RX63T Group

POE PWM Output Cutoff by Comparator Detection

R01AN1404EJ0100
Rev.1.00
May 14, 2014

Introduction

This application note describes three-phase complementary pulse width modulation (PWM) waveform output using the general PWM timer (GPT) of the RX63T Group. The use of the comparator function of the 12-bit A/D converter (S12ADB) to operate the port output enable 3 (POE3) register and cut off PWM output is described. This function can be used as a failsafe mechanism to stop motor control when an abnormality in the monitored voltage is detected.

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

In this sample task, the GPT is used to generate three-phase complementary PWM waveform output. The comparator function of the 12-bit A/D converter (S12ADB) is used. When the comparator detects a voltage outside the safe voltage range, PWM output is cut off by operating the port output enable 3 (POE3) register. In the recovery example, PWM output is started when the comparator detects that the voltage is once again within the safe voltage range. The specifications of the sample task are shown below.

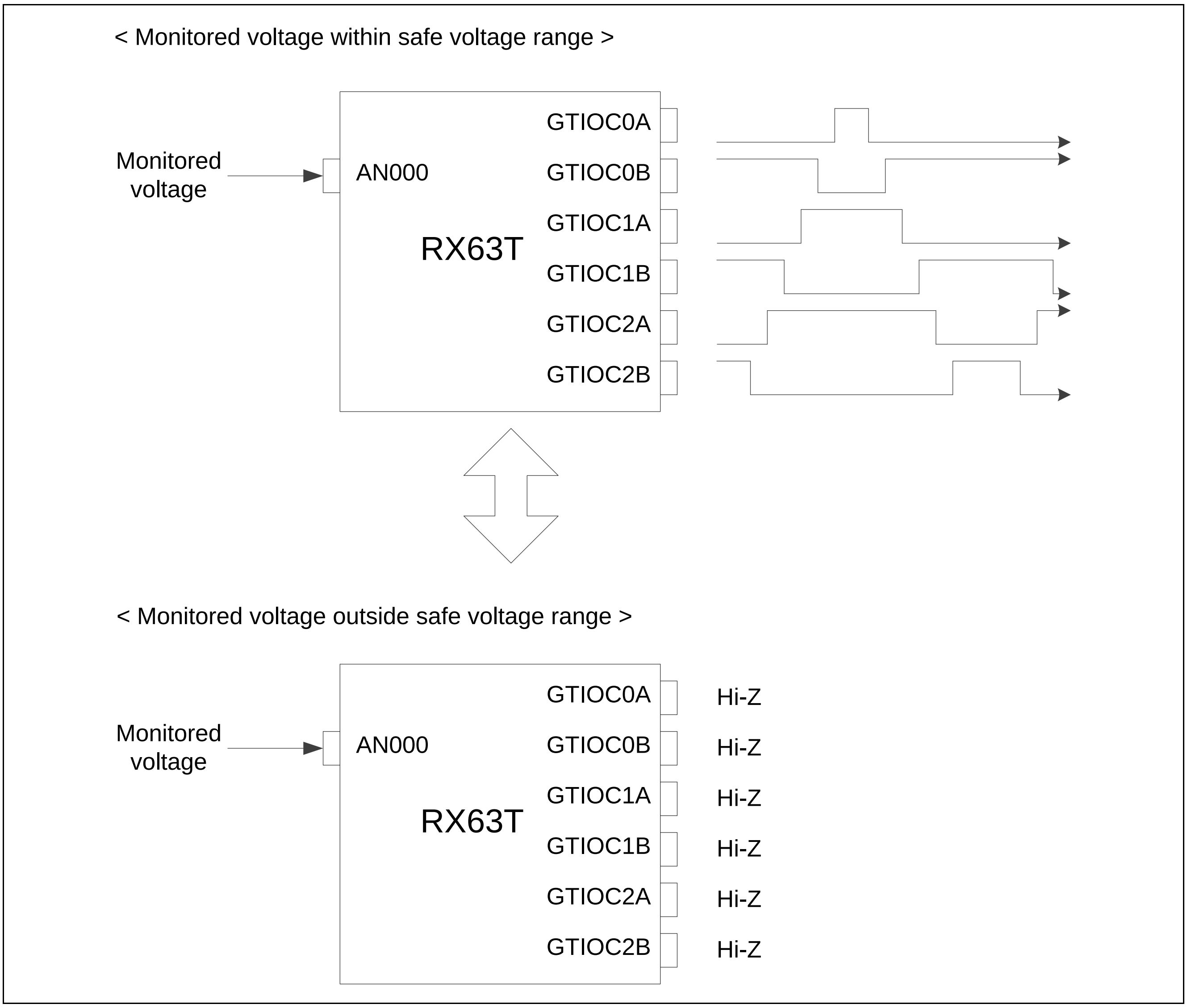

Figure 1.1 Usage Example

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 (PCLKA): 96 MHz (PLL divided by 2) Peripheral module clock B (PCLKB): 48 MHz (PLL divided by 4) S12AD clock (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 High-performance Embedded Workshop Version 4.09.01.007
C compiler	Renesas Electronics RX Standard Toolchain Version 1.2.1.0
	Compiler options (The integrated development environment default settings are used.)
iodefine.h version	2.00
Endian	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 No. 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	Output	Abnormality detection indicator LED control
P71/GTIOC0A	Output	Triangle-wave three-phase complementary PWM output pin 1
P72/GTIOC1A	Output	Triangle-wave three-phase complementary PWM output pin 2
P73/GTIOC2A	Output	Triangle-wave three-phase complementary PWM output pin 3
P74/GTIOC0B	Output	Triangle-wave three-phase complementary PWM output pin 1' (negative phase of 1)
P75/GTIOC1B	Output	Triangle-wave three-phase complementary PWM output pin 2' (negative phase of 2)
P76/GTIOC2B	Output	Triangle-wave three-phase complementary PWM output pin 3' (negative phase of 3)
P40/AN000	Input	Analog input pin

4. Software

4.1 Operation Overview

4.1.1 POE PWM Output Cutoff by Comparator Detection

- The GPT generates three-phase complementary PWM waveform output.
- 12-bit A/D converter monitors the voltage of the internal power supply on the AN000 pin in window comparator mode.

Figure 4.1 shows an operation example.

[1] Case where the monitored voltage exceeds the upper limit value (determined by A/D conversion after occurrence of comparator interrupt)

— Hi-Z control is applied to the GPT timer output, and the timer counter is stopped and cleared. Then an interrupt is generated and an LED lights to indicate detection of an abnormal condition.

Note: In the sample code, the operation described in [2] is implemented within the interrupt handler, so the operating mode is set to low-level comparator, and the safe level detection standard value is set.

[2] Case where after exceeding the upper limit value, the monitored voltage is detected at the safe level detection standard value by the comparator

— In this case, after an interrupt is generated and the LED indicating detection of an abnormal condition turns off, Hi-Z control of the GPT timer output is canceled, and the GPT timer starts.

Note: This is an example of recovery following abnormal voltage detection. In the sample code, the operation described in [1] or [3] is implemented within the interrupt handler, so the operating mode is set to window comparator, and the abnormal level detection upper and lower limit values are set.

[3] Case where the monitored voltage drops below the lower limit value (determined by A/D conversion after occurrence of comparator interrupt)

— Hi-Z control is applied to the motor timer output, and the timer counter is stopped and cleared. Then, an interrupt is generated and an LED lights to indicate detection of an abnormal condition.

Note: In the sample code, the operation described in [4] is implemented within the interrupt handler, so the operating mode is set to high-level comparator, and the safe level detection standard value is set.

[4] Case where after dropping below the lower limit value, the monitored voltage is detected at the safe level detection standard value by the comparator

— In this case, after an interrupt is generated and the LED indicating detection of an abnormal condition turns off, Hi-Z control of the GPT timer output is canceled, and the GPT timer starts.

