RH850/U2B

Control of Permanent Magnetic Synchronous Motor with resolver

Introduction

This application note describes how to control the Permanent Magnetic Synchronous Motor with resolver at RH850/U2B6.

Target Device

This application note applies to RH850/U2B6.

If you apply this application note to another microcomputer, change according to the specification of that microcomputer and evaluate it sufficiently.

Contents

1. Vector Control of Permanent Magnet Synchronous Motor with Resolver

This application note describes how to use the motor control timer (TSG3) of RH850/C1M-A.

1.1 Operation of PMSM

A PMSM has a stator fixed to the motor housing and a rotor, which rotates. The stator has phase-U, phase-V, and W-phase coils mounted at angles of 120 degrees to each other. The rotor has permanent magnets built in.

Applying a voltage across a coil causes a current to flow through it, and thereby generates a magnetic field. When a permanent magnet is placed in the magnetic field, an attractive or repulsive force acts on the permanent magnet. When currents flow through the phase-U, phase-V, and W-phase coils, the rotor moves because its permanent magnets are attracted in a synthetic magnetic field made by vector synthesis of the magnetic fields generated by the coils. When the synthetic magnetic field is rotated, the rotor rotates. A magnetic field that rotates at a constant speed and has a constant magnitude can be generated by passing sinusoidal currents different in phase by 120 degrees through the phase-U, phase-V, and W-phase coils. Figure 1.1 shows the structure of the PMSM and the synthetic magnetic field.

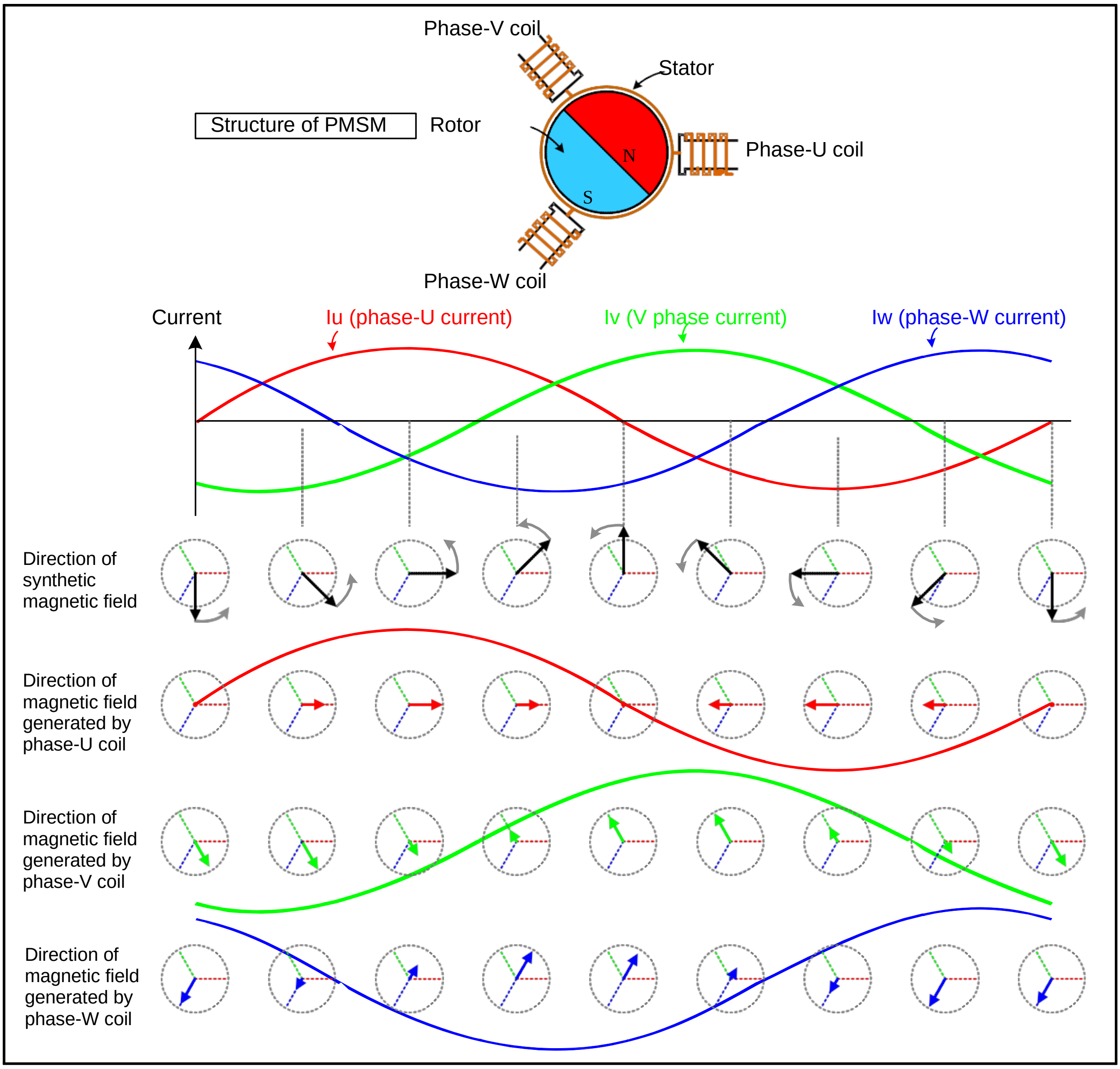

Figure 1.1 PMSM Structure and Synthetic Magnetic Field

Figure 1.2 shows the relationship between the synthetic magnetic field and torque.

When the magnetic pole of a permanent magnet forms an angle of 90o with the direction of synthetic magnetic field, the torque (force to turn the permanent magnet) is maximized. The synthetic magnetic field perpendicular to the magnetic pole is called the "transverse magnetic field". Here, assume that the direction of the magnetic pole of the permanent magnet is the d axis and the direction of the transverse magnetic field is the q axis.

Efficient rotation of the motor requires appropriate current control to keep a transverse magnetic field generated constantly. To consider generation of the transverse magnetic field, assume that a coil is positioned in the direction of the q axis and the current to be passed through the coil is the q-axis current (Iq). The intensity of the transverse magnetic field is proportional to the intensity of the q-axis current.

If the motor speed is lower than expected, the q-axis current must be increased to increase the torque for acceleration. If the motor speed is higher than expected, the q-axis current must be reduced to reduce the torque for deceleration.

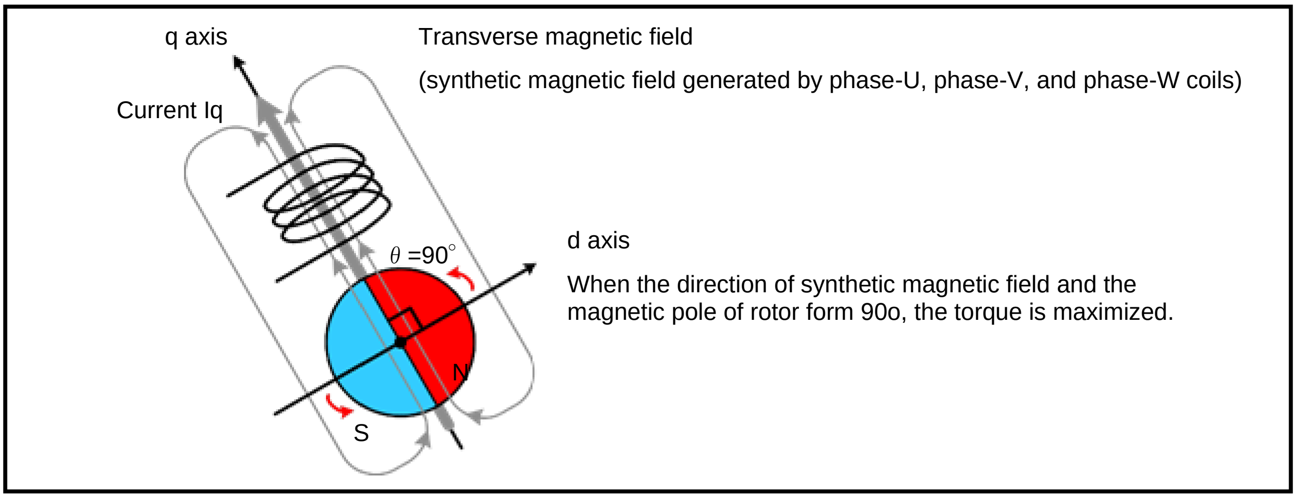

Figure 1.2 Relationship between Synthetic Magnetic Field and Torque

1.2 Concept of Motor Control

To efficiently control the motor, the d-axis and q-axis currents must be controlled according to the motor speed. Therefore, values of d-axis and q-axis currents must be calculated. Because the q-axis current has intensity and direction, which are treated as vector quantities, this control method is called "vector control".

