

RA Family

Sensorless vector control for dual permanent magnetic synchronous motor For Renesas Flexible Motor Control Series

Introduction

This application note describes the sample program for a permanent magnetic synchronous motor drive with sensorless vector control 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 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)
- RA8T1 (R7FA8T1AHECBD)

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1. Overview

This application note explains how to implement the sensorless vector control software that drives dual permanent magnetic synchronous motor (PMSM) using the microcontroller RA series. The sample program of this application note can drive a motor easily with the kit of motor control (Renesas Flexible Motor Control series). And the program also supports the tool of motor control development support 'Renesas Motor Workbench'. With the tool, you can confirm internal data of software and use as user interface. Please utilize to choose the MCU and develop software with reference of this sample program in setting of peripherals or measurement of period of interrupt process.

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

2. Development environment

2.1 Test environments

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

Table 2-1 Hardware development environment

Category	Product used
Microcontroller / CPU board product type	RA6T2 (R7FA6T2BD3CFP) / RTK0EMA270C00000BJ RA8T1(R7FA8T1AHECBD) / RTK0EMA5K0C00000BJ
Inverter board	MCI-LV-1 / RTK0EM0000S04020BJ
Motor	R42BLD30L3

Table 2-2 Software development environment

e2studio version	FSP version	Toolchain version
V2023-10	V5.1.0	GCC ARM Embedded: 10.3.1.20210824 (RA6T2,RA6T3,RA4T1) 13.2.1.arm-13-7 (RA8T1)

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

2.2 Hardware specifications

2.2.1 Hardware configuration diagram

(1) Overall configuration

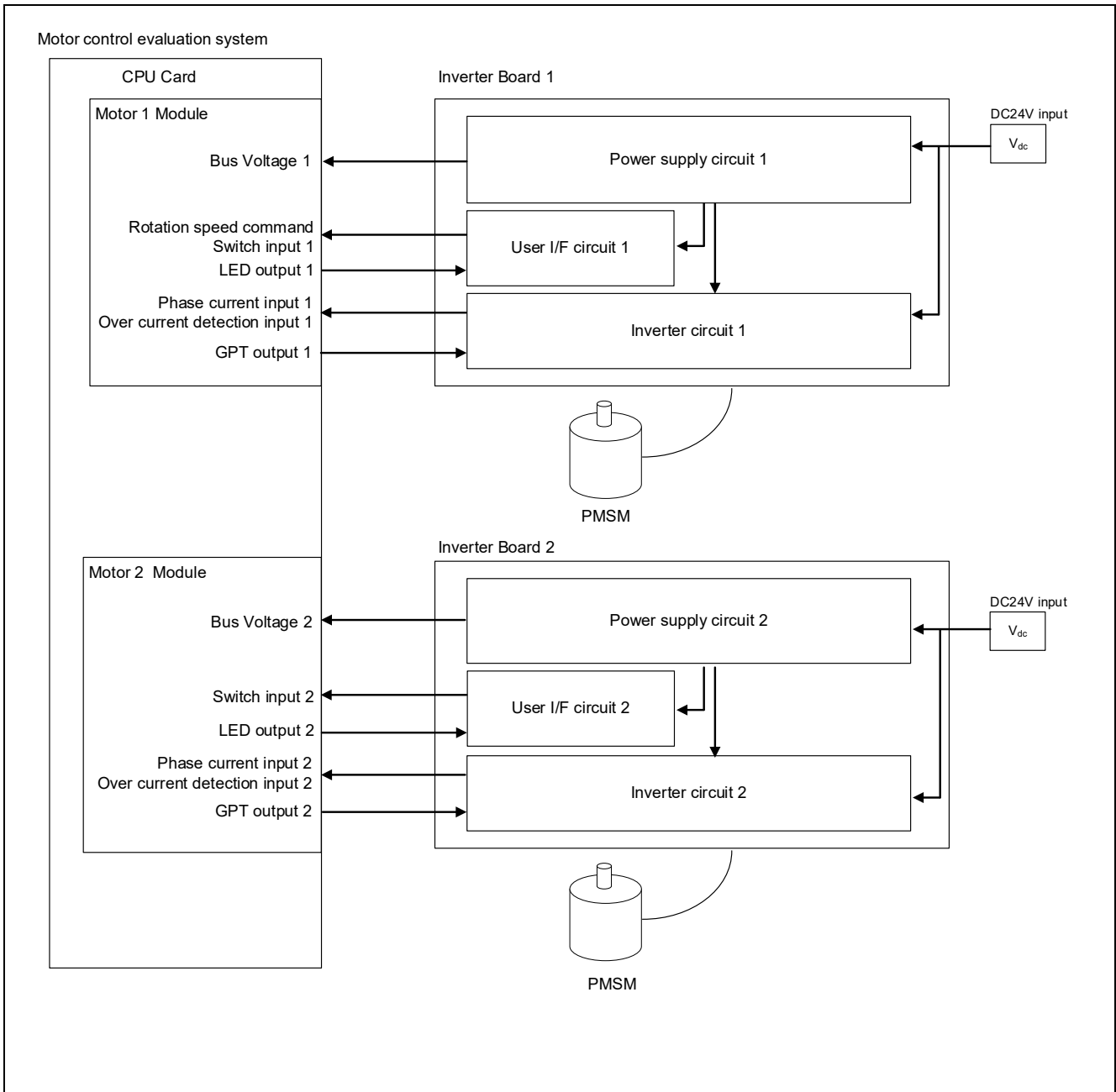


Figure 2-1 Hardware configuration diagram

(2) Motor 1 module configuration

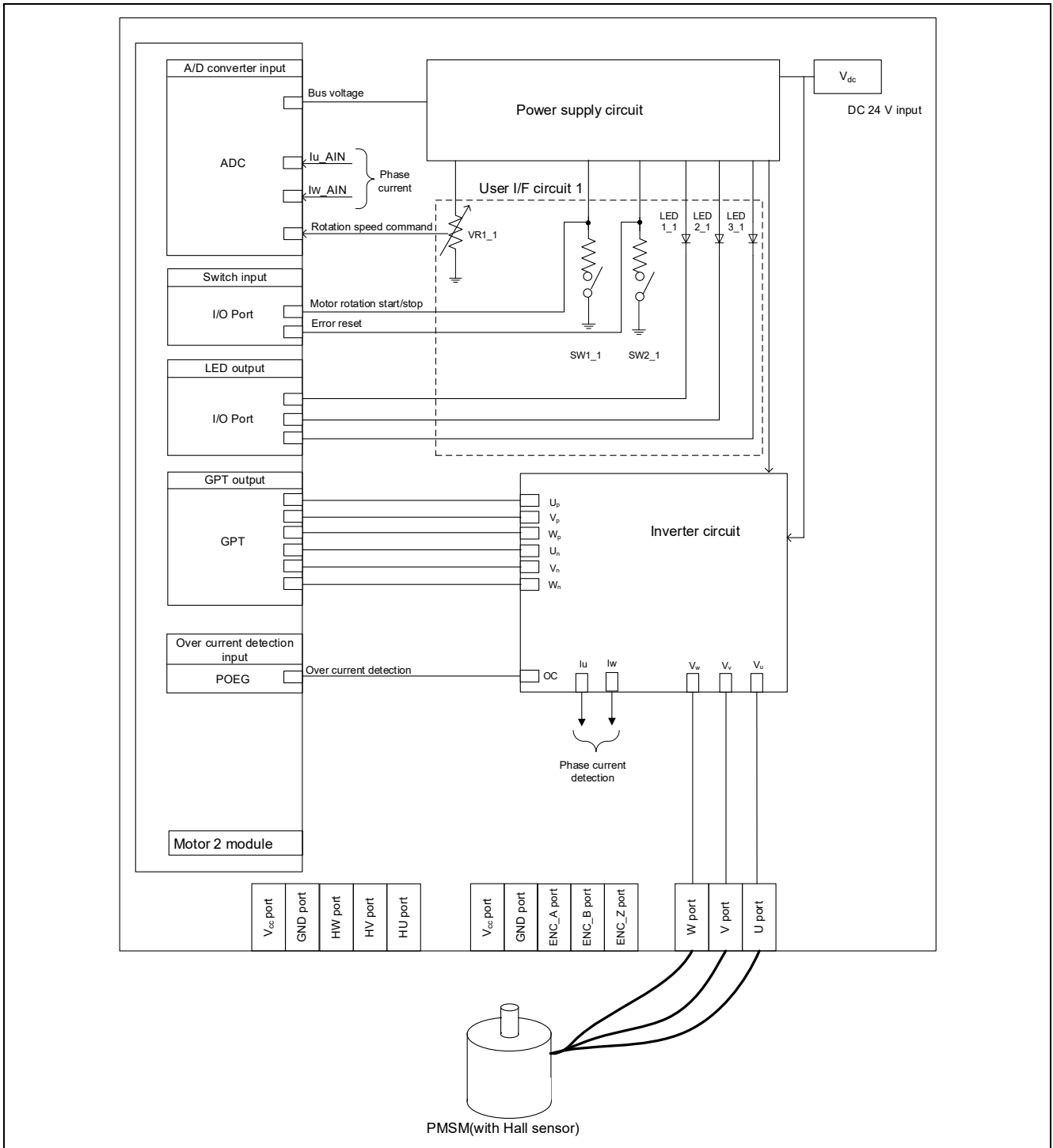


Figure 2-2 Hardware configuration diagram (Motor 1 module)

(3) Motor 2 module configuration

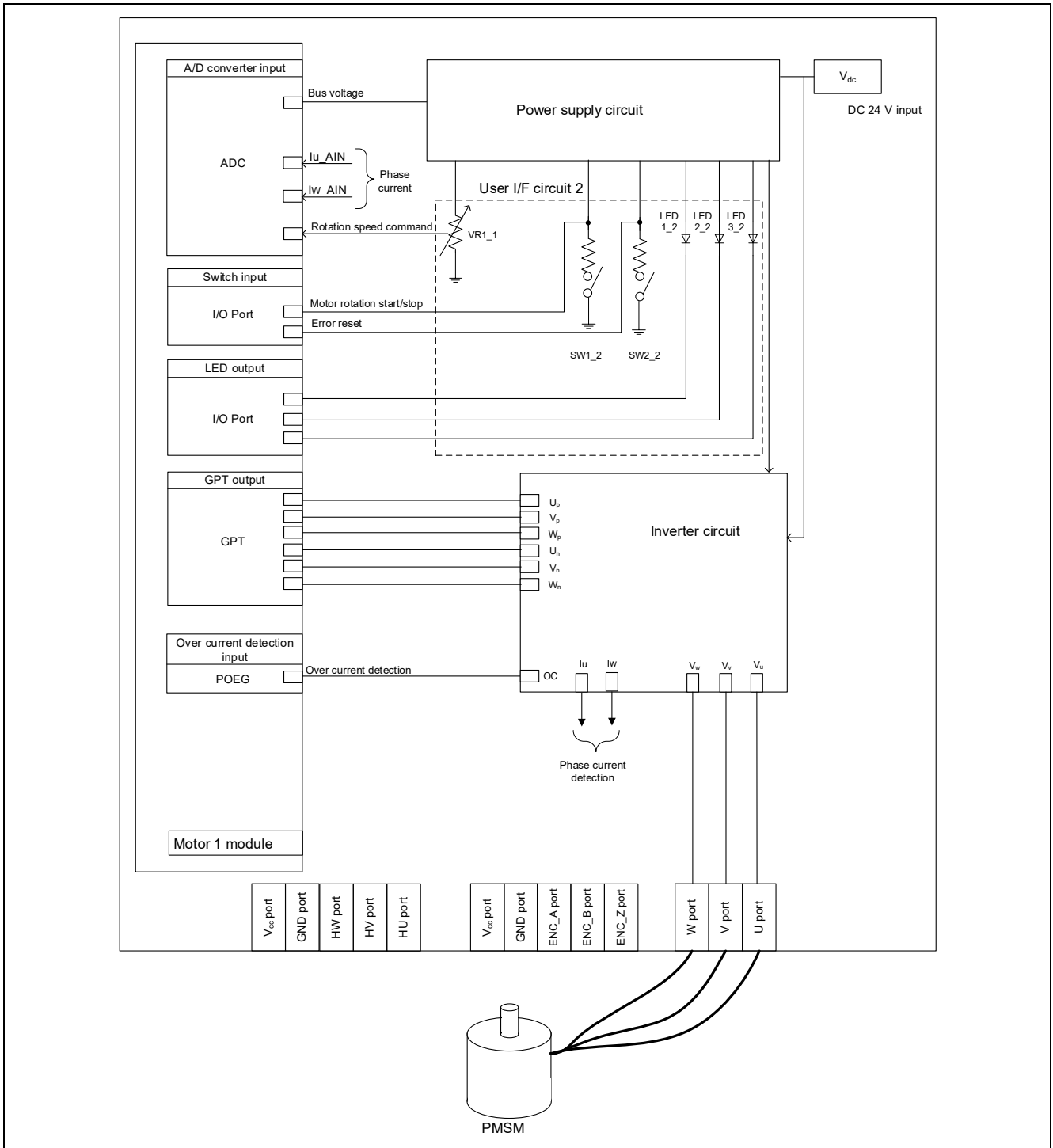


Figure 2-3 Hardware configuration diagram (Motor 2 module)

2.2.2 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.

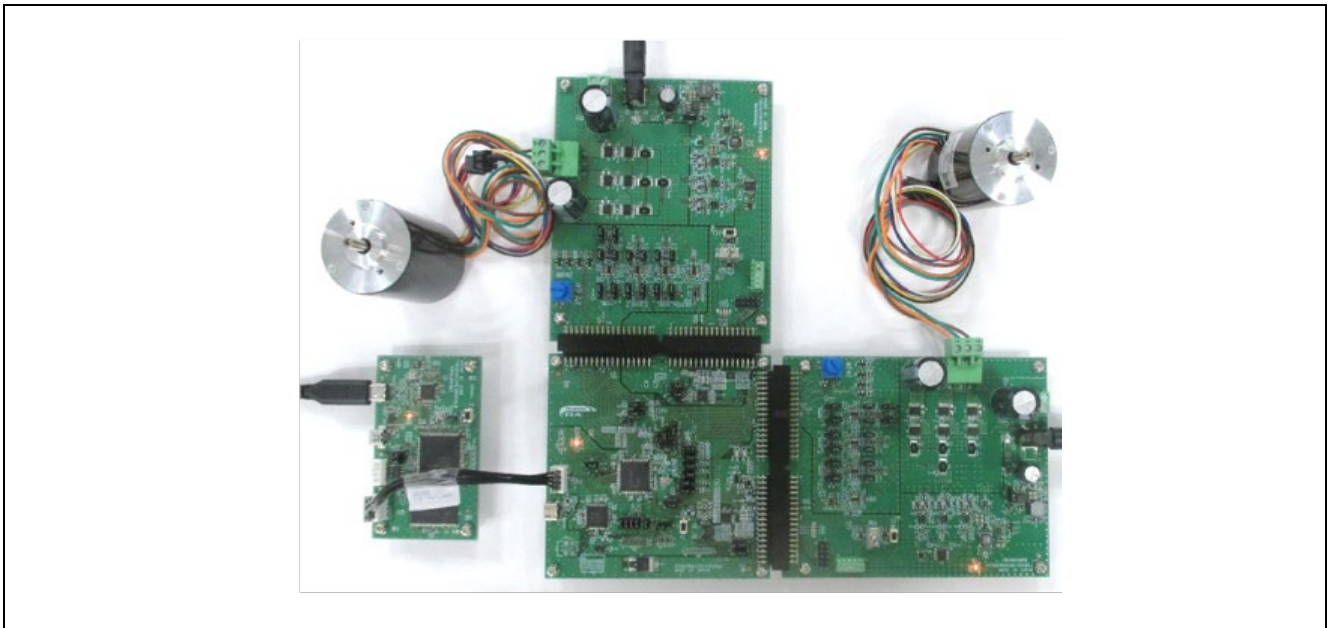


Figure 2-4 Connection for CPU board and inverter board

2.2.3 User interface

Table 2-3 is the list of user interface of this system.

Table 2-3 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> At the time of error detection: ON At the time of normal operation: OFF

Table 2-4 and Table 2-5 are the lists of port interface of this system.

Table 2-4 Port interfaces (Motor 1 side)

Function	RA6T2	RA8T1
Inverter bus voltage measurement	PA06/ AN006	P008 / AN008
For rotation speed command value input (VR1_1)	PB00 / AN008	P014 / AN007
START/STOP toggle switch (SW1_1)	PD04	PA15
ERROR RESET push switch (SW2_1)	PD07	PA13
LED1_1 ON/OFF control	PD01	PA12
LED2_1 ON/OFF control	PD02	PA14
U1 phase current measurement	PA04 / AN004	P004 / AN000
W1 phase current measurement	PA00 / AN000	P006 / AN002
PWM output (Up1)	PB04 / GTIOC4A	P115 / GTIOC5A
PWM output (Vp1)	PB06 / GTIOC5A	P113 / GTIOC2A
PWM output (Wp1)	PB08 / GTIOC6A	P300 / GTIOC3A
PWM output (Un1)	PB05 / GTIOC4B	P609 / GTIOC5B
PWM output (Vn1)	PB07 / GTIOC5B	P114 / GTIOC2B
PWM output (Wn1)	PB09 / GTIOC6B	P112 / GTIOC3B
PWM emergency stop input at the time of overcurrent detection	PC13 / GTETRGD	P613 / GTETRGA

Table 2-5 Port interfaces (Motor 2 side)

Function	RA6T2	RA8T1
Inverter bus voltage measurement	PE13 / AN025	P000 / AN100
For rotation speed command value input (VR1_2)	PE14 / AN026	P009 / AN006
START/STOP toggle switch (SW1_2)	PC00	P604
ERROR RESET push switch (SW2_2)	PC01	P504
LED1_2 ON/OFF control	PD15	P606
LED2_2 ON/OFF control	PC06	PA06
U2 phase current measurement	PB02/ AN018	P513 / AN016
W2 phase current measurement	PE09 / AN021	P002 / AN102
PWM output (Up2)	PC08 / GTIOC7A	P802 / GTIOC12A
PWM output (Vp2)	PA08 / GTIOC8A	P603 / GTIOC7A
PWM output (Wp2)	PA10 / GTIOC9A	P601 / GTIOC6B
PWM output (Un2)	PC09 / GTIOC7B	P803 / GTIOC12B
PWM output (Vn2)	PA09 / GTIOC8B	P602 / GTIOC7B
PWM output (Wn2)	PA11 / GTIOC9B	P600 / GTIOC6B
PWM emergency stop input at the time of overcurrent detection	PA12 / GTETRGB	P804 / GTETRGD

2.2.4 Peripheral functions

List of the peripheral functions used in this system is given in Table 2-6.

