APPLICATION NOTE

RX63N Group, RX631 Group

Using the Temperature Sensor to Calculate the Ambient Temperature

R01AN2463EJ0100
Rev. 1.00
Mar. 9, 2015

Abstract

This document describes a method of using the RX63N Group, RX631 Group temperature sensor to calculate the ambient temperature.

Products

RX63N Group 176-pin package with a ROM size between 768 Kbytes to 2 Mbytes

RX63N Group 144-pin package with a ROM size between 768 Kbytes to 2 Mbytes

RX63N Group 100-pin package with a ROM size between 768 Kbytes to 2 Mbytes

RX631 Group 176-pin package with a ROM size between 256 Kbytes to 2 Mbytes

RX631 Group 144-pin package with a ROM size between 256 Kbytes to 2 Mbytes

RX631 Group 100-pin Package with a ROM size between 256 Kbytes to 2 Mbytes

RX631 Group 64-pin and 48-pin packages with a ROM size between 256 Kbytes to 512 Kbytes

Note: Only the G version (operating temperature: –40°C to +105°C) of the products are the target products.

Contents

1. Specifications

This document describes using the temperature sensor to measure the ambient temperature of the MCU. The ambient temperature is measured and the result is displayed on a 7-segment LED (hereinafter referred to as 7SEG).

In order to measure the ambient temperature of the MCU, the temperature sensor is calibrated beforehand. The calibration performed in this application note calculates the temperature slope necessary for the formula for the temperature characteristic.

In the G version of the RX63N Group and RX631 Group MCUs, the calibration data for the temperature sensor that is measured for every chip is stored when shipped. The temperature slope can be calculated using the data stored on the chip and a temperature obtained by the user in the trial measurement.

In the accompanying sample code, an ambient temperature of 25°C (hereinafter referred to as normal reference temperature) is assumed as the temperature obtained in the user trial measurement and used to calculate the ambient temperature. Refer to section 5.1.1 Formula for the Temperature Characteristic for details on calibration.

Table 1.1 lists the Peripheral Functions and Their Applications.

Table 1.1 Peripheral Functions and Their Applications

Peripheral Function	Application
12-bit A/D converter (hereinafter referred to as AD)	The AD measures temperature sensor output.
Temperature sensor	The temperature sensor measures the ambient temperature of the MCU.
Compare match timer (CMT0) (hereinafter referred to as CMT)	The CMT is used as a timer for the temperature measurement cycle.
External pin interrupt (IRQ15) (hereinafter referred to as IRQ)	Switch input (SW3 on the RSK board) for calibrating with the normal reference temperature (25°C).
I/O ports	I/O ports are used to display the result of the temperature measurement on the 7SEG.

Figure 1.1 shows the Transitioning States and Patterns Displayed on the 7SEG.

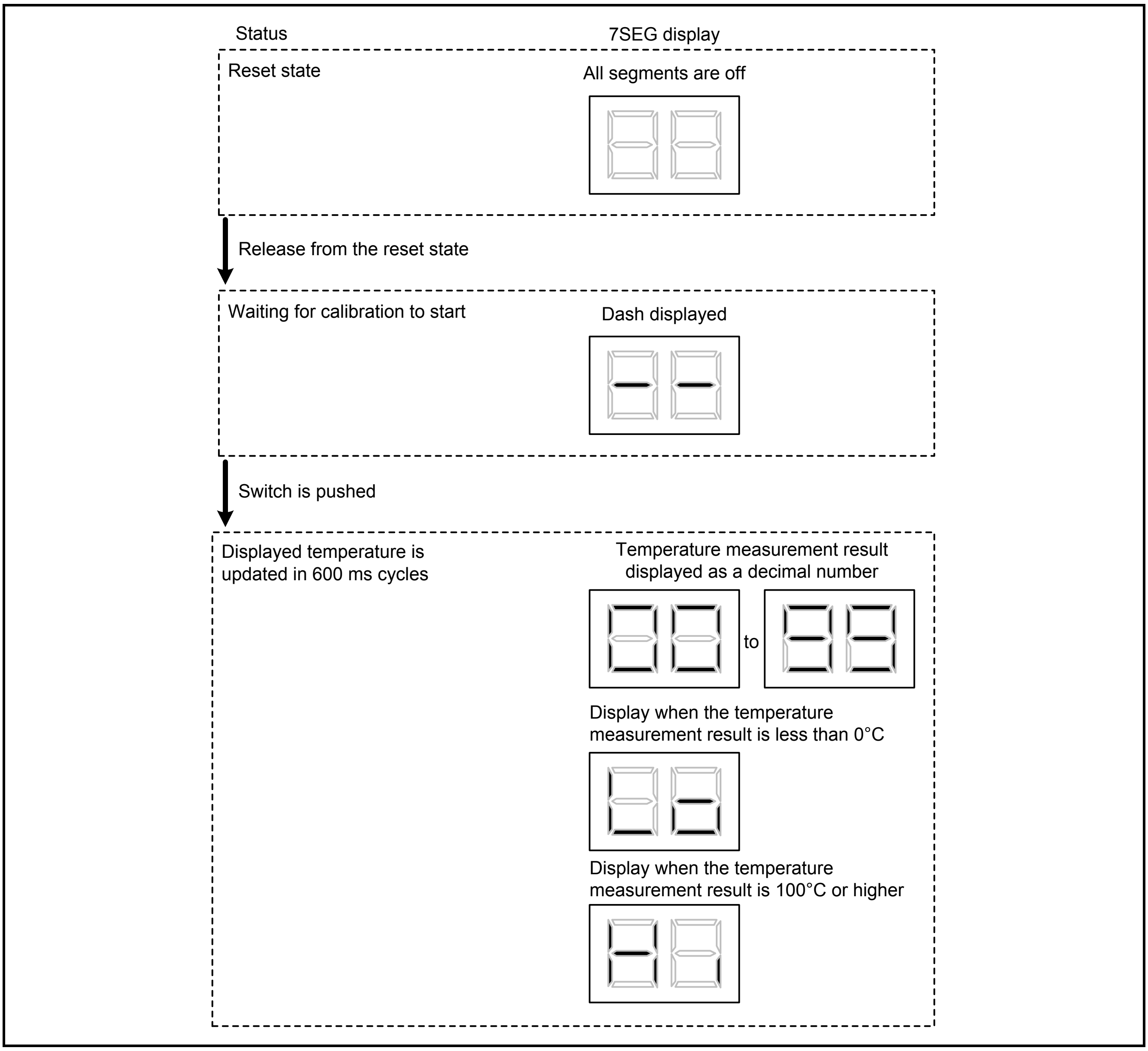


Figure 1.1 Transitioning States and Patterns Displayed on the 7SEG

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	R5F563NBDGFC (RX63N Group)
Operating frequencies	Main clock: 12 MHz PLL: 192 MHz (main clock divided by 1 and multiplied by 16) System clock (ICLK): 96 MHz (PLL divided by 2) Peripheral module clock B (PCLKB): 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
C compiler	Renesas Electronics Corporation C/C++ Compiler Package for RX Family V.1.02 Release 01
	Compile options –cpu=rx600 –output=obj="$(CONFIGDIR)\$(FILELEAF).obj" –debug –nologo The integrated development environment default settings are used.
iodefine.h version	Version 1.6A
Endian	Little endian
Operating mode	Single-chip mode
Processor mode	Supervisor mode
Sample code version	Version 1.00
Board used	Renesas Starter Kit+ for RX63N (part number: R0K50563NSxxxBE)

3. Reference Application Notes

For additional information associated with this document, refer to the following application notes.

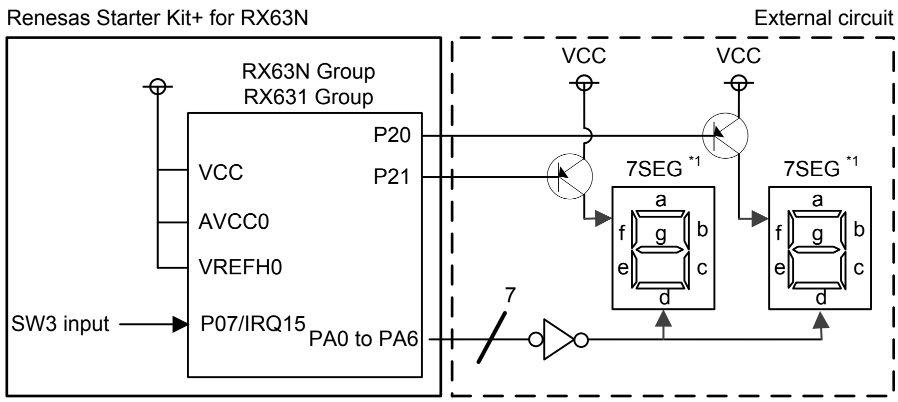
- RX63N Group, RX631 Group Initial Setting Rev. 1.10 (R01AN1245EJ)
- RX Family Coding Example of Wait Processing by Software Rev. 1.00 (R01AN1852EJ)

The initial setting functions and wait processing by software in the reference application notes are used in the sample code in this application note. The revision numbers of the reference application notes are current as of the issue date of this application note. Note that iodefine.h is partially modified according to the specification of this application note. The latest versions are always recommended. Visit the Renesas Electronics Corporation website to check and download the latest versions.

4. Hardware

4.1 Hardware Configuration

Figure 4.1 shows the Connection Example.



Note 1. This example assumes 7SEG dynamic common anodes are used.

Figure 4.1 Connection Example

4.2 Note on Using the RSK Board

VCC and VREFH0 are connected to Renesas Starter Kit+ for RX63N. When disconnecting VCC and VREFH0, remove the option link resistor R5 (0 Ω) on the solder side of the RSK board and connect an option link resistor R6 (0 Ω). VREFH0 can be applied to CON_VREFH0 (header JA1, pin 7). Refer to Renesas Starter Kit+ for RX63N User's Manual and circuit diagrams for details.

4.3 Pins Used

Table 4.1 lists the Pins Used and Their Functions. The pins used assume that the target product is a 176-pin MCU. When using products with less than 176 pins, select pins appropriate to the product used.

Table 4.1 Pins Used and Their Functions

Pin Name	I/O	Function
P07/IRQ15	Input	Switch input for executing calibration
PA0	Output	Outputs segment a of the 7SEG
PA1	Output	Outputs segment b of the 7SEG
PA2	Output	Outputs segment c of the 7SEG
PA3	Output	Outputs segment d of the 7SEG
PA4	Output	Outputs segment e of the 7SEG
PA5	Output	Outputs segment f of the 7SEG
PA6	Output	Outputs segment g of the 7SEG
P20	Output	Outputs the first digit of the 7SEG
P21	Output	Outputs the second digit of the 7SEG

5. Software

5.1 Operation Overview

After the MCU is released from the reset state, the I/O ports and peripheral functions are initialized, and the MCU enters the waiting for calibration state. If the IRQ15 interrupt request is generated in this state, calibration is performed. The normal reference temperature is A/D converted in the calibration. The A/D converted value and the temperature sensor calibration data are used to calculate the temperature slope.