Note: This is an example of recovery following abnormal voltage detection. In the sample code, the operation described in [1] or [3] is implemented within the interrupt handler, so the operating mode is set to window comparator, and the abnormal level detection upper and lower limit values are set.

Note that when the monitored voltage returns to the safe level detection standard value immediately after having exceeded the upper limit value or dropped below the lower limit value (determined by A/D conversion after occurrence of comparator interrupt), operation [2] or [4] occurs.

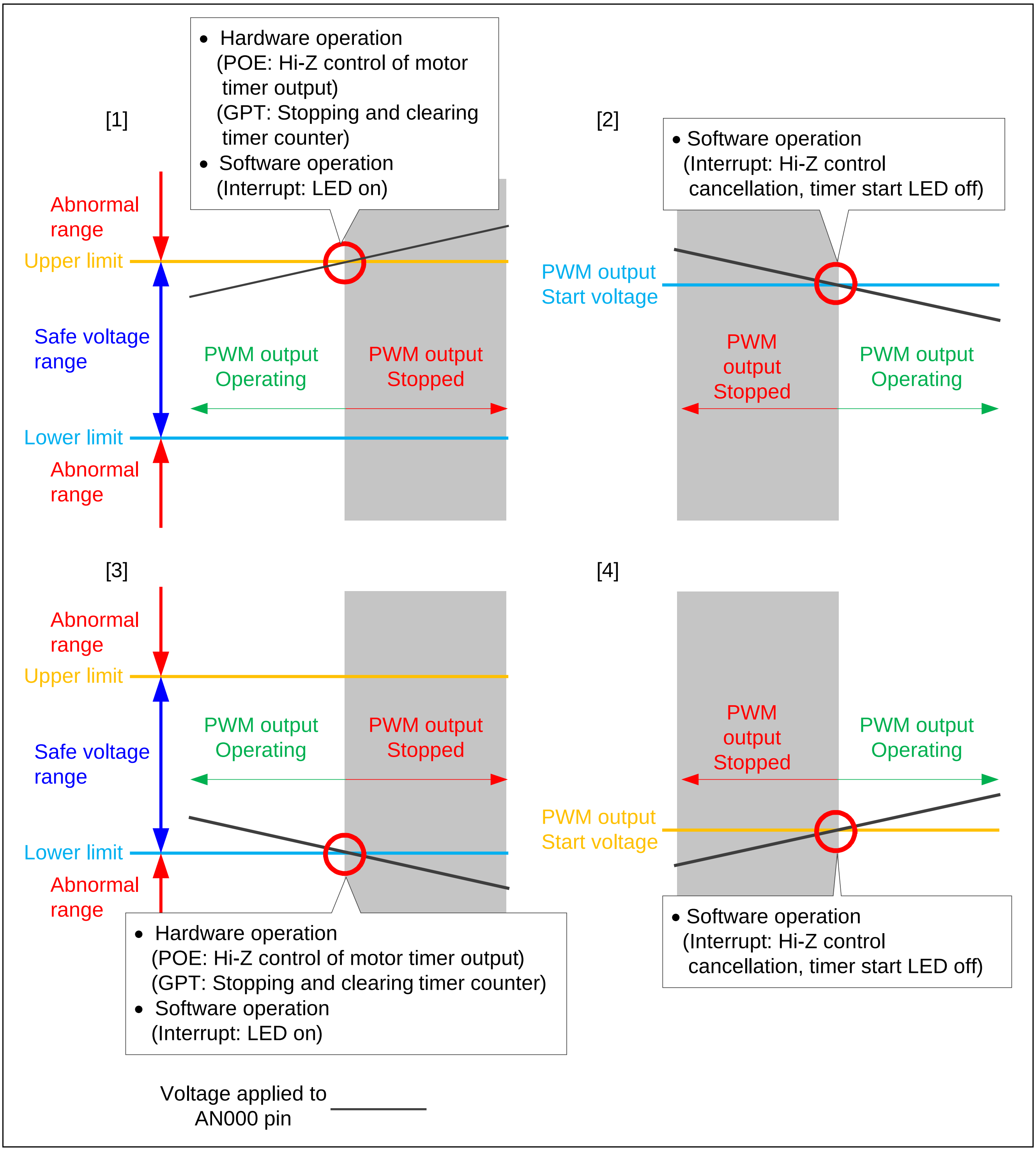

Figure 4.1 Operation Example of POE PWM Output Cutoff by Comparator Detection

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 Group 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 Comparator interrupt functions added	
main.c	Main processing, GPT initial settings, S12ADB initial settings, POE3 initial settings, ICU initial settings, monitored voltage confirmation, comparator interrupt handling	

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	 FFFF FFFFh FFFF FFF8h	(In single-chip mode) Little endian 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
LOW	0	Low-level definition
HIGH	1	High-level definition
NORMAL	2	Normal level definition
S12AD_DATA_MAX	0FFFh	12-bit A/D conversion result maximum value
GPT_CYCLE	029Fh	GPT period setting value
GPT_GTIOC0A	023Fh	GTIOC0A output switching timing
GPT_GTIOC0B	01DFh	GTIOC0B output switching timing
GPT_GTIOC1A	017Fh	GTIOC1A output switching timing
GPT_GTIOC1B	011Fh	GTIOC1B output switching timing
GPT_GTIOC2A	00BFh	GTIOC2A output switching timing
GPT_GTIOC2B	005Fh	GTIOC2B output switching timing
CMP_MD_NOT_USE	0	Do-not-use comparator setting
CMP_MD_LOW	1	Low-level comparator setting
CMP_MD_HIGH	2	High-level comparator setting
CMP_MD_WINDOW	3	Window comparator setting
DANGER_RANGE_H	7	Normal voltage upper limit setting for detecting abnormal voltage
DANGER_RANGE_L	1	Normal voltage lower limit setting for detecting abnormal voltage
NORMAL_FROM_H	6	Level setting for return to normal voltage after exceeding upper limit
NORMAL_FROM_L	2	Level setting for return to normal voltage after going below lower limit

4.5 Functions

Table 4.4 lists the functions.

Table 4.4 Functions

Function Name	Outline
main	Main processing
icu_init	ICU initialization function
gpt0_init	GPT initialization function
s12ad_init	S12AD initialization function
poe_init	POE initial settings function
mpc_gpt_init	MPC initial settings function for GPT
mpc_s12ad_init	MPC initial settings function for S12AD
mpc_init	MPC initial settings function
pmr_gpt_init	PMR initial settings function for GPT
check_High_or_Low	Monitored voltage confirmation function
cmp0_interrupt	Comparator interrupt function

4.6 Function Specifications

The following tables list the sample code function specifications.

main

Outline Main function

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))
- Turns off LED.
- Initializes GPT.
- Initializes S12AD.
- Initializes POE.
- Initializes MPC.
- Initializes ICU.
- Enables interrupts.
- Starts counting by GPT0 to GPT2.

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.

- Clears interrupt request flags.
- Sets interrupt priority.
- Enables interrupts.

Arguments None

Return Value None

gpt0_init

Outline GPT initialization function

Header None

Declaration static void gpt0_init(void)

Description This function performs the following processing.

