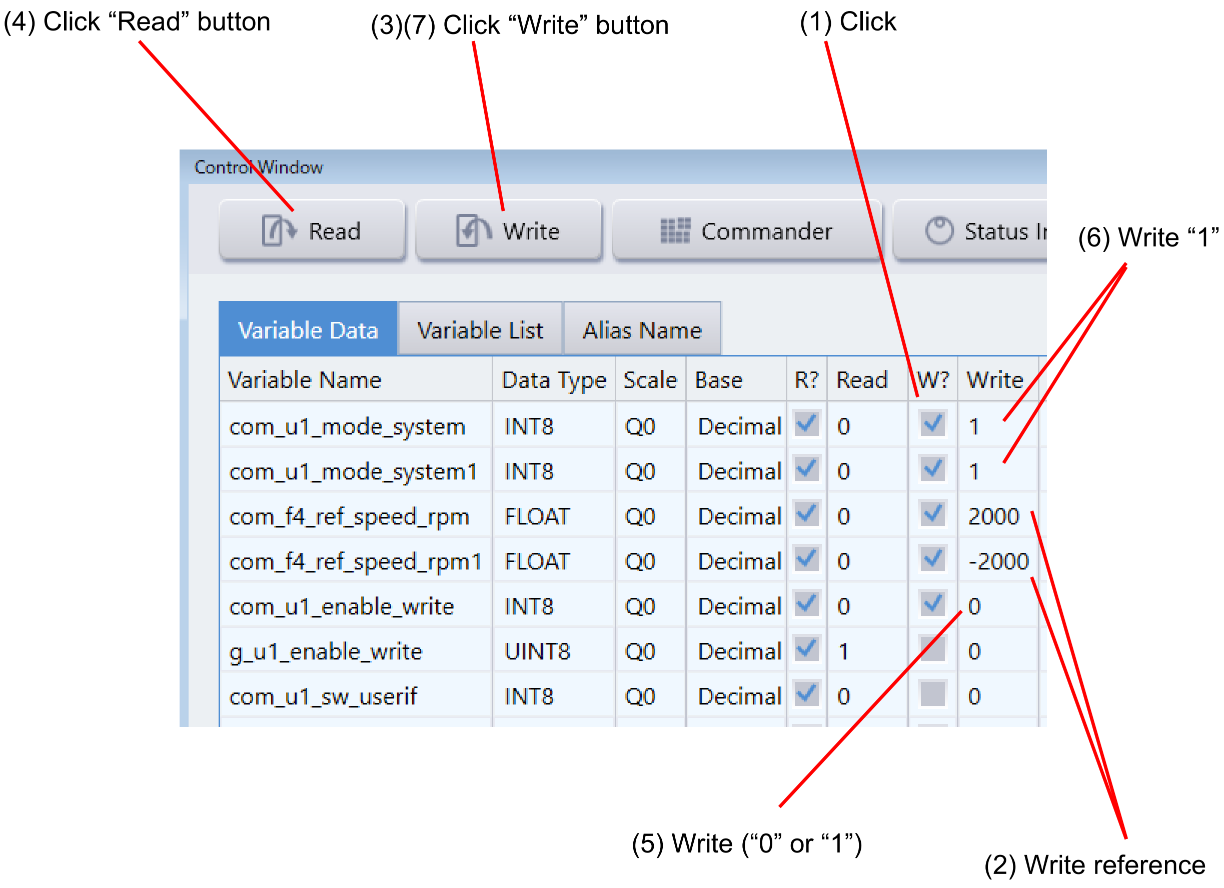


Figure 4-5 Procedure - Driving the motor

- Stop the motor
  (1) Type a value of “0” in the [Write] box of “com_u1_mode_system”.
  (2) Click the “Write” button.

