V/f Control of Induction Motor

RL78/G14

R01AN2196EJ0100
Rev.1.00
Aug. 22, 2014

Abstract

This application note aims at explaining sample programs for operating V/f control of single phase and three-phase induction motors, by using the RL78/G14 microcontroller, and how to use a library of the development support tool, In Circuit Scope.

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

In particular, the use of high voltage is extremely dangerous. Before using each development environment, be sure to read respective user's manuals carefully. Renesas Electronics assumes no liability whatsoever for any damages arising from the use of development environment described in this application note.

Operation Confirmation Device

The sample programs described in this application note have been confirmed with the device below.

- RL78/G14 (R5F104LEAFP)

Target Sample Programs

The target sample programs of this application note are shown below.

(1) RL78G14_T1102_1IM_LESS_VF_ICS_CSP_V100

V/f control sample program of a single phase induction motor for RL78/G14 (R5F104LEAFP) T1102

(2) RL78G14_T1102_3IM_LESS_VF_ICS_CSP_V100

V/f control sample program of a three-phase induction motor for RL78/G14 (R5F104LEAFP) T1102

Reference Documents

- RL78/G14 User's Manual: Hardware (R01UH0186EJ0200)
- V/f Control of Single Phase Induction Motor: Algorithm (R01AN2194EJ0100)
- V/f Control of Three-phase Induction Motor: Algorithm (R01AN2195EJ0100)
- 'In Circuit Scope Manual' and 'How to set CubeSuite+ for using ICS'

  Downloadable from: http://www.desktoplab.co.jp/download.html
- Trial series "T1102" 3kW 4kVA Inverter Unit User's Manual
- Trial series "T5101" RL78G14 64pin CPU card User's Manual

Contents

1. Overview

This application note explains the sample programs for operating V/f control of single phase and three-phase induction motors, by using the RL78/G14 microcontroller, and how to use a library of the development support tool, In Circuit Scope[Note1] (hereinafter referred to as ICS). These sample programs use algorithm described in application notes: 'V/f Control of Single Phase Induction Motor: Algorithm' and 'V/f Control of Three-phase Induction Motor: Algorithm'.

1.1 Development Environment

Table 1-1 shows development environment for the target sample programs of this application note.

Table 1-1 Development Environment for the Sample Programs

Sample program	Microcontroller	Inverter board	Motor	CubeSuite+ version
(1)	R5F104LEAFP	T1102 [Note1]	5IK150A-BW2 [Note2]	V2.02.00
(2)	R5F104LEAFP	T1102 [Note1]	5IK150A-TW2 [Note2]	V2.02.00

Please contact Renesas Electronics sales agents for purchase and technical support of the inverter board T1102.

Notes

1. The inverter board T1102 and the development support tool In Circuit Scope are the products of Desk Top Laboratories Inc.

   Desk Top Laboratories Inc. (http://www.desktoplab.co.jp/)

2. 5IK150A-BW2 and 5IK150A-TW2 are the products of ORIENTAL MOTOR CO., LTD.

   ORIENTAL MOTOR CO., LTD. (http://www.orientalmotor.co.jp/)

2. System Overview

Overview of this system is explained below.

2.1 Hardware Configuration

Hardware configuration is illustrated below.

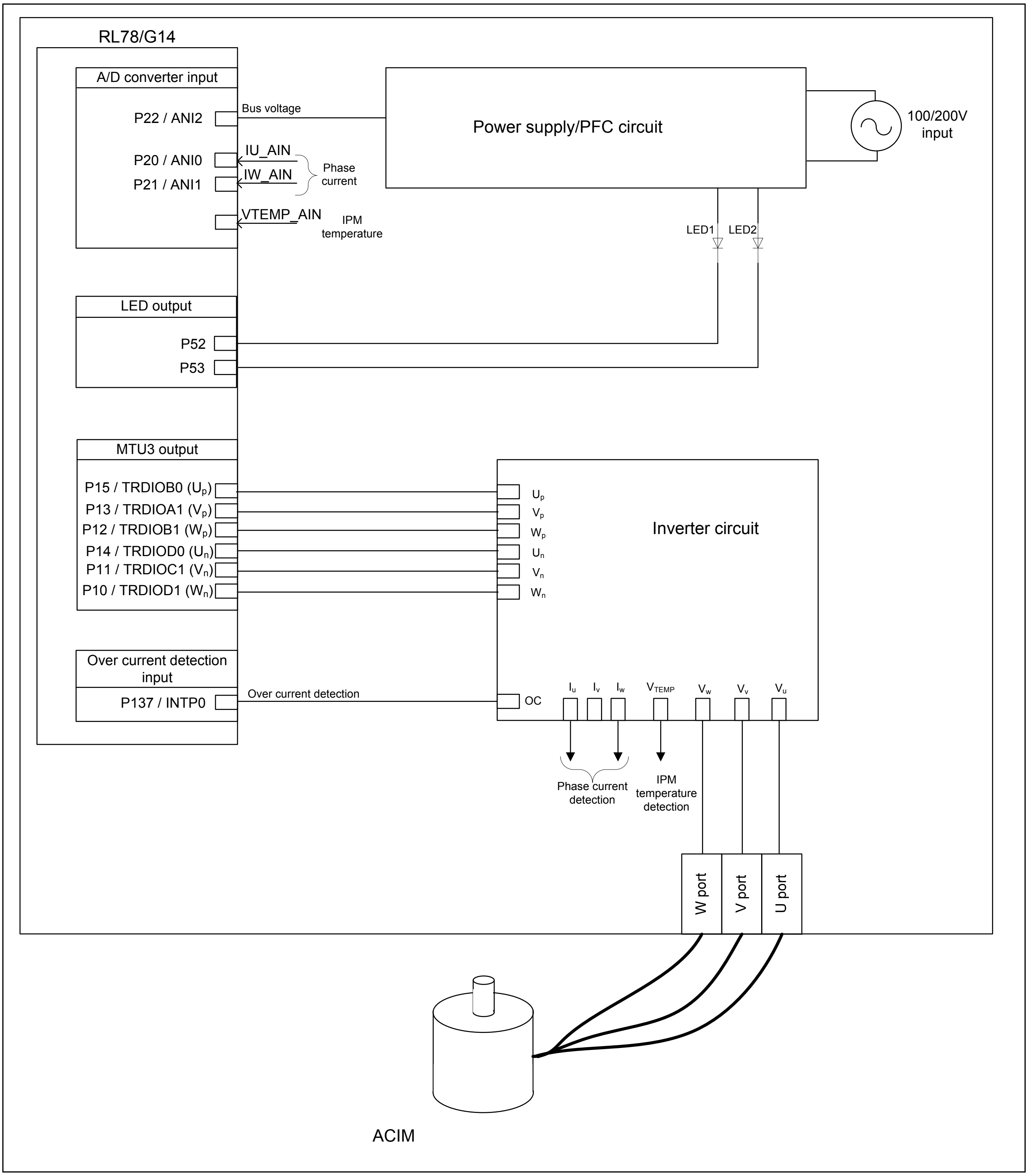

Figure 2-1 Hardware Configuration Diagram

2.2 Hardware Specifications

2.2.1 User Interface

A list of user interfaces of this system is given in Table 2-1.

Table 2-1 User Interface

Item	Interface component	Function
LED1	Yellow green LED	· At the time of Motor rotation: ON · At the time of stop: OFF
LED2	Yellow green LED	· At the time of error detection: ON · At the time of normal operation: OFF
RESET	Push switch (RESET1)	System reset

Table 2-2 is a list of terminal interfaces of this system.