The target values (command values) of d-axis and q-axis currents are determined by the difference between target motor speed and present motor speed. Simple modeling of vector control assumes the D-axis current to be 0 because the D-axis current does not contribute to any torque components. The voltage value to be output next is obtained based on the difference (deviation) between the d-axis current and q-axis current values that is calculated from the command values of d-axis current and q-axis currents and measured coil current. The control operation in which the previous output results (present motor speed and coil current value) are fed back and reflected in the next output is called "feedback control".

To calculate the voltage to be output next from the deviation of present current value, components proportional to the cumulated past deviation are added to those proportional to present deviation. This processing is repeated to control the output voltage and the coil current flowing as the result of voltage output to adjust present motor speed to the target motor speed. This control method is called "proportional-integral (PI) control."

Values of q-axis current and d-axis current are obtained by coordinate conversions (3-phase to 2-phase conversion, then rotating coordinate conversion) of coil currents. Figure 1.3 shows the coordinate conversions.

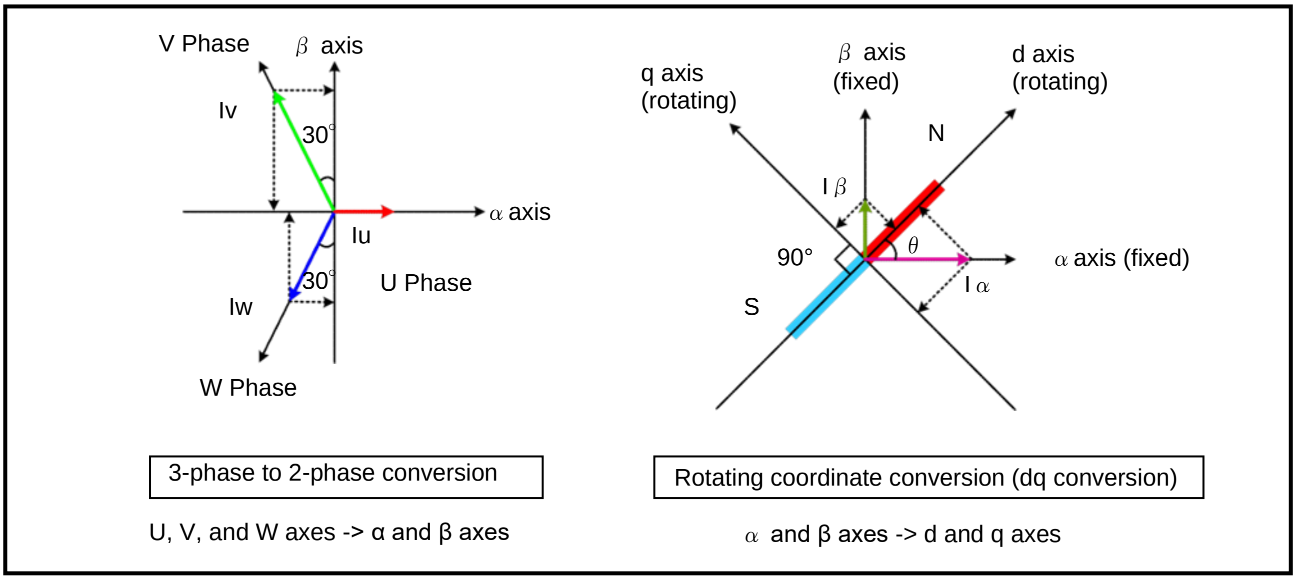

Figure 1.3 Coordinate Conversions

Calculate values of currents Iα and Iβ on the α and β axes by 3-phase to 2-phase conversion of the values of currents Iu, Iv, and Iw that are flowing through the phase-U, phase-V, and phase-W coils and were measured by the n'th measurement.

$$\begin{pmatrix} I_\alpha(n) \\ I_\beta(n) \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} \cos 0 & \cos\frac{2}{3}\pi & \cos\frac{4}{3}\pi \\ \sin 0 & \sin\frac{2}{3}\pi & \sin\frac{4}{3}\pi \end{pmatrix} \begin{pmatrix} I_u(n) \\ I_v(n) \\ I_w(n) \end{pmatrix}$$

Perform rotating coordinate conversion of Iα and Iβ obtained by the 3-phase to 2-phase conversion to calculate values of currents Id and Iq on the d and q axes.

$$\begin{pmatrix} I_d(n) \\ I_q(n) \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} I_\alpha(n) \\ I_\beta(n) \end{pmatrix}$$

Calculate the deviation between d-axis and q-axis currents, and then calculate d-axis and q-axis voltages by PI control.

$$\varepsilon_d(n) = I_{dt} - I_d(n)$$

$$\varepsilon_q(n) = I_{qt} - I_q(n)$$

$$V_d(n) = V_d(n-1) + K_P \cdot \{\varepsilon_d(n) - \varepsilon_d(n-1)\} + K_I \cdot \varepsilon_d(n) \cdot \Delta t$$

$$V_q(n) = V_q(n-1) + K_P \cdot \{\varepsilon_q(n) - \varepsilon_q(n-1)\} + K_I \cdot \varepsilon_q(n) \cdot \Delta t$$

Remarks:
- Idt: Command value of d-axis current
- Iqt: Command value of q-axis current
- Id(n): d-axis current sampled by n'th sampling
- Iq(n): q-axis current sampled by n'th sampling
- KP: Proportional gain
- KI: Integration gain
- Δt: Sampling time
- ε d: Deviation of d-axis current
- ε q: Deviation of q-axis current

Convert the q-axis and d-axis voltages calculate above by coordinate conversions (fixed coordinate conversion and 2-phas to 3-phase conversion) to obtain output voltages in U, V, and W phases. The equation of fixed coordinate conversion is as follows:

$$\begin{pmatrix} V_\alpha(n) \\ V_\beta(n) \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} V_d(n) \\ V_q(n) \end{pmatrix}$$

The equation of 2-phase to 3-phase conversion is as follows:

$$\begin{pmatrix} V_u(n) \\ V_v(n) \\ V_w(n) \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} \cos 0 & \sin 0 \\ \cos\frac{2}{3}\pi & \sin\frac{2}{3}\pi \\ \cos\frac{4}{3}\pi & \sin\frac{4}{3}\pi \end{pmatrix} \begin{pmatrix} V_\alpha(n) \\ V_\beta(n) \end{pmatrix}$$

1.3 PWM Output Using U/V/W-Phase Voltages

To actually output a PWM waveform from the microcontroller, the phase-U, phase-V, and phase-W voltages (Vu, Vv, and Vw) obtained by two-phase to three-phase voltage conversion of d-axis and q-axis voltages, which are operating quantities, must be reflected in the PWM duty. This section describes how to reflect the voltages.

1.3.1 Triangular Wave Comparison Method

The triangular wave comparison method is a PWM control method. As shown in Figure 1.4, a PWM signal is generated through magnitude comparison between the phase-U/V/W voltage waveform and a triangular wave. This method has still been used widely since the days when PWM signals were generated by using analog circuits. This triangular wave is called the "carrier wave" of which the frequency specifies the operating cycle of PWM. When the phase-U/V/W voltage is higher than the magnitude of triangular wave, the PWM signal is set to the high level (active level). When the phase-U/V/W voltage is lower than the magnitude of triangular wave, the PWM signal is set to the low level (inactive level). Changing the average voltage in such a way enables the phase-U/V/W voltage (sinusoidal wave) to be reproduced in a pseudo manner. For details about this method, see a relevant technical document.

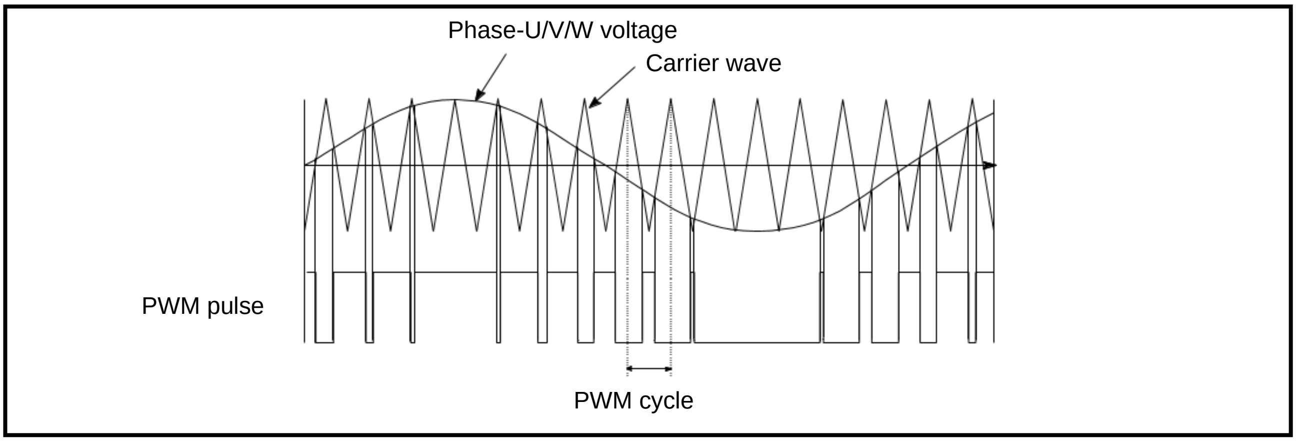

Figure 1.4 Triangular Wave Comparison Method

The triangular wave comparison method is also called "triangular wave modulation". Using the triangular wave comparison method, you can perform PWM control of the three-phase voltage of the permanent magnet synchronous motor. Then, the type of PWM output to be used is complemented PWM output (that is, PWM output with dead time).