- Cancels GPT module standby.
- Sets GPT0 to GPT2 to triangle-wave PWM mode 1.
- Sets GTCNT of GPT0 to GPT2 to up-counting.
- Sets clock source of GPT0 to GPT2 to PCLKA.
- Sets period in GTPR of GPT0 to GPT2.
- Clears GTCNT of GPT0 to GPT2.
- Sets AN000 comparator detection as count stop/clear source of GPT0 to GPT2.
- Sets counter clear at hardware source falling edge on GPT0 to GPT2.
- Sets counter stop at hardware source falling edge on GPT0 to GPT2.
- Sets GTIOCnA (n = 0, 1, 2) pins of GPT0 to GPT2 to initial output low, hold output at end of period, toggle output at GTCCRA compare match, low output at count stop.
- Sets GTIOCnB (n = 0, 1, 2) pins of GPT0 to GPT2 to initial output high, hold output at end of period, toggle output at GTCCRB compare match, high output at count stop.
- Makes MPC initial settings for GPT.
- PMR initial settings function
- Enables output on GTIOC0A, GTIOC0B, GTIOC1A, GTIOC1B, GTIOC2A, and GTIOC2B.
- Sets compare match registers of GPT0 to GPT2.
- Disables writing to GPT0 to GPT2 register.

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.

- Cancels S12AD module standby.
- Compares the internal voltage to the comparator low side standard voltage and sets the reference voltage.
- Compares the internal voltage to the comparator high side standard voltage and sets the reference voltage.
- Sets the comparator noise cancelling filter for AN000.
- Clears the comparator detection flag for AN000.
- Enables the comparator detection interrupt for AN000.
- Sets the comparator to window comparator mode for AN000.

Arguments None

Return Value None

Remarks None

poe_init	
Outline	POE initialization function
Header	None
Declaration	static void poe_init(void)
Description	This function performs the following processing. • Adds CFLAG to high-impedance control conditions for GPT0 and GPT1. • Adds CFLAG to high-impedance control conditions for GPT2 and GPT3. • Enables high-impedance control on GPT0, GPT1, GPT2, and GPT3.
Arguments	None
Return Value	None
Remarks	None

mpc_gpt_init	
Outline	MPC initial settings function for GPT
Header	None
Declaration	void mpc_gpt_init(void)
Description	Assigns the following functions to the following pins in MPC. • P76 → GTIOC2B • P75 → GTIOC1B • P74 → GTIOC0B • P73 → GTIOC2A • P72 → GTIOC1A • P71 → GTIOC0A
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	Assigns the following functions to the following pins in 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	• Makes MPC initial settings for S12AD.
Arguments	None
Return Value	None
Remarks	None

pmr_gpt _init	
Outline	PMR initial settings function for GPT
Header	None
Declaration	void pmr_gpt _init(void)
Description	Makes PMR initial settings for the GPT. • Sets P76, P75, P74, P73, P72, and P71 to peripheral function mode.
Arguments	None
Return Value	None
Remarks	None

check_High_or_Low	
Outline	Monitored voltage confirmation function
Header	None
Declaration	static uint8_t check_High_or_Low(void)
Description	This function performs the following processing. • Sets AN000 as subject to A/D conversion. • Starts A/D conversion of AN000 pin and gets the A/D conversion result. • Determines if going above the upper limit or below the lower limit of the safe voltage range was detected. • Determines if the value is in the safe voltage range. • Sets AN000 as not subject to A/D conversion.
Arguments	None
Return Value	High: above upper limit, Low: below lower limit, NORMAL: within safe voltage range
Remarks	None

cmp0_int

Outline Comparator interrupt function

Header None

Declaration void cmp0_interrupt(void)

Description This function performs the following processing.

- Set comparator to “do-not-use.”
- Confirm monitored voltage.

Within safe voltage range detected

- Turns off LED.
- Sets reference voltage for comparator high side standard voltage.
- Sets reference voltage for comparator low side standard voltage.
- Sets to window comparator mode.
- Starts count on GPT0 to GPT2.

Outside safe voltage range detected

- Turns on LED.
  Under lower limit
  — Sets reference voltage for comparator high side standard voltage.
  — Sets to high-level comparator mode (to detect return to safe voltage range).
  Above upper limit
  — Sets reference voltage for comparator low side standard voltage.
  — Sets to low-level comparator mode (to detect return to safe voltage range).

- Clears the AN000 comparator detection flag.

Arguments None

Return Value None

Remarks None

4.7 Flowcharts

4.7.1 Main Processing

Figure 4.2 shows the main processing.

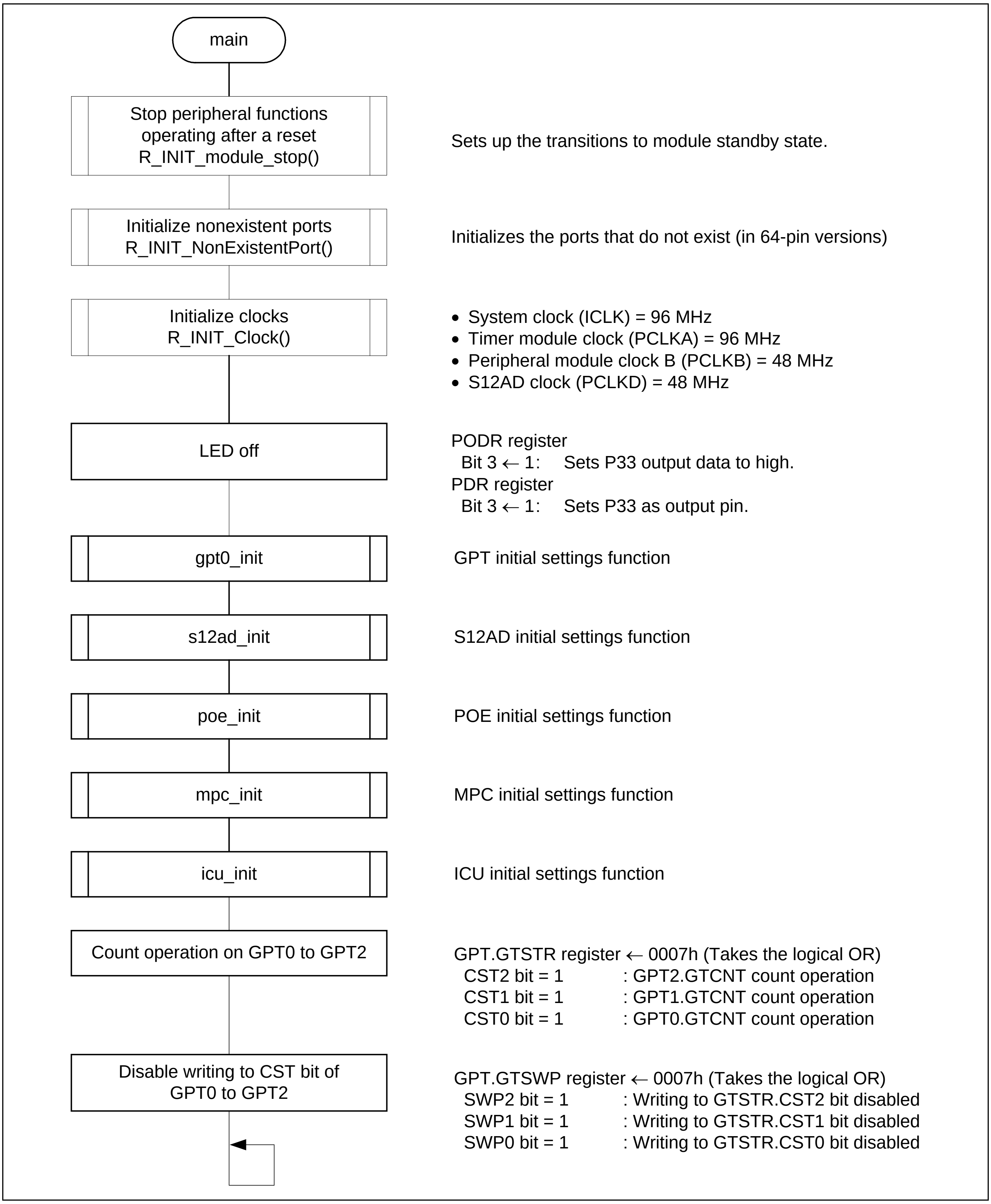

Figure 4.2 Main Processing

4.7.2 ICU Initialization Function

Figure 4.3 shows the flowchart for the ICU initialization function.

