R01AN5630EJ0100
Rev.1.00
20.10.2020

RL78/G1F

Sensorless 120-degree conducting control for permanent magnetic synchronous motor (high-speed rotation)

Summary

The purpose of this application note is to describe how to use the RL78/G1F microcontroller to drive a permanent magnet synchronous motor using high-speed rotation control by sensorless 120-degree conducting. We demonstrate the implementation using a sample program and Renesas Motor Workbench (RMW), a motor control development support tool.

These sample programs are to be used as references only, and Renesas Electronics Corporation does not guarantee their operations. Please use after carrying out a thorough evaluation in a suitable environment.

Evaluation Device

Operations of the sample programs have been checked using the following device:

RL78/G1F(R5F11BGEAFB)

Target sample programs

The target sample programs of this application note are as follows.

- RL78G1F_MRSSK_120HS_CSP_CC_V100 (IDE: CS+ for CC)
- RL78G1F_MRSSK_120HS_E2S_CC_V100 (IDE: e^{2}studio)

Sample program for high-speed rotation control by sensorless 120-degree conducting on RL78/G1F demo board

Reference

- RL78/G1F Group User's Manual: Hardware (R01UH0516EJ0110)
- Application note: '120-degree conducting control of permanent magnet synchronous motor: algorithm' (R01AN2657EJ0120)
- Renesas Motor Workbench 2.0 User's Manual (R21UZ0004EJ0202 : Renesas-Motor-Workbench-V2-0d)
- RL78/G1F Motor Driver Board GB01 User's Manual (R12UT0012EJ0100)

Table of Contents

1. Overview 3

2. System overview 4

3. Descriptions of the control program 13

4. How to Run the Demo System 40

1. Overview

This application note describes how to implement the 120-degree conduction control sample program for a permanent magnet synchronous motor (PMSM) using a RL78/G1F microcontroller and how to use the Renesas Motor Workbench (RMW), a motor control development support tool. Note that these sample programs use the algorithm described in the application note '120degree conducting control of permanent magnet synchronous motor: algorithm'.

1.1 Development environment

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

Table 1-1 – Development Environment of the Sample Programs (H/W)

Microcontroller	Evaluation board	motor
RL78/G1F (R5F11BGEAFB)	RL78/G1F Motor Driver Board GB01 (P13130-D1-003)[1] Communication board (RTK0EMX6B0Z00000BJ)[1,2]	TF037C-2000-F[3]

Table 1-2 – Development Environment of the Sample Programs (S/W)

CS+ version	Build tool version
V8.03.00	CC-RL V1.09.00

e[2]studio version	Build tool version
v7.8.0	CC-RL V1.09.00

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

Notes:

1. The RL78/G1F demo board (P13130-D1-003) and the communication board (RTK0EMX6B0Z00000BJ) are for testing only and are not for sale. For technical support, equipment loans, etc., contact a Renesas sales representative or dealer.
2. For the communication board used for debugging, ICS++ (In Circuit Scope plus) made by Desk Top Laboratories Inc. is also available.

   Desk Top Laboratories Inc. (http://desktoplab.co.jp/)
3. TF037C-2000-F is a product of Nidec Copal Electronics Co., Ltd.

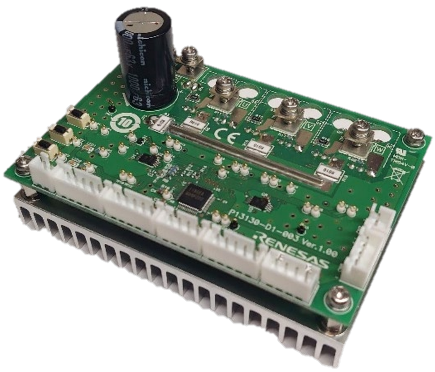
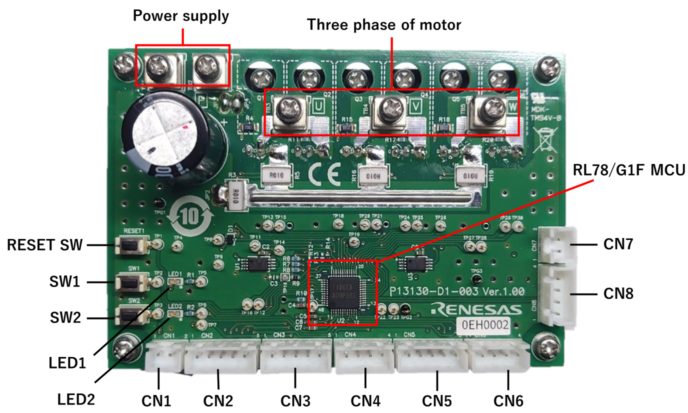
   Nidec Copal Electronics Co., Ltd. (https://www.nidec-copal-electronics.com/)

2. System overview

An overview of this system is provided below.

2.1 Hardware specifications

Table 2.1 – RL78/G1F demo board specifications

Item	Specification
Operating input voltage	12V - 50V
Maximum output current	30 A (peak current for each phase)
Motor to be driven	3-phase permanent magnet synchronous motor
Current detection method	3-phase current detection and current detection using DC link shunt resistor
DC bus voltage detection	Detection by resistive divider
Three-phase output voltage detection	Detection by resistive divider
PWM logic	Positive logic in both upper and lower arms
Overcurrent detection	Implemented by RL78/G1F MCU setting (PWMOPA); detection circuit not yet implemented
Dead time	1 μs or more
Switch	3 tact switches (one of which is a CPU reset)
LED	2
connectors	• Connector for emulator connection (using conversion cable): CN3 • I2C communication connector: CN6 • 2 serial communication connectors: CN4, CN8 • ABZ encoder signal input connector: CN2 • Hall sensor signal input connector: CN5 • 2 analog signal inputs: CN1, CN7
Exterior view	
Heat dissipation	Natural air cooling by heat sink
Names of parts	

2.2 Hardware configuration

The hardware configuration is shown below.

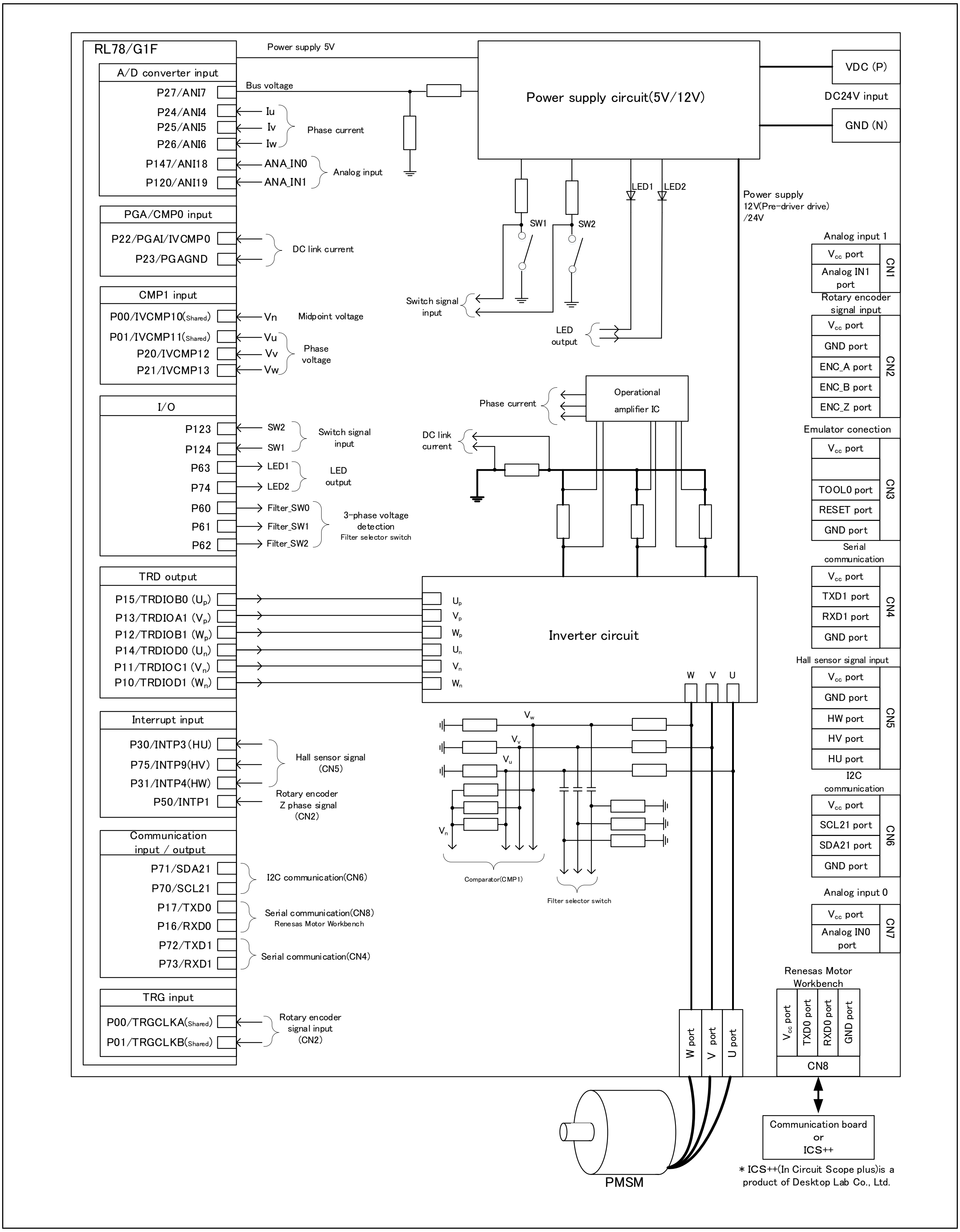


Figure 2-1 – Hardware Configuration Diagram

2.3 Hardware specifications

2.3.1 User interface

Table 2.2 is a list of user interfaces of this system.

Table 2.2 – User Interfaces

Item	Interface component	Function
SW1	Tact switch	Motor drive
SW2	Tact switch	Motor stop / error cancellation
RESET	Tact switch (RESET1)	System reset
LED1	Yellow green LED	Indicate the running status
LED2	Yellow green LED	Error status display

The system's connector interfaces are listed in Table 2.3.

Table 2.3 – Connector Interfaces

Item	Number of ports	Function
CN1	2	Analog input (not used in this system)
CN2	5	ABZ encoder signal input (not used in this system)
CN3	5	Emulator connection (using conversion board)
CN4	4	Serial communication (SCI1) (not used in this system)
CN5	5	Hall sensor signal input (not used in this system)
CN6	4	I2C communication (not used in this system)
CN7	2	Analog input (not used in this system)
CN8	4	Serial communication (SCI0) communication with Renesas Motor Workbench

Table 2.4 is a list of port interfaces of the RL78/G1F microcontroller of this system.

Table 2.4 – Port Interfaces

R5F11BGEAFB port name	Function
P27 / ANI7	Inverter bus voltage measurement
P24 / ANI4	U-phase current measurement (not used in this system)
P25 / ANI5	V-phase current measurement (not used in this system)
P26 / ANI6	W-phase current measurement (not used in this system)
P147 / ANI18	Analog input (not used in this system)
P120 / ANI19	Analog input (not used in this system)
P22 / PGAI / IVCMP0	DC link current detection (A/D, PGA, CMP)
P23 / PGAGND	DC link current detection GND
P00 / IVCMP10	3-phase midpoint voltage measurement (CMP1) (shared port)
P01 / IVCMP11	Uphase voltage measurement (CMP1) (shared port)
P20 / IVCMP12	Vphase voltage measurement (CMP1)
P21 / IVCMP13	Wphase voltage measurement (CMP1)
P123	Tact switch (SW2)
P124	Tact switch (SW1)
P63	LED1 ON / OFF control
P74	LED2 ON / OFF control
P60	U-phase voltage detection filter change switch (not used in this system)
P61	V-phase voltage detection filter change switch (not used in this system)
P62	W-phase voltage detection filter change switch (not used in this system)
P15 / TRDIOB0	PORT output / PWM output (U_p)
P13 / TRDIOA1	PORT output / PWM output (V_p)
P12 / TRDIOB1	PORT output / PWM output (W_p)
P14 / TRDIOD0	PORT output / PWM output (U_n)
P11 / TRDIOC1	PORT output / PWM output (V_n)
P10 / TRDIOD1	PORT output / PWM output (W_n)
P30 / INTP3	Hall sensor input (HU) (not used in this system)
P75 / INTP9	Hall sensor input (HV) (not used in this system)
P31 / INTP4	Hall sensor input (HW) (not used in this system)
P50 / INTP1	Encoder Z-phase input (not used in this system)
P71 / SDA21	I2C communication (not used in this system)
P70 / SCL21	I2C communication (not used in this system)
P17 / TXD0	Serial communication (SCI0)
P16 / RXD0	Serial communication (SCI0)
P72 / TXD1	Serial communication (SCI1) (not used in this system)
P73 / RXD1	Serial communication (SCI1) (not used in this system)
P00 / TRDCLKA	Encoder A-phase input (shared port) (not used in this system)
P01 / TRDCLKB	Encoder B-phase input (shared port) (not used in this system)
P40 / TOOL0	Data I/O for debugger
P125 / RESET	System reset input
VSS	Ground potential of the port
VDD	Positive power supply of the port
REGC	Regulator output stabilization capacitance connection for internal operation

2.3.2 About Shared Ports

The RL78/G1F demo board switches the terminal function by means of a 0Ω resistor on the board circuitry.