Table 2-2 Terminal Interface

R5F104LEAFP Terminal name	Function
P52	LED1 ON/OFF control
P53	LED2 ON/OFF control
P54	PFC
P55	Inrush current prevention circuit relay
P20 / ANI0	U phase current measurement
P21 / ANI1	W phase current measurement
P22 / ANI2	Bus voltage measurement
P27 / ANI7	IPM temperature measurement
P15	Complimentary PWM output (U_p)
P13	Complimentary PWM output (V_p)
P12	Complimentary PWM output (W_p)
P14	Complimentary PWM output (U_n)
P11	Complimentary PWM output (V_n)
P10	Complimentary PWM output (W_n)
P137 / INTP0	PWM forced shut down at the time of over current detection

2.2.2 Peripheral Functions

Table 2-3 shows a list of peripheral functions used for this system.

Table 2-3 Peripheral Functions for Each Sample Program

	10-bit A/D	Timer array unit	Timer RD
(1) (2)	· Current of each U/W phase · Inverter bus voltage · IPM temperature	· 250 [μs] interval timer · 2 [ms] interval timer	· Complimentary PWM output · Pulse output forced shut down

1. 10-bit A/D converter
   A 10-bit A/D converter is used for measuring the U phase current, W phase current, inverter bus voltage, and IPM temperature.

   'Software trigger mode (select mode, one-shot conversion mode)' is used for conversion mode.

2. Timer array unit
   Channel 1 and channel 2 of unit 0 are used for 250-μs interval timer and 2-ms interval timer respectively.

3. Timer RD
   Output with dead time ("High" active) is perfomed using the complementary PWM mode. The pulse output forced shut down function is used with over current signals from IPM.

2.3 Software Configuration

2.3.1 Software File Configuration

Folder and file configuration of the sample programs are given in Table 2-4.

Table 2-4 Folder and File Configuration of the Sample Program (Target Software: (1))

RL78G14_T1102_1IM_LESS_VF_ICS_CSP_V100	inc	main.h	Main function, user interface control header
		mtr_common.h	Common definition header
		mtr_ctrl_rl78g14.h	RL78/G14 dependent processing header
		mtr_ctrl_rl78g14_t1102.h	Board & RL78/G14 dependent processing header
		mtr_ctrl_t1102.h	Board dependent processing header
		mtr_1im_less_vf.h	V/f control header
		r_dsp.h	Header for operation library
		r_stdint.h	Header for operation library
	ics	ics_R5F104LE.rel	ICS library
		RL78G14_vector.c	Vector setting for ICS
		ics_R5F104LE.h	Header for ICS
	lib	R_dsp_rl78.lib	Operation library
	src	main.c	Main function, user interface control
		mtr_ctrl_rl78g14.c	RL78/G14 dependent processing
		mtr_ctrl_rl78g14_t1102.c	Board & RL78/G14 dependent processing
		mtr_ctlr_t1102.c	Board dependent processing
		mtr_interrupt.c	Interrupt handler
		mtr_1im_less_vf.c	V/f control

Table 2-5 Folder and File Configuration of the Sample Program (Target Software: (2))

RL78G14_T1102_3IM_LESS_VF_ICS_CSP_V100	inc	main.h	Main function, user interface control header
		mtr_common.h	Common definition header
		mtr_ctrl_rl78g14.h	RL78/G14 dependent processing header
		mtr_ctrl_rl78g14_t1102.h	Board & RL78/G14 dependent processing header
		mtr_ctrl_t1102.h	Board dependent processing header
		mtr_3im_less_vf.h	V/f control header
		r_dsp.h	Header for operation library
		r_stdint.h	Header for operation library
	ics	ics_R5F104LE.rel	ICS library
		RL78G14_vector.c	Vector setting for ICS
		ics_R5F104LE.h	Header for ICS
	lib	R_dsp_rl78.lib	Operation library
	src	main.c	Main function, user interface control
		mtr_ctrl_rl78g14.c	RL78/G14 dependent processing
		mtr_ctrl_rl78g14_t1102.c	Board & RL78/G14 dependent processing
		mtr_ctlr_t1102.c	Board dependent processing
		mtr_interrupt.c	Interrupt handler
		mtr_3im_less_vf.c	V/f control

2.3.2 Module Configuration

Figure 2-2 and Table 2-6 show the module configuration of the sample programs.

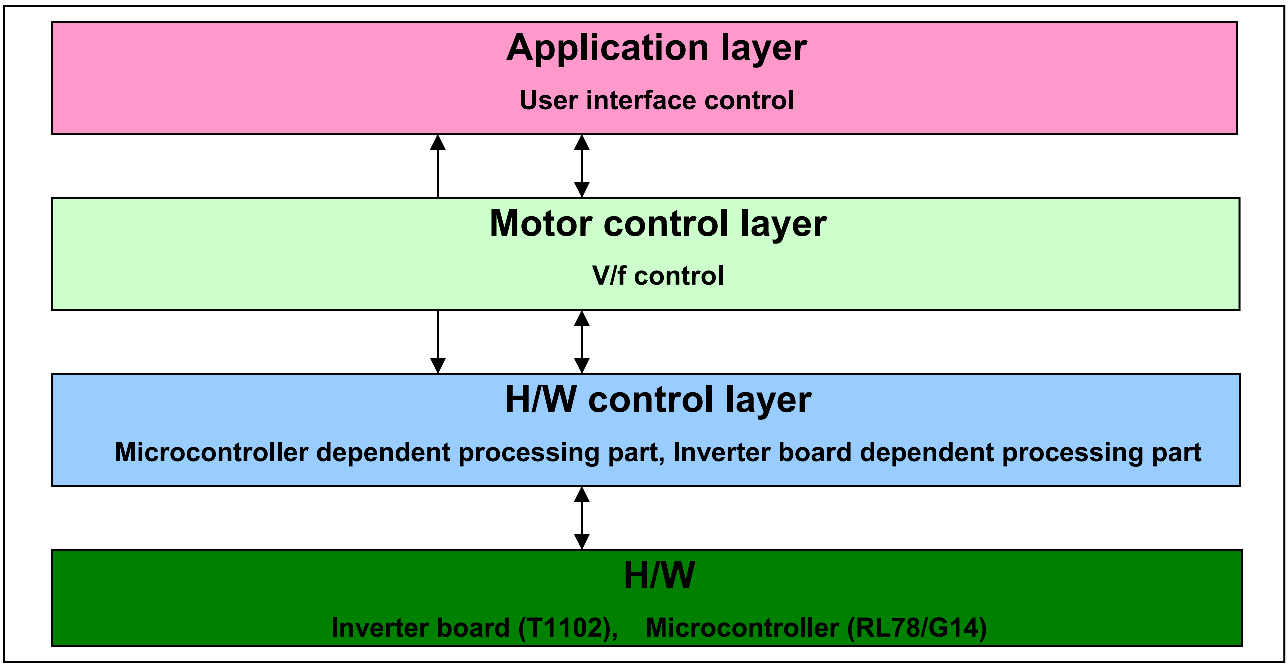

Figure 2-2 Module Configuration of the Sample Programs

Table 2-6 Module Structure of the Sample Programs

	(1)	(2)
Application layer	main.c	main.c
Motor control layer	mtr_1im_less_vf.c	mtr_3im_less_vf.c
H/W control layer	mtr_ctrl_rl78g14_t1102.c mtr_ctrl_rl78g14.c mtr_ctrl_t1102.c	mtr_ctrl_ rl78g14_t1102.c mtr_ctrl_ rl78g14.c mtr_ctrl_t1102.c

2.4 Software Specifications

Table 2-7 shows basic software specifications of this system. For details on V/f control, refer to the application note 'V/f Control of Single Induction Motor: Algorithm' and 'V/f control of Three-phase Induction Motor: Algorithm.