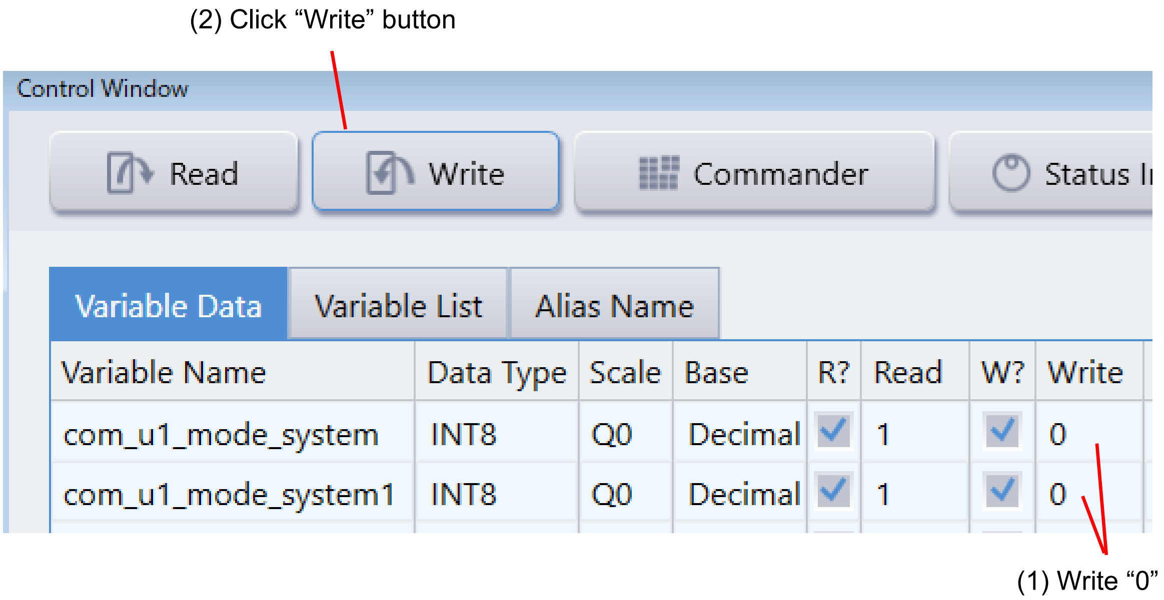


Figure 4-6 Procedure - Stop the motor

- Error cancel operation
  (1) Type a value of “3” in the [Write] box of “com_u1_mode_system”.
  (2) Click the “Write” button.

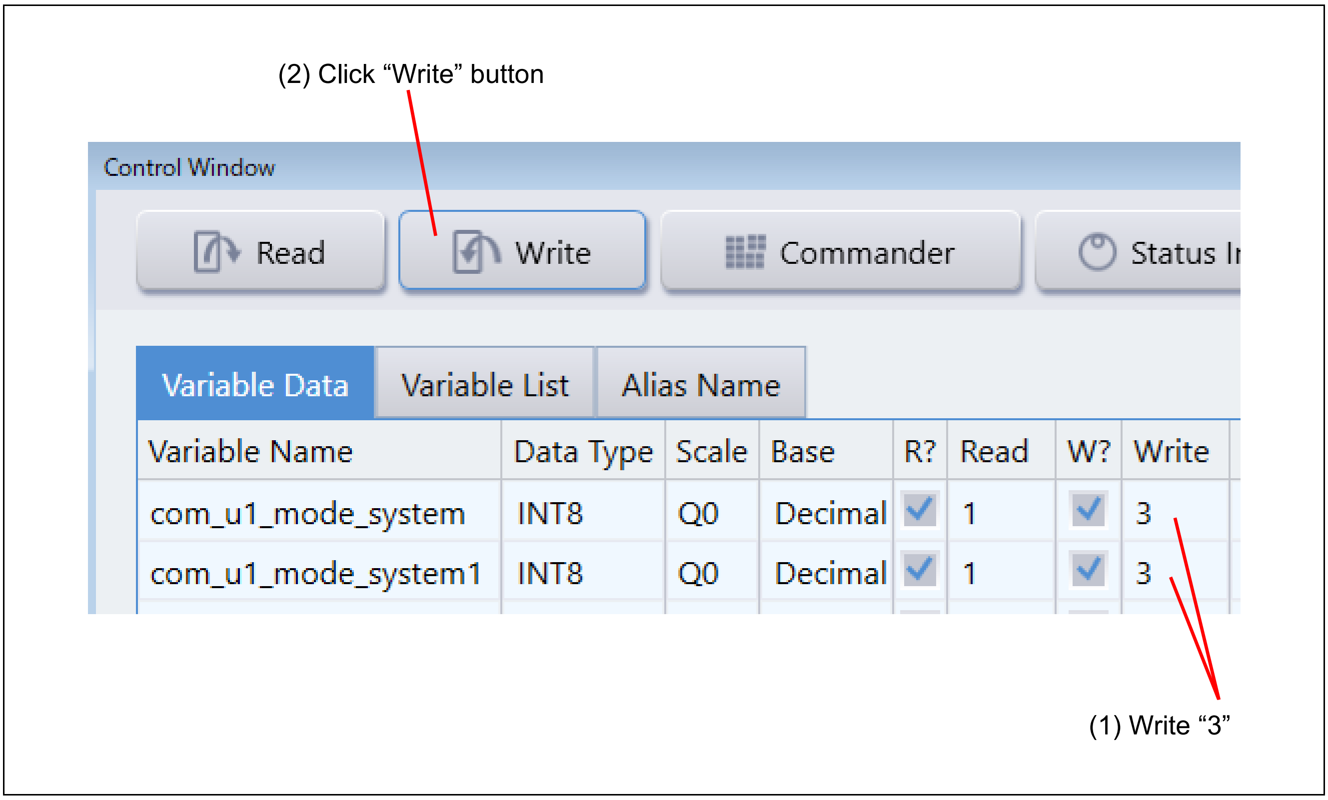


Figure 4-7 Procedure - Error cancel operation

5. Reference Documents

- RA6T2 Group User's Manual: Hardware (R01UH0951)
- Renesas Flexible Software Package User's manual
  (PDF version : R11UM0155, Web version : RA Flexible Software Package Documentation)
- Application note: Sensorless vector control for permanent magnet synchronous motor (Algorithm) (R01AN3786)
- Renesas Motor Workbench User's Manual (R21UZ0004)
- MCK-RA6T2 User's Manual (R12UZ0091)

Revision History

Rev.	Date	Description	
		Page	**Summary**
1.00	Aug.04.23	-	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.

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(Rev.5.0-1 October 2020)

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