Table 2.5 – Switching shared ports

Port number	Circuit short	Port function used	Function
P00	R9	ANI17 / IVCMP10	Midpoint voltage detection
	R12	TRGCLKA	Encoder A phase
P01	R14	ANI16 / IVCMP11	U-phase voltage detection
	R13	TRGCLKB	Encoder B phase

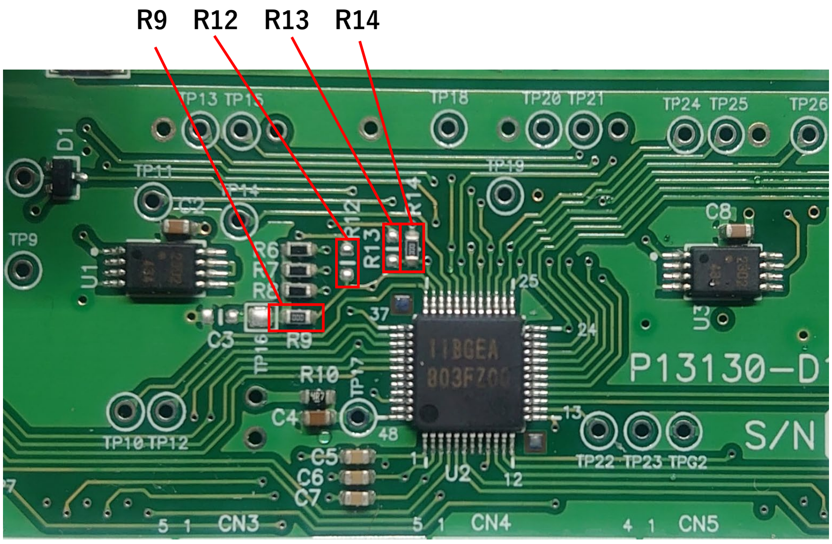


Figure 2-2 – Arrangement on the board - switching shared ports

2.3.3 Peripheral functions

Table 2.6 is a list of peripheral functions used in this system.

Table 2.6 – List of peripheral functions supported by sample programs

Peripheral functions	Purpose
10-bit A/D converter	• Inverter bus voltage measurement • Temperature sensor signal • DC link current detection
8-bit D/A converter	CMP0 comparison value
12-bit interval timer	200 ms cycle counter (LED, for rotation stop control)
Timer Array Unit (TAU)	• TAU02: Free-run counter for rotation speed measurement • TAU00: Delay timer for reversal
Timer RD (TRD)	Complementary PWM output
PWM option unit A (PWMOPA)	Forced cut-off of PWM output depending on CMP0 output
Programmable gain amplifier (PGA)	DC link current detection amplification
Comparator (CMP0)	Overcurrent detection
Comparator (CMP1)	Induced voltage zero-crossing detection
Serial array unit (SCIO)	Communicates with Renesas Motor Workbench
Data transfer controller (DTC)	
Standby function	MCU transitions to STOP mode when there is no operation for a certain period of time

(1) 10 bit A/D converter

The inverter bus voltage is rated using the 10-bit A/D converter.
The operation mode is set as below. - The channel selection mode: the select-mode - The conversion operation mode: the one-shot conversion mode - Trigger: Software trigger

(2) 8 bit A/D converter

Used as CMP0 comparison value. Current limit setting.

(3) 12-bit interval timer

Periodic control for LED flashing, spinning down, and STANDBY mode transition

(4) Timer Array Unit (TAU)

a. Free-running timer for rotational speed measurement
This channel 1 of TAU is used as a free-running counter for rotational speed calculation.

b. Delay timer for reversal
The channel 3 of TAU is used as a delay timer for changing the conducting pattern with π/6 phase from the zero-crossing point.

(5) Timer RD (TRD)

Three-phase PWM output of upper arm chopping is performed using the Complementary PWM Mode.

(6) PWM option unit A (PWMOPA)

Force the PWM output to be cut off from the overcurrent signal detected in CMP0.
After detecting the cause of the cut-off release (CMP0 falling edge), the forced cut-off of the output is released from the TRDIOC0 edge timing.

(7) Comparator (CMP0)

Detect overcurrent by comparing to the internal reference value.

(8) Comparator (CMP1)

Detect the zero-crossing of the induced voltage by comparing the phase voltage with the midpoint voltage.

(9) Serial array unit (SCI0)

Used to communicate with Renesas Motor Workbench.

(10) Data transfer controller (DTC)

To avoid overloading the CPU when communicating with Renesas Motor Workbench, a data copy is made to the send/receive memory region.

2.4 Software structure

2.4.1 Software file structure

The folder and file configurations of the sample programs Table 2.7 are given below.

Table 2.7 – Folder and File Configurations of the Sample Programs

Folder		File	Description
config		r_mtr_config.h	Common definition for software configuration
		r_mtr_motor_parameter.h	Configuration definition for motor parameters
		r_mtr_control_parameter.h	Configuration definition for control parameters
		r_mtr_inverter_parameter.h	Configuration definition for inverter parameters
application	main	main.h main.c	Main function
	ics	r_mtr_ics.h	RMW-related function definitions
		ics_RL78G1F.h	CPU definition for RMW
		RL78G1F_vector.c RL78G1F_vector.h	Interrupt vector function definition for RMW
		ics_RL78G1F.obj	Communication library for RMW
driver	auto_generation	cstart.asm hdwinit.asm iodefine.h stkinit.asm	Auto generation files
		r_mtr_ctrl_rl78g1f.h, r_mtr_ctrl_rl78g1f.c	Function definition for MCU control
middle		r_mtr_common.h	Common definition
		r_mtr_temp_table.h	NTC Thermistor Table

Note 1: Regarding the specification of the Analyzer function in the motor control development support tool 'Renesas Motor Workbench(RMW)', please refer to Chapter 4.
The identifier 'ics/ICS (ICS is the previous motor control development support tool, 'In Circuit Scope') is attached to the names of folders, files, functions, and variables related to 'Renesas Motor Workbench'.

2.5 Software specifications

Table 2.9 shows the basic specifications of the software discussed in this application note. For details on 120-degree conducting control, refer to the application note '120-degree conducting control of permanent magnet synchronous motor: algorithm'

Table 2.8 – Basic Specifications of Software

Item	Description
Control method	120-degree conducting method (chopping upper arm)
Motor rotation start/stop	• Determined by analog switch level • Operated by Renesas Motor Workbench motor control development support tool
Position detection of rotor magnetic pole	Position detection using induced voltage by comparator (every 60 degrees) • When the position of the rotor is detected, PWM duty and conducting pattern are set at same time.
Input voltage	DC 24 [V]
Main clock frequency	CPU clock: f_{CLK} 32[MHz] TRD clock: f_{HOCO} 64[MHz]
Carrier frequency (PWM)	20 [kHz]
Dead time	1.2 [μs] (during complementary PWM output)
Control cycle	Dependent on rotation speed in main loop
Rotation speed control range	20,000 [rpm]
Forced cut-off of PWM output	Forced cut-off reference value: Uses PGA and CMP0 for forced cut-off of the PWM output. If it falls below the reference value, the cut-off is released.
Compiler optimization settings	Default settings
Protective stop processing	• When one of the following conditions occurs, an error is generated and the motor control signal outputs (6 outputs) are deactivated 1. Inverter bus voltage exceeds 25.2 [V] 2. Inverter bus voltage falls below 19.8[V] 3. Zero-crossing detection has not occurred for a certain period of time 4. High temperature is detected by the temperature sensor

2.6 User option bytes

The settings of the user option byte area of the RL78/G1F flash memory are shown below.

Table 2.9 – User option byte settings

Setting	Address	value	Description
6E7BF8H	000C0H/010C0H	01101110B	Disable watchdog timer counter operation (stop count after reset)
	000C1H/010C1H	01110010B	LVD: interrupt & reset mode Rising edge: 2.92 V Falling edge: 2.86 V
	000C2H/010C2H	11111000B	HS mode, fHOCO: 64 MHz CPU clock fCLK: 32 MHz

3. Descriptions of the control program

The target sample programs of this application note are explained here.

3.1 Control overview

The purpose of the sample programs covered by this application note is to use the comparator integrated into the RL78/G1F for high-speed rotation control of the permanent magnet synchronous motor.
For fast rotation, it rotates the motor using a 120-degree conducting method with low computational processing that switches among six conducting patterns every 60 degrees. In addition, because the switching interval between these six patterns is tighter during high-speed rotation, the zero-crossing detection of the induced voltage is carried out by a built-in comparator, rather than by A/D, which would require conversion time.

Two built-in comparators are implemented. The first is connected to PGA output so it can be used for current limiting and forced cut-off. The second allows you to switch between 4 inputs for comparison. It can be used for motor phase detection by entering a 3-phase voltage and a 3-phase neutral voltage as a comparison value.

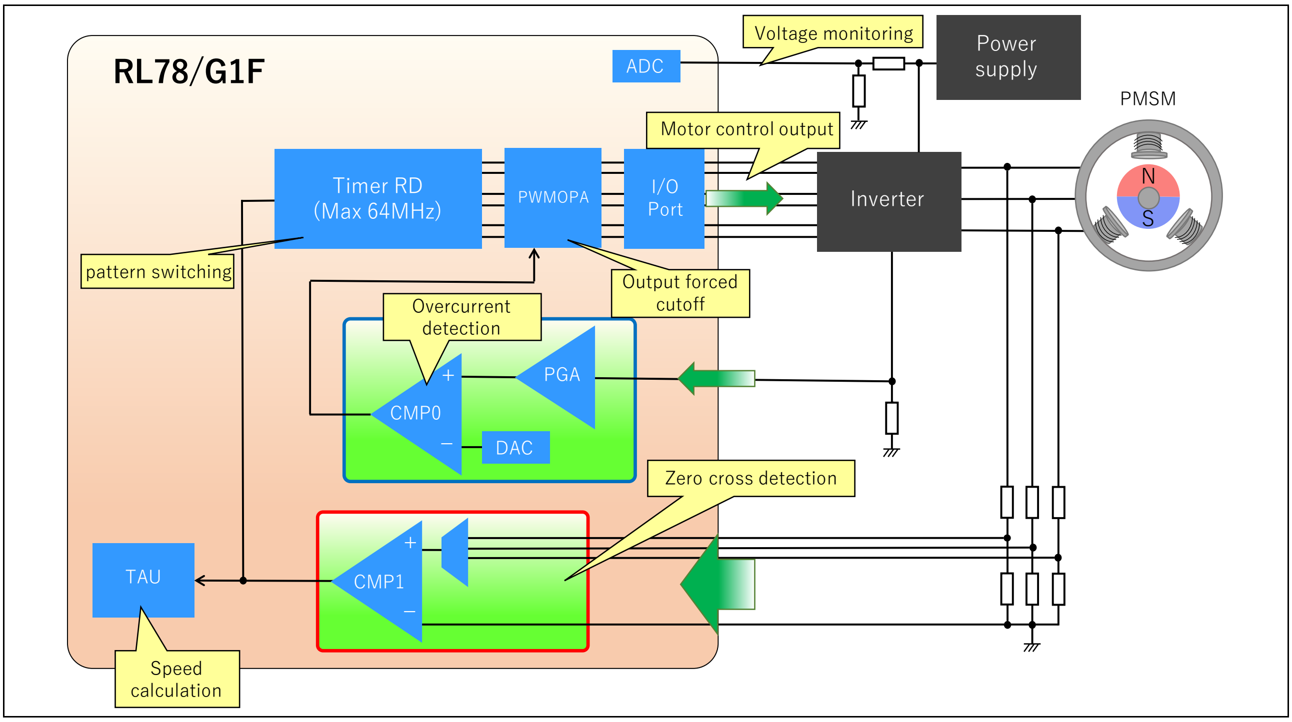


Figure 3-1 – Control system configuration

3.2 Peripheral function behavior

3.2.1 Motor start/stop

Motor start-up and shutdown are controlled by inputs from the motor control development support tool or external analog switches.

