Vector control for permanent magnetic synchronous motor with inductive sensor

For Renesas Flexible Motor Control Series

Abstract

This application note aims for an explanation of vector control for permanent magnetic synchronous motor with induction sensors by using functions of microcontroller, and how to use the motor control development support tool, 'Renesas Motor Workbench'.

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

Operation checking device

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

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

Target software

The following shows the target software for this application note:

- RA6T2_MCILV1_SPM_IS_FOC_E2S_V110
- RA6T3_MCILV1_SPM_IS_FOC_E2S_V100
- RA4T1_MCILV1_SPM_IS_FOC_E2S_V100

Contents

1. Overview

This application note explains how to implement the vector control software that drives permanent magnetic synchronous motor (PMSM) with inductive sensors using the RA6T2 microcontroller and how to use the motor control development support tool, 'Renesas Motor Workbench'.

Note that this software uses the vector control algorithm described in the application note 'Vector control with encoder for permanent magnet synchronous motor (Algorithm)' (R01AN3789), so please refer to that for the details of the algorithm.

2. Development environment

2.1 Operation check environment

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

Table 2-1 Hardware Development Environment

Classification	Product used
Microcomputer / CPU card P/N	RA6T2 (R7FA6T2BD3CFP) / RTK0EMA270C00000BJ RA4T1 (R7FA4T1BB3CFM) / RTK0EMA430C00000BJ RA6T3(R7FA6T3BB3CFM) / RTK0EMA330C00000BJ
Inverter board	MCI-LV-1 / RTK0EM0000S04020BJ
motor	BLY171D-24V-4000 (manufactured by Anaheim Automation)
Sensor	Inductive sensor(Note3): IPS2200

Table 2-2 Software Development Environment

e^2studio version	FSP version	Toolchain version
e^2studio：2023-04	V4.4.0	GCC ARM Embedded : V10.3.1.20210824

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

2.2 Hardware specifications

2.2.1 Hardware configuration diagram

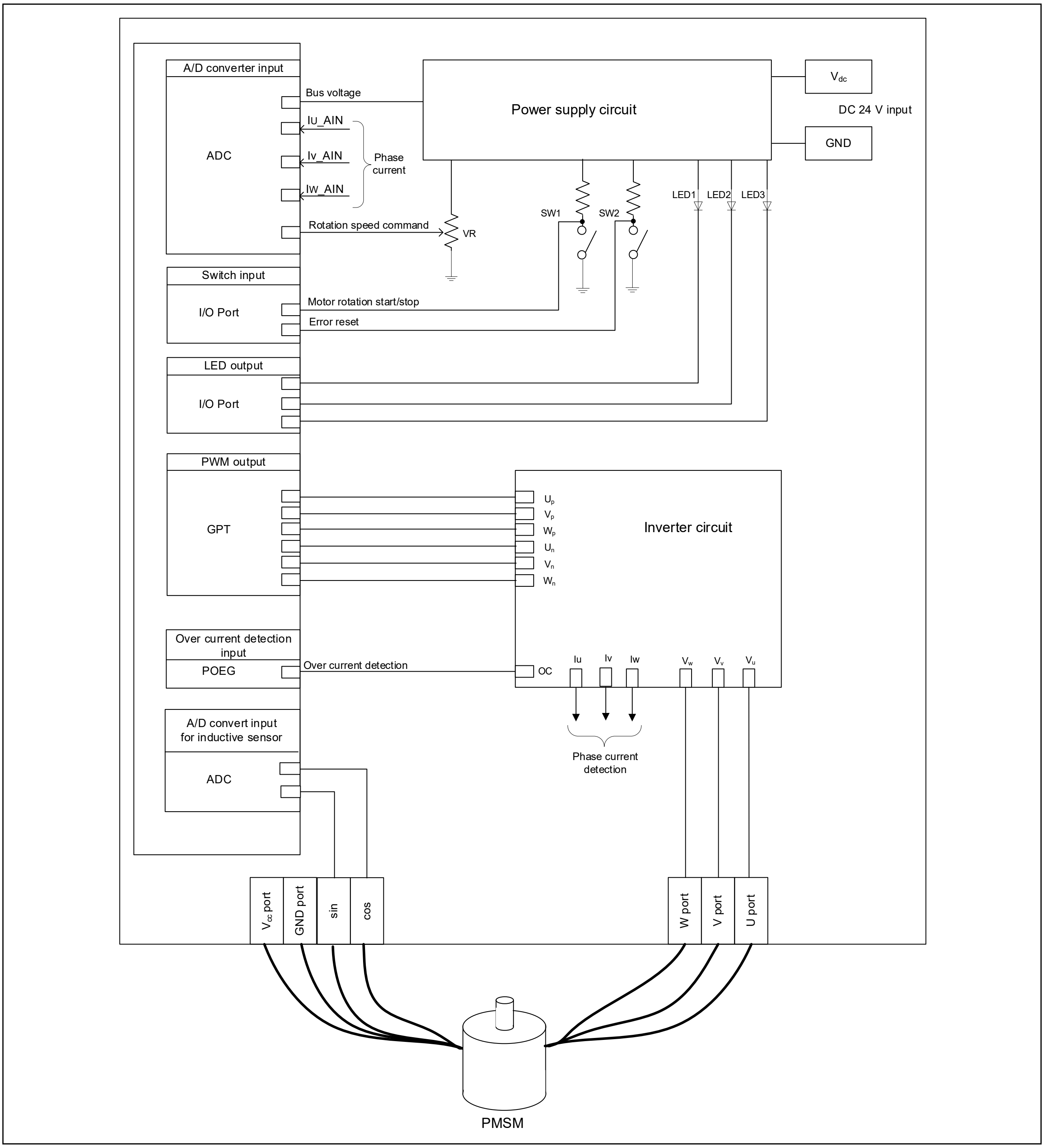


Figure 2-1 Hardware Configuration Diagram

2.2.2 Hardware modification details

Jumper pins need to be changed to use this system.

(1) RA6T2

Please change the connection of a jumper (JP4) to connect 2-3 pins from 1-2 pins.

Please change the connection of a jumper (JP17 and JP18) to connect 1-2 pins from 2-3 pins.

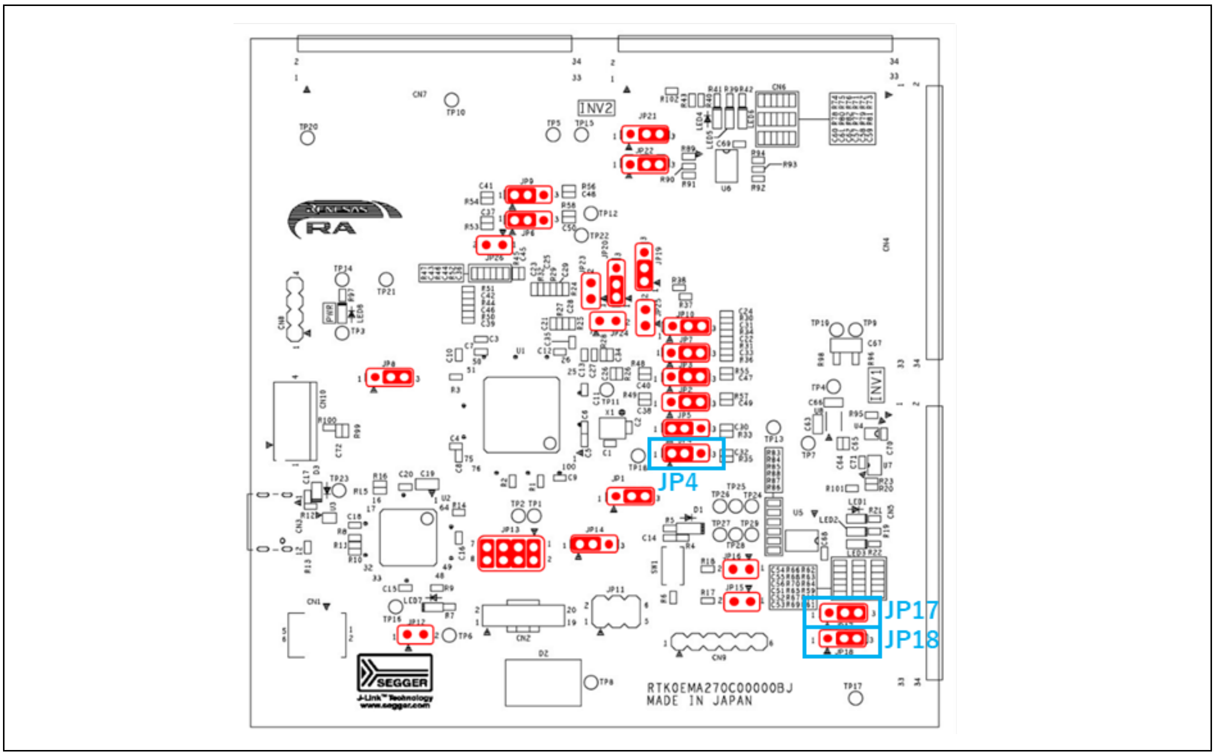


Figure 2-2 Change the connection of a jumper

(2) RA4T1/RA6T3

Please change the connection of a jumper (JP1 and JP3) to connect 2-3 pins from 1-2 pins.
Please change the connection of a jumper (JP5 and JP6) to connect 1-2 pins from 2-3 pins.

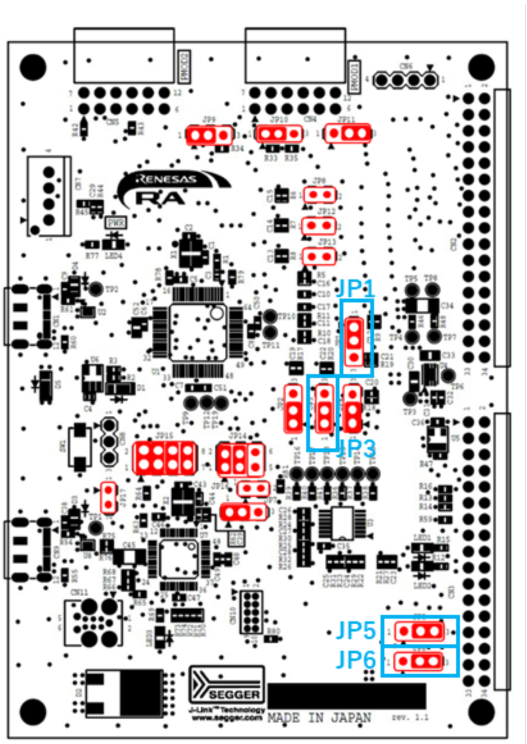


Figure 2-3 Change the connection of a jumper

2.2.3 User interface

List of user interfaces of this system is given in Table 2-3.

Table 2-3 User interface

Item	Interface component	Function
Rotation speed command	Variable resistor (VR)	Reference value of rotation speed input (analog value)
START/STOP	Toggle switch (SW1)	Motor rotation start/stop command
ERROR RESET	Push switch (SW2)	Command of recovery from error status
LED1	Orange LED	- At the time of motor rotation: ON - At the time of stop: OFF
LED2	Orange LED	- At the time of error detection: ON - At the time of normal operation: OFF
LED3	Orange LED	- Positioning completed: ON - Positioning not completed: OFF (Only RA6T2)
RESET	Push switch (RESET)	System reset

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

Table 2-4 Port Interfaces

Function	RA6T2	RA4T1	RA6T3
Inverter bus voltage measurement	PA06 / AN006	P004 / AN004	P004 / AN004
For rotation speed command value input (analog value)	PB00 / AN008	P005 / AN005	P005 / AN005
START/STOP toggle switch (SW1)	PD04	P304	P304
ERROR RESET push switch (SW2)	PD07	P200	P200
LED1 ON/OFF control	PD01	P113	P113
LED2 ON/OFF control	PD02	P106	P106
LED3 ON/OFF control	PD03	-	-
U phase current measurement	PA04 / AN004	P000 / AN000	P000 / AN000
V phase current measurement	PA02 / AN002	P001 / AN001	P001 / AN001
W phase current measurement	PA00 / AN000	P002 / AN002	P002 / AN002
PWM output (U_p)	PB04 / GTIOC4A	P409 / GTIOC1A	P409 / GTIOC1A
PWM output (V_p)	PB06 / GTIOC5A	P103 / GTIOC2A	P103 / GTIOC2A
PWM output (W_p)	PB08 / GTIOC6A	P111 / GTIOC3A	P111 / GTIOC3A
PWM output (U_n)	PB05 / GTIOC4B	P408 / GTIOC1B	P408 / GTIOC1B
PWM output (V_n)	PB07 / GTIOC5B	P102 / GTIOC2B	P102 / GTIOC2B
PWM output (W_n)	PB09 / GTIOC6B	P112 / GTIOC3B	P112 / GTIOC3B
Inductive sensor sine signal input	PC04 / AN014	P500 / AN016	P500 / AN016
Inductive sensor cosine signal input	PE15 / AN027	P006 / AN006	P006 / AN006
PWM emergency stop input at the time of overcurrent detection	PC13 / GTETRGD	P104 / GTETRGB	P104 / GTETRGB

List of port interfaces of the sensor.

Table 2-5 Port Interfaces

Function	MCI-LV-1
VCC	CN7 1pin
Inductive sensor sine signal input	CN7 6pin
Inductive sensor cosine signal input	CN7 8pin
GND	CN7 10pin

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	RA4T1	RA6T3
12-bit A/D Converter	U phase current measurement	AN004	AN000	AN000
	V phase current measurement	AN002	AN001	AN001
	W phase current measurement	AN000	AN002	AN002
	Inverter bus voltage measurement	AN006	AN004	AN004
	For rotation speed command value input (analog value)	AN008	AN005	AN005
	Inductive sensor sine signal input	AN014	AN016	AN016
	Inductive sensor cosine signal input	AN027	AN006	AN006
AGT	Speed control interval timer	AGT0	AGT0	AGT0
GPT	U phase PWM output	CH4	CN1	CN1
	V phase PWM output	CH5	CN2	CN2
	W phase PWM output	CH6	CN3	CN3
POEG	PWM emergency stop input at the time of overcurrent detection	Group D	Group B	Group B

2.2.4.1 RA6T2

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

U-phase current, V-phase current, W-phase current, inverter bus voltage, inductive sensor output and rotation speed command are measured in "Single scan mode" (use a hardware trigger).

(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 and 6, 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 GTETRGD port is detected)

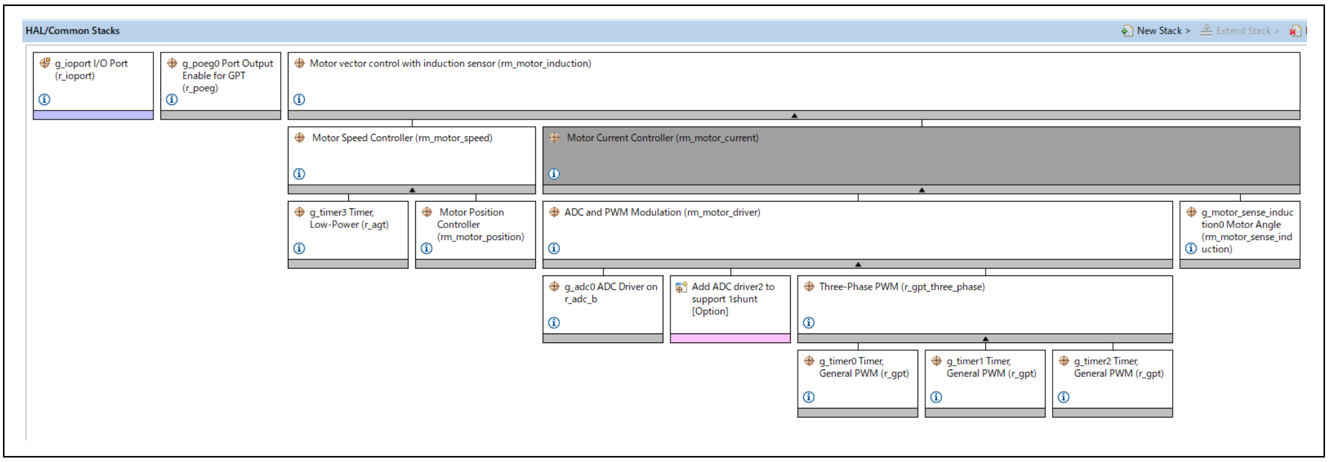
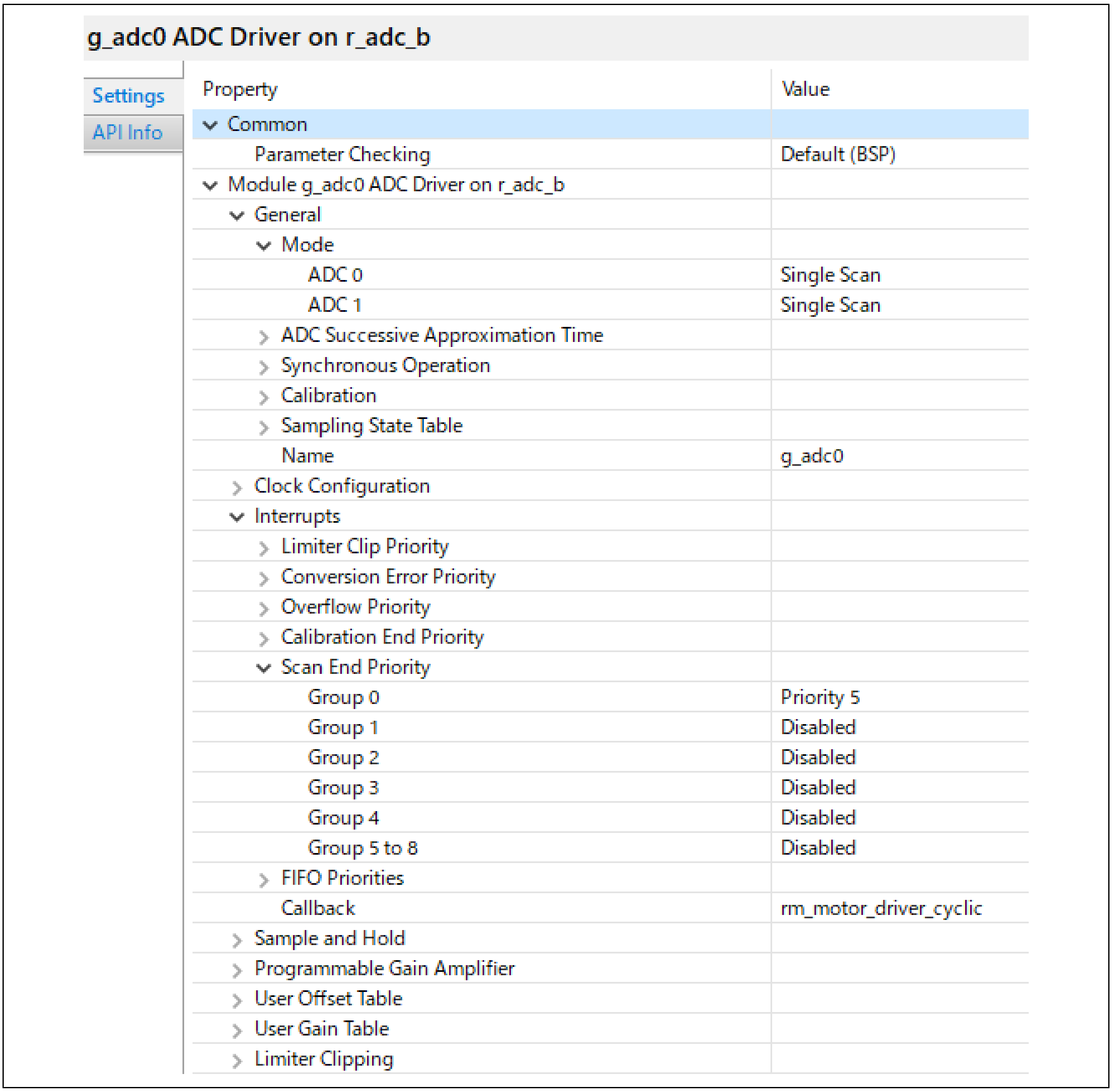


Figure 2-4 Overall FSP Stacks diagram



g_adc0 ADC Driver on r_adc_b

Settings
API Info

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

Figure 2-5 FSP Configuration of ADC Driver [1/4]

g_adc0 ADC Driver on r_adc_b

Settings
API Info

Property	Value
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

Figure 2-6 FSP Configuration of ADC Driver [2/4]

g_adc0 ADC Driver on r_adc_b

Settings
API Info

Property	Value
Virtual Channel 6	
Scan Group	Scan Group 1
Channel Select	AN027
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 1
Channel Select	AN028
Sampling State Table ID	Sampling State Entry 0
Channel Gain Table	Disabled
Channel Offset Table	Disabled
Add/Average Mode	Disabled
Add/Average Count	1-time conversion (Normal Conversion)
Limit Clip Table Id	Disabled
Conversion Resolution Format Select	12-bit Data Format