Table 2-6 List of the peripheral functions

Peripheral	Purpose	RA6T2	RA8T1
A/D converter	U phase current measurement_1	AN004	AN000
	W phase current measurement_1	AN000	AN002
	U phase current measurement_2	AN018	AN008
	W phase current measurement_2	AN021	AN007
	Inverter bus voltage measurement_1	AN006	AN016
	Inverter bus voltage measurement_2	AN025	AN102
	For rotation speed command value input (analog value)_1	AN008	AN100
	For rotation speed command value input (analog value)_2	AN026	AN006
AGT	Speed control interval timer_1	AGT0	AGT0
	Speed control interval timer_2	AGT1	AGT1
GPT	U phase PWM output_1	CH4	CH5
	V phase PWM output_1	CH5	CH2
	W phase PWM output_1	CH6	CH3
	U phase PWM output_2	CH7	CH12
	V phase PWM output_2	CH8	CH7
	W phase PWM output_2	CH9	CH6
POEG	PWM emergency stop input at the time of overcurrent detection_1	Group D	GTETRGA
	PWM emergency stop input at the time of overcurrent detection_2	Group B	GTETRGD

2.2.4.1 RA6T2

(1) A/D Converter (ADC)

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 GTETRGA/GTETRGD port is detected).

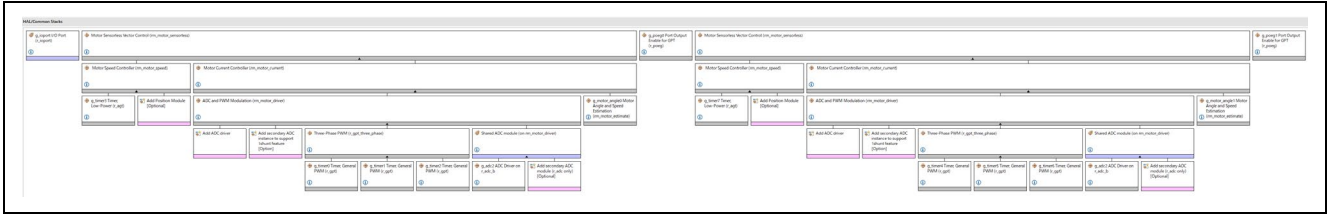


Figure 2-5 Overall FSP stacks diagram

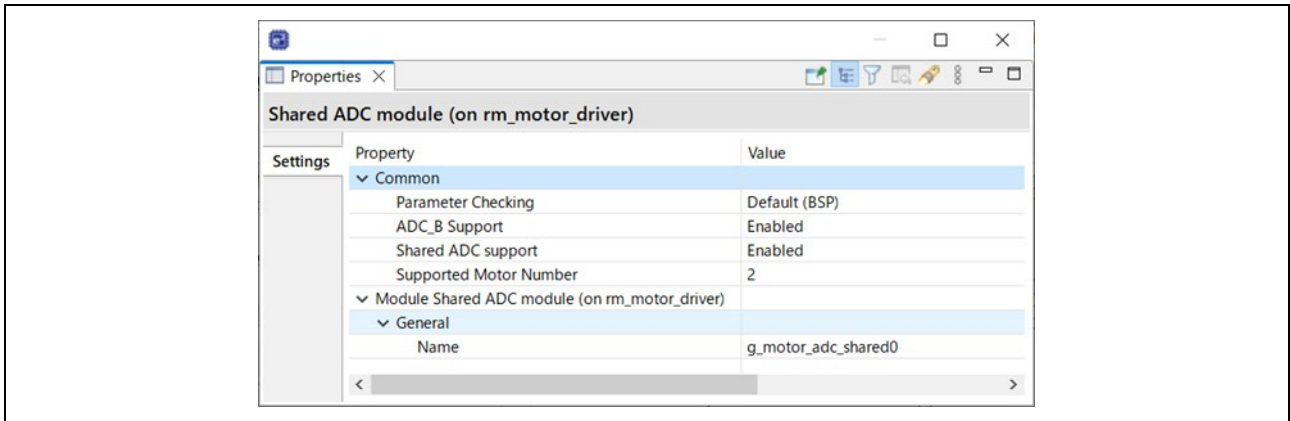


Figure 2-6 FSP configuration of ADC shared module

<ul style="list-style-type: none"> ▼ Virtual Channel 0 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 1 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 2 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 3 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 4 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection 	<ul style="list-style-type: none"> Scan Group 0 AN000 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 0 AN002 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 0 AN004 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 1 AN006 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 1 AN008 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled 	<ul style="list-style-type: none"> ▼ Virtual Channel 5 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 6 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 7 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 8 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection ▼ Virtual Channel 9 Scan Group Channel Select Sampling State Table ID Channel Gain Table Channel Offset Table Add/Average Mode Add/Average Count Limit Clip Table Id Conversion Data Format Select Digital Filter Selection 	<ul style="list-style-type: none"> Scan Group 2 AN018 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 2 AN020 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 2 AN021 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 3 AN025 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled Scan Group 3 AN026 Sampling State Entry 0 Disabled Disabled Disabled 1-time conversion (Normal Conversion) Disabled 12-bit Data Format Disabled
Motor 1		Motor 2	

Figure 2-7 FSP configuration of ADC driver [1/3]

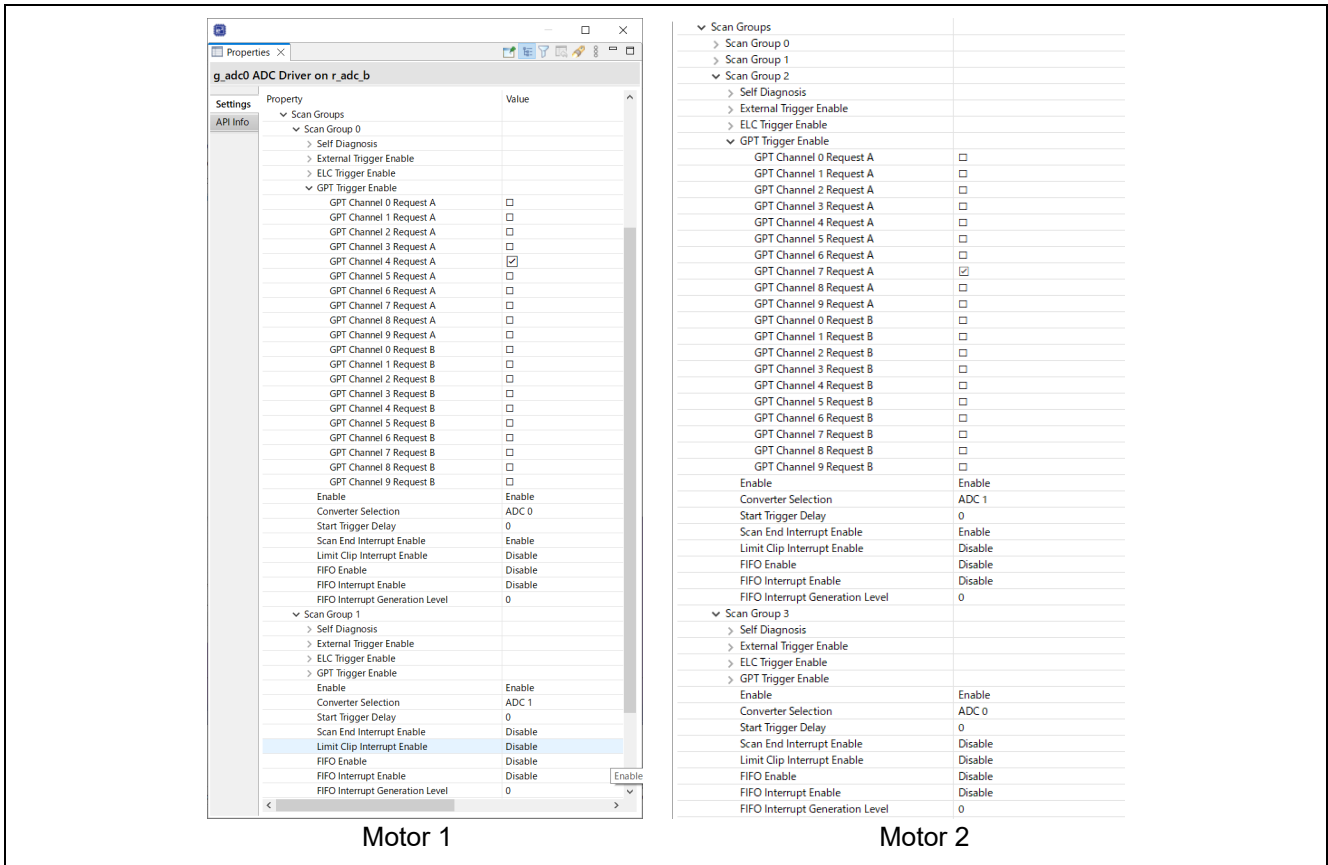


Figure 2-8 FSP configuration of ADC driver [3/3]

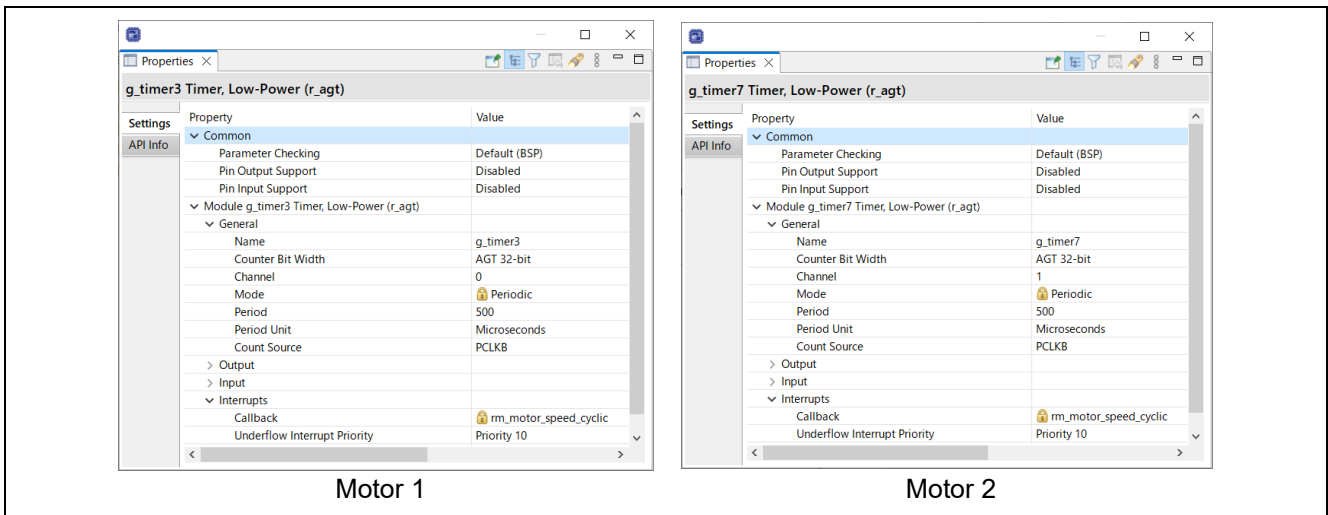


Figure 2-9 FSP configuration of AGT driver

<ul style="list-style-type: none"> Common <ul style="list-style-type: none"> 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) <ul style="list-style-type: none"> General <ul style="list-style-type: none"> Name: g_timer0 Channel: 4 Mode: Triangle-Wave Symmetric PWM Period: 50 Period Unit: Microseconds Output <ul style="list-style-type: none"> Custom Waveform <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> Output Disable <ul style="list-style-type: none"> Output Disable POEG Trigger <ul style="list-style-type: none"> POEG Link: POEG Channel 3 GTIOCA Disable Setting: Set Hi Z GTIOCB Disable Setting: Set Hi Z ADC Trigger <ul style="list-style-type: none"> Start Event Trigger (Channels with GTINTAD) <ul style="list-style-type: none"> Trigger Event A/D Converter Start Request: <input type="checkbox"/> Trigger Event A/D Converter Start Request: <input checked="" type="checkbox"/> Trigger Event A/D Converter Start Request: <input type="checkbox"/> Trigger Event A/D Converter Start Request: <input type="checkbox"/> Dead Time (Value range varies with Channel) <ul style="list-style-type: none"> Dead Time Count Up (Raw Counts): 240 Dead Time Count Down (Raw Counts) (Channel): 240 ADC Trigger (Channels with GTADTRA only) ADC Trigger (Channels with GTADTRB only) Interrupt Skipping (Channels with GTITC only) Extra Features: Enabled Pins <ul style="list-style-type: none"> GTIOC4A: PB04 GTIOC4B: PB05

Motor 1 U phase setting (example)

Figure 2-10 FSP configuration of GPT driver

<ul style="list-style-type: none"> Common <ul style="list-style-type: none"> Parameter Checking: Default (BSP) Module g_poeg0 Port Output Enable for GPT (r_poeg) <ul style="list-style-type: none"> General <ul style="list-style-type: none"> Trigger <ul style="list-style-type: none"> GTETRQ Pin: <input checked="" type="checkbox"/> GPT Output Level: <input type="checkbox"/> Oscillation Stop: <input type="checkbox"/> ACMPHS0: <input type="checkbox"/> ACMPHS1: <input type="checkbox"/> ACMPHS2: <input type="checkbox"/> ACMPHS3: <input type="checkbox"/> Name: g_poeg0 Channel: 3 Input <ul style="list-style-type: none"> GTETRQ Polarity: Active Low GTETRQ Noise Filter: PCLKB/32 Interrupts <ul style="list-style-type: none"> Callback: g_poe_overcurrent0 Interrupt Priority: Priority 0 (highest) 	<ul style="list-style-type: none"> Common <ul style="list-style-type: none"> Parameter Checking: Default (BSP) Module g_poeg1 Port Output Enable for GPT (r_poeg) <ul style="list-style-type: none"> General <ul style="list-style-type: none"> Trigger <ul style="list-style-type: none"> GTETRQ Pin: <input checked="" type="checkbox"/> GPT Output Level: <input type="checkbox"/> Oscillation Stop: <input type="checkbox"/> ACMPHS0: <input type="checkbox"/> ACMPHS1: <input type="checkbox"/> ACMPHS2: <input type="checkbox"/> ACMPHS3: <input type="checkbox"/> Name: g_poeg1 Channel: 1 Input <ul style="list-style-type: none"> GTETRQ Polarity: Active Low GTETRQ Noise Filter: PCLKB/32 Interrupts <ul style="list-style-type: none"> Callback: g_poe_overcurrent1 Interrupt Priority: Priority 0 (highest)
--	--

Motor 1
Motor 2

Figure 2-11 FSP Configuration of POEG driver

2.2.4.2 RA8T1

(1) 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 2,3,5,6,7 and 12, 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).

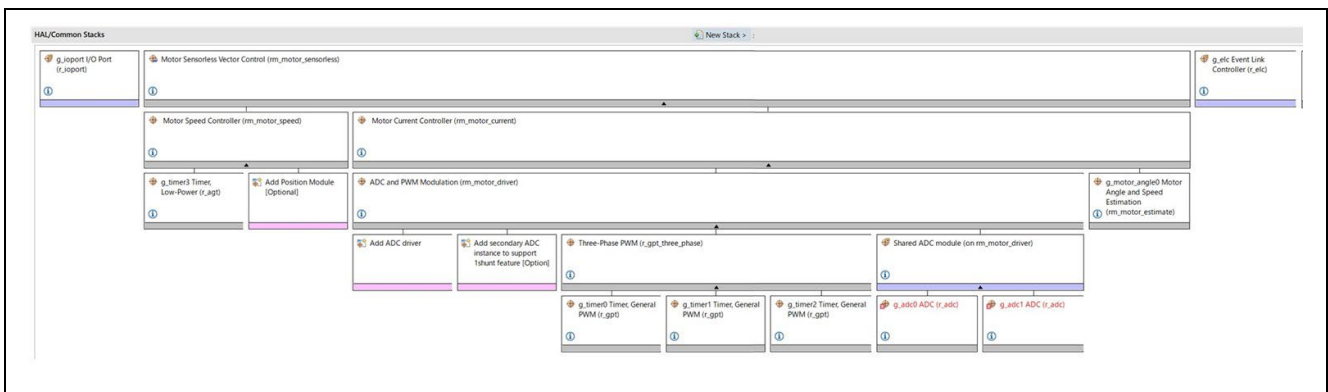


Figure 2-12 Overall FSP stacks diagram (side of motor#1)

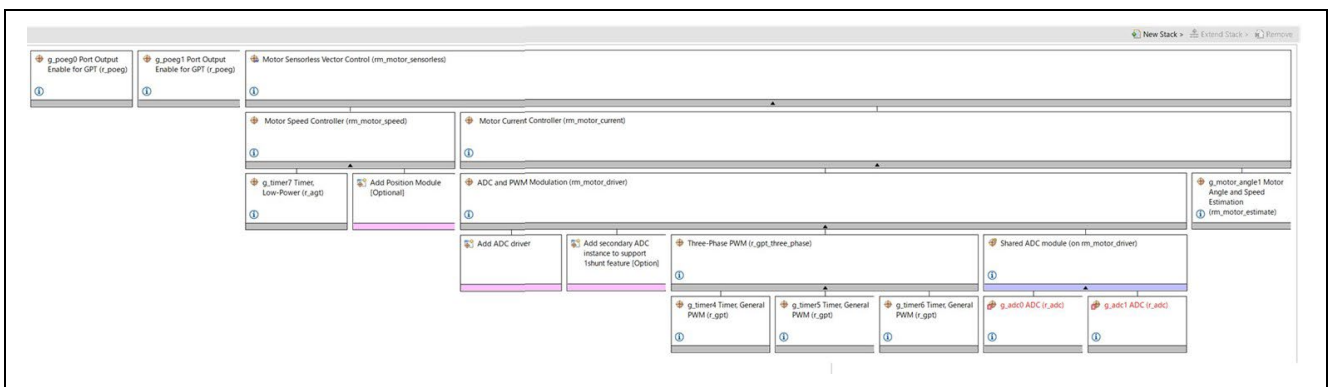


Figure 2-13 Overall FSP stacks diagram (side of motor#2)