When calibration is complete, A/D conversion continues. The A/D converted value and temperate slope are used to calculate the ambient temperature, and the calculated value is displayed on the 7SEG.

In this application note, A/D conversion is performed every 100 ms. Also, in order to calculate the average A/D converted value, six A/D converted values are stored to the RAM, the highest and lowest values are eliminated, and the average of the remaining four values is calculated as the ambient temperature.

The CMT CMI0 interrupt is used to start A/D conversion every 100 ms. The CMT is set to generate a compare match interrupt request in 1 ms cycles, and for each compare match interrupt request generated, the A/D converter cycle counter variable (cnt_cycle) is incremented up to 100 ms.

Settings for the CMT, AD, and temperature sensor are listed below.

<u>CMT0</u>

- Count clock: PCLKB divided by 32
- Compare match interrupt cycle: 1 ms

<u>AD</u>

- Operating mode: Single scan mode
- A/D conversion start condition: Software trigger
- Number of sampling states: 240 states (sampling time is 5 µs)
- A/D-converted value addition mode: Not used
- A/D conversion clock: PCLK

<u>Temperature sensor</u>

- Temperature sensor output enable: Enable output from the temperature sensor to the 12-bit A/D converter.

Figure 5.1 shows the Temperature Measurement Timing Diagram.

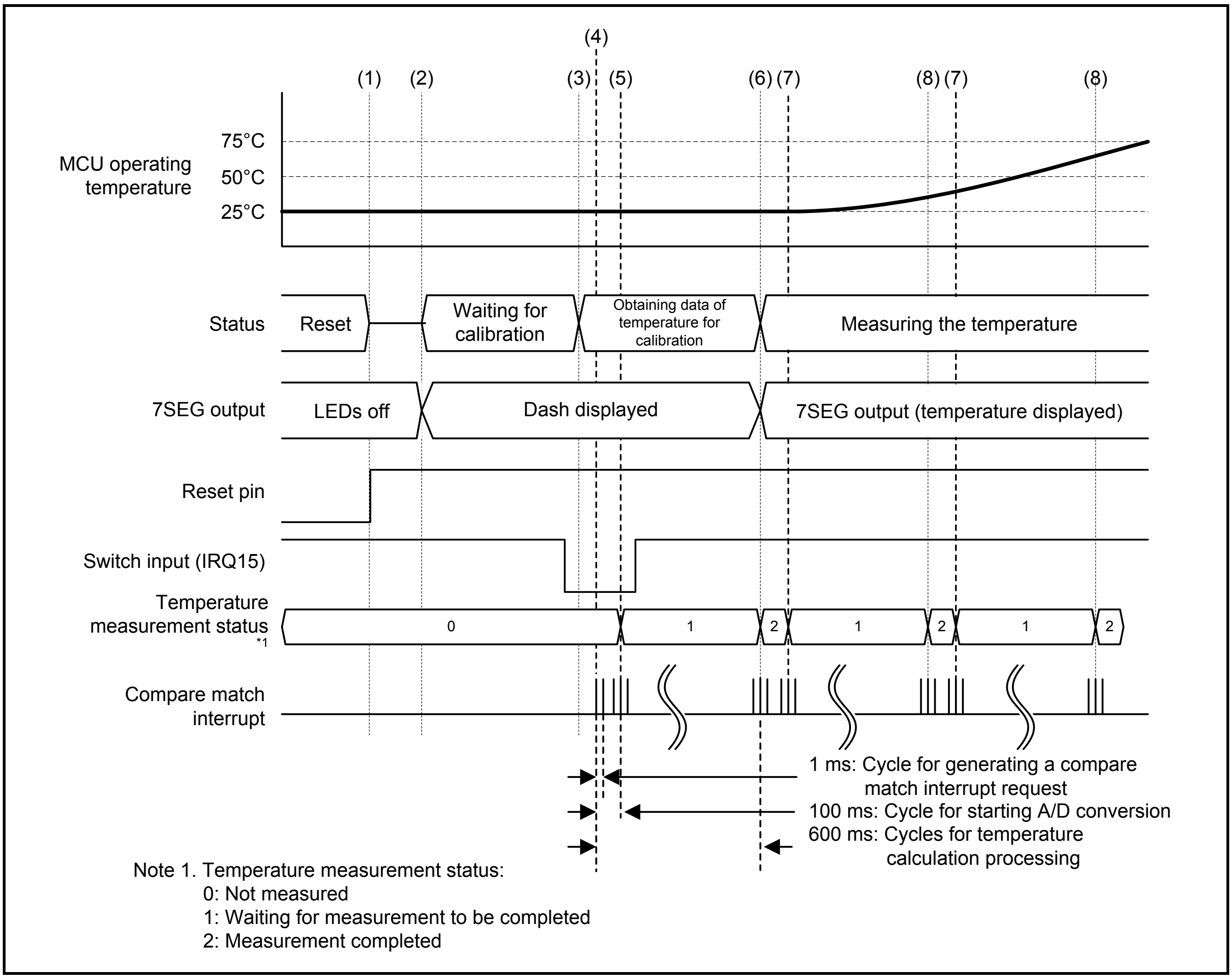


Figure 5.1 Temperature Measurement Timing Diagram

(1) After the MCU is released from the reset state, the CMT and IRQ15 are initialized, and the AD and the temperature sensor are released from the module stop state.

(2) After the AD and the temperature sensor are released from the module stop state, the MCU waits 10 ms *1, and then enters the calibration wait state. At this time, a dash is displayed on the 7SEG.

(3) When a falling edge is detected on the switch (IRQ15), the CMT count starts.

(4) The CMT is set to generate a compare match interrupt request in 1 ms cycles, and for each compare match interrupt request generated, the A/D converter cycle counter variable (cnt_cycle) is incremented.

(5) When the A/D converter cycle counter variable reaches 100 (100 ms), the AD and the temperature sensor are initialized, and the ADST bit is set to 1 (starts PGA) to start A/D conversion.

(6) A/D conversion is performed six times. Their average becomes the A/D converted value of the normal reference temperature, the temperature slope is calculated, and calibration is done.

(7) When the A/D converter cycle counter variable reaches 100 (100 ms), the AD and the temperature sensor are initialized, and the ADST bit is set to 1 to start A/D conversion.

(8) After performing A/D conversion six times, the current temperature is calculated using the average and the temperature slope, and then displayed on the 7SEG.

Note 1. After the AD is released from the module stop state, wait 10 ms before starting A/D conversion.

5.1.1 Formula for the Temperature Characteristic

In this application note, the slope necessary for the temperature characteristic formula is calculated using the following items:

- An ambient temperature of 128°C (hereinafter referred to as high reference temperature) stored in the temperature sensor calibration data registers (TSCDR)
- The A/D converted value of the normal reference temperature measured after the MCU is released from the reset state.

Refer to the *RX63N Group, RX631 Group User's Manual: Hardware* (hereinafter referred to as UMH) for details on the TSCDR register.

Table 5.1 lists the Conditions for Measuring the A/D Converted Values of the Temperature Sensor Output Values Stored in the TSCDR Register.

Table 5.1 Conditions for Measuring the A/D Converted Values of the Temperature Sensor Output Values Stored in the TSCDR Register

Register Symbol	Conditions for Measuring A/D Converted Values	
	Voltage applied to AVCC0 and VREFH0	Temperature for measurement
TSCDR	3.3 V	128°C

When applying voltage not listed in Table 5.1 to AVCC0 and VREFH, the A/D converted value must be calculated according to the applied voltage. The A/D conversion value to be calculated is defined as CAL_{128} here.

When AVCC0 is 1.8 V ≤ AVCC0 < 2.7 V, then formula [1] below is used to calculate CAL_{125};
When AVCC0 is 2.7 V ≤ AVCC0 ≤ 3.6 V, then formula [2] below is used to calculate CAL_{125}.

$CAL_{128} = 3.3 \div VREFH0 \times TSCDR$ (TSCDR: TSCDR.TSCD[11:0] bit value)

To calculate the ambient temperature, the temperature slope must be calculated first. Here, the temperature slope become is defined as the increment value of the A/D converted value to the temperature. Note that the UMH describes the method to calculate the temperature slope and temperature after converting the A/D converted value to voltage, but this application note calculates the temperature slope and temperature using the A/D converted value with no conversion to voltage.

The formula for calculating the temperature slope is below.

Temperature slope: Slope

High reference temperature (128°C): T1

Normal reference temperature (25°C): T2

A/D converted value of the high reference temperature (128°C): CAL_{128}

A/D converted value of the normal reference temperature (25°C): CAL_{25} (value measured using the normal reference temperature after the MCU is released from the reset state)

Temperature slope: Slope = $(CAL_{128} - CAL_{25}) \div (T1 - T2)$

Since T1 = 128(°C) and T2 = 25(°C), the slope becomes the following:

Slope = $(CAL_{128} - CAL_{25}) \div (128 - 25) = (CAL_{128} - CAL_{25}) \div 103$

The formula for calculating the ambient temperature is below.

Measured temperature: T (°C)

A/D converted value of the temperature sensor when the temperature was measured: CAL_S

$$T = T2 + (CAL_S - CAL_{25}) \div Slope$$
$$= 25 + (CAL_S - CAL_{25}) \div ((CAL_{128} - CAL_{25}) \div 103)$$
$$= 25 + 103((CAL_S - CAL_{25}) \div (CAL_{128} - CAL_{25}))$$

When measuring the temperature to the tenths place, temperature data (T1, T2) is multiplied by 10.

Measured temperature: Ts (°C)

$$Ts = T \times 10 = (25 + 103((CAL_S - CAL_{25}) \div (CAL_{128} - CAL_{25}))) \times 10$$
$$= (25 \times 10) + (103((CAL_S - CAL_{25}) \div (CAL_{128} - CAL_{25})) \times 10)$$
$$= 250 + 1030((CAL_S - CAL_{25}) \div (CAL_{128} - CAL_{25}))$$

Refer to the UMH for basic information.

5.2 File Composition

Table 5.2 lists the Files Used in the Sample Code, Table 5.3 lists the Standard Include Files, and Table 5.4 lists Functions and Setting Values for the Reference Application Notes. Files generated by the integrated development environment are not included in this table.