Table 2-7 Basic Specification of Sensorless Vector Control Software (Target Software: (1), (2))

Item	Content
Control method	V/f control
Motor rotation start/stop	Input from ICS Note1
Position detection of rotor magnetic pole	Sensorless
Input voltage	AC100 to 240 V (PFC used)
Carrier frequency (PWM)	16 [kHz]
Control cycle	250 [μs] (Carrier cycle × 4)
Inverter output frequency range	15 [Hz] to 60 [Hz]
Processing stop for protection	· Disables the motor control signal output (six outputs), under any of the following four conditions. 1. Current of each phase exceeds 10 [A] (monitored per 250 [μs]) 2. Inverter bus voltage exceeds 440 [V] (monitored per 250 [μs]) 3. Inverter bus voltage is less than 120 [V] (monitored per 250 [μs]) 4. IPM temperature output value exceeds 3 [V] (60 ± 10 [˚C]) (monitored per 250 [μs]) · When an external over current signal is detected (when a falling edge of the INTP0 port is detected), the ports executing PWM output are set to high impedance state.

Note:

1. For more details, refert to 4. Development Support Tool: In Circuit Scope.

3. Control Program

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

3.1 Contents of Control

3.1.1 Motor Start/Stop

Starting and stopping the motor are controlled by input from ICS.

3.1.2 Inverter Output Frequency Command Change Amount

The variation amount of the inverter output frequency command is determined by input from ICS.

3.1.3 Inverter Output Frequency Command Value

The inverter output frequency command value is determined by input from ICS.

3.1.4 V/f Ratio

The V/f ratio of each phase is determined by input from ICS respectively.

3.1.5 Inverter Bus Voltage

The inveter bus voltage is measured as shown in below table.

It is used for calculating the modulation factor and detecting over voltage (PWM is stopped in case of the occurrence of the abnormality)

Table 3-1 Inverter Bus Voltage Conversion Ratio

Item	Sample software	Conversion ratio (Inverter bus voltage : A/D conversion value)	Channel
Inverter bus voltage	(1)	0 [V] to 686.5 [V] : 0000H to 0FFFH	ANI2
	(2)		

3.1.6 Phase Current

As shown in the below table, U phase and W phase currents are measured to be used for over current detection.

Table 3-2 Conversion Ratio of U and W Phase Current

Item	Sample software	Conversion ratio (U phase, W phase current : A/D conversion ratio)	Channel
U phase, W phase current	(1)	-50 [A] to 50 [A] : 0000H to 0FFFH	Iu : ANI0 Iw : ANI1
	(2)		

3.1.7 Modulation

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

(1) Triangular wave comparison method

As one of the methods to actually output the command value voltage, the triangular wave comparison method which determines the pulse width of the output voltage by comparing the carrier waveform (triangular wave) and command value voltage waveform is used. Output of the command value voltage of the pseudo sinusoidal wave can be performed by turning the switch on or off when the command value voltage is larger or smaller than the carrier wave voltage respectively.

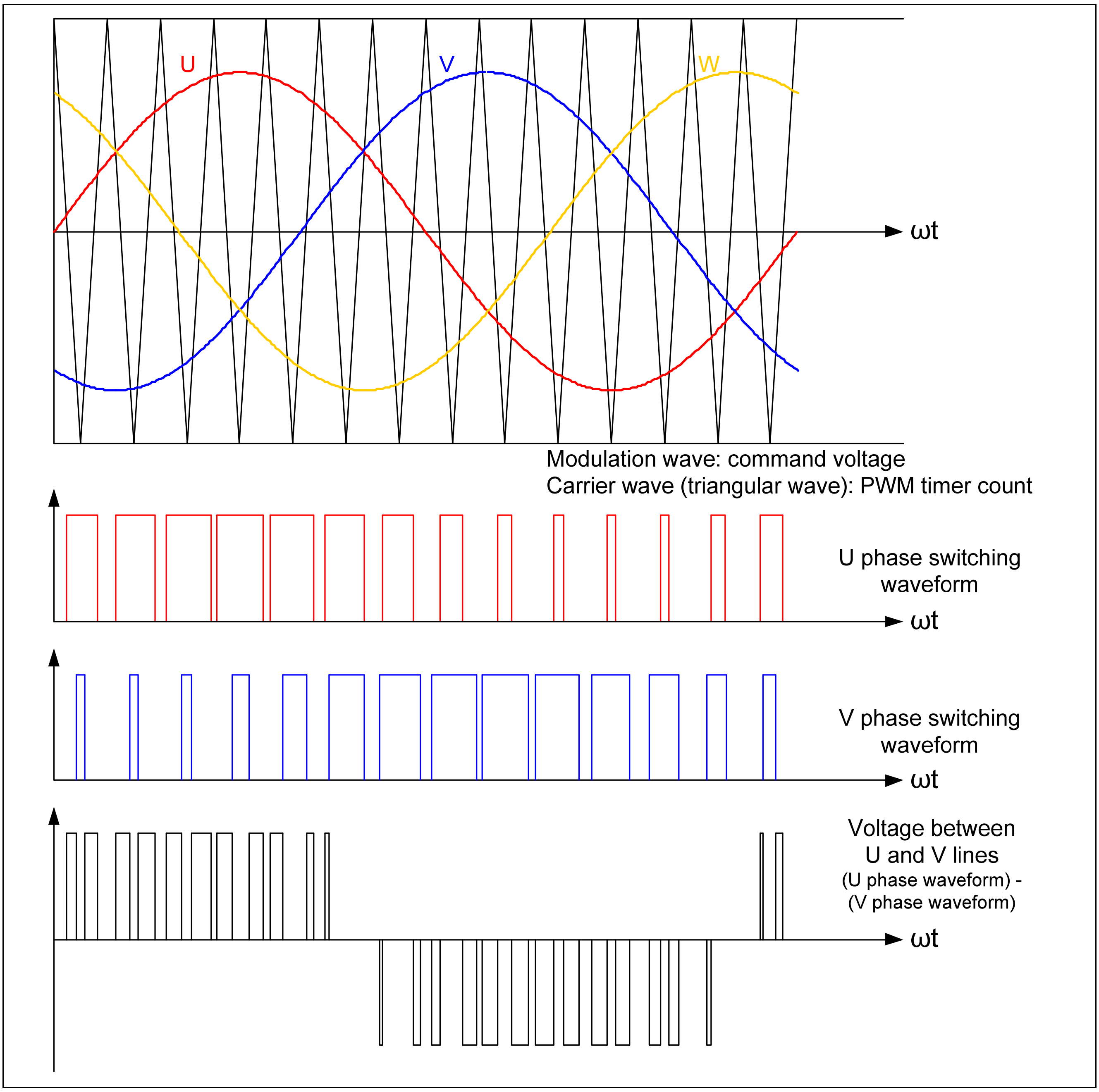

Figure 3-1 Conceptual Diagram of the Triangular Wave Comparison Method

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

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

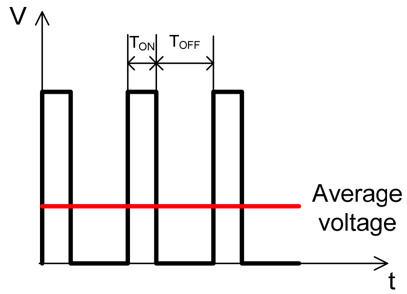

Figure 3-2 Definition of Duty

Modulation factor m is defined as follows.

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

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

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

3.1.8 State Transition

Figure 3-3 is a state transition diagram of the sensorless vector control software.