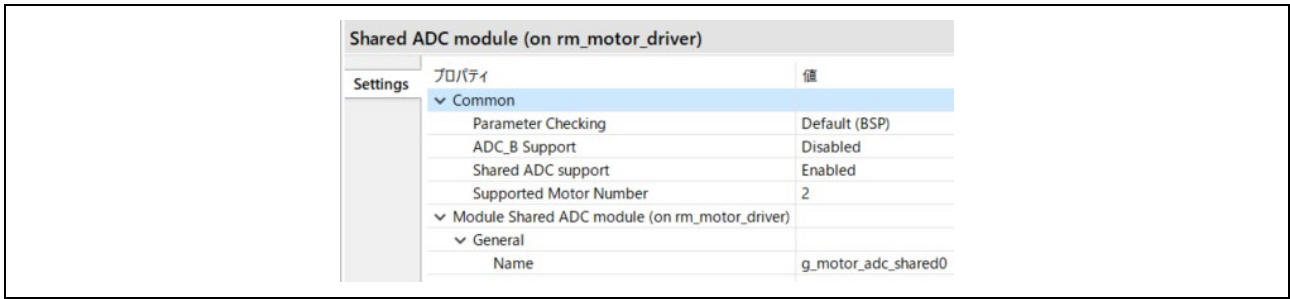


Figure 2-14 FSP configuration of ADC shared module

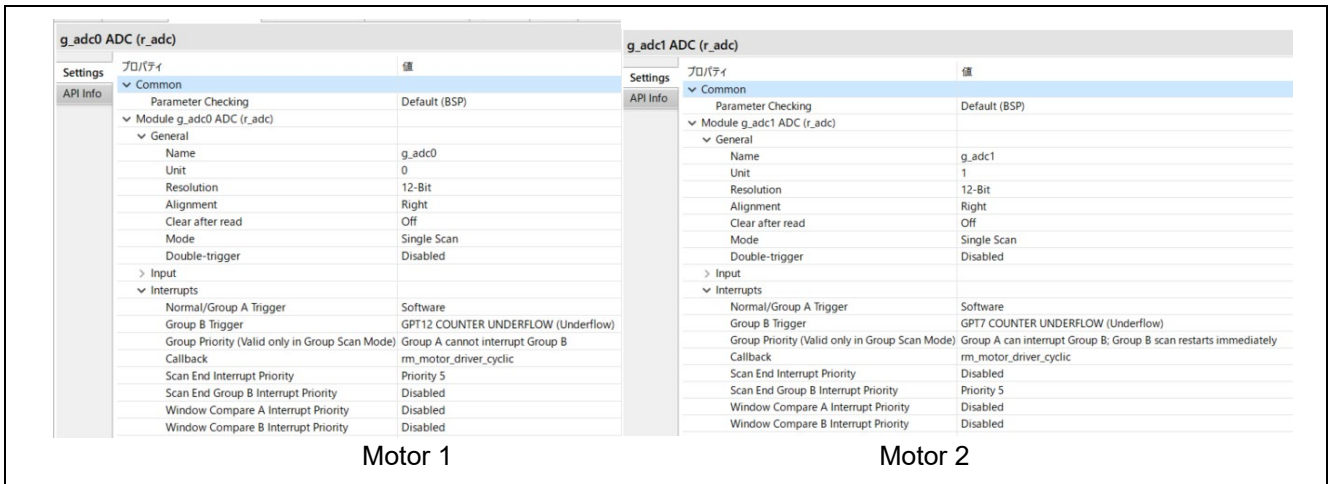


Figure 2-15 FSP configuration of ADC driver [1/3]

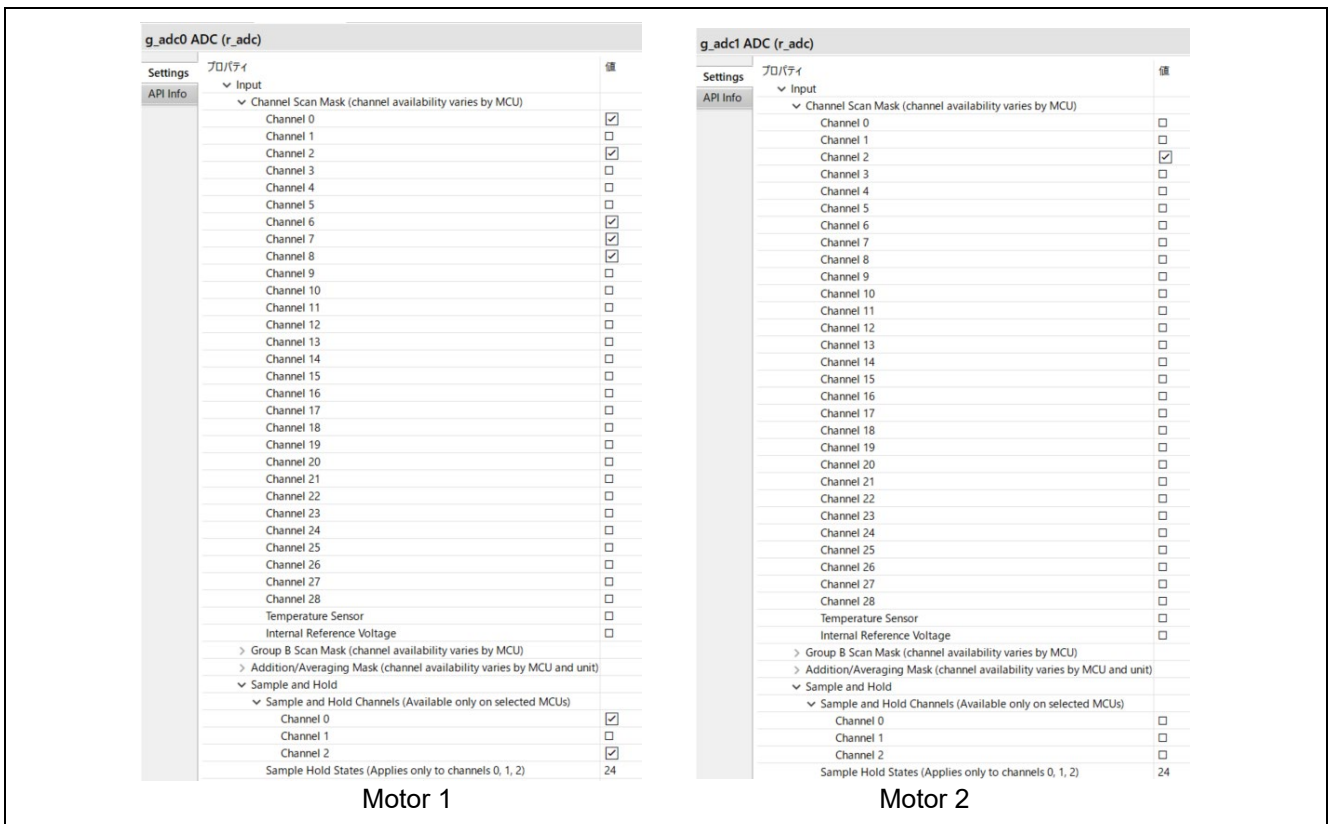


Figure 2-16 FSP configuration of ADC driver [2/3]

▼ Group B Scan Mask (channel availability varies by MCU)		▼ Group B Scan Mask (channel availability varies by MCU)	
Channel 0	<input type="checkbox"/>	Channel 0	<input checked="" type="checkbox"/>
Channel 1	<input type="checkbox"/>	Channel 1	<input type="checkbox"/>
Channel 2	<input type="checkbox"/>	Channel 2	<input type="checkbox"/>
Channel 3	<input type="checkbox"/>	Channel 3	<input type="checkbox"/>
Channel 4	<input type="checkbox"/>	Channel 4	<input type="checkbox"/>
Channel 5	<input type="checkbox"/>	Channel 5	<input type="checkbox"/>
Channel 6	<input type="checkbox"/>	Channel 6	<input type="checkbox"/>
Channel 7	<input type="checkbox"/>	Channel 7	<input type="checkbox"/>
Channel 8	<input type="checkbox"/>	Channel 8	<input type="checkbox"/>
Channel 9	<input type="checkbox"/>	Channel 9	<input type="checkbox"/>
Channel 10	<input type="checkbox"/>	Channel 10	<input type="checkbox"/>
Channel 11	<input type="checkbox"/>	Channel 11	<input type="checkbox"/>
Channel 12	<input type="checkbox"/>	Channel 12	<input type="checkbox"/>
Channel 13	<input type="checkbox"/>	Channel 13	<input type="checkbox"/>
Channel 14	<input type="checkbox"/>	Channel 14	<input type="checkbox"/>
Channel 15	<input type="checkbox"/>	Channel 15	<input type="checkbox"/>
Channel 16	<input checked="" type="checkbox"/>	Channel 16	<input type="checkbox"/>
Channel 17	<input type="checkbox"/>	Channel 17	<input type="checkbox"/>
Channel 18	<input type="checkbox"/>	Channel 18	<input type="checkbox"/>
Channel 19	<input type="checkbox"/>	Channel 19	<input type="checkbox"/>
Channel 20	<input type="checkbox"/>	Channel 20	<input type="checkbox"/>
Channel 21	<input type="checkbox"/>	Channel 21	<input type="checkbox"/>
Channel 22	<input type="checkbox"/>	Channel 22	<input type="checkbox"/>
Channel 23	<input type="checkbox"/>	Channel 23	<input type="checkbox"/>
Channel 24	<input type="checkbox"/>	Channel 24	<input type="checkbox"/>
Channel 25	<input type="checkbox"/>	Channel 25	<input type="checkbox"/>
Channel 26	<input type="checkbox"/>	Channel 26	<input type="checkbox"/>
Channel 27	<input type="checkbox"/>	Channel 27	<input type="checkbox"/>
Channel 28	<input type="checkbox"/>	Channel 28	<input type="checkbox"/>
Temperature Sensor	<input type="checkbox"/>	Temperature Sensor	<input type="checkbox"/>
Internal Reference Voltage	<input type="checkbox"/>	Internal Reference Voltage	<input type="checkbox"/>

Motor 1
Motor 2

Figure 2-17 FSP configuration of ADC driver [3/3]

g_timer3 Timer, Low-Power (r_agt)		g_timer7 Timer, Low-Power (r_agt)	
Settings	プロパティ	Settings	プロパティ
API Info	値	API Info	値
▼ Common		▼ Common	
Parameter Checking	Default (BSP)	Parameter Checking	Default (BSP)
Pin Output Support	Disabled	Pin Output Support	Disabled
Pin Input Support	Disabled	Pin Input Support	Disabled
▼ Module g_timer3 Timer, Low-Power (r_agt)		▼ Module g_timer7 Timer, Low-Power (r_agt)	
▼ General		▼ General	
Name	g_timer3	Name	g_timer7
Counter Bit Width	AGT 16-bit	Counter Bit Width	AGT 16-bit
Channel	0	Channel	1
Mode	Periodic	Mode	Periodic
Period	500	Period	500
Period Unit	Microseconds	Period Unit	Microseconds
Count Source	PCLKB	Count Source	PCLKB
> Output		> Output	
> Input		> Input	
▼ Interrupts		▼ Interrupts	
Callback	rm_motor_speed_cyclic	Callback	rm_motor_speed_cyclic
Underflow Interrupt Priority	Priority 10	Underflow Interrupt Priority	Priority 10

Motor 1
Motor 2

Figure 2-18 FSP configuration of AGT driver

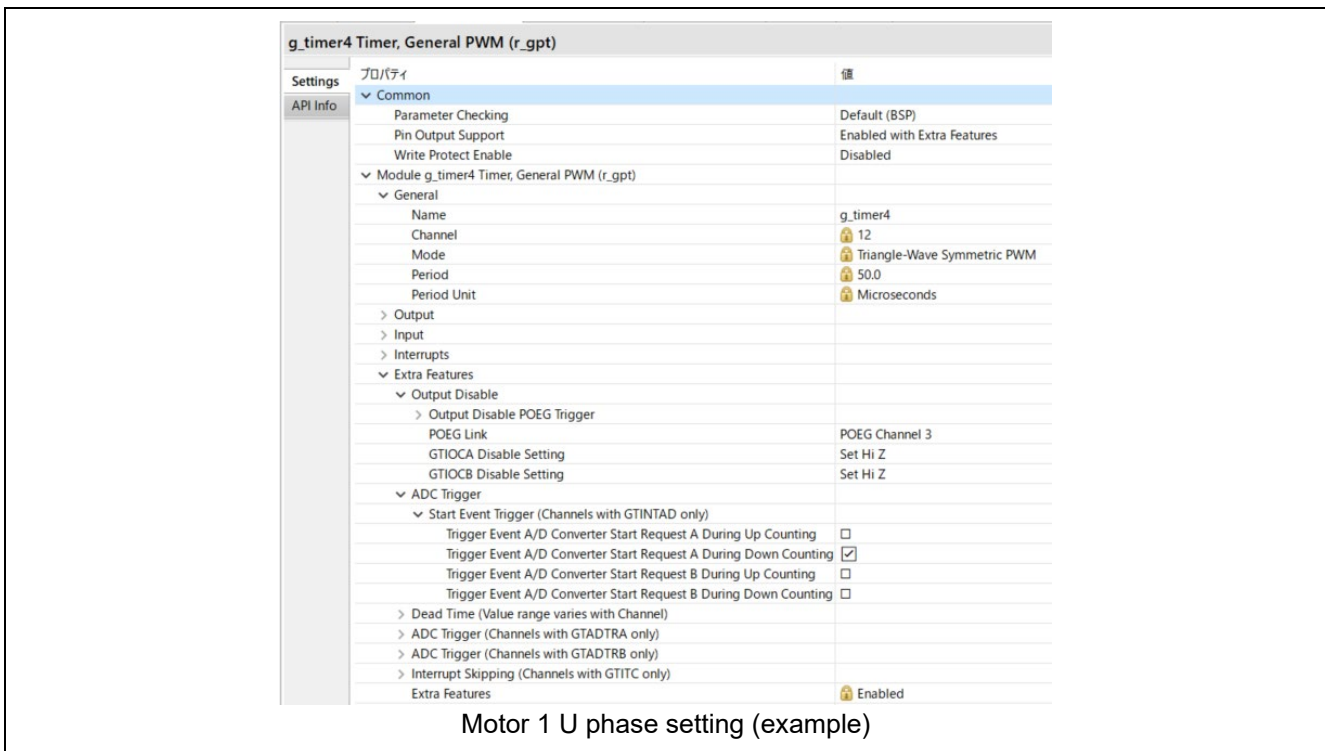


Figure 2-19 FSP configuration of GPT driver

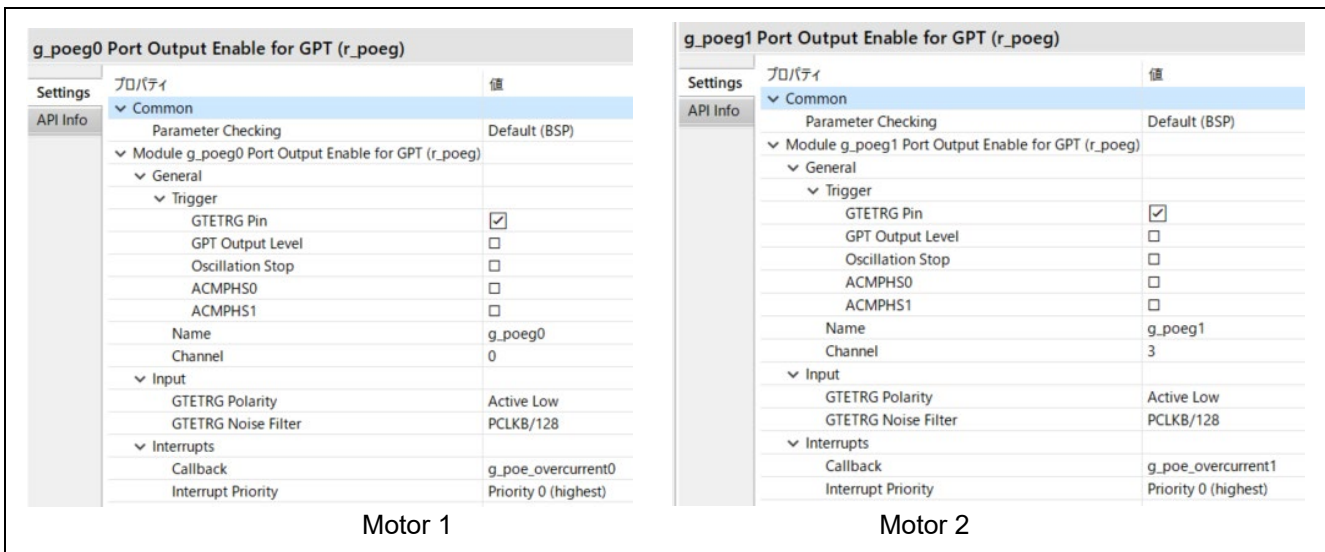


Figure 2-20 FSP Configuration of POEG driver

2.3 Software configuration

2.3.1 Software file configuration

Folder and file configuration of the software is given below.