Table 5.2 Files Used in the Sample Code

File Name	Outline
main.c	Main processing
r_temps.c	Temperature sensor processing
r_temps.h	Header file for r_temps.c

Table 5.3 Standard Include Files

File Name	Outline
stdbool.h	This file defines the macros associated with the Boolean and its value.
stdint.h	This file defines the macros declaring the integer type with the specified width.
machine.h	This file defines the types of intrinsic functions for the RX Family.

Table 5.4 Functions and Setting Values for the Reference Application Notes (RX63N Group Initial Setting, RX Family Coding Example of Wait Processing by Software)

File Name	Function	Setting Value
r_init_stop_module.c	R_INIT_StopModule()	—
r_init_stop_module.h	—	—
r_init_non_existent_port.c	R_INIT_NonExistentPort()	—
r_init_non_existent_port.h	—	Set to the 176-pin package
r_init_clock.c	R_INIT_Clock()	—
r_init_clock.h	—	—
r_delay.c	R_DELAY_Us(unsigned long us, unsigned long khz)	Set the wait time.
r_delay.h	—	—

5.3 Option-Setting Memory

Table 5.5 lists the Option-Setting Memory Configured in the Sample Code. When necessary, set a value suited to the user system.

Table 5.5 Option-Setting Memory Configured in the Sample Code

Symbol	Address	Setting Value	Contents
OFS0	FFFF FF8Fh to FFFF FF8Ch	FFFF FFFFh	The IWDT is stopped after a reset. The WDT is stopped after a reset.
OFS1	FFFF FF8Bh to FFFF FF88h	FFFF FFFFh	The voltage monitor 0 reset is disabled after a reset. HOCO oscillation is disabled after a reset.
MDES	FFFF FF83h to FFFF FF80h	FFFF FFFFh	Little endian

5.4 Constants

Table 5.6 to Table 5.9 list the constants used in the sample code.

Table 5.6 Constants Used in the Sample Code (main.c)

Constant Name	Setting Value	Contents
CMT_CYCLE_MS	100	A/D conversion cycle (ms)
SEG_CYCLE_MS	8	7SEG select output switch cycles (ms)
ONES_DIGIT	0	7SEG output flag value
SEG_TBL_DASH	10	7SEG display table index: "—"
SEG_TBL_H	11	7SEG display table index: "H"
SEG_TBL_i	12	7SEG display table index: "i"
SEG_TBL_L	13	7SEG display table index: "L"
SEG_TBL_o	14	7SEG display table index: "o"
SEG_TBL_BLANK	15	7SEG display table index: Blank

Table 5.7 Constants Used in the Sample Code (r_temps.h) (Changeable by the User)

Constant Name	Setting Value	Contents
VREF_VOLTAGE	3.3f	Voltage applied to the VREFH0 pin (in units of V)
ORDINARY_REF_TEMP	25	Normal reference temperature (°C): If the value set is 25, then the normal reference temperature is assumed to be 25°C.
TEMP_ACCURACY	10	Temperature calculation accuracy: The multiplication rate is set. When the value set is "10", the value is calculated to the tenths place. When the value set is "100", the value is calculated to the hundreds place. Do not set a multiplier other than a multiple of 10, and do not set a negative value.
CNV_CNT_MAX	6	Number of average value samplings: If the set value is 6, when six A/D converted values have been accumulated, the highest and lowest values are excluded, and the average of the remaining four becomes the A/D converted value. Do not set 2 or less for this constant.

Table 5.8 Constants Used in the Sample Code (r_temps.h) (Not Changeable by the User)

Constant Name	Setting Value	Contents
STA_AD_IDLE	0	A/D conversion status: Not performed
STA_AD_WAIT	1	A/D conversion status: Waiting for A/D conversion to be completed
STA_AD_FINISH	2	A/D conversion status: A/D conversion completed
HIGH_REF_VOLTAGE	3.3f	Voltage for measuring the high reference temperature (128°C)
HIGH_REF_TEMP	128	High reference temperature (°C)
ADCONV_IN_OPERATION	0xFFFF	A/D converted value during A/D conversion (invalid value)
TSCDR_VALUE	(TEMPSCONST.TSCDR.BIT.TSCD)	TSCDR register value
HIGH_REF_POTENTIAL_VAL	(uint16_t)(HIGH_REF_VOLTAGE / VREF_VOLTAGE * TSCDR_VALUE)	A/D converted value of the high reference temperature (128°C)
SLOPE_COEFFICIENT_TEMP	(HIGH_REF_TEMP – ORDINARY_REF_TEMP) * TEMP_ACCURACY	Temperature slope
ORDINARY_REF_TEMP_IN_ACC	ORDINARY_REF_TEMP * TEMP_ACCURACY	Value of the normal reference temperature (25°C) multiplied by the temperature calculation accuracy

5.5 Variables

Table 5.9 and Table 5.10 list the static variables, and Table 5.11 lists the const Variable.

Table 5.9 static Variables (main.c)

Type	Variable Name	Contents	Function Used
static volatile uint16_t	cnt_cycle	A/D conversion cycle counter	Excep_CMT0_CMI0
static volatile uint16_t	cnt_led_cycle	7SEG select output switch cycle counter	Excep_CMT0_CMI0
static uint8_t	digit_10	7SEG second digit display data	disp_7seg disp_comswitch_7seg disp_bar_7seg
static uint8_t	digit_1	7SEG first digit display data	disp_7seg disp_comswitch_7seg disp_bar_7seg

Table 5.10 static Variables (r_temps.c)

Type	Variable Name	Contents	Function Used
static volatile int16_t	slope_potential	Slope of the A/D converted value	R_TEMPS_Calibration R_TEMPS_Calc
static volatile int16_t	ordinary_potential	A/D converted value of the normal reference temperature (= CAL_{25})	R_TEMPS_Calibration R_TEMPS_Calc
static volatile int8_t	ad_status	A/D conversion status	main R_TEMPS_GetADStatus R_TEMPS_Calibration R_TEMPS_Measurement Excep_S12AD_S12ADI0
static volatile int16_t	now_temp	Calculated current temperature	R_TEMPS_GetNowTemp Excep_S12AD_S12ADI0
static volatile uint16_t	now_potential	Current A/D converted value	R_TEMPS_Calibration Excep_S12AD_S12ADI0
static volatile uint16_t	buf_ad_value[CNT_CNT_MAX]	A/D converted value buffer	Excep_S12AD_S12ADI0
static volatile uint16_t	ad_max_value	Highest A/D converted value	Excep_S12AD_S12ADI0
static volatile uint16_t	ad_min_value	Lowest A/D conversion value	Excep_S12AD_S12ADI0
static volatile uint8_t	ad_smp_cnt	Write pointer for the A/D converted value buffer	Excep_S12AD_S12ADI0
static volatile uint8_t	f_startup_wait	First start time wait determination Flag	r_temps_init

Table 5.11 const Variable

Type	Variable Name	Contents	Function Used
static const uint8_t	seg_pattern_table	7SEG display table	disp_comswitch_7seg

5.6 Functions

Table 5.12 lists the Functions.

Table 5.12 Functions

Function Name	Outline	Location
main	Main processing	main.c
port_init	Port initialization	main.c
peripheral_init	Peripheral function initialization	main.c
cmt_init	CMT initialization	main.c
irq_init	IRQ initialization	main.c
disp_7seg	Processing to update the 7SEG display data	main.c
disp_comswitch_7seg	Processing to switch the 7SEG select output	main.c
disp_bar_7seg	Processing to display a dash on the 7SEG	main.c
Excep_CMT0_CMI0	Compare match interrupt handling	main.c
r_temps_init	AD and temperature sensor initialization	r_temps.c
r_temps_getpotential	Obtain the temperature sensor measurement result	r_temps.c
r_temps_calc	Processing to calculate the current temperature	r_temps.c
R_TEMPS_ModuleStopCancel	Release the AD and the temperature sensor from the module stop state	r_temps.c
R_TEMPS_GetADStatus	Obtain the A/D conversion status	r_temps.c
R_TEMPS_GetNowTemp	Obtain the current temperature	r_temps.c
R_TEMPS_Calibration	Processing for temperature sensor calibration	r_temps.c
R_TEMPS_Measurement	Processing for temperature sensor measurement	r_temps.c
Excep_S12AD_S12ADI0	A/D conversion complete interrupt handling	r_temps.c

5.7 Function Specifications

The following tables list the sample code function specifications.

main	
Outline	Main processing
Header	None
Declaration	void main(void)
Description	After initialization, this function performs temperature sensor calibration once. After that, it converts the temperature sensor output from digital to analog every 100 ms, and the calculated temperature is displayed on the 7SEG.
Arguments	None
Return value	None

port_init	
Outline	Port initialization
Header	None
Declaration	static void port_init(void)
Description	This function initializes the ports.
Arguments	None
Return value	None

peripheral_init	
Outline	Peripheral function initialization
Header	None
Declaration	static void peripheral_init(void)
Description	This function initializes the peripheral functions.
Arguments	None
Return value	None

cmt_init	
Outline	CMT initialization
Header	None
Declaration	static void cmt_init(void)
Description	This function initializes CMT0.
Arguments	None
Return value	None

irq_init	
Outline	IRQ initialization
Header	None
Declaration	static void irq_init(void)
Description	This function initializes IRQ15.
Arguments	None
Return value	None

disp_7seg	
Outline	Processing to update the 7SEG display data
Header	None
Declaration	static void disp_7seg(int16_t disp_data)
Description	This function sets the value specified in the argument as the data to be displayed in the 7SEG.
Arguments	int16_t disp_data : 7SEG display Less than 0 (negative value): "Lo" is displayed 100 or higher: "Hi" is displayed Other than above: Temperature is displayed
Return value	None

disp_comswitch_7seg	
Outline	Processing to switch the 7SEG select output
Header	None
Declaration	static void disp_comswitch_7seg(void)
Description	This function switches the 7SEG select signal to be output.
Arguments	None
Return value	None

disp_bar_7seg	
Outline	Processing to display a dash on the 7SEG
Header	None
Declaration	static void disp_bar_7seg(void)
Description	This function displays a dash on the 7SEG.
Arguments	None
Return value	None

