RX63T Group

Decimation of A/D Converter Activations Using the MTU3 Module

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Introduction

This application note describes the settings for delayed activation of the 12-bit A/D converter (S12ADB) used when generating three output phase complementary PWM (pulse-width modulation) waveforms using the RX63T Group microcontrollers' multifunction timer unit 3 (MTU3). This functionality allows A/D conversions to be performed with arbitrary timing.

Target Device

RX63T Group

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Contents

1. Specifications

The 12-bit A/D converter is activated multiple times during output of the three phases of complementary PWM waveforms from channels 3 and 4 (ch3 and ch4) of the MTU3 module. This sample code reduces that activation count by multiple instances (decimation). This section describes the specifications of this sample code.

Channels 3 and 4 of the MTU3 module output three phases of complementary PWM waveforms and also output a signal that is toggled in synchronization with the period of that waveform from the TIOC3A pin.

The 12-bit A/D converter is started on the compare match of TCNT_4 and TADCORA_4 when TCNT_4 is incremented.

The 12-bit A/D converter activation count is linked to the interrupt decimation of the ch3 compare match interrupt (TGIA3), and decimated by two activations.

The 12-bit A/D converter is operated in single mode.

The result of the 12-bit A/D conversion is stored in RAM at the 12-bit A/D conversion complete interrupt.

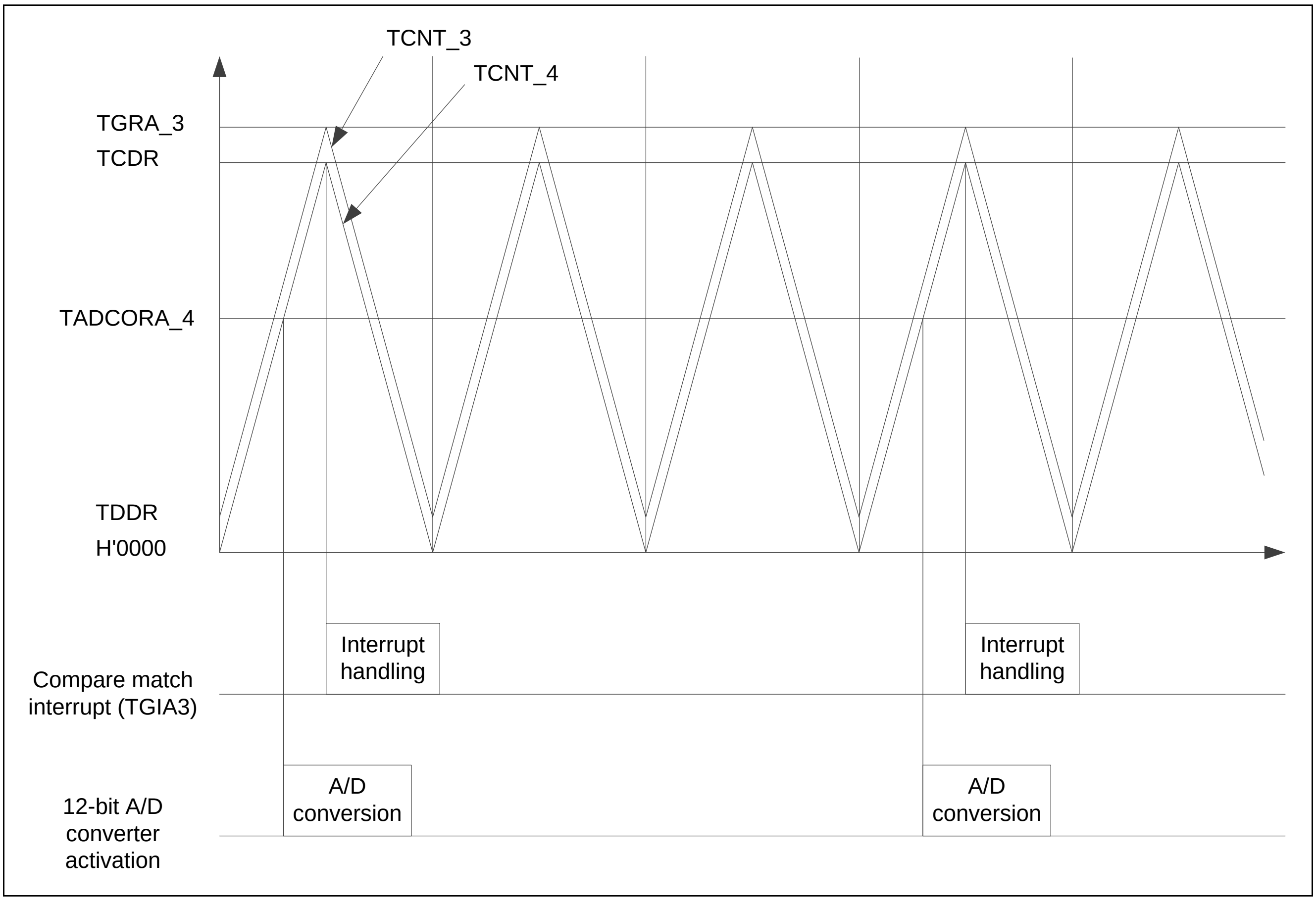

Figure 1.1 Usage Example

2. Operation Confirmation Conditions

The sample code accompanying this application note has been run and confirmed under the conditions below.

Table 2.1 Operation Confirmation Conditions

Item	Contents
MCU used	R5F563T6EDFM (RX63T Group)
Operating frequency	Main clock: 16.0 MHz PLL: 192 MHz (main clock divided by 1 and multiplied by 12) System clock (ICLK): 96 MHz (PLL divided by 2) Timer module clock A (PCLKA): 96 MHz (PLL divided by 2) Peripheral module clock B (PCLKB): 48 MHz (PLL divided by 4) S12AD module clock D (PCLKD): 48 MHz (PLL divided by 4) Flash IF clock (FCLK): 48 MHz (PLL divided by 4)
Operating voltage	3.3 V
Integrated development environment	Renesas Electronics Corporation High-performance Embedded Workshop Version 4.09.01.007
C compiler	Renesas Electronics Corporation RX Standard Toolchain Version 1.2.1.0
	Compiler option (The integrated development environment default settings are used.)
iodefine.h version	2.00
Endian order	Little endian
Operating mode	Single-chip mode
Processor mode	Supervisor mode
Sample code version	Version 1.00
Board used	Renesas Starter Kit for RX63T (Product number: R0K50563TS000BE)

3. Hardware

3.1 Pins Used

Table 3.1 lists the pins used and their functions.