Table 2-7 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.c(Only RA8T1)		ELC API definition
		r_ioport_api.h		I/O API definition
		r_poeg_api.h		POEG API definition
		r_three_phase_api.h		Three phase PWM API definition
		r_timer_api.h		Timer API definition
		r_transfer_api.h		Transfer 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_speed_api.h		Speed API definition
		fsp/inc/instances	r_adc_b.h(RA6T2) r_adc.h(RA8T1)	
	r_agt.h			Function definition for AGT
	r_elc.h(Only RA8T1)			Function definition for ELC
	r_gpt_three_phase.h			Function definition for 3 Phase PWM
	r_gpt.h			Function definition for GPT
	r_ioport.h			Function definition for I/O
	r_poeg.h			Function definition for POEG
	rm_motor_current.h			Function definition for current control
	rm_motor_driver.h			Function definition for motor driver
	rm_motor_estimate.h			Function definition for angle estimate
	rm_motor_sensorless.h			Function definition for Sensorless
	rm_motor_speed.h			Function definition for Speed

Table 2-8 File and folder configuration [2/2]

Folder	Subfolder	File	Remarks
ra	fsp/lib		Library files
	fsp/src	bsp	BSP driver
		r_adc_b/r_adc_b.c(RA6T2) r_adc/r_adc.c(RA8T1)	AD driver
		r_agt/r_agt.c	AGT driver
		r_elc/r_elc.c(Only RA8T1)	ELC driver
		r_gpt/r_gpt.c	GPT driver
		r_gpt_three_phase/r_gpt_three_phase.c	Three phase PWM driver
		r_ioport/r_ioport.c	I/O driver
		r_poeg/r_poeg.c	POEG driver
		rm_motor_current/rm_motor_current.c	Current control driver
		rm_motor_current/rm_motor_current_library.h	Current control library API definition
		rm_motor_estimate/rm_motor_estimate	Angle estimate driver
		rm_motor_sensorless/rm_motor_sensorless.c	Sensorless driver
		rm_motor_speed/rm_motor_speed.c	Speed control driver
		rm_motor_speed/rm_motor_speed_library.h	Speed control library API definition
src	application/main	mtr_main.h , mtr_main.c	User main function
		r_mtr_control_parameter.h	Control parameters definition
		r_mtr_motor_parameter.h	Motor parameters definition
	application/ user_interface/ics	r_mtr_ics.h , r_mtr_ics.c	Function definition for Analyzer
		ICS2_RA6T2.h , ICS2_RA8T1.h	Function definition for GUI tool
		ICS2_RA6T2.o , ICS2_RA8T1.o	Communication library for GUI tool

2.3.2 Module configuration

Module configuration of the software is described below.

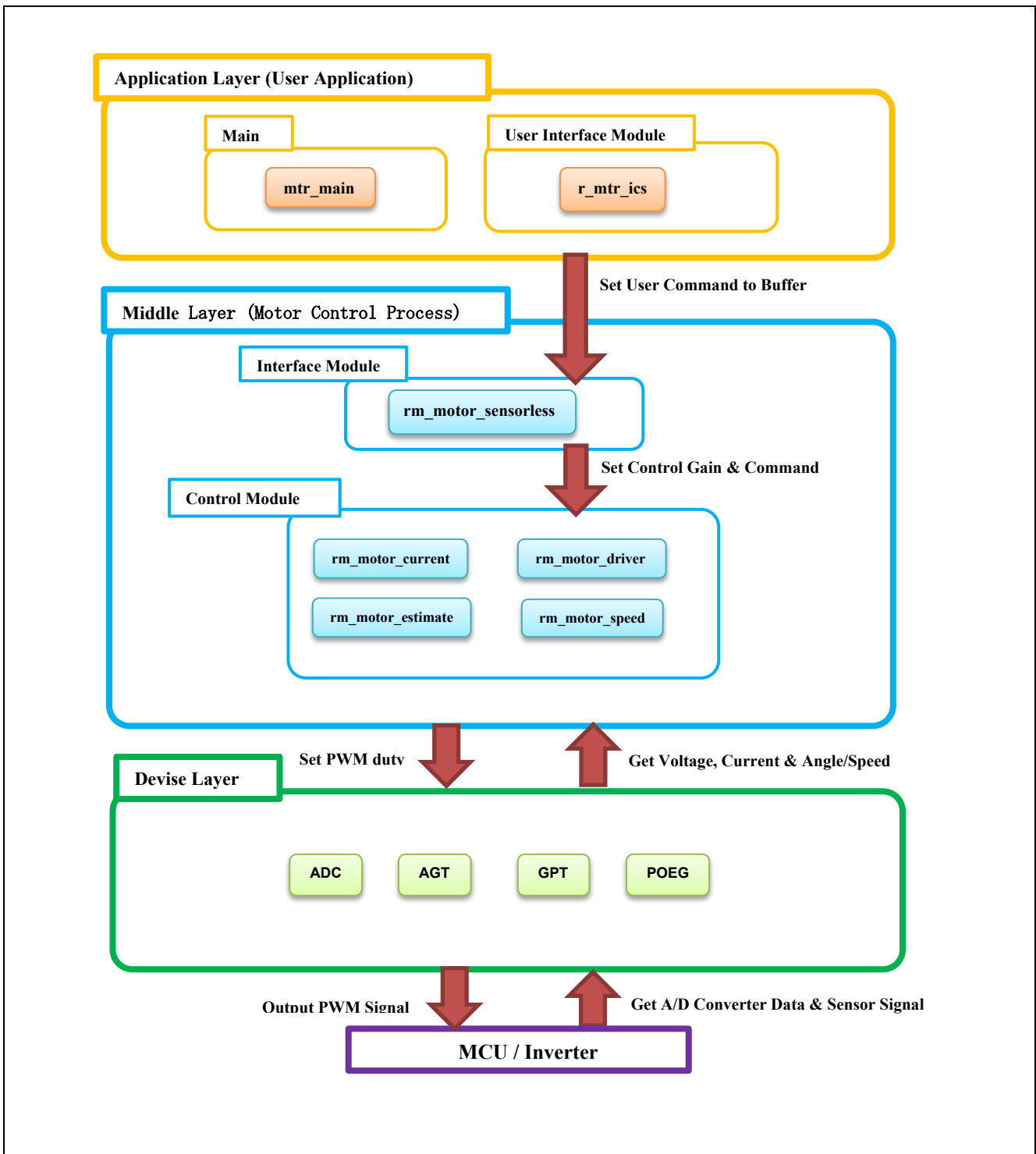


Figure 2-21 Module configuration

2.4 Software Specifications

Table 2-9 shows basic software specification of this system.

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

Table 2-9 Basic specifications of sensorless vector control software

Item	Content	
Control method	Vector control	
Position detection method	Sensorless	
Motor rotation start/stop	Determined depending on the level of SW1_1 for Motor 1 and SW1_2 for Motor 2, or input from Renesas Motor Workbench	
Input voltage	DC 24V	
Main clock frequency	RA6T2: 240 [MHz] RA8T1: 480 [MHz]	
Carrier frequency (PWM)	20 [kHz] (Carrier period: 50 [μs])	
Dead time	2 [μs]	
Current control period	RA6T2: 50 [μs] RA8T1: 50 [μs]	
Speed control period	RA6T2: 500 [μs] RA8T1: 500 [μs]	
Rotation speed control range	CW : 0 [rpm] to 2400 [rpm] CCW : 0 [rpm] to 2400 [rpm] However, 500 [rpm] or less is driven by a speed open loop.	
Natural frequency of each control system	Current control system : 300 [Hz] Speed control system : 5 [Hz] BEMF estimation system : 1000 [Hz] Position estimation system : 50 [Hz]	
Optimization setting of compiler	Optimization level	Optimize more(-O2) (default setting)
Processing stop for protection	<p>[Motor 1] Disables the Motor 1 control signal output (six outputs), under any of the following conditions.</p> <ol style="list-style-type: none"> 1. Instantaneous value of current of any phase exceeds $3.54(=1.67 \times \sqrt{2}) \times 1.5$ [A] (monitored in current control period) 2. Inverter bus voltage exceeds 60 [V] (monitored in current control period) 3. Inverter bus voltage is less than 8 [V] (monitored in current control period) 4. Rotation speed exceeds 4500 [rpm] (monitored in current control period) <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>	<p>[Motor 2] Disables the Motor 2 control signal output (six outputs), under any of the following conditions.</p> <ol style="list-style-type: none"> 1. Instantaneous value of current of any phase exceeds $3.54(=1.67 \times \sqrt{2}) \times 1.5$ [A] (monitored in current control period) 2. Inverter bus voltage exceeds 60 [V] (monitored in current control period) 3. Inverter bus voltage is less than 8 [V] (monitored in current control period) 4. Rotation speed exceeds 4500 [rpm] (monitored in current control period) <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

Table 2-10 shows the interrupt and priorities used in this system.

Table 2-10 Interrupt priority

Interrupt level	Priority	Function
15		
14		
13		
12		
11		
10		AGT0/1 INT 500 [µsec] Interrupt handling (Motor 1, 2 are same priority)
9		
8		
7		
6		
5		ADC0 ADI0/2(RA6T2) ADC0/1 SCAN END(RA8T1) A/D complete interrupt (Motor 1, 2 are same priority)
4		
3		
2		
1		
0		POEG1/3 EVENT(RA6T2) POEG0/3 EVENT(RA8T1) 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 2-22 RA6T2 FSP Interrupts configuration

Allocations		
Interrupt	Event	ISR
0	AGT0 INT (AGT interrupt)	agt_int_isr
1	ADC0 SCAN END (End of A/D scanning operation)	adc_scan_end_isr
2	ADC1 SCAN END B (End of A/D scanning operation for Group B)	adc_scan_end_b_isr
3	POEG0 EVENT (Port Output disable interrupt A)	poeg_event_isr
4	POEG3 EVENT (Port Output disable interrupt D)	poeg_event_isr
5	AGT1 INT (AGT interrupt)	agt_int_isr

Figure 2-23 RA8T1 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 "High" level, it is determined that the start switch is being pressed. Conversely, when the level is switched to "Low", the software determines that the motor should be stopped.

"High" level: Motor Start

"Low" level: Motor Stop

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)	
Rotation speed reference	CW	0 [rpm] to 2400[rpm] : 0800H to 0FFFH
	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)
Inverter bus voltage	0 [V] to 73.26 [V] : 0000H to 0FFFH

(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 current : A/D conversion value)
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

3.1.3 Modulation (current control module)

A modulated voltage can be output to improve the efficiency of voltage usage. The modulation operation is set from the API of the current control module.

3.1.3.1 Sine wave modulation (MOD_METHOD_SPWM)

The modulation factor m is defined as follows.

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

m : Modulation ratio V : Reference voltage E : Inverter input voltage

3.1.3.2 Space Vector Modulation (MOD_METHOD_SVPWM)

In vector control of a permanent magnet synchronous motor, generally, the desired voltage command value of each phase is generated sinusoidally. However, if the generated value is used as-is for the modulation wave for PWM generation, voltage utilization as applied to the motor (in terms of line voltage) is limited to a maximum of 86.7% with respect to inverter bus voltage. As such, as shown in the following expression, the average of the maximum and minimum values is calculated for the voltage command value of each phase, and the value obtained by subtracting the average from the voltage command value of each phase is used as the modulation wave. As a result, the maximum amplitude of the modulation wave is multiplied by $\sqrt{3}/2$, while voltage utilization becomes 100% and line voltage is unchanged.

$$\begin{pmatrix} V'_u \\ V'_v \\ V'_w \end{pmatrix} = \begin{pmatrix} V_u \\ V_v \\ V_w \end{pmatrix} + \Delta V \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$$

$$\therefore \Delta V = -\frac{V_{max} + V_{min}}{2}, \quad V_{max} = \max\{V_u, V_v, V_w\}, \quad V_{min} = \min\{V_u, V_v, V_w\}$$

V_u, V_v, V_w : Command values of U-, V-, and W-phases

V'_u, V'_v, V'_w : Command values of U-, V-, and W-phases for PWM generation (modulation wave)

The modulation factor m is defined as follows.

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

m : Modulation ratio V' : Reference phase voltage for PWM
 E : Inverter input voltage

3.1.4 State transition

Figure 3-1 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.

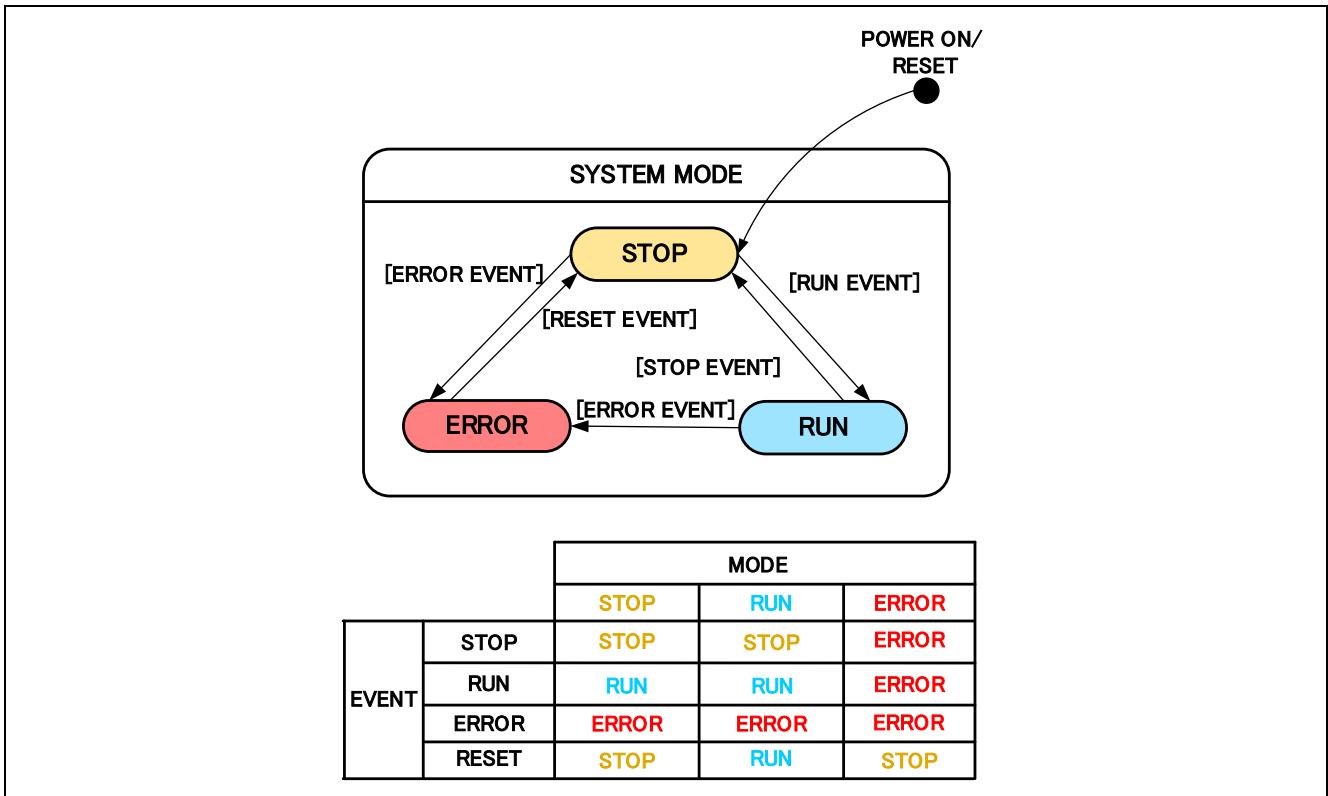


Figure 3-1 State transition diagram of sensorless vector control software

(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 3-1, 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 Start-up method

Figure 3-2 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.

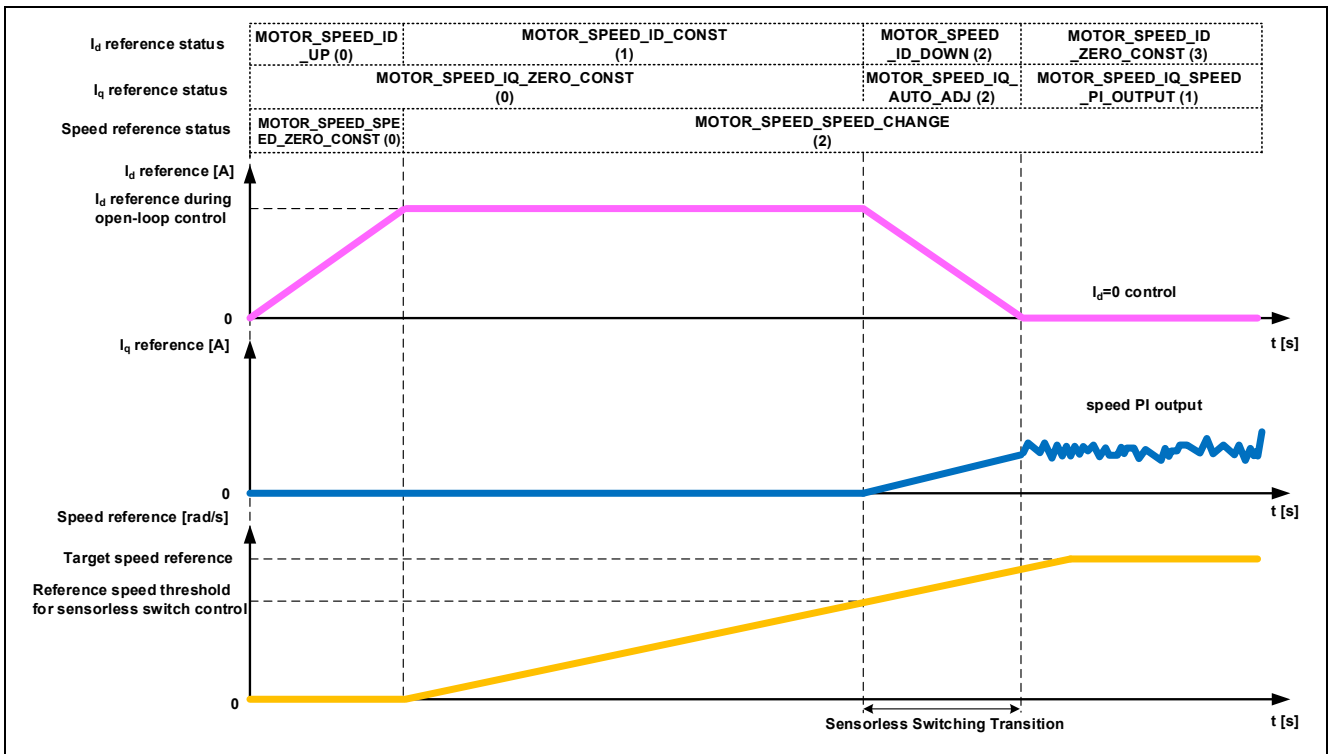


Figure 3-2 Startup control of vector control software

3.1.6 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		Monitoring cycle
	Parameter	Value	
Over current error	Over current limit [A]	3.54	Current control
Over voltage error	Over voltage limit [V]	60	Current control
Low voltage error	Low voltage limit [V]	8	Current control
Over speed error	Speed limit [rpm]	4500	Current control

3.1.7 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.