Excep_CMT0_CMI0	
Outline	Compare match interrupt handling
Header	None
Declaration	static void Excep_CMT0_CMI0(void)
Description	This function performs interrupt handling in 1 ms cycles. The counter is incremented each time an interrupt request is generated. When the counter reaches 100 (100 ms), temperature measurement is started. Also, after the counter reaches 8 (8 ms), the 7SEG select signal to be output is switched.
Arguments	None
Return value	None

r_temps_init	
Outline	AD and temperature sensor initialization
Header	None
Declaration	static void r_temps_init(void)
Description	This function initializes the AD and the temperature sensor.
Arguments	None
Return value	None

r_temps_getpotential	
Outline	Obtain the temperature sensor measurement result
Header	None
Declaration	static uint16_t r_temps_getpotential (void)
Description	This function obtains the measured A/D converted value.
Arguments	None
Return value	uint16_t: A/D converted value of the temperature sensor: : ADCONV_IN_OPERATION: A/D conversion in process : Other than ADCONV_IN_OPERATION: A/D converted value

r_temps_calc	
Outline	Processing to calculate the current temperature
Header	None
Declaration	static int16_t r_temps_calc(uint16_t w_now_potential)
Description	This function calculates the temperature from the A/D converted value in the argument.
Arguments	uint16_t w_now_potential : A/D converted value
Return value	int16_t: Current temperature (°C)

R_TEMPS_ModuleStopCancel	
Outline	Release the AD and the temperature sensor from the module stop state
Header	r_temps.h
Declaration	void R_TEMPS_ModuleStopCancel (void)
Description	This function releases the AD and the temperature sensor from the module stop state.
Arguments	None
Return value	None

R_TEMPS_GetADStatus	
Outline	Obtain the A/D conversion status
Header	r_temps.h
Declaration	uint8_t R_TEMPS_GetADStatus(void)
Description	This function obtains the current status of the A/D conversion.
Arguments	None
Return value	uint8_t: A/D conversion status STA_AD_IDLE: Not performed STA_AD_WAIT: Waiting for A/D conversion to be completed STA_AD_FINISH: A/D conversion completed

R_TEMPS_GetNowTemp	
Outline	Obtain the current temperature
Header	r_temps.h
Declaration	int16_t R_TEMPS_GetNowTemp (void)
Description	This function obtains the current temperature.
Arguments	None
Return value	int16_t: Current temperature

R_TEMPS_Calibration	
Outline	Processing for temperature sensor calibration
Header	r_temps.h
Declaration	void R_TEMPS_Calibration(void)
Description	This function obtains the A/D converted value of the normal reference temperature and calculates the temperature slope.
Arguments	None
Return value	None

R_TEMPS_Measurement	
Outline	Processing for temperature sensor measurement
Header	r_temps.h
Declaration	void R_TEMPS_Measurement(void)
Description	This function starts measuring the current temperature.
Arguments	None
Return value	None

Excep_S12AD_S12ADI0	
Outline	A/D conversion complete interrupt handling
Header	None
Declaration	static void Excep_S12AD_S12ADI0(void)
Description	When A/D conversion is completed, the A/D converted values are saved in the RAM. After the sixth A/D conversion is completed, the highest and lowest A/D converted values are excluded, and the average of the remaining four A/D converted values is calculated.
Arguments	None
Return value	None

5.8 Flowcharts

5.8.1 Main Processing

Figure 5.2 shows the Main Processing.

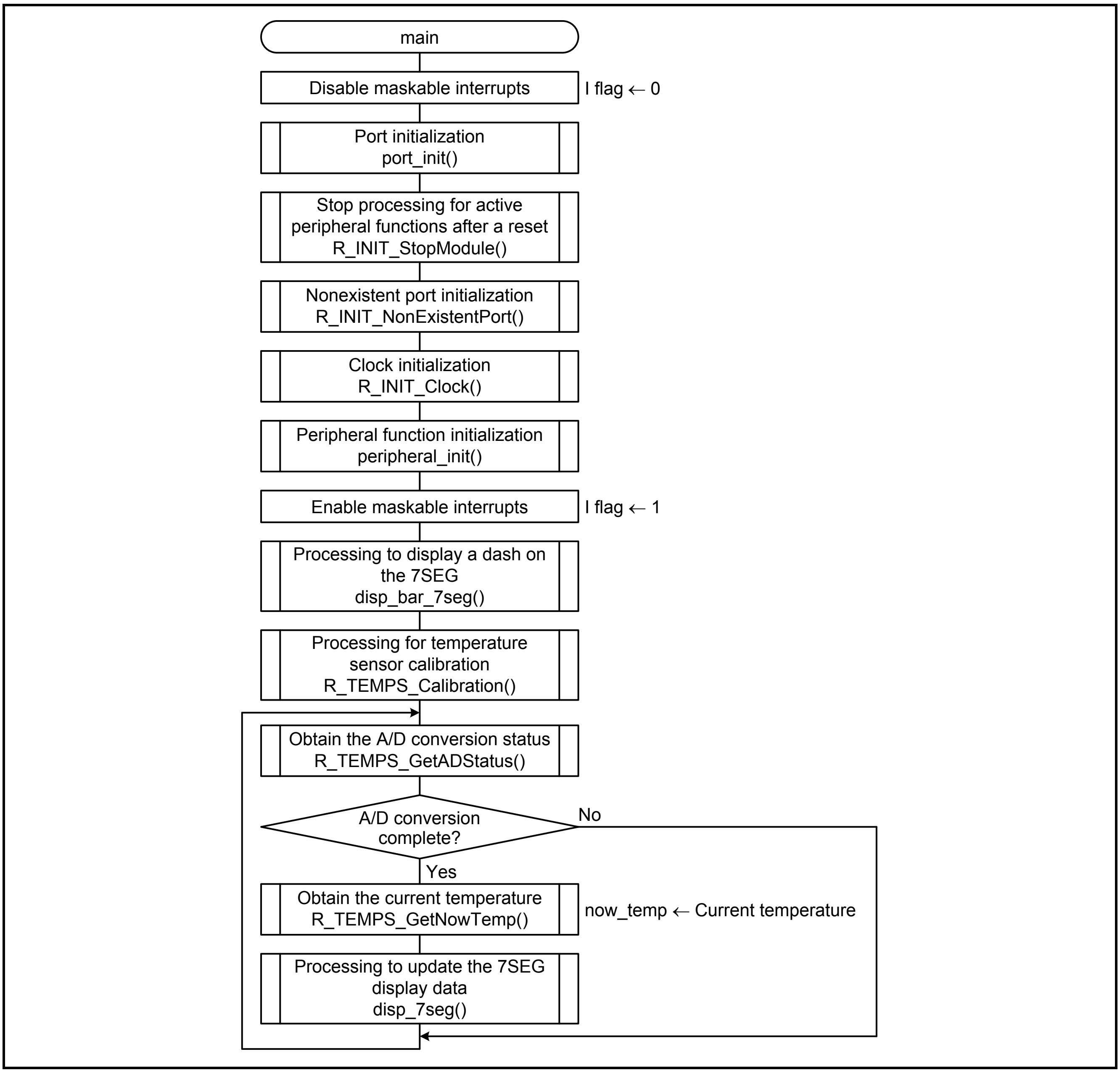


Figure 5.2 Main Processing

5.8.2 Port Initialization

Figure 5.3 shows Port Initialization.

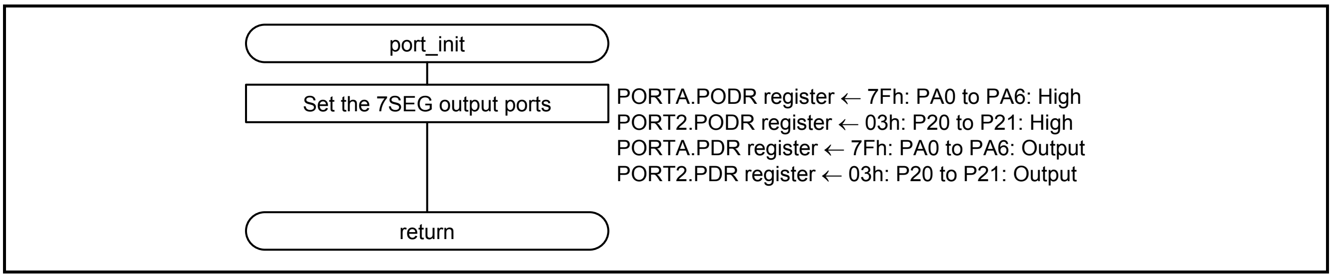


Figure 5.3 Port Initialization

5.8.3 Peripheral Function Initialization

Figure 5.4 shows Peripheral Function Initialization.

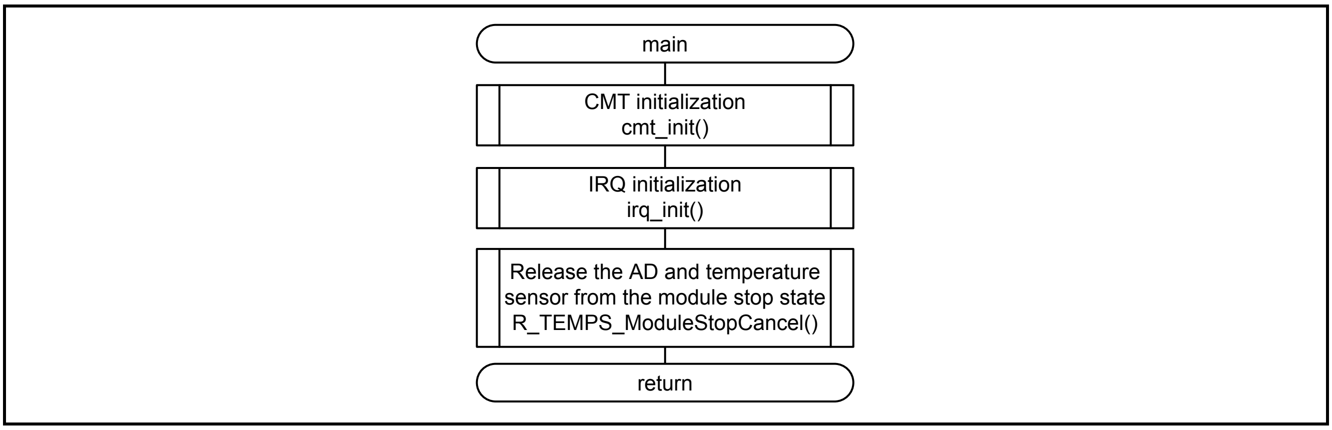


Figure 5.4 Peripheral Function Initialization

5.8.4 CMT Initialization

Figure 5.5 shows CMT Initialization.