Figure 2-7 FSP Configuration of ADC Driver [3/4]

g_adc0 ADC Driver on r_adc_b

Settings | API Info

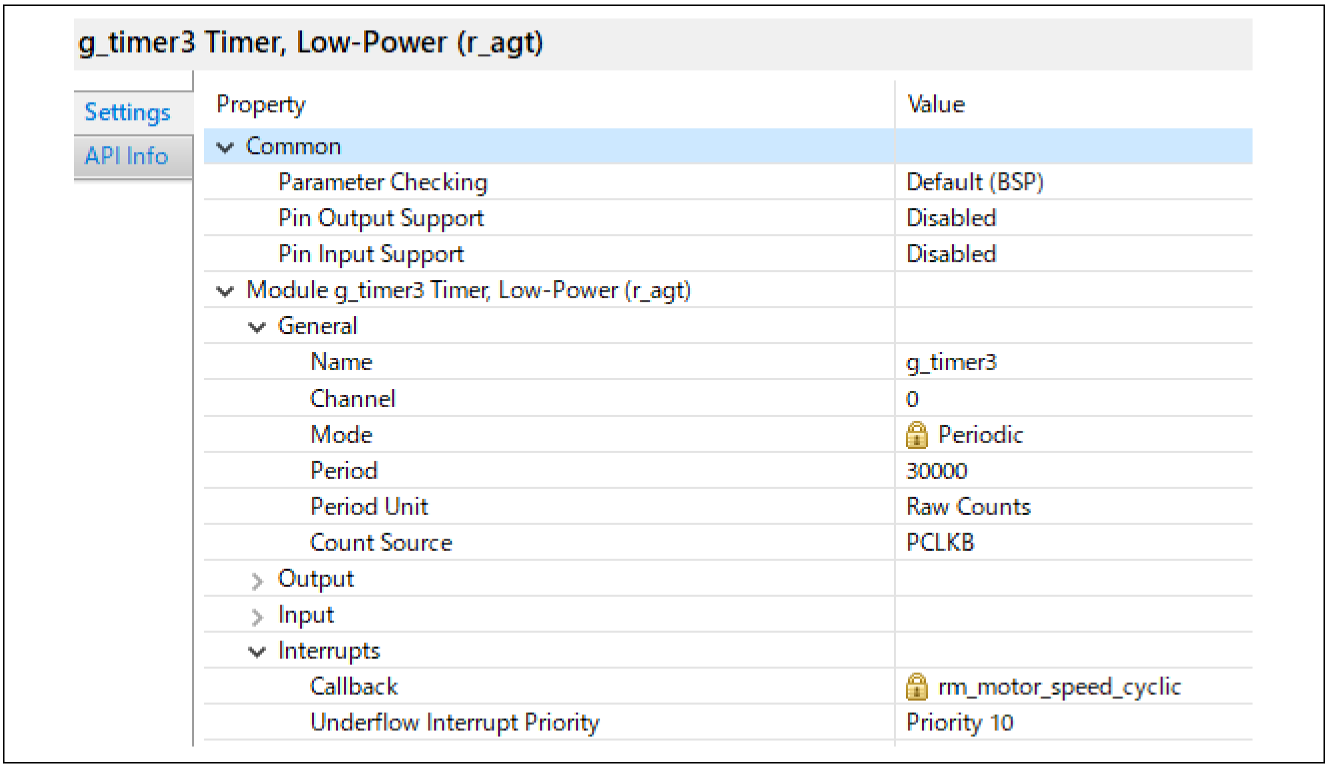
Property	Value
∨ Scan Group 0	
> Self Diagnosis	
> External Trigger Enable	
> ELC Trigger Enable	
∨ GPT Trigger Enable	
GPT Channel 0 Request A	☐
GPT Channel 1 Request A	☐
GPT Channel 2 Request A	☐
GPT Channel 3 Request A	☐
GPT Channel 4 Request A	☑
GPT Channel 5 Request A	☐
GPT Channel 6 Request A	☐
GPT Channel 7 Request A	☐
GPT Channel 8 Request A	☐
GPT Channel 9 Request A	☐
GPT Channel 0 Request B	☐
GPT Channel 1 Request B	☐
GPT Channel 2 Request B	☐
GPT Channel 3 Request B	☐
GPT Channel 4 Request B	☐
GPT Channel 5 Request B	☐
GPT Channel 6 Request B	☐
GPT Channel 7 Request B	☐
GPT Channel 8 Request B	☐
GPT Channel 9 Request B	☐
Enable	Enable
Converter Selection	ADC 0
Start Trigger Delay	0
Scan End Interrupt Enable	Enable
Limit Clip Interrupt Enable	Disable
FIFO Enable	Disable
FIFO Interrupt Enable	Disable
FIFO Interrupt Generation Level	0

g_adc0 ADC Driver on r_adc_b

Settings | API Info

Property	Value
∨ Scan Group 1	
> Self Diagnosis	
> External Trigger Enable	
> ELC Trigger Enable	
∨ GPT Trigger Enable	
GPT Channel 0 Request A	☐
GPT Channel 1 Request A	☐
GPT Channel 2 Request A	☐
GPT Channel 3 Request A	☐
GPT Channel 4 Request A	☑
GPT Channel 5 Request A	☐
GPT Channel 6 Request A	☐
GPT Channel 7 Request A	☐
GPT Channel 8 Request A	☐
GPT Channel 9 Request A	☐
GPT Channel 0 Request B	☐
GPT Channel 1 Request B	☐
GPT Channel 2 Request B	☐
GPT Channel 3 Request B	☐
GPT Channel 4 Request B	☐
GPT Channel 5 Request B	☐
GPT Channel 6 Request B	☐
GPT Channel 7 Request B	☐
GPT Channel 8 Request B	☐
GPT Channel 9 Request B	☐
Enable	Enable
Converter Selection	ADC 1
Start Trigger Delay	0
Scan End Interrupt Enable	Disable
Limit Clip Interrupt Enable	Disable
FIFO Enable	Disable
FIFO Interrupt Enable	Disable
FIFO Interrupt Generation Level	0

Figure 2-8 FSP Configuration of ADC Driver [4/4]

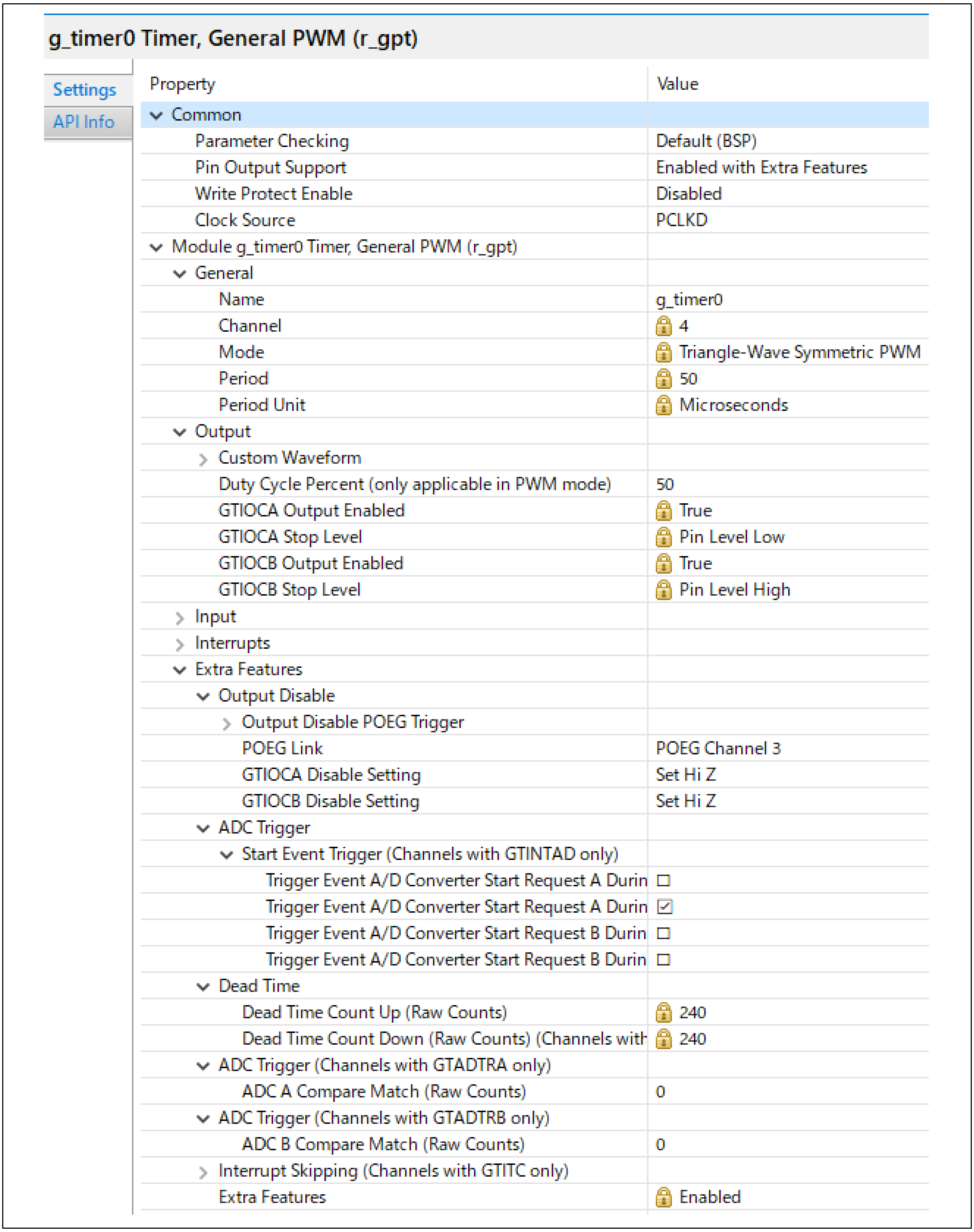


g_timer3 Timer, Low-Power (r_agt)

Settings
API Info

Property	Value
Common	
Parameter Checking	Default (BSP)
Pin Output Support	Disabled
Pin Input Support	Disabled
Module g_timer3 Timer, Low-Power (r_agt)	
General	
Name	g_timer3
Channel	0
Mode	Periodic
Period	30000
Period Unit	Raw Counts
Count Source	PCLKB
Output	
Input	
Interrupts	
Callback	rm_motor_speed_cyclic
Underflow Interrupt Priority	Priority 10

Figure 2-9 FSP Configuration of AGT Driver



g_timer0 Timer, General PWM (r_gpt)

Settings | API Info

Property	Value
Common	
Parameter Checking	Default (BSP)
Pin Output Support	Enabled with Extra Features
Write Protect Enable	Disabled
Clock Source	PCLKD
Module g_timer0 Timer, General PWM (r_gpt)	
General	
Name	g_timer0
Channel	4
Mode	Triangle-Wave Symmetric PWM
Period	50
Period Unit	Microseconds
Output	
Custom Waveform	
Duty Cycle Percent (only applicable in PWM mode)	50
GTIOCA Output Enabled	True
GTIOCA Stop Level	Pin Level Low
GTIOCB Output Enabled	True
GTIOCB Stop Level	Pin Level High
Input	
Interrupts	
Extra Features	
Output Disable	
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 only)	
Trigger Event A/D Converter Start Request A Durin	☐
Trigger Event A/D Converter Start Request A Durin	☑
Trigger Event A/D Converter Start Request B Durin	☐
Trigger Event A/D Converter Start Request B Durin	☐
Dead Time	
Dead Time Count Up (Raw Counts)	240
Dead Time Count Down (Raw Counts) (Channels with	240
ADC Trigger (Channels with GTADTRA only)	
ADC A Compare Match (Raw Counts)	0
ADC Trigger (Channels with GTADTRB only)	
ADC B Compare Match (Raw Counts)	0
Interrupt Skipping (Channels with GTITC only)	
Extra Features	Enabled

Figure 2-10 FSP Configuration of GPT Driver

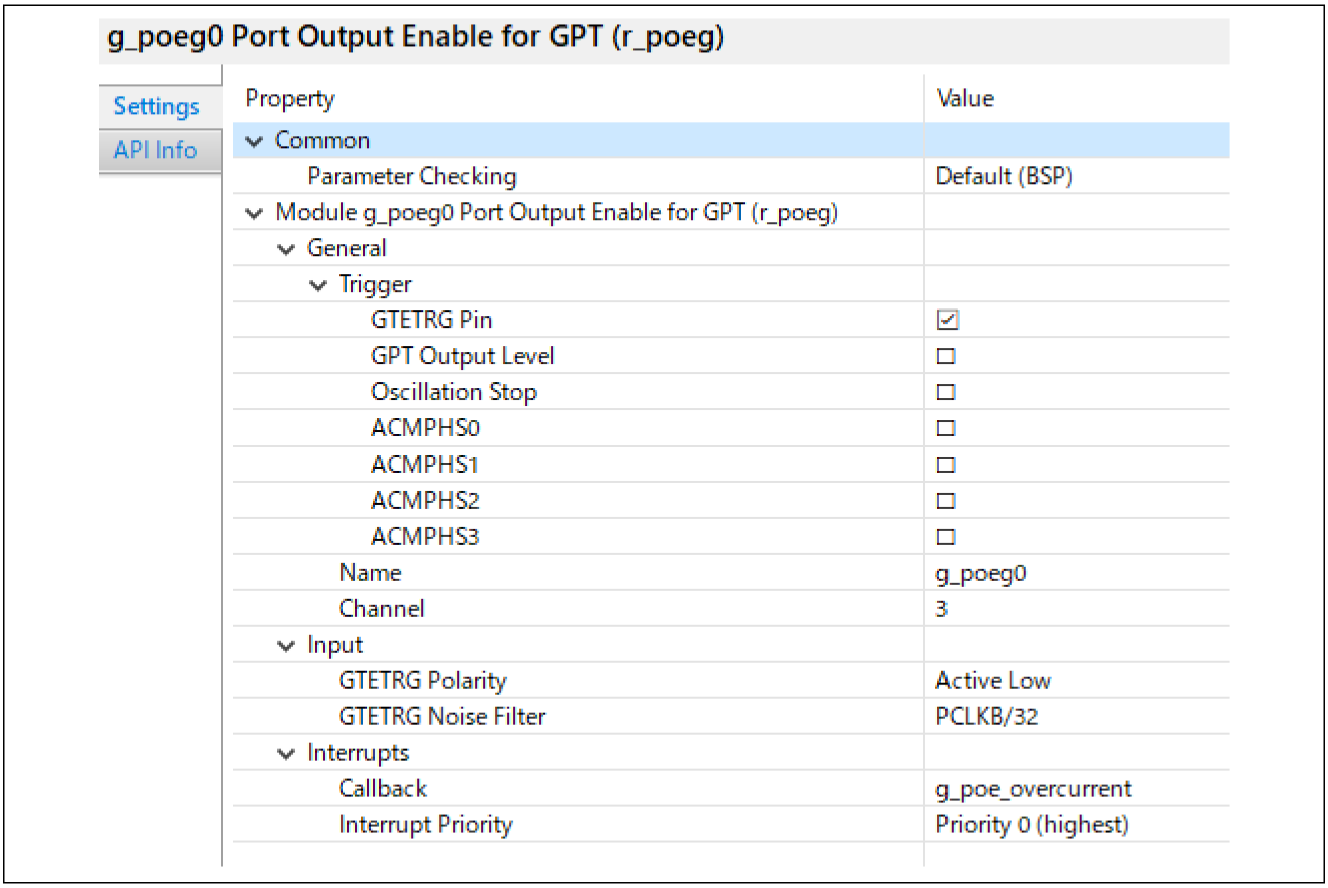


Figure 2-11 FSP Configuration of POEG Driver

2.2.4.2 RA4T1

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

U-phase current, V-phase current, W-phase current, inverter bus voltage, inductive sensor output and rotation speed command are measured in "Single scan mode" (use a hardware trigger).

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

(4) Port Output Enable for GPT (POEG)

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

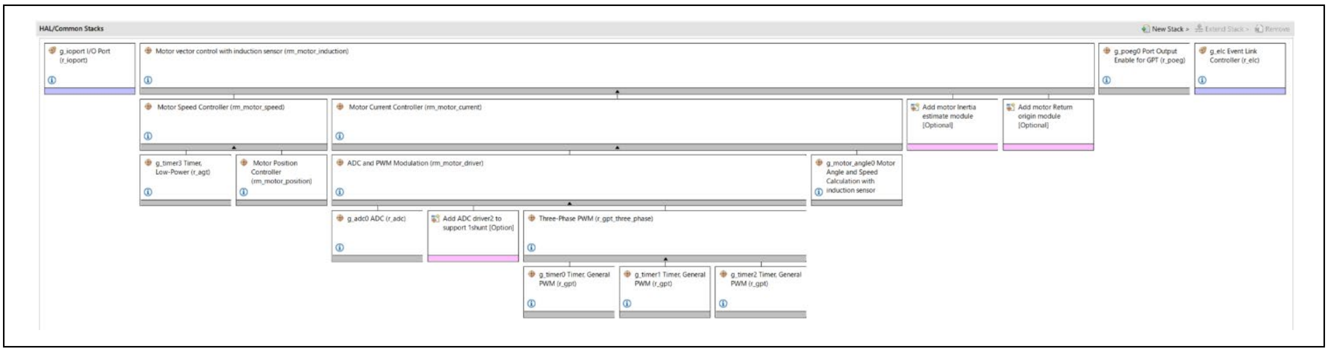
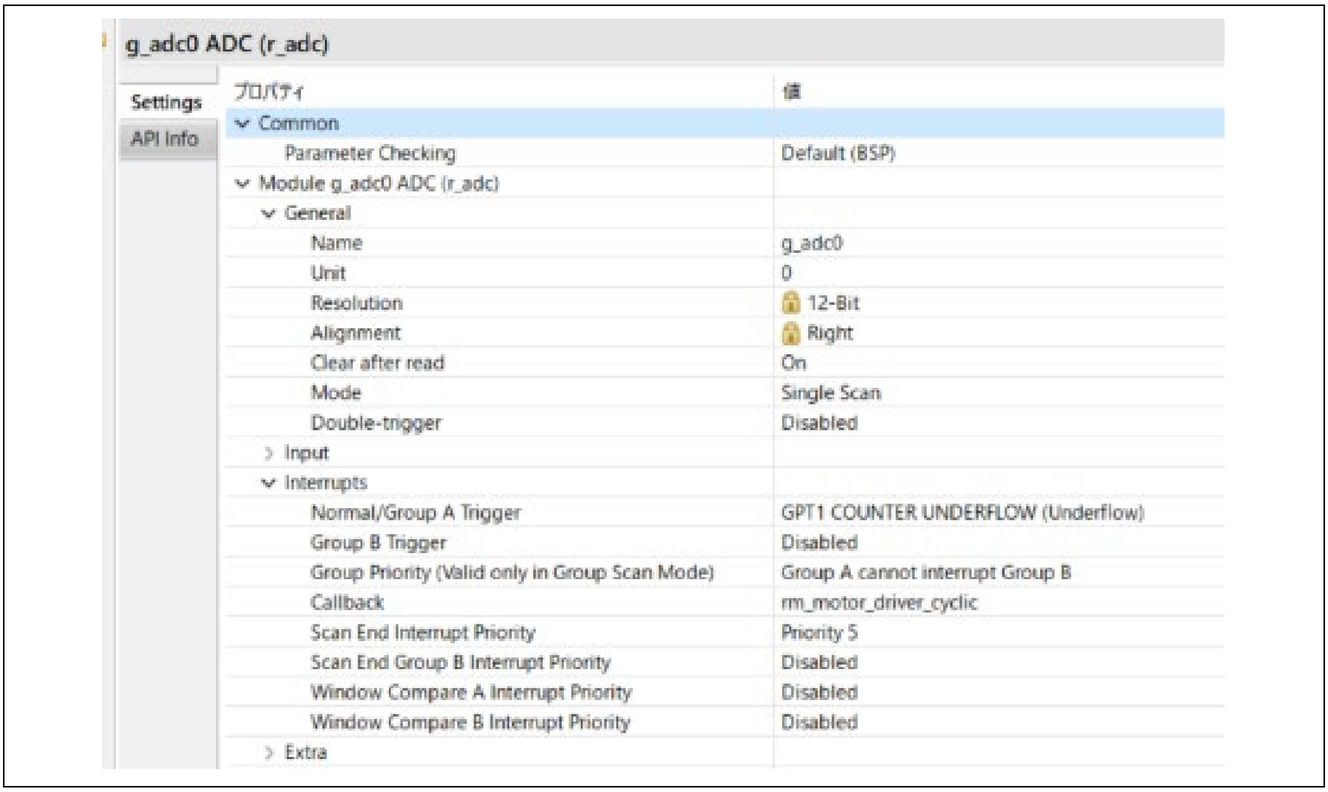


Figure 2-12 Overall FSP Stacks diagram



g_adc0 ADC (r_adc)

Settings
API Info

プロパティ	値
Common	
Parameter Checking	Default (BSP)
Module g_adc0 ADC (r_adc)	
General	
Name	g_adc0
Unit	0
Resolution	12-Bit
Alignment	Right
Clear after read	On
Mode	Single Scan
Double-trigger	Disabled
Input	
Interrupts	
Normal/Group A Trigger	GPT1 COUNTER UNDERFLOW (Underflow)
Group B Trigger	Disabled
Group Priority (Valid only in Group Scan Mode)	Group A cannot interrupt Group B
Callback	rm_motor_driver_cyclic
Scan End Interrupt Priority	Priority 5
Scan End Group B Interrupt Priority	Disabled
Window Compare A Interrupt Priority	Disabled
Window Compare B Interrupt Priority	Disabled
Extra	

Figure 2-13 FSP Configuration of ADC Driver [1/2]