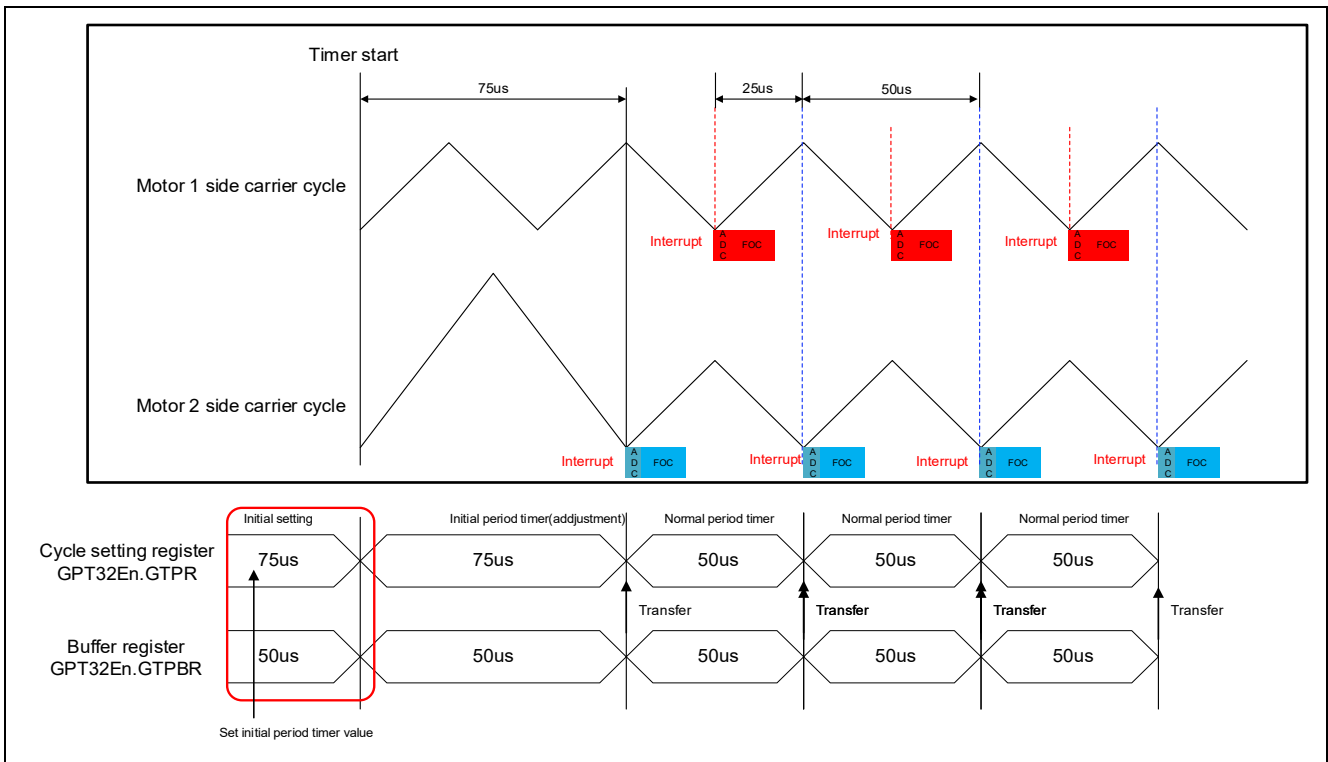


Figure 3-3 Start carrier output

By this setting, the two motors all have 50µs 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 Sensorless Vector Control Software

The block diagram of sensorless vector control is shown below.

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.

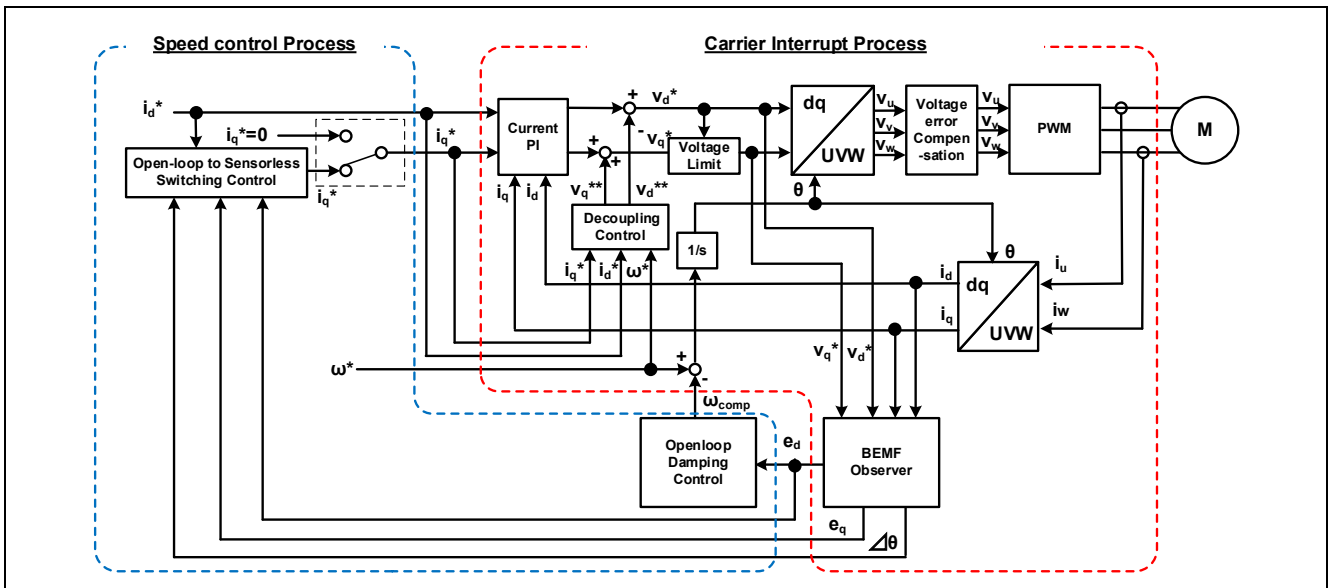


Figure 3-4 Block diagram of sensorless vector control (open-loop control)

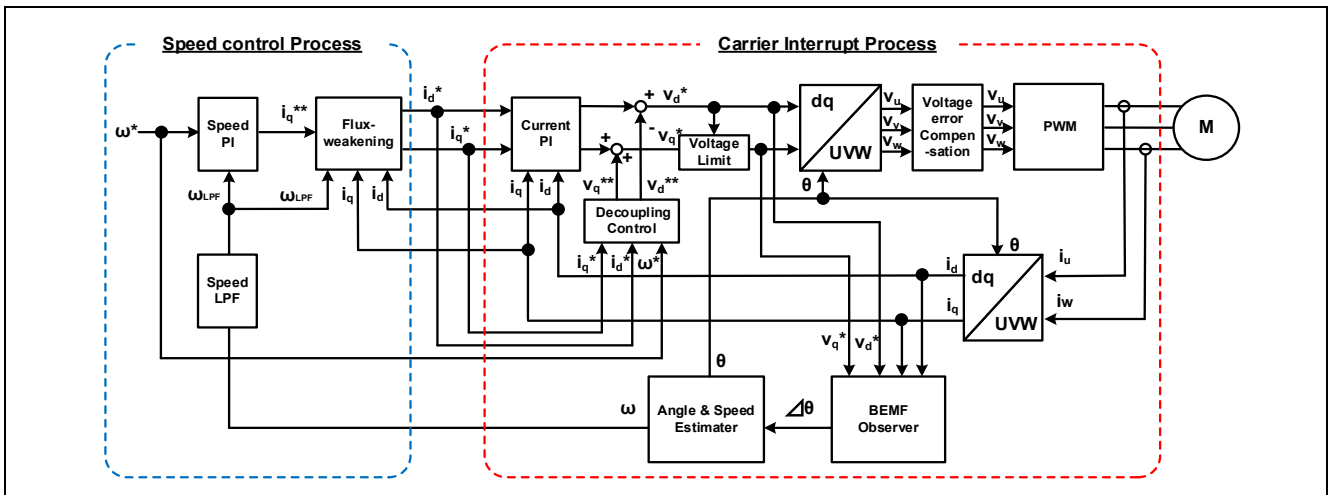


Figure 3-5 Block diagram of sensorless vector control (sensorless control)

3.3 List of functions

Table 3-6 List of functions executed in current control interrupt (1/5)

File name	Function name	Process overview
mtr_main.c	mtr_callback_event0 Input : (motor_callback_args_t *) p_args / Callback argument Output : None	Sensorless vector control callback function for motor 1
	mtr_callback_event1 Input : (motor_callback_args_t *) p_args / Callback argument Output : None	Sensorless vector control callback function for motor 2
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 current control interrupt (2/5)

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 current control interrupt (3/5)

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_uv_w_dq_abs Input : (const float) f_angle / Rotor angle (const float *) f_uv_w / Pointer to UVW-phase array in [U,V,W] format (float *) f_dq / Where to store [d,q] formatted array on dq coordinates Output : None	Coordinate transform UVW to dq (absolute transform)

Table 3-9 List of functions executed in current control interrupt (4/5)

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 / Rotational speed (float const) phase / 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) id_reference / D-axis current Reference (float const) iq_reference / 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_ctrl / 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 current control interrupt (5/5)

File name	Function name	Process overview
rm_motor_current.c	motor_current_transform_dq_uvuw_abs Input : (const float) f_angle / Rotor angle (const float *) f_dq / Pointer to dq-axis value array in [D,Q] format (float *) f_uvuw / 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_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
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 3-11 List of functions executed in speed control 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	Sensorless vector control callback function for motor1
	mtr_callback_event1 Input : (motor_callback_args_t *) p_args / Callback argument Output : None	Sensorless vector control callback function for motor2
	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_output_t const * const) p_st_output / Pointer to output current data Output : fsp_err_t / Execution result	Set (input) parameter 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 3-12 List of functions executed in speed control 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 3-13 List of functions executed in speed control 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

3.4 Contents of Control

3.4.1 Configuration options

The configuration options of the 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 3-14 Configuration options(`rm_motor_sensorless.h`)

Options	Description
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 3-15 Configuration options(`rm_motor_sensorless.h`)

Options	RA6T2	RA8T1
Limit of over current (A)	1.67	1.67
Limit of over voltage (V)	60.0	60.0
Limit of over speed (rpm)	4500.0	4500.0
Limit of low voltage (V)	8.0	8.0

3.4.2 Configuration Options for included modules

The sensorless vector control module for motor includes below modules.

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

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

The settings are not different between motor 1 and 2 except driver module.

Some settings are not listed, because these are invalid for this sample program of this application note.

Table 3-16 Configuration options (rm_motor_current.h)

Options	Description
General Shunt type	Selects how many shunt resistances to use current detection.
General Current control decimation	Counts of decimation about carrier interrupt
General PWM carrier frequency (kHz)	PWM carrier frequency [kHz]
General Input voltage (V)	Input voltage [V]
General Sample delay compensation	Selects whether to “enable” or “disable” sample delay compensation
General Period magnification value	Period magnification value for sampling delay compensation.
General Voltage error compensation	Selects whether to “enable” or “disable” voltage error compensation.
General Voltage error compensation table of voltage 1	Table of voltage error compensation about voltage #1
General Voltage error compensation table of voltage 2	Table of voltage error compensation about voltage #2
General Voltage error compensation table of voltage 3	Table of voltage error compensation about voltage #3
General Voltage error compensation table of voltage 4	Table of voltage error compensation about voltage #4
General Voltage error compensation table of voltage 5	Table of voltage error compensation about voltage #5
General Voltage error compensation table of current 1	Table of voltage error compensation about current #1
General Voltage error compensation table of current 2	Table of voltage error compensation about current #2
General Voltage error compensation table of current 3	Table of voltage error compensation about current #3
General Voltage error compensation table of current 4	Table of voltage error compensation about current #4
General Voltage error compensation table of current 5	Table of voltage error compensation about current #5
Design Parameter Current PI loop omega	Current PI control omega parameter [Hz].
Design Parameter Current PI loop zeta	Current PI control zeta parameter.
Motor Parameter Pole pairs	Pole pairs of target motor.
Motor Parameter Resistance (ohm)	Resistance of motor [ohm].
Motor Parameter Inductance of d-axis (H)	D-axis inductance [H].
Motor Parameter Inductance of q-axis (H)	Q-axis inductance [H].
Motor Parameter Permanent magnetic flux (Wb)	Magnetic flux [Wb].
Motor Parameter Rotor inertia (kgm ²)	Rotor inertia [kgm ²].

Table 3-17 Configuration Options initial value (rm_motor_current.h)

Options	RA6T2	RA8T1
General Shunt type	2shunt	2shunt
General Current control decimation	0	0
General PWM carrier frequency (kHz)	20.0	20.0
General Input voltage (V)	24.0	24.0
General Sample delay compensation	Disable	Disable
General Period magnification value	1.5	1.5
General Voltage error compensation	Enable	Enable
General Voltage error compensation table of voltage 1	0.477	0.477
General Voltage error compensation table of voltage 2	0.742	0.742
General Voltage error compensation table of voltage 3	0.892	0.892
General Voltage error compensation table of voltage 4	0.979	0.979
General Voltage error compensation table of voltage 5	1.009	1.009
General Voltage error compensation table of current 1	0.021	0.021
General Voltage error compensation table of current 2	0.034	0.034
General Voltage error compensation table of current 3	0.064	0.064
General Voltage error compensation table of current 4	0.158	0.158
General Voltage error compensation table of current 5	0.400	0.400
Design Parameter Current PI loop omega	300.0	300.0
Design Parameter Current PI loop zeta	1.0	1.0
Motor Parameter Pole pairs	4	4
Motor Parameter Resistance (ohm)	1.3	1.3
Motor Parameter Inductance of d-axis (H)	0.0013	0.0013
Motor Parameter Inductance of q-axis (H)	0.0013	0.0013
Motor Parameter Permanent magnetic flux (Wb)	0.01119	0.01119
Motor Parameter Rotor inertia (kgm ²)	0.000003666	0.000003666

Table 3-18 Configuration options (rm_motor_speed.h)

Options	Description
Common Position support	Support position control
General Speed control period (sec)	The period of speed control process [sec].
General Step of speed climbing (rpm)	The step of speed fluctuation [rpm]. Program controls speed by this step at acceleration and deceleration.
General Maximum rotational speed (rpm)	Maximum rotational speed [rpm]
General Speed LPF omega	Speed LPF parameter omega [Hz].
General Limit of q-axis current (A)	Limit of q-axis current [A].
General Step of speed feedback at open-loop	Rate of reference speed for feedback speed limiter at Open-Loop.
General Natural frequency	Natural frequency for disturbance speed observer.
General Open-loop damping	Select enable/disable of damping control at Open-Loop.
General Flux weakening	Select enable/disable of flux weakening control at high speed.
General Torque compensation for sensorless transition	Select enable/disable of soft switching at the transition from Open-Loop to PI control.
General Speed observer	Select enable/disable of speed observer process
General Selection of speed observer	Select the method of speed observer
General Control method	Select the position control method.
Open-Loop Step of d-axis current climbing	The d-axis current reference ramping up rate [A/msec].
Open-Loop Step of d-axis current descending	The d-axis current reference ramping down rate [A/msec].
Open-Loop Step of q-axis current descending ratio	The q-axis current reference ramping down proportion to reference before open-loop [A/msec].
Open-Loop Reference of d-axis current	The d-axis current reference in open-loop drive [A].
Open-Loop Threshold of speed control descending	The speed threshold [rad/s] to ramp down the d-axis current [rpm].
Open-Loop Threshold of speed control climbing	The speed threshold [rad/s] to ramp up the d-axis current [rpm].
Open-Loop Period between open-loop to BEMF (sec)	Time to switch open-loop to sensor-less [sec].
Open-Loop Phase error(degree) to decide sensor-less switch timing	Phase error to decide sensor-less switch timing (electrical angle) [degree].
Design parameter Speed PI loop omega	Speed PI Control parameter omega.
Design parameter Speed PI loop zeta	Speed PI Control parameter zeta.
Design parameter Estimated d-axis HPF omega	Natural frequency [Hz] for HPF in open-loop damping gain design.
Design parameter Open-loop damping zeta	Damping ratio for open-loop damping gain design.
Design parameter Cutoff frequency of phase error LPF	The cut-off frequency [Hz] of phase error LPF gain design.
Design parameter Speed observer omega	Speed observer omega.
Design parameter Speed observer zeta	Speed observer zeta.
Motor Parameter Pole pairs	Pole pairs of target motor.
Motor Parameter Resistance (ohm)	Resistance of motor [ohm].
Motor Parameter Inductance of d-axis (H)	D-axis inductance [H].
Motor Parameter Inductance of q-axis (H)	Q-axis inductance [H].
Motor Parameter Permanent magnetic flux (Wb)	Magnetic flux [Wb].
Motor Parameter Rotor inertia (kgm ²)	Rotor inertia [kgm ²].