Table 3.1 Pins Used and Their Functions

Pin Name	I/O	Function
P33/MTIOC3A	Output	Toggle output synchronized with the PWM output
P71/MTIOC3B	Output	PWM output 1 (Positive phase waveform)
P74/MTIOC3D	Output	PWM output 1’ (Reverse phase waveform)
P72/MTIOC4A	Output	PWM output 2 (Positive phase waveform)
P75/MTIOC4C	Output	PWM output 2’ (Reverse phase waveform)
P73/MTIOC4B	Output	PWM output 3 (Positive phase waveform)
P76/MTIOC4D	Output	PWM output 3’ (Reverse phase waveform)
P40/AN000	Input	Analog input pin

4. Software

4.1 Operation Overview

4.1.1 A/D converter activation decimation using MTU3

The 12-bit A/D converter (S12ADB) is started by the linking of the interrupt decimation function and the A/D conversion start request delay function of the multifunction timer unit 3 (MTU3). In the sample code, the decimation count is set to two times.

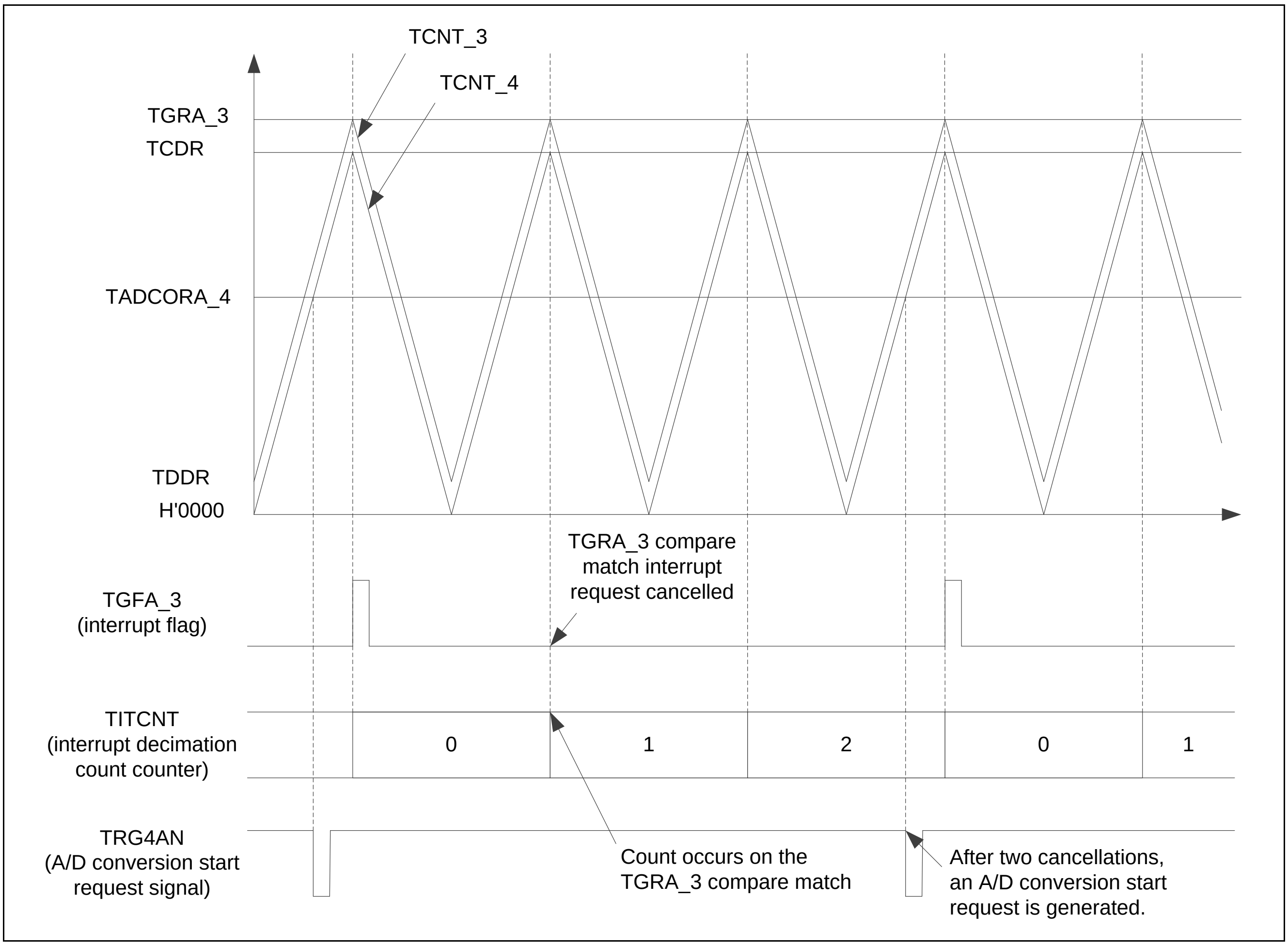

Figure 4.1 MTU3-Based A/D Converter Activation Decimation Operation Example

4.2 File Composition

Table 4.1 lists the files used in the sample code. Note that of the files automatically generated by the integrated development environment, those whose contents are not changed are not shown here.

Table 4.1 Files Used in the Sample Code

File Name	Outline	Remarks
r_init_stop_module.h	RX63T Group Sample initialization program	See the application note that describes the RX63T initialization example for details.
r_init_stop_module.c		
r_init_clock.h		
r_init_clock.c		
r_init_non_existent_port.h		
r_init_non_existent_port.c		
intprg.c	Vector function definitions TGIA3 interrupt and S12ADI interrupt functions added	
main.c	Main processing, MTU3 initialization, S12AD initialization, ICU initialization, TGIA3 interrupt handler, S12ADI interrupt handler	

4.3 Option-Setting Memory

Table 4.2 lists the option-setting memory configured in the sample code. When necessary, set a value suited to the user system.

Table 4.2 Option-Setting Memory Configured in the Sample Code

Symbol	Address	Setting Value	Contents
OFS0	FFFF FF8Fh to FFFF FF8Ch	FFFF FFFFh	After a reset, the IWDT is stopped. After a reset, the WDT is stopped.
OFS1	FFFF FF8Bh to FFFF FF88h	FFFF FFFFh	After a reset, voltage monitoring reset 0 is ignored.
MDES*[1]	FFFF FF83h to FFFF FF80h		(In single-chip mode)
		FFFF FFFFh	Little endian
		FFFF FFF8h	Big endian

Note: 1. The settings in this sample code set up little endian operation. See section 5.1, Endian, for details on switching the endian mode.