3.2.2 A/D Converter

(1) Inverter bus voltage

The inverter bus voltage is measured as shown below. It is used for modulation factor calculation and over/low voltage detection. (When an abnormality is detected, PWM is stopped).

Table 3.1 – Inverter Bus Voltage Conversion Ratio

Item	Conversion ratio (Inverter bus voltage: A/D conversion value)	Channel
Inverter bus voltage	0 [V] to111[V]：0000H to 03FFH	ANI7

[Note] For more information about A/D conversion, see “RL78/G1F User’s Manual – Hardware”.

(2) NTC thermistor temperature detection

Temperature detection is performed using the NTC thermistor.

Table 3.2 Temperature conversion ratio

Item	Conversion ratio (temperature: A/D conversion value)	Channel
temperature	-19[°C] to 100[°C]: 00H to 7FH	ANI19

Table 3.3 NTC thermistor temperature table

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19
1	-19	-19	-18	-17	-15	-14	-12	-11	-10	-9
2	-8	-7	-6	-5	-4	-3	-2	-1	-1	0
3	1	2	3	4	5	6	6	7	8	9
4	9	10	10	11	11	12	13	13	14	15
5	16	16	17	18	18	19	20	20	21	22
6	22	23	24	24	25	26	27	27	28	29
7	30	30	31	32	32	33	34	35	36	37
8	37	38	39	40	41	41	42	43	44	45
9	46	47	48	49	50	51	52	54	55	56
10	58	59	60	61	63	65	66	68	70	72
11	74	76	79	81	83	85	88	93	97	100
12	100	100	100	100	100	100	100	100		

The A/D of the RL78/G1F is 10-bit resolution, and we can calculate the temperature by using the first 7 bits of data of the A/D value. Which means:

Temp = Table [ADCR >> 9]

For example, when ADCR>>9 is 112, we can get the Temp value from row 11 and column 2. From the table above, we can see that the temperature that can be tested is between -20 and 100°C.

3.2.3 PGA (Programmable gain amplifier)

(1) DC link current detection

The PGA is used to detect the DC link current in the inverter circuit.

Table 3.4 – DC link current detection

Item	Description	Remarks
PGA gain selection	4x	Choose from 4/8/16/32x
GND selection	PGAGND	Vss or PGAGND

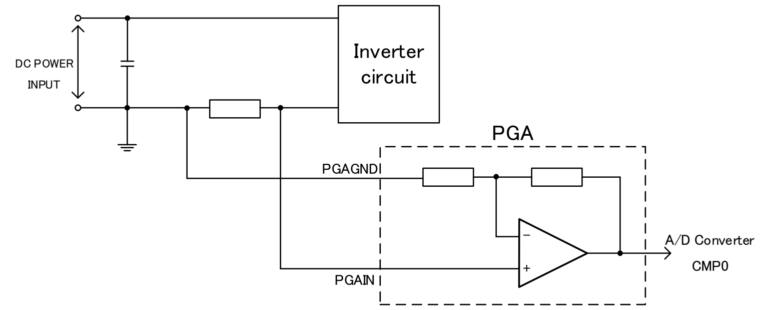


Figure 3-2 – Connecting the PGA to the inverter circuit

3.2.4 Comparator

(1) Overcurrent detection (CMP0)

The output of the PGA is compared with the reference value of the internal D/A converter to detect overcurrent.

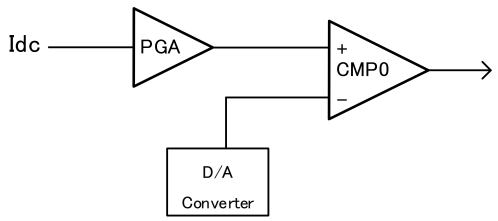


Figure 3-3 – Overcurrent detection by CMP0

(2) Induced voltage zero-crossing detection (CMP1)

Select neutral voltage Vn if CMP1 is '－' or the 3-phase induced voltage according to the conduction pattern if CMP1 is '+'.

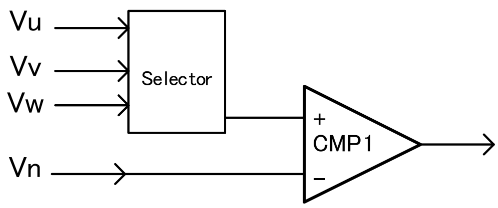


Figure 3-4 – Induced voltage zero-crossing detection by CMP1

Table 3.5 – Conducting patterns and selector selection patterns

Selector selection pattern	Conduction pattern	CMP1 '+' input
0	High: W Low: V	Vu
1	High: W Low: U	Vv
2	High: V Low: U	Vw
3	High: V Low: W	Vu
4	High: U Low: W	Vv
5	High: U Low: V	Vw

3.3 Voltage control by PWM

PWM control is used to control output voltage. The PWM control is a control method that continuously adjusts the average voltage by varying the pulse duty cycle, as shown in Figure 3-5.

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

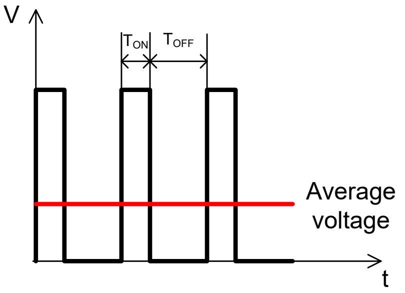


Figure 3-5 – PWM Control

Here, modulation factor “m” is defined as follows.

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

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

This modulation factor is set to resisters for PWM duty in TRD.

In the software discussed in this application note, upper arm chopping is used to control the output voltage and speed. Figure 3-6 and エラー! 参照元が見つかりません。 show an example of output waveforms at upper arm chopping.

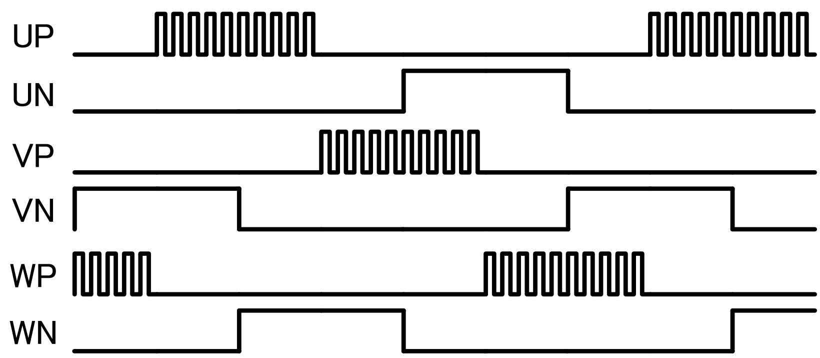


Figure 3-6 – Upper Arm Chopping (Non-complementary PWM)

3.4 State transitions

The state transition diagram of the system is shown below.

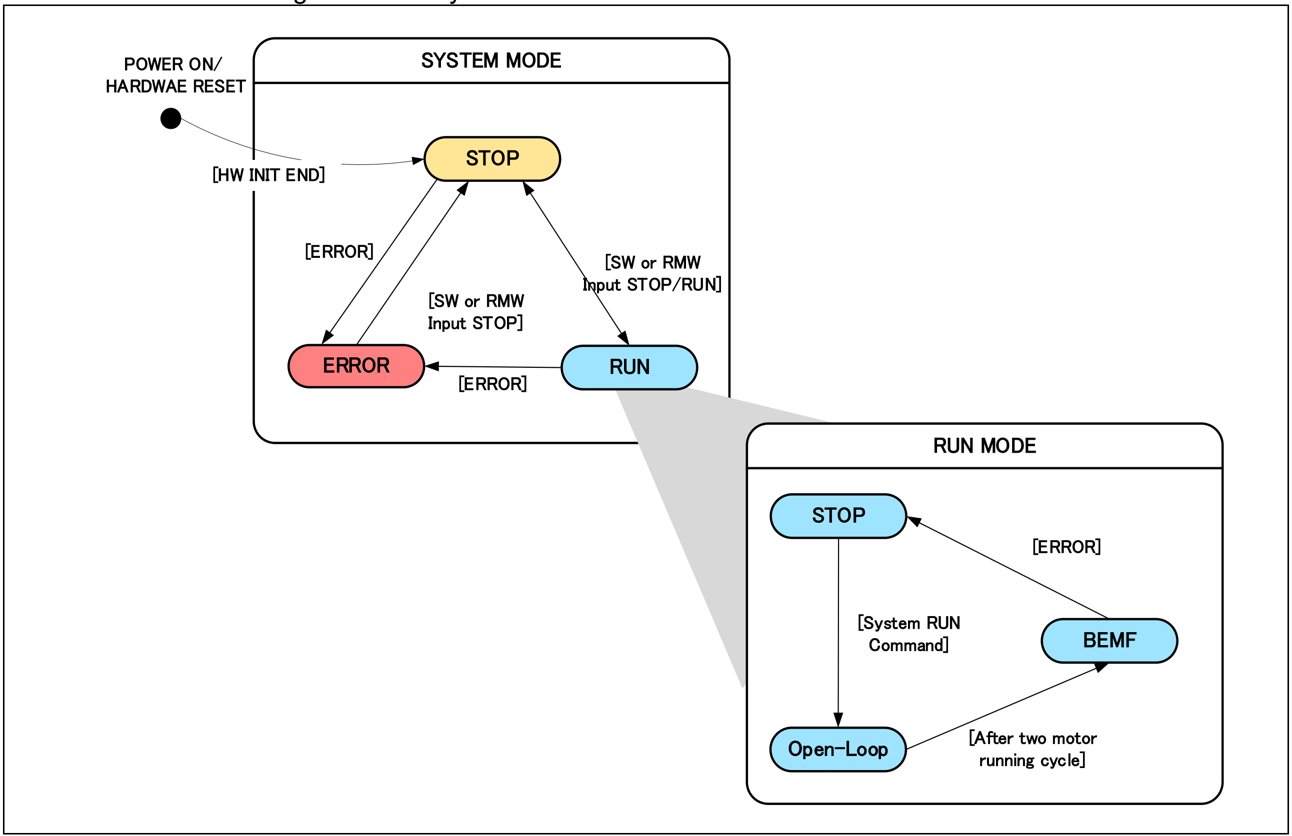


Figure 3-7 – State transition diagram

(1) SYSTEM MODE

"SYSTEM MODE" indicates the operating states of the system. State transitions are caused by input from RMW or SW, or the occurrence of an error.

(2) RUN MODE

"RUN MODE" indicates the condition of the motor control. It transitions depending on the running status of the motor.

In case of an error, it transitions to the STOP state.

3.5 Start-up method

Under BEMF-based control, the induced voltage due to the change in the magnetic flux of the permanent magnet (rotor) is used to detect the position of the magnetic pole every 60 degrees. However, because the magnitude of the induced voltage depends on the speed of rotation, the position of the magnetic pole cannot be detected if the speed of rotation is small.

Therefore, as the start-up method, we use the technique of generating and forcibly synchronizing the rotating magnetic field by forcibly changing the conduction pattern regardless of the position of the permanent magnet.

In an open loop, we accelerate the motor while holding the voltage constant and forcibly changing the conduction pattern for two cycles. Rotating continues until an induced voltage is generated that can be detected by the comparator. After that, it transitions to BEMF mode, where the comparator detects the position and changes the pattern. The conduction pattern on the RMW display is stuck at zero, but this is due to an problem updating the display variable. In fact, the six conduction patterns change according to the speed.