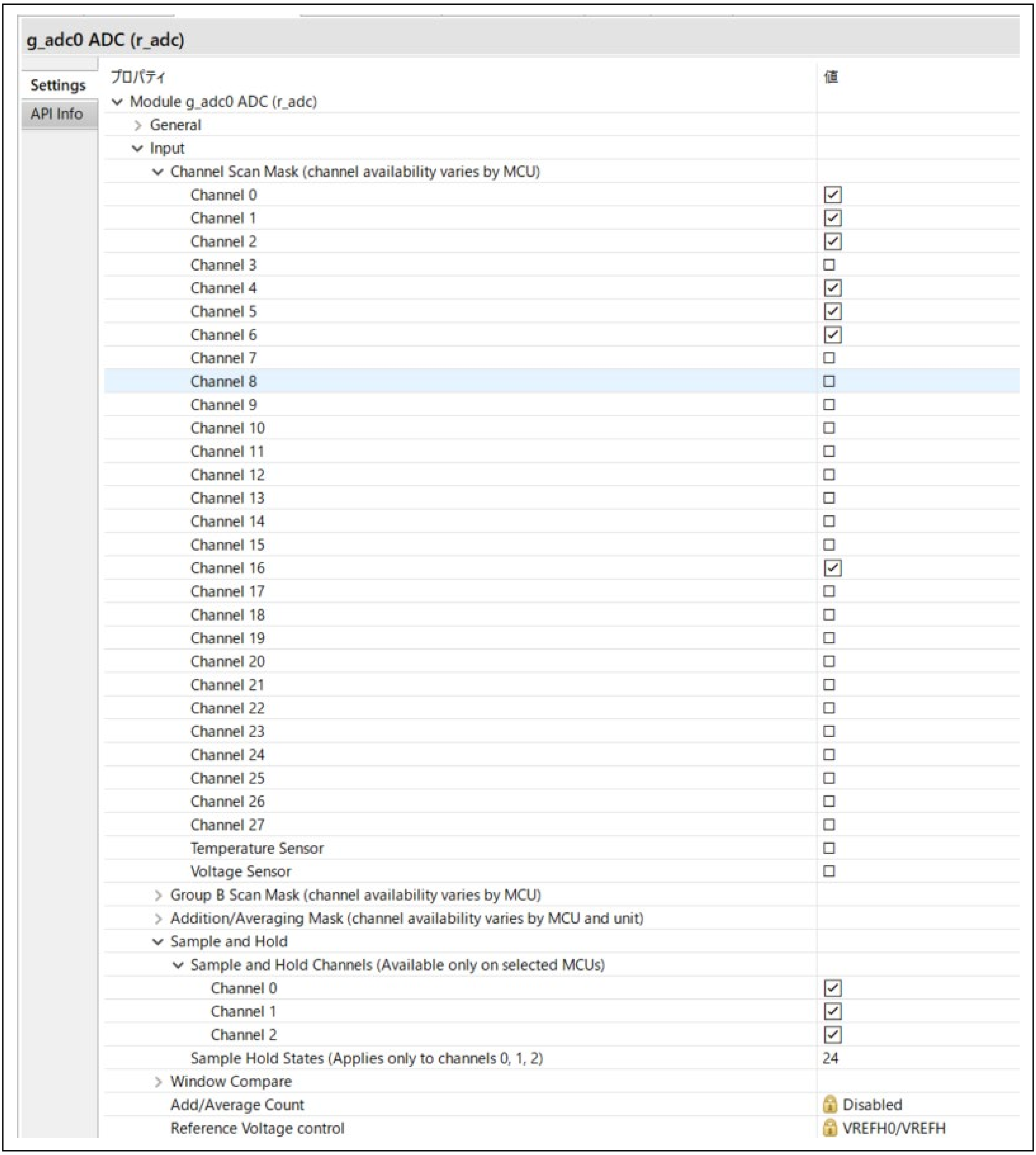


Figure 2-14 FSP Configuration of ADC Driver [2/2]

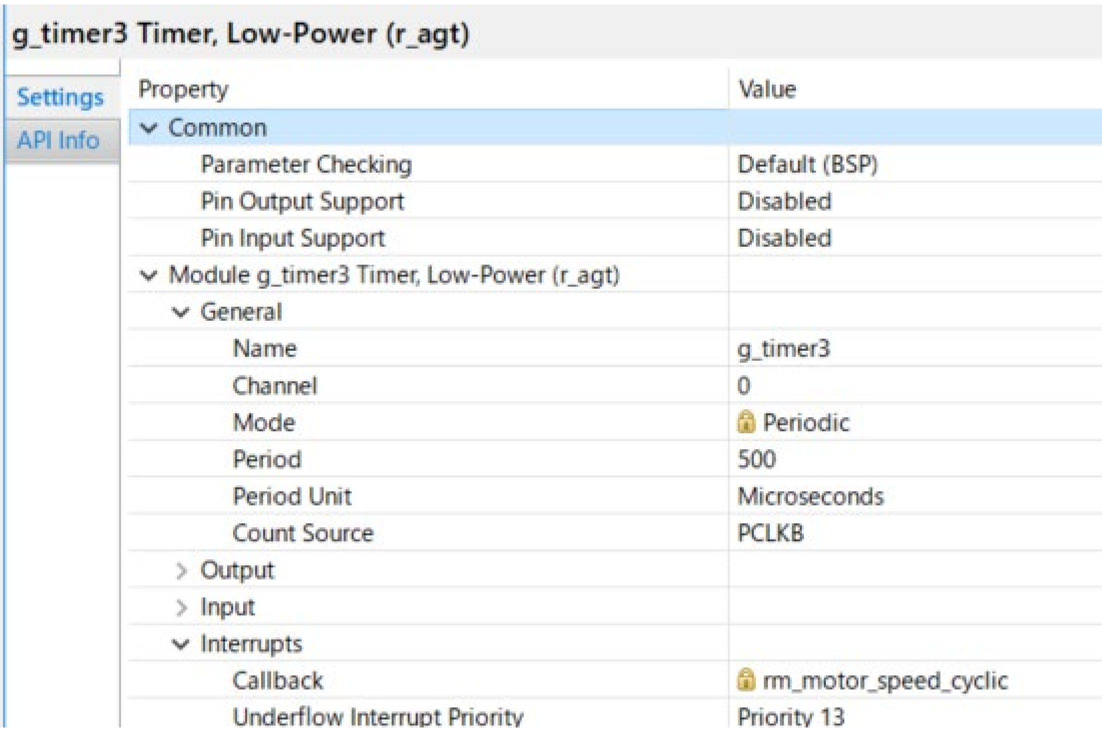
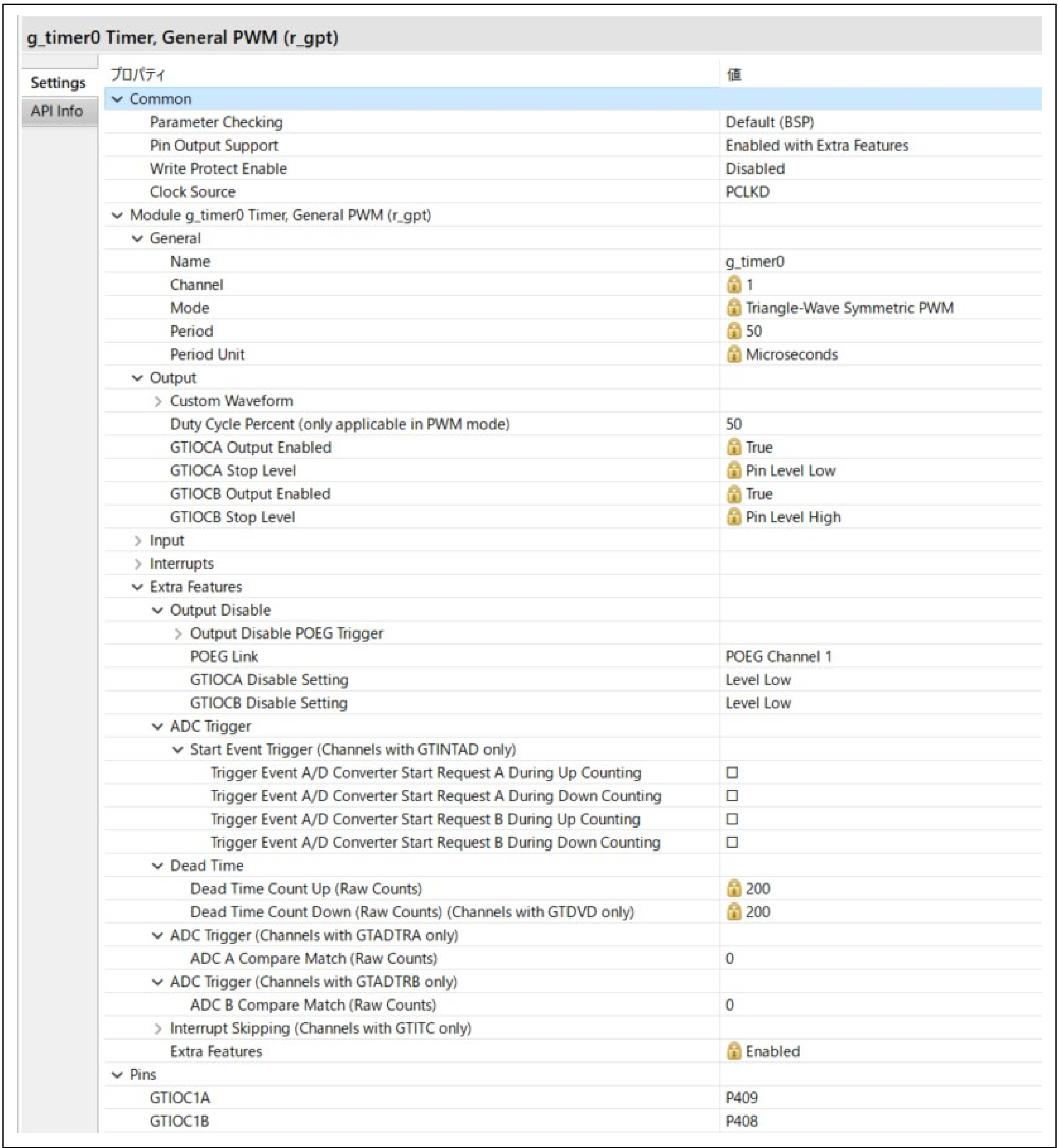


Figure 2-15 FSP Configuration of AGT Driver



g_timer0 Timer, General PWM (r_gpt)

Settings | API Info

プロパティ	値
Common	
Parameter Checking	Default (BSP)
Pin Output Support	Enabled with Extra Features
Write Protect Enable	Disabled
Clock Source	PCLKD
Module g_timer0 Timer, General PWM (r_gpt)	
General	
Name	g_timer0
Channel	1
Mode	Triangle-Wave Symmetric PWM
Period	50
Period Unit	Microseconds
Output	
Custom Waveform	
Duty Cycle Percent (only applicable in PWM mode)	50
GTIOCA Output Enabled	True
GTIOCA Stop Level	Pin Level Low
GTIOCB Output Enabled	True
GTIOCB Stop Level	Pin Level High
Input	
Interrupts	
Extra Features	
Output Disable	
Output Disable POEG Trigger	
POEG Link	POEG Channel 1
GTIOCA Disable Setting	Level Low
GTIOCB Disable Setting	Level Low
ADC Trigger	
Start Event Trigger (Channels with GTINTAD only)	
Trigger Event A/D Converter Start Request A During Up Counting	☐
Trigger Event A/D Converter Start Request A During Down Counting	☐
Trigger Event A/D Converter Start Request B During Up Counting	☐
Trigger Event A/D Converter Start Request B During Down Counting	☐
Dead Time	
Dead Time Count Up (Raw Counts)	200
Dead Time Count Down (Raw Counts) (Channels with GTDVD only)	200
ADC Trigger (Channels with GTADTRA only)	
ADC A Compare Match (Raw Counts)	0
ADC Trigger (Channels with GTADTRB only)	
ADC B Compare Match (Raw Counts)	0
Interrupt Skipping (Channels with GTITC only)	
Extra Features	Enabled
Pins	
GTIOC1A	P409
GTIOC1B	P408

Figure 2-16 FSP Configuration of GPT Driver

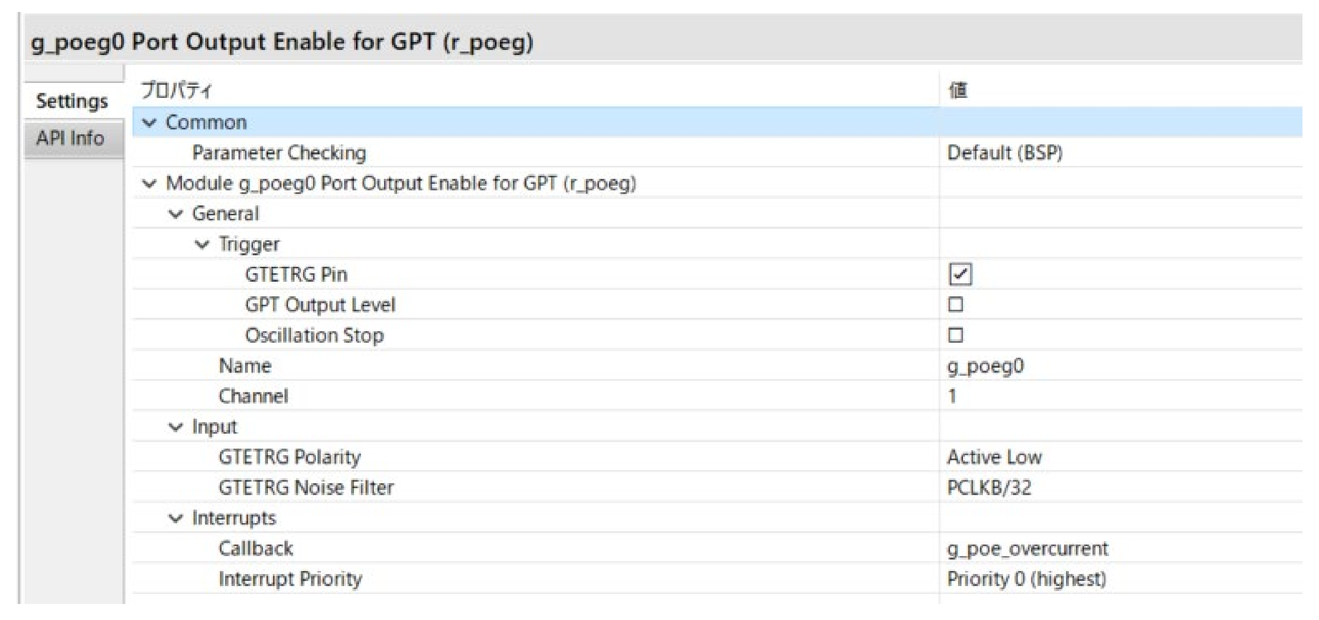


Figure 2-17 FSP Configuration of POEG Driver

2.2.4.3 RA6T3

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

U-phase current, V-phase current, W-phase current, inverter bus voltage, inductive sensor output and rotation speed command are measured in "Single scan mode" (use a hardware trigger).

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

(4) Port Output Enable for GPT (POEG)

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

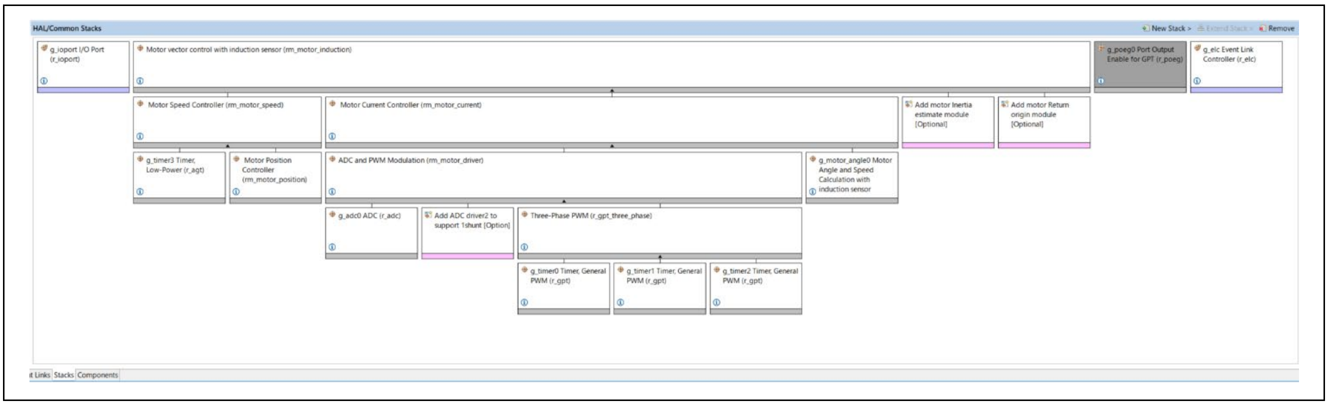
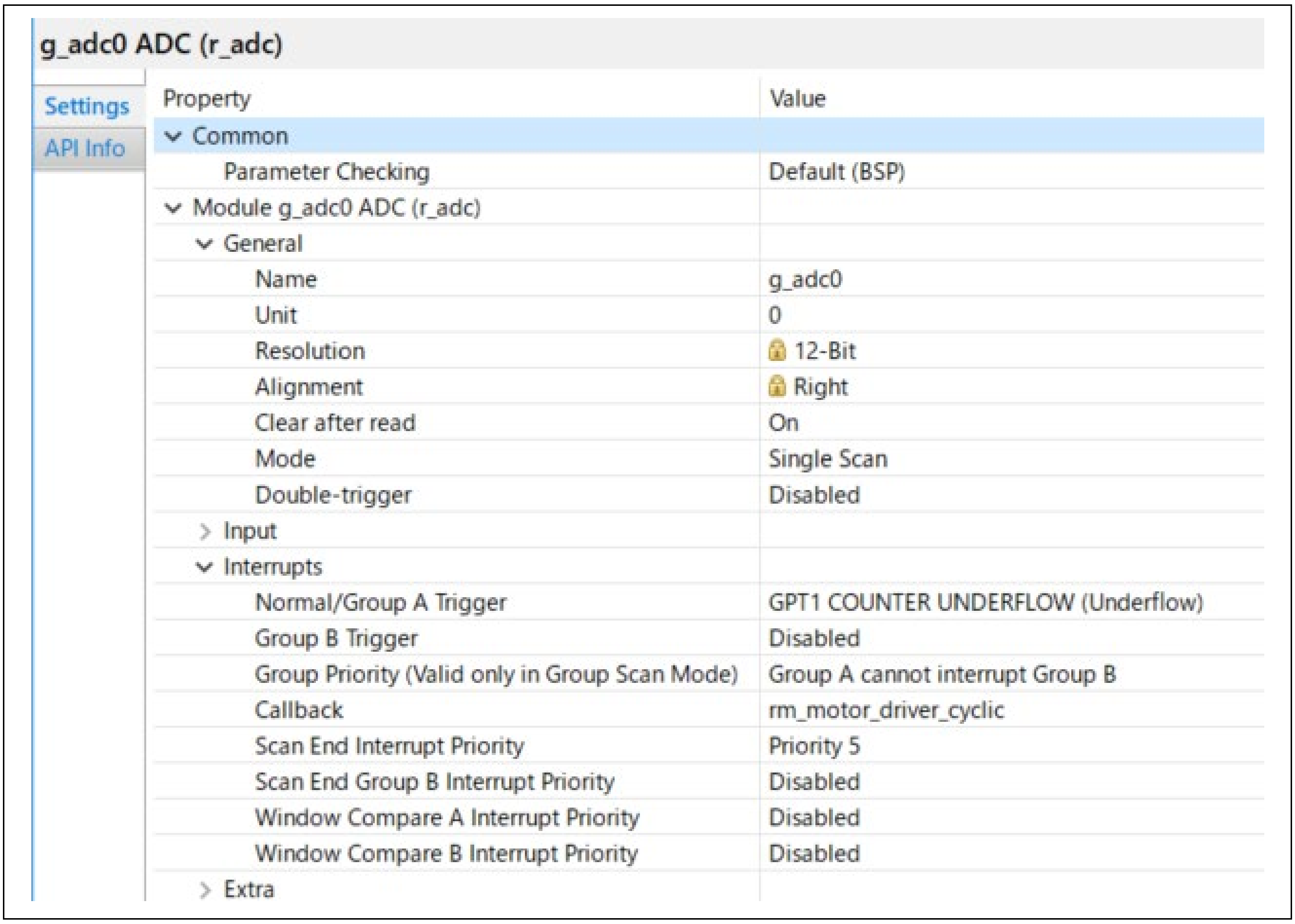


Figure 2-18 Overall FSP Stacks diagram



g_adc0 ADC (r_adc)

Settings
API Info

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

Figure 2-19 FSP Configuration of ADC Driver [1/2]

Figure 2-20 FSP Configuration of ADC Driver [2/2]