1.4 Voltage Equation for PMSM Voltages in dq Coordinate System (Reference Information)

1.4.1 Voltage Equation

The voltage equation for the PMSM voltages in the dq coordinate system is shown below. This voltage equation can be used to convert currents Id an Iq into voltages Vd and Vq. Note, however, that this sample program uses PI control for current conversion into voltages.

$$\begin{bmatrix} vd \\ vq \end{bmatrix} = \begin{bmatrix} Ra + pLd & -\omega Lq \\ \omega Ld & Ra + pLq \end{bmatrix} \begin{bmatrix} id \\ iq \end{bmatrix} + \begin{bmatrix} 0 \\ \omega\varphi a \end{bmatrix} \quad p = \frac{d}{dt}$$

Remarks:

vd, vq ：: Armature voltage in individual phase

Ra: Armature resistance in individual phase

Ld, Lq: Self-inductance in individual phase

id, iq: Armature current in individual phase

ω: Angular speed of motor

ϕ: Flux of permanent magnet φa=√(2/3) φ

p: Differential operator

For details about the process of deriving this equation, see a relevant technical document.

This equation is not used for actual control (but is only used to derive the equation for non-interference control from the voltage equation).

1.4.2 Non-Interference Control

Laplace transformation transforms the motor voltage equation shown in Section 1.4.1 into the following expressions:

$$Id = \frac{1}{Ra + sLd}(Vd + \omega LqIq)$$

$$Iq = \frac{1}{Ra + sLq}\left(Vq - \omega\left(LdId + \sqrt{\frac{2}{3}}\varphi\right)\right)$$

Remarks: s: Laplace operator

These expressions show that the expression for the d axis includes some information on the q axis and the expression for the q axis includes some information on the d axis. Non-interference control refers to the control method in which said information is removed beforehand.

To perform non-interference control, you need to know motor parameters in advance. Note that the Non-interference control is a type of feed forward control.

Actual current control uses PI control. If, however, another factor affects the PI control while currents (Id and Iq) are not controlled constantly, adjustment of the PI control is difficult. Non-interference control is used to avoid such a problem.

2. Specifications

In this application note, motor control is performed using 12-bit A/D converter (ADCK), R/D converter (RDC3AL), Generic Timer Module (GTM), and Peripheral Interconnection (PIC).

Measure the motor current value with the A/D converter and get angle information in the R/D converter. When conversion is complete, the CPU performs vector control based on the motor current value, angle information, and generates a PWM compare value. Based on the compare value, GTM generates and outputs a sine wave PWM waveform in a triangular wave comparison method.

In this application note, the CPU performs only the current command value setting and PWM compare value generation, and other controls are only done with hardware without the CPU.

The RH850/U2B6 supports two motors.

Table 2.1 shows the motor control specifications, Table 2.2 shows the setting contents of each module, Figure 2.1 shows the system configuration diagram (RH850/U2B6) for 2 motors, and Figure 2.2 shows the control flow diagram of fully automatic processing.

Table 2.1 Motor Control Specifications

Item	Specification
Output waveform	Complemented 3-phase PWM waveform
Carrier frequency	8 kHz (125 µsec/cycle)
Control method	180-degree excitation drive method
Active level	Active high
Short-circuit prevention time (dead time)	2.5 µsec
Timing of updating compare register and carrier frequency	Trough of the carrier wave
Timing of starting A/D conversion	Trough of the carrier wave
Interrupt	Used (125usec interrupt) Transfer completed career wave valley time
Motor current value	The ADCK0 obtains values of phase-U, V, W currents.
Motor angle information	The RDC3AL obtains angle information from resolver.

Table 2.2 Module Settings

Peripheral Function	Setting
RDC3AL	· Use an excitation signal of 10 kHz generated inside RDC3AL · PI compensator bandwidth is automatic setting · BIST and self-diagnosis will not be performed
sDMAC	・Hardware transfer factors ・Transfer the angle value from RDC3AL to RAM with the signal from GTM as a trigger
PIC	· Use signal from GTM to trigger of ADCK0 scan group 4
ADCK	· A/D conversion of scan group 4(SG4) consisting of Virtual channels 0 (V phase), 1 (W phase), 2 (U-phase) · T&H A/D conversion mode · Scan once for each trigger in multi-cycle scan mode · Scan group 4 hardware trigger input is valid · Scan group 4 end interrupt signal is enabled
GTM	· SOMP mode (up-down count mode) · Career cycle: 125us · Deadtime: 2.5us · Activate A/D conversion at the valley timing of carrier wave
CPU processing	・Generate PWM compare value with AD completion interrupt function ・Get current value from ADCK and angle from RDC3AL

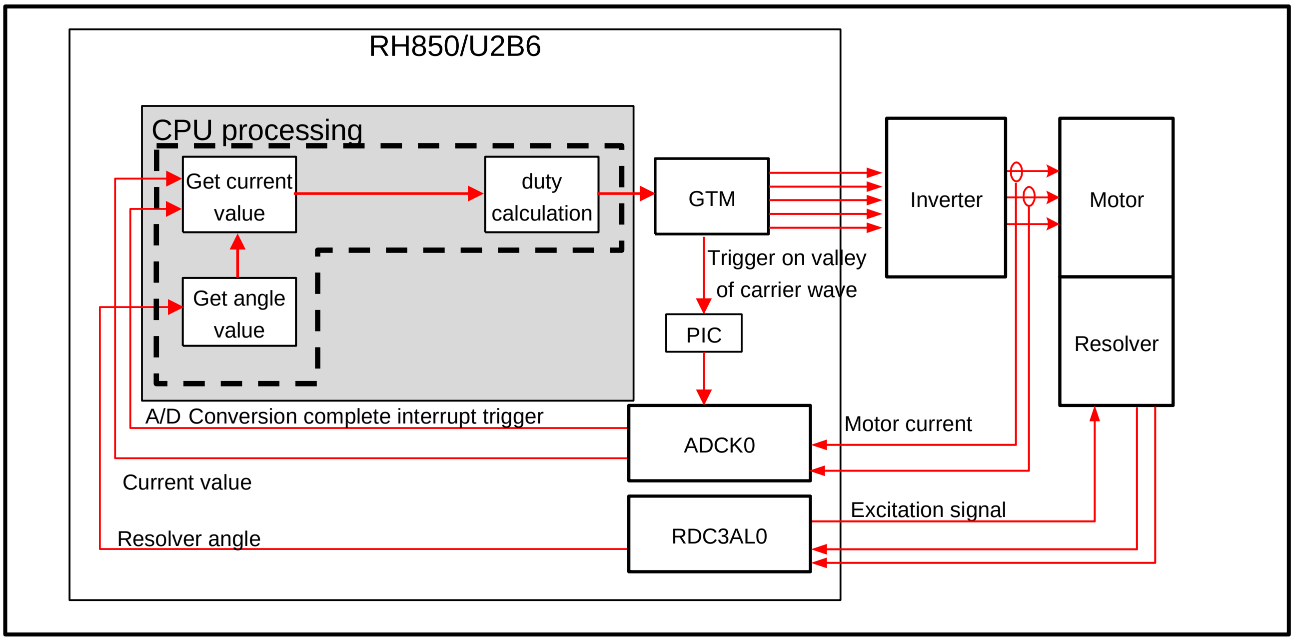

Figure 2.1 System Configuration (RH850/U2B6)