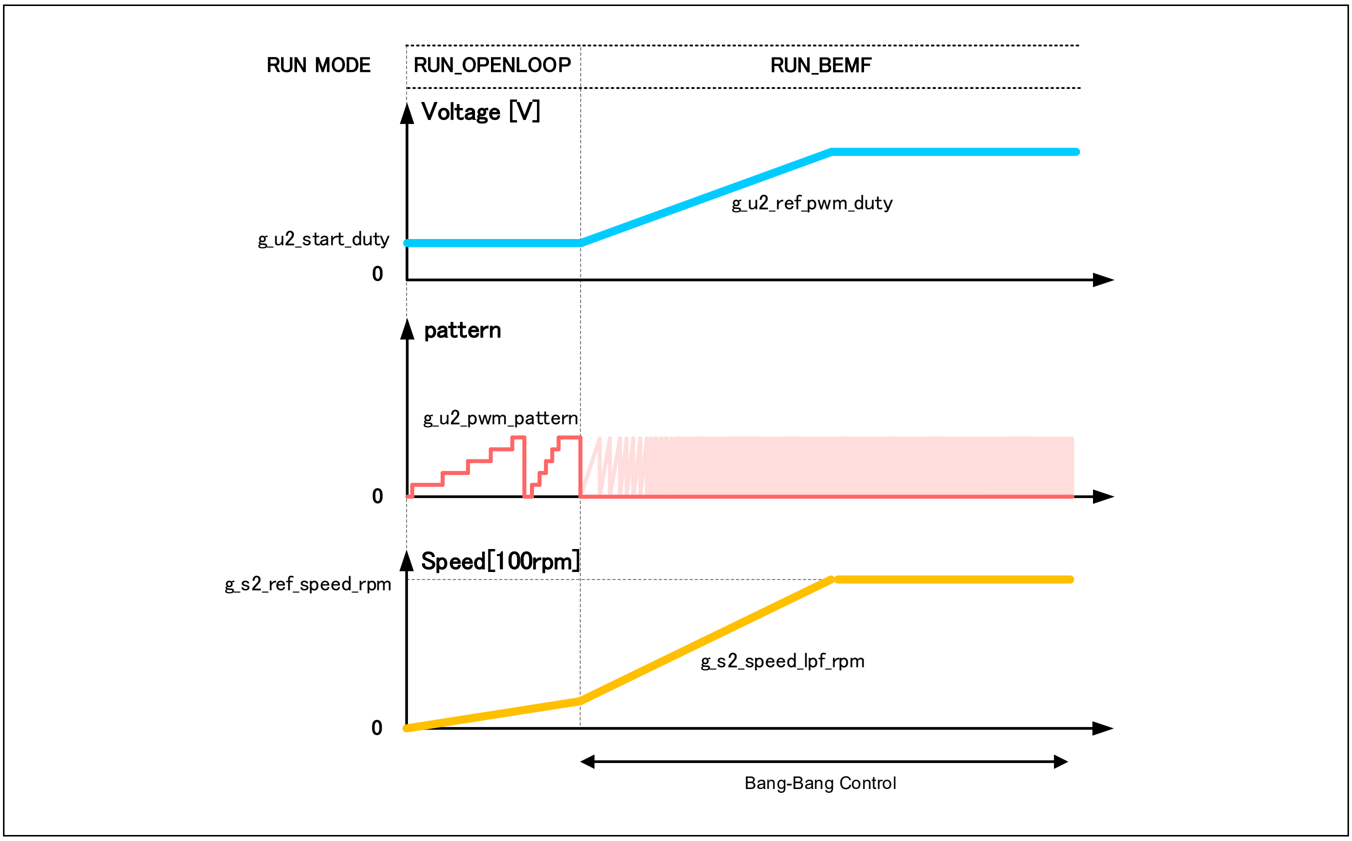


Figure 3-8 – Startup sequence

3.6 BEMF mode processing

When switching from open loop drive to BEMF drive, while the processing of each of the six patterns is changed in sequence, the conduction pattern is updated by zero-crossing detection by the comparator.

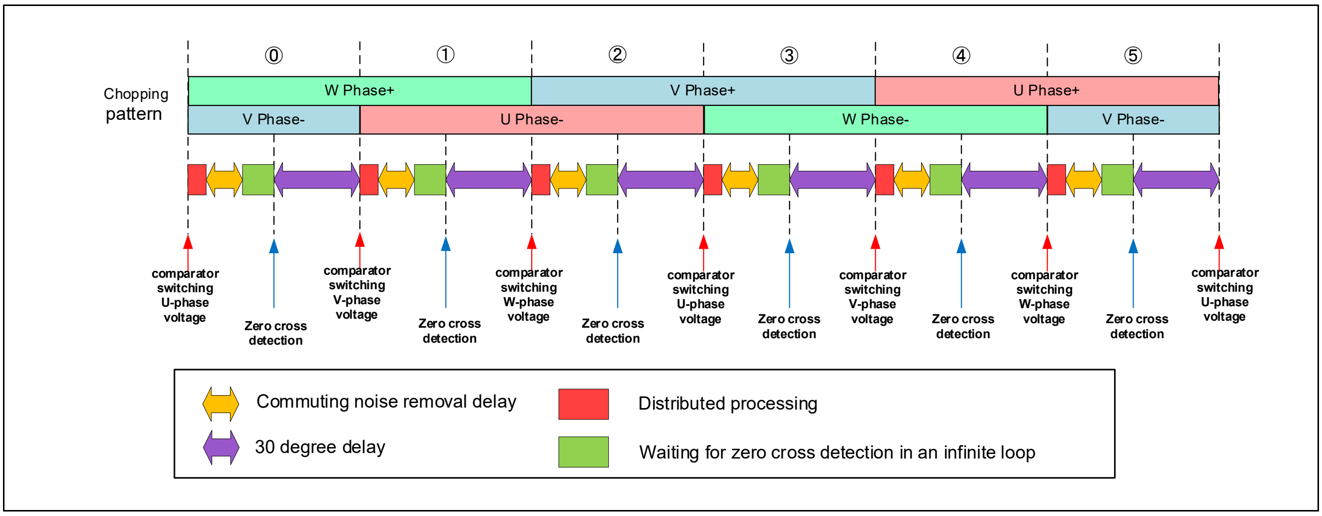


Figure 3-9 – Switching processing when in BEMF mode

Immediately after changing the conduction pattern (commutation), a delay process is added for masking to avoid false detection of zero crossing due to noise. During this time, processes such as speed control are distributed. Thereafter, it waits for zero-crossing detection in an infinite loop.

After zero-crossing detection, delay processing is performed to wait for the phase to advance by 30 degrees, and then the conduction pattern is changed.

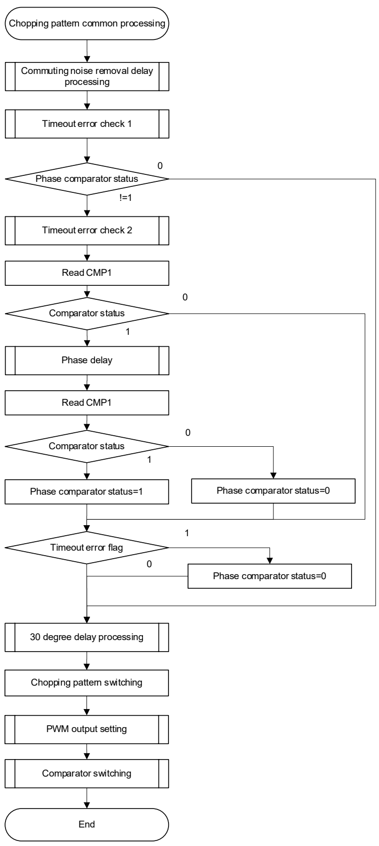
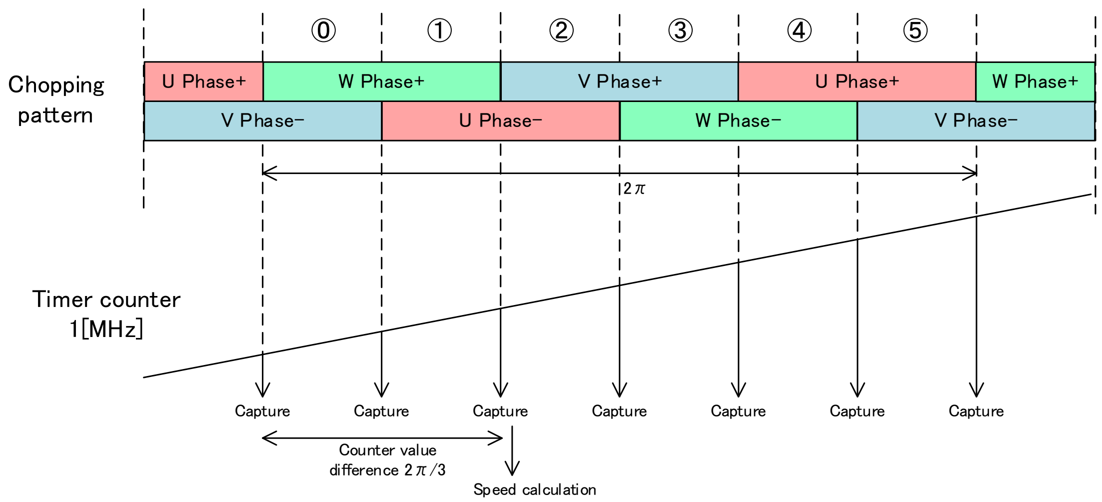


Figure 3-10 – Flowchart of common processing of conduction patterns excluding distributed processing

3.7 Speed control

This system uses a free-running timer for rotational speed measurement. After the run mode transitions to BEMF mode, the speed calculation is performed in step 2 of the six PWM patterns.

The counter values obtained in steps 0 and 1 give a counter value of 2π/3 minutes, from which the speed is calculated in units of 100 rpm. After calculating the speed, LPF processing is done. In order to reduce the processing time, the LPF gain is not held at a fixed point, and shift processing is used instead.



rotation speed[100rpm] = (60 × Timer count frequency 1[MHz])/(3*Counter value difference)/100
=20000/Counter value difference

Rotation speed for LPF[100rpm] += K_lpf * (rotation speed− previous rotation speed for LPF)
+= (rotation speed−previous rotation speed for LPF)>>(Shift value of K_lpf)
(K_lpf = 0.125 -> Shift value of K_lpf = 3)

Figure 3-11 – Method of Calculation for Rotational Speed

Speed control uses hysteresis control. The control cycle is performed in step 4 for each cycle of the conduction pattern. It is not a fixed cycle.

To update the PWM Duty, the value obtained by dividing the control gain Ka by the LPF rotation speed Speed_lpf is added to Duty as the operation amount. Ka is a tuning parameter.

$$\mathrm{Duty(n)} = \begin{cases} \mathrm{Duty(n-1) + Ka/Speed\_lpf} & \mathrm{(Speed\_error\_i > Error\_band)} \\ \mathrm{Duty(n-1) - Ka/Speed\_lpf} & \mathrm{(Speed\_error\_i < -Error\_band)} \end{cases}$$

In hysteresis control, the integral value speed_error_i of the speed deviation is calculated, and if it exceeds a certain range, it is added to Duty. If the deviation becomes large on the + side of the speed deviation band Error-band, the manipulated variable is added to Duty. If the deviation becomes large on the - side of Error-band, the manipulated variable is subtracted from Duty. Error-band is also a tuning parameter.

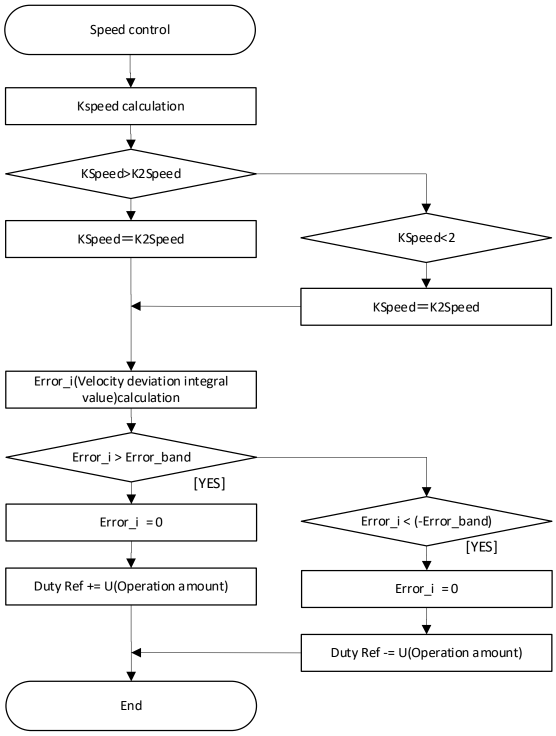


Figure 3-12 – Speed control processing

3.8 High speed stop

Shifting from high-speed rotation to stop mode takes time due to inertia, etc. This means it may take some time before the next start. To decelerate the motor in a short time, after shifting to stop mode, all the low-arms of the inverter are turned on to short the 3 phases of the motor, and then the stop processing is implemented.