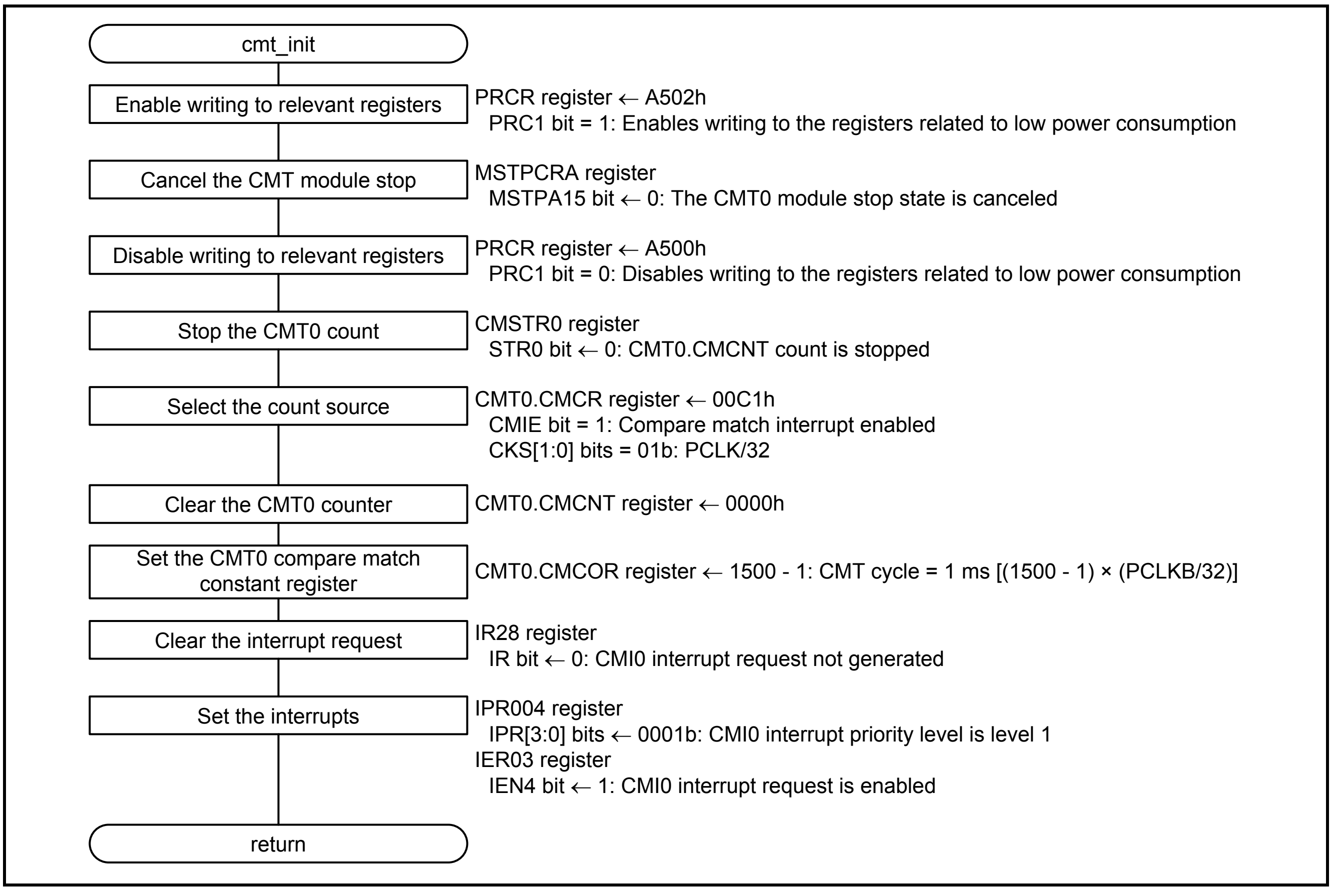


Figure 5.5 CMT Initialization

5.8.5 IRQ Initialization

Figure 5.6 shows IRQ Initialization.

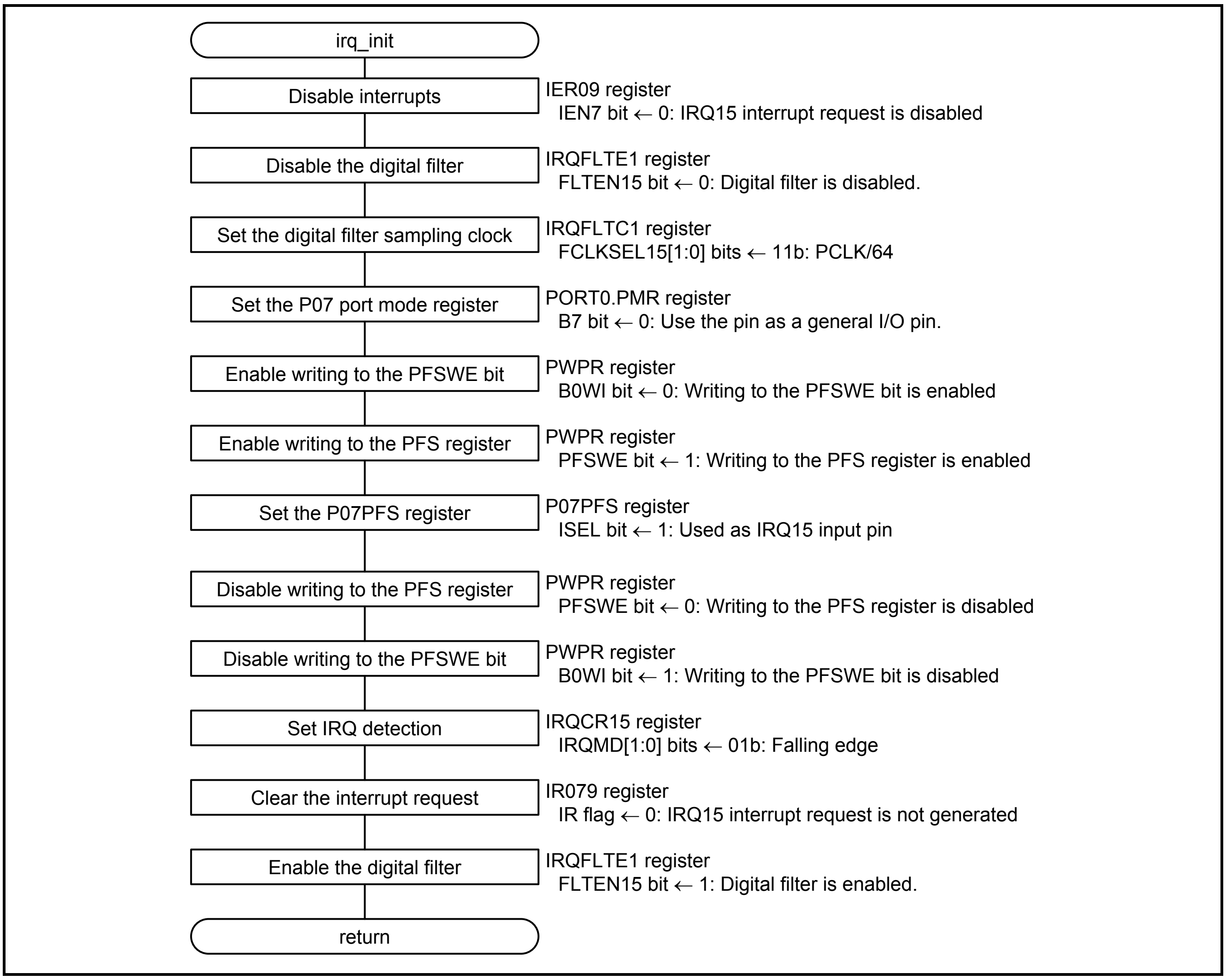


Figure 5.6 IRQ Initialization

5.8.6 Processing to Update the 7SEG Display Data

Figure 5.7 shows the Processing to Update the 7SEG Display Data.

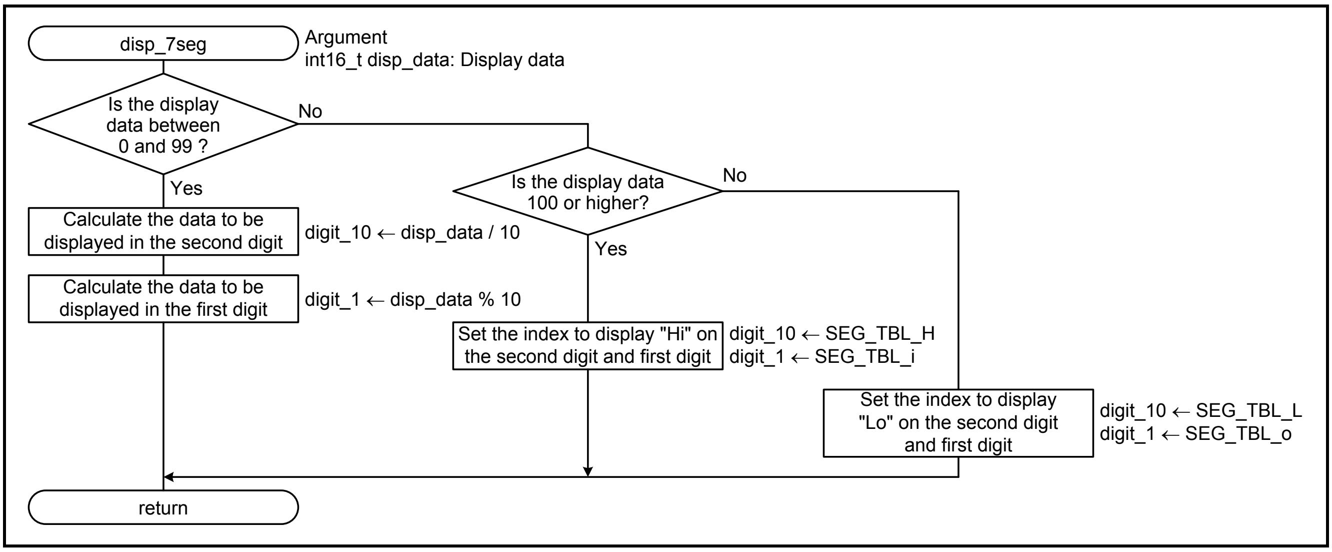


Figure 5.7 Processing to Update the 7SEG Display Data

5.8.7 Processing to Switch the 7SEG Select Output

Figure 5.8 shows the Processing to Switch the 7SEG Select Output.