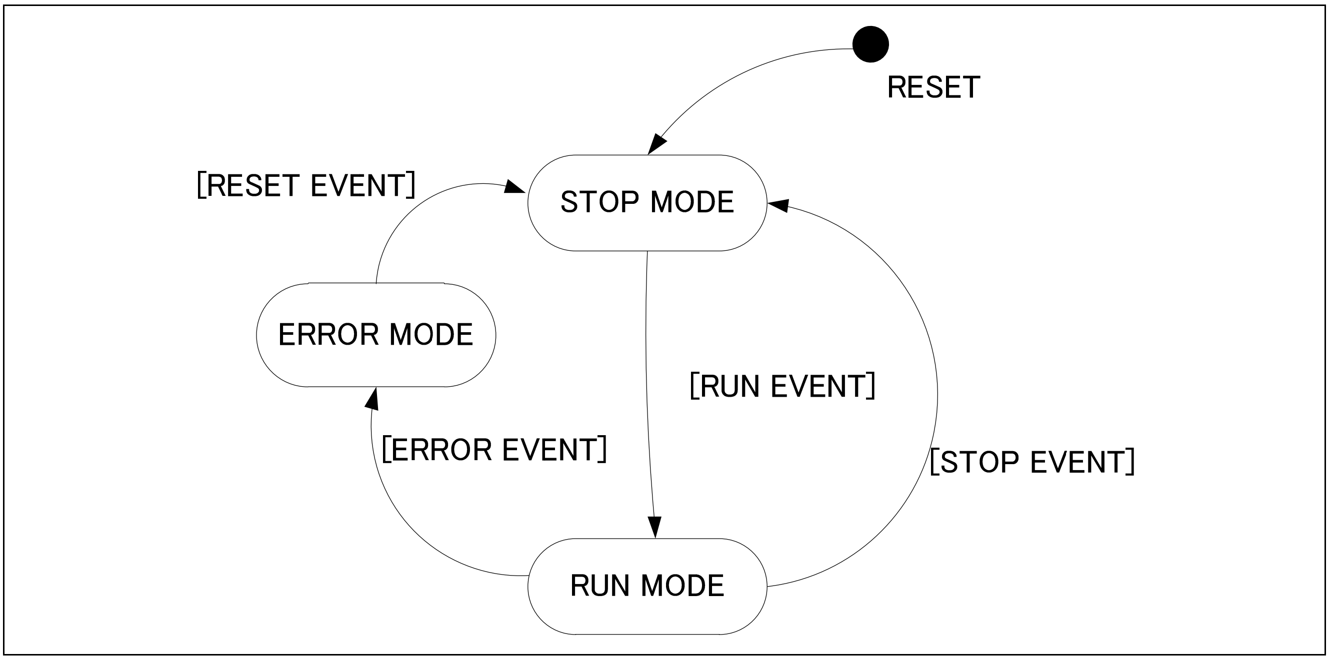

Figure 3-3 Sate Transition Diagram of V/f Control Software

3.1.9 System Protection Function

These control programs have the following four types of error status and execute emergency stop functions in case of occurrence of respective errors. Table 3-3 shows each setting value for the system protection function.

• Over current error

High impedance output is made to the PWM output port in response to an emergency stop signal (over current detection) from hardware. In addition, U, V, and W phase currents are monitored. When an over current (when the current exceeds the over current limit value) is detected, the CPU executes emergency stop (software detection).

• Over voltage error

The inverter bus voltage is monitored by over current monitoring cycles. When an over voltage is detected (when the voltage exceeds the over voltage limit value), the CPU performs emergency stop.

• Low voltage error

The inverter bus voltage is monitored by low-voltage monitoring cycles. The CPU performs emergency stop when low voltage (when voltage falls below the limit value) is detected.

• IPM temperature error

The IPM temperature is monitored by IPM temperature monitoring cycles. When high temperature is detected (when it exceeds the IPM temperature limit value), the CPU performs emergency stop

Table 3-3 Setting Value of Each System Protection Function

		(1)	(2)
Over current error	Over current limit value [A]	10	
	Monitoring cycle [μs]	250	
Over voltage error	Over voltage limit value [V]	440	
	Monitoring cycle [μs]	250	
Low voltage error	Low voltage limit value [V]	120	
	Monitoring cycle [μs]	250	
IPM temperature error	High temperature limit value [V]	3	
	Monitoring cycle [μs]	250	

3.2 Function Specifications of V/f Control Software

These control programs use multiple control functions. The following tables show lists of the control functions.

For more details on processing, refer to flowcharts or source files.

Table 3-4 List of Control Functions (1/5)

File name	Function name	Processing overview
main.c	main Input: None Output: None	・Hardware initialization function call ・User interface initialization function call ・Initialization function call of the variable used in the main processing ・Status transition and event execution function call ・Main processing ⇒ Main process execution function call ⇒ Watchdog timer clear function call
	ics_ui Input: None Output: None	Using ICS user interface
	software_init Input: None Output: None	Initialization of the variable used in the main processing
mtr_ctrl_t1102.c	R_MTR_ChargeCapacitor Input: None Output: None	Wait for smoothing capacitor recharge time
	inrush_gate_on Input: None Output: None	Turn a gate signal for inrush current prevention ON
	led1_cpu_on Input: None Output: None	Turning LED1 ON
	led2_cpu_on Input: None Output: None	Turning LED2 ON
	led1_cpu_off Input: None Output: None	Turning LED1 OFF
	led2_cpu_off Input: None Output: None	Turning LED2 OFF

Table 3-5 List of Control Functions (2/5)

File name	Function name	Processing overview
mtr_ctrl_rl78g14.c	R_MTR_InitHardware Input: None Output: None	Initialization of the clock and peripheral functions
	mtr_init_tau Input: None Output: None	Initialization of the timer array unit
	mtr_init_external_interrupt Input: None Output: None	Initialization of INTP0
	clear_wdt Input: None Output: None	Clearing the watchdog timer
	mtr_clear_oc_flag Input: None Output: None	Clearing the high impedance state

Table 3-6 List of Control Functions (3/5)

File name	Function name	Processing overview
mtr_interrupt.c	mtr_over_current_interrupt Input: None Output: None	Over current detection processing ・Event processing selection function call ・Changing the motor status ・High impedance state clearing function call
	mtr_tau01_interrupt Input: None Output: None	Calling per 250 [μs] ・Current detection ・Error check ・Three-phase output voltage setting
	mtr_tau02_interrupt Input: None Output: None	Calling per 2 [ms] ・Output frequency command generation ・Three-phase voltage amplitude value setting

Table 3-7 Table 3-8 List of Control Functions (4/5)

File name	Function name	Processing overview
(1) mtr_1im_less_vf.c (2) mtr_3im_less_vf.c	R_MTR_InitSequence Input: None Output: None	Initialization of the sequence processing
	R_MTR_ExecEvent Input: (uint8)u1_event / occurred event Output: None	・Changing the status ・Calling an appropriate process execution function for the occurred event
	mtr_act_run Input: (uint8)u1_state / motor status Output: (uint8)u1_state / motor status	・Variable initialization function call upon motor startup ・Motor control start function call
	mtr_act_stop Input: (uint8)u1_state / motor status Output: (uint8)u1_state / motor status	Motor control stop function call
	mtr_act_none Input: (uint8)u1_state / motor status Output: (uint8)u1_state / motor status	No processing is performed.
	mtr_act_reset Input: (uint8)u1_state / motor status Output: (uint8)u1_state / motor status	Initialization of the global variables
	mtr_act_error Input: (uint8)u1_state / motor status Output: (uint8)u1_state / motor status	Motor control stop function call
	mtr_set_variables Input: None Output: None	Setting motor variables
	R_MTR_IcsInput Input: MTR_ICS_INPUT *ics_input /structure for ICS Output: None	Setting the buffer
	R_MTR_GetStatus Input: None Output: (uint8)g_u1_mode_system / motor status	Obtaining the motor status
	mtr_error_check Input: None Output: None	Monitoring and detecting errors
	mtr_vector_generation Input: None Output: None	・Setting phase ・Setting three-phase modulation factor