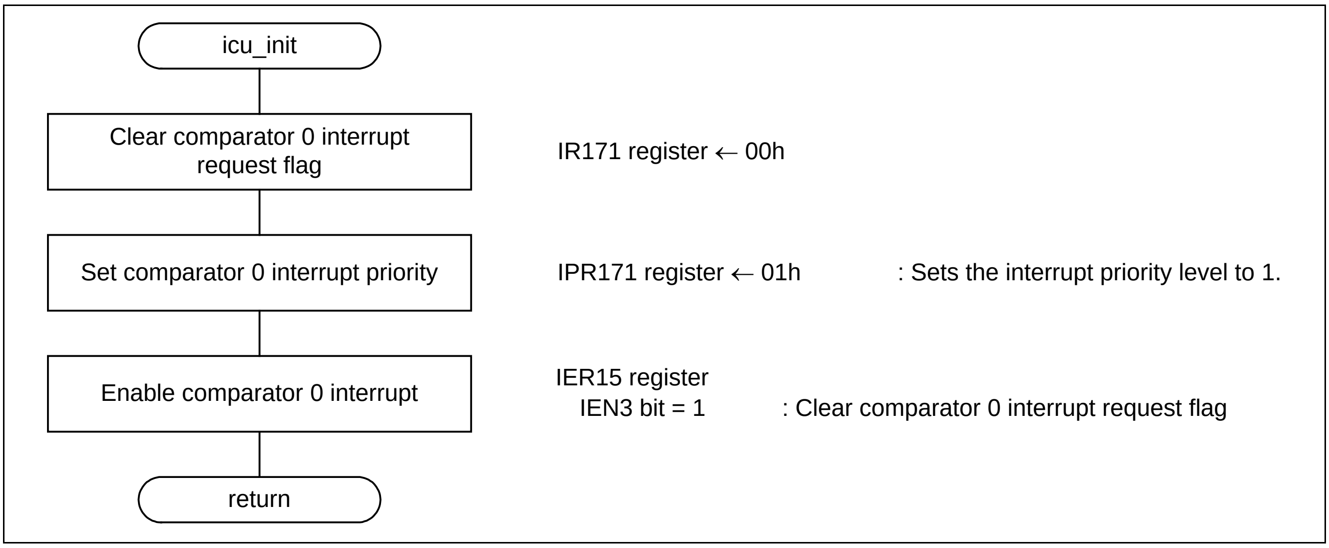

Figure 4.3 ICU Initialization Function

4.7.3 GPT Initialization Function

Figure 4.4, 4.5, and 4.6 are flowcharts of GPT initialization function 1, GPT initialization function 2, and GPT initialization function 3.

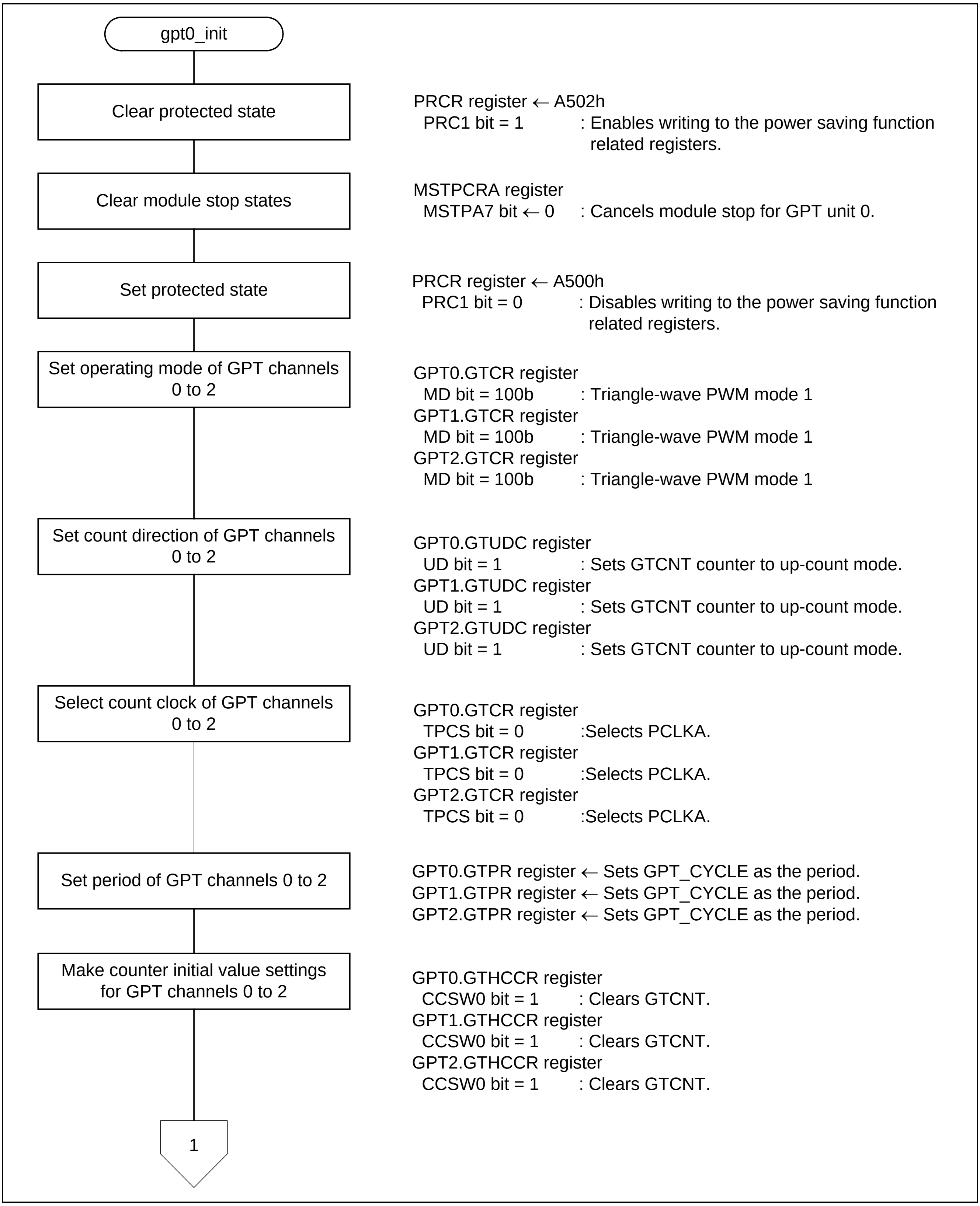

Figure 4.4 GPT Initialization Function 1

1

Set hardware count stop/clear on GPT channels 0 to 2

GPT.GTHCCR register
- CCHW0 bit = 10b : Sets counter clear at hardware source falling edge on channel 0.
- CCHW1 bit = 10b : Sets counter clear at hardware source falling edge on channel 1.
- CCHW2 bit = 10b : Sets counter clear at hardware source falling edge on channel 2.

GPT.GTHSCR register
- CPHW0 bit = 10b : Sets counter stop at hardware source falling edge.
- CPHW1 bit = 10b : Sets counter stop at hardware source falling edge.
- CPHW2 bit = 10b : Sets counter stop at hardware source falling edge.