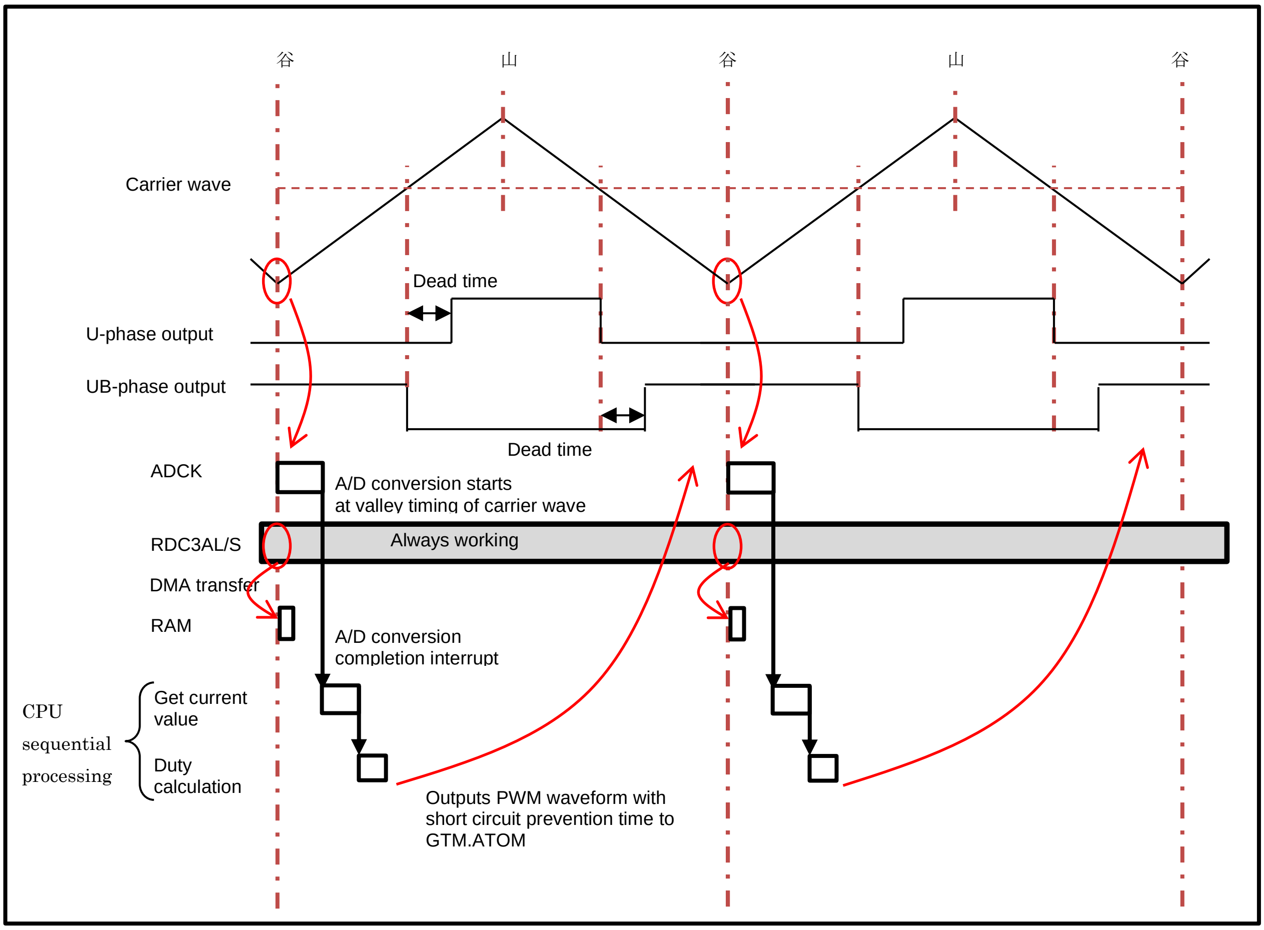

Figure 2.2 Control flow

3. Operation Conditions

The sample code for this application note is checked under the following conditions.

Table 3.1 Operation Check Conditions

Item	Condition
Microcontroller	RH850/U2B6
Operating frequency	- Main OSC: 20 MHz - CPU clock: 400 MHz Unmodulated high-speed peripheral clock: 80 MHz Unmodulated low-speed peripheral clock: 40 MHz GTM-ATOM operating clock: 100MHz
Operating voltage	VDD = 1.12 V PVCC = 5.0 V
Integrated development environment	Renesas Electronics' CS+ E8.08.00
C compiler	Renesas Electronics' C Compiler Package for RH850 Family V2.02.00
	Compilation options Default settings of the integrated development environment
Sample code version	Version 1.00

4. Used terminal and function

Table 4.1 lists the pins to be used and their functions.

Table 4.1 Pins to be Used and their Functions

Module	Pin name	In/Out	Function
ADCK	ADCK0I00	Input	Input of measured phase-V current
	ADCK0I01	Input	Input of measured phase-W current
	ADCK0I02	Input	Input of measured phase-U current
RDC3AL	RDC3AL0S1	Input	Input of resolver signal (cosθ)
	RDC3AL0S3	Input	Input of resolver signal (cosθ)
	RDC3AL0S2	Input	Input of resolver signal (sinθ)
	RDC3AL0S4	Input	Input of resolver signal (sinθ)
	RDC3AL0RSO	Output	Output of excitation signal
	RDC3AL0COM	Output	Output of common voltage for excitation signal
PORT	P12_0: ATOM0_CH0_OUT	Output	Output of upper-armature phase-U signal
	P12_1: ATOM0_CH1_OUT	Output	Output of lower-armature phase-U signal
	P12_2: ATOM0_CH2_OUT	Output	Output of upper-armature phase-V signal
	P12_4: ATOM0_CH0_OUT_N	Output	Output of lower-armature phase-V signal
	P12_5: ATOM0_CH1_OUT_N	Output	Output of upper-armature phase-W signal
	P12_6: ATOM0_CH2_OUT_N	Output	Output of lower-armature phase-W signal

Table 4.2 PORT setting

Register name	Setting value	Function
PCR12_0	0x0000004D	ATOM0ch0 output
PCR12_1	0x0000004D	ATOM0ch1 output
PCR12_2	0x0000004D	ATOM0ch2 output
PCR12_4	0x0000004D	ATOM0ch0_N output
PCR12_5	0x0000004D	ATOM0ch1_N output
PCR12_6	0x0000004D	ATOM0ch2_N output

Table 4.3 INTC2 setting

Register name	Setting value	Function
EIC70	0x004F	INTSDMAC0CH0 SDMAC transfer end interrupt
EIC086	0x004F	Activate to CH0-CH2
EIC441	0x004F	INTADCK0I0 AD conversion SG4 completion interrupt

5. Hardware Operation

5.1 Operation overview

The following describes motor control operation:

(1) A trigger signal is input from the GTM to the A/D converter via the PIC at the trough timing of the carrier wave. A/D converts virtual channels 0 to 3 of ADCK0 group 4 to obtain the current values of the U, V, and W phases of the motor. At the same time, sDMAC transfers the angle converted by RDC3AL to RAM.

(2) When the A/D conversion is completed, the A/D conversion completion interrupt function is called and the PWM compare value is calculated.

(3) The PWM compare value is stored in the GTM ATOM shadow register and set to the GTM ATOM compare register at the next reload timing. Three-phase PWM waveforms are output from the corresponding GTM ATOM pins.

5.2 R/D Converter 3AL (RDC3AL)

The RDC3AL converts the analog signal output from the resolver into digital signals, and calculates an angle value (resolver angle value) and angular velocity.

5.3 DMA Controller (sDMAC)

Based on the signal output in synchronization with the carrier wave from GTM, the angle value from RDC3AL is transferred to RAM.

5.4 Peripheral Interconnection (PIC)

ADCK hardware trigger signal is generated based on the signal output from GTM in synchronization with the carrier wave.

5.5 A/D Converter (ADCK)

The ADCK performs A/D conversion of a motor current value, and inputs the converted value to the EMU3S. In the case of the motor control described in this application note, A/D conversion starts with a trigger that the PIC generates in response to a signal output from the EMU3S. When the trigger signal is input, the ADCK converts the phase-V current value input from AN000 pin, phase-W current value input from AN001 pin and phase-U current value input from AN002 pin. The phase-W current value is not used in the process.

5.6 General Timer Module (GTM)

GTM outputs a three-phase PWM waveform based on the compare value transferred by the interrupt function. In GTM, the 24-bit base counter (CHx_CN) transitions between 0 and CHx_CM0. A duty is generated from a compare match with the 24-bit compare register (CHx_CM1), and a three-phase PWM waveform with a short-circuit prevention time added is output. Figure 5.1 shows the three-phase PWM waveform timing diagram.

