APPLICATION NOTE

RX21A Group

Using the Temperature Sensor to Calculate the Ambient Temperature

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Abstract

This document describes a method of using the RX21A Group temperature sensor to calculate the ambient temperature.

Products

RX21A Group, 64-Pin Package, ROM Capacity: 256 Kbytes to 512 Kbytes

RX21A Group, 80-Pin Package, ROM Capacity: 256 Kbytes to 512 Kbytes

RX21A Group, 100-Pin Package, ROM Capacity: 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 3

2. Operation Confirmation Conditions 5

3. Reference Application Notes 5

4. Hardware 6
4.1 Hardware Configuration 6
4.2 Pins Used 6

5. Software 7
5.1 Operation Overview 7
5.1.1 Formula for the Temperature Characteristic 9
5.2 File Composition 11
5.3 Option-Setting Memory 12
5.4 Constants 12
5.5 Variables 15
5.6 Functions 16
5.7 Function Specifications 17
5.8 Flowcharts 21
5.8.1 Main Processing 21
5.8.2 Port Initialization 22
5.8.3 Peripheral Function Initialization 22
5.8.4 CMT Initialization 23
5.8.5 IRQ Initialization 24
5.8.6 Processing to Update the 7SEG Display Data 25
5.8.7 Processing to Switch the 7SEG Select Output 25
5.8.8 Processing to Display a Dash on the 7SEG 26
5.8.9 Compare Match Interrupt Handling 26
5.8.10 AD and Temperature Sensor Initialization 27
5.8.11 Obtain the A/D Conversion Status 28
5.8.12 Obtain the Temperature Sensor Measurement Result 28
5.8.13 Obtain the Current Temperature 28
5.8.14 Processing for Temperature Sensor Calibration 29
5.8.15 Processing for Temperature Sensor Measurement 29
5.8.16 Processing to Calculate the Current Temperature 29
5.8.17 A/D Conversion Complete Interrupt Handling 30

6. Sample Code 31

7. Reference Documents 31

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 RX21A Group MCU, 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 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
10-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 (IRQ2) (hereinafter referred to as IRQ)	Switch input for calibrating with the normal reference temperature.
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.