Set hardware source operation on GPT channels 0 to 2

GPT.GTHPSR register
- CSHPL0 bit = 0000b : Comparator detection for AN000
- CSHPL1 bit = 0000b : Comparator detection for AN000
- CSHPL2 bit = 0000b : Comparator detection for AN000

Set GTIOC pin functions

GPT0.GTIOR register
- GTIOA bit = 000011b : Initial output low, hold output at end of period, toggle output at GTCCRA compare match
- OADFLT bit = 0 : Low output from GTIOC0A pin at count stop
- GTIOB bit = 010011b : Initial output high, hold output at end of period, toggle output at GTCCRB compare match
- OBDFLT bit = 1 : High output from GTIOC0B pin at count stop

GPT1.GTIOR register
- GTIOA bit = 000011b : Initial output low, hold output at end of period, toggle output at GTCCRA compare match
- OADFLT bit = 0 : Low output from GTIOC1A pin at count stop
- GTIOB bit = 010011b : Initial output high, hold output at end of period, toggle output at GTCCRB compare match
- OBDFLT bit = 1 : High output from GTIOC1B pin at count stop

GPT2.GTIOR register
- GTIOA bit = 000011b : Initial output low, hold output at end of period, toggle output at GTCCRA compare match
- OADFLT bit = 0 : Low output from GTIOC2A pin at count stop
- GTIOB bit = 010011b : Initial output high, hold output at end of period, toggle output at GTCCRB compare match
- OBDFLT bit = 1 : High output from GTIOC2B pin at count stop

2

Figure 4.5 GPT Initialization Function 2

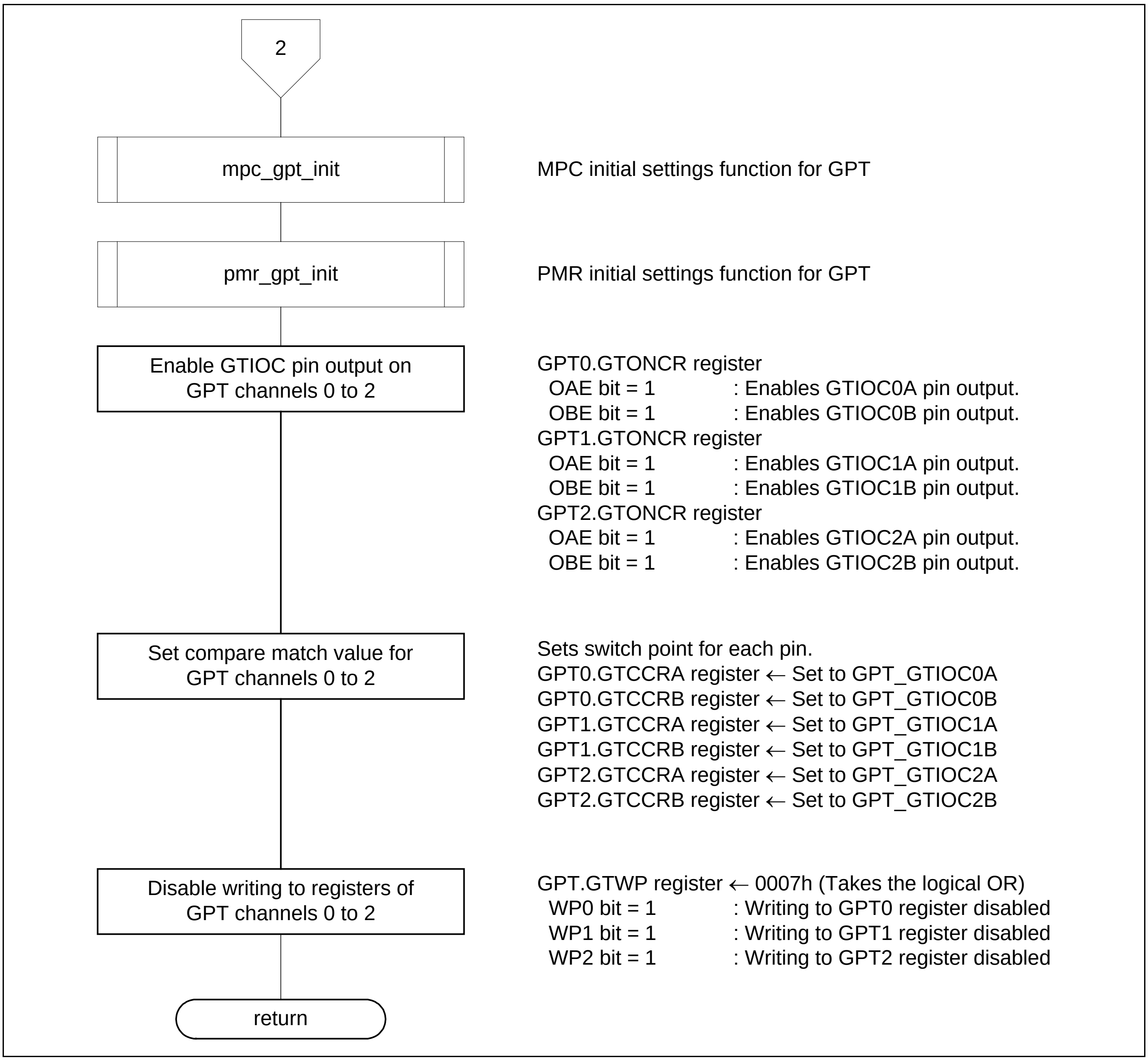

Figure 4.6 GPT Initialization Function 3

4.7.4 S12AD Initialization Function

Figure 4.7 is a flowchart of the S12AD initialization function.