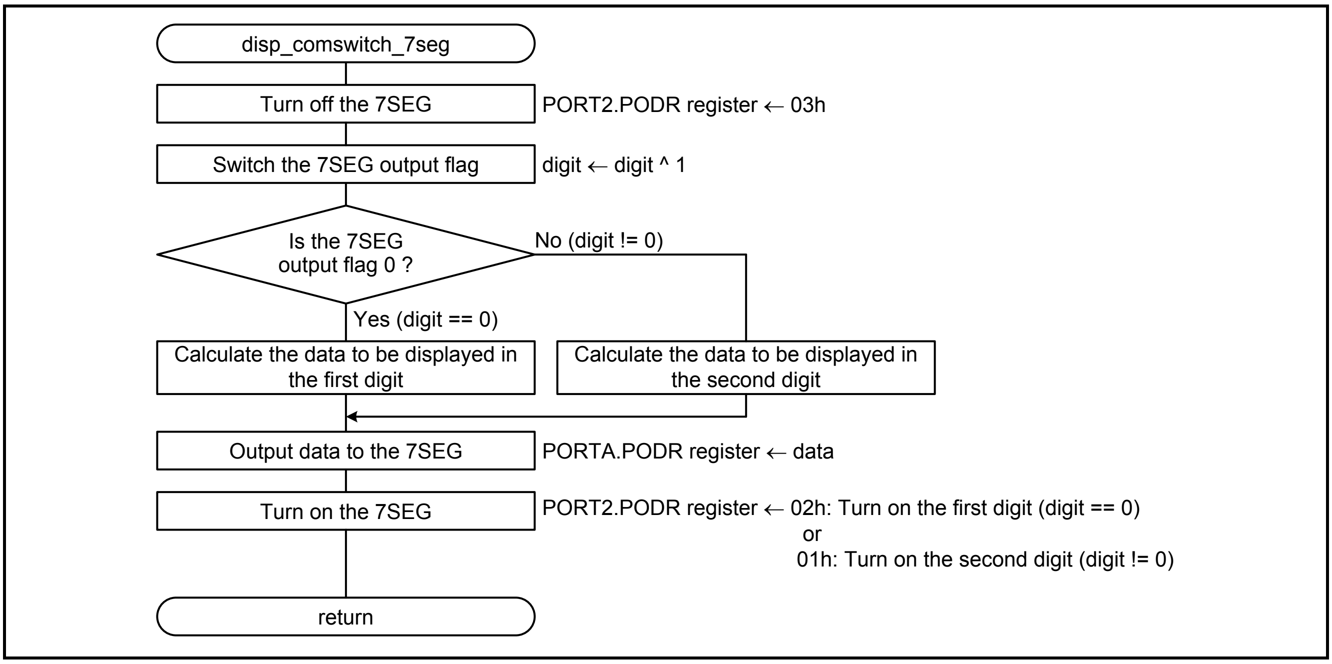


Figure 5.8 Processing to Switch the 7SEG Select Output

5.8.8 Processing to Display a Dash on the 7SEG

Figure 5.9 shows the Processing to Display a Dash on the 7SEG.

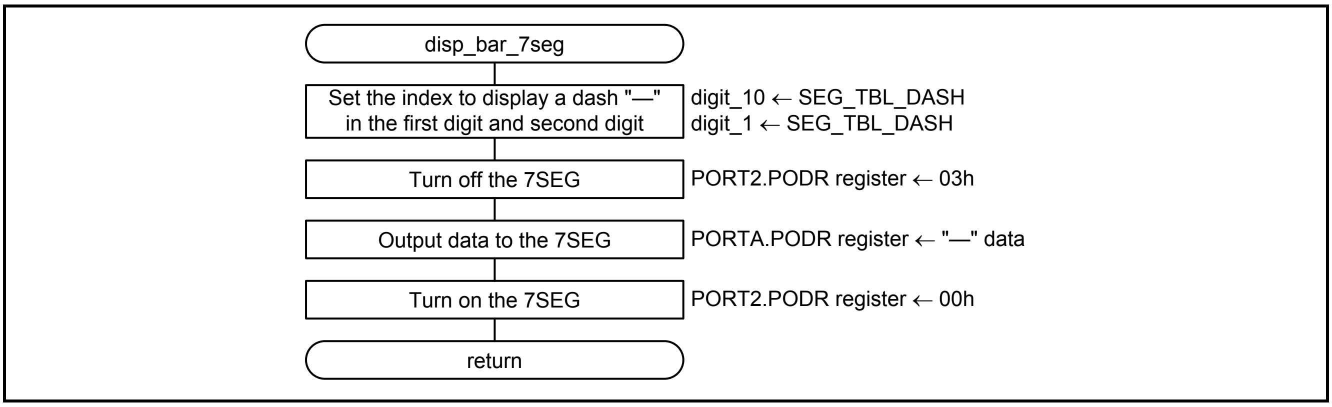


Figure 5.9 Processing to Display a Dash on the 7SEG

5.8.9 Compare Match Interrupt Handling

Figure 5.10 shows the Compare Match Interrupt Handling.

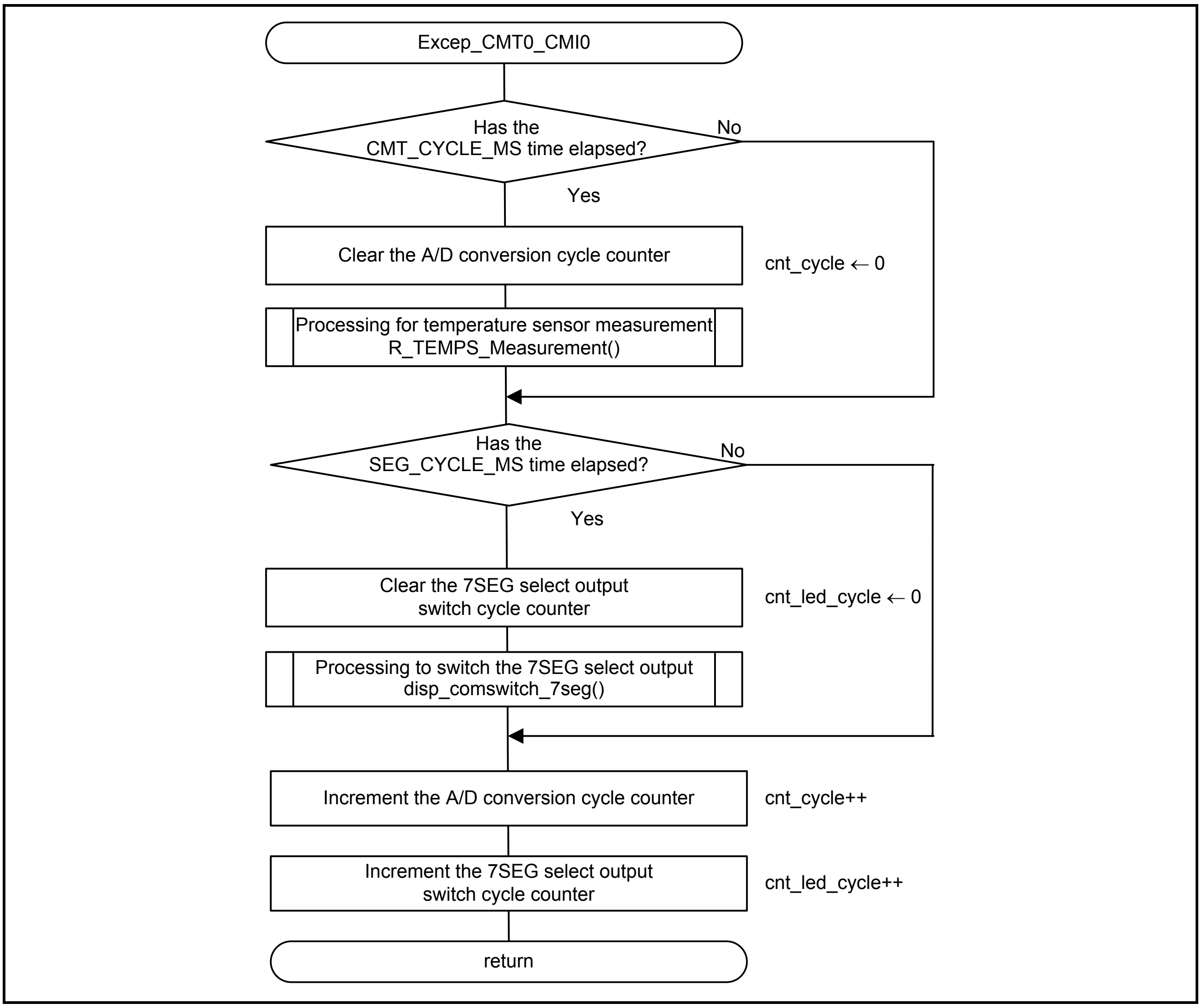


Figure 5.10 Compare Match Interrupt Handling

5.8.10 AD and Temperature Sensor Initialization

Figure 5.11 shows the AD and Temperature Sensor Initialization.

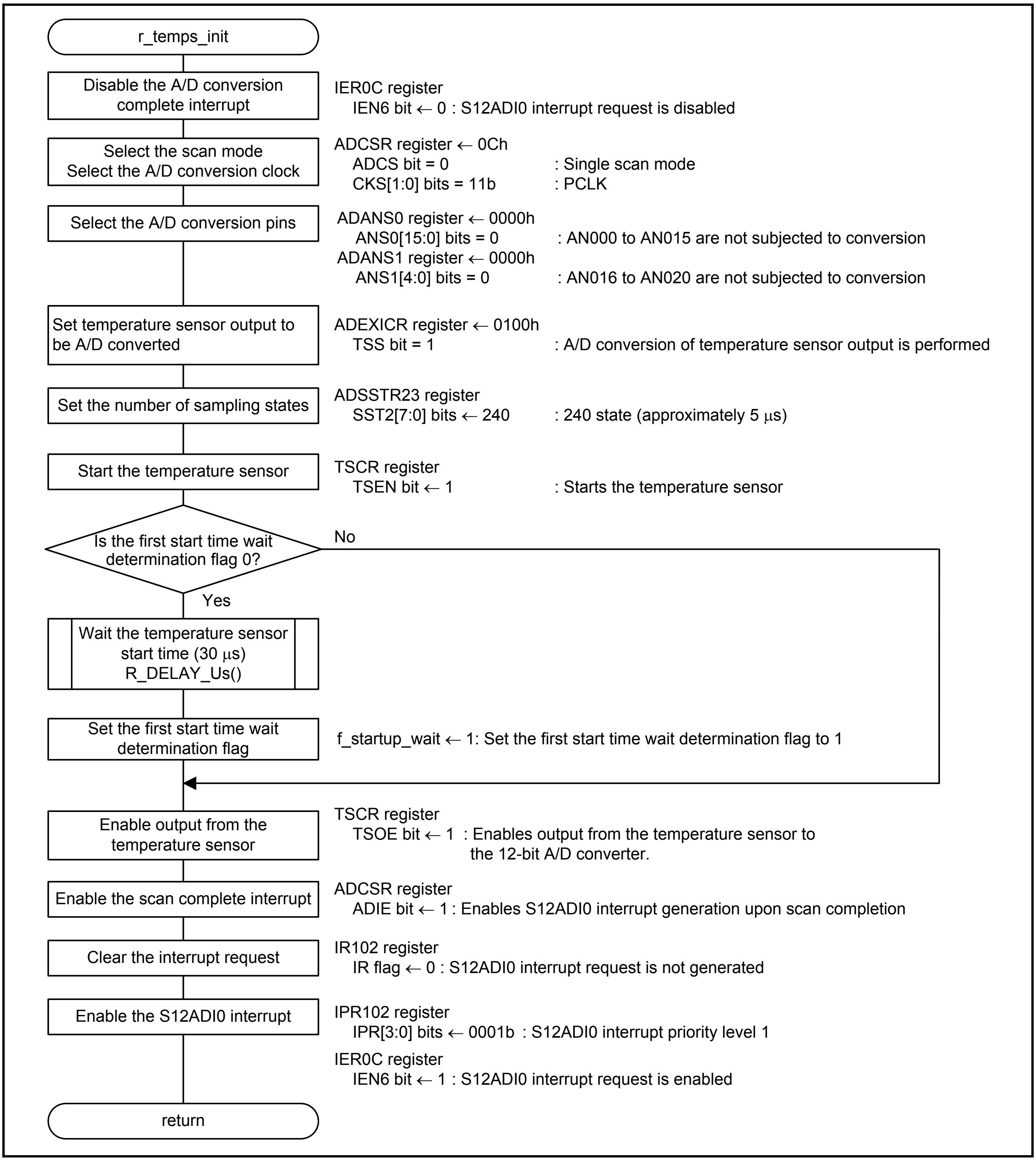


Figure 5.11 AD and Temperature Sensor Initialization

5.8.11 Obtain the Temperature Sensor Measurement Result

Figure 5.12 shows Obtain the Temperature Sensor Measurement Result.