4.4 Constants

Table 4.3 lists the constants used in the sample code.

Table 4.3 Constants Used in the Sample Code

Constant Name	Setting Value	Contents
PWM_DEAD_TIME	12BFh	Sets the dead time
CARRIER_1_2CYCLE	BB7Fh	Sets one-half of the carrier period
PWM_DUTY3D	95FFh	Sets the PWM1 duty
PWM_DUTY4C	707Fh	Sets the PWM2 duty
PWM_DUTY4D	4AFFh	Sets the PWM3 duty
AD_START	5DBFh	Sets the 12-bit A/D converter start timing

4.5 Variables

Table 4.4 lists the static variables.

Table 4.4 static Variables

Type	Variable Name	Contents	Function Used
uint16_t	g_adc_data	Storage for the A/D conversion result	s12adi_interrupt
uint16_t	g_ad_start	A/D conversion start timing (set in TADCOBRA_4)	main, tgia3_interrupt
uint16_t	g_pwm_duty3d	Duty of the PWM waveform output from the TIOC3D pin (set in MTU3.TGRD)	
uint16_t	g_pwm_duty4c	Duty of the PWM waveform output from the TIOC4C pin (set in MTU4.TGRC)	
uint16_t	g_pwm_duty4d	Duty of the PWM waveform output from the TIOC4D pin (set in MTU4.TGRD)	
uint16_t	g_dead_time	Dead time (set in TDDRA)	
uint16_t	g_carrier_1_2cycle	One-half of the PWM carrier period (set in TCBRA)	

4.6 Functions

Table 4.5 lists the functions.

Table 4.5 Functions

Function Name	Outline
main	Main processing
icu_init	ICU initialization function
mtu_init	MTU3 initialization function
s12ad_init	S12AD initialization function
mpc_init	MPC initial settings function
pmr_init	PMR initial settings function
tgia3_interrupt	TGIA3 interrupt function
s12adi_interrupt	12-bit A/D conversion complete interrupt handler

4.7 Function Specifications

The following tables list the sample code function specifications.

main

Outline Main processing

Header None

Declaration void main(void)

Description This function performs the following processing.

- Setup for transition to the module stop state
- Initialization for ports that do not exist (64-pin package products)
- Clock setup
  (System clock (ICLK), timer module clock (PCLKA), peripheral module clock (PCLKB), and S12AD clock (PCLKD))
- MTU3 initialization
- S12AD initialization
- MPC initialization
- PMR initialization
- ICU initialization
- Starting the MTU3 channel 3 and 4 counter

Arguments None

Return Value None

icu_init

Outline ICU initialization function

Header None

Declaration static void icu_init(void)

Description This function performs the following processing.

- Clearing the TGIA3 interrupt request flag
- Setting the TGIA3 interrupt priority level
- Enabling the TGIA3 interrupt
- Clearing the S12ADI interrupt request flag
- Setting the S12ADI interrupt priority level
- Enabling the S12ADI interrupt

Arguments None

Return Value None

mtu_init	
Outline	MTU3 initialization function
Header	None
Declaration	static void mtu_init(void)
Description	This function performs the following processing. • Clearing the MTU3 module standby state • Stopping the MTU3 count output • Setting the MTU3 channel 3 and 4 counter clock • Setting the PWM period, the PWM1 to PWM3 duty ratio, the carrier period, and the dead time • Enabling the toggle output synchronized with the PWM period, setting the output level • Setting MTU3 channel 3 and 4 to complementary PWM mode • Enabling PWM waveform output
Arguments	None
Return Value	None

s12ad_init	
Outline	S12AD initialization function
Header	None
Declaration	static void s12ad_init(void)
Description	This function performs the following processing. • Clearing the S12AD module standby state • Sets the A/D data register to 12-bit precision right justified format. • Sets the A/D conversion start trigger to be compare match between MTU4.TADCORA and MTU4.TCNT. • Sets the A/D sampling state • Selects AN000 as the target for A/D conversion. • Sets the A/D converter to single cycle scan mode. • Enables the A/D conversion complete interrupt. • Enables the start of A/D conversion by synchronous and asynchronous triggers.
Arguments	None
Return Value	None
Remarks	None

mpc_s12ad_init	
Outline	MPC initial settings function for S12AD
Header	None
Declaration	void mpc_s12ad_init(void)
Description	The pins are set to the following functions using the MPC. • P40 → AN000
Arguments	None
Return Value	None
Remarks	None

mpc_init	
Outline	MPC initial settings function
Header	None
Declaration	void mpc_init(void)
Description	The pins are set to the following functions using the MPC. • P76 → MTIOC4D • P75 → MTIOC4C • P74 → MTIOC3D • P73 → MTIOC4B • P72 → MTIOC4A • P71 → MTIOC3B • P40 → AN000
Arguments	None
Return Value	None
Remarks	None

pmr_init	
Outline	PMR initial settings function
Header	None
Declaration	void pmr_init(void)
Description	Initializes the PMR. • Ports P76, P75, P74, P73, P72, P71, and P40 are used as peripheral functions.
Arguments	None
Return Value	None
Remarks	None

tgia3_interrupt	
Outline	TGIA3 interrupt function
Header	None
Declaration	void tgia3_interrupt(void)
Description	This function performs the following processing. • Clears the compare match request flag (MTU3.TSR.TGFA). <If the compare match request flag (MTU3.TSR.TGFA) was set:> — Sets the interrupt request flag (IR). • Updates the duty for each PWM output. • Updates the A/D conversion start timing.
Arguments	None
Return Value	None
Remarks	None

s12adi_interrupt

Outline	S12ADI interrupt function
Header	None
Declaration	void s12adi_interrupt(void)
Description	This function performs the following processing. • Stores the A/D conversion result in RAM.
Arguments	None
Return Value	None
Remarks	None

4.8 Flowcharts

4.8.1 Main Processing

Figure 4.2 shows the main processing.