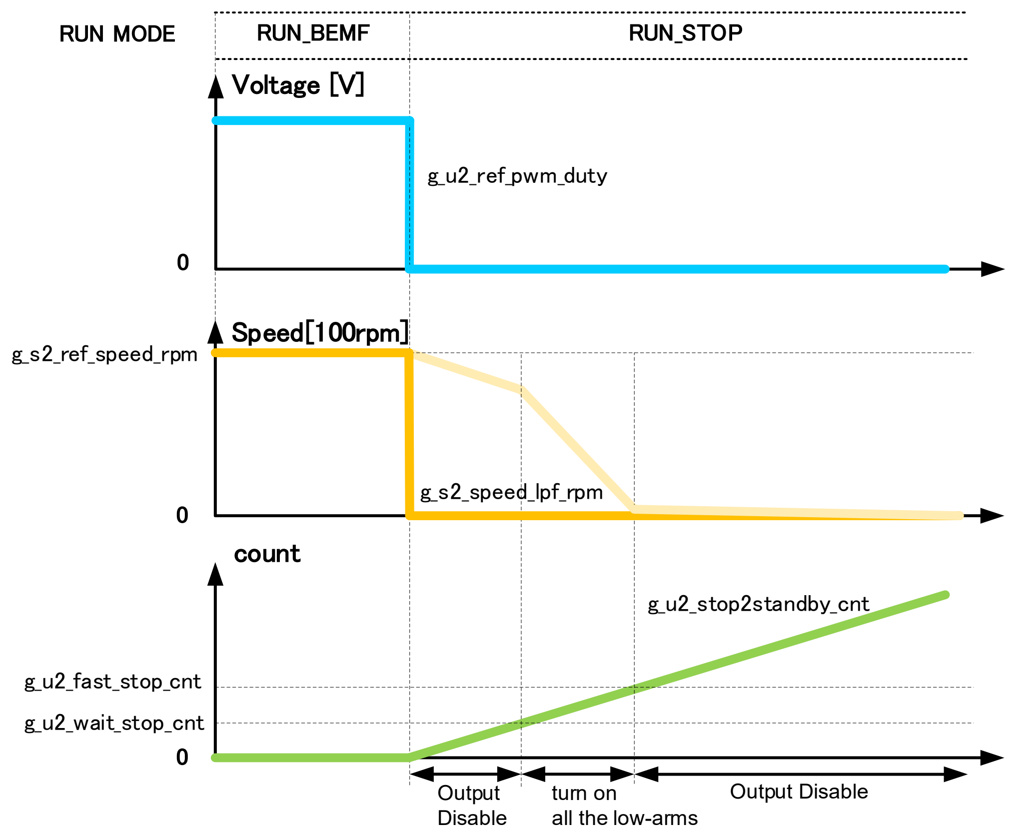


Figure 3-13 – Stop sequence

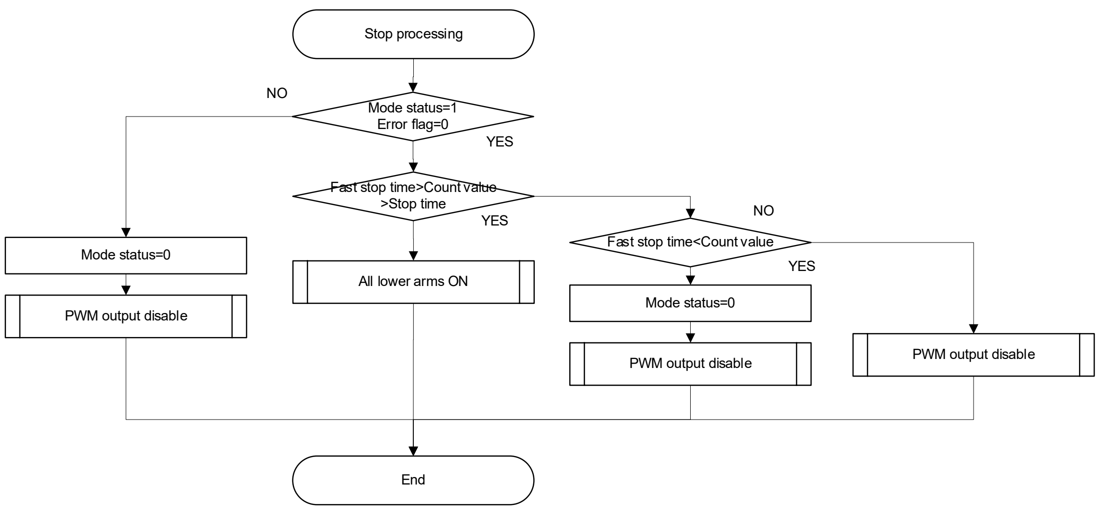


Figure 3-14 – Stop process flowchart

3.9 PWM output forced cut-off (upper and lower arm low-level output)

In this system, the DC link current is amplified from both ends of the shunt by the built-in PGA. When the built-in comparator exceeds the D/A converter reference value, the PWMOPA function forcibly cuts off the timer RD output.

This suppresses the flow of excessive current in an instant. When the current flowing through the shunt falls below the reference value,

the cutoff is released at the timing of the next peak-valley after the carrier signal set by the timer RD.

The state at the time of cut-off is configurable, and both the upper and lower arms are set to low level output.

[Note] The PWMOPA cutoff release is done by TRDIOC0 edge detection.
TRDIOC0 output setting is done by the TRDIOC1 register, so the corresponding P16 can be used for input setting. However, note that if output is set, the peak-valley toggle signal will be output at the carrier cycle of timer RD.

3.10 System protection stop function

This system has the following types of error status and emergency stop functions in case any of the listed errors occur. Refer to Table 3.7 for settings related to the system protection function .

- Overvoltage error

The inverter bus voltage is monitored at the overvoltage monitoring cycle. When the inverter bus voltage exceeds the overvoltage limit, voltage output is stopped. The threshold value of the overvoltage is set in consideration of the error of resistance value of the detection circuit.

- Low voltage error

The inverter bus voltage is monitored at the low voltage monitoring cycle. When the inverter bus voltage lowers the undervoltage limit, voltage output is stopped. The low voltage threshold value is set in consideration of the error of resistance value of the detection circuit.

- Timeout error

The timeout counter is monitored at the timeout monitoring cycle, and if the induced voltage zero crossing does not occur for a certain period of time, the voltage output is stopped.

- Temperature error

The temperature is monitored, and if it exceeds the temperature limit value, voltage output is stopped.

Table 3.6 – Setting Value of Each System Protection Function

Error	Threshold	
Overvoltage error	Overvoltage limit [V]	28
Undervoltage error	Low voltage limit [V]	15
Timeout error	Zero crossing not detected	—
Temperature error	Temperature limit value [°C]	65

3.11 LED display (external switchboard)

This section describes the LED display specifications.

Table 3.7 – LED display status and conditions

LED status	Condition
Steady green	System is in STOP mode
Flashing green: every 1 second	Low battery voltage
Flashing green: every 0.4 second	Motor running
Flashing red	Error occurred

When an error occurs, the red LED flashes every 0.4 seconds (ON/OFF = 0.2 seconds). The number of times the LED flashes red indicates the error number.

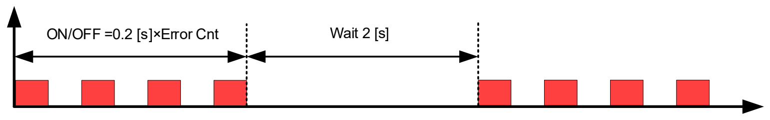


Figure 3-15 – Stop sequence

Table 3.8 – Number of flashes for each error

Error	Number of flashes
Overvoltage error	1
Undervoltage error	2
Timeout error	4
Temperature error	8