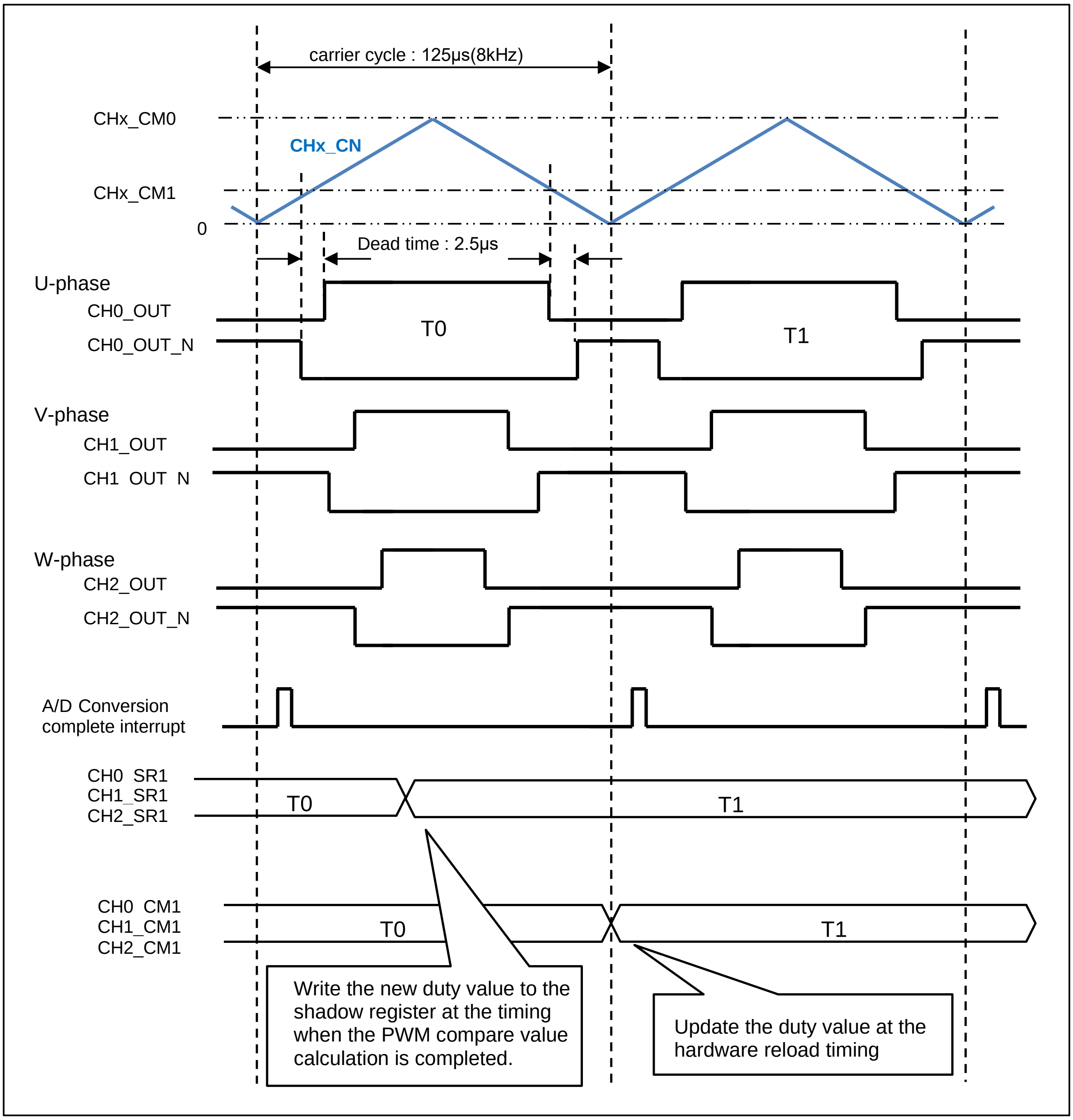

Figure 5.1 Three phase PWM waveform timing diagram

Table 5.1 GTM Operations

Items	Contents
Main clock	160MHz
Use clusters	Cluster 0
Main clock frequency	2 frequency division
Interrupt	Enable ATOM cyclic interrupts

Table 5.2 GTM common settings

Register Name	Set Value	Description
GTM_CTRL.RF_PROT	0	RST and FORCINT protection
GTM_CLS_CLK_CFG	0x0000002A	Supply a divide-by-2 clock to each cluster
GTM_IRQ_SEL000	0x00010000	Enable to ATOM0 CH0 interrupt output
GTM_DMA_SEL00	0x00000024	Select DMA trigger from GTM output
TBU_CHEN	0x00000056	Enable TBU channel ch0

Table 5.3 CMU setting

Register Name	Set Value	Description
CMU_CLK_EN	0x0000002A	Enable ch0 to ch2
CMU_GCLK_NUM	0x00000001	Default value. Don't change the frequency division.
CMU_GCLK_DEN	0x00000001	Default value. Don't change the frequency division.
CMU_CLK_0_CTRL	0x00000000	Default value. Don't change the frequency division.
CMU_CLK_1_CTRL	0x00000000	Default value. Don't change the frequency division.
CMU_CLK_2_CTRL	0x00000000	Default value. Don't change the frequency division.
CMU_CLK_CTRL	0x00000000	Default value.

Table 5.4 ATOM unit setting

Register Name	Set Value	Description
ATOM0_AGC_GLB_CTRL	0x00150000	Enable reloading of CM0, CM1, SL, CLK_SRC from ch0 to ch2
ATOM0_AGC_ENDIS_CTRL	0x0000002A	Enable ch0 to ch2
ATOM0_AGC_ENDIS_STAT	0x0000002A	Enable ch0 to ch2
ATOM0_AGC_OUTEN_CTRL	0x0000002A	Enable channel output ch0 to ch2
ATOM0_AGC_OUTEN_STAT	0x0000002A	Enable channel output ch0 to ch2
ATOM0_AGC_FUPD_CTRL	0x0015002A	Enable forced update of CN0 ch0 to ch2
ATOM0_AGC_INT_TRIG	0x0000002A	Enable interrupt trigger ch0 to ch2

Table 5.5 ATOM CH0 to CH2 setting

Register Name	Set Value	Description
ATOM0_CHx_CTRL	0x01040002	Select SOMP mode Select High as the initial signal level Select CM0 compare match as reset trigger Select TRIG_CCU0 as trigger output
ATOM0_CHx_CN0	0x00000000	Counter starts at 0
ATOM0_CHx_CM0	0x00001388	Since CN0 goes up and down by 1, set a value that is half of the target cycle.
ATOM0_CHx_SR0	0x00001388	
ATOM0_CHx_CM1	0x00000001	A compare value for the output. Set to a non-zero value for initial compare match
ATOM0_CHx_SR1	0x00000001	
ATOM0_CHx_IRQ_NOTIFY	0x00000003	Clear interrupt source
ATOM0_CHx_IRQ_EN	0x00000003	Enable interrupt

Table 5.6 DTM setting

Register Name	Set Value	Description
CDTM0_DTM4_CTRL	0x00000001	Do not update CTRL2 Clock selects CMU_CLK0
CDTM0_DTM4_CH_CTRL1	0x00000000	Do not route DTM_IN_T to DTM_OUT_N
CDTM0_DTM4_CH_CTRL2	0x00888888	Use dead time function from ch0-ch2
CDTM0_DTM4_CH_CTRL3	0x00000000	Default value
CDTM0_DTM4_CH0_DTV	0x00C800C8	Set 2.5us dead time on both edges
CDTM0_DTM4_CH1_DTV	0x00C800C8	Set 2.5us dead time on both edges
CDTM0_DTM4_CH2_DTV	0x00C800C8	Set 2.5us dead time on both edges
CDTM0_DTM4_CH0_DTV_SR	0xC0C8C0C8	Set 2.5us reload value on both edges
CDTM0_DTM4_CH1_DTV_SR	0xC0C8C0C8	Set 2.5us reload value on both edges
CDTM0_DTM4_CH2_DTV_SR	0xC0C8C0C8	Set 2.5us reload value on both edges

5.7 CPU interrupt processing PWM compare value generation

In this application note, a PWM compare value is generated in CPU interrupt processing.

5.8 File Configuration

Table 5.7 lists the files that are used for the sample code. Note that the list of files excludes the files that are automatically generated in the integrated development environment. This sample program has been confirmed to operate with Renesas' evaluation board. The process to confirm the operation is included.

Table 5.7 File Configuration

File name	Descript	Remarks
main0.c	CPU0 main module	CPU1: main1.c CPU2: main2.c CPU1, CPU2 main: infinite loop
user_int.c	Implement interrupt operation.	
rdc3al.c	R/D converter 3AL setting module	
pic.c	PIC setting module	
adck.c	A/D converter setting module	
gtm.c	GTM setting module	
port.c	Pin setting module	
sdmac.c	sDMAC setting module	
sdmac.h	sDMAC setting module header file	
iodefine.h	Register header file	
typedefs.h	type definition header file	

5.9 Functions

Table 5.8 lists functions.