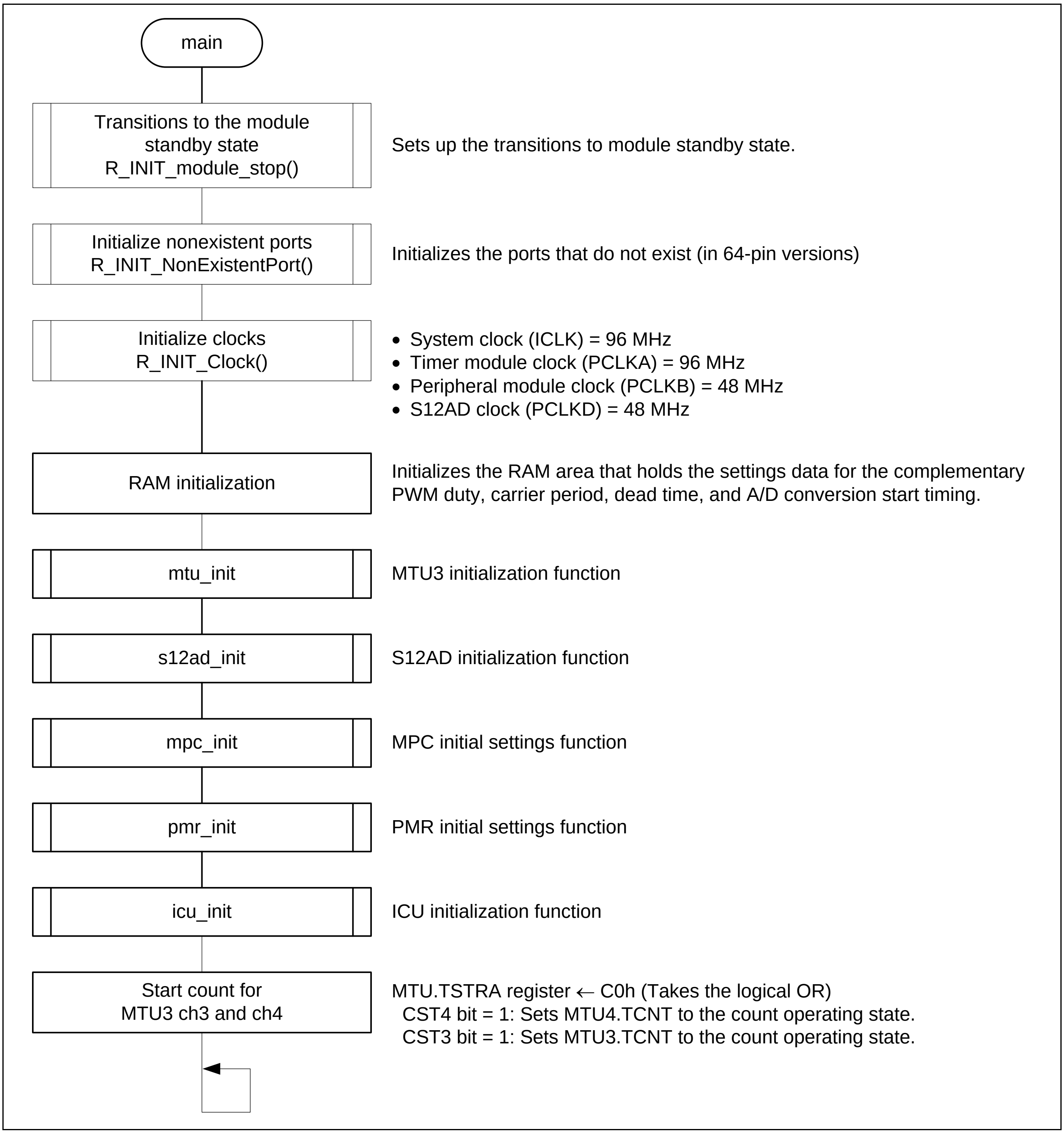

Figure 4.2 Main Processing

4.8.2 ICU Initialization Function

Figure 4.3 shows the flowchart for the ICU initialization function.