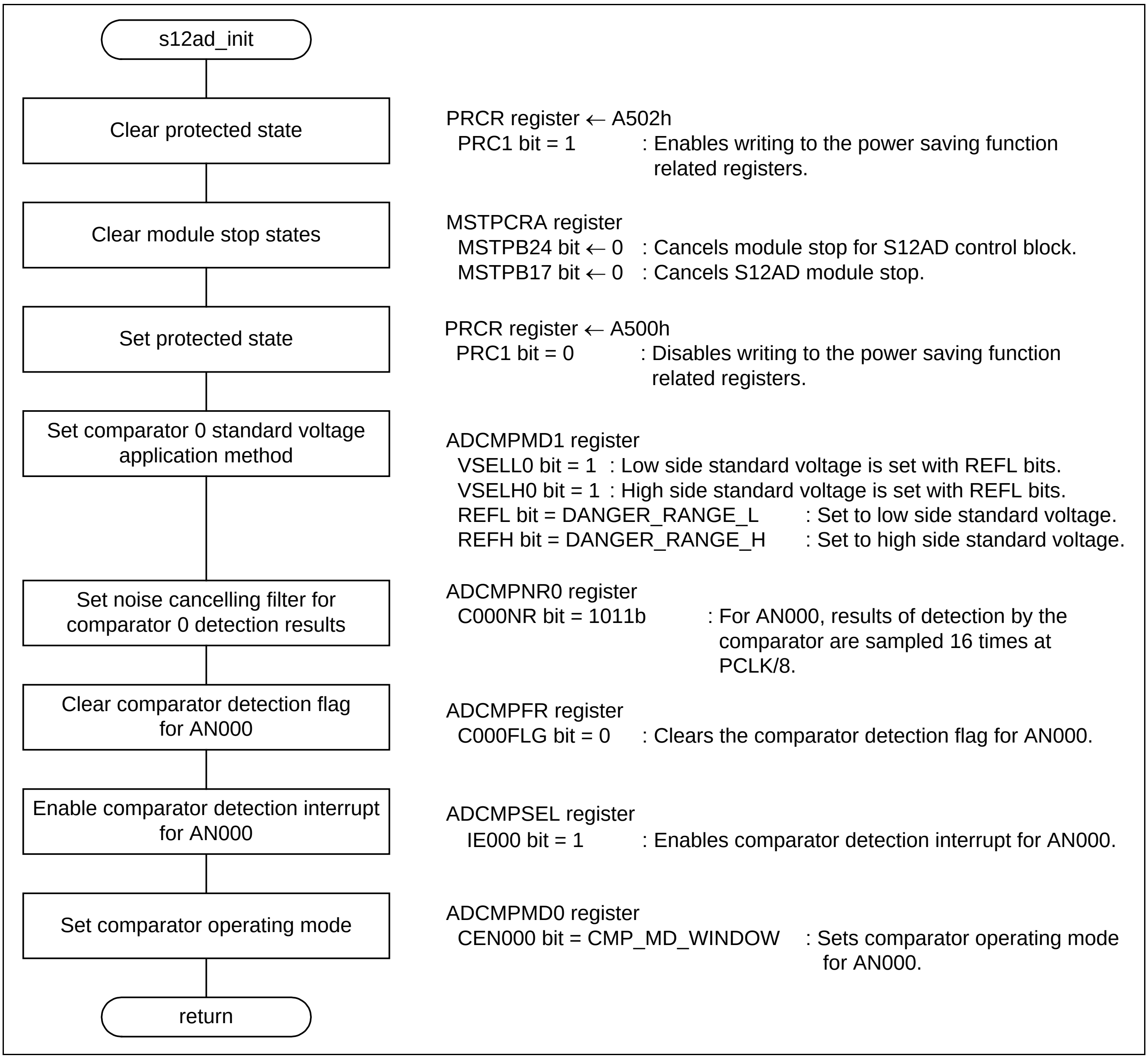

Figure 4.7 S12AD Initialization Function

4.7.5 POE Initialization Function

Figure 4.8 is a flowchart of the POE initialization function.

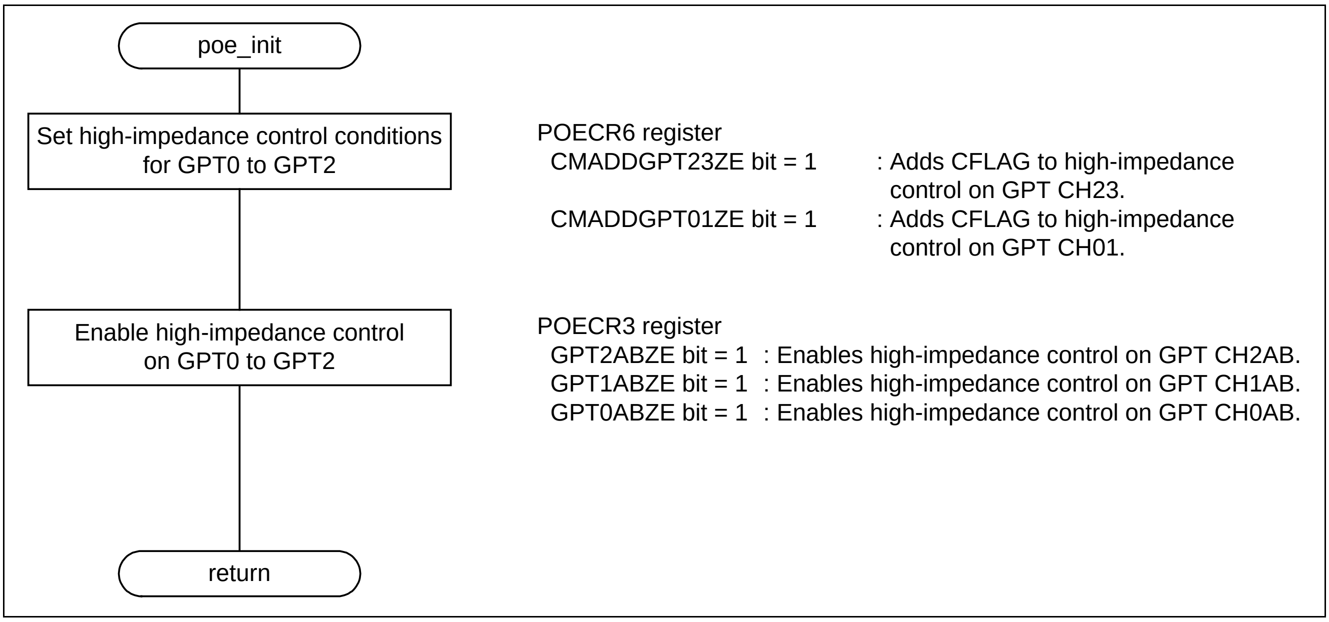

Figure 4.8 POE Initialization Function

4.7.6 MPC Initial Settings Function for GPT

Figure 4.9 is a flowchart of the MPC initial settings function for the GPT.

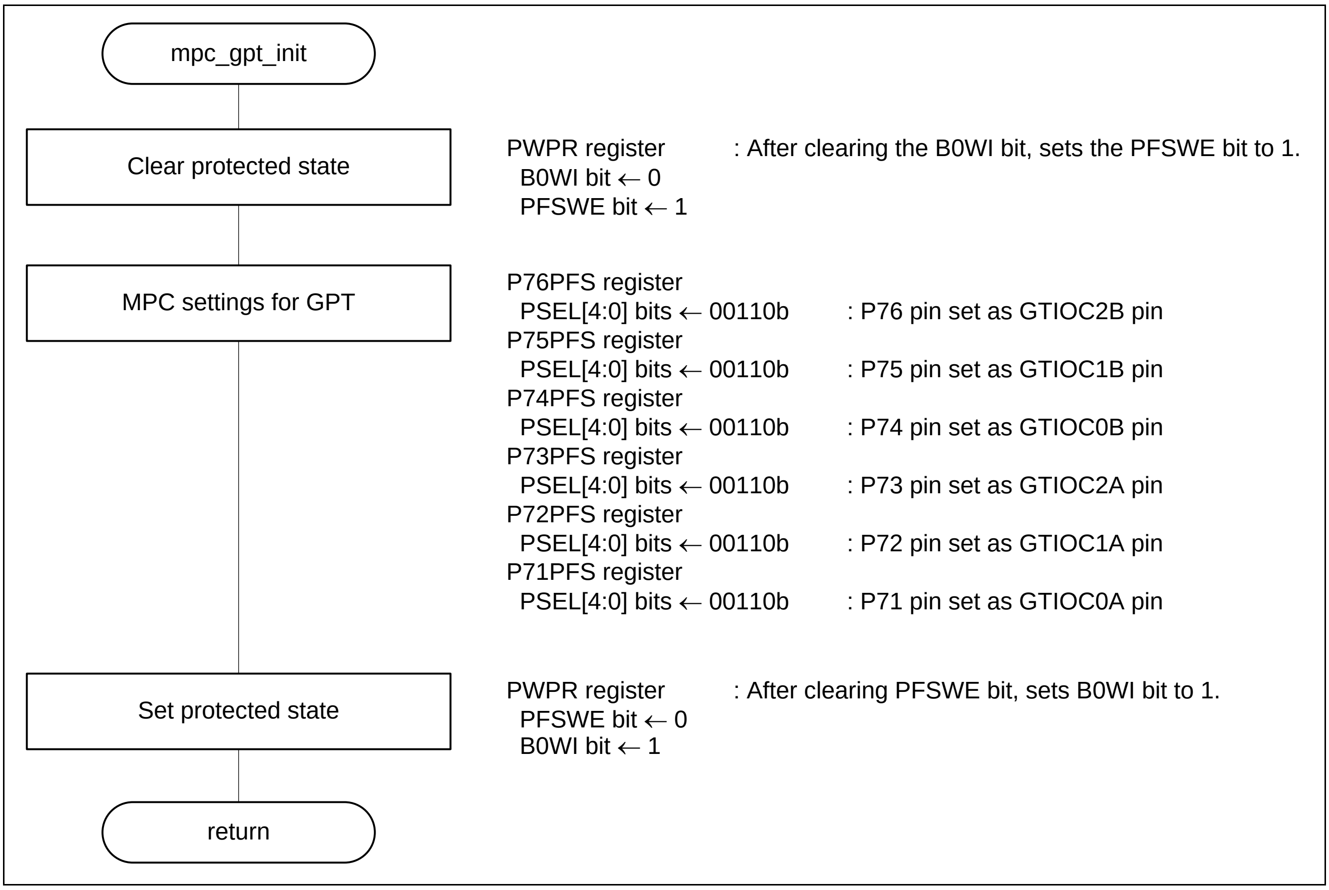

Figure 4.9 MPC Initial Settings Function for GPT

4.7.7 MPC Initial Settings Function for S12AD

Figure 4.10 is a flowchart of the MPC initial settings function for the S12AD.