Table 5.8 Functions

Function Name	Description
rdc3a_init	Initializes the R/D converter 3A.
pic_init	Initializes the PIC.
adck_init	Initializes the A/D converter.
gtm_init	Initializes the GTM
gtm_atom_enable	Enable ATOM channels
int_init	Initializes the Interrupts
int_ADCK0_VCH0_irq	ADCK SG4 A/D conversion completion interrupt processing
int_GTM0_ATOM_CH0_irq	GTM shared interrupt processing
int_SDMAC0_CH0_irq	sDMAC transfer end interrupt processing
port_init	Initializes the pins.
sdmac0_ch0_init	Initializes the sDMAC
sdmac0_ch0_start	Enable sDMAC transfer

5.10 Specifications of Functions Functional Specification

Indicates the function specification of the sample code.

rdc3al_init	
overview	Initialize R/D Converter 3AL.
header	iodefine.h
declaration	void rdc3al_init(void)
explanation	Initialize R/D Converter 3AL.
argument	none
return	none
remarks	none

pic_init	
overview	Initialize PIC.
header	iodefine.h
declaration	void pic_init(void)
explanation	This initial settings for PIC.
argument	none
return	none
remarks	none

adck_init	
overview	Initialize A/D converter.
header	iodefine.h
declaration	void adck_init(void)
explanation	Initialize A/D converter.
argument	none
return	none
remarks	none

gtm_init	
overview	Initialize GTM.
header	iodefine.h
declaration	void gtm_init(void)
explanation	Initialize GTM.
argument	none
return	none
remarks	none

gtm_ATOM_enable	
overview	Allow GTM ATOM operation.
header	iodefine.h
declaration	void gtm_ATOM_enable
explanation	Allow GTM Atom operation.
argument	none
return	none
remarks	none

int_init	
overview	Initialize the interrupt setting.
header	iodefine.h
declaration	void int_init(void)
explanation	Initialize the interrupt setting.
argument	none
return	none
remarks	none

int_ADCK0_VCH0_irq	
overview	ADCK SG4 A/D conversion completion interrupt processing is performed.
header	iodefine.h, typedefs.h, emu3.h
declaration	void int_ADCK0_VCH0_irq(void)
explanation	ADCK SG4 A/D conversion completion interrupt processing is performed.
argument	none
return	none
remarks	none

port_init	
overview	Initialize the terminal Port.
header	iodefine.h
declaration	void port_init(void)
explanation	Initialize the terminal Port.
argument	none
return	none
remarks	none

sdmac0_ch0_init	
overview	Initialize the sDMAC
header	iodefine.h, sdmac.h, emu3.h
declaration	void sdmac0_ch0_init (void)
explanation	Initialize the sDMAC
argument	none
return	none
remarks	none

sdmac0_ch0_start	
overview	Enable sDMAC transfer
header	iodefine.h, sdmac.h
declaration	void sdmac0_ch0_start (void)
explanation	Enable sDMAC transfer
argument	none
return	none
remarks	none

5.11 Flowcharts

Figure 5.2 shows the flow of main processing. Figure 5.3 shows the flow of RDC3AL initialization. Figure 5.4 shows the flow of PIC initialization. Figure 5.5 shows the flow of ADCK initialization. Figure 5.6 shows the flow of GTM initialization. Figure 5.7 shows the flow of pin initialization and Figure 5.8 shows the flow of sDMAC initialization.

Clock supply settings and register synchronization processing are inserted in each function as necessary, but they are omitted in the flow chart.