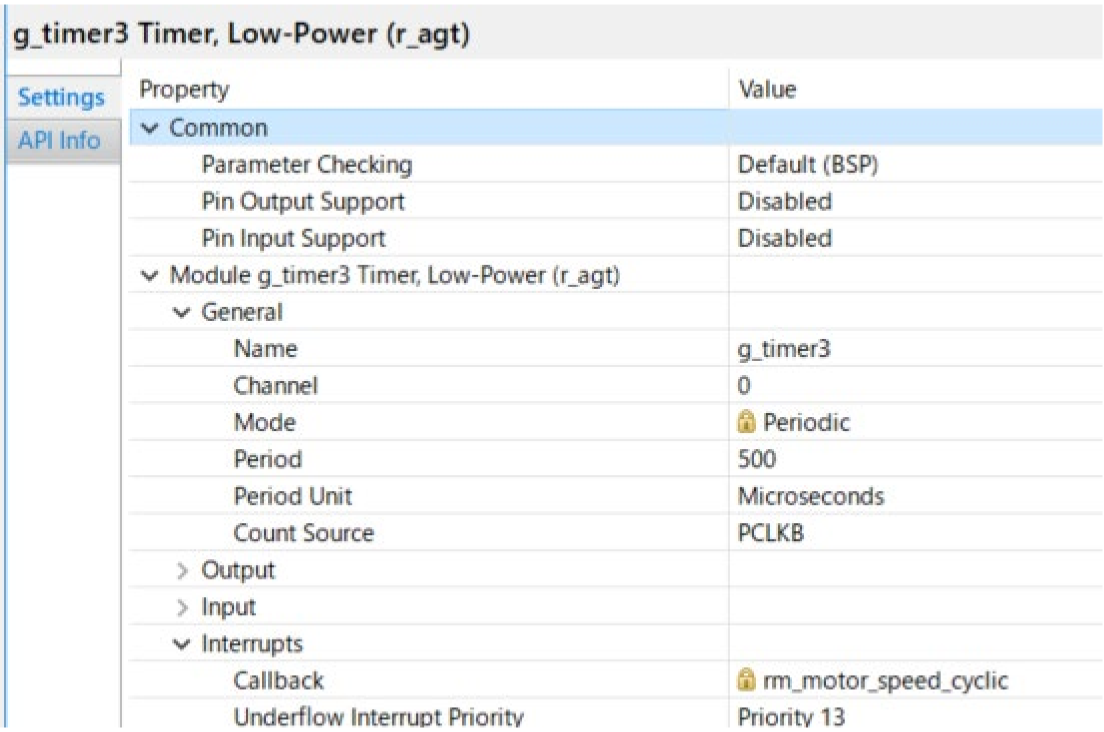


Figure 2-21 FSP Configuration of AGT Driver

g_timer0 Timer, General PWM (r_gpt)

Settings | API Info

プロパティ	値
∨ Common	
Parameter Checking	Default (BSP)
Pin Output Support	Enabled with Extra Features
Write Protect Enable	Disabled
Clock Source	PCLKD
∨ Module g_timer0 Timer, General PWM (r_gpt)	
∨ General	
Name	g_timer0
Channel	1
Mode	Triangle-Wave Symmetric PWM
Period	50
Period Unit	Microseconds
∨ Output	
> Custom Waveform	
Duty Cycle Percent (only applicable in PWM mode)	50
GTIOCA Output Enabled	True
GTIOCA Stop Level	Pin Level Low
GTIOCB Output Enabled	True
GTIOCB Stop Level	Pin Level High
> Input	
> Interrupts	
∨ Extra Features	
∨ Output Disable	
> Output Disable POEG Trigger	
POEG Link	POEG Channel 1
GTIOCA Disable Setting	Level Low
GTIOCB Disable Setting	Level Low
∨ ADC Trigger	
∨ Start Event Trigger (Channels with GTINTAD only)	
Trigger Event A/D Converter Start Request A During Up Counting	☐
Trigger Event A/D Converter Start Request A During Down Counting	☐
Trigger Event A/D Converter Start Request B During Up Counting	☐
Trigger Event A/D Converter Start Request B During Down Counting	☐
∨ Dead Time	
Dead Time Count Up (Raw Counts)	200
Dead Time Count Down (Raw Counts) (Channels with GTDVD only)	200
∨ ADC Trigger (Channels with GTADTRA only)	
ADC A Compare Match (Raw Counts)	0
∨ ADC Trigger (Channels with GTADTRB only)	
ADC B Compare Match (Raw Counts)	0
> Interrupt Skipping (Channels with GTITC only)	
Extra Features	Enabled
∨ Pins	
GTIOC1A	P409
GTIOC1B	P408

Figure 2-22 FSP Configuration of GPT Driver

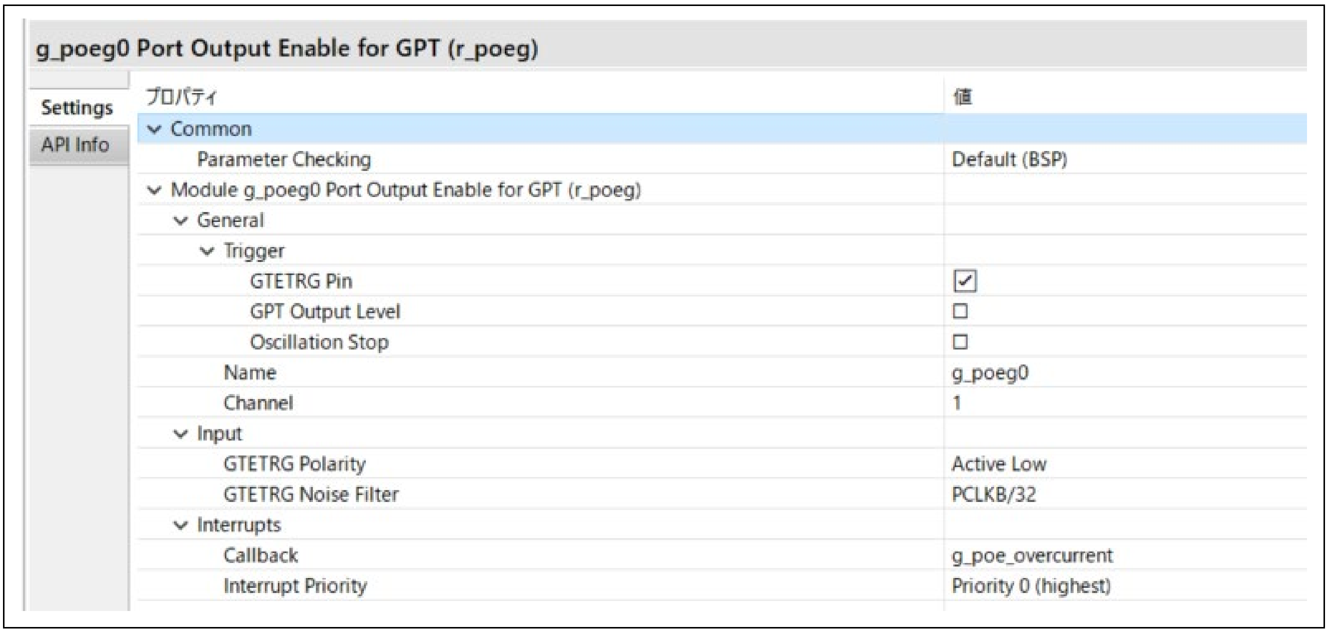


Figure 2-23 FSP Configuration of POEG Driver

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.h	ELC API definition
		r_ioport_api.h	I/O API definition
		r_poeg_api.h	POEG API definition
		r_three_phase_api.h	3phase PWM API definition
		r_timer_api.h	Timer API definition
		r_transfer_api.h	Transfer API definition
		rm_motor_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_inertia_estimate_api.h (Only RA4T1 and RA6T3)	Inertia estimate API definition
		rm_motor_position_api.h	Position API definition
		rm_motor_return_origin_api.h (Only RA4T1 and RA6T3)	Return origin API definition
		rm_motor_speed_api.h	Speed API definition
	fsp/inc/instances	r_adc_b.h(RA6T2) r_adc.h(RA4T1,RA6T3)	Function definition for AD
		r_agt.h	Function definition for AGT
		r_elc.h(Only RA4T1 and RA6T3)	Function definition for ELC
		r_gpt_three_phase.h	Function definition for 3 Phase PWM
		r_gpt.h	Function definition for GPT

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

Folder	Subfolder	File	Remarks
ra	fsp/inc/instances	r_ioport.h	Function definition for I/O
		r_poeg.h	Function definition for POEG
		rm_motor_current.h	Function definition for current control
		rm_motor_driver.h	Function definition for motor driver
		rm_motor_induction.h	Function definition for motor
		rm_motor_position_api.h	Function definition for position control
		rm_motor_sense_induction.h	Function definition for angle/speed by inductive sensors
		rm_motor_speed.h	Function definition for Speed
	fsp/lib		Library files
	fsp/src	bsp	BSP driver
		r_adc_b/r_adc_b.c(RA6T2) r_adc/r_adc.c(RA4T1,RA6T3)	AD driver
		r_agt/r_agt.c	AGT driver
		r_elc/r_elc.c(Only RA4T1 and RA6T3)	ELC driver
		r_gpt/r_gpt.c	GPT driver
		r_gpt_three_phase/ r_gpt_three_phase.c	3 phase PWM driver
		r_ioport/r_ioport.c	I/O driver
		r_poeg/r_poeg.c	POEG driver
		rm_motor_current/rm_motor_current.c	Current control driver
		rm_motor_current/rm_motor_current_library.h	Current control library API definition
		rm_motor_driver/rm_motor_driver.c	Motor driver
		rm_motor_induction/rm_motor_induction.c	Motor control status driver
		rm_motor_position/rm_motor_position.c	Position control driver
		rm_motor_position/rm_motor_position_library.h	Position control library API definition
		rm_motor_sense_inductionrm_motor_sense_induction.c	Angle detection with induction sensor 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_RA4T1.h , ICS2_RA6T3.h	Function definition for GUI tool
		ICS2_RA6T2.o , ICS2_RA4T1.o , ICS2_RA6T3.o	Communication library for GUI tool

2.3.2 Module configuration

Module configuration of the software is described below.

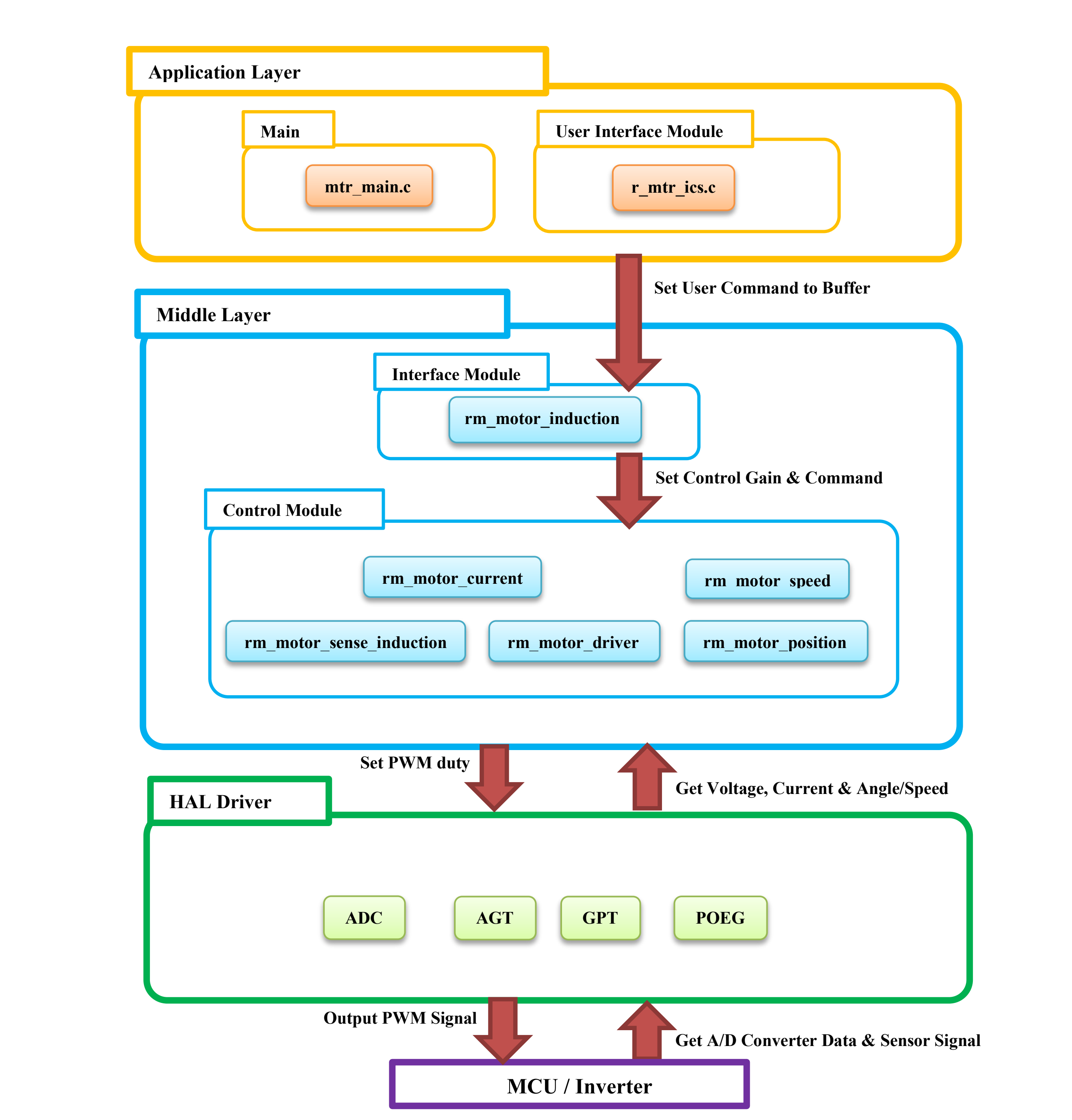


Figure 2-24 Module Configuration

2.4 Software specifications

Table 2-9 shows basic software specification of this system. For details of the vector control, refer to the application note 'Vector control with encoder for permanent magnet synchronous motor (Algorithm)' (R01AN3789).

Table 2-9 Basic Specifications of Vector Control with induction sensors Software

Item	Content	
Control method	Vector control	
Position detection method	Inductive sensor	
Motor rotation start/stop	Determined depending on the level of SW1 or input from Renesas Motor Workbench	
Input voltage	DC 24 [V]	
Main clock frequency	RA6T2: 240 [MHz] RA6T3: 200 [MHz] RA4T1: 100 [MHz]	
Carrier frequency (PWM)	20 [kHz] (Carrier period: 50 [μs])	
Dead time	2 [μs]	
Current control period	RA6T2: 50 [μs] RA6T3: 50 [μs] RA4T1: 100 [μs]	
Speed control period	RA6T2: 500 [μs] RA6T3: 500 [μs] RA4T1: 1000 [μs]	
Rotation speed control range	CW: 0 [rpm] to 4000 [rpm] CCW: 0 [rpm] to 4000 [rpm]	
Position control range	At board_ui Position command generation: Voltage input divided by VR (input range) -180° to 180°	
	At ics_ui Position command generation: Position profile of trapezoidal curve for speed command value (input range) -32768° to 32767° (Max speed) CW / CCW: 4000[rpm]	
Optimization setting of compiler	Optimization level	Optimize more(-O2) (default setting)
Processing stop for protection	Disables the motor 1 control signal output (six outputs), under any of the following conditions. 1. Instantaneous value of current of each phase exceeds 3.82(=1.8*sqrt(2)*1.5) [A] (RA6T2) 3.54(=1.67*sqrt(2)*1.5) [A] (RA4T1,RA6T3) (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) When an external over current signal is detected (when a low level is detected), the PWM output ports are set to high impedance state.	

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	Min	
14		
13		
12		
11		
10		AGT0 INT 500 [µs] Interrupt
9		
8		
7		
6		
5		ADC0 ADI0(RA6T2) ADC0 SCAN END(RA4T1,RA6T3) A/D complete interrupt
4		
3		
2		
1		
0	Max	POEG3 EVENT(RA6T2) POEG1 EVENT(RA4T1,RA6T3) Over current error interrupt

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

Figure 2-25 RA6T2 FSP Interrupts Configuration

Allocations

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

Figure 2-26 RA4T1/RA6T3 FSP Interrupts Configuration

3. Descriptions of the control program

The target software of this application note is explained here.

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.

SW1 is 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 VR output value (analog value). The A/D converted VR value is used as rotation speed command value, as shown below.

Table 3-1 Conversion Ratio of the Rotation Speed and Position Reference

Item	Conversion ratio (reference: A/D conversion value)	
Rotation speed reference	CW	0 rpm to 4000 rpm: 0800H to 0FFFH
	CCW	0 rpm to 4000 rpm: 07FFH to 0000H
Position reference	CW	0 rpm to 180 degrees: 0800H to 0FFFH
	CCW	0 rpm to 180 degrees: 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-voltage/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, V, W phase current

The U, V and W phase currents are measured as shown in Table 3-3 and used for vector control. User can select only U and W phase currents to use as 2shunt resistances detection.

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

Item	Conversion ratio (U, V, W phase current: A/D conversion value)
U, V, 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.

(a) 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

(b) 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.

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

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

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)

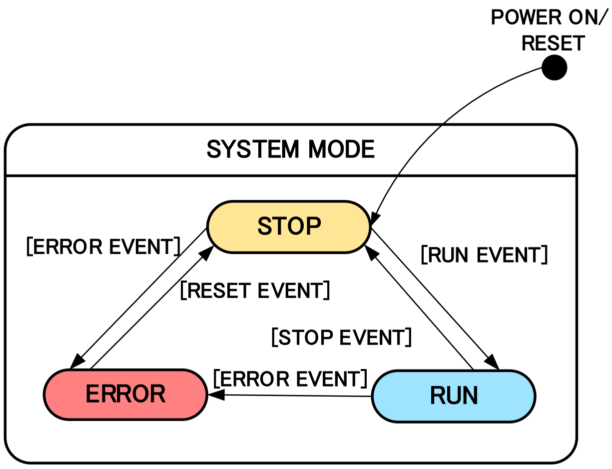
The modulation factor m is defined as follows.

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

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 vector control with inductive sensors software. In the target software of this application note, the software state is managed by "SYSTEM MODE".



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

Figure 3-1 State Transition Diagram of Vector Control with inductive sensors 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** and Figure **3-3** show the software implementation of d-axis and inductive sensor alignment method. The d-axis alignment method used as startup control of position control method, in initialization mode (MOTOR_SENSE_INDUCTIVE_MODE_INIT) and Boot mode (MOTOR_SENSE_INDUCTIVE_MODE_BOOT). In drive mode (MOTOR_SENSE_INDUCTIVE_MODE_DRIVE) vector control is implemented for PMSM with inductive sensor. Each reference value setting of d-axis current, q-axis current and speed is managed by respective status.

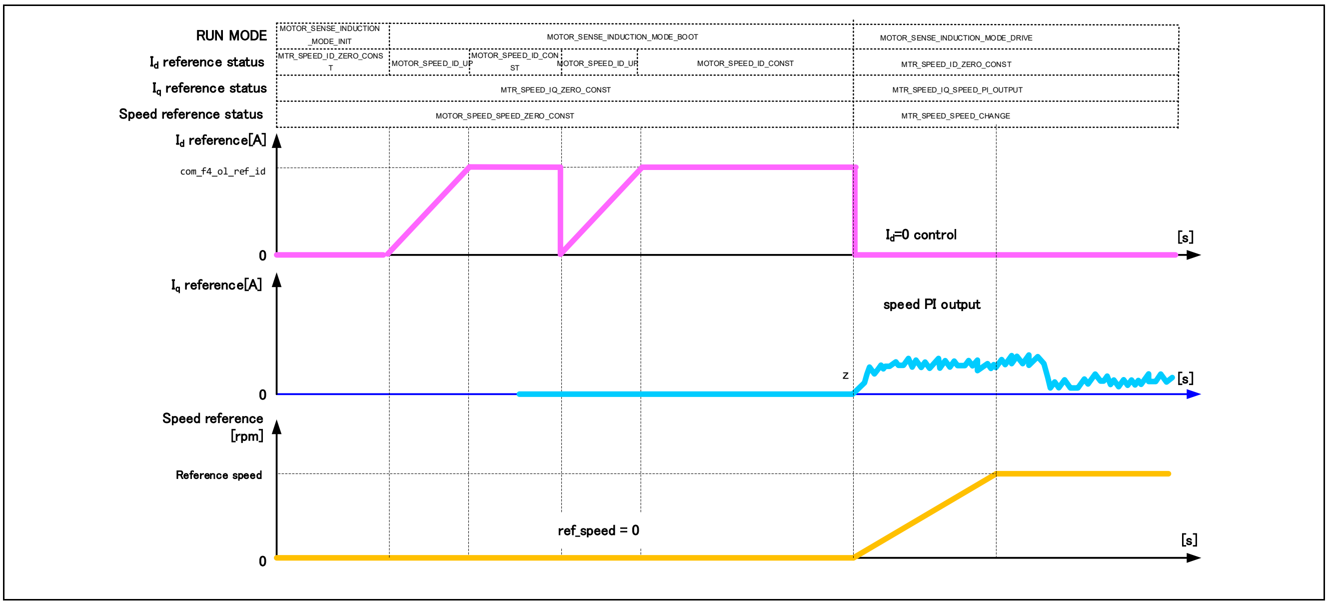


Figure 3-2 Startup Speed Control of Vector Control PMSM with inductive sensor Software

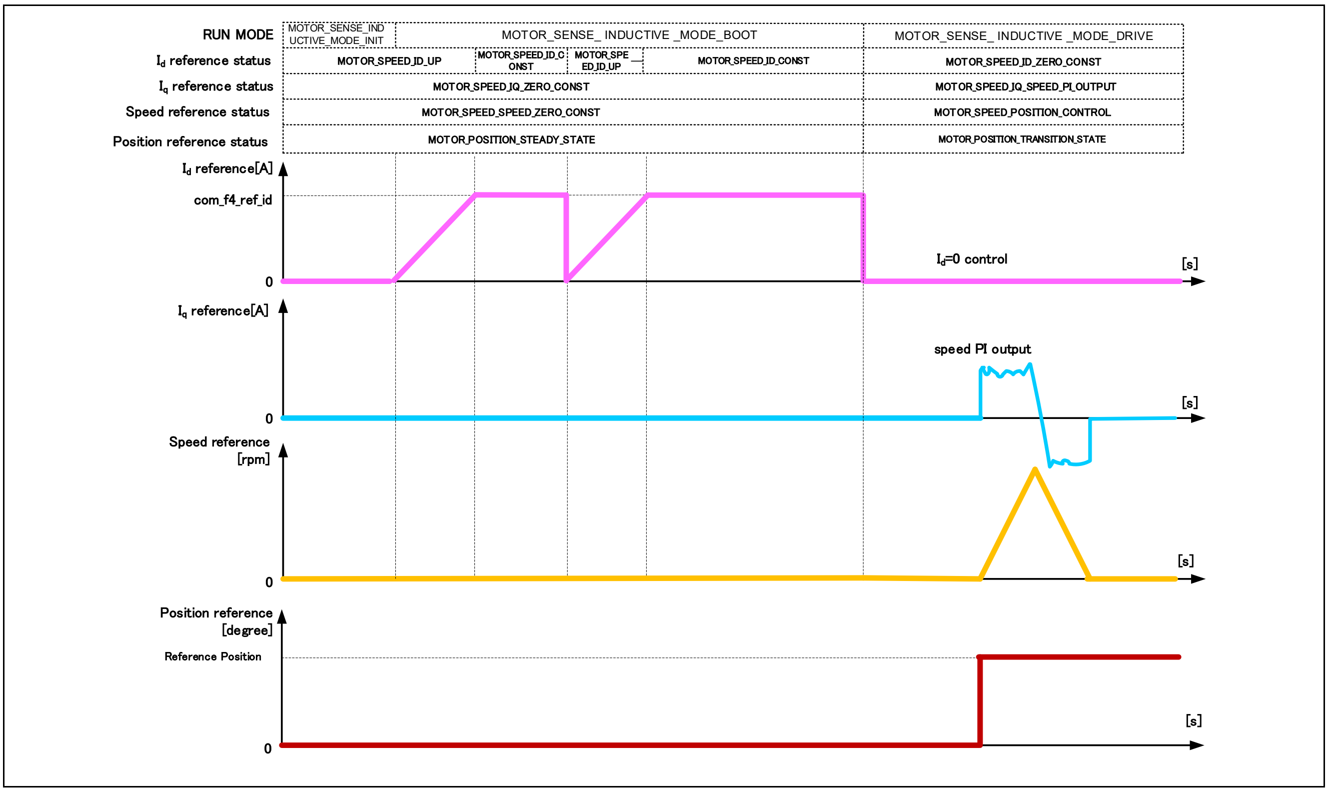


Figure 3-3 Startup Position Control of Vector Control PMSM with inductive sensor Software

3.1.6 Generation of Position Profile

(Position profile of trapezoidal curve for speed command value)

In vector control software for PMSM with inductive sensor, the position profile generation is used to create command value (input position value). The implementation of command value in each control cycle is used as method of managing acceleration and the maximum speed value with respect to target position value.