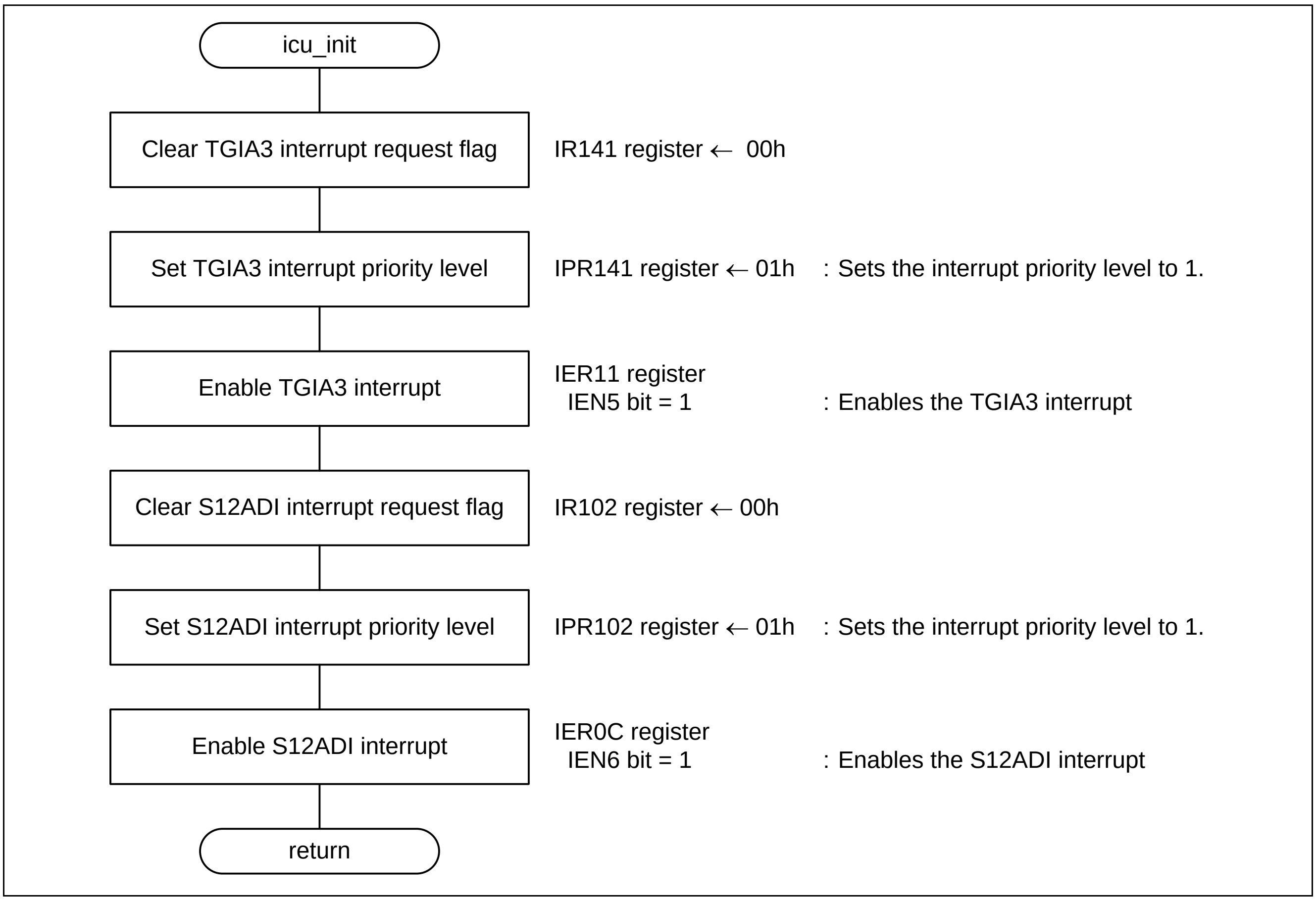

Figure 4.3 ICU Initialization Function

4.8.3 MTU3 Initialization Function

Figure 4.4 and figure 4.5 show the flowcharts for the MTU3 initialization function 1 and MTU3 initialization function 2.