3.12 Control flows (flow charts)

3.12.1 Main process

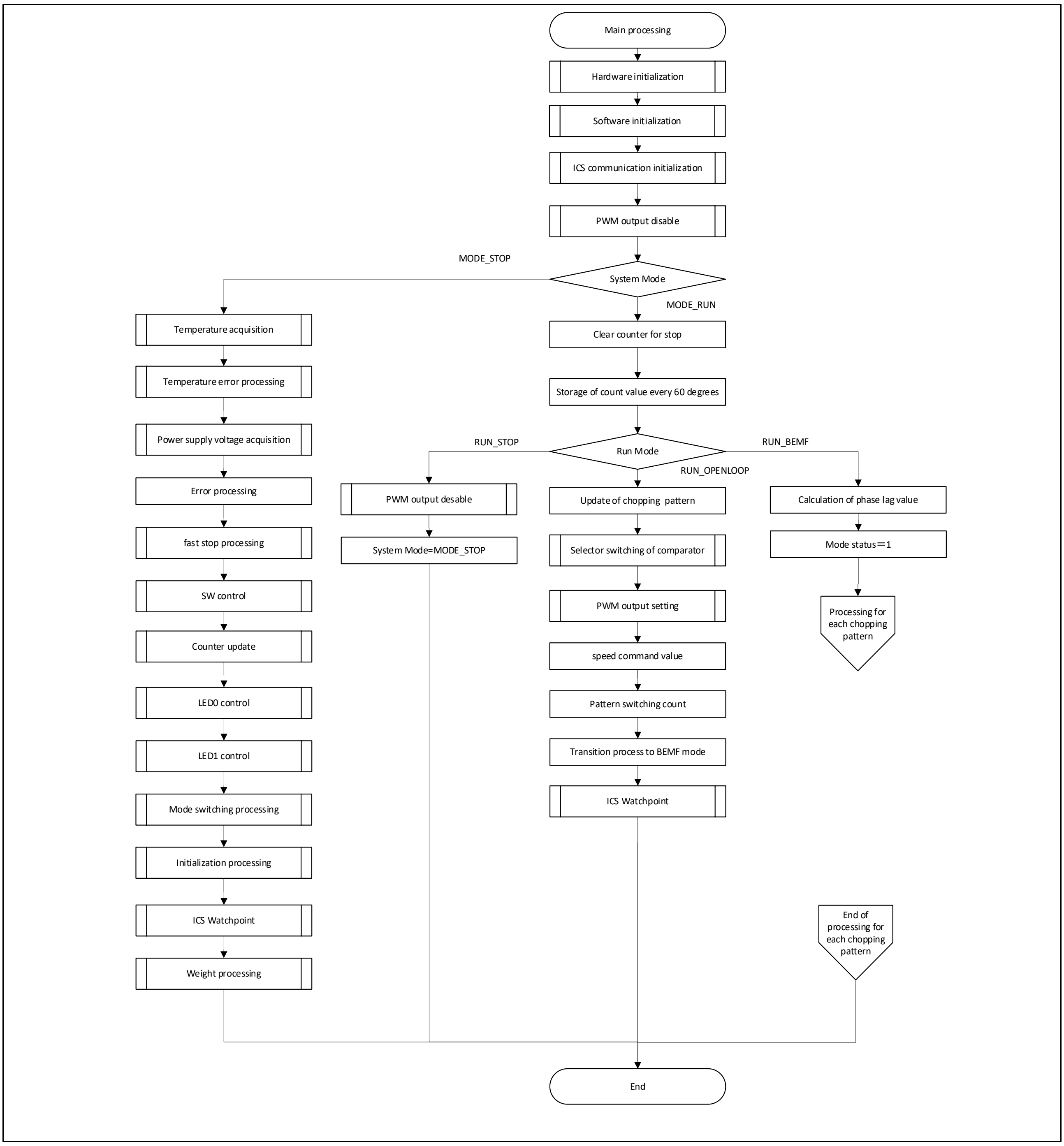


Figure 3-16 – Main Process Flowchart

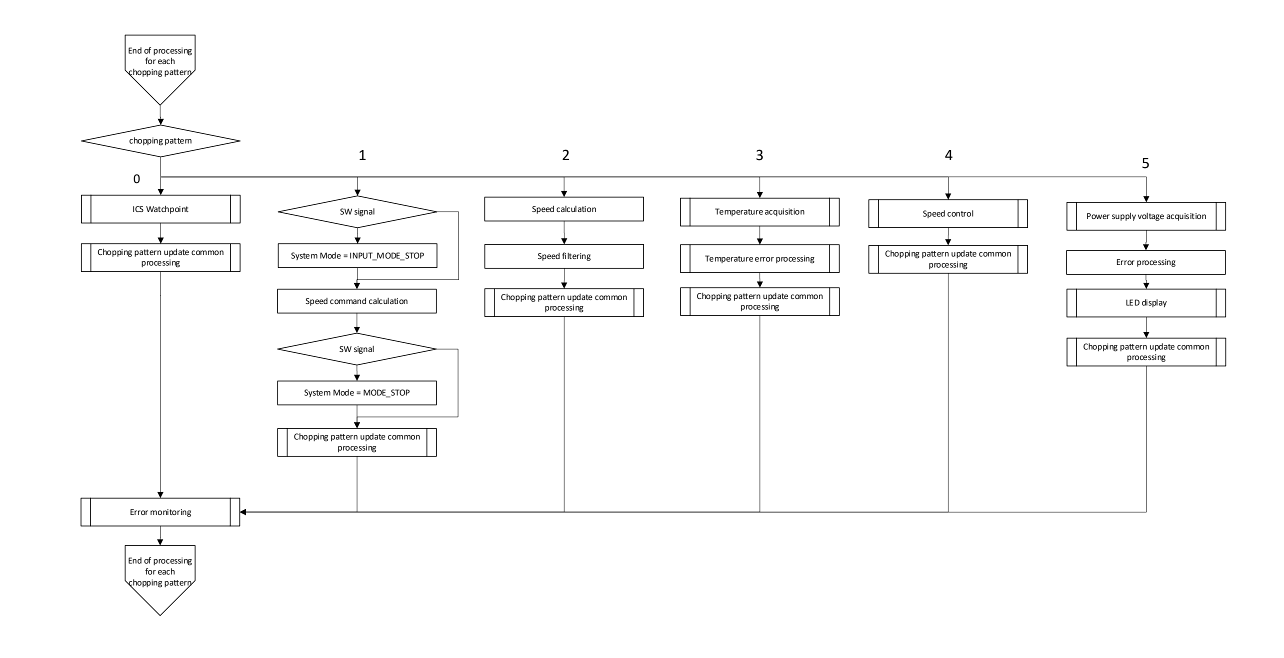


Figure 3-17 – Flow chart of processing for each conduction pattern

3.13 Function specifications of 120-degree conducting control software

Lists of functions used in this control program are shown below. Functions not used in this system are not described.

Table 3.9 – List of Functions in “main.c” (1/2)

File name	Function name	Processing overview
main.c	main argument: none return: none	Initialization and main loop ・initialization ⇒initialization of hardware ⇒initialization of variables ⇒initialization of ICS communication ⇒PWM output prohibited ・main loop ⇒motor system control
	mtr_display_led1 argument: uint16_t u2_system_mode / system mode return: none	LED1 control
	mtr_display_led2 argument: uint16_t u2_err_flag / error status return: none	LED2 control
	mtr_temp_error argument: int16_t s2_temp / temperature (temperature table value) return: uint16_t u2_flag	Temperature error processing
	mtr_time_increase_bemf argument: none return: none	Counter processing for LED control (during motor control)
	mtr_time_increase argument: none return: none	Counter processing for LED control (during stop)
	mtr_timeouterror_step1 argument: none return: none	Timeout error processing 1 (obtain count value)
	mtr_timeouterror_step2 argument: none return: none	Timeout error processing 2 (error detection)
	mtr_error_stop argument: none return: none	Error processing ・ Transition to STOP mode

Table 3.10 – List of Functions in "main.c" (2/2)

File name	Function name	Processing overview
main.c	mtr_tau00_delay argument: uint16_t u2_delayValue / delay count value return: none	Delay processing
	mtr_cmp1_change argument: int16_t s2_ch / conduction pattern return: none	Switch CMP1 input setting
	mtr_inv_output_120 argument: int16_t s2_ch / conduction pattern int16_t s2_duty / duty setting value return: none	Conduction pattern and duty setting and PWM output
	mtr_stop_init argument: none return: none	Initialization when stopped
	mtr_software_init argument: none return: none	Initialization

Table 3.11 – List of Functions in "ics_RL78G1F.obj"

File name	Function name	Processing overview
main.c	ics2_init argument: unsigned int addr / DTC vector table start address char pin / Pins used by SCI char level / Interrupt level char num / Top address of DTC structure char brr / communication speed char mode / Communication mode return: none	Communication initialization
	ics2_watchpoint argument: none return: none	Call transfer function Must be called at intervals of 250us or more.

Table 3.12 – List of functions in “r_mtr_ctrl_rl78g1f.c” (1/2)

File	function	Processing overview
r_mtr_ctrl_rl78g1f.c	R_MTR_InitHardware argument: none return: none	Initialization of peripheral functions
	mtr_init_ui argument: none return: none	Initialization of ports to be used by UI
	mtr_init_clock argument: none return: none	Initialization of clock
	mtr_init_12intt argument: none return: none	Initialization of 12-bit interval timer
	mtr_init_tau argument: none return: none	Initialization of timer array unit (TAU)
	mtr_init_trd argument: none return: none	Initialization of timer RD (TRD)
	mtr_init_pwmopa argument: none return: none	Initialization of PWMOPA
	mtr_init_pga argument: none return: none	Initialization of programmable gain amplifier (PGA)
	mtr_init_cmp argument: none return: none	Initialization of comparators (CMP0, CMP1)
	mtr_init_ad_converter argument: none return: none	Initialization of A/D converter
	R_MTR_get_adc argument: (uint8_t) u1_ad_ch / channel of A/D conversion return: (int16_t) s2_ad_value / result of A/D conversion	Get the result of A/D conversion
	R_MTR_SelCmp1Ch argument: int16_t u1_cmp1_ch / select comparatorch return: none	Select CMP1 input channel
	R_MTR_InvOutLow argument: none return: none	Output with all low-arms turned ON
	R_MTR_InvOutDisable argument: none return: none	Stop PWM output
	R_MTR_InvOutUV argument: uint16_t u2_pwm_duty / duty setting value return: none	UV phase conduction
	R_MTR_InvOutUW argument: uint16_t u2_pwm_duty / duty setting value return: none	UW phase conduction

Table 3.13 – List of functions in “r_mtr_ctrl_rl78g1f.c” (2/2)

File	function	Processing overview
r_mtr_ctrl_rl78g1f.c	R_MTR_InvOutVW argument: uint16_t u2_pwm_duty / duty setting value return: none	VW phase conduction
	R_MTR_InvOutVU argument: uint16_t u2_pwm_duty / duty setting value return: none	VU phase conduction
	R_MTR_InvOutWU argument: uint16_t u2_pwm_duty / duty setting value return: none	WU phase conduction
	R_MTR_InvOutWV argument: uint16_t u2_pwm_duty / duty setting value return: none	WV phase conduction

Table 3.14 – List of functions in "r_mtr_ctrl_rl78g1f.h"

File	function	Processing overview
r_mtr_ctrl_rl78g1f.h	R_MTR_StartTRD argument: none return: none	Start count of timer RD
	R_MTR_StartTRD argument: none return: none	Stop count of timer RD
	R_MTR_StartTAU02 argument: none return: none	Start count of TAU02
	R_MTR_StopTAU02 argument: none return: none	Stop count of TAU02
	R_MTR_StartTAU00 argument: none return: none	Start count of TAU00
	R_MTR_StopTAU00 argument: none return: none	Stop count of TAU00
	R_MTR_ClearIFTAU00 argument: none return: none	Clear TAU00 interrupt flag

3.14 Lists of variables of sensorless 120-degree conducting control software

Lists of the variables used in this control program are provided below. However, note that the local variables are not mentioned.

Table 3.15 – List of variables in “main.c”

variable	type	content	Remarks
g_u2_system_mode	uint16_t	Variable for system mode management	0: SYSTEM_STOP 1: SYSTEM_RUN
g_u2_run_mode	uint16_t	Variable for run mode management	0: RUN_OPENLOOP 1: RUN_BEMF 2: RUN_STOP
g_u2_input_mode	uint16_t	Variable for input mode management	0: INPUT_MODE_STOP 1: INPUT_MODE_RUN
g_u2_system_status	uint16_t	System status	0: SYSTEM_STOP 1: SYSTEM_RUN
g_u2_err_status	uint16_t	Error status	0x00: ERROR_NONE 0x01: ERROR_VDC_LOW 0x02: ERROR_VDC_HIGH 0x04: ERROR_STEP_OUT 0x08: ERROR_TEMP
g_u2_current_limit	uint16_t	Current limit value	[A]
g_u2_tau02_cnt	uint16_t	PWM output time counter	–
g_u2_pre_tau02_cnt	uint16_t	PWM output time counter previous value	–
g_u2_cnt_err	uint16_t	PWM output time counter deviation	–
g_u2_cnt_err_buf [6]	uint16_t	PWM output time counter deviation buffer	–
g_u2_pwm_pattern	uint16_t	PWM output conduction phase	–
g_u2_ref_pwm_duty	uint16_t	PWM output reference value	–
g_u2_start_duty	uint16_t	Startup duty	–
g_u2_cmp1_status	uint16_t	CMP1 detection status	–
g_u2_vu_flag	uint16_t	U-phase voltage status flag	–
g_u2_vv_flag	uint16_t	V-phase voltage status flag	–
g_u2_vw_flag	uint16_t	W-phase voltage status flag	–
g_u2_delay_cnt_buf1	uint16_t	Temporary storage variable for calculating Delay	–
g_u2_delay_cnt_buf2	uint16_t	Temporary storage variable for calculating Delay	–
g_u2_delay30_cnt	uint16_t	Stores the 30-degree delay	–
g_u2_delay_noise_cnt	uint16_t	Stores the delay for pattern change noise rejection	–
g_s2_lead_cnt	uint16_t	Sets the Delay offset	–
g_s2_delay_temp	uint16_t	Delay temporary variable	—
g_u2_cmp1_skip_cnt	uint16_t	CMP1 zero-crossing detection filter value	–
g_u2_ol_loop_cnt	uint16_t	Loop count during open-loop drive	–
g_u2_ol_speed_cnt	uint16_t	Speed management count during open-loop drive	–
g_u2_ol_start_speed_cnt	uint16_t	Initial value of speed management count during open-loop drive	–

Table 3.16 – List of variables in “main.c”

variable	type	content	Remarks
g_u2_ol2bemf_speed_cnt	uint16_t	Change speed count value from open loop	–
g_u2_ol2bemf_loop_cnt	uint16_t	Change loop count value from open loop	–
g_u2_ol_speed_rate_cnt	uint16_t	Rate of change in speed count value	–
g_s2_speed_rpm	uint16_t	Speed	(Electric angle) [100 rpm]
g_s2_speed_lpf_rpm	uint16_t	Low pass filter speed	(Electric angle) [100 rpm]
g_s2_ref_speed_rpm	uint16_t	Reference rotational speed	(Electric angle) [100 rpm]
g_s2_std_speed_rpm	uint16_t	Standard mode speed	(Mechanical angle) [100 rpm]
g_u2_st_timeout_cnt	uint16_t	Stores the count for timeout detection For storing the value at the start of processing	–
g_u2_ed_timeout_cnt	uint16_t	Stores the count for timeout detection For waiting for zero-crossing detection	–
g_u2_timeout_err_flag	uint16_t	Timeout error flag	–
g_u2_vdc_ad	uint16_t	Power supply voltage A/D conversion value	–
g_s2_sensor0_temp	int16_t	Temperature detected by temperature sensor	[°C]
g_s2_spd_err_i	int16_t	Integral value for speed control	–
g_s2_spd_err_limit_band	int16_t	Duty update bandwidth for speed control	–
g_u2_spd_out	uint16_t	Output for speed control	–
g_u2_spd_out_max	uint16_t	Maximum output for speed control	–
g_u2_spd_out_min	uint16_t	Minimum output for speed control	–
g_u2_spd_ka	uint16_t	Speed control gain	–
g_u2_fast_stop_cnt	uint16_t	Counter for stop processing	–
g_u2_wait_stop_cnt	uint16_t	Counter for stop processing	–
g_u2_cnt	uint16_t	Counter for stop processing	–
g_s2_led1_disp_cnt	int16_t	Counter for LED1 display	–
g_s2_led2_disp_cnt	int16_t	Counter for LED2 display	–
g_s2_pre_led2_disp_cnt	int16_t	Previous value of counter for LED2 display	–

3.15 Macro definitions of sensorless 120-degree conducting control software

Lists of the macro definitions used in this control program are provided below.