Table 3-9 Table 3-10 List of Control Functions (5/5)

File name	Function name	Processing overview
mtr_ctrl_rl78g14_t1102.c	mtr_init_io_port Input: None Output: None	Initial setting of the IO ports
	mtr_init_trd Input: None Output: None	Initial setting of the timer RD
	mtr_init_ad_converter Input: None Output: None	Initial setting of the A/D converter
	init_ui Input: None Output: None	Initialization of UI
	mtr_ctrl_start Input: None Output: None	Motor start processing
	mtr_ctrl_stop Input: None Output: None	Motor stop processing
	mtr_get_adc Input: uint8 ad_ch/ AD conversion channel Output: u2_temp / AD conversion value	AD conversion
	mtr_inv_set_uvw Input: int16 s2_u / U phase modulation factor : int16 s2_v / V phase modulation factor : int16 s2_w / W phase modulation factor Output: None	Setting PWM output

3.3 V/f Control Software Variables

Lists of variables used in these control programs are given below. Note that the local variables are not mentioned. The variables with a figure in [ ] are used only in the indicated sample software.

Table 3-11 List of Variables (1/2)

Variable name	Type	Content	Remarks
g_u1_enable_write	unit8	Variable for ICS UI	
g_u1_error_status	unit8	Error status management	1: Over current error 2: Over voltage error 7: Low voltage error 8: IPM temperature error 0xFF: Undefined error
g_u1_mode_system	unit8	State management	0: Stop mode 1: Run mode 2: Error mode
g_s2_accel_rad	int16	Acceleration	[(rad/s)/speed update cycle]
g_s2_ref_speed_rad	int16	Command output speed	[rad/s]
g_s2_coef_run [(1)]	int16	V/f ratio of RUN phase	[V/Hz]
g_s2_coef_start [(1)]	int16	V/f ratio of START phase	[V/Hz]
g_s2_coef_r [(2)]	int16	V/f ratio of R phase	[V/Hz]
g_s2_coef_s [(2)]	int16	V/f ratio of S phase	[V/Hz]
g_s2_coef_t [(2)]	int16	V/f ratio of T phase	[V/Hz]
g_s2_vmax_run [(1)]	int16	RUN phase voltage amplitude	[V]
g_s2_vmax_start [(1)]	int16	START phase voltage amplitude	[V]
g_s2_vmax_r [(2)]	int16	R phase voltage amplitude	[V]
g_s2_vmax_s [(2)]	int16	S phase voltage amplitude	[V]
g_s2_vmax_t [(2)]	int16	T phase voltage amplitude	[V]
g_s2_iu_ad	int16	U phase current AD conversion value	[A]
g_s2_iu_lpf	int16	U phase current	[A]
g_s2_pre_iu_lpf	int16	Previous value of U phase current	[A]
g_s2_offset_iu	int16	U phase current offset value	[A]
g_s2_iv_lpf	int16	V phase current	[A]
g_s2_iw_ad	int16	W phase current AD conversion value	[A]
g_s2_iw_lpf	int16	W phase current	[A]
g_s2_pre_iw_lpf	int16	Previous value of W phase current	[A]
g_s2_offset_iw	int16	W phase current offset value	[A]
g_s2_cnt_adjust	int16	Current offset calculation counter	
g_u2_vdc_ad	uint16	Inverter bus voltage	[V]
g_s2_speed_rad	int16	Output speed	[rad/s]
g_s2_offset_calc_time	int16	Current offset value calculation time	
g_s2_current_lpf_k	int16	Current LPF gain	
g_s2_offset_lpf_k	int16	Current offset value LPF gain	

Table 3-12 List of Variables (2/2)

Variable name	Type	Content	Remarks
g_s2_duty_max	int16	Maximum limit value of duty	
g_s2_duty_min	int16	Minimum limit value of duty	
g_s2_over_current_limit	int16	Over current limit value	[A]
g_s2_over_vdc_limit	int16	Over voltage limit value	[V]
g_s2_under_vdc_limit	int16	Low voltage limit value	[V]
g_s2_over_ipmtemperature_limit	int16	IPM temperature limit value	
g_s2_reci_vdc_ad	int16	Reciprocal number of bus voltage	[1/V]
g_s2_theta_ref	int16	Phase	[rad]
g_s2_phase_diff [(1)]	int16	RUN-START phase difference	[rad]
g_s2_vu_ref	int16	U phase voltage command value	[V]
g_s2_vv_ref	int16	V phase voltage command value	[V]
g_s2_vw_ref	int16	W phase voltage command value	[V]
g_s2_mu_ref	int16	U phase modulation factor	
g_s2_mv_ref	int16	V phase modulation factor	
g_s2_mw_ref	int16	W phase modulation factor	
g_s2_ipm_temperature_ad	int16	IPM temperature AD conversion value	
ics_input_buff	MTR_ICS_INPUT	Structure for ICS UI	ics_input_buff

3.4 V/f Control Software Structures

A list of structure used in these control programs is given below. The members with a figure in [ ] are used only in the indicated sample software.

Table 3-13 List of Structure

	Member name	Type	Content	Remarks
MTR_ICS_INPUT	s2_accel	int16	Acceleration	[(rad/s)/speed update cycle]
	s2_ref_speed	int16	Command output frequency	[rad/s]
	s2_coef_run [(1)]	int16	V/f ratio of RUN phase	[V/Hz]
	s2_coef_start [(1)]	int16	V/f ratio of START phase	[V/Hz]
	s2_coef_r [(2)]	int16	V/f ratio of R phase	[V/Hz]
	s2_coef_s [(2)]	int16	V/f ratio of S phase	[V/Hz]
	s2_coef_t [(2)]	int16	V/f ratio of T phase	[V/Hz]
	s2_phase_diff [(1)]	int16	RUN-START phase difference	[rad]

3.5 Sensorless Vector Control Software Macro Definitions

Lists of macro definitions used in these control programs are shown below. The macros with a figure in [ ] are used only in the indicated sample software.

Table 3-14 List of Macro Definitions (1/4)

File name	Macro name	Definition value	Remarks
main.h	ACCEL_FREQ	0.05*256	Default value of acceleration
	REF_FREQ	50*256	Default value of inverter output frequency command value
	COEF_RUN [(1)]	1*512	Default value of RUN phase V/f ratio
	COEF_START [(1)]	1*512	Default value of START phase V/f ratio
	COEF_R [(2)]	1*512	Default value of R phase V/f ratio
	COEF_S [(2)]	1*512	Default value of S phase V/f ratio
	COEF_T [(2)]	1*512	Default value of T phase V/f ratio
	PHASE_DIFF [(1)]	90*64	Default value of phase difference
	ACCEL_LIMIT	60*256	Default value of acceleration limit value
	FREQ_MAX_LIMIT	60*256	Default value of output frequency maximum limit value
	FREQ_MIN_LIMIT	15*256	Default value of output frequency minimum limit value
	COEF_LIMIT	8*512	Default value of V/f ratio limit

Table 3-15 List of Macro Definitions (2/4)