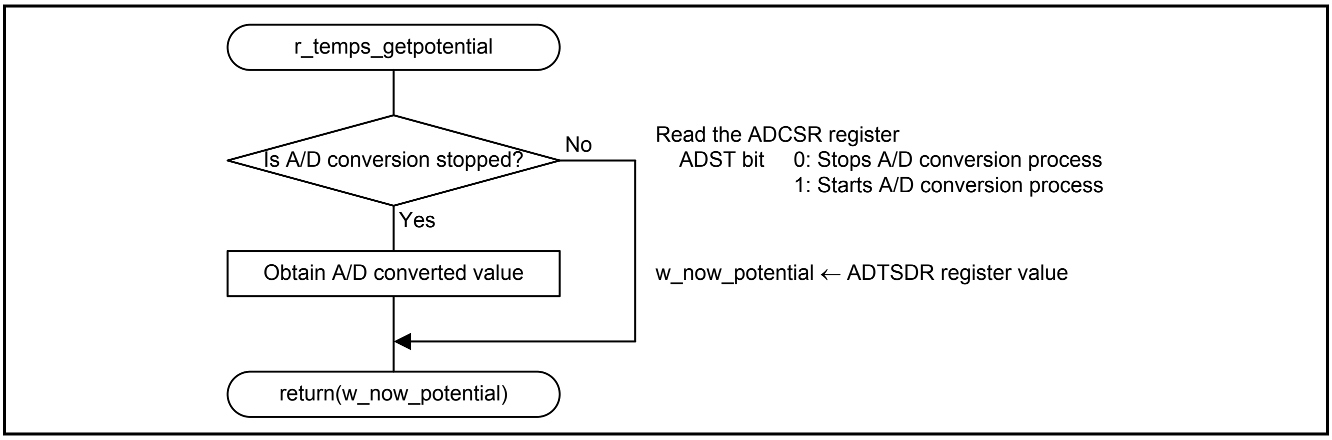


Figure 5.12 Obtain the Temperature Sensor Measurement Result

5.8.12 Processing to Calculate the Current Temperature

Figure 5.13 shows Calculate the Current Temperature.

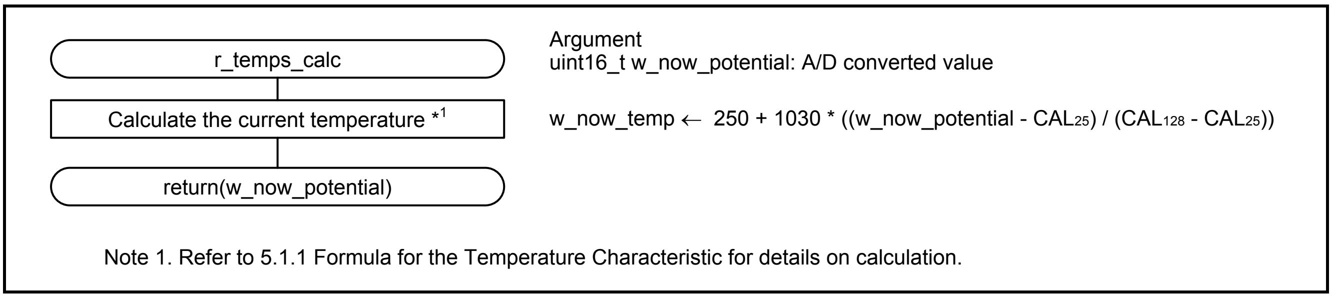


Figure 5.13 Calculate the Current Temperature

5.8.13 Release the AD and the Temperature Sensor from the Module Stop State

Figure 5.14 shows Release the AD and the Temperature Sensor from the Module Stop State.

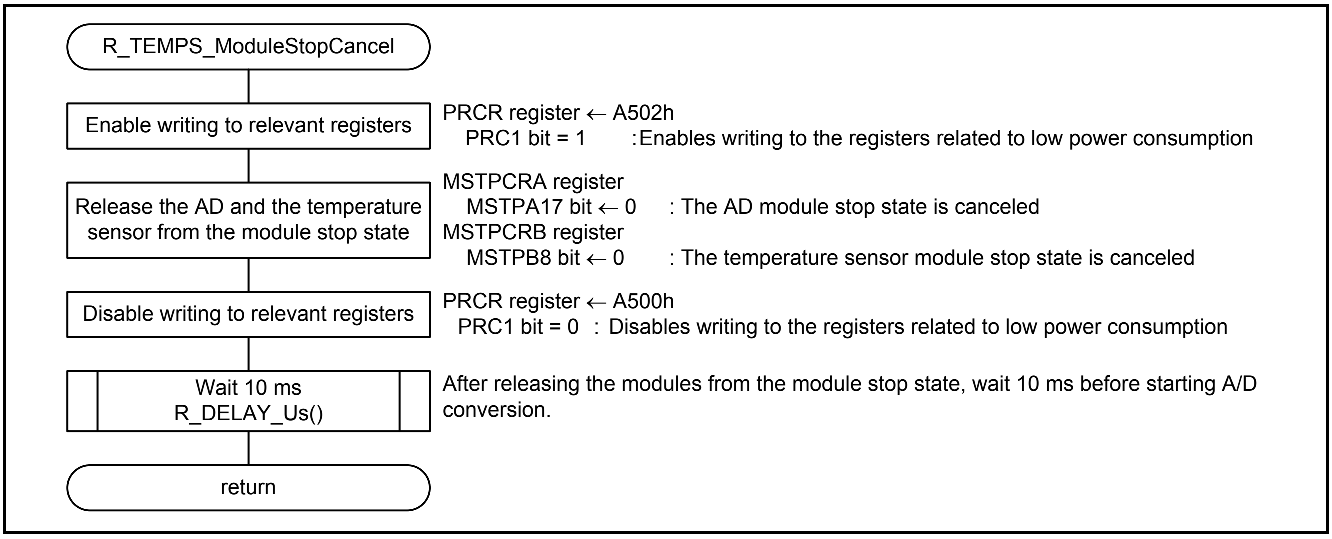


Figure 5.14 Release the AD and the Temperature Sensor from the Module Stop State

5.8.14 Obtain the A/D Conversion Status

Figure 5.15 shows Obtain the A/D Conversion Status.

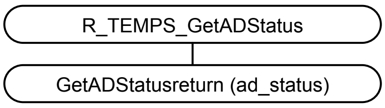


Figure 5.15 Obtain the A/D Conversion Status

5.8.15 Obtain the Current Temperature

Figure 5.16 shows Obtain the Current Temperature.

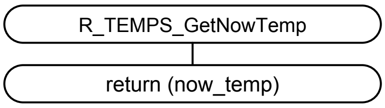


Figure 5.16 Obtain the Current Temperature

5.8.16 Processing for Temperature Sensor Calibration

Figure 5.17 shows the Processing for Temperature Sensor Calibration.

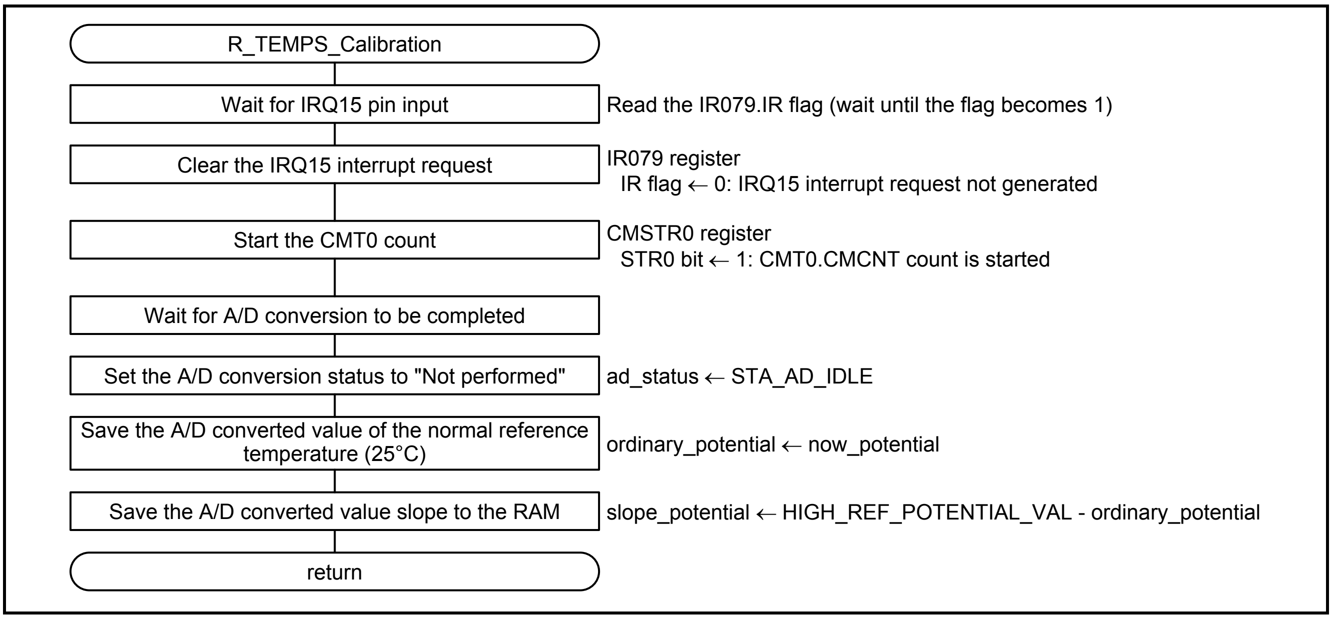


Figure 5.17 Processing for Temperature Sensor Calibration

5.8.17 Processing for Temperature Sensor Measurement

Figure 5.18 shows the Processing for Temperature Sensor Measurement.