Table 3.17 – List of macro definitions in “r_mtr_config.h”

Macro	Definition value	content	Remarks
RL78_G1F_GB	-	Select CPU board	–
IP_GB	-	Select inverter board	–
MP_Nidec_11F108P131	-	Select motor parameters	–
CP_Nidec_11F108P131	-	Select control parameters	–

Table 3.18 – List of macro definitions in “r_mtr_motor_parameter.h”

Macro	Definition value	content	Remarks
MP_POLE_PAIRS	4	Number of pole pairs	–
MP_RESISTANCE	0.4f	Resistance	[Ω]
MP_D_INDUCTANCE	0.000023f	d-axis inductance	[H]
MP_Q_INDUCTANCE	0.000023f	q-axis inductance	[H]
MP_MAGNETIC_FLUX	0.0026f	Induced voltage constant	[V s/rad]
MP_NOMINAL_CURRENT_RMS	1.2f	Rated current	[A]

Table 3.19 – List of Macro definitions “r_mtr_inverter_parameter.h”

Macro	Definition value	content	Remarks
IP_DEADTIME	1.2f	Dead time	[s]
IP_VDC_RANGE	111.0f	Range of bus voltage	[V]
IP_CURRENT_LIMIT	5.0f	Current limit	[A]
IP_OVERVOLTAGE_LIMIT	50.0f	Maximum limit for voltage	[V]
IP_UNDERVOLTAGE_LIMIT	12.0f	Minimum limit for voltage	[V]
IP_SHUNT_RESISTANCE	0.1f	Shunt resistor value	[Ω]
IP_AMP_GAIN	4	PGA gain	Multiplying factor

Table 3.20 – List of Macro definitions “r_mtr_control_parameter.h”

Macro	Definition value	content	Remarks
CP_SPEED_STANDARD	200	Standard mode speed	(Mechanical angle) [100 rpm]
CP_OL_START_SPEED_CNT	40000	Start speed count value	–
CP_OL_CHANGE_SPEED_CNT	20000	Change speed count value	–
CP_OL_CHANGE_PATTERN_CNT	4	Change loop count value	–
CP_OL_PWM_DUTY	300	Open loop Duty	–
CP_DELAY_CNT_MIN	2	Delay count minimum value	–
CP_LEAD_CNT	-10	Delay count offset value	–
CP_CMP1_SKIP_CNT	7	CMP1 signal filter value	–
CP_GAIN_KA	200	Control gain	–
CP_GAIN_OUT_MAX	120	Maximum output	–
CP_GAIN_OUT_MIN	1	Minimum output	–
CP_ERR_LIMIT_BAND	2000	Duty update control band	–

Table 3.21 – List of macro definitions in “r_mtr_ics.h”

Macro	Definition value	content	Remarks
ICS_ADDR	0xFE00	DTC vector table start address	–
ICS_INT_LEVEL	2	Interrupt level	–
ICS_NUM	0x40	Top address of DTC structure	–
ICS_BRR	15	Communication speed	–
ICS_INT_MODE	0	Communication mode	–

Table 3.22 – List of macro definitions in "main.h"

Macro	Definition value	content	Remarks
SYSTEM_STOP	0	System mode: stop	–
SYSTEM_RUN	1	System mode: drive	–
SYSTEM_ERROR	2	System mode: error	–
RUN_OPENLOOP	0	Run mode: open loop	–
RUN_BEMF	1	Run mode: BEMF	–
RUN_STOP	2	Run mode: stop	–
INPUT_MODE_STOP	0	Input mode: stop	–
INPUT_MODE_RUN	1	Input mode: standard drive	–
ERROR_NONE	0x00	Error mode: no error	–
ERROR_VDC_LOW	0x01	Error mode: voltage drop	–
ERROR_VDC_HIGH	0x02	Error mode: voltage elevation	–
ERROR_STEP_OUT	0x04	Error mode: no location information detected	–
ERROR_TEMP	0x0	Error mode: temperature	–
VDC_HIGH	(uint16_t) ((25.2/IP_VDC_RANGE) *1024)	Over voltage	–
VDC_LOW	(uint16_t) ((19.8/IP_VDC_RANGE) *1024)	Under voltage	–
LED1_TIME_SETTING	10	LED off time in the event of an error	*0.2 sec
TIME_FAST_STOP	10	Lower arm ON time	*0.2 sec
TIME_WAIT_STOP	5	All OFF time	*0.2 sec
TEMP_ERROR	65	Temperature error value	–
LED0_TIME_MED	2	LED0 flashing time	*0.2 sec

Table 3.23 – List of macro definitions in "r_mtr_ics.h"

Macro	Definition value	content	Remarks
ICS_ADDR	0xFE00	System mode: stop	–
ICS_INT_LEVEL	2	System mode: drive	–
ICS_NUM	0x40	System mode: error	–
ICS_BRR	15	Run mode: open loop	–
ICS_INT_MODE	0	Run mode: BEMF	–

Table 3. 24 – List of macros in “r_mtr_ctrl_rl78g1f.h” (1/2)

Macro	Definition value	content
MTR_INTVAL_TIMER_FREQ	32.0f	32 [MHz] system clock
MTR_PWM_TIMER_FREQ	64.0f	64 [Mhz] PWM timer frequency
MTR_TAU0_SETTING	50000	TAU0 period count value
MTR_TAU0_SETTING_M1000	48999	49000 count
MTR_TAU0_SETTING_P1000	1000	1000 count
MTR_CARRIER_FREQ	20.0f	20 [kHz] carrier frequency
MTR_CARRIER_CNT	(uint16_t)(MTR_PWM_TIMER_FREQ * 1000 / MTR_CARRIER_FREQ * 0.5f)	Timer RD peak count value
MTR_HALF_CARRIER_CNT	(uint16_t)(MTR_CARRIER_CNT * 0.5f)	Timer RD half count value
MTR_PORT_UP	P1_bit.no5	U phase (positive phase) output port
MTR_PORT_UN	P1_bit.no4	U phase (negative phase) output port
MTR_PORT_VP	P1_bit.no3	V phase (positive phase) output port
MTR_PORT_VN	P1_bit.no1	V phase (negative phase) output port
MTR_PORT_WP	P1_bit.no2	W phase (positive phase) output port
MTR_PORT_WN	P1_bit.no0	W phase (negative phase) output port
MTR_POTR_ENC_A	P0_bit.no0	Encoder A phase
MTR_POTR_ENC_B	P0_bit.no1	Encoder B phase
MTR_PORT_ENC_Z	P5_bit.no0	Encoder Z phase
MTR_PORT_HALL_U	P5_bit.no2	U phase Hall effect sensor input port
MTR_PORT_HALL_V	P5_bit.no3	V phase Hall effect sensor input port
MTR_PORT_HALL_W	P5_bit.no4	W phase Hall effect sensor input port
MTR_PORT_LED1	P6_bit.no3	LED1 output port
MTR_PORT_LED2	P7_bit.no4	LED2 output port
MTR_PORT_SW1	P12_bit.no3	SW1 input port
MTR_PORT_SW2	P12_bit.no4	SW2 input port
MTR_ADCCH_IU	4	Iu
MTR_ADCCH_IV	5	Iv
MTR_ADCCH_IW	6	Iw
MTR_ADCCH_VDC	7	Vdc
MTR_ADCCH_VN	17	Vn
MTR_ADCCH_VU	16	Vu
MTR_ADCCH_VV	0	Vv
MTR_ADCCH_VW	1	Vw
MTR_ADCCH_AIN0	18	Analog IN0
MTR_ADCCH_AIN1	19	Analog IN1
MTR_ADCCH_IDC	25	Idc (PGA)
MTR_ADC_DATA_SHIFT	6	A/D conversion data shift amount
MTR_CMP0_CALC_BASE	255/5	For CMP0 conversion 8-bit/5 V
MTR_SPEED_CALC_BASE	200000	Base amount for speed calculation

Table 3.25 – List of macros in “r_mtr_ctrl_rl78g1f.h” (2/2)

Macro	Definition value	content
CMP1_SEL_VU	1	CMP1 comparison value selection Vu
CMP1_SEL_VV	2	CMP1 comparison value selection Vv
CMP1_SEL_VW	3	CMP1 comparison value selection Vw
CMP1_READ	C1MON	CMP1 monitor flag
TAU02_COUNT	TCR02	TAU02 count value
COMP_INT_REF	C0RVM	CMP1 comparison value setting
INREVAL_TIMER_INTRRUPT_REQ_FLAG	ITIF	Interval timer interrupt flag
TAU00_TIMER_INTRRUPT_REQ_FLAG	TMIF00	TAU00 interrupt flag
TAU00_TIMER_DATA	TDR00	TAU00 timer data register setting

4. How to Run the Demo System

4.1 Connection Configuration

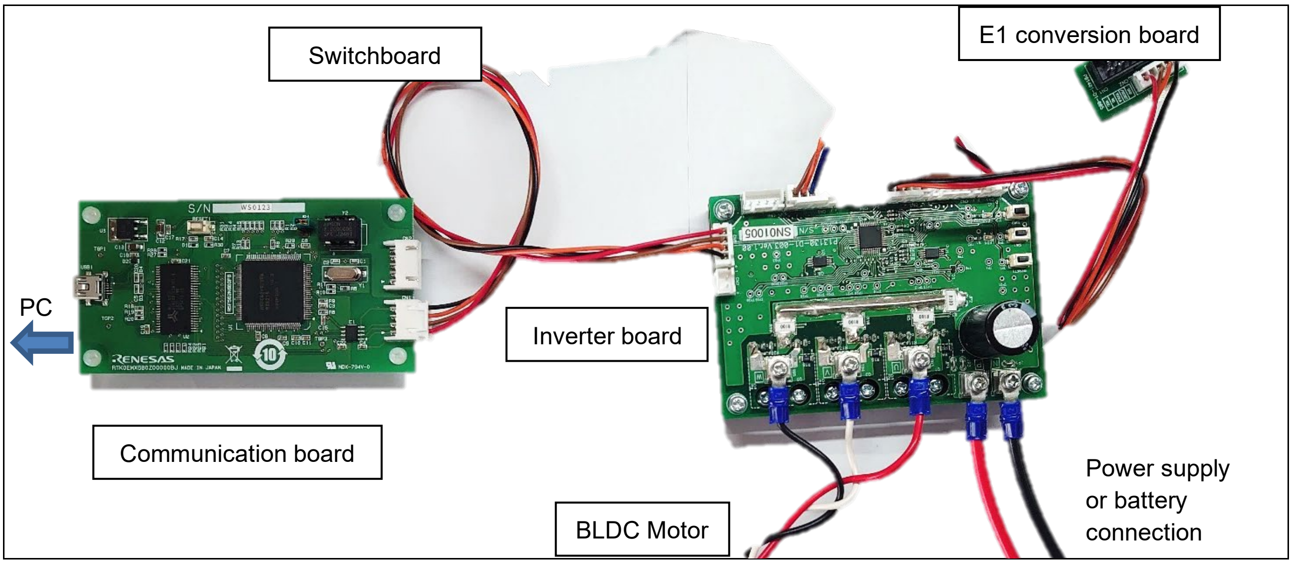


Figure 4-1 – Connection configuration diagram

4.2 How to use the Renesas Motor Workbench motor control development support tool

The target sample programs described in this application note use the user interfaces (rotating/stop command, rotation speed command, etc.) in the Renesas Motor Workbench, a motor control development support tool. To learn more about how it is used, refer to the Renesas Motor Workbench 2.0 User's Manual. You can find 'Renesas Motor Workbench' on Renesas Electronics Corporation website.