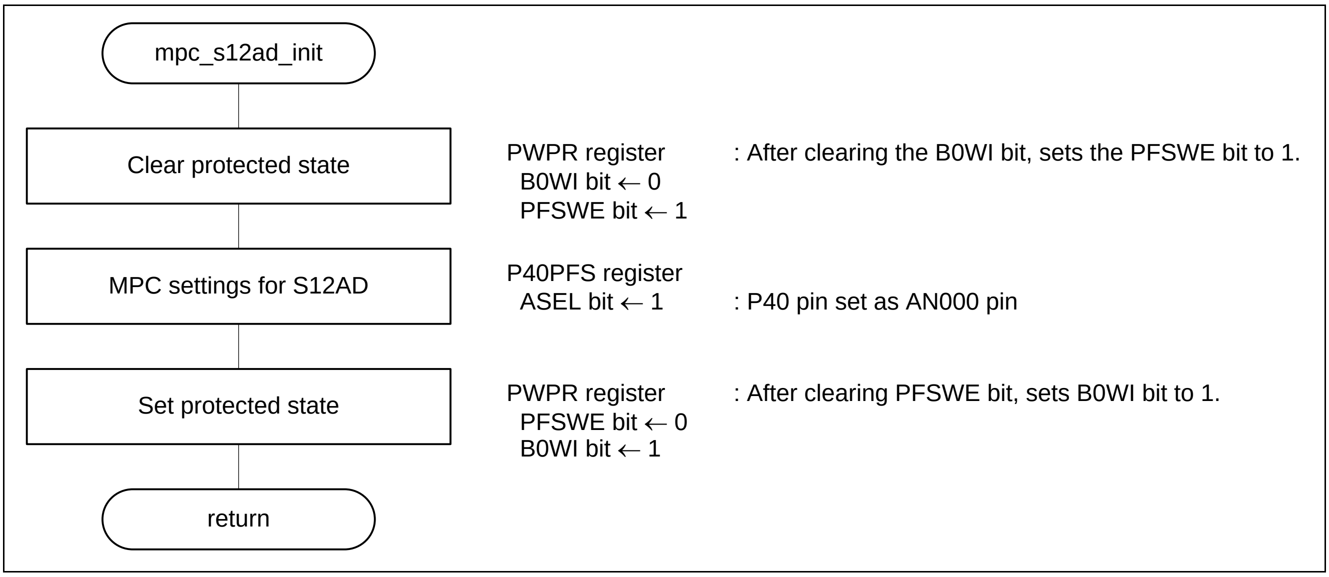

Figure 4.10 MPC Initial Settings Function for S12AD

4.7.8 MPC Initial Settings Function

Figure 4.11 is a flowchart of the MPC initial settings function.

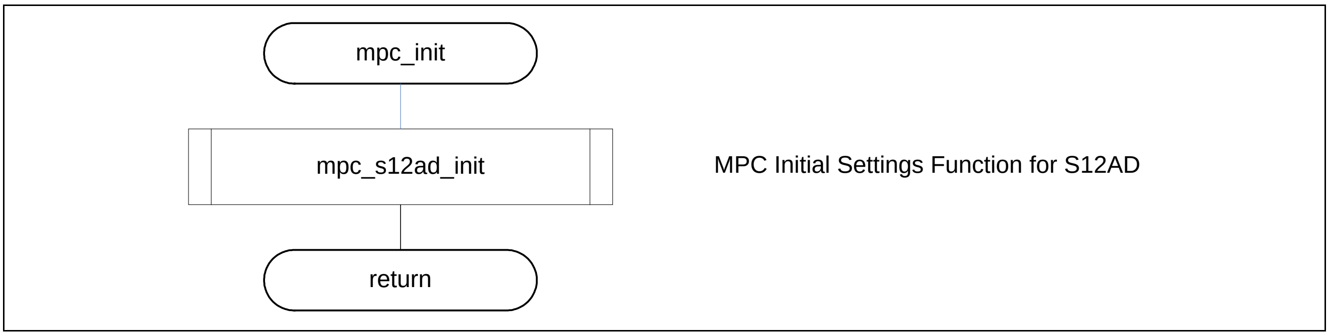

Figure 4.11 MPC Initial Settings Function

4.7.9 PMR Initial Settings Function for GPT

Figure 4.12 is a flowchart of the MPC initial settings function.

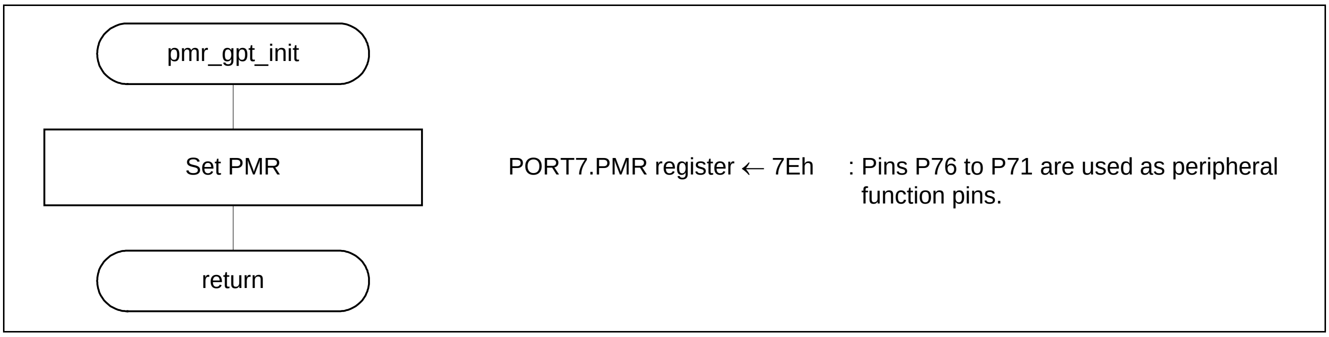

Figure 4.12 PMR Initial Settings Function for GPT

4.7.10 Monitored Voltage Confirmation Function

Figure 4.13 is a flowchart of the monitored voltage confirmation function.