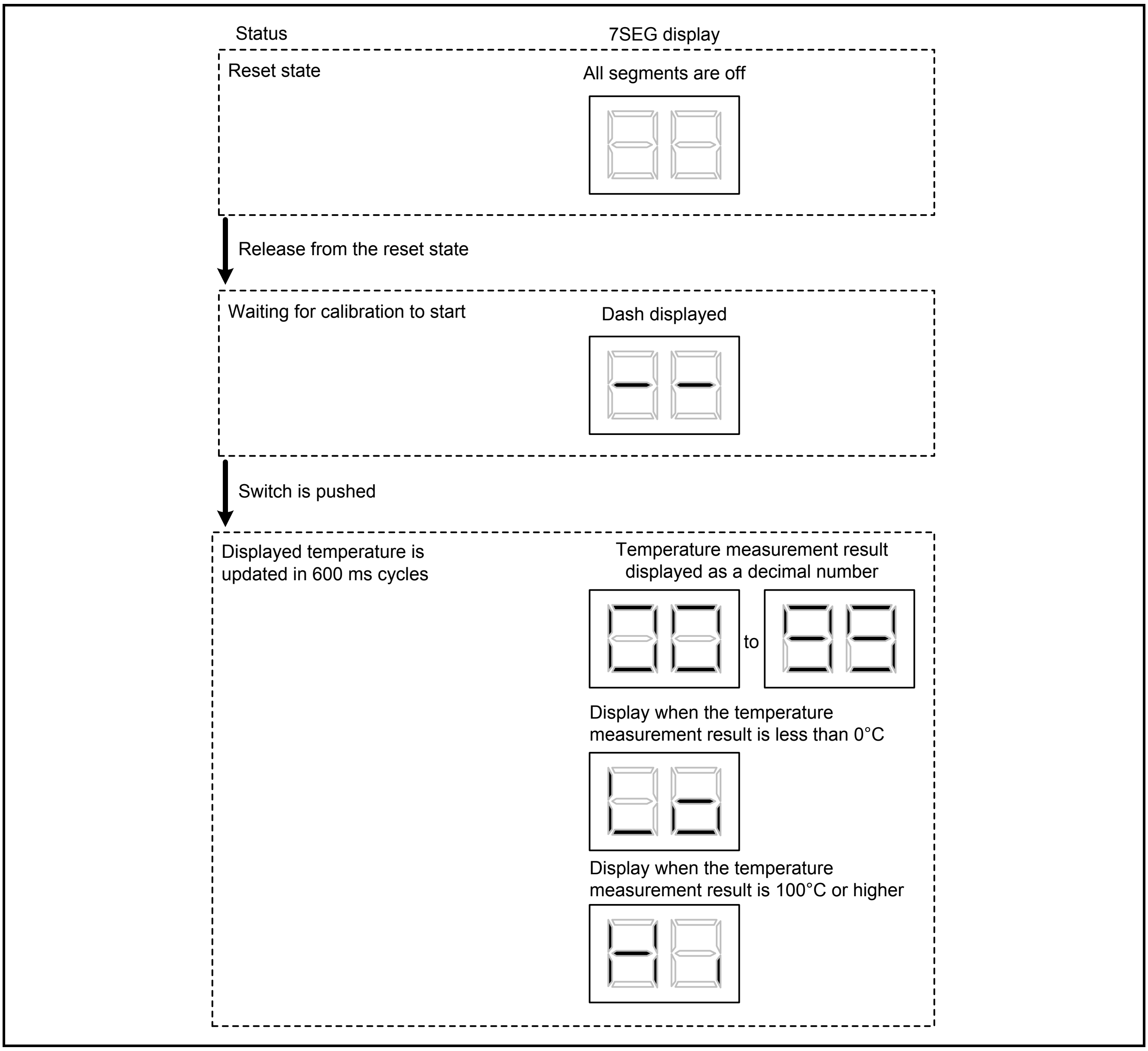


Figure 1.1 Transitioning States and Patterns Displayed on the 7SEG

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	R5F521A8BDFP (RX21A Group)
Operating frequencies	Main clock: 20 MHz System clock (ICLK): 20 MHz Peripheral module clock B (PCLKB): 20 MHz Peripheral module clock D (PCLKD): 2.5 MHz
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=rx200 –output=obj="$(CONFIGDIR)\$(FILELEAF).obj" –debug –nologo The integrated development environment default settings are used.
iodefine.h version	Version 1.1
Endian	Little endian
Operating mode	Single-chip mode
Processor mode	Supervisor mode
Sample code version	Version 1.00

3. Reference Application Notes

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

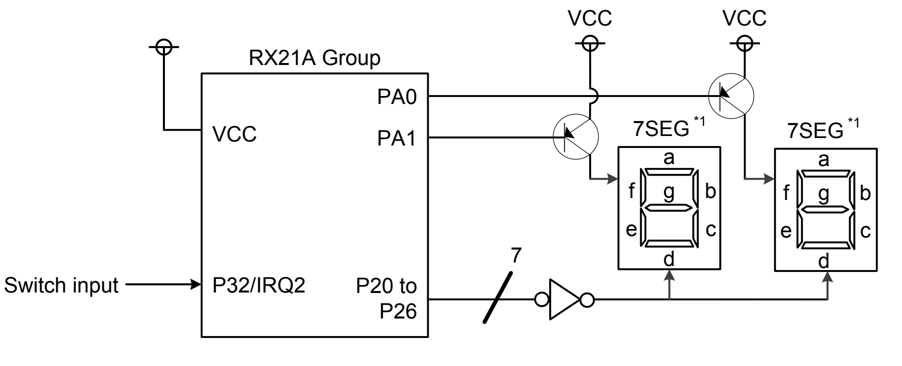
- RX21A Group Initial Setting Rev. 1.00 (R01AN1486EJ)
- RX Family Coding Example of Wait Processing by Software Rev. 1.00 (R01AN1852EJ)

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. However, 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 Pins Used

Table 4.1 lists the Pins Used and Their Functions. The pins used assume that the target product is a 100-pin MCU. When using products with less than 100 pins, select pins appropriate to the product used.

Table 4.1 Pins Used and Their Functions

Pin Name	I/O	Function
P32/IRQ2	Input	Switch input for executing calibration
P20	Output	Outputs segment a of the 7SEG
P21	Output	Outputs segment b of the 7SEG
P22	Output	Outputs segment c of the 7SEG
P23	Output	Outputs segment d of the 7SEG
P24	Output	Outputs segment e of the 7SEG
P25	Output	Outputs segment f of the 7SEG
P26	Output	Outputs segment g of the 7SEG
PA0	Output	Outputs the first digit of the 7SEG
PA1	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 IRQ2 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.

CMT0

- Count clock: PCLKB divided by 8
- Compare match interrupt cycle: 1 ms

AD

- Operating mode: Single scan mode
- A/D conversion start condition: Synchronous trigger (trigger from the temperature sensor)
- Number of sampling states: 180 states (sampling time is 72 µs)
- Analog input disconnection detection assist: Not used
- A/D-converted value addition mode: Not used
- Self-diagnosis of 10-bit A/D converter: Not used

Temperature sensor

- PGA gain [*1]: 2.7 V ≤ AVCC0 ≤ 3.6 V [*2]

  Note 1. PGA: Programmable gain amplifier

  Note 2. Change the constant settings as needed for the user system.

Figure 5.1 shows the Temperature Measurement Timing Diagram.

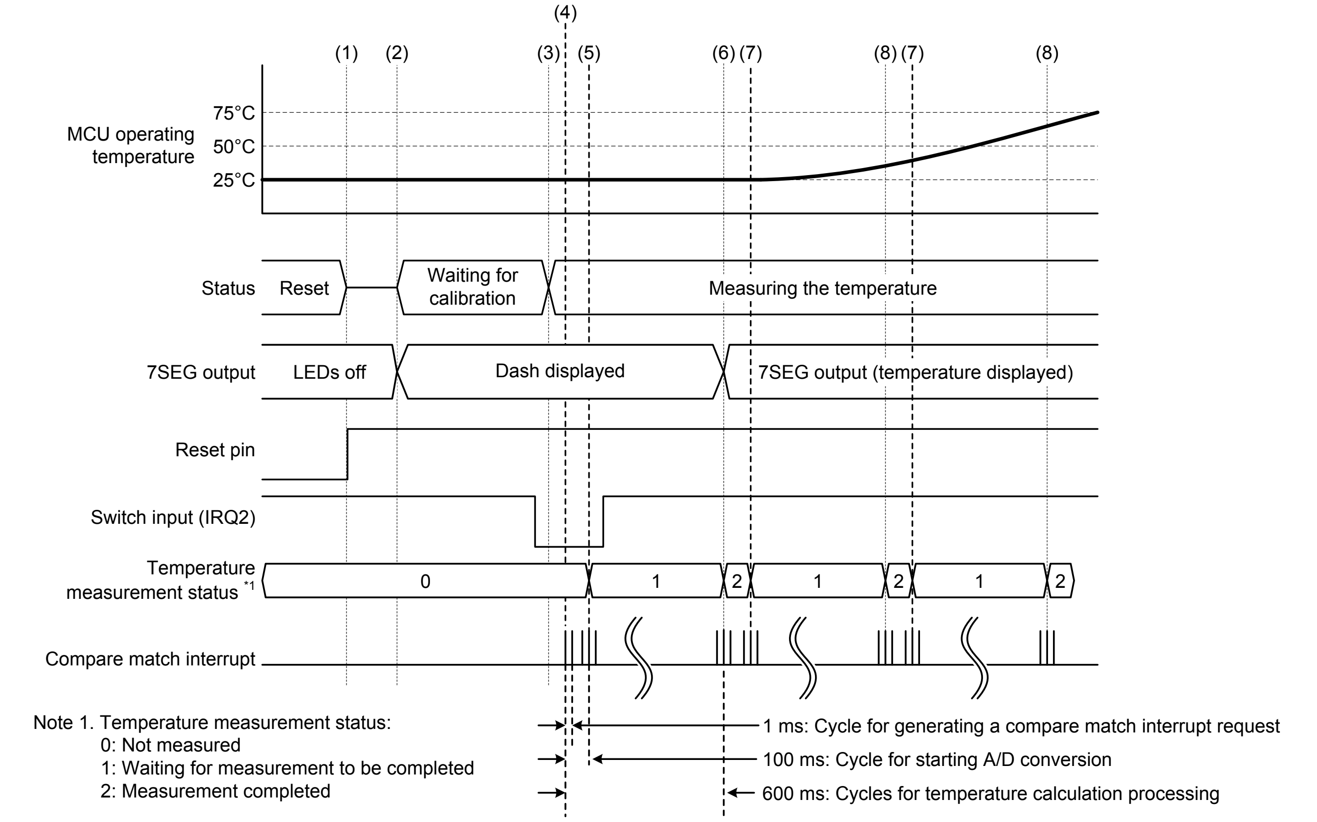


Figure 5.1 Temperature Measurement Timing Diagram

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

(2) After the AD is released from the module stop state, the MCU waits 1 μs *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 (IRQ2), 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 TSCR.PGAEN bit is set to 1 (starts PGA), and A/D conversion starts.

(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 TSCR.PGAEN bit is set to 1, and A/D conversion starts.

(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 at least 1 μs 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 125°C (hereinafter referred to as high reference temperature) stored in the temperature sensor calibration data registers (TSCDRn (n=0,1,3))
- The A/D converted value of the normal reference temperature measured after the MCU is released from the reset state.

Refer to the *RX21A User's Manual: Hardware* (hereinafter referred to as UMH) for details on the TSCDRn register (n=0,1,3).

Table 5.1 lists the Conditions for Measuring the A/D Converted Values of the Temperature Sensor Output Values Stored in the TSCDRn Register (n=0,1,3).

Table 5.1 Conditions for Measuring the A/D Converted Values of the Temperature Sensor Output Values Stored in the TSCDRn Register (n=0,1,3)

Register Symbol	Conditions for Measuring A/D Converted Values		
	Voltage applied to AVCC0 and VREFH0	TSCR.PGAGAIN[1:0] bits	Temperature for measurement
TSCDR0	1.8 V	00b	125°C
TSCDR1	2.7 V	01b	
TSCDR3	3.3 V	01b	

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_{125} 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}.

[1] $CAL_{125} = 1.8 \div VREFH0 \times TSCDR(0)$

[2] $CAL_{125} = 2.7 \div VREFH0 \times TSCDR(1) + \{3.3 \div VREFH0 \times TSCDR(3) - 2.7 \div VREFH0 \times TSCDR(1)\} \times (AVCC0 - 2.7) \div 0.6$

TSCDR(n): TSCDRn.TSCD[9:0] bit value (n = 0, 1, 3)

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 (125°C): T1

Normal reference temperature (25°C): T2

A/D converted value of the high reference temperature (125°C): CAL_{125}

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: $Slope = (CAL_{125} - CAL_{25}) \div (T1 - T2)$

Since T1 = 125(°C) and T2 = 25(°C), the slope becomes the following:

$Slope = (CAL_{125} - CAL_{25}) \div (125 - 25) = (CAL_{125} - CAL_{25}) \div 100$

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

$$T = T2 + (CAL_S - CAL_{25}) \div Slope$$
$$= T2 + (CAL_S - CAL_{25}) \div ((CAL_{125} - CAL_{25}) \div (T1 - T2))$$
$$= T2 + (T1 - T2) ((CAL_S - CAL_{25}) \div (CAL_{125} - CAL_{25}))$$
$$= 25 + 100((CAL_S - CAL_{25}) \div (CAL_{125} - CAL_{25}))$$

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

Measured temperature: Ts (°C)

$$Ts = T \times 10 = (25 + 100((CAL_S - CAL_{25}) \div (CAL_{125} - CAL_{25}))) \times 10$$
$$= (25 \times 10) + (100((CAL_S - CAL_{25}) \div (CAL_{125} - CAL_{25})) \times 10)$$
$$= 250 + 1000((CAL_S - CAL_{25}) \div (CAL_{125} - CAL_{25}))$$

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
temps.c	Temperature sensor processing
temps.h	Header file for 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 (RX21A 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 100-pin package
r_init_clock.c	R_INIT_Clock()	—
r_init_clock.h	—	Example of clock selection: No.5 selected. Change PCLKD division ratio to divided by 8.
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 (temps.c)

Constant Name	Setting Value	Contents
HIGH_REF_TEMP	125	High reference temperature (°C)
ADCONV_IN_OPERATION	0xFFFF	A/D converted value during A/D conversion (invalid value)
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 multiplied by the temperature calculation accuracy

Table 5.8 Constants Used in the Sample Code (temps.h) (Changeable by the User)

Constant Name	Setting Value	Contents
SEL_PGAGAIN	GAIN_RANGE1	Select PGA gain *1 GAIN_RANGE0: 1.8 V ≤ AVCC0 < 2.7 V GAIN_RANGE1: 2.7 V ≤ AVCC0 ≤ 3.6 V
AVCC_VOLTAGE	3.3	Voltage applied to the AVCC0 pin (in units of V) *1
VREF_VOLTAGE	3.3	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.

Note 1. Specify the value according to the voltage applied. If the value specified is inappropriate, the calculated result will be incorrect.

Table 5.9 Constants Used in the Sample Code (temps.h) (Not Changeable by the User)

Constant Name	Setting Value	Contents
GAIN_RANGE0	00h	PGA gain: 1.8 V ≤ AVCC0 < 2.7 V
GAIN_RANGE1	01h	PGA gain: 2.7 V ≤ AVCC0 ≤ 3.6 V
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
TSCDR0_VALUE	(TEMPSCONST.TSCDR0.BIT.TSCD)	TSCDR0 register value
TSCDR1_VALUE	(TEMPSCONST.TSCDR1.BIT.TSCD)	TSCDR1 register value
TSCDR3_VALUE	(TEMPSCONST.TSCDR3.BIT.TSCD)	TSCDR3 register value
HIGH_REF_POTENTIAL_VAL	See Note 1	A/D converted value of the high reference temperature

Note 1. The setting value varies according to the PGA gain selected. The following shows the setting value for each PGA gain.

When GAIN_RANGE0 is selected:
(uint16_t)(1.8 ÷ VREF_VOLTAGE × TSCDR0_VALUE)

When GAIN_RANGE1 is selected:
(uint16_t)((2.7 ÷ VREF_VOLTAGE × TSCDR1_VALUE) + ((3.3 ÷ VREF_VOLTAGE × TSCDR3_VALUE) – (2.7 ÷ VREF_VOLTAGE × TSCDR1_VALUE)) × (AVCC_VOLTAGE – 2.7) ÷ 0.6)

5.5 Variables

Table 5.10 and Table 5.11 list the static variables, and Table 5.12 lists the const Variable.

Table 5.10 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 5.11 static Variables (temps.c)

Type	Variable Name	Contents	Function Used
static int16_t	high_ref_potential	A/D converted value of the high reference temperature (= CAL_{125})	temps_init temps_calibration
static volatile int16_t	slope_potential	Slope of the A/D converted value	temps_calibration temps_calc
static volatile int16_t	ordinary_potential	A/D converted value of the normal reference temperature (= CAL_{25})	temps_calibration temps_calc
static volatile int8_t	ad_status	A/D conversion status	main temps_get_ad_status temps_calibration temps_measurement Excep_AD_ADI
static volatile int16_t	now_temp	Calculated current temperature	temps_get_now_temp Excep_AD_ADI
static volatile uint16_t	now_potential	Current A/D converted value	temps_calibration Excep_AD_ADI
static volatile uint16_t	buf_ad_value[CNT_CNT_MAX]	A/D converted value buffer	Excep_AD_ADI
static volatile uint16_t	ad_max_value	Highest A/D converted value	Excep_AD_ADI
static volatile uint16_t	ad_min_value	Lowest A/D conversion value	Excep_AD_ADI
static volatile uint8_t	ad_smp_cnt	Write pointer for the A/D converted value buffer	Excep_AD_ADI

Table 5.12 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 5.13 lists the Functions.

Table 5.13 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
temps_init	AD and temperature sensor initialization	temps.c
temps_get_ad_status	Obtain the A/D conversion status	temps.c
temps_get_potential	Obtain the temperature sensor measurement result	temps.c
temps_get_now_temp	Obtain the current temperature	temps.c
temps_calibration	Processing for temperature sensor calibration	temps.c
temps_measurement	Processing for temperature sensor measurement	temps.c
temps_calc	Processing to calculate the current temperature	temps.c
Excep_AD_ADI	A/D conversion complete interrupt handling	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 A/D converts the temperature sensor output 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 IRQ2.
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

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

temps_get_ad_status	
Outline	Obtain the A/D conversion status
Header	temps.h
Declaration	uint8_t temps_get_ad_status(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

temps_get_potential	
Outline	Obtain the temperature sensor measurement result
Header	None
Declaration	static uint16_t temps_get_potential(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

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

temps_calibration	
Outline	Processing for temperature sensor calibration
Header	temps.h
Declaration	void temps_calibration(void)
Description	This function obtains the A/D converted value of the normal reference temperature, and saves it to the RAM.
Arguments	None
Return value	None

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

temps_calc	
Outline	Processing to calculate the current temperature
Header	None
Declaration	static uint16_t 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)

Excep_AD_ADI	
Outline	A/D conversion complete interrupt handling
Header	None
Declaration	static void Excep_AD_ADI(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.

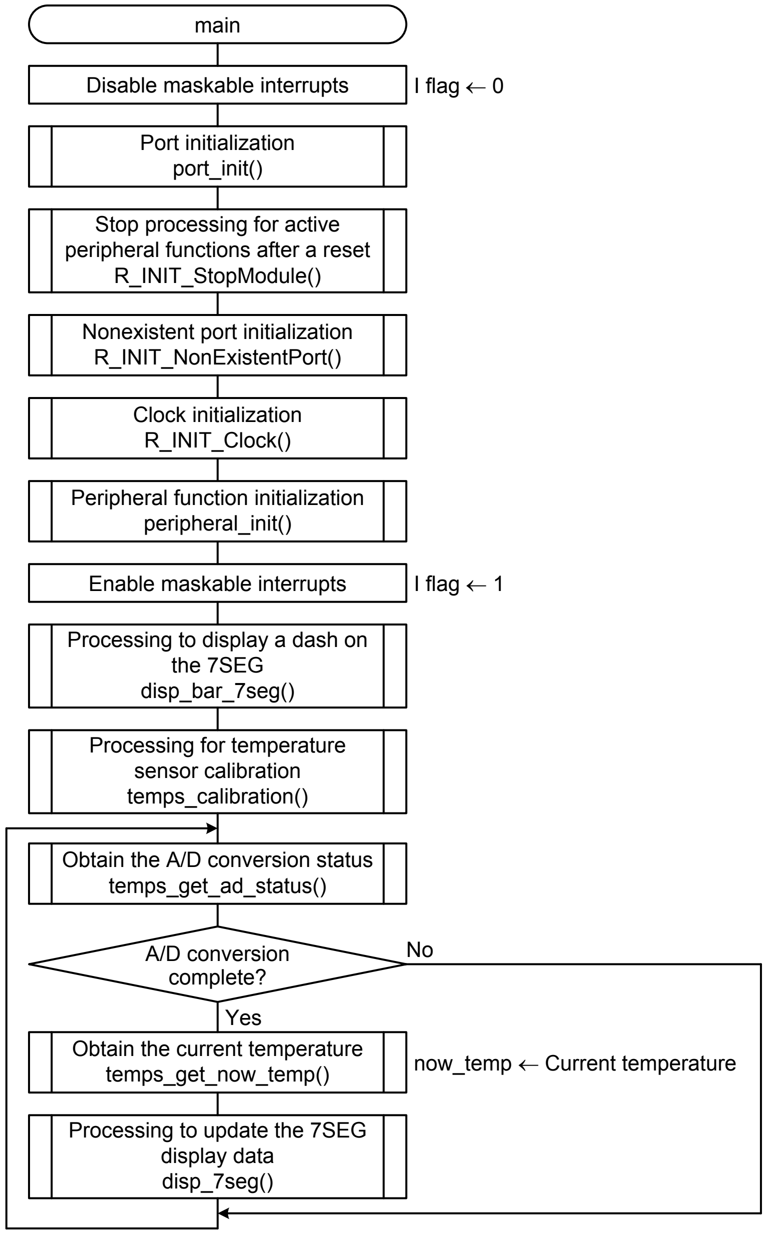


Figure 5.2 Main Processing

5.8.2 Port Initialization

Figure 5.3 shows Port Initialization.

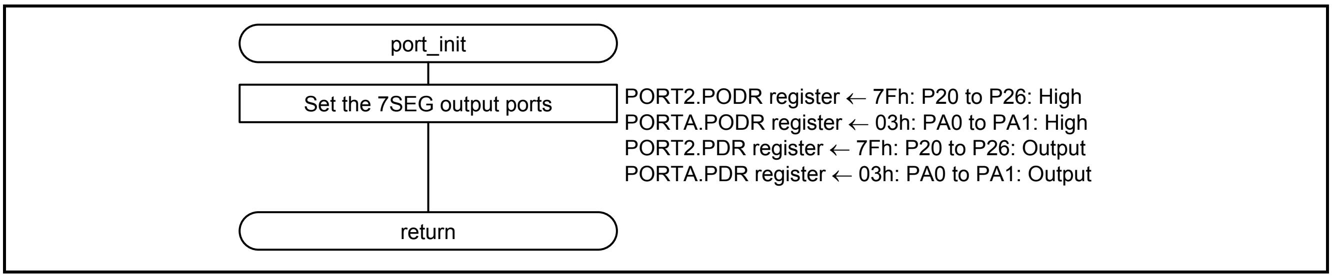


Figure 5.3 Port Initialization

5.8.3 Peripheral Function Initialization

Figure 5.4 shows Peripheral Function Initialization.

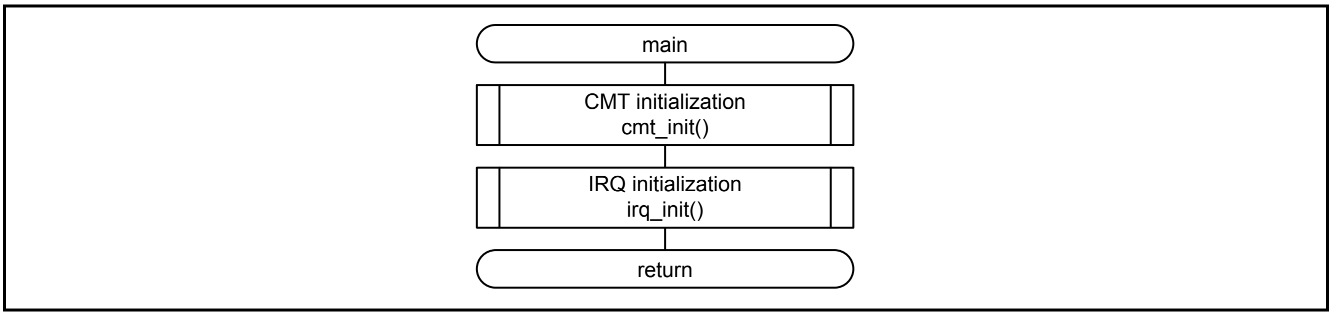


Figure 5.4 Peripheral Function Initialization

5.8.4 CMT Initialization

Figure 5.5 shows CMT Initialization.

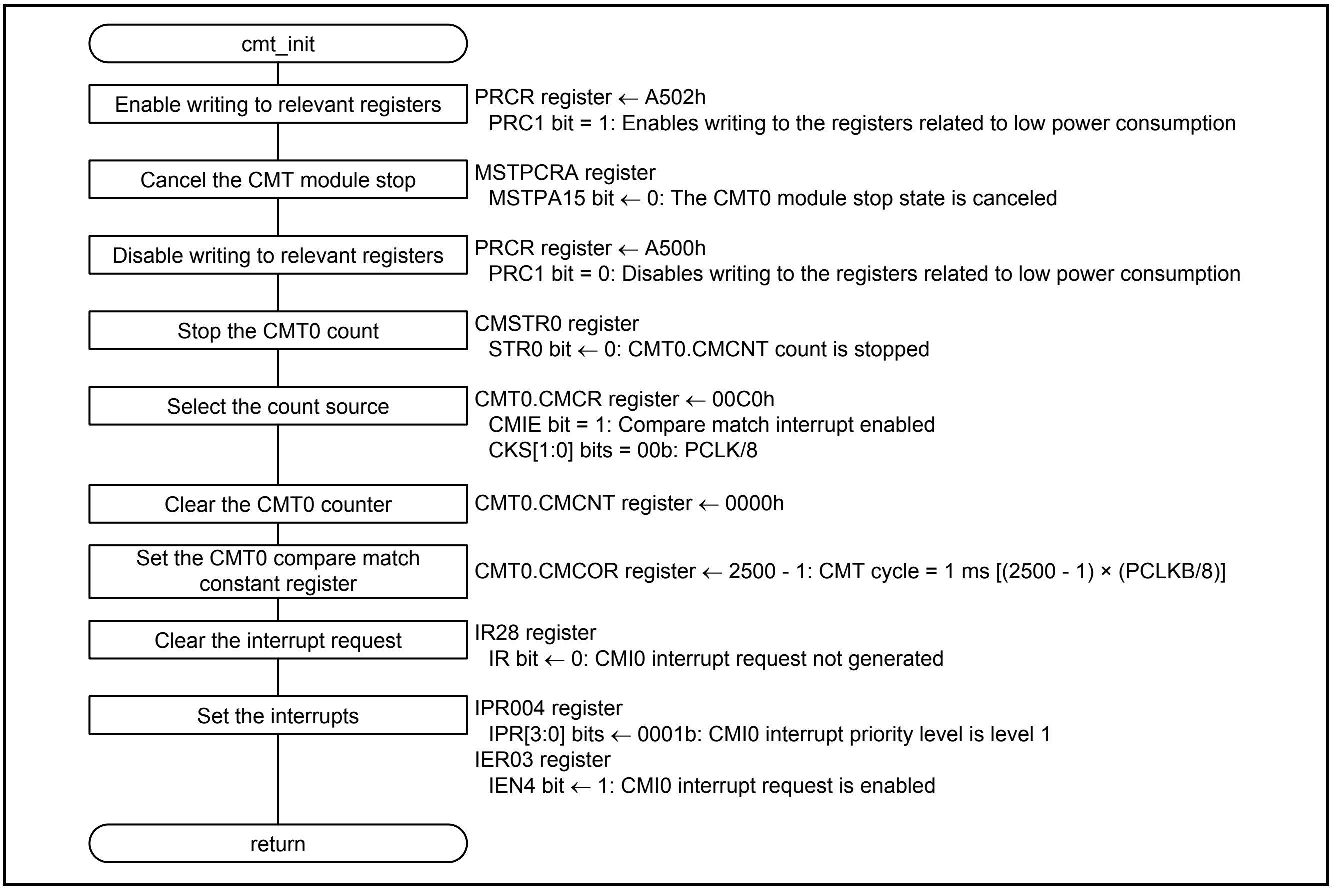


Figure 5.5 CMT Initialization

5.8.5 IRQ Initialization

Figure 5.6 shows IRQ Initialization.

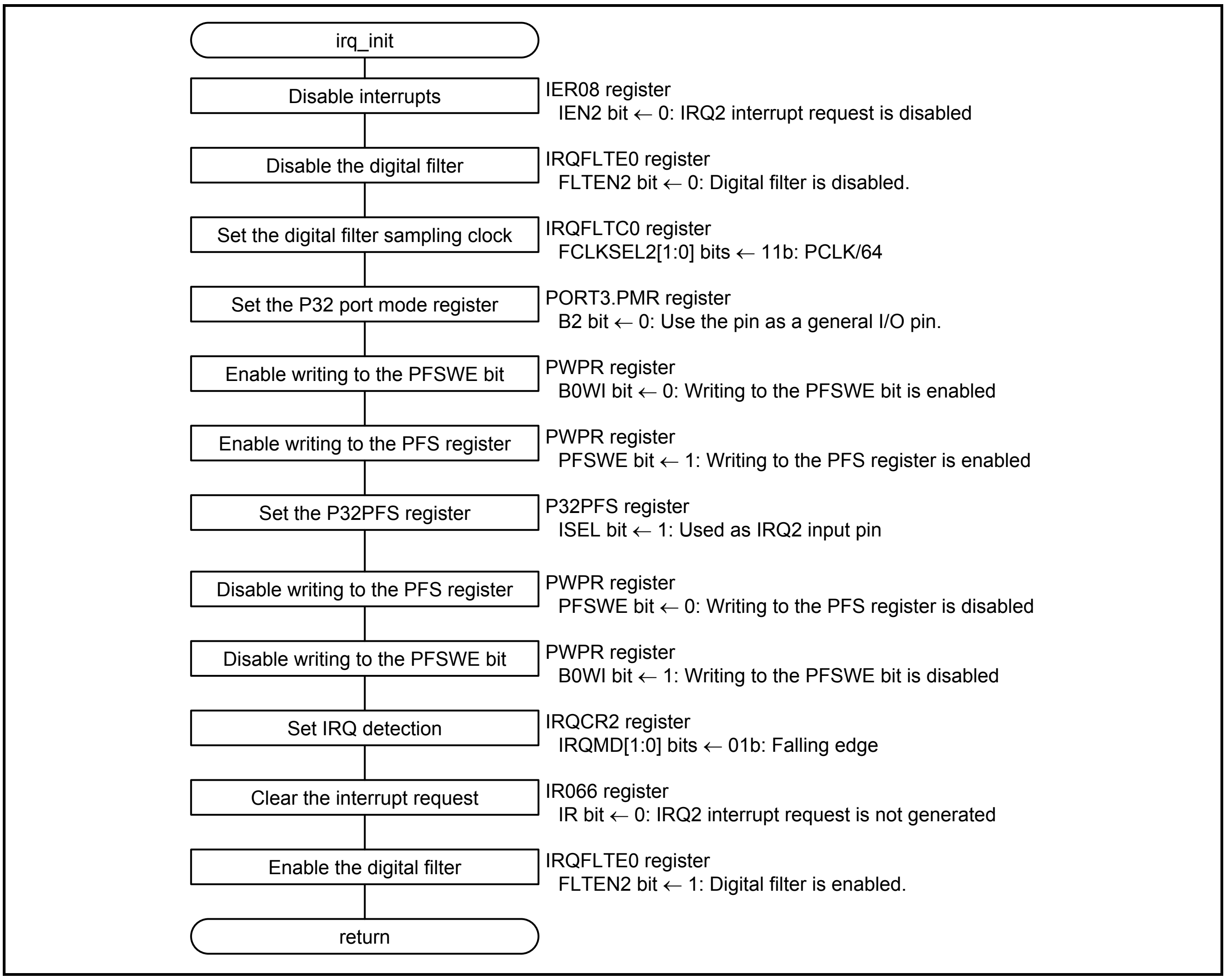


Figure 5.6 IRQ Initialization

5.8.6 Processing to Update the 7SEG Display Data

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

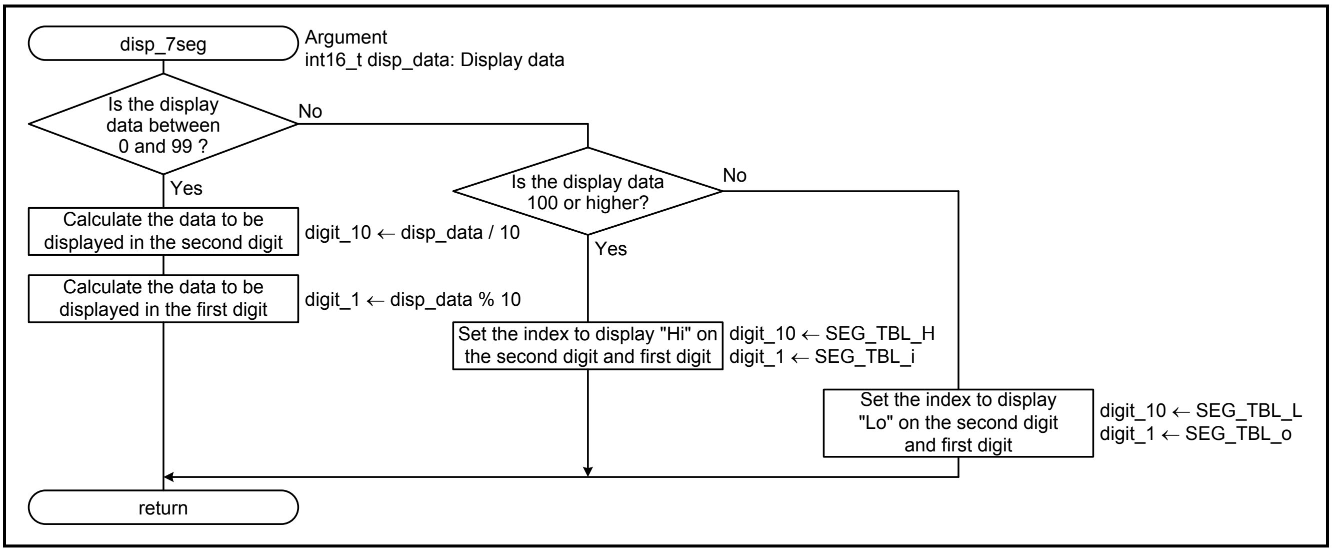


Figure 5.7 Processing to Update the 7SEG Display Data

5.8.7 Processing to Switch the 7SEG Select Output

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