Table 3-19 Configuration Options initial value (rm_motor_speed.h)

Options	RA6T2	RA8T1
Common Position support	-	-
General Speed control period (sec)	0.0005	0.0005
General Step of speed climbing (rpm)	0.5	0.5
General Maximum rotational speed (rpm)	2400.0	2400.0
General Speed LPF omega	10.0	10.0
General Limit of q-axis current (A)	1.67	1.67
General Step of speed feedback at open-loop	0.2	0.2
General Natural frequency	100.0	100.0
General Open-loop damping	Enable	Enable
General Flux weakening	Disable	Disable
General Torque compensation for sensorless transition	Enable	Enable
General Speed observer	Disable	Disable
General Selection of speed observer	Normal	Normal
General Control method	-	-
Open-Loop Step of d-axis current climbing	0.3	0.3
Open-Loop Step of d-axis current descending	0.3	0.3
Open-Loop Step of q-axis current descending ratio	1.0	1.0
Open-Loop Reference of d-axis current	0.3	0.3
Open-Loop Threshold of speed control descending	500	500
Open-Loop Threshold of speed control climbing	400	400
Open-Loop Period between open-loop to BEMF (sec)	0.025	0.025
Open-Loop Phase error(degree) to decide sensor-less switch timing	10	10
Design parameter Speed PI loop omega	5.0	5.0
Design parameter Speed PI loop zeta	1.0	1.0
Design parameter Estimated d-axis HPF omega	2.5	2.5
Design parameter Open-loop damping zeta	1.0	1.0
Design parameter Cutoff frequency of phase error LPF	10.0	10.0
Design parameter Speed observer omega	-	-
Design parameter Speed observer zeta	-	-
Motor Parameter Pole pairs	4	4
Motor Parameter Resistance (ohm)	1.3	1.3
Motor Parameter Inductance of d-axis (H)	0.0013	0.0013
Motor Parameter Inductance of q-axis (H)	0.0013	0.0013
Motor Parameter Permanent magnetic flux (Wb)	0.01119	0.01119
Motor Parameter Rotor inertia (kgm ²)	0.000003666	0.000003666

Table 3-20 Configuration options (rm_motor_estimate.h)

Options	Description
Motor Parameter Pole pairs	Pole pairs of target motor.
Motor Parameter Resistance (ohm)	Resistance of motor [ohm].
Motor Parameter Inductance of d-axis (H)	D-axis inductance [H].
Motor Parameter Inductance of q-axis (H)	Q-axis inductance [H].
Motor Parameter Permanent magnetic flux (Wb)	Magnetic flux [Wb].
Motor Parameter Rotor inertia (kgm ²)	Rotor inertia [kgm ²].
Motor Parameter Nominal current (Arms)	Nominal current [Arms]
Openloop damping	Select enable/disable of Open-Loop Damping Control
Natural frequency of BEMF observer	Natural frequency for BEMF observer [Hz].
Damping ratio of BEMF observer	Damping ratio for BEMF observer.
Natural frequency of PLL Speed estimate loop	Natural frequency for rotor position Phase-Locked Loop [Hz].
Damping ratio of PLL Speed estimate loop	Damping ratio for rotor position Phase-Locked Loop.
Control period	Period of Speed Control [sec]

Table 3-21 Configuration Options initial value (rm_motor_estimate.h)

Options	RA6T2	RA8T1
Motor Parameter Pole pairs	4	4
Motor Parameter Resistance (ohm)	1.3	1.3
Motor Parameter Inductance of d-axis (H)	0.0013	0.0013
Motor Parameter Inductance of q-axis (H)	0.0013	0.0013
Motor Parameter Permanent magnetic flux (Wb)	0.01119	0.01119
Motor Parameter Rotor inertia (kgm ²)	0.000003666	0.000003666
Motor Parameter Nominal current (Arms)	1.67	1.67
Openloop damping	Enable	Enable
Natural frequency of BEMF observer	1000.0	1000.0
Damping ratio of BEMF observer	1.0	1.0
Natural frequency of PLL Speed estimate loop	20.0	20.0
Damping ratio of PLL Speed estimate loop	1.0	1.0
Control period	0.00005	0.00005

Table 3-22 Configuration options (rm_motor_driver.h)

Options	Description
Common ADC_B Support	ADC_B module support
Common Shared ADC support	Selection of using shared ADC module
Common Supported Motor Number	Number of driven motors
General Shunt type	Current detection method selection
General Modulation method	Selection of the method of modulation
General PWM output port UP	Port setting of U phase upper arm
General PWM output port UN	Port setting of U phase lower arm
General PWM output port VP	Port setting of V phase upper arm
General PWM output port VN	Port setting of V phase lower arm
General PWM output port WP	Port setting of W phase upper arm
General PWM output port WN	Port setting of W phase lower arm
General PWM Timer Frequency (MHz)	PWM Timer Clock Frequency [MHz]
General PWM Carrier Period (Microseconds)	PWM Carrier Period [Micro seconds]
General Dead Time (Raw Counts)	PWM Dead time [raw counts]
General Current Range (A)	Measurement Range of Electric current [A]
General Voltage Range (V)	Measurement Range of Inverter Voltage [V]
General Counts for current offset measurement	Counts of measurement the offset of A/D Conversion at electric current input.
General A/D conversion channel for U Phase current	A/D channel for U-phase current
General A/D conversion channel for W Phase current	A/D channel for W-phase current
General A/D conversion channel for Main Line Voltage	A/D channel for main line voltage
General A/D conversion channel for V Phase current	A/D channel for V-phase current
General A/D conversion channel for sin signal	A/D channel for sin signal
General A/D conversion channel for cos signal	A/D channel for cos signal
General Using ADC scan group	Set ADC scan group according to ADC module setting.
General A/D conversion unit for U Phase current	Select the A/D conversion module for U phase current
General A/D conversion unit for W Phase current	Select the A/D conversion module for W phase current
General A/D conversion unit for main line voltage	Select the A/D conversion module for main line voltage
General A/D conversion unit for V Phase current	Select the A/D conversion module for V phase current
General A/D conversion unit for sin signal	Select the A/D conversion module for sin signal
General A/D conversion unit for cos signal	Select the A/D conversion module for cos signal
General ADC interrupt module	Select from which module ADC interrupt happens
General Adjustment value to current A/D	Current A/D timing adjustment (for 1shunt)
General Minimum difference of PWM duty	Minimum difference of PWM duty setting (for 1shunt)
General Adjustment delay of A/D conversion	A/D conversion delay timing adjustment (for 1shunt)
General 1shunt interrupt phase	Which phase is used to detect 1shunt current (for 1shunt)
General Input Voltage (V)	Range of input for main line voltage
General Resolution of A/D conversion	Resolution of A/D conversion Please set same value with ADC module setting.
General Offset of A/D conversion for current	Offset level of A/D conversion input for current Please set according to the circuit.
General Conversion level of A/D conversion for voltage	Conversion level of A/D conversion for voltage Please set when the CPU main voltage is different.
General GTIOCA stop level	Output level of upper arm at stop status
General GTIOCB stop level	Output level of lower arm at stop status
Modulation Maximum duty	Maximum duty of PWM Maximum duty except dead time.

Table 3-23 Configuration Options initial value (rm_motor_driver.h)

Options	RA6T2	RA8T1
Common ADC_B Support	Enabled	-
Common Shared ADC support	Enabled	Enabled
Common Supported Motor Number	2	2
General Shunt type	2shunt	2shunt
General Modulation method	SVPWM	SVPWM
General PWM output port UP	1 : BSP_IO_PORT _11_PIN_04 2 : BSP_IO_PORT _12_PIN_08	1 : BSP_IO_PORT _01_PIN_15 2 : BSP_IO_PORT _08_PIN_02
General PWM output port UN	1 : BSP_IO_PORT _11_PIN_05 2 : BSP_IO_PORT _12_PIN_09	1 : BSP_IO_PORT _06_PIN_09 2 : BSP_IO_PORT _08_PIN_03
General PWM output port VP	1 : BSP_IO_PORT _11_PIN_06 2 : BSP_IO_PORT _10_PIN_08	1 : BSP_IO_PORT _01_PIN_13 2 : BSP_IO_PORT _06_PIN_03
General PWM output port VN	1 : BSP_IO_PORT _11_PIN_07 2 : BSP_IO_PORT _10_PIN_09	1 : BSP_IO_PORT _01_PIN_14 2 : BSP_IO_PORT _06_PIN_02
General PWM output port WP	1 : BSP_IO_PORT _11_PIN_08 2 : BSP_IO_PORT _10_PIN_10	1 : BSP_IO_PORT _03_PIN_00 2 : BSP_IO_PORT _06_PIN_01
General PWM output port WN	1 : BSP_IO_PORT _11_PIN_09 2 : BSP_IO_PORT _10_PIN_11	1 : BSP_IO_PORT _01_PIN_12 2 : BSP_IO_PORT _06_PIN_00
General PWM Timer Frequency (MHz)	120.0	120.0
General PWM Carrier Period (Microseconds)	50.0	50.0
General Dead Time (Raw Counts)	240	240
General Current Range (A)	16.5	16.5
General Voltage Range (V)	73.26	73.26
General Counts for current offset measurement	500	500
General A/D conversion channel for U Phase current	1 : 4 2 : 18	1:0 2:16
General A/D conversion channel for W Phase current	1 : 0 2 : 21	1:2 2:2
General A/D conversion channel for Main Line Voltage	1 : 6 2 : 25	1:8 2:0
General A/D conversion channel for V Phase current	-	-
General A/D conversion channel for sin signal	-	-
General A/D conversion channel for cos signal	-	-
General Using ADC scan group	1 : 0 2 : 2	-

Table 3-24 Configuration Options initial value (rm_motor_driver.h)

Options	RA6T2	RA8T1
General A/D conversion unit for U Phase current	-	1 : 0 2 : 0
General A/D conversion unit for W Phase current	-	1 : 0 2 : 1
General A/D conversion unit for main line voltage	-	1 : 0 2 : 1
General A/D conversion unit for V Phase current	-	-
General A/D conversion unit for sin signal	-	-
General A/D conversion unit for cos signal	-	-
General ADC interrupt module	-	1 : 1st 2 : 2nd
General Adjustment value to current A/D	-	-
General Minimum difference of PWM duty	-	-
General Adjustment delay of A/D conversion	-	-
General 1shunt interrupt phase	-	-
General Input Voltage (V)	24.0	24.0
General Resolution of A/D conversion	0xFFF	0xFFF
General Offset of A/D conversion for current	0x7FF	0x7FF
General Conversion level of A/D conversion for voltage	1.0	1.0
General GTIOCA stop level	Pin Level Low	Pin Level Low
General GTIOCB stop level	Pin Level High	Pin Level High
Modulation Maximum duty	0.9375	0.9375

3.5 Control flowcharts

3.5.1 Main process

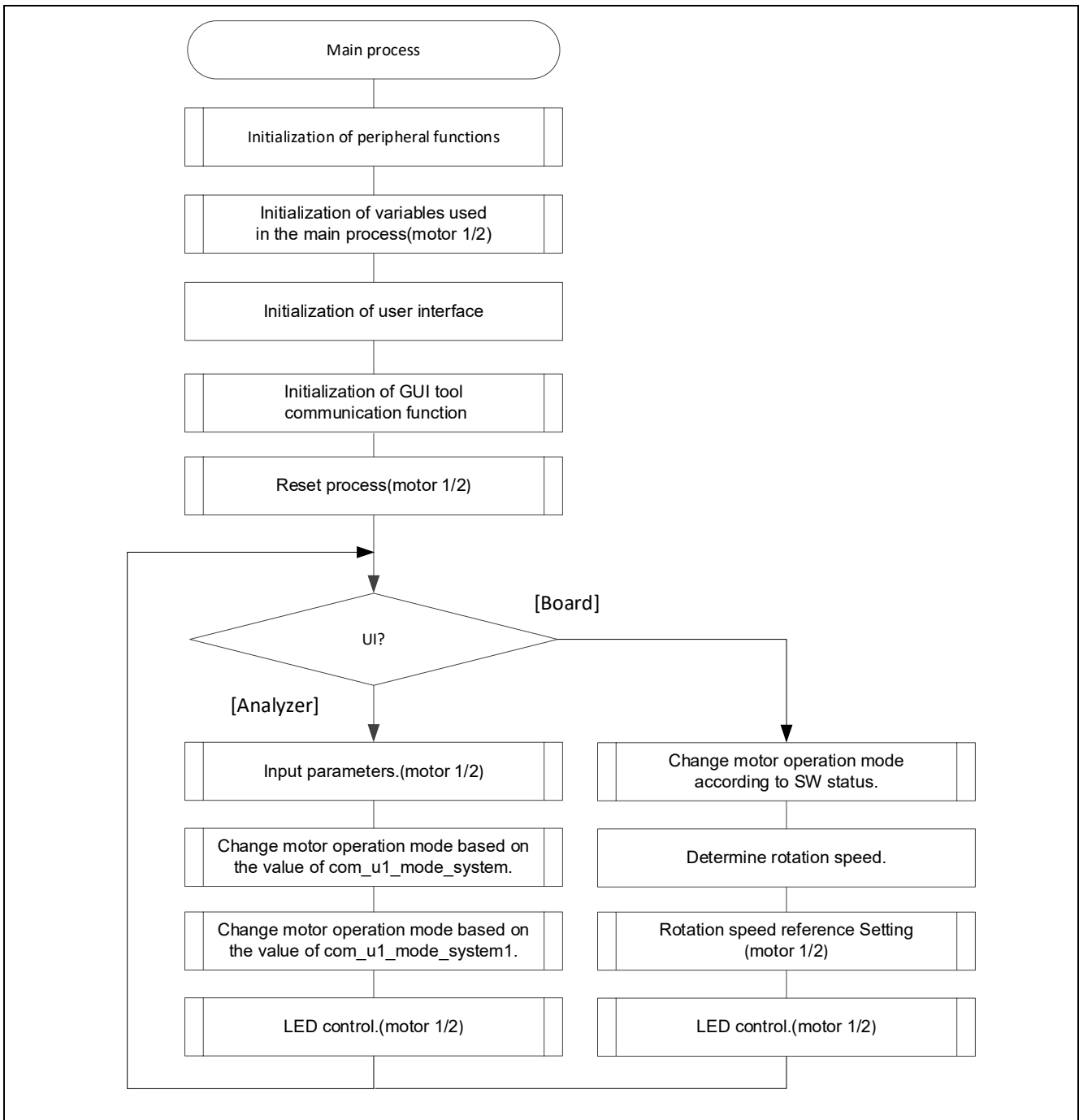


Figure 3-6 Main process flowchart

3.5.2 Current Control Period Interrupt (carrier synchronized interrupt) process

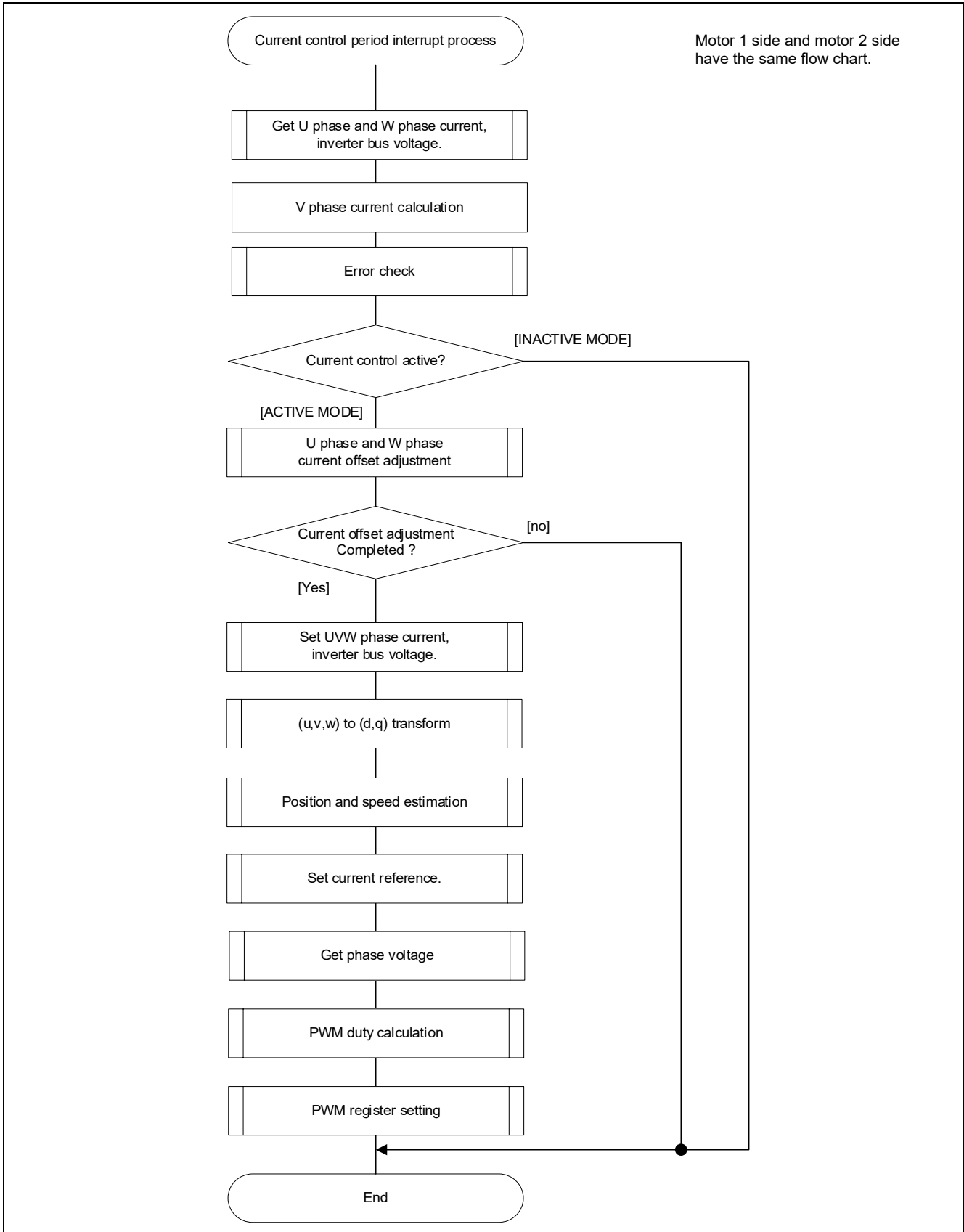


Figure 3-7 Current control Period Interrupt (carrier interrupt) process flowchart