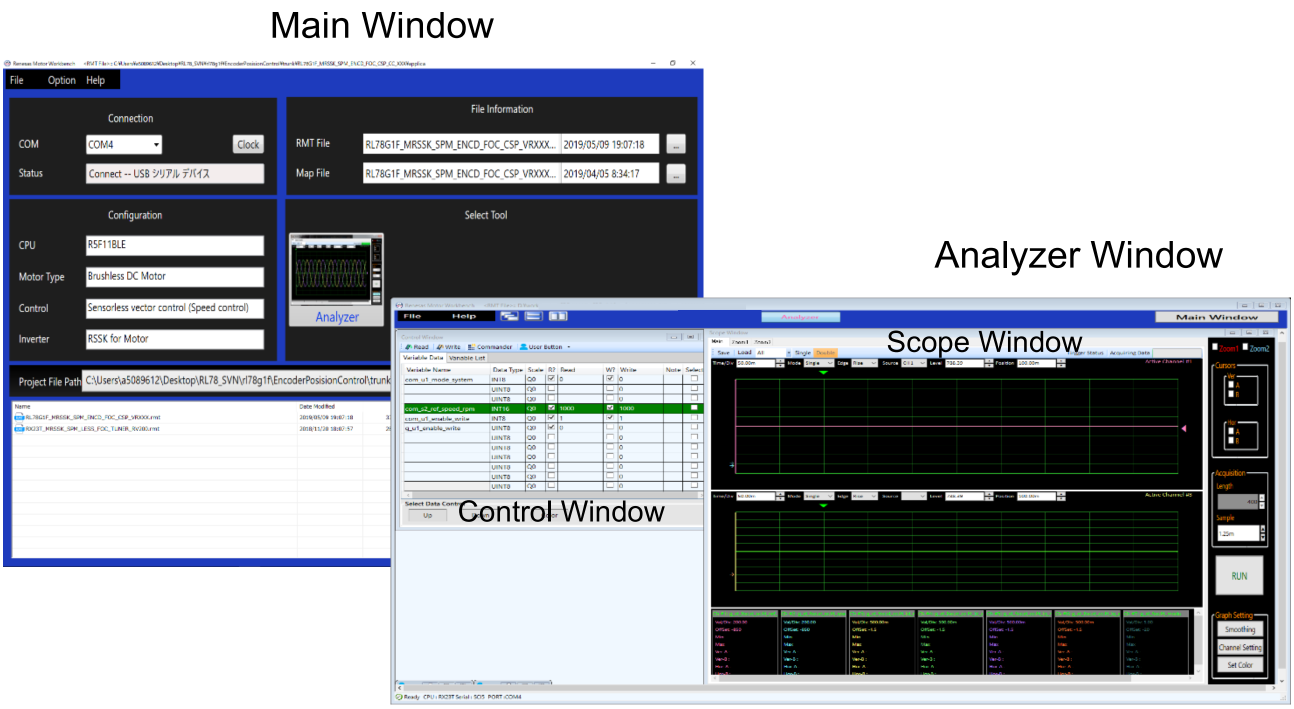
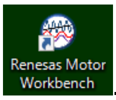


Figure 4-2 – Screenshots of Renesas Motor Workbench

<u>How to use Renesas Motor Workbench, the motor control development support tool</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]/application/ics/'.

(3) Use the 'Connection' COM select menu to choose the COM port.

(4) Click the 'Analyzer' icon in right side of Main Window.
(Then, "Analyzer Window" will be displayed.)

(5) Please refer to '4.3 Analyzer Operation Example' for motor driving operation.

Note that if the board goes into STANDBY mode, it will not be operable.
If STANDBYMODE_USE of "r_mtr_config.h" is set to NON_USE, it will not transition to STANDBY mode.

4.3 Analyzer Operation Example

An example of debugging using Analyzer is shown below. Operation is performed in the Control Window shown in Figure 4-2, and the waveform observation is performed in the Scope Window. For details on the Control Window and Scope Window, refer to the Renesas Motor Workbench 2.0 User's Manual.

- Waveform observation:
  (1) Press the RUN button in the Scope Window.
  (2) Press S1 or S2 on the switchboard to rotate the motor.
  It will display a startup waveform like the one below.

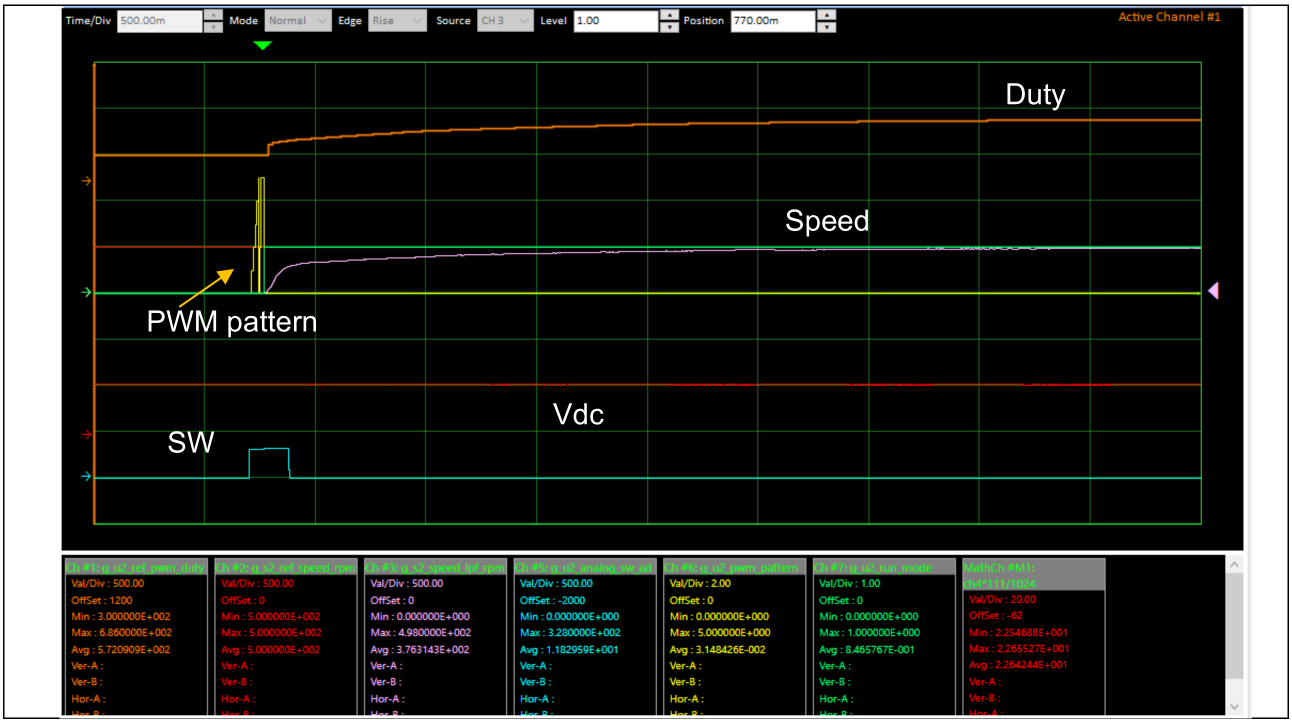


Figure 4-3 – Observation of the startup waveform in the Scope Window

- Operations in the Control Window
  The Control Window can be used to directly rewrite variables.

  (1) The motor can be driven/stopped without the operation of the switch by rewriting “g_u2_input_mode”. (0: stop, 1: standard mode, 2: power mode)

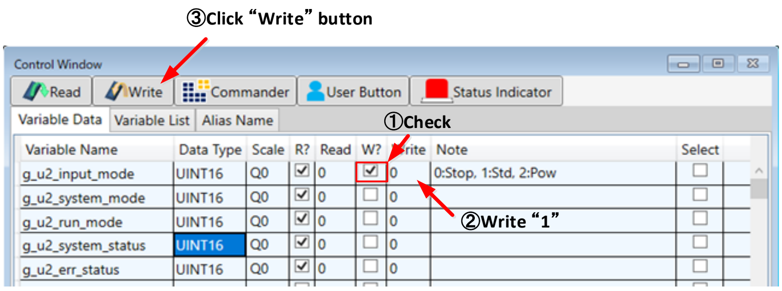


Figure 4-4 – Procedure - Driving the motor

(2) Adjust the responsiveness

For hysteresis control, you can adjust the response with g_u2_spd_ka and g_s2_spd_err_band.

If you increase g_u2_spd_ka, you get a faster rise.

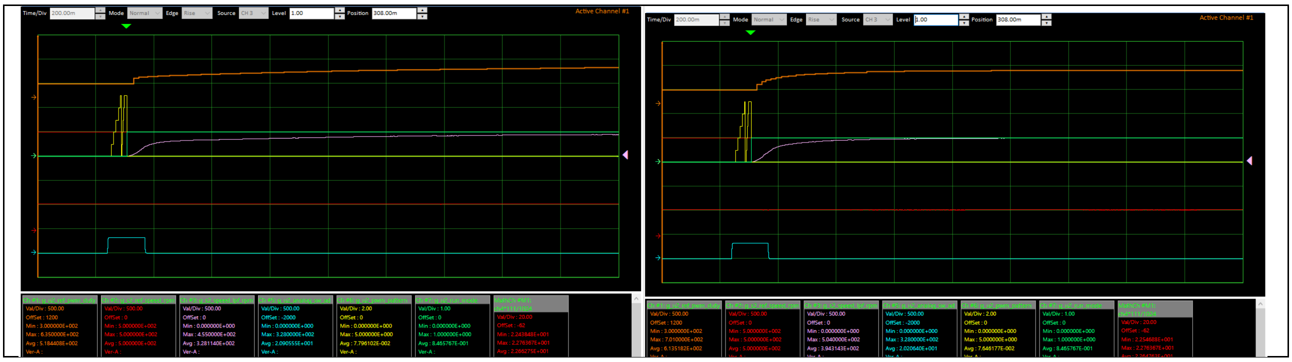


Figure 4-5 – Comparison of response by changing g_u2_spd_ka (left: 200, right 800)

The smaller the value of g_s2_spd_err_band, the faster the rise.

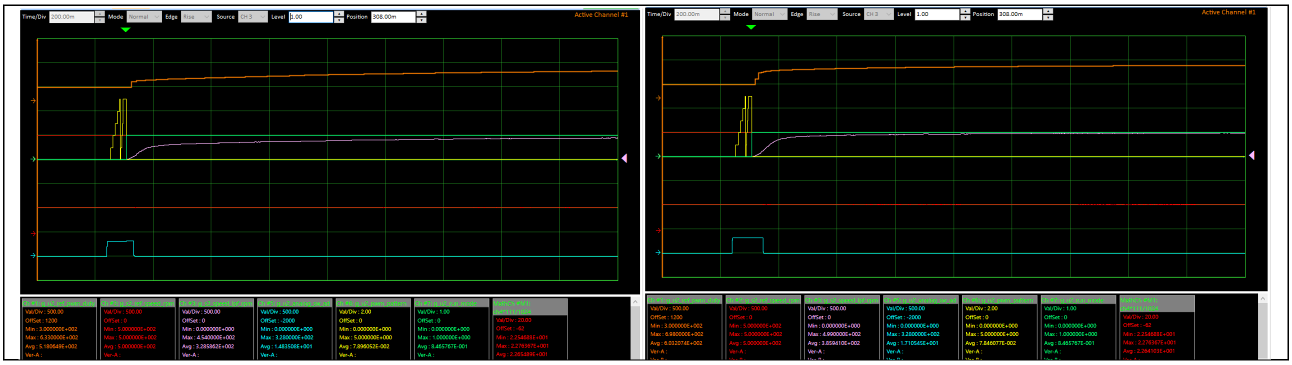


Figure 4-6 – Comparison of response by changing g_s2_spd_err_band (left：2000, right 1000)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	20.10.2020	-	First edition issued

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

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

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.
   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

Corporate Headquarters

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

Trademarks

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

Contact information

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

© 2020 Renesas Electronics Corporation. All rights reserved.