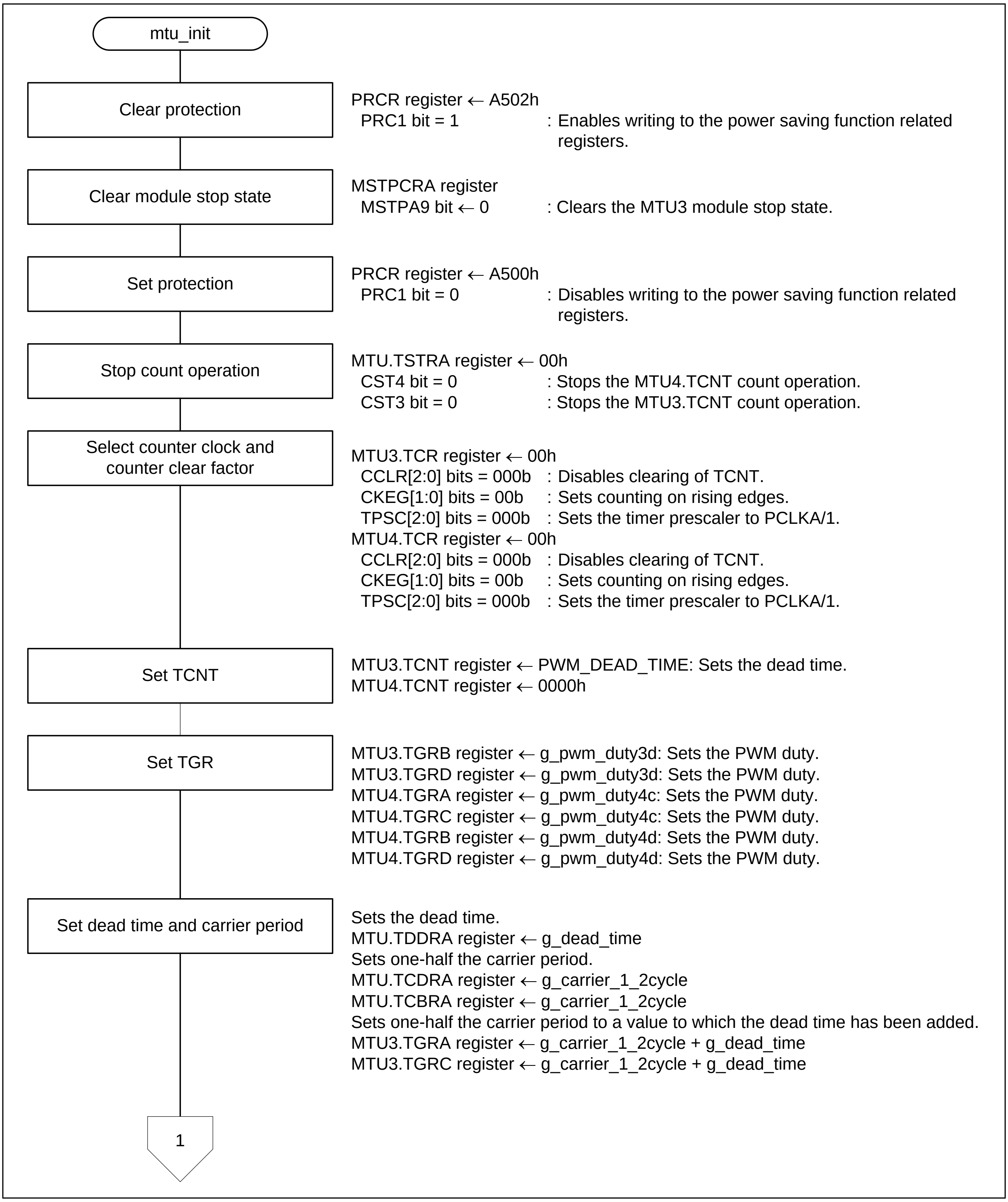

Figure 4.4 MTU3 Initialization Function 1

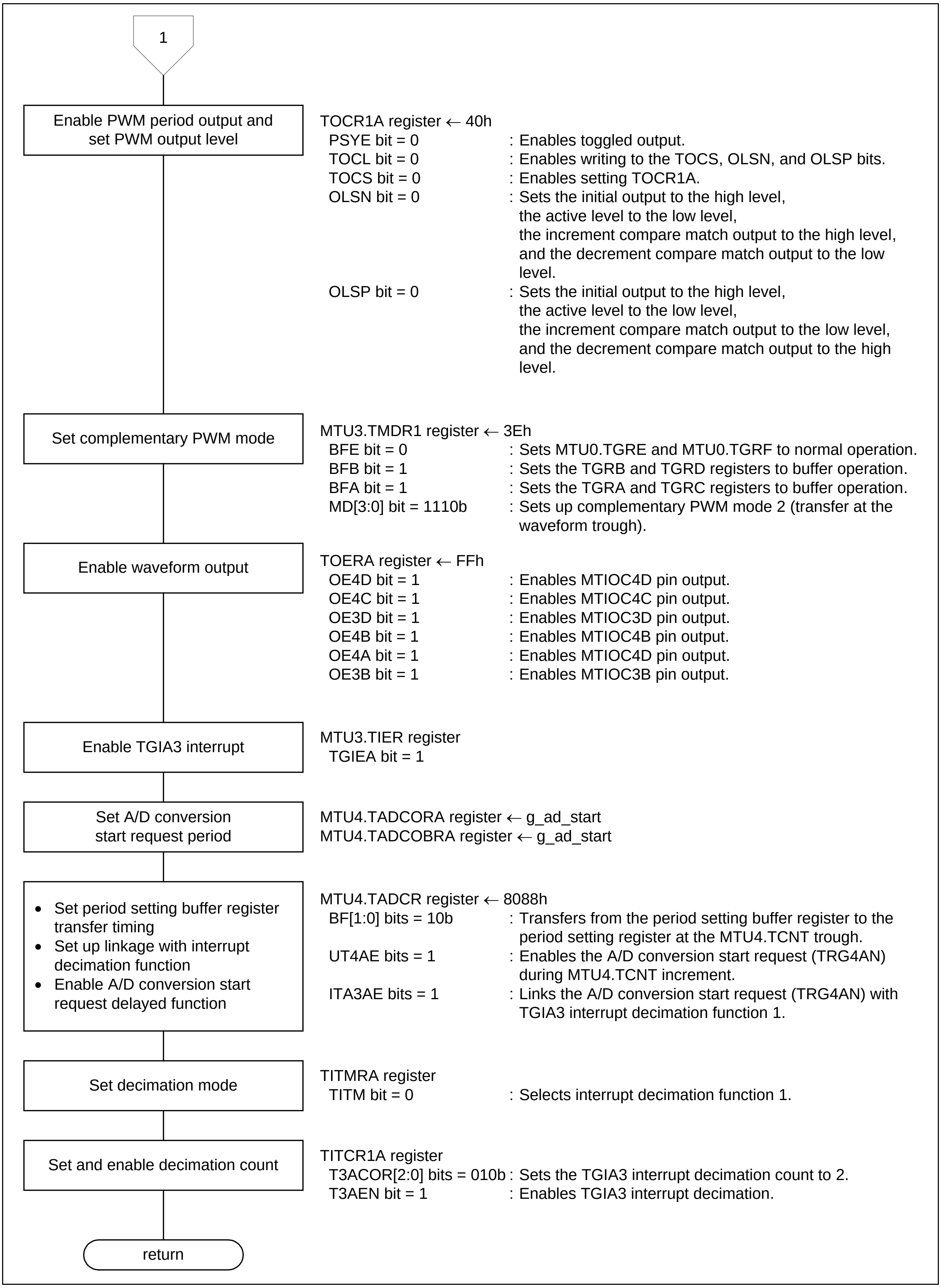

Figure 4.5 MTU3 Initialization Function 2

4.8.4 S12AD Initialization Function

Figure 4.6 shows the flowchart for the S12AD initialization function.

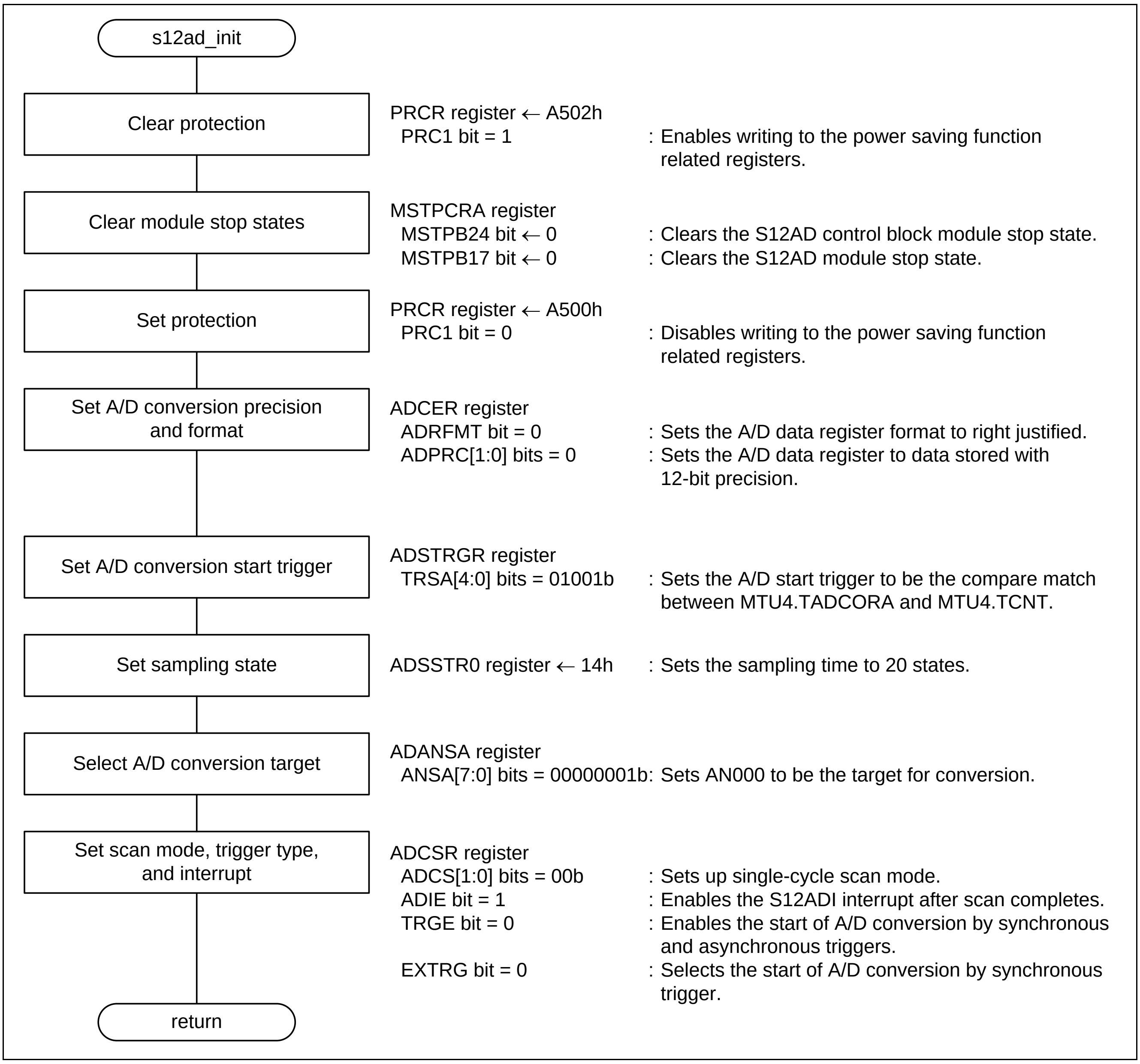

Figure 4.6 S12AD Initialization Function

4.8.5 MPC Initialization Function

Figure 4.7 shows the flowchart for the MPC initialization function.