3.5.3 Speed control Period interrupt process

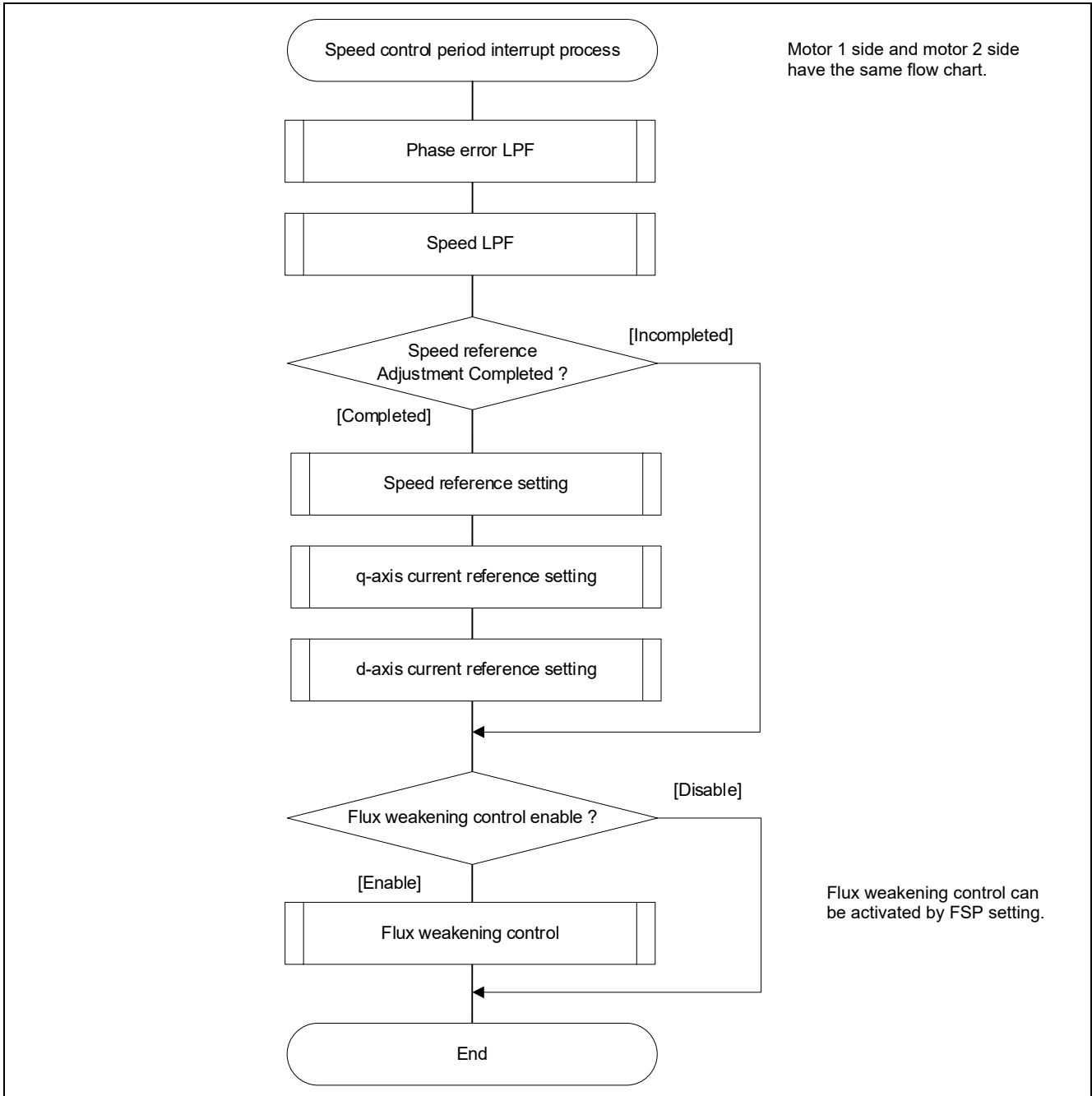


Figure 3-8 Speed Control period interrupt process flowchart

3.5.4 Over current detection interrupt process

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.

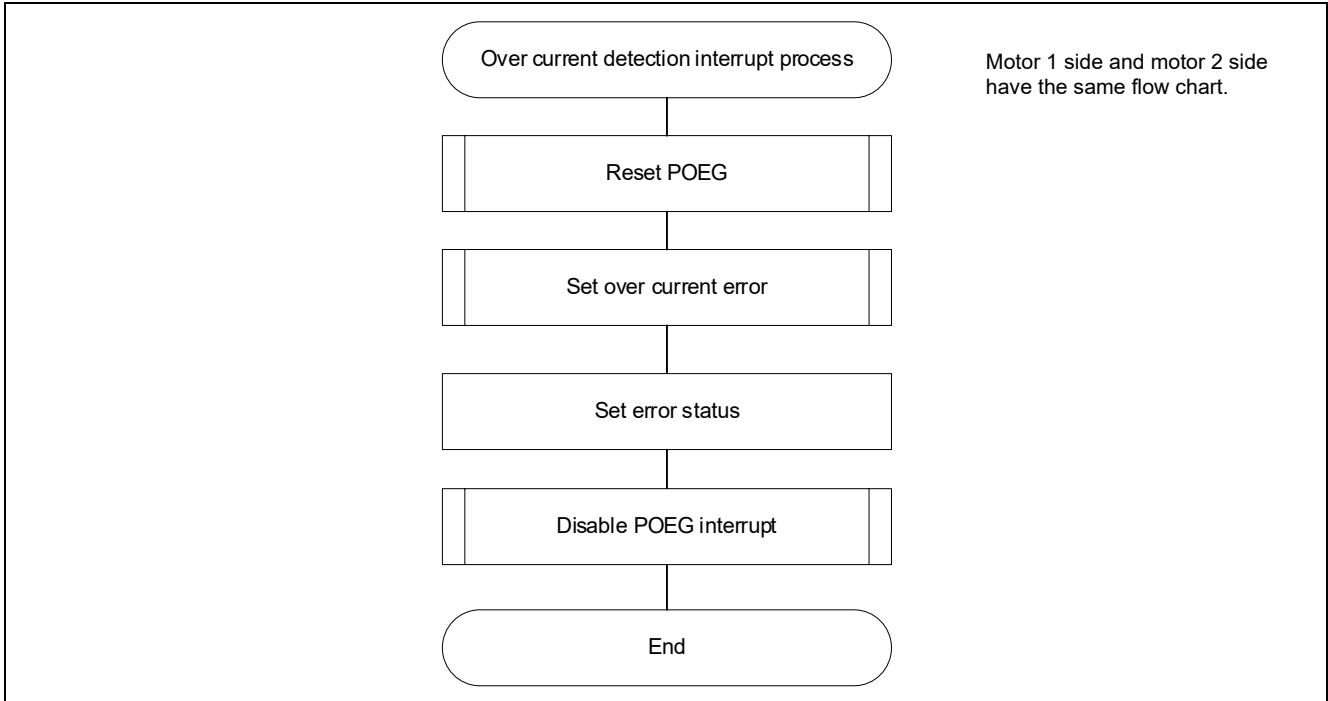


Figure 3-9 Over current detection interrupt process flowchart

4. Project Operation Overview

This section explains the operation of the sample program.

4.1 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.

4.2 Motor Control Development Support Tool ‘Renesas Motor Workbench’

4.2.1 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.

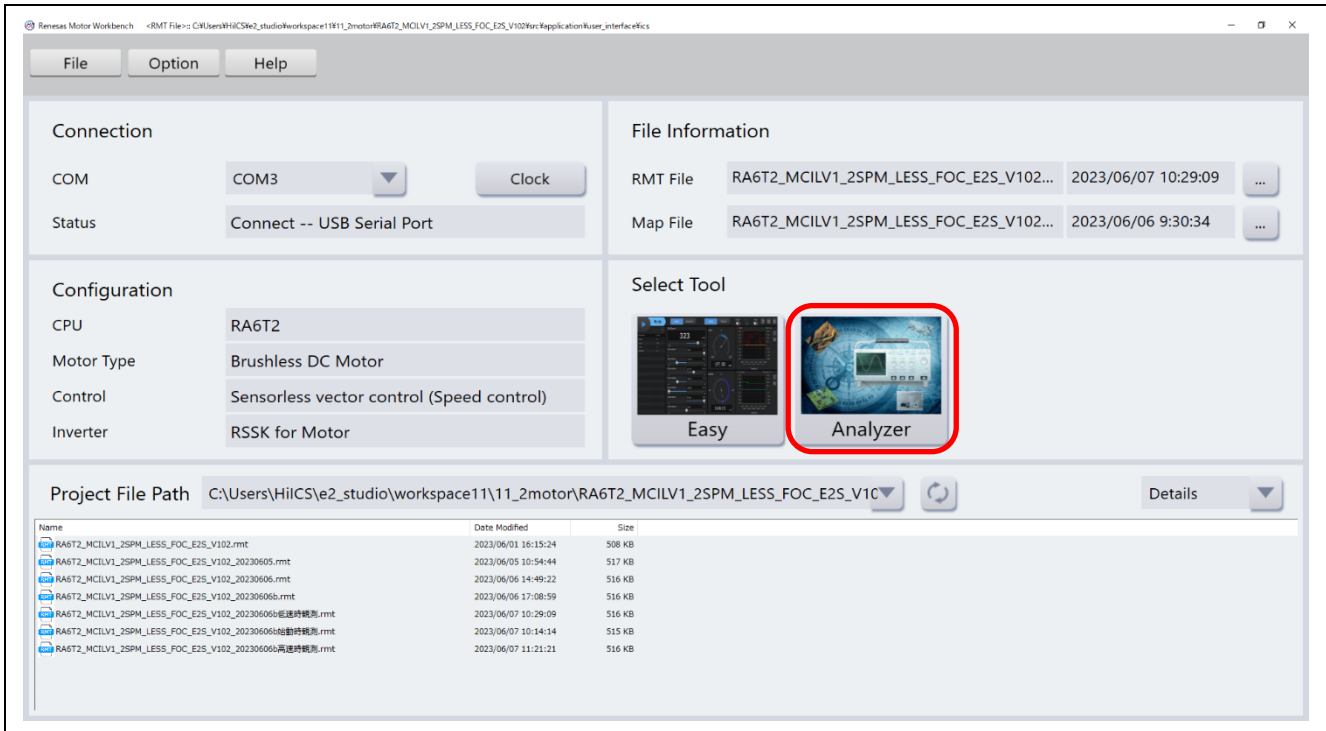


Figure 4-1 Renesas Motor Workbench – Appearance

- Set up for ‘Renesas Motor Workbench’



- Start ‘Renesas Motor Workbench’ by clicking this icon.
- Drop down menu [File] → [Open RMT File(O)].
And select RMT file in ‘[Project Folder]/src/application/user_interface/ics/’.
- Use the ‘Connection’ [COM] select menu to choose the COM port.
- Click the Analyzer button of Select Tool to activate Analyzer function.
- Please refer to ‘4.2.3 Operation example for Analyzer’ for motor driving operation.

4.2.2 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
<code>com_u1_sw_userif (*)</code>	<code>uint8_t</code>	User interface switch 0: Analyzer use 1: Board user interface use (default)
<code>com_u1_mode_system(*)</code>	<code>uint8_t</code>	State management 0: Stop mode 1: Run mode 3: Reset
<code>com_f4_ref_speed_rpm</code>	<code>float</code>	Speed reference (mechanical angle) [rpm]
<code>com_u2_mtr_pp</code>	<code>uint16_t</code>	Number of pole pairs
<code>com_f4_mtr_r</code>	<code>float</code>	Resistance [Ω]
<code>com_f4_mtr_ld</code>	<code>float</code>	d-axis Inductance [H]
<code>com_f4_mtr_lq</code>	<code>float</code>	q-axis Inductance [H]
<code>com_f4_mtr_m</code>	<code>float</code>	Magnetic Flux [Wb]
<code>com_f4_mtr_j</code>	<code>float</code>	Inertia [kgm^2]
<code>com_f4_current_omega</code>	<code>float</code>	Natural frequency of current control system [Hz]
<code>com_f4_current_zeta</code>	<code>float</code>	Damping ratio of current control system
<code>com_f4_speed_omega</code>	<code>float</code>	Natural frequency of speed control system [Hz]
<code>com_f4_speed_zeta</code>	<code>float</code>	Damping ratio of speed control system
<code>com_f4_e_obs_omega</code>	<code>float</code>	Natural frequency of BEMF estimation system [Hz]
<code>com_f4_e_obs_zeta</code>	<code>float</code>	Damping ratio of BEMF estimation system
<code>com_f4_pll_est_omega</code>	<code>float</code>	Natural frequency of position estimation system [Hz]
<code>com_f4_pll_est_zeta</code>	<code>float</code>	Damping ratio of position estimation system
<code>com_f4_ref_id</code>	<code>float</code>	d-axis current reference in open loop mode [A]
<code>com_f4_ol_id_up_step</code>	<code>float</code>	d-axis current reference ramping up rate
<code>com_f4_ol_id_down_step</code>	<code>float</code>	d-axis current reference ramping down rate
<code>com_f4_id_down_speed_rpm</code>	<code>float</code>	Speed when start to subtract d-axis current reference (mechanical angle) [rpm]
<code>com_f4_id_up_speed_rpm</code>	<code>float</code>	Speed when start to add d-axis current reference (mechanical angle) [rpm]
<code>com_f4_max_speed_rpm</code>	<code>float</code>	Maximum speed value (mechanical angle) [rpm]
<code>com_f4_overspeed_limit_rpm</code>	<code>float</code>	Speed limit (mechanical angle) [rpm]
<code>com_f4_overcurrent_limit</code>	<code>float</code>	Over current limit [A]
<code>com_f4_iq_limit</code>	<code>float</code>	q-axis current limit [A]
<code>com_f4_limit_speed_change</code>	<code>float</code>	Change speed limit (electrical angle) [rad/s]
<code>com_u1_enable_write</code>	<code>uint8_t</code>	Enabled to rewriting variables (rewritten when the same values as <code>g_u1_enable_write</code> are written)

4.2.3 Operation example for Analyzer

This section shows an example of motor driving operation using the Analyzer. Please refer to Figure 4-2 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.

(4) Click “Read” button

(3)(7) Click “Write” button

(1) Click

(6) Write “1”

(5) Write (“0” or “1”)

(2) Write reference

Variable Name	Data Type	Scale	Base	R?	Read	W?	Write
com_u1_mode_system	INT8	Q0	Decimal	<input checked="" type="checkbox"/>	0	<input checked="" type="checkbox"/>	1
com_u1_mode_system1	INT8	Q0	Decimal	<input checked="" type="checkbox"/>	0	<input checked="" type="checkbox"/>	1
com_f4_ref_speed_rpm	FLOAT	Q0	Decimal	<input checked="" type="checkbox"/>	0	<input checked="" type="checkbox"/>	2000
com_f4_ref_speed_rpm1	FLOAT	Q0	Decimal	<input checked="" type="checkbox"/>	0	<input checked="" type="checkbox"/>	-2000
com_u1_enable_write	INT8	Q0	Decimal	<input checked="" type="checkbox"/>	0	<input checked="" type="checkbox"/>	0
g_u1_enable_write	UINT8	Q0	Decimal	<input checked="" type="checkbox"/>	1	<input type="checkbox"/>	0
com_u1_sw_userif	INT8	Q0	Decimal	<input checked="" type="checkbox"/>	0	<input type="checkbox"/>	0

Figure 4-2 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.