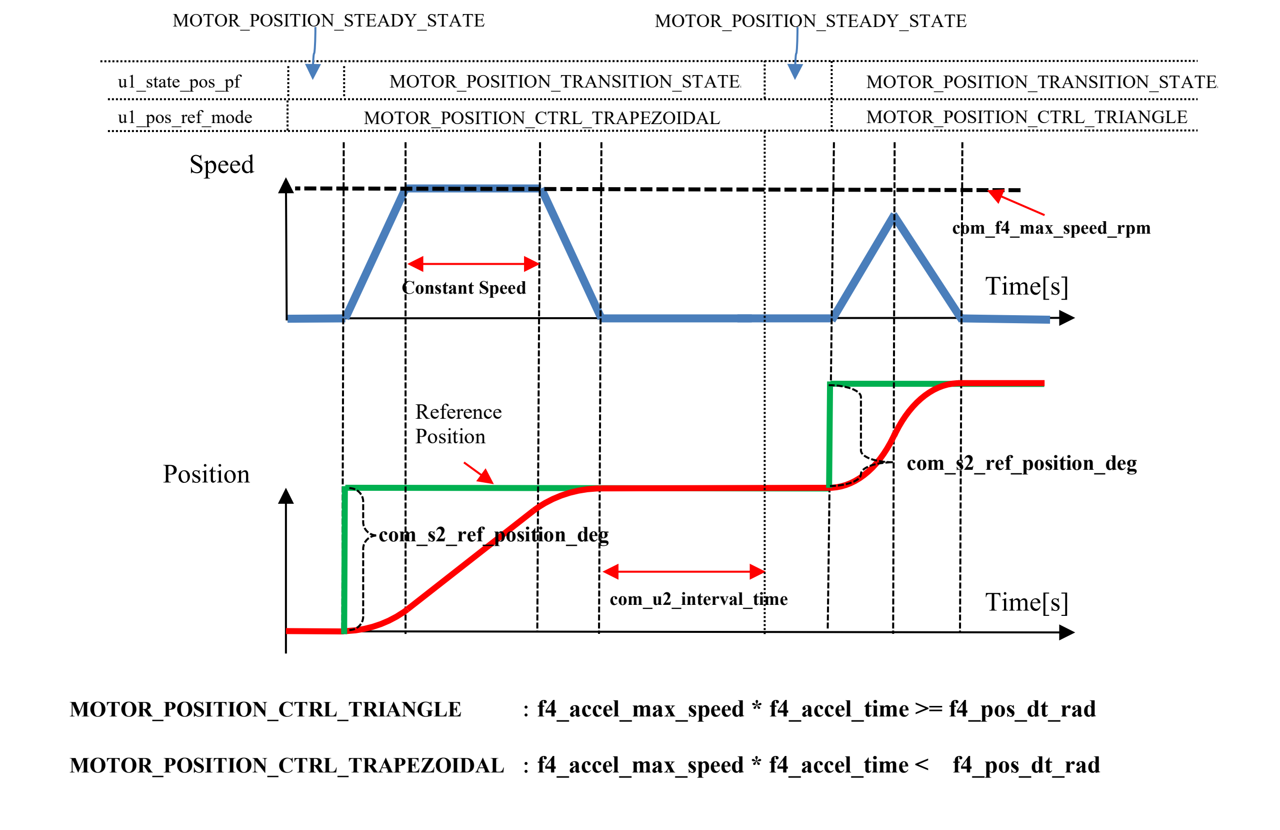


Figure 3-4 Generation of position profile

By inputting the following variables from the Analyzer, it is possible to create command values that enable acceleration/deceleration response.

• Acceleration time (com_f4_accel_time)

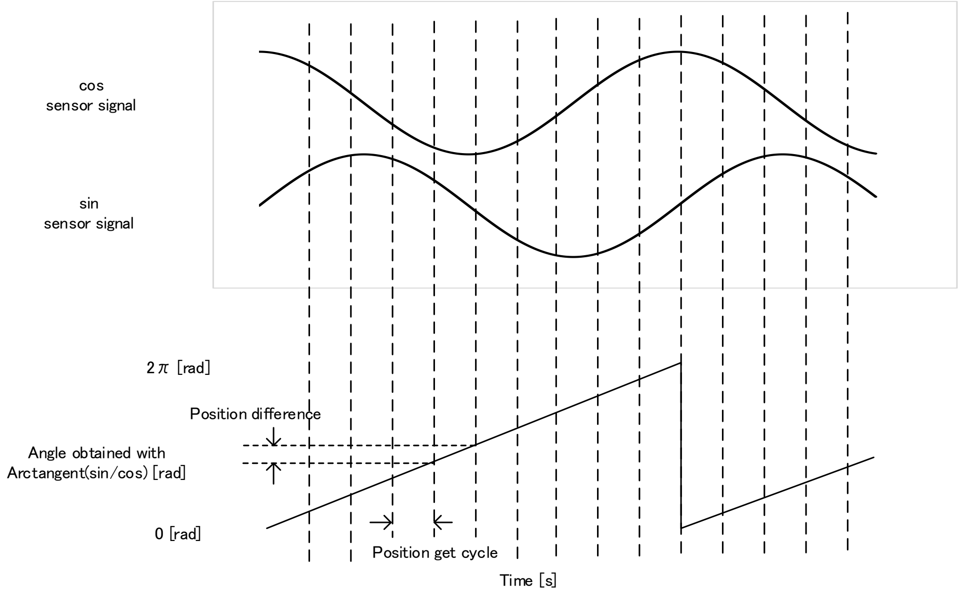
• Maximum speed (com_f4_max_speed_rpm)

• Position stabilization wait time (com_u2_interval_time)

When the speed calculated from the position deviation and acceleration time is higher than the maximum speed during acceleration, the trapezoidal speed command value is used.

3.1.7 Speed measurement

The sample software calculates speed information from the deviation of angle information acquired at each current control cycle.

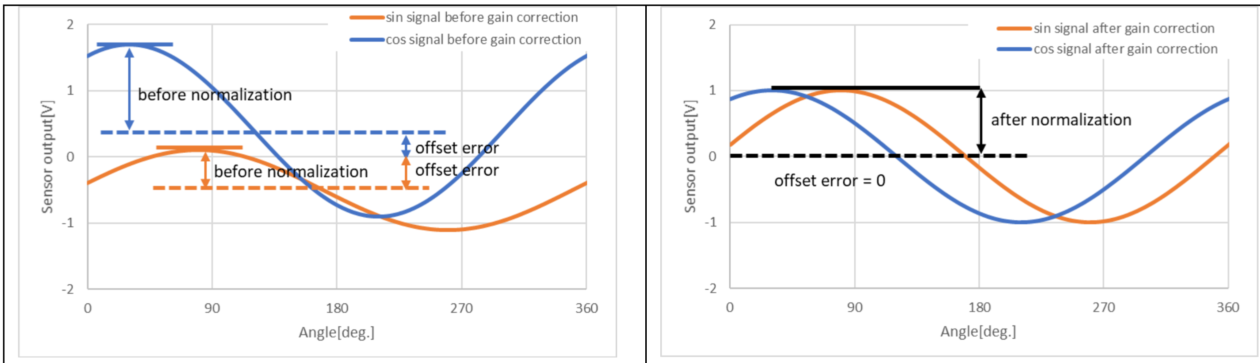


$$speed[\mathrm{rad/s}] = (Position\ difference)/(Position\ get\ cycle)$$

Figure 3-5 Speed calculation using inductive sensor

3.1.8 Error correction of inductive sensor

This control program has a function to correct the analog output of the inductive sensor. When an angle is detected from the sin signal and cos signal with an analog output sensor, the sensor output offset and output variation will cause an angle error. This control program can use the function to correct the sensor output. The concept of gain correction is shown in Figure 3-6 and the concept of phase correction is shown in Figure 3-7.

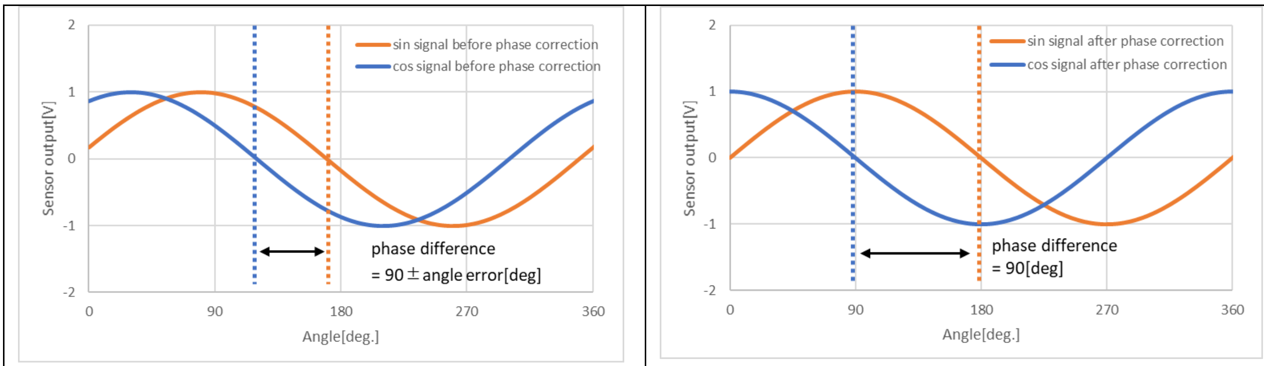


(a) Sensor signal before gain correction (b) Sensor signal after gain correction

Figure 3-6 Analog output error gain correction concept

When the sensor output correction function is enabled, the sensor output data acquisition processing is performed at the first start. It is used when calculating the correction coefficient with software based on the acquired data and calculating the angle from the sensor output. The output data of the sensor is acquired by open loop operation. Figure 3-8 shows the flow of data acquisition and correction.

In addition, regardless of whether the correction function is enabled or disabled, the d-axis alignment method is performed at startup, and the angle of the sensor detected at that time is corrected to 0 degrees.



(a) Sensor signal before phase correction (b) Sensor signal after phase correction

Figure 3-7 Analog output error phase correction concept

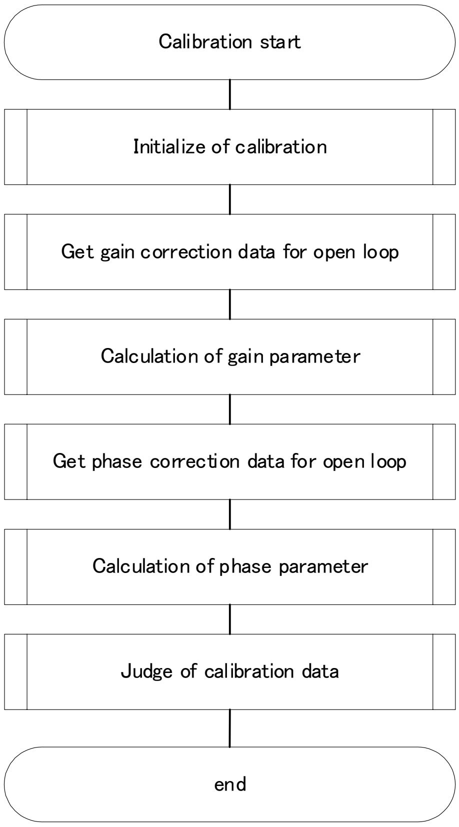


Figure 3-8 Error correction process flowchart

3.1.9 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). When this error occurs, the CPU performs emergency stop in the side of the motor in which the error occurred.

- 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. When this error occurs, the CPU performs emergency stop in the side of the motor in which the error occurred.

- 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. When this error occurs, the CPU performs emergency stop in the side of the motor in which the error occurred.

- 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. When this error occurs, the CPU performs emergency stop in the side of the motor in which the error occurred.

Table 3-5 Setting Values of the System Protection Function

Error name	Threshold		Monitoring cycle
Over current error	Over current limit [A]	3.82(RA6T2) 3.54(RA4T1,RA6T3)	Current control period
Over voltage error	Over voltage limit [V]	60	Current control period
Low voltage error	Low voltage limit [V]	8	Current control period
Over speed error	Speed limit [rpm]	4500	Current control period

3.1.10 AD triggers

Shows the timing of AD triggers and scan groups.

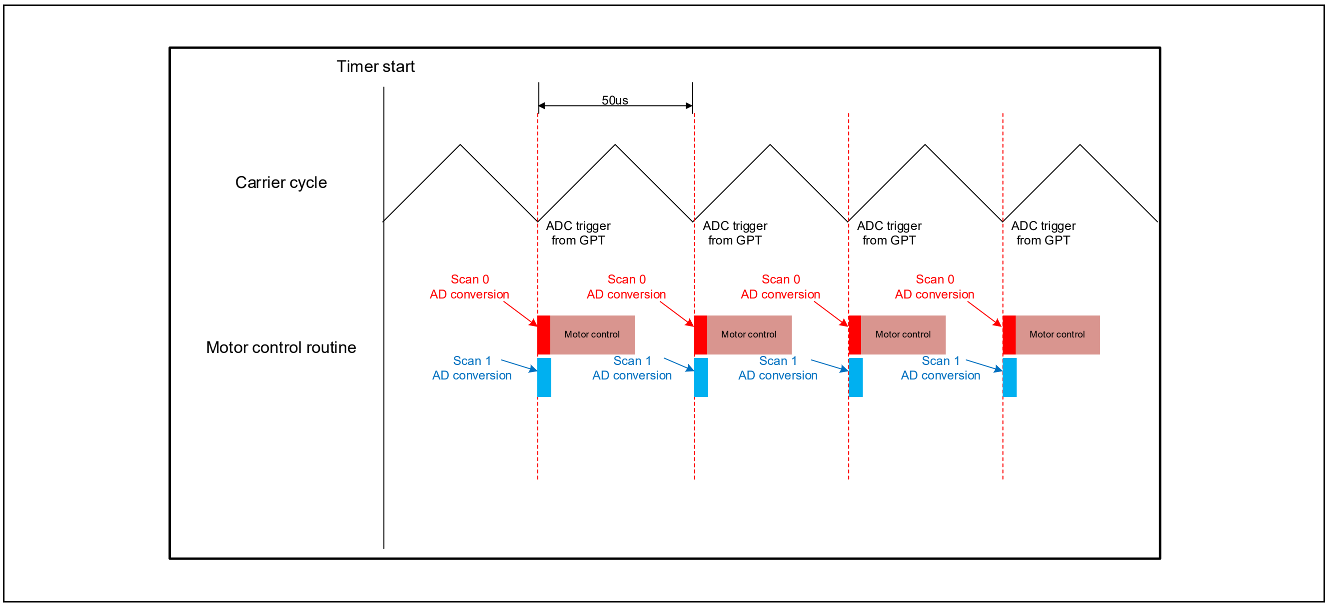


Figure 3-9 AD trigger timing

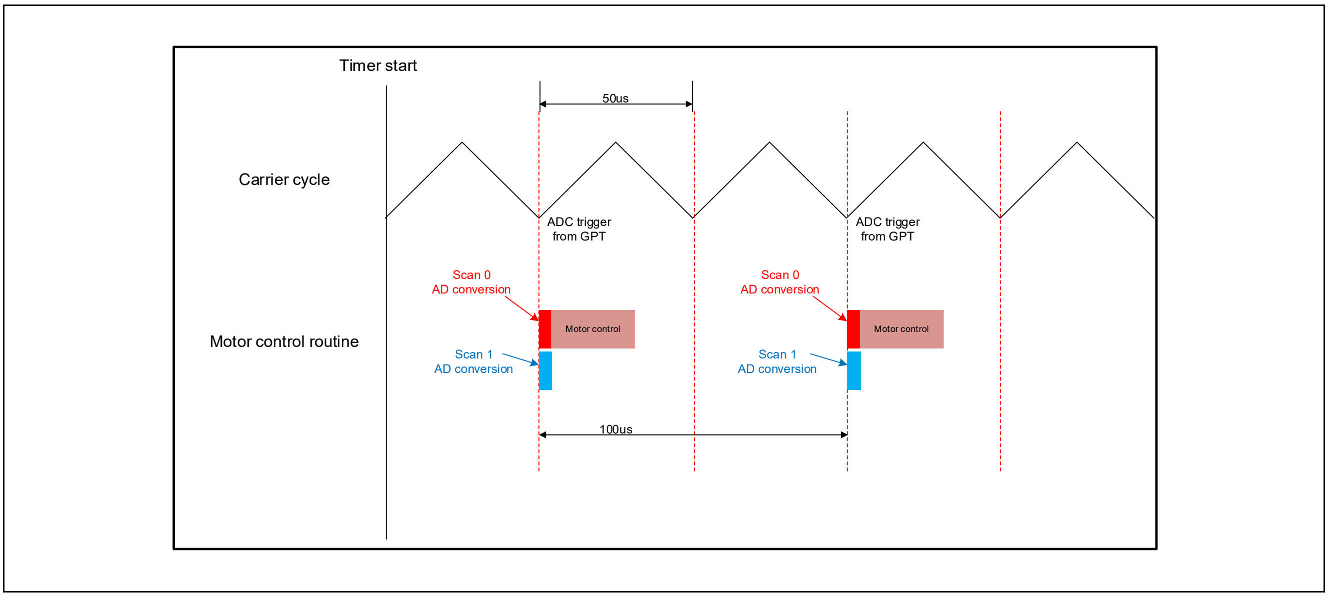


Figure 3-10 AD trigger timing (one time decimation)

3.2 Function specifications of vector control with inductive sensors software

The block diagram of the vector control with inductive sensor is shown below.