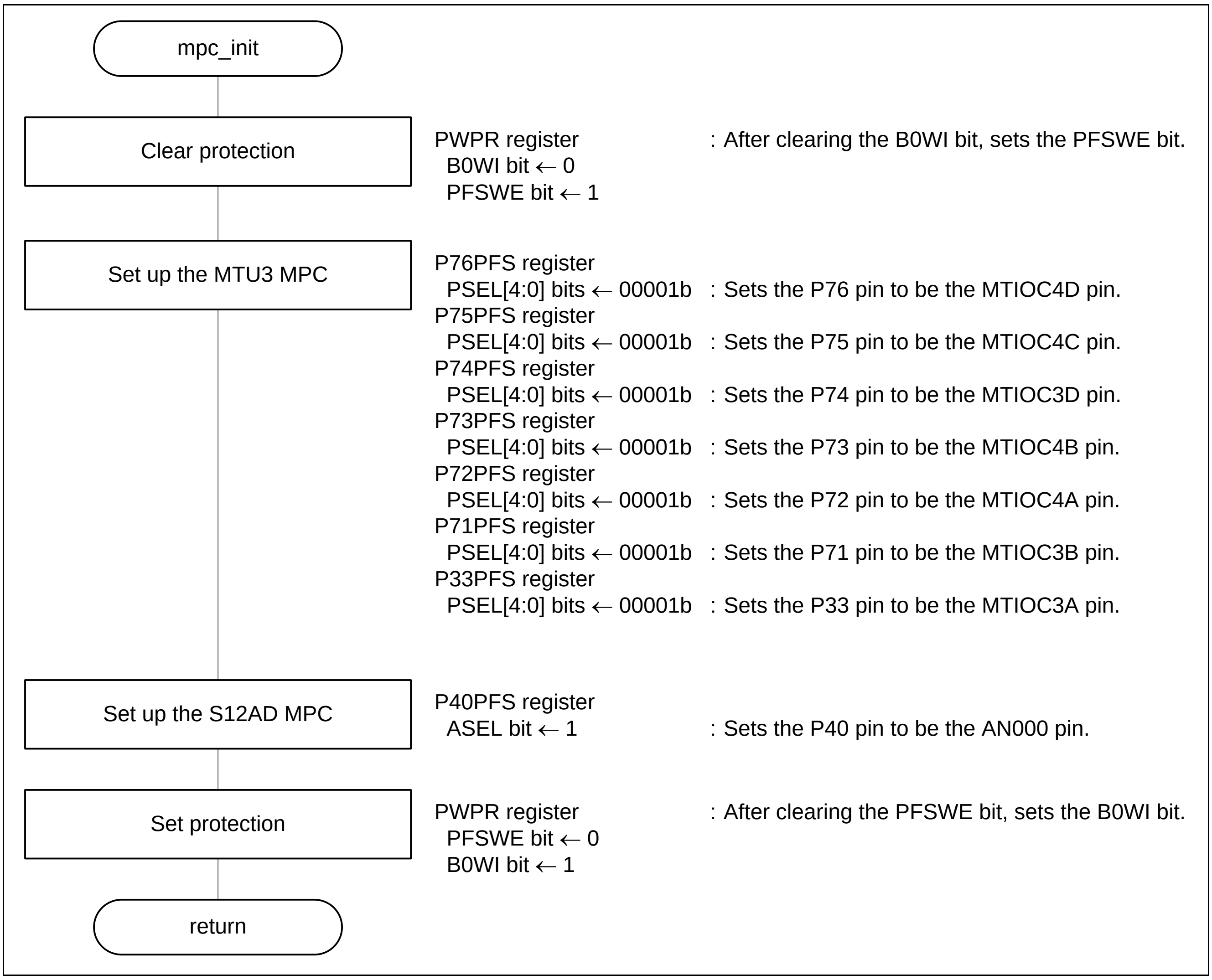

Figure 4.7 MPC Initialization Function

4.8.6 PMR Initialization Function

Figure 4.8 shows the flowchart for the PMR initialization function.

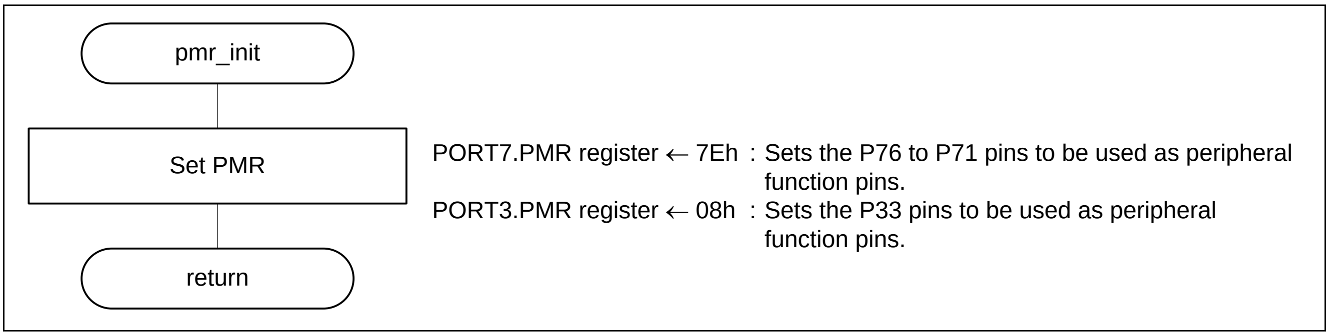

Figure 4.8 PMR Initialization Function

4.8.7 TGIA3 Interrupt Function

Figure 4.9 shows the flowchart for the PMR interrupt function.