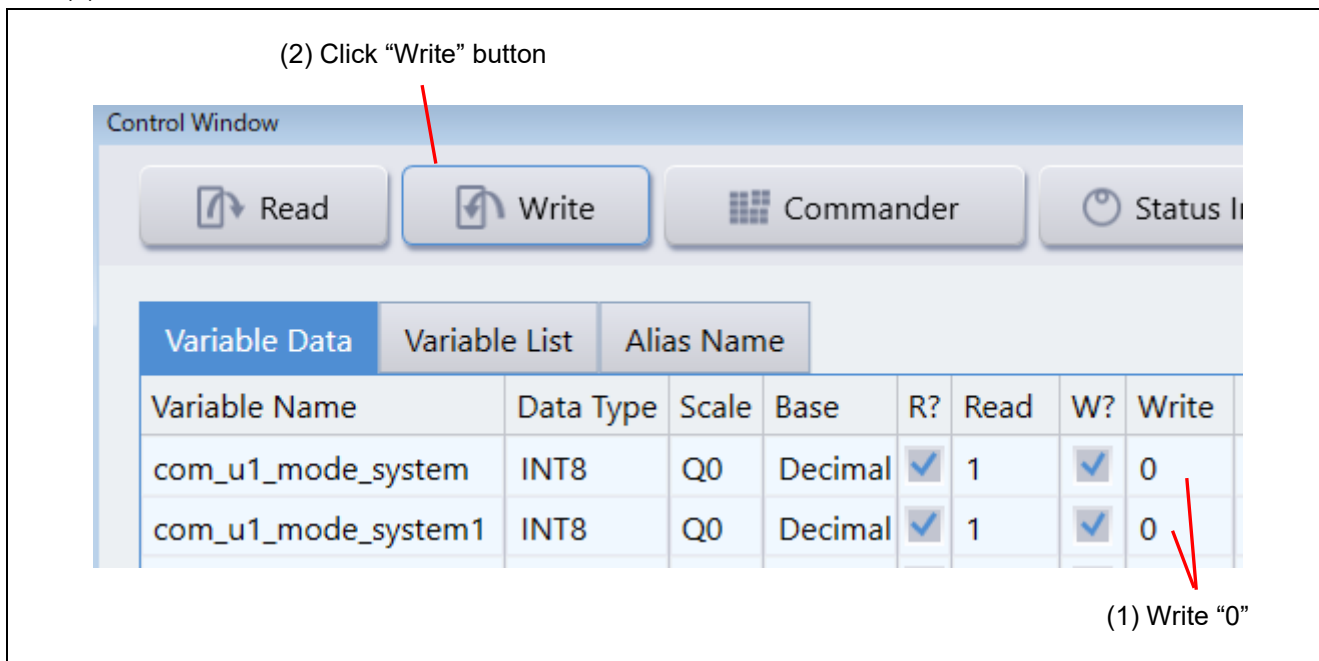


Figure 4-3 Procedure - Stop the motor

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

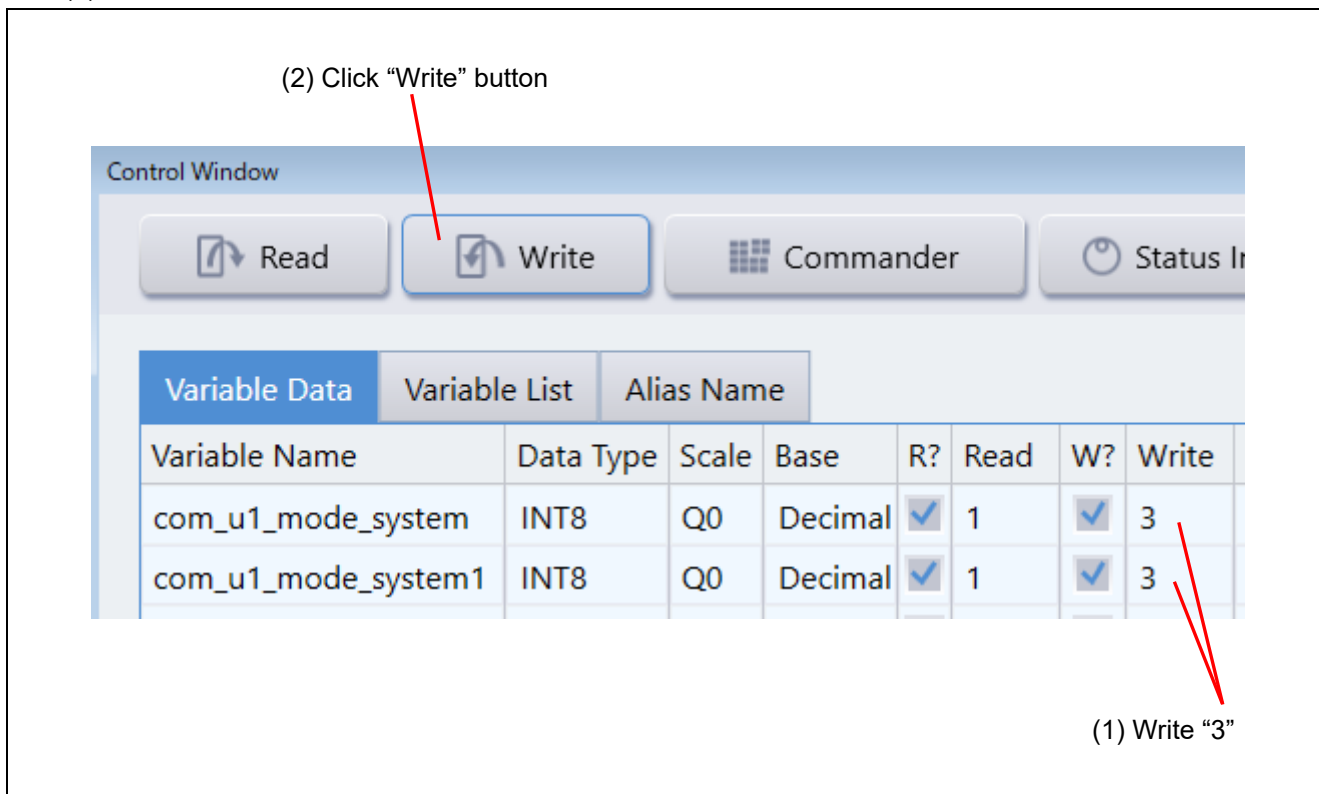


Figure 4-4 Procedure - Error cancel operation

4.2.4 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.

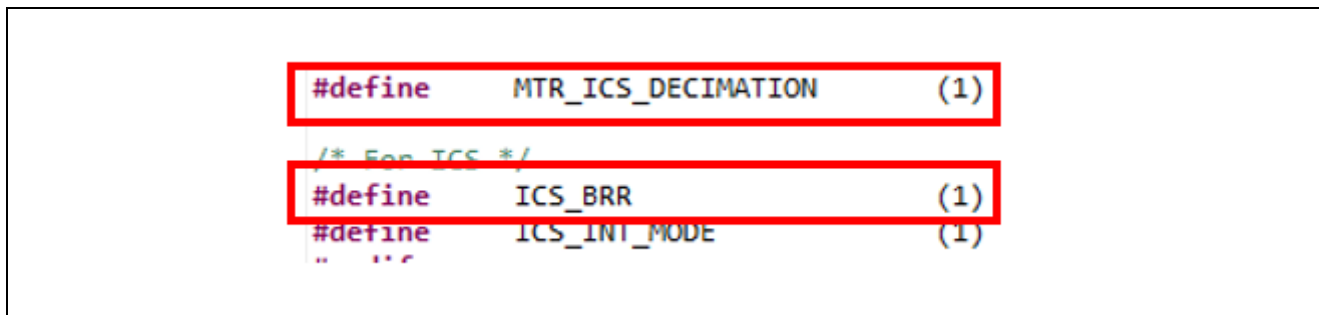


Figure 4-5 Modification of r_mtr_ics.h

- 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

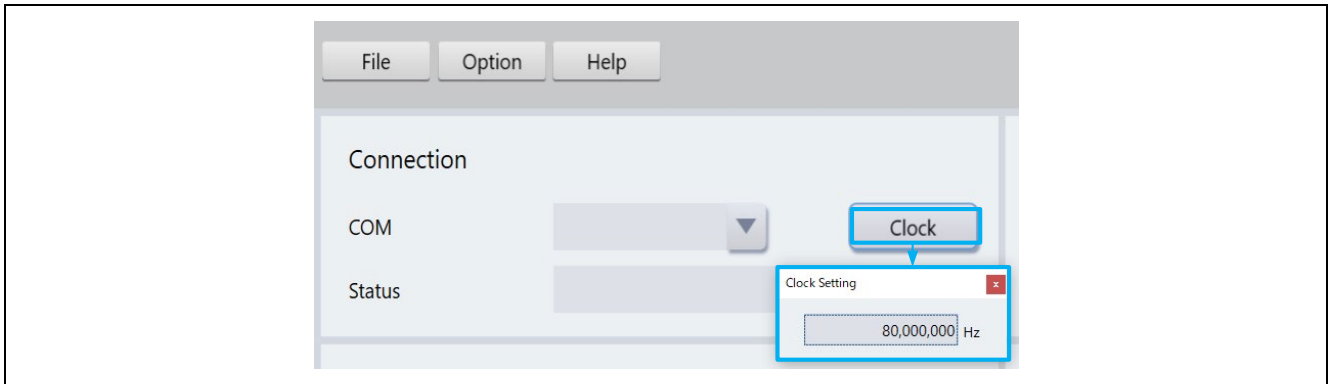


Figure 4-6 Clock frequency setting

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

4.2.5 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

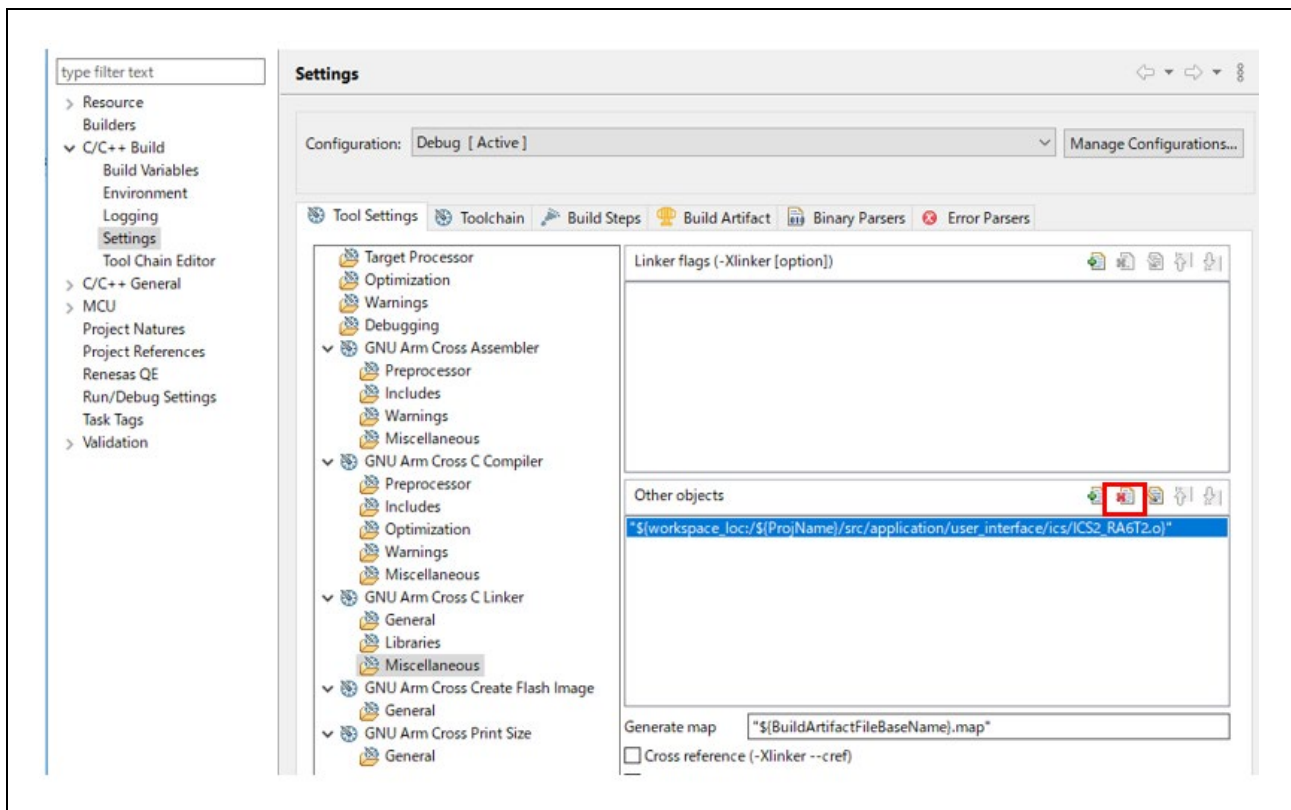


Figure 4-7 Unregister ICS2_RA6T2.o

(2) Register ICS2_RA6T2_Built_in.o

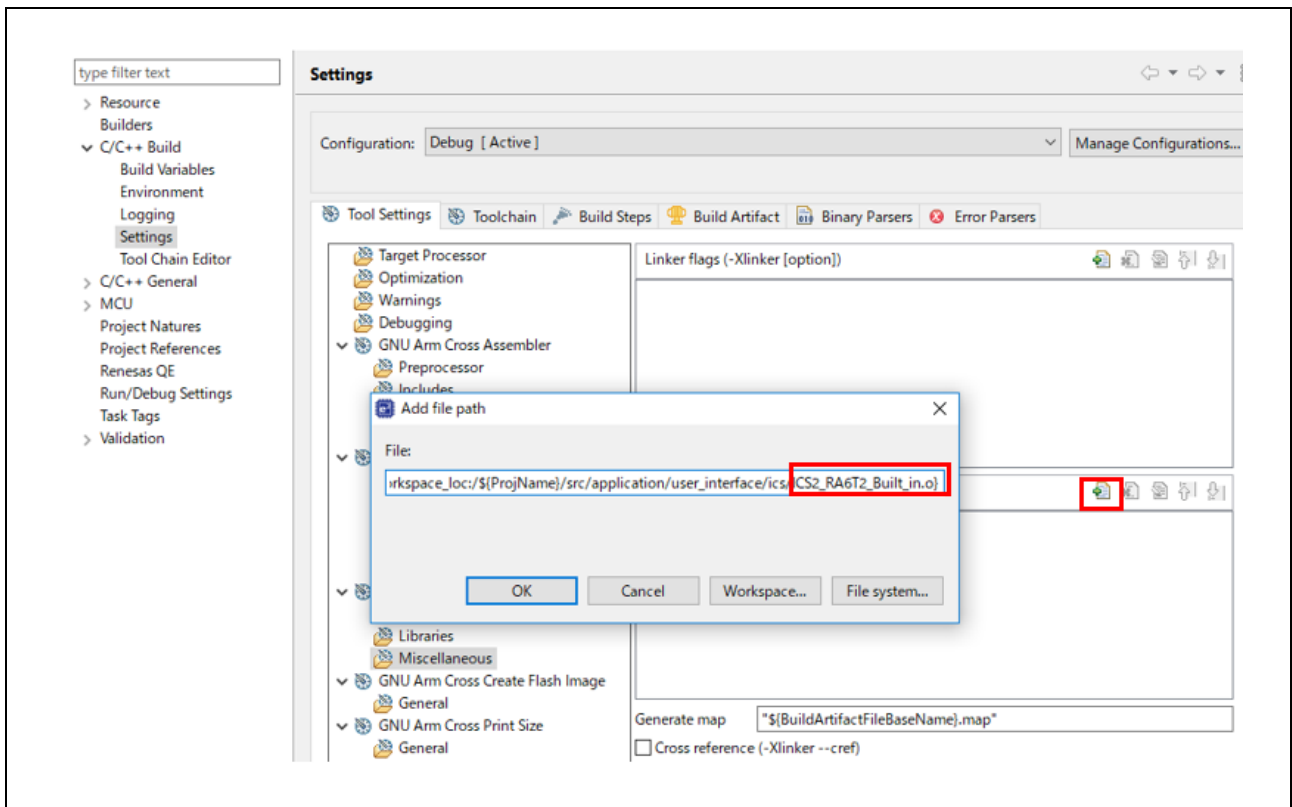


Figure 4-8 Register ICS2_RA6T2.o

(3) Change the value of USE_BUILT_IN in r_mtr_ics.h to 1.

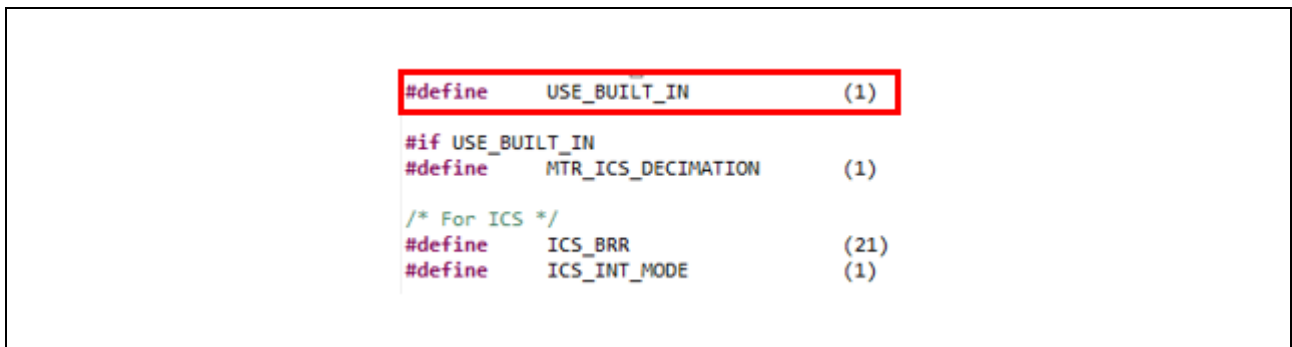


Figure 4-9 Modification of r_mtr_ics.h

- 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.

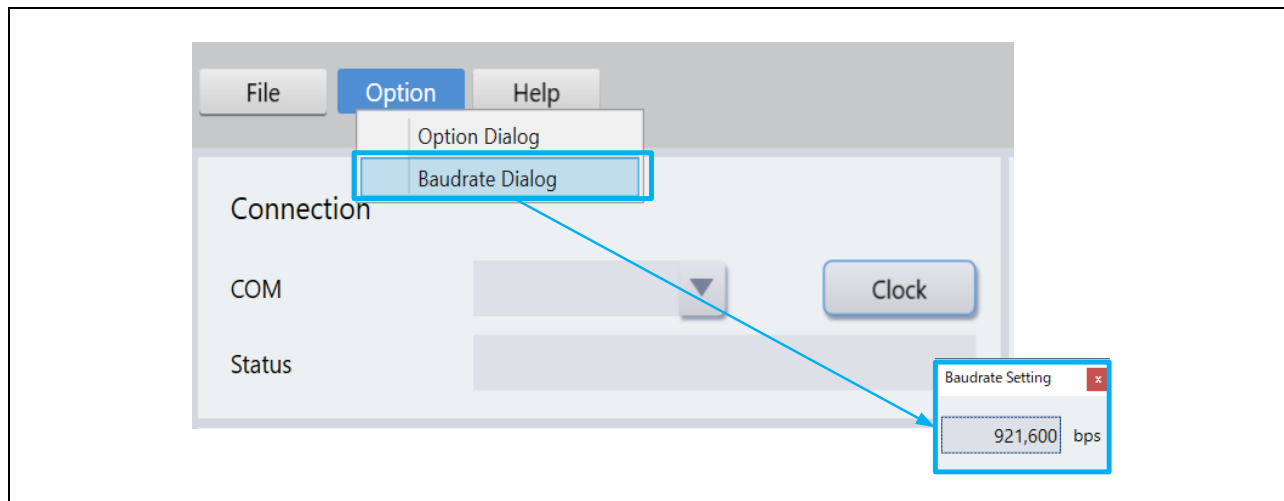


Figure 4-10 Baud rate setting

5. Reference Documents

- RA6T2 Group User's Manual: Hardware (R01UH0951)
- RA8T1 Group User's Manual: Hardware (R01UH1016)
- Renesas Flexible Software Package User's manual
(PDF version : R11UM0155, Web version : RA Flexible Software Package Documentation)
- Renesas e2 studio 2022-07 or higher User's Manual: Quick Start Guide (R20UT5210)
- Application note: Sensorless vector control for permanent magnet synchronous motor (Algorithm)
(R01AN3786)
- Renesas Motor Workbench User's Manual (R21UZ0004)
- Renesas Motor Workbench Quick start guide (R21QS0011)
- MCK-RA6T2 User's Manual (R12UZ0091)
- MCK-RA8T1 User's Manual (R12UZ0133)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Apr 28, 2022	-	First edition issued
1.01	Oct 18, 2022	-	For FSP V4.1.0
1.10	Aug 30, 2023	-	<ul style="list-style-type: none">Updated for Renesas Flexible Motor Control SeriesSupport for Dual Motor in FSP V4.6.0 rm_motor_driver module
1.20	Jan 23, 2024	—	<ul style="list-style-type: none">Added description related to RA8T1

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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