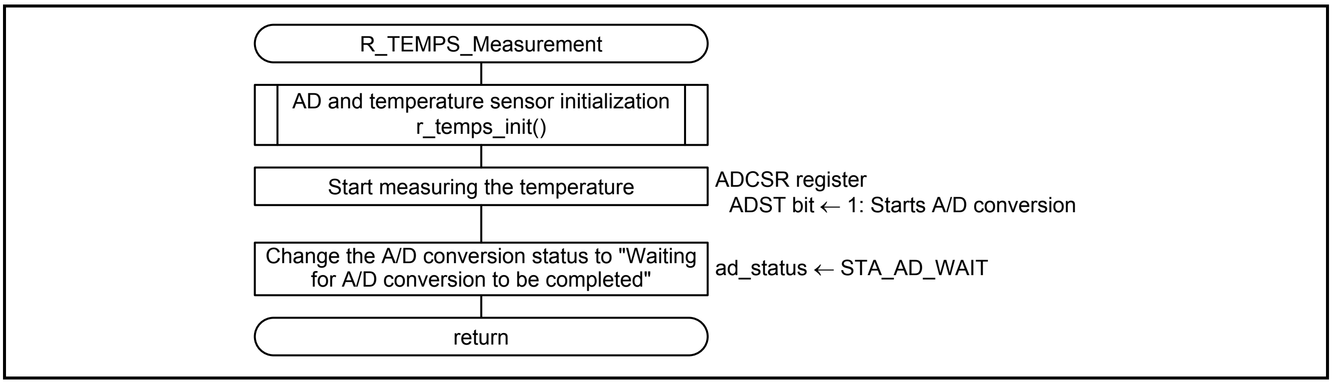


Figure 5.18 Processing for Temperature Sensor Measurement

5.8.18 A/D Conversion Complete Interrupt Handling

Figure 5.1 shows the A/D Conversion Complete Interrupt Handling.

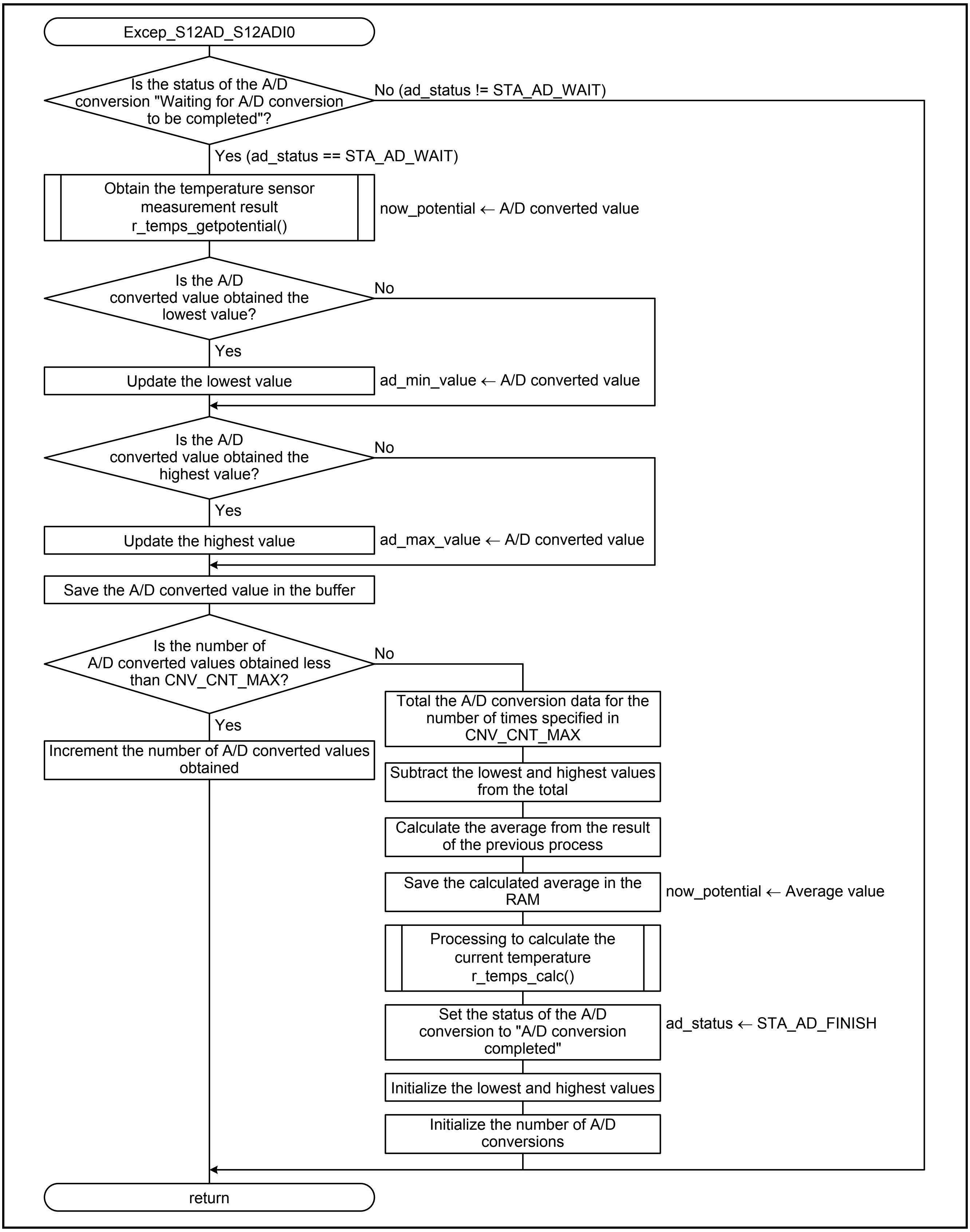


Figure 5.19 A/D Conversion Complete Interrupt Handling

6. Appendix (A/D Converted Value and Measured Temperature of the Temperature Sensor)

The ambient temperature of the MCU rises depending on the operating frequency or operation of the peripheral functions, and it takes several tens of seconds to stabilize the temperature after a reset is released. The time necessary to stabilize the temperature also varies depending on the operating environment. Accordingly, the A/D converted value rises for a while after a reset is released as shown in Figure 6.1.

When obtaining the A/D converted value of the temperature sensor at the normal reference temperature, measure the MCU surface temperature, and perform the A/D conversion of the temperature sensor after the MCU temperature becomes stable.

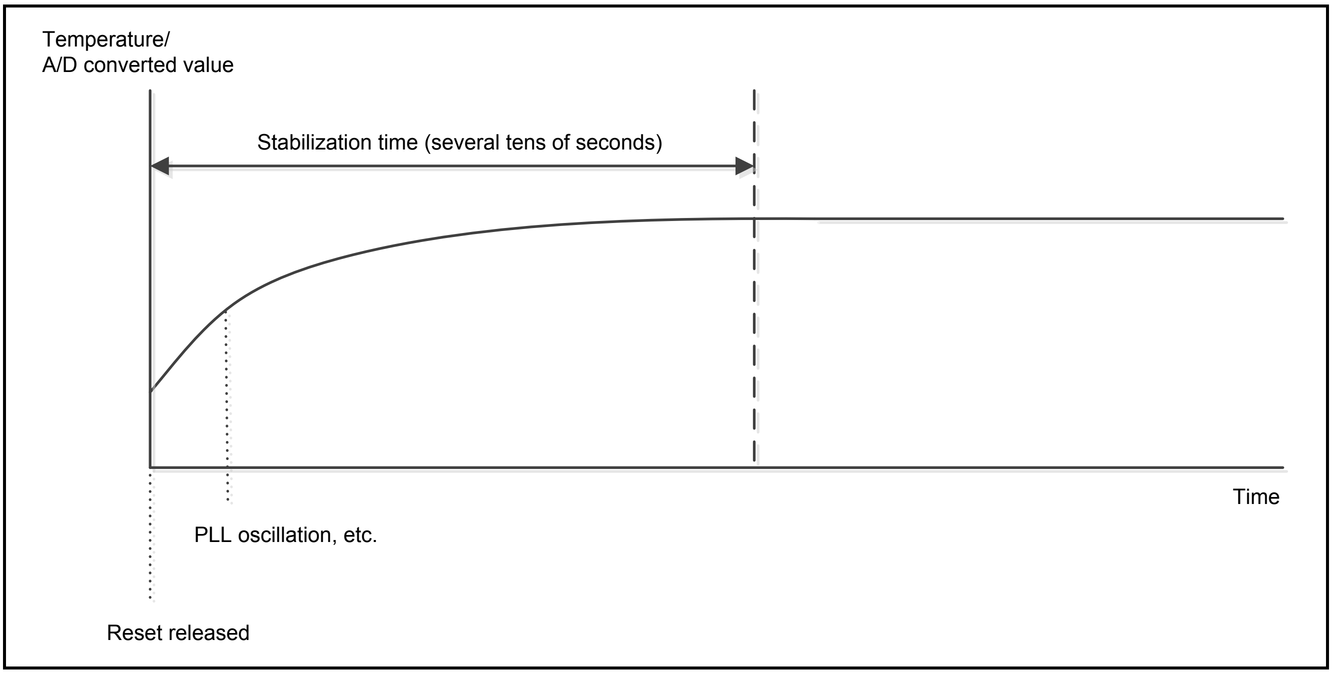


Figure 6.1 Relation Between the Temperature / A/D Converted Value and Operating Time

7. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

8. Reference Documents

User's Manual: Hardware
RX63N Group, RX631 Group User's Manual: Hardware Rev.1.80 (R01UH0041EJ)
The latest version can be downloaded from the Renesas Electronics website.

Technical Update/Technical News
The latest information 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 (R20UT0570EJ)
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	RX63N Group, RX631 Group Application Note Using the Temperature Sensor to Calculate the Ambient Temperature

Rev.	Date	Description	
		Page	Summary
1.00	Mar. 9, 2015	—	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
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

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 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

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 1207, 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 India Pvt. Ltd.
No.777C, 100 Feet Road, HALII Stage, Indiranagar, Bangalore, India
Tel: +91-80-67208700, Fax: +91-80-67208777

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 5.0