File name	Macro name	Definition value	Remarks
mtr_ctrl_rl78g14_t1102.h	MTR_PWM_TIMER_FREQ	32.0f	PWM timer frequency
	MTR_DEADTIME_SET	MTR_DEADTIME * MTR_PWM_TIMER_FREQ / 1000	Dead time setting value
	MTR_CARRIER_SET	(MTR_PWM_TIMER_FREQ * 1000000UL / MTR_CARRIER_FREQ / 2) + MTR_DEADTIME_SET - 2	Carrier frequency setting value
	MTR_HALF_CARRIER_SET	MTR_CARRIER_SET / 2	Intermediate value of carrier frequency setting value
	MTR_SYNCTAU_SET	(MTR_PWM_TIMER_FREQ * 1000000UL / MTR_CARRIER_FREQ) * MTR_FREQ_MULTIPLY - 1	Setting value of carrier synchronous timer frequency
	MTR_PORT_UP	P1.5	U phase (positive phase) output port
	MTR_PORT_UN	P1.4	U phase (negative phase) output port
	MTR_PORT_VP	P1.3	V phase (positive phase) output port
	MTR_PORT_VN	P1.1	V phase (negative phase) output port
	MTR_PORT_WP	P1.2	W phase (positive phase) output port
	MTR_PORT_WN	P1.0	W phase (negative phase) output port
	MTR_ADCCH_IU	0	U phase current AD conversion ch
	MTR_ADCCH_IW	1	W phase current AD conversion ch
	MTR_ADCCH_VDC	2	Bus voltage AD conversion ch
	MTR_ADCCH_IMPTEMPERATURE	7	IPM temperature AD conversion ch
	MTR_AD_BIT_SGN	0x8000U	For converting current value
	MTR_ADSCALE_CUR	(100.0f / 1023) * 65536	Current scaling
	MTR_ADSCALE_VDC	(686.8f / 1023) * 8192	Bus voltage scaling
	MTR_ADSCALE_IPMTEMPERATURE	(5.0f / 1023) * 1048576	
	MTR_PORT_LED1_CPU	P5.2	LED1 output port
	MTR_PORT_LED2_CPU	P5.3	LED2 output port
	MTR_LED_ON	0	Active in case of “Low”
	MTR_LED_OFF	1	
	MTR_PORT_INRUSH_GATE	P5.5	Inrush current prevention gate
	MTR_INRUSH_GATE_ON	1	Active in case of “High”

Table 3-16 List of Macro Definitions (3/4)

File name	Macro name	Definition value	Remarks
(1) mtr_1im_less_vf.h (2) mtr_3im_less_vf.h	MTR_FREQ_MULTIPLY	4	Carrier frequency multiplication number for control period
	MTR_DEADTIME	1500	Dead time [ns]
	MTR_CARRIER_FREQ	16000	Carrier frequency [Hz]
	MTR_TWOPI	2*3.14159265*512	2 π
	MTR_2_3_PI [(2)]	4096.0f/3	2 π/3 (4096 = 2 π)
	MTR_4_3_PI [(2)]	4096.0f*2/3	4π/3 (4096 = 2 π)
	MTR_RAD_ANGLE	334	For converting speed to phase
	MTR_PHASE_SCALING	11651	Phase scaling
	MTR_RAD_CONV_VECCOEF	0.159155*32768	For converting speed to voltage
	MTR_VDC_CONV_RECIVDC	32	For calculating reciprocal number of bus voltage
	MTR_OVERVOLTAGE_LIMIT	440*32	Over voltage limit value [V]
	MTR_UNDERVOLTAGE_LIMIT	120*32	Low voltage limit value [V]
	MTR_OVERCURRENT_LIMIT	10*1024	Over current limit value [A]
	MTR_OVERIPMTEMPERATURE_LIMIT	3*4096	IPM temperature limit value [V] (3 [V] = 60 ± 10[˚C])
	MTR_PWM_DUTY_MAX_LIMIT	3277	Maximum limit of modulation factor
	MTR_PWM_DUTY_MIN_LIMIT	-4096	Minimum limit of modulation factor
	MTR_PWM_DUTY_RANGE	4096	Range of modulation factor
	MTR_ANGLE_RANGE	4096	4096 = 2π
	MTR_CURRENT_LPF_K	0.3*16384	Current LPF gain
	MTR_OFFSET_LPF_K	0.1*16384	Current offset value LPF gain
	MTR_OFFSET_CALC_TIME	1000	Current offset measurement time [ms]
	MTR_FLG_CLR	0	Flag management
	MTR_FLG_SET	1	
	MTR_OVER_CURRENT_ERROR	0x01	Over current error
	MTR_OVER_VOLTAGE_ERROR	0x02	Over voltage error
	MTR_OVER_SPEED_ERROR	0x03	Over speed error
	MTR_TIMEOUT_ERROR	0x04	Timeout error
	MTR_UNDER_VOLTAGE_ERROR	0x07	Low voltage error
	MTR_OVER_IPMTEMPERATURE_ERROR	0x08	IPM temperature error
	MTR_UNKNOWN_ERROR	0xff	Undefined error
	MTR_MODE_STOP	0x00	Stop status
	MTR_MODE_RUN	0x01	Rotating
	MTR_MODE_ERROR	0x02	Error status
	MTR_SIZE_STATE	3	Number of states
	MTR_EVENT_STOP	0x00	Motor stop event
	MTR_EVENT_RUN	0x01	Motor start event
	MTR_EVENT_ERROR	0x02	Motor error event
	MTR_EVENT_RESET	0x03	Motor reset event
	MTR_SIZE_EVENT	4	Event counts

Table 3-17 List of Macro Definitions (4/4)

File name	Macro name	Definition value	Remarks
mtr_ctrl_t1102.h	MTR_INPUT_V	390	Inverter input voltage
	MTR_INRUSH_GATE_ON_V	MTR_INPUT_V*0.8*32	Inrush current prevention circuit gate ON voltage