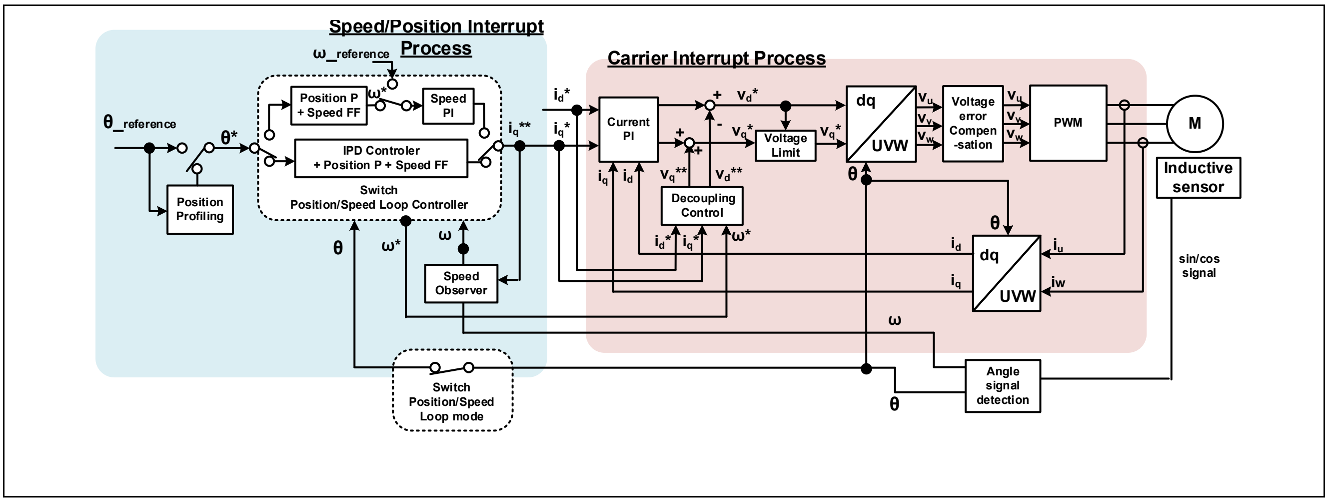


Figure 3-11 Block Diagram of Vector Control with inductive sensors

Table 3-6 List of Functions Executed in Current Control Period Interrupt (1/4)

File name	Function name	Process overview
mtr_main.c	mtr_callback_event Input : (motor_ callback_args_t *) p_args / Callback argument Output : None	Vector control with induction sensor callback function
rm_motor_induction.c	rm_motor_induction_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_INDUCTION_ErrorCheck Input : (motor_ctrl_t * const) p_ctrl / Pointer to control structure. (uint16_t * const) p_error / Pointer to get occured error Output : fsp_err_t / Execution result	Check the occurrence of Error.
	rm_motor_induction_copy_speed_current Input : (motor_speed_output_t *) st_output / Pointer to the structure of Speed Control output (motor_current_input_t *) st_input / Pointer to the structure of Current Control input Output :None	Copy speed output data to current input data
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 / The pointer to the motor driver module 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 / The pointer to the motor driver module instance Output :None	Perform PWM modulation

Table 3-7 List of Functions Executed in Current Control Period Interrupt (2/4)

File name	Function name	Process overview
rm_motor_driver.c	rm_motor_driver_mod_run Input : (motor_driver_instance_ctrl_t *) p_ctrl / Pointer to Motor Driver instance (const float *) p_f4_v_in / Pointer to the 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 / The duty cycle of Phase-U (float) f_duty_v / The duty cycle of Phase-V (float) f_duty_w / The 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
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 _t const * const) p_st_input / Pointer to input data 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 / the pointer to the UVW-phase array in [U,V,W] format (float *) f_dq / where to store the [d,q] formated array on dq coordinates Output :None	Coordinate transform UVW to dq (absolute transform)

Table 3-8 List of Functions Executed in Current Control Period Interrupt (3/4)

File name	Function name	Process overview
rm_motor_current.c	motor_current_angle_cyclic Input : (motor_current_instance_t *) p_instance / The 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 / The pointer to the FOC current control structure Output :None	Calculates the output voltage vector from current vector command and actual current vector
	motor_current_pi_control Input : (motor_current_pi_params_t *) pi_ctrl / The pointer to the 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 / The pointer to the FOC current control instance (float) f_speed_rad / The electrical speed (const motor_current_motor_parameter_t *) p_mtr / The pointer to the motor parameter data structure Output :None	Decoupling control
	motor_current_voltage_limit Input : (motor_current_instance_ctrl_t *) p_ctrl / The pointer to the FOC current control structure Output :None	Limit voltage vector

Table 3-9 List of Functions Executed in Current Control Period Interrupt (4/4)

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 / The pointer to the dq-axis value array in [D,Q] format (float *) f_uvw / Where to store the [U,V,W] formated 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_induction.c	RM_MOTOR_SENSE_INDUCTION_FlagPiCtrlSet Input : (motor_angle_ctrl_t * const) p_ctrl / Pointer to control structure (uint32_t const) flag_pi / The flag of PI control runs Output : fsp_err_t / Execution result	Set the flag of PI Control runs.
	RM_MOTOR_SENSE_INDUCTION_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.)
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 3-10 List of Functions Executed in Speed Control Interrupt (1/2)

File name	Function name	Process overview
mtr_main.c	mtr_callback_event Input : (motor_ callback_args_t *) p_args / Callback argument Output :None	Vector control with induction sensors 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_output_t * const) p_st_output / Pointer to output data structure Output : fsp_err_t / Execution result	Get speed control input data from current control
rm_motor_induction.c	rm_motor_induction_speed_callback Input : (motor_speed_callback_args_t *) p_args / Callback argument Output :None	Speed control callback function
	rm_motor_induction_copy_current_speed Input : (motor_current_output_t *) p_output / Pointer to the structure of Current Control output (motor_speed_input_t *) p_input / Pointer to the structure of Speed Control input Output :None	Copy current output data to speed input data
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 to 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 / The pointer to the FOC data instance Output : float / Speed reference	Updates the speed reference
	rm_motor_speed_set_iq_ref Input : (motor_speed_instance_ctrl_t *) p_ctrl / The pointer to the ctrl 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 / The pointer to the ctrl instance Output : float / Id reference	Updates the d-axis current reference
	RM_MOTOR_SPEED_ParameterGet Input : (motor_speed_ctrl_t * const) p_ctrl / The pointer to the ctrl instance (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 3-11 List of Functions Executed in Speed Control Interrupt (2/2)

File name	Function name	Process overview
librm_motor_speed.a	rm_motor_speed_first_order_lpf Input : (motor_speed_lpf_t *) p_lpf / First order LPF structure (float) f4_omega / Natural frequency (float) f4_ctrl_period / Control period Output : None	First Order LPF
	rm_motor_speed_fluxwkn_set_vamax Input : (motor_speed_flux_weakening_t *) p_fluxwkn / The 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 / The pointer to flux weakening structure (float) f4_speed_rad / The electrical speed of motor (const float *) p_f4_idq / The pointer to the measured current vector in format d/q (float *) p_f4_idq_ref / The pointer to the reference current vector in format d/q Output :None	Executes the flux-weakening module

3.3 Contents of control

3.3.1 Configuration Options

The configuration options of the vector control with induction sensors module for motor can be configured using the RA Configurator. The changed options are automatically reflected to common_data.c/h and hal_data.c/h files when generating code. The option names and setting values are listed in the Table 3-12 shown as follows.

Table 3-12 Configuration Options for motor_induction module

Configuration Options (rm_motor_induction.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 over speed (rpm)	When an inverter voltage becomes below this value, PWM output ports are set to off.

Table 3-13 Configuration Options Initial Value(rm_motor_encoder.h)

Options	**RA6T2**	**RA4T1**	**RA6T3**
Limit of over current (A)	1.8	1.8	1.8
Limit of over voltage (V)	60.0	60.0	60.0
Limit of over speed (rpm)	4500.0	4500.0	4500.0
Limit of over speed (rpm)	8.0	8.0	8.0

3.3.2 Configuration Options for included modules

The vector control with induction sensors module includes below modules.

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

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

Table 3-14 Configuration Options for Current Control

Configuration Options (rm_motor_current.h)	
Options	**Description**
Voltage error compensation	Selects whether to “enable” or “disable” voltage error compensation.
Shunt type	Selects how many shunt resistances to use current detection. Please set to “1shunt”.
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 d-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].
Design Parameter | Current PI loop omega	Current PI control omega parameter [Hz].
Design Parameter | Current PI loop zeta	Current PI control zeta parameter.

Table 3-15 Configuration Options Initial Value(rm_motor_current.h)

Options	RA6T2	RA4T1	RA6T3
Voltage error compensation	Enable	Enable	Enable
Shunt type	2shunt	2shunt	2shunt
Motor Parameter | Pole pairs	4	4	4
Motor Parameter | Resistance (ohm)	0.84	0.84	0.84
Motor Parameter | Inductance of d-axis (H)	0.0011	0.0011	0.0011
Motor Parameter | Inductance of q-axis (H)	0.0011	0.0011	0.0011
Motor Parameter | Permanent inductionic flux (Wb)	0.00623	0.00623	0.00623
Motor Parameter | Rotor inertia (kgm^2)	0.0000041	0.0000041	0.0000041
Design Parameter | Current PI loop omega	300.0	300.0	300.0
Design Parameter | Current PI loop zeta	1.0	1.0	1.0

Table 3-16 Configuration Options for Speed Control

Configuration Options (rm_motor_speed.h)	
Options	**Description**
Speed control period (sec)	The period of speed control process [sec].
Step of speed climbing (rpm)	The step of speed fluctuation [rpm]. Program controls speed by this step at acceleration and deceleration.
Maximum rotational speed (rpm)	Maximum rotational speed [rpm]
Speed LPF omega	Speed LPF parameter omega [Hz].
Speed at Id climbing (rpm)	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)	Limit of q-axis current [A].
Flux weakening	Select enable/disable of flux weakening control at high speed.
Design parameter | Speed PI loop omega	Speed PI Control parameter omega.
Design parameter | Speed PI loop zeta	Speed PI Control parameter zeta.
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 3-17 Configuration Options Initial Value(rm_motor_speed.h)

Options	RA6T2	RA4T1	RA6T3
Speed control period (sec)	0.0005	0.0005	0.0005
Step of speed climbing (rpm)	0.5	0.5	0.5
Maximum rotational speed (rpm)	4000	4000	4000
Speed LPF omega	10.0	10.0	10.0
Speed at Id climbing (rpm)	500	400	400
Limit of q-axis current (A)	1.8	1.8	1.8
Flux weakening	Disable	Disable	Disable
Design parameter | Speed PI loop omega	30.0	5.0	5.0
Design parameter | Speed PI loop zeta	1.0	1.0	1.0
Design parameter | Speed observer omega	200.0	200.0	200.0
Design parameter | Speed observer zeta	1.0	1.0	1.0
Motor Parameter | Pole pairs	4	4	4
Motor Parameter | Resistance (ohm)	0.84	0.84	0.84
Motor Parameter | Inductance of d-axis (H)	0.0011	0.0011	0.0011
Motor Parameter | Inductance of q-axis (H)	0.0011	0.0011	0.0011
Motor Parameter | Permanent inductionic flux (Wb)	0.00623	0.00623	0.00623
Motor Parameter | Rotor inertia (kgm^2)	0.0000041	0.0000041	0.0000041

Table 3-18 Configuration Options for Position control module

Configuration Options (rm_motor_position.h)	
Options	**Description**
Position dead band	Position dead band
Position band limit	Zero position error range
Speed feedforward ratio	Speed feedforward ratio
Position omega	Position control omega parameter [Hz].
Period of speed control (sec)	Speed control execution cycle
Position Profiling | Interval time	Position response steady-state waiting time
Position Profiling | Accel time	Acceleration time
Position Profiling | Maximum accel time	Maximum acceleration time calculation parameter
Position Profiling | Accelaration maximu speed	Position profile maximum rotation speed
Position Profiling | Update step of timer	Position profile update cycle
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_position.h)

Options	RA6T2	RA4T1	RA6T3
Position dead band	1	1	1
Position band limit	3	3	3
Speed feedforward ratio	0.8	0.8	0.8
Position omega	10.0	10.0	10.0
Period of speed control (sec)	0.0005	0.0005	0.0005
Position Profiling | Interval time	400	400	400
Position Profiling | Accel time	0.3	0.3	0.3
Position Profiling | Maximum accel time	11077.904	11077.904	11077.904
Position Profiling | Accelaration maximum speed	4000.0	4000.0	4000.0
Position Profiling | Update step of timer	0.0005	0.0005	0.0005
Motor Parameter | Pole pairs	4	4	4
Motor Parameter | Resistance (ohm)	0.84	0.84	0.84
Motor Parameter | Inductance of d-axis (H)	0.0011	0.0011	0.0011
Motor Parameter | Inductance of q-axis (H)	0.0011	0.0011	0.0011
Motor Parameter | Permanent inductionic flux (Wb)	0.00623	0.00623	0.00623
Motor Parameter | Rotor inertia (kgm^2)	0.0000041	0.0000041	0.0000041

Table 3-20 Configuration Options for Angle and Speed with induction sensors

Configuration Options (rm_motor_sense_induction.h)	
Options	**Description**
Frequency of current control (kHz)	PWM carrier frequency [kHz]
Decimation of Interrupt	Speed correction count
Counts to get signal	Error correction time division
Limit of signal error	Error judgment threshold at error correction
Coefficent of speed LPF	LPF factor
A/D reference voltage	A/D reference voltage [V]
A/D conversion scale	A/D conversion scale
Openloop speed (rpm)	Open loop rotation speed [rpm]
D-axis current at openloop (A)	Open loop d-axis current [A]
Angle adjustment times	Hold time setting at initialization of rotor angle
Induction sensor pole pairs	Inductive sensor pole pairs
Motor pole pairs	Motor pole pairs

Table 3-21 Configuration Options Initial Value(rm_motor_sense_induction.h)

Options	RA6T2	RA4T1	RA6T3
Frequency of current control (kHz)	20.0	10.0	10.0
Decimation of Interrupt	1	1	1
Counts to get signal	10	10	10
Limit of signal error	100	100	100
Coefficent of speed LPF	0.07	0.07	0.07
A/D reference voltage	3.3	3.3	3.3
A/D conversion scale	4095.0	4095.0	4095.0
Openloop speed (rpm)	6.0	6.0	6.0
D-axis current at openloop (A)	1.0	1.0	1.0
Angle adjustment times	512	512	512
Induction sensor pole pairs	4	4	4
Motor pole pairs	4	4	4

Table 3-22 Configuration Options for Driver Access

Configuration Options (rm_motor_driver.h)	
Options	**Description**
PWM timer frequency (MHz)	PWM Timer Clock Frequency [MHz]
PWM carrier period (micro seconds)	PWM Carrier Period [micro seconds]
Dead time (raw counts)	PWM Dead time [raw counts]
Current range (A)	Measurement Range of Electric current [A]
Voltage range (V)	Measurement Range of Inverter Voltage [V]
Counts for current offset measurement	Counts of measurement the offset of A/D Conversion at electric current input.
Shunt type	Selects how many shunt resistances to use current detection.
A/D conversion channel for U phase current	A/D channel for U-phase current
A/D conversion channel for V phase current	A/D channel for V-phase current It is invalid at 2shunt detection.
A/D conversion channel for W phase current	A/D channel for W-phase current
A/D conversion channel for main line voltage	A/D channel for main line voltage
General|A/D conversion channel for sin signal	A/D channel for Sine signal input
General|A/D conversion channel for cos signal	A/D channel for Cosine signal input
Input voltage	Range of input for main line voltage
Resolution of A/D conversion	Resolution of A/D conversion Please set same value with ADC module setting.
Offset of A/D conversion for current	Offset level of A/D conversion input for current Please set according to the circuit.
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.
GTIOCA stop level	Output level of upper arm at stop status
GTIOCB stop level	Output level of lower arm at stop status
Maximum duty	Maximum duty of PWM Maximum duty except dead time.

Table 3-23 Configuration Options Initial Value(rm_motor_driver.h)

Options	**RA6T2**	**RA4T1**	**RA6T3**
PWM timer frequency (MHz)	120	100	100
PWM carrier period (michro seconds)	50	50	50
Dead time (raw counts)	240	200	200
Current range (A)	16.5	16.5	16.5
Voltage range (V)	73.26	73.26	73.26
Counts for current offset measurement	500	500	500
Shunt type	2shunt	2shunt	2shunt
A/D conversion channel for U phase current	4	0	0
A/D conversion channel for V phase current	2	1	1
A/D conversion channel for W phase current	0	2	2
A/D conversion channel for main line voltage	6	4	4
General|A/D conversion channel for sin signal	27	16	16
General|A/D conversion channel for cos signal	28	6	6
Input voltage	24.0	24.0	24.0
Resolution of A/D conversion	0xFFF	0xFFF	0xFFF
Offset of A/D conversion for current	0x7FF	0x7FF	0x7FF
Conversion level of A/D conversion for voltage	1.0	1.0	1.0
GTIOCA stop level	Pin level Low	Pin level Low	Pin level Low
GTIOCB stop level	Pin level High	Pin level High	Pin level High
Maximum duty	0.9375	0.9375	0.9375

3.4 Control flowcharts

3.4.1 Main process

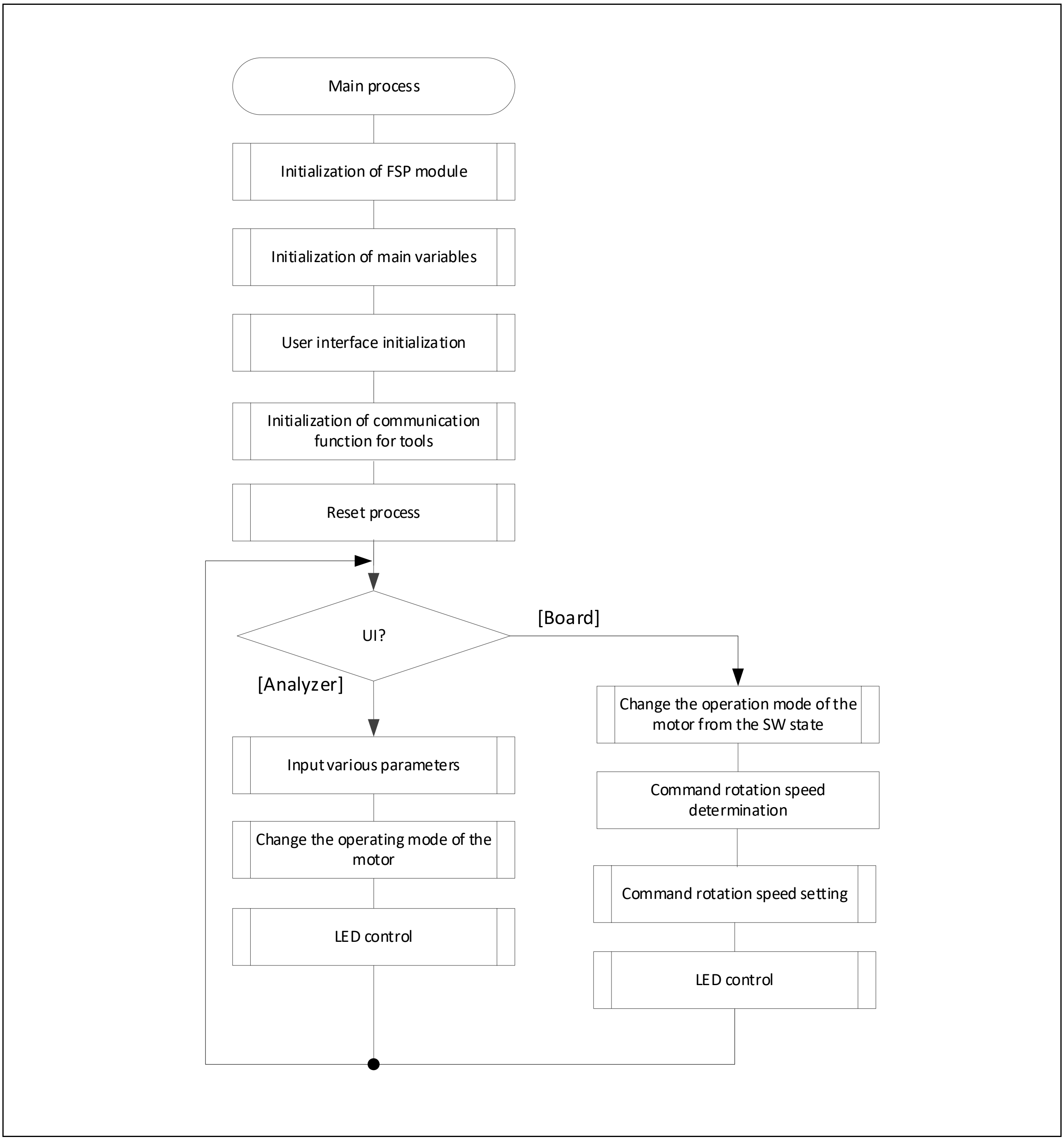


Figure 3-12 Main Process Flowchart

3.4.2 Current Control Period Interrupt (Carrier synchronized Interrupt) Process

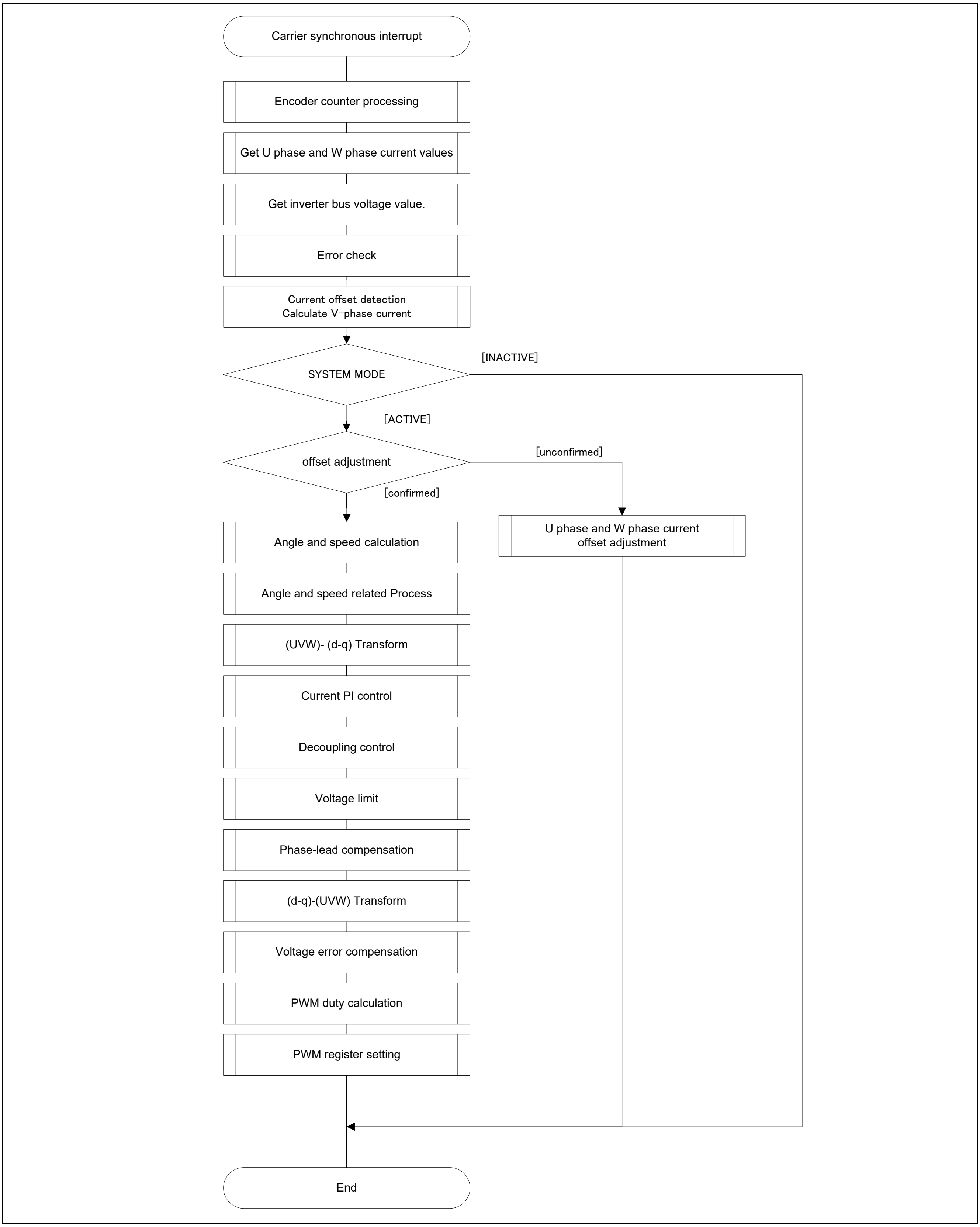


Figure 3-13 Current Control Period Interrupt (Carrier Interrupt) Process Flowchart