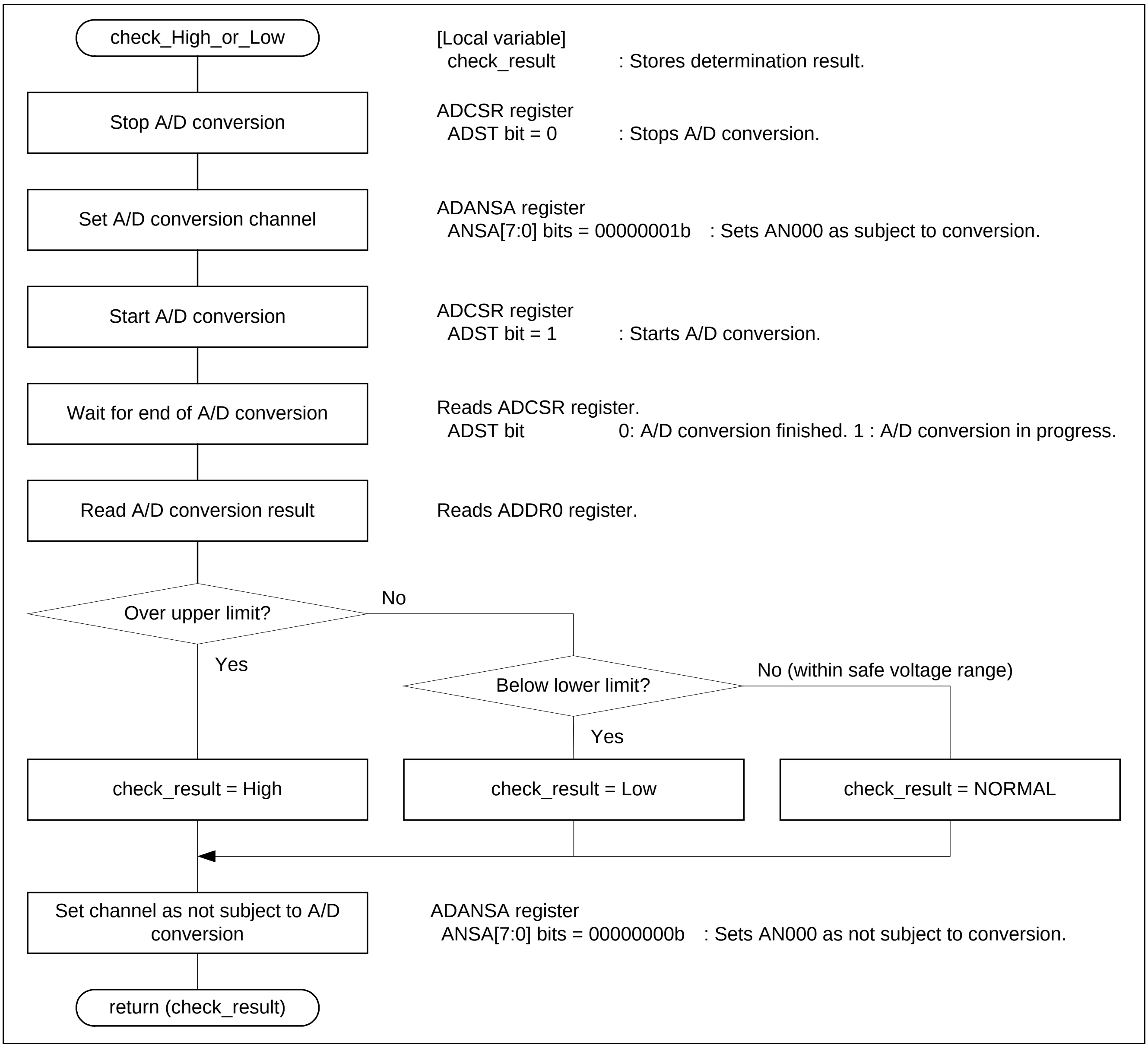

Figure 4.13 Monitored Voltage Confirmation Function

4.7.11 Comparator Interrupt Function

Figure 4.14 is a flowchart of the comparator interrupt function.

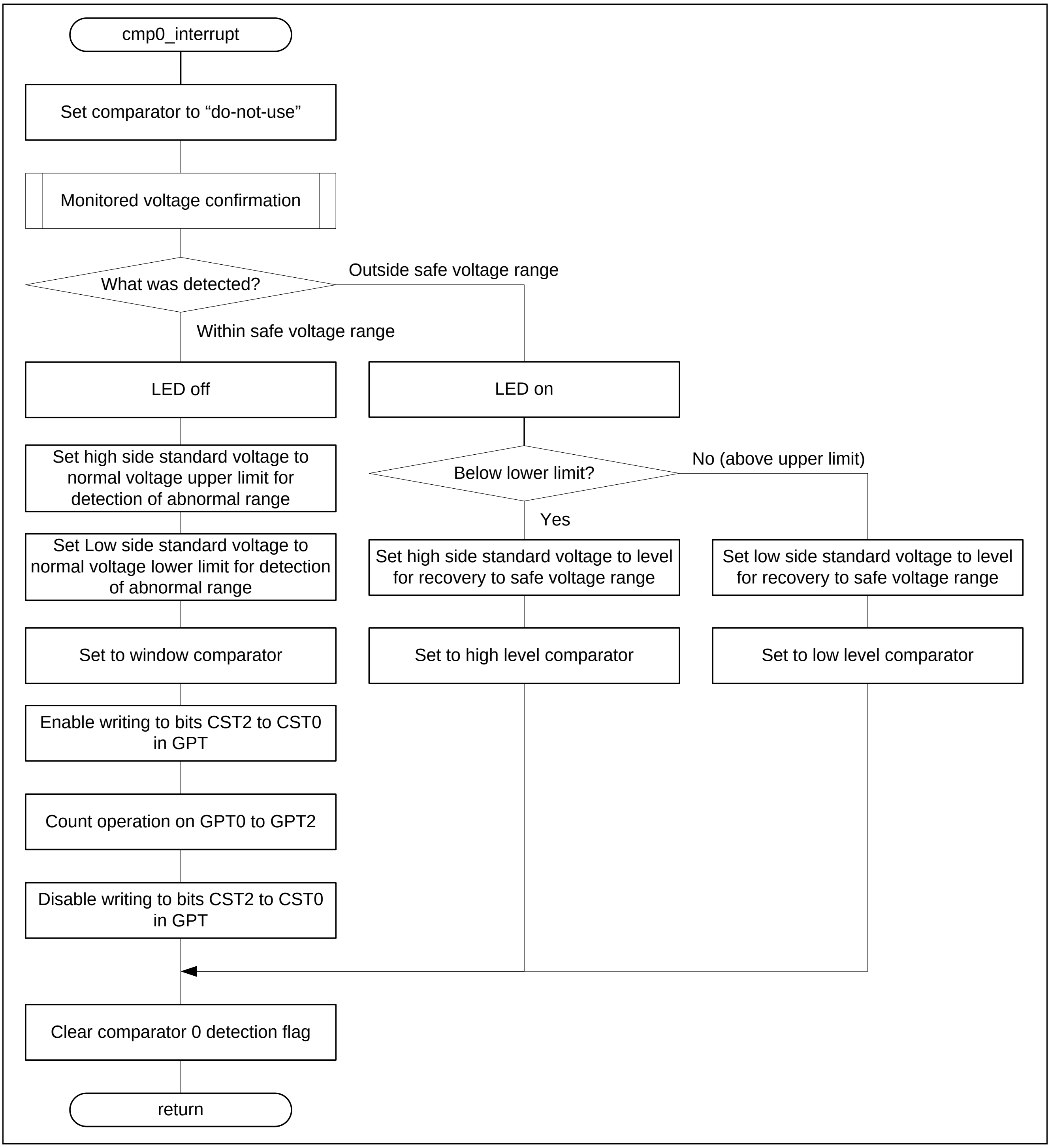

Figure 4.14 Comparator Interrupt Function

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 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.)

Website and Support

Renesas Electronics Website
http://www.renesas.com/

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

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.

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 of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
3. Renesas Electronics does not assume any liability for infringement of 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. 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 should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from such alteration, modification, copy or otherwise misappropriation of Renesas Electronics product.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The recommended 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; and industrial robots etc.
   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; and safety equipment etc.
   Renesas Electronics products are neither intended nor 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 damages (nuclear reactor control systems, military equipment etc.). You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application for which it is not intended. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for which the product is not intended by Renesas Electronics.
6. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, 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, please evaluate 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. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technology may 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 should not use Renesas Electronics products or technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. When exporting the Renesas Electronics products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, who distributes, disposes of, or otherwise places the product with a third party, to notify such third party in advance of the contents and conditions set forth in this document, Renesas Electronics assumes no responsibility for any losses incurred by you or third parties as a result of unauthorized use of Renesas Electronics products.
11. This document may not be 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, or if you have any other inquiries.

(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

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.
2880 Scott Boulevard Santa Clara, CA 95050-2554, 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: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-65030, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, 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 Rd., Putuo District, Shanghai, China
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: +852-2886-9318, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei, 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-Gu, Seoul, 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141

Colophon 3.0