3.6 Control Flow (Flowcharts)

3.6.1 Main Processing

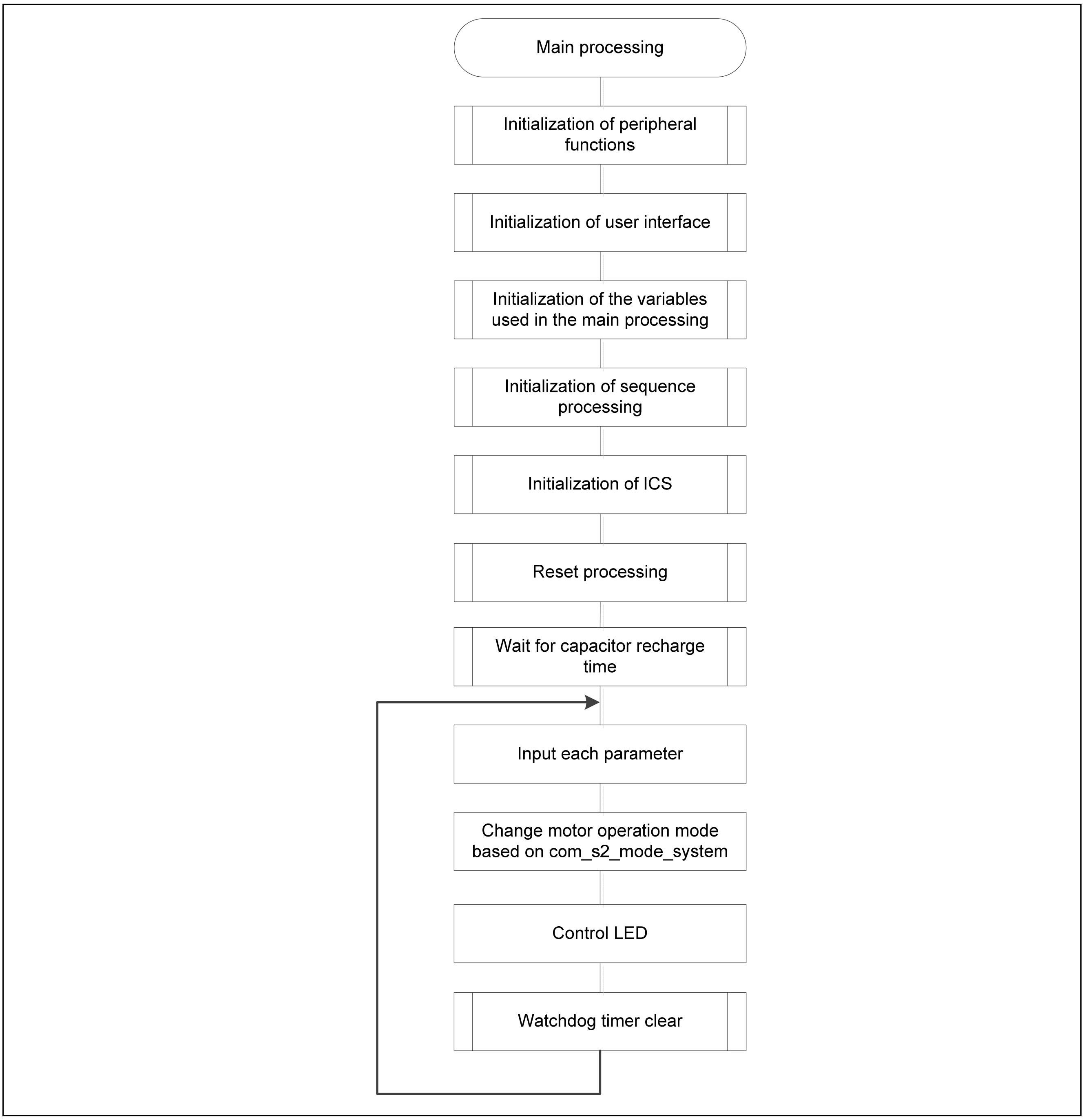

Figure 3-4 Main Processing

3.6.2 250 [µs] Cycle Interrupt Handling

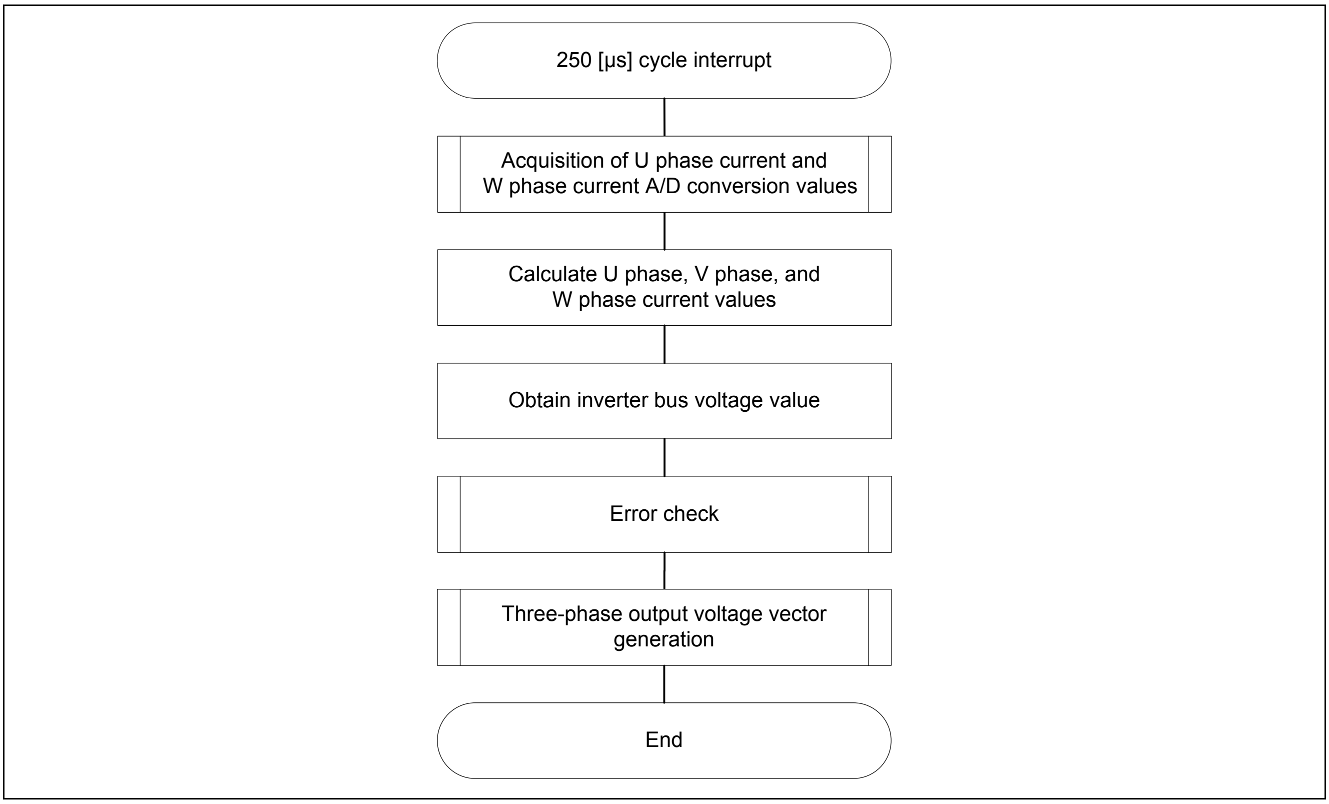

Figure 3-5 250 [µs] Cycle Interrupt Handling

3.6.3 2 [ms] Interrupt Handling

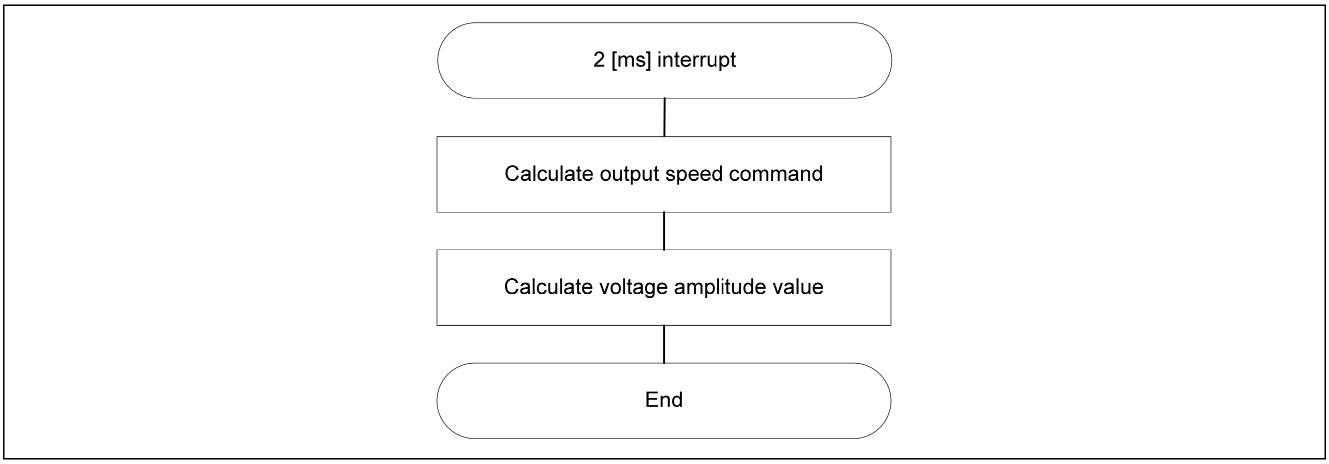

Figure 3-6 2 [ms] Interrupt Handling

3.6.4 Over Current Detection Interrupt Handling

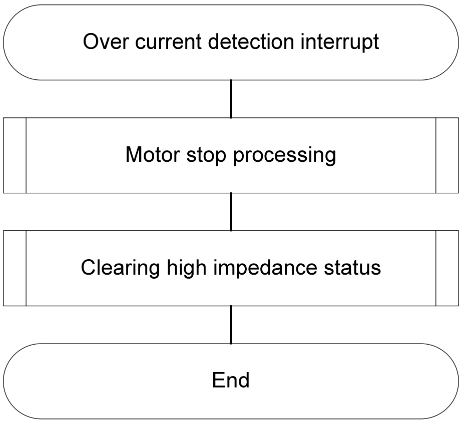

Figure 3-7 Over Current Detection Interrupt Handling

4. Development Support Tool: In Circuit Scope

4.1 Overview

In the target sample programs described in this application note, user interfaces (rotating/stop command, rotation speed command, etc.) based on the development support tool ‘In Circuit Scope’ (ICS) can be used. ICS is a tool which displays real-time waveforms on PC of global variables of the program being executed on the target system. Refer to ‘In Circuit Scope manual’ and ‘How to set CubeSuite+ for using ICS’ for usage and more details.

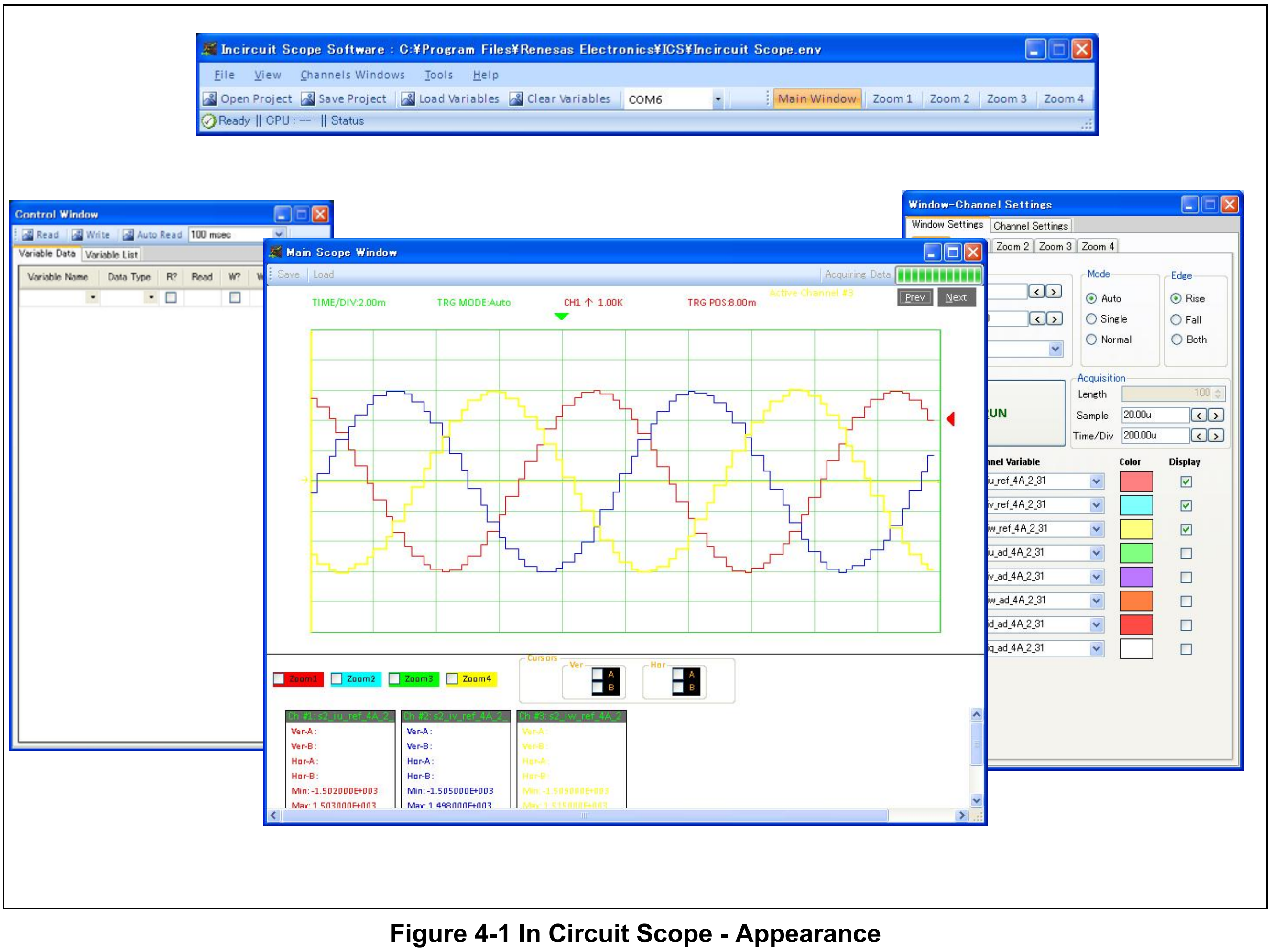

Figure 4-1 In Circuit Scope - Appearance

4.2 List of Variable for ICS

Table 4-1 is a list of variables for ICS. When a change is made to these variables for ICS, the change is not yet reflected to variables of the motor control layer. The variables of the motor control layer are rewritten when a same value is written to com_s2_enable_write and g_s2_enable_write. Note that the variables with (*) do not depend on com_s2_enable_write and the variables with a figure in [ ] are used only in the indicated sample software.

Table 4-1 List of Variables for ICS

Name of variable for ICS	Type	Content	Reflection destination variable (Variables of motor control layer)