3.4.3 Speed Control Period Interrupt Process

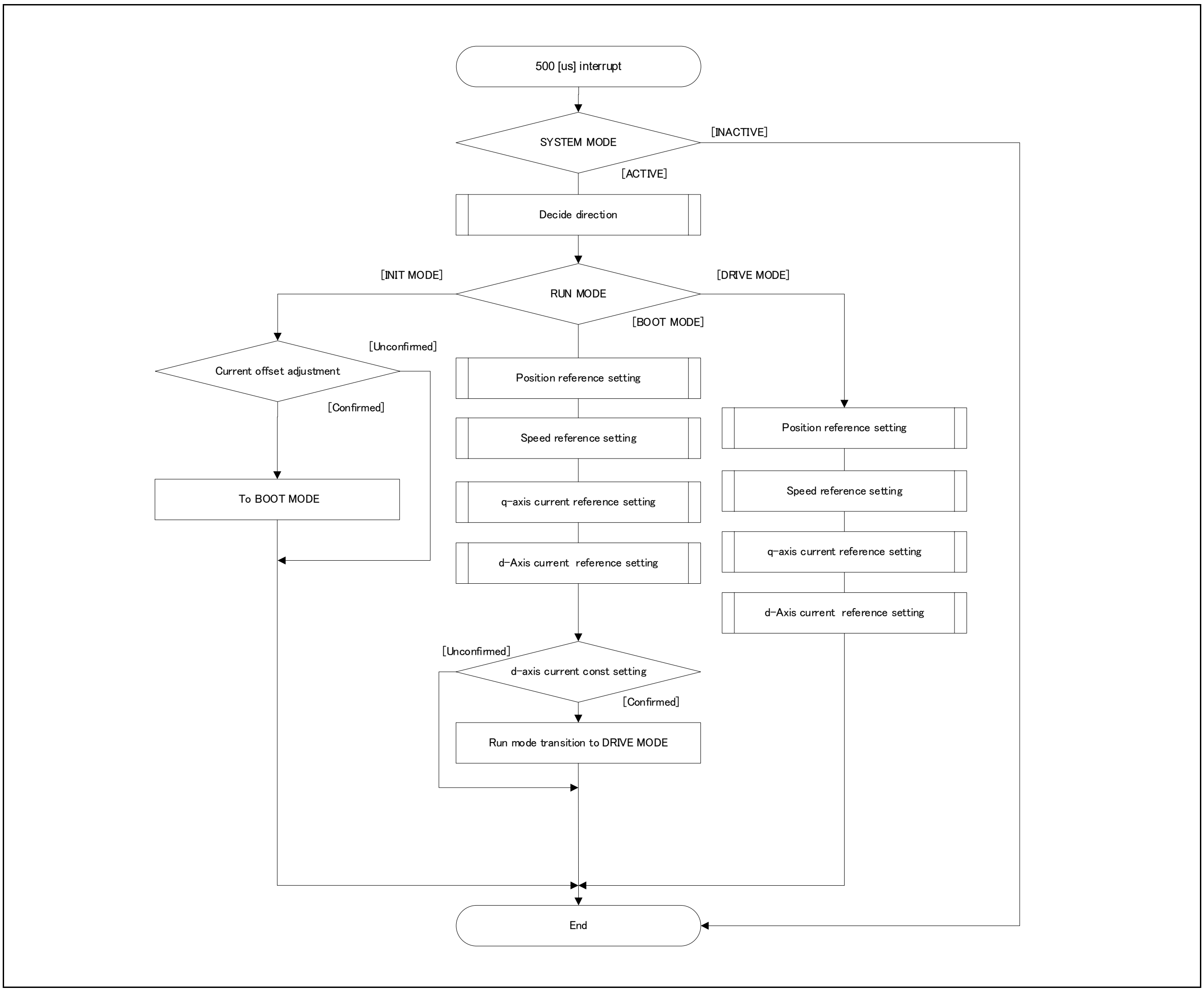


Figure 3-14 Speed Control Period Interrupt Process Flowchart

3.4.4 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.

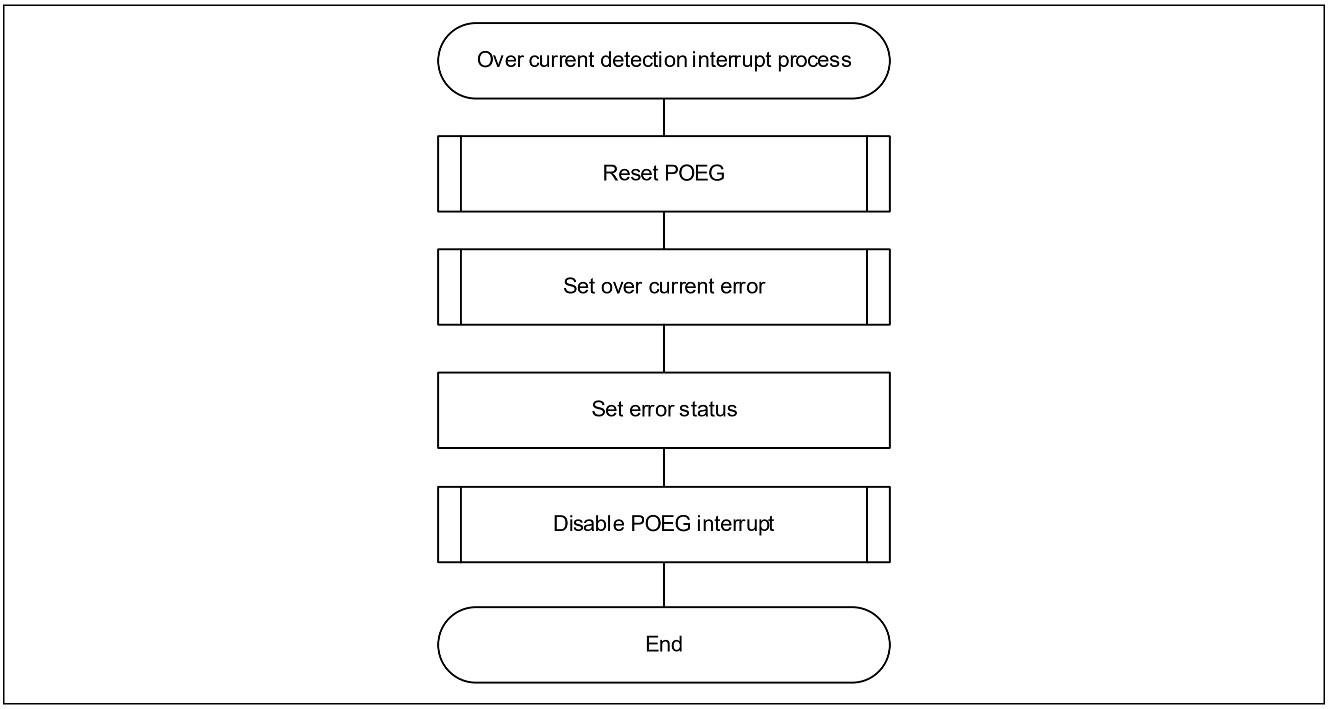


Figure 3-15 Over Current Detection Interrupt Process Flowchart

4. Project Operation Overview

4.1 Importing the Demo Project

The sample application provided with this document may be imported into e²studio using the steps in this section.

1. Select File → Import.

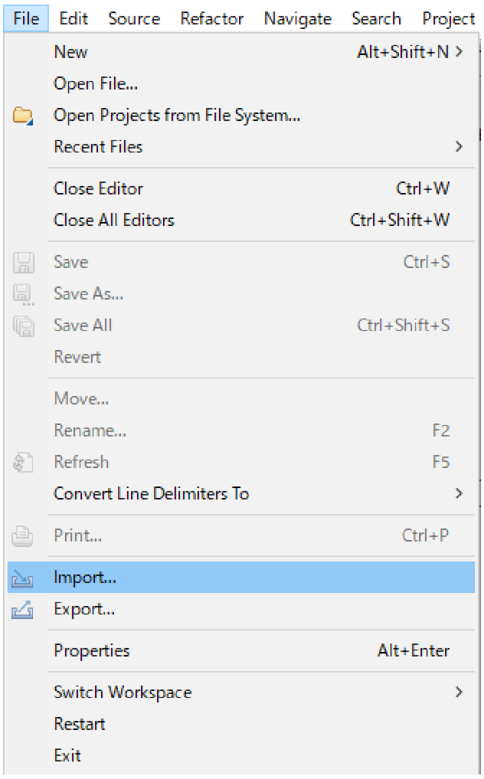


Figure 4-1 File Menu

2. Select "Existing Projects into Workspace".

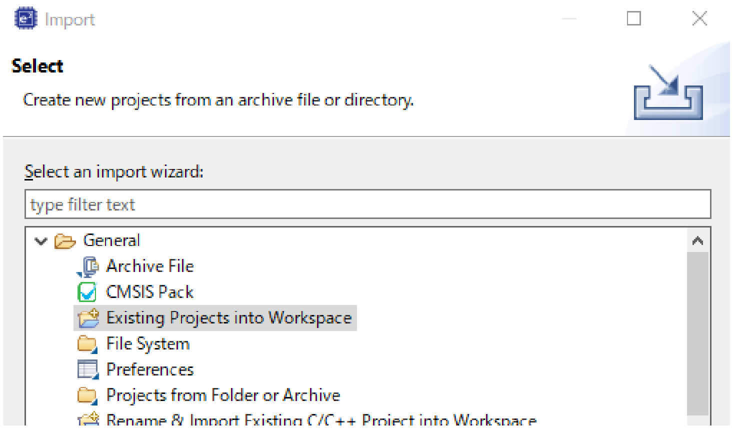


Figure 4-2 Import Wizard Selection

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

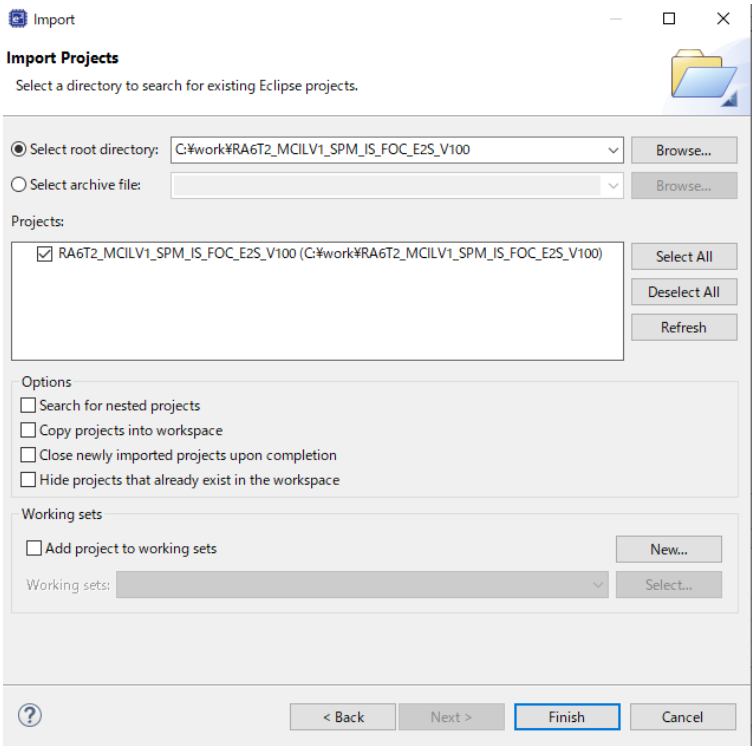


Figure 4-3 Import Projects

4.2 Building and Debugging

Refer to the "e^{2}studio Getting Started Guide (R20UT4204)".

4.3 Quick Start

When executing the sample code only in the evaluation environment without using Renesas motor workbench, the Quick Start Sample Project can be executed with the following procedure.

(1) After turning on stabilized power supply or executing reset, LED1, and LED2 on the inverter board are both off and the motor stops.

(2) IF the toggle switch (SW1) on the inverter board is turned on, the motor starts to rotate. Every time the toggle switch (SW1) is changed, motor rotation starts/stops alternately. If the motor rotates normally, LED1 is on. However, if LED2 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 (VR) on the inverter board.

- Turn the variable resistor (VR) right: Motor rotates clockwise
- Turn the variable resistor (VR) left: Motor rotates counterclockwise

(4) If error occurs, LED2 on the inverter board lighten, and the motor rotation stops. To restore, the toggle switch (SW1) on the inverter board needs to be turned off, then the switch (SW2) 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.

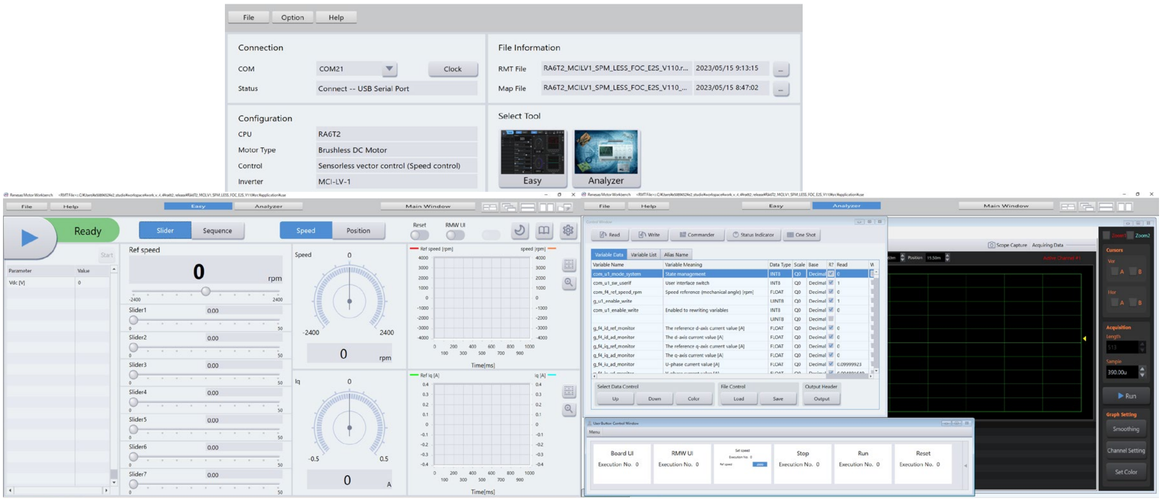
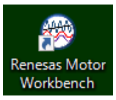


Figure 4-4 Renesas Motor Workbench – Appearance

<u>Set up for “Renesas Motor Workbench”</u>

(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 ‘Easy function operation example’ or ‘Operation Example for Analyzer’ for motor driving operation.

4.4.2 Easy function operation example

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

4.4.2.1 Position control

- Set the control mode to Position
  (1) Select the Position tab.
  (2) Turn on “Position”.
  If it has already been turned on, turn it off and then turn it on again.

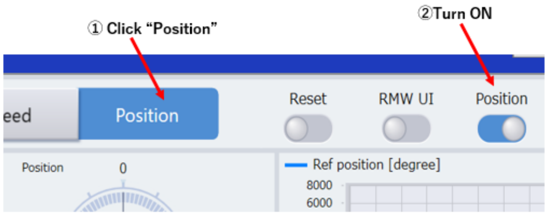


Figure 4-5 Procedure for setting the control mode to Position

- Change the user interface to use Renesas Motor Workbench
  (1) Turn on "RMW UI".
  If it has already been turned on, turn it off and then turn it on again.

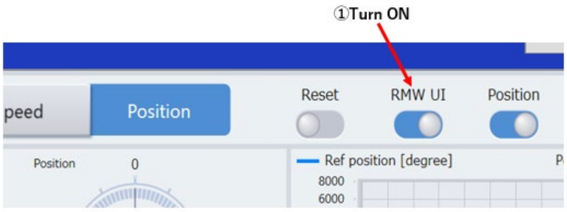


Figure 4-6 Procedure for changing to use Renesas Motor Workbench

- Run the motor
  (1) Press the “Run” button
  (2) Enter the command position with the "Ref position" slider.

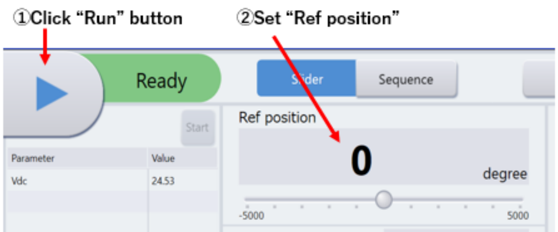


Figure 4-7 Motor rotation procedure

- Stop the motor

  (1) Press the “Stop” button

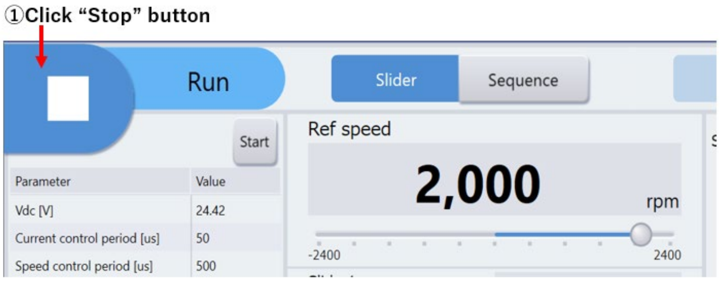


Figure 4-8 Motor stop procedure

- Processing when it stops (error)

  (1) Turn on "Reset" button.

  (2) Turn off “Reset” button

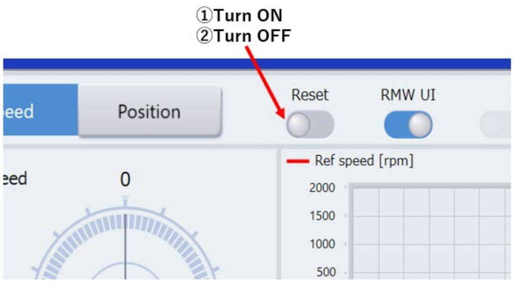


Figure 4-9 Error clearing procedure

4.4.2.2 Speed control

- Set the control mode to Speed
  (1) Select the Speed tab.
  (2) Turn on “Speed”.
  If it has already been turned on, turn it off and then turn it on again.

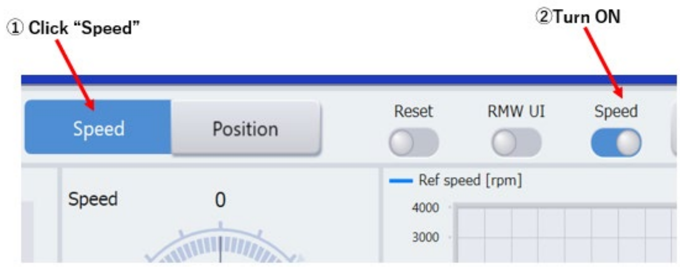


Figure 4-10 Procedure for setting the control mode to Speed

- Change the user interface to use Renesas Motor Workbench
  (1) Turn on "RMW UI".
  If it has already been turned on, turn it off and then turn it on again.