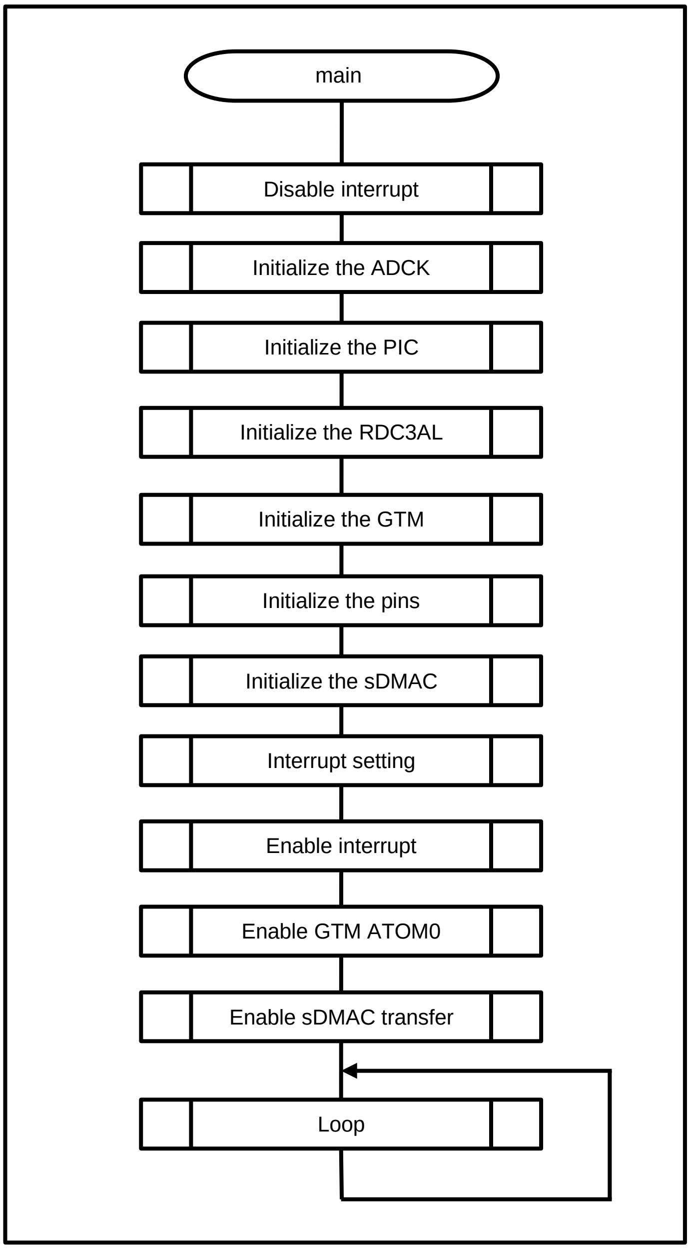

Figure 5.2 PE1 Main Processing

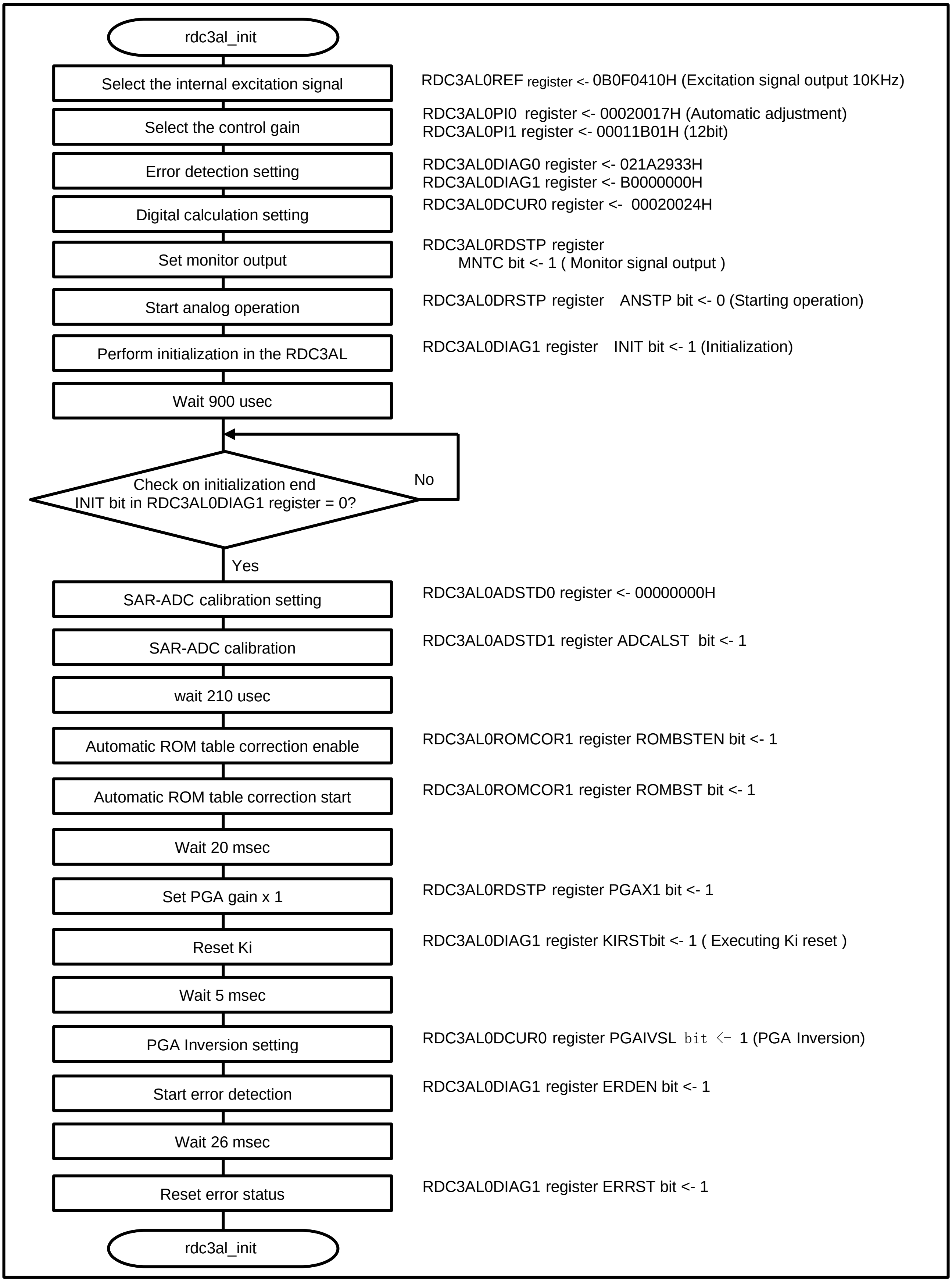

Figure 5.3 RDC3AL Initialization

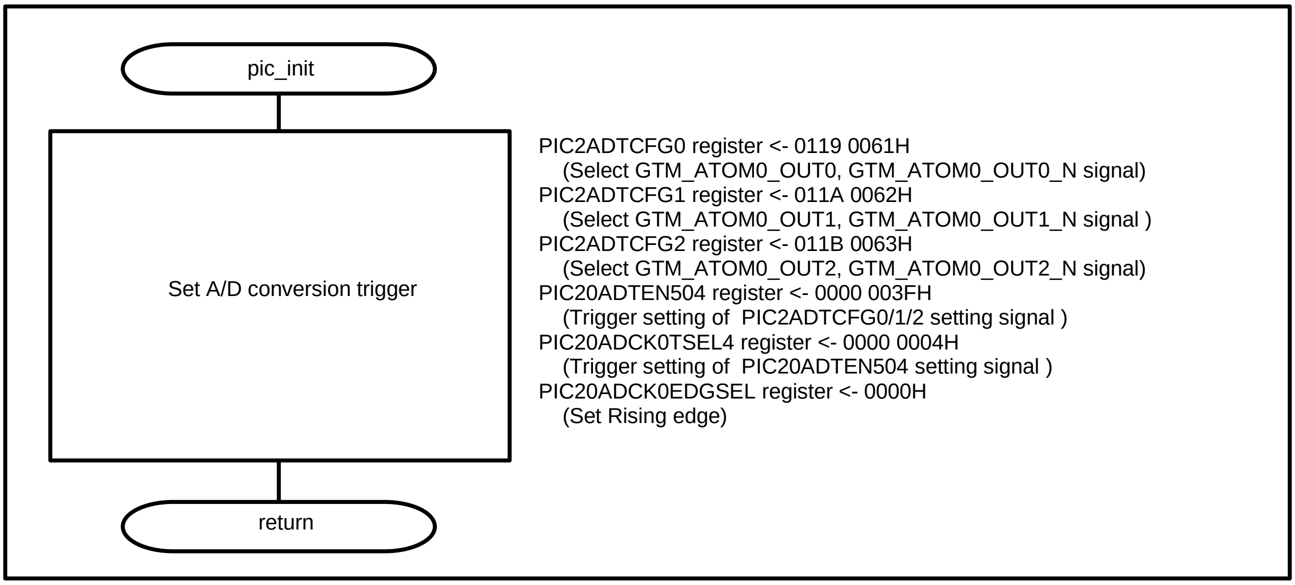

Figure 5.4 PIC Initialization

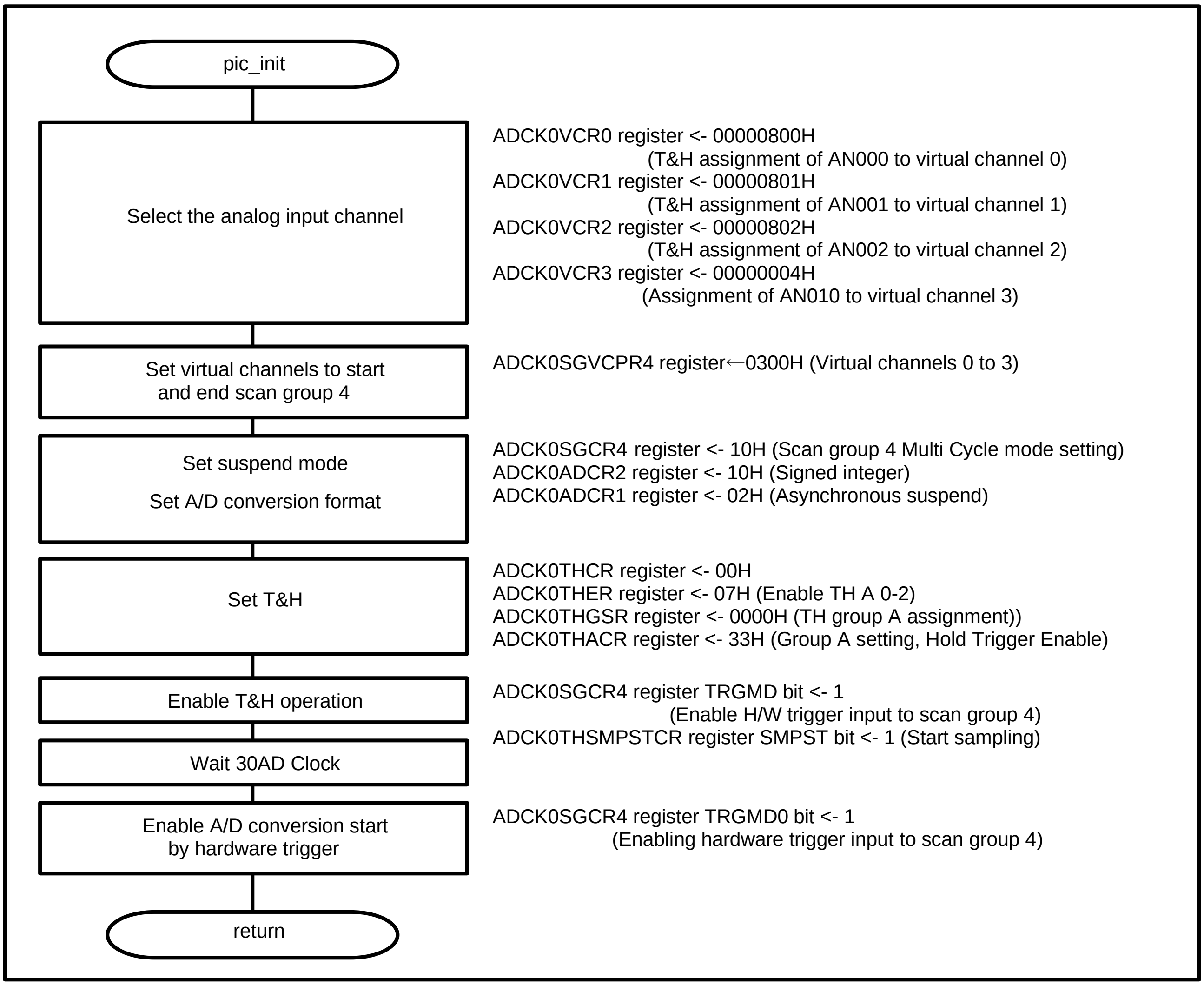

Figure 5.5 ADCK Initialization

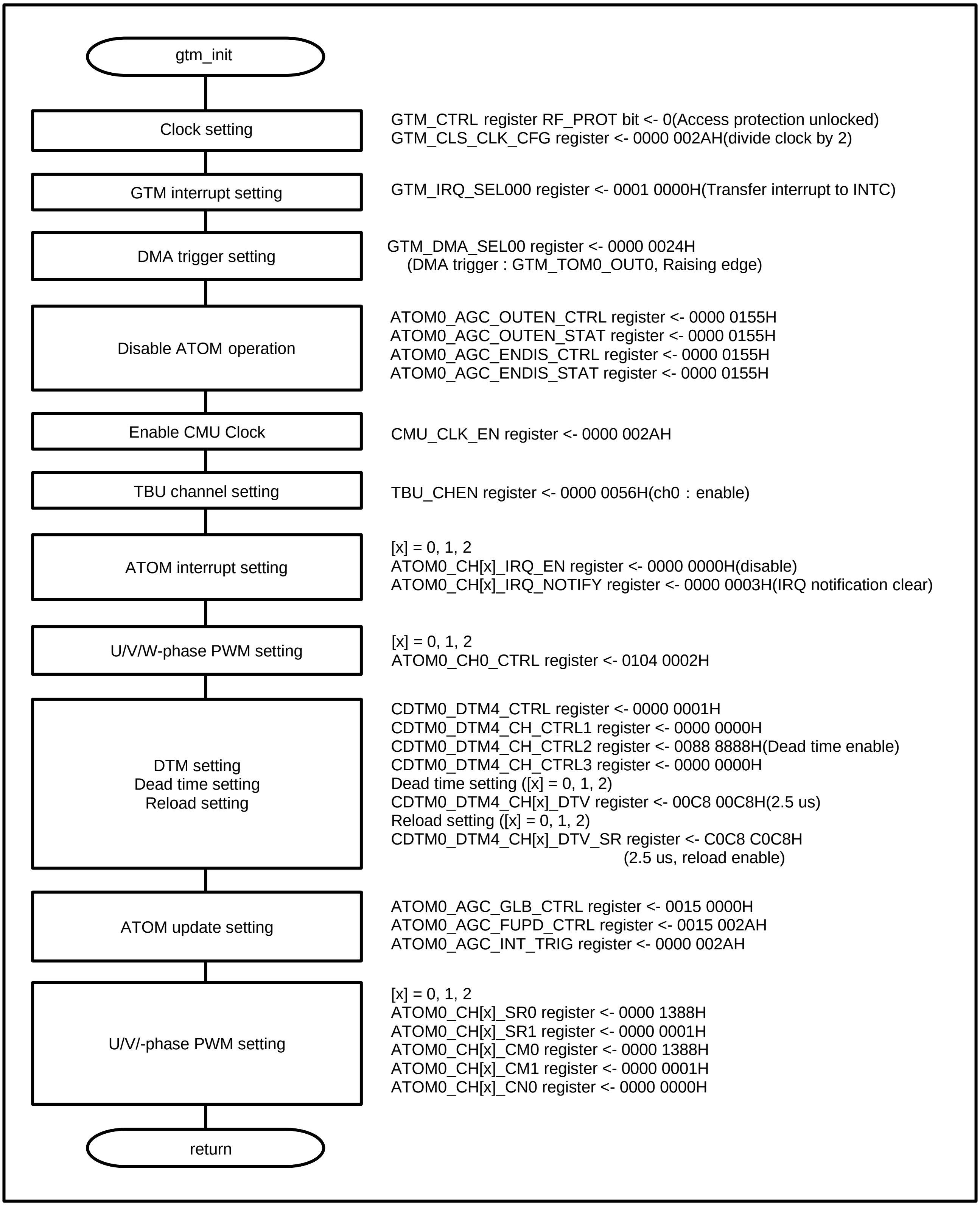

Figure 5.6 GTM Initialization

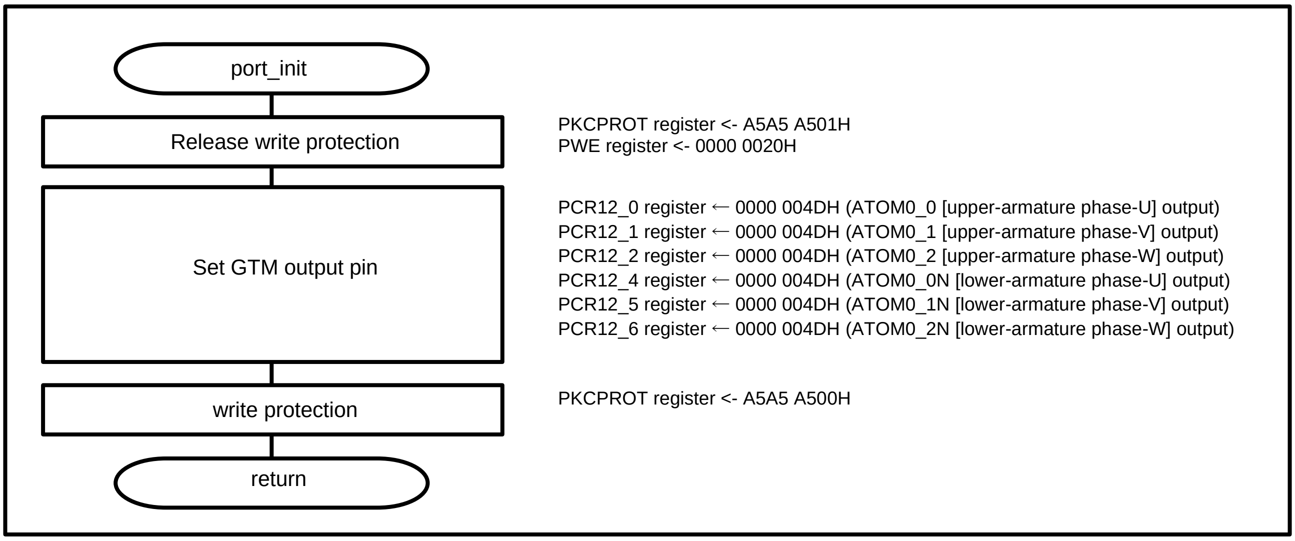

Figure 5.7 Pin setting

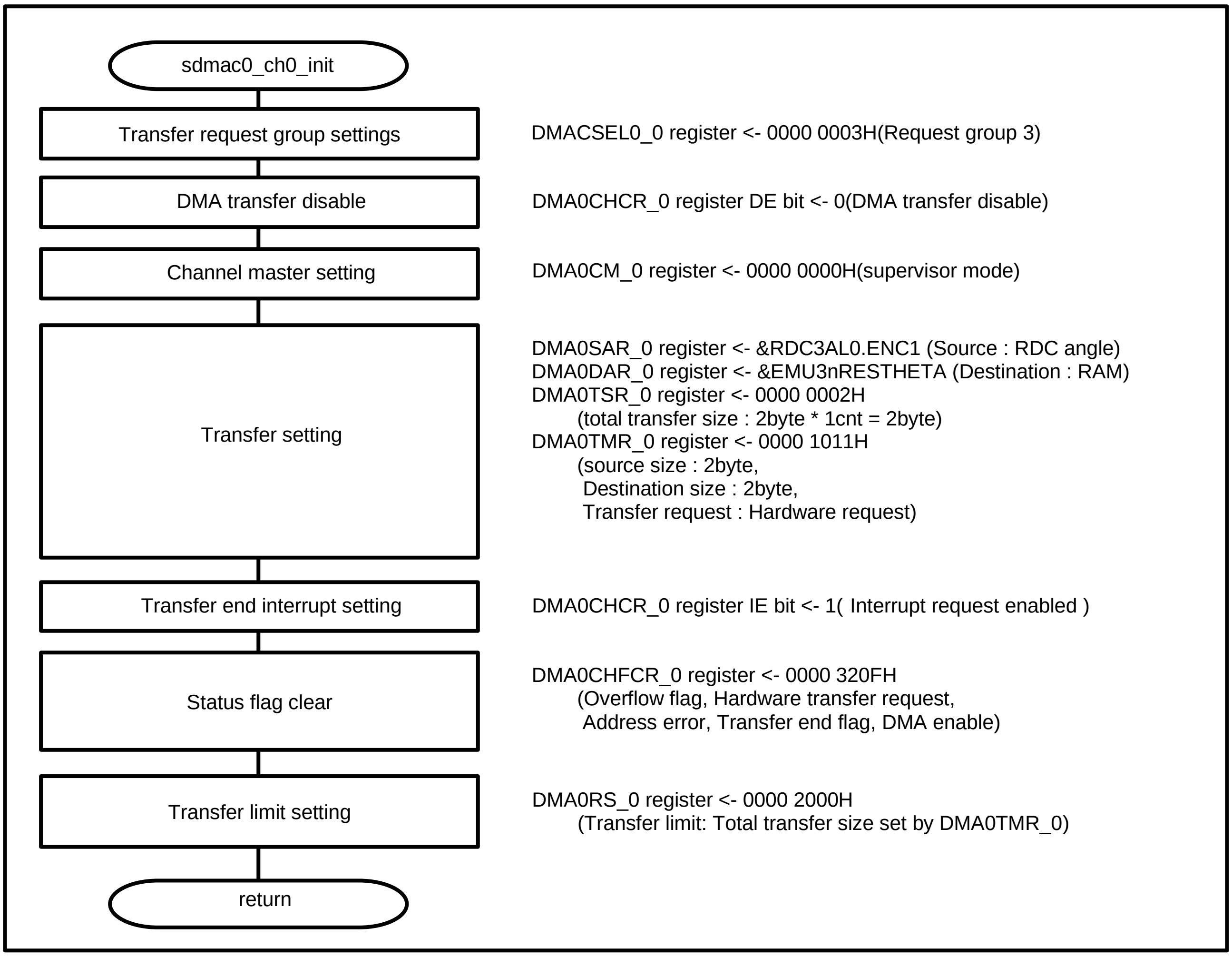

Figure 5.8 Current command value write processing with 100us interrupt

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	2022.10.12	-	First edition

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

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

1. Precaution against Electrostatic Discharge (ESD)

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

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

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

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

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

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

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

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

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(Rev.5.0-1 October 2020)

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