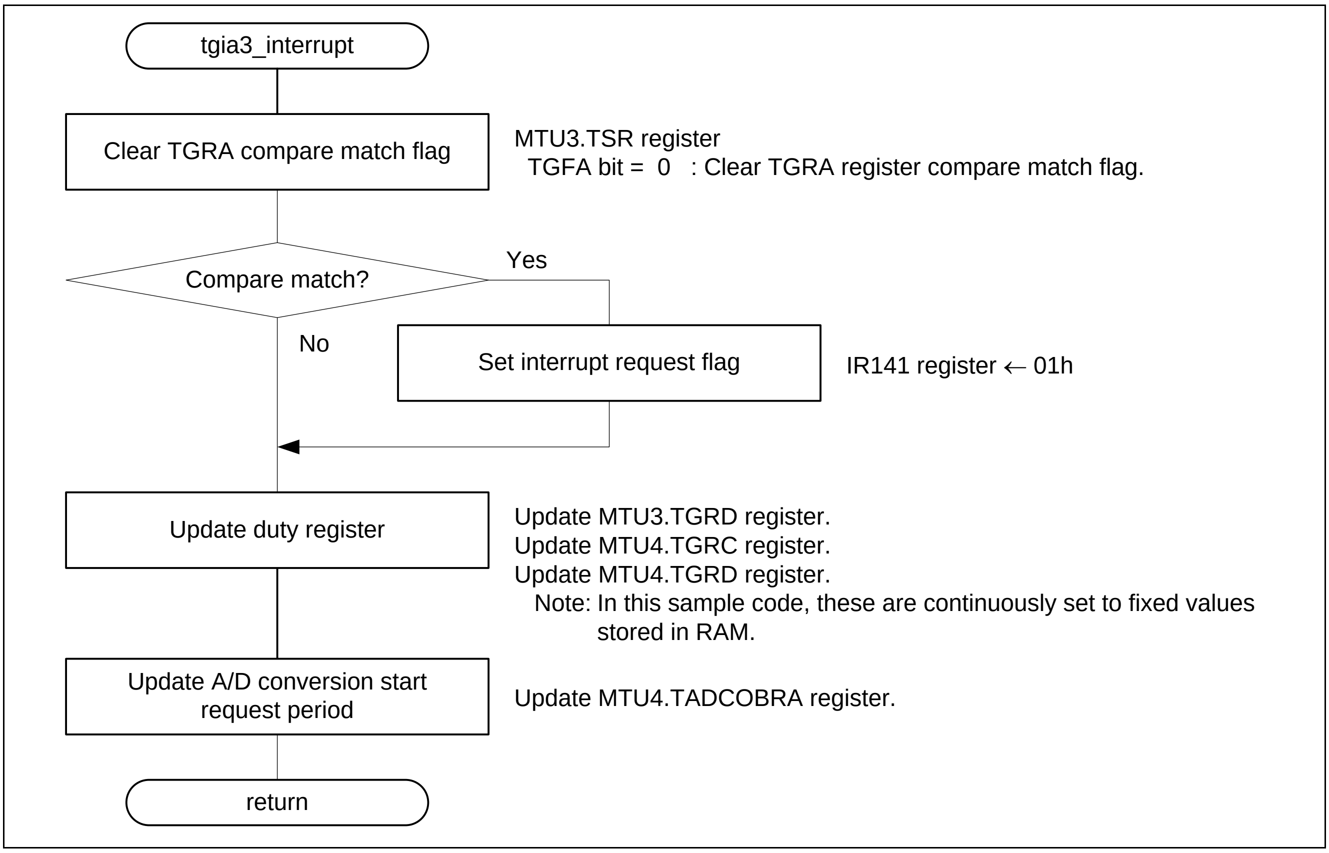

Figure 4.9 TGIA3 Interrupt Function

4.8.8 S12ADI Interrupt Function

Figure 4.10 shows the flowchart for the S12ADI interrupt function.

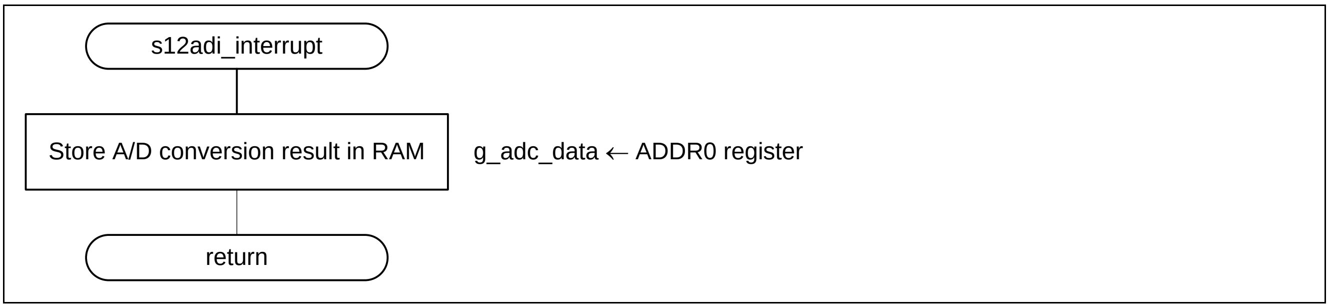

Figure 4.10 S12ADI Interrupt Function

5. Notes

5.1 Endian

The sample code provided with this application note supports both little endian and big endian operation.

5.1.1 When Using Little Endian

When operating in little endian mode, specify “little endian data” as the compiler option endian setting. The MDES setting shown in section 4.3, Option-Setting Memory, is the value for little endian operation.

5.1.2 When Using Big Endian

When operating in big endian mode, specify “big endian data” as the compiler option endian setting. The MDES setting shown in section 4.3, Option-Setting Memory, is the value for big endian operation.

6. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

7. Reference Documents

User's Manual: Hardware

RX63T Group User's Manual: Hardware Rev.2.00

(The latest version can be downloaded from the Renesas Electronics website.)

Technical Update/Technical News

The content of the following technical data publication applies to this application note.

Document No.	Title
TN-RX*-A023A	Note on Using Multi-Function Timer Pulse Unit 3 (MTU3) Interrupts

(The latest version can be downloaded from the Renesas Electronics website.)

User's Manual: Development Tools

RX Family C/C++ Compiler Package V.1.01 User's Manual Rev.1.00

(Including the documentation included with V.1.0.2)

(The latest version can be downloaded from the Renesas Electronics website.)

Application Note

RX63T Group Initialization Example Rev.1.00 (R01AN1252EJ0100)

(The latest version can be downloaded from the Renesas Electronics website.)

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Revision History

Rev.	Date	Description	
		Page	Summary
1.00	May 14, 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 accord 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 type 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.

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