Figure 4-11 Procedure for changing to use Renesas Motor Workbench

- Run the motor
  (1) Press the “Run” button
  (2) Enter the command speed with the "Ref speed" slider.

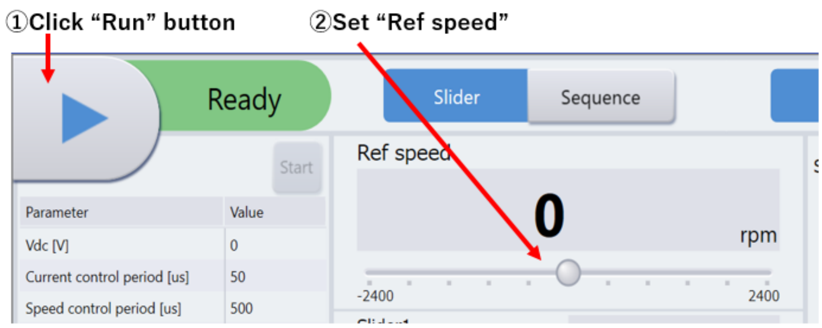


Figure 4-12 Motor rotation procedure

- Stop the motor

  (1) Press the “Stop” button

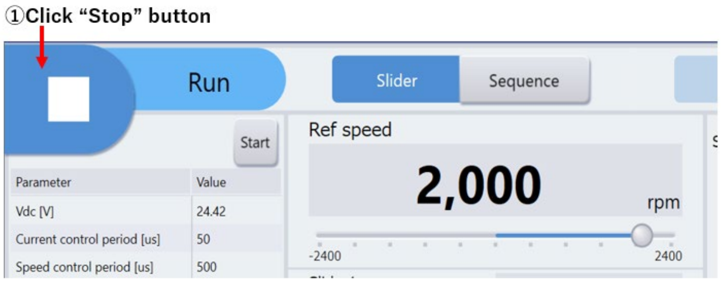


Figure 4-13 Motor stop procedure

- Processing when it stops (error)

  (1) Turn on "Reset" button.

  (2) Turn off “Reset” button

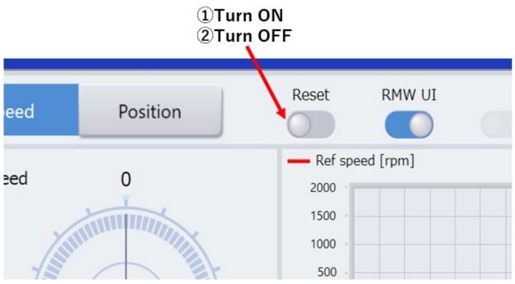


Figure 4-14 Error clearing procedure

4.4.3 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.

Table 4-1 List of Variables for Analyzer

Variable name	Type	Content
com_u1_sw_userif (*)	uint8_t	User interface switch 0: GUI use 1: Board user interface use (default)
com_u1_mode_system (*)	uint8_t	State management 0: Stop mode 1: Run mode 3: Reset
com_u1_ctrl_loop_mode	uint8_t	Control loop mode switch 0: Speed control 1: Position control (default)
com_f4_ref_speed_rpm	float	Speed reference (Mechanical) [rpm]
com_s2_ref_position_deg	int16_t	Position command value [degree]
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	Flux [Wb]
com_f4_mtr_j	float	Inertia [kgm^2]
com_f4_pos_omega	float	Natural frequency of current control system [Hz]
com_f4_sob_omega	float	Damping ratio of current control system
com_f4_sob_zeta	float	Natural frequency of speed control system [Hz]
com_f4_speed_omega	float	Damping ratio of speed control system
com_f4_speed_zeta	float	Natural frequency of the position loop[Hz]
com_f4_current_omega	float	Natural frequency of the speed observer [Hz]
com_f4_current_zeta	float	Damping ratio of the speed observer
com_f4_ol_ref_id	float	d-axis current reference in open loop mode [A]
com_f4_id_up_time	float	d-axis current command value addition time [ms]
com_f4_max_speed_rpm	float	Maximum speed
com_f4_speed_limit_rpm	float	Over speed limit
com_u2_pos_dead_band	uint16_t	Dead band of position
com_u2_pos_band_limit	uint16_t	Positioning complete range
com_u2_interval_time	uint16_t	Time interval of the position command changes
com_f4_accel_time	float	Acceleration time [s] (for position control)
com_f4_speed_rate_limit	float	Acceleration limit [s] (for speed control)

4.4.4 Operation Example for Analyzer

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

- Change the user interface to Analyzer

(1) Confirm the check-boxes 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_system1","com_s2_ref_position_deg", "com_u1_enable_write"
(2) Type a reference position value in the [Write] box of "com_s2_ref_position_deg".
(3) Click the "Write" button.
(4) Click the "Read" button. Confirm the [Read] box of "com_s2_ref_position_deg" , "g_u1_enable_write".
(5) Enter the same value of "g_u1_enable_write" in the [Write] box of "com_u1_enable_write".
(6) Enter "1" in the [Write] box of "com_u1_mode_system".
(7) Click the "Write" button.

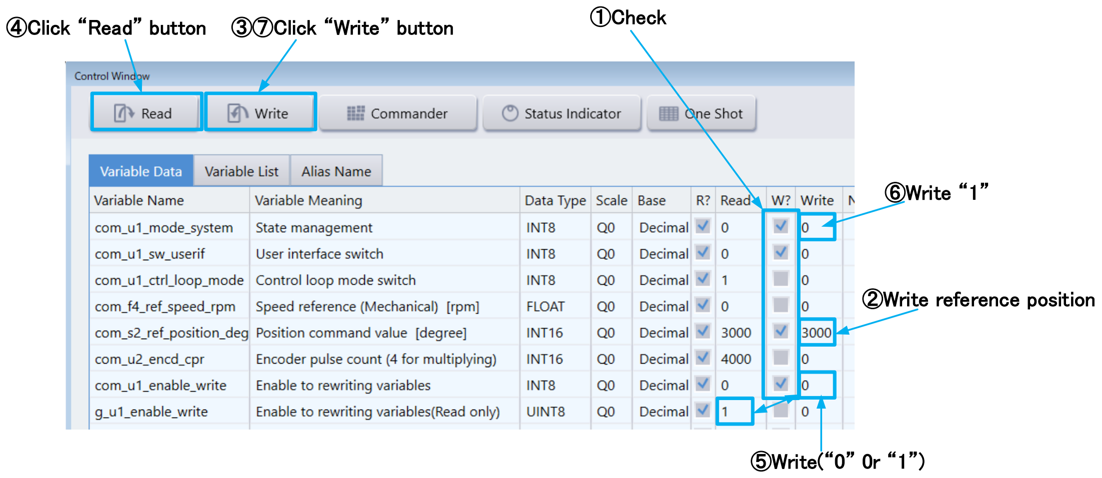


Figure 4-15 Procedure - Driving the motor

- Stop the motor

(1) Enter "0" in the [Write] box of "com_u1_mode_system".
(2) Click the "Write" button.

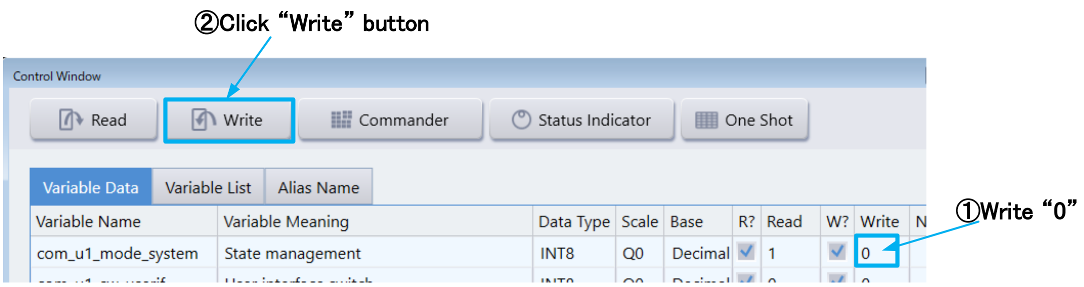


Figure 4-16 Procedure - Stop the motor

- Error cancel operation

(1) Enter “3” in the [Write] box of “com_u1_mode_system”.
(2) Click the “Write” button.

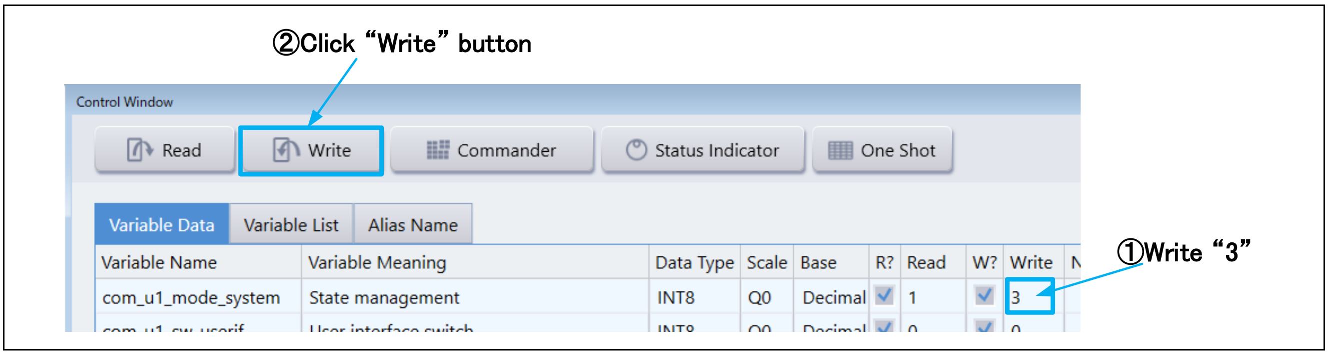


Figure 4-17 Procedure - Error cancel operation

4.4.5 Tuner function

To use the Tuner function, use the executable file provided by Renesas Motor Workbench or "RA6T2_MCILV1_SPM_IS_FOC_TUNER_E2S_V100" included in the sample software.

For details on how to use the Tuner function, refer to the Tuner function manual (R20AN0528) included in the Renesas Motor Workbench download file.

4.4.6 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.

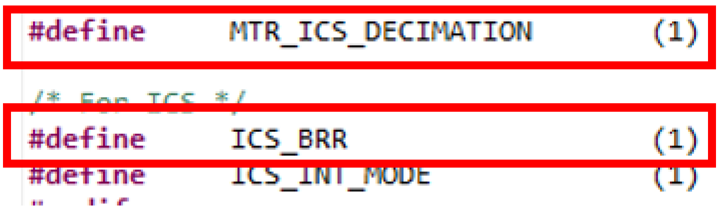


Figure 4-18 Modification of r_mtr_ics.h

- 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

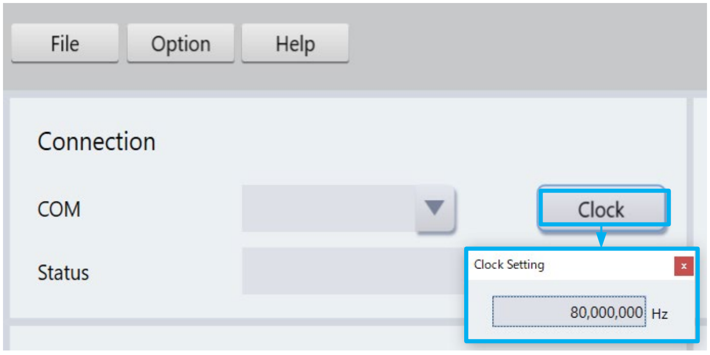


Figure 4-19 Clock frequency setting

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

4.4.7 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

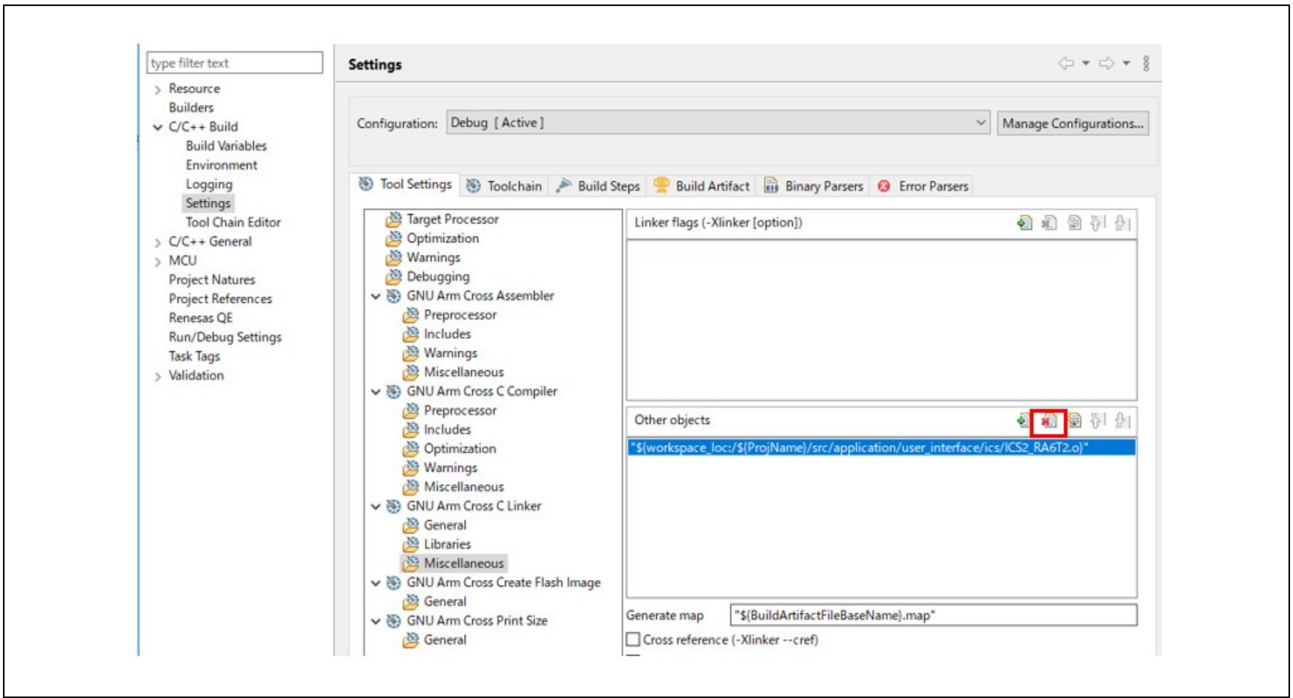


Figure 4-20 Unregister ICS2_RA6T2.o

(2) Register ICS2_RA6T2_Built_in.o

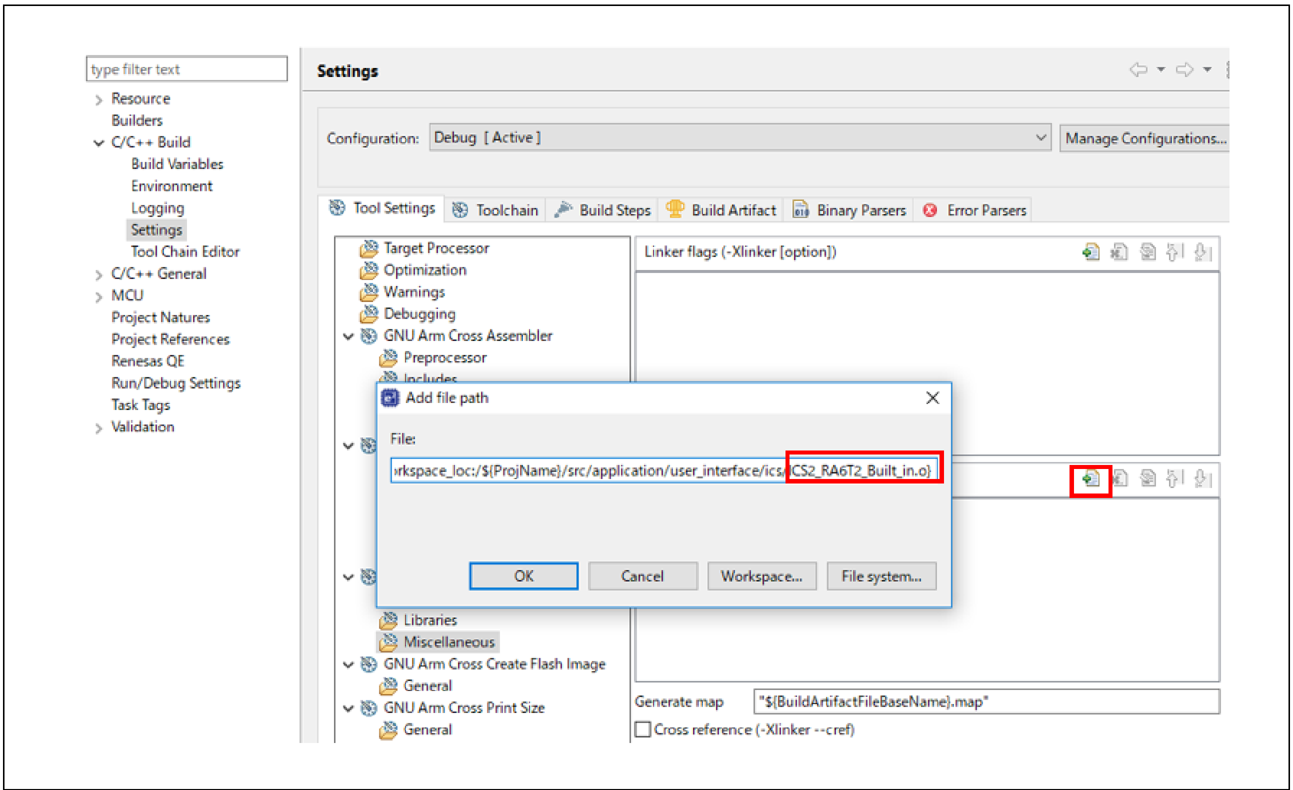


Figure 4-21 Register ICS2_RA6T2.o

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

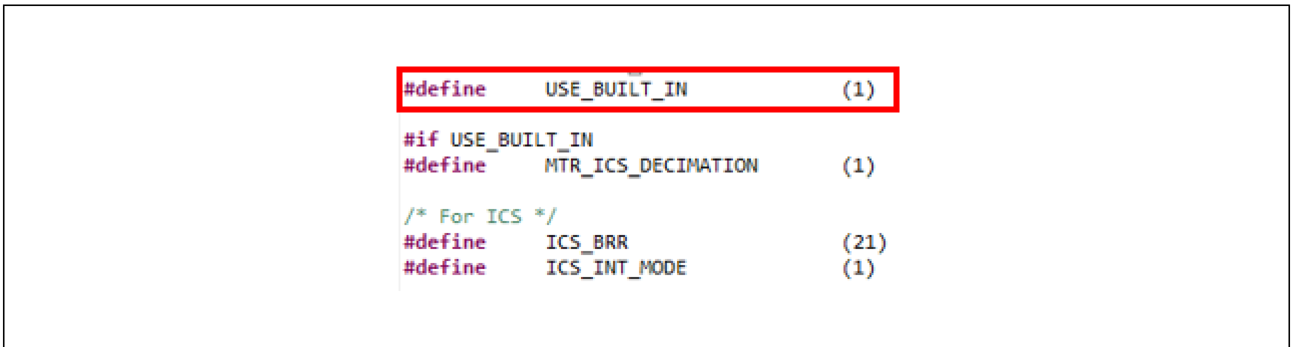


Figure 4-22 Modification of r_mtr_ics.h

- 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.

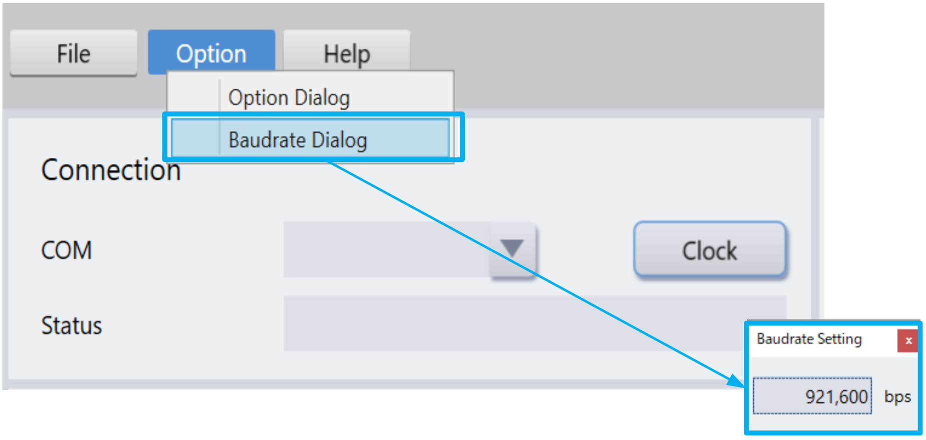


Figure 4-23 Baud rate setting

5. Reference Documents

RA6T2 Group User’s Manual: Hardware (R01UH0951)
RA4T1 Group User’s Manual: Hardware (R01UH0998)
RA6T3 Group User’s Manual: Hardware (R01UH0999)
RA Flexible Software Package Documentation
Application note: ‘Encoder vector control for permanent magnet synchronous motor (Algorithm)’ (R01AN3789)
Renesas Motor Workbench User’s Manual (R21UZ0004)
Renesas Motor Workbench Quick start guide (R21QS0011)
MCK-RA6T2 User's Manual (R12UZ0091)
MCK-RA4T1 User's Manual (R12UZ0114)
MCK-RA6T3 User's Manual (R12UZ0115)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	May 23, 2023	-	First edition issued

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

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

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

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