com_s2_mode_system(*)	int16	State management 0: Stop mode 1: Run mode 3: Reset	When rewritten, reflected to g_s2_mode_system
com_s2_accel_freq	int16	Acceleration	g_s2_accel_rad
com_s2_ref_freq	int16	Inverter command output frequency	g_s2_ref_speed_rad
com_s2_coef_run [(1)]	int16	V/f ratio of RUN phase	g_s2_coef_run
com_s2_coef_start [(1)]	int16	V/f ratio of START phase	g_s2_coef_start
com_s2_coef_r [(2)]	int16	V/f ratio of R phase	g_s2_coef_r
com_s2_coef_s [(2)]	int16	V/f ratio of S phase	g_s2_coef_s
com_s2_coef_t [(2)]	int16	V/f ratio of T phase	g_s2_coef_t
com_s2_phase_diff [(1)]	int16	RUN-START phase difference	g_s2_phase_diff
com_s2_enable_write	int16	Enabling to rewrite variables	—

Website and Support

Renesas Electronics Website

http://www.renesas.com/

Inquiries

http://www.renesas.com/contact/

Revision History

Rev.	Date	Description	
		Page	Summary
1.0	Aug. 22, 2014	—	First edition issued

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU 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. 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.
5. Differences between Products
   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.
   — The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the 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.

SALES OFFICES Renesas Electronics Corporation http://www.renesas.com

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
2801 Scott Boulevard Santa Clara, CA 95050-2549, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited
1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100191, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, P. R. China 200333
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.
12F., 234 Teheran-ro, Gangnam-Ku, Seoul, 135-920, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141

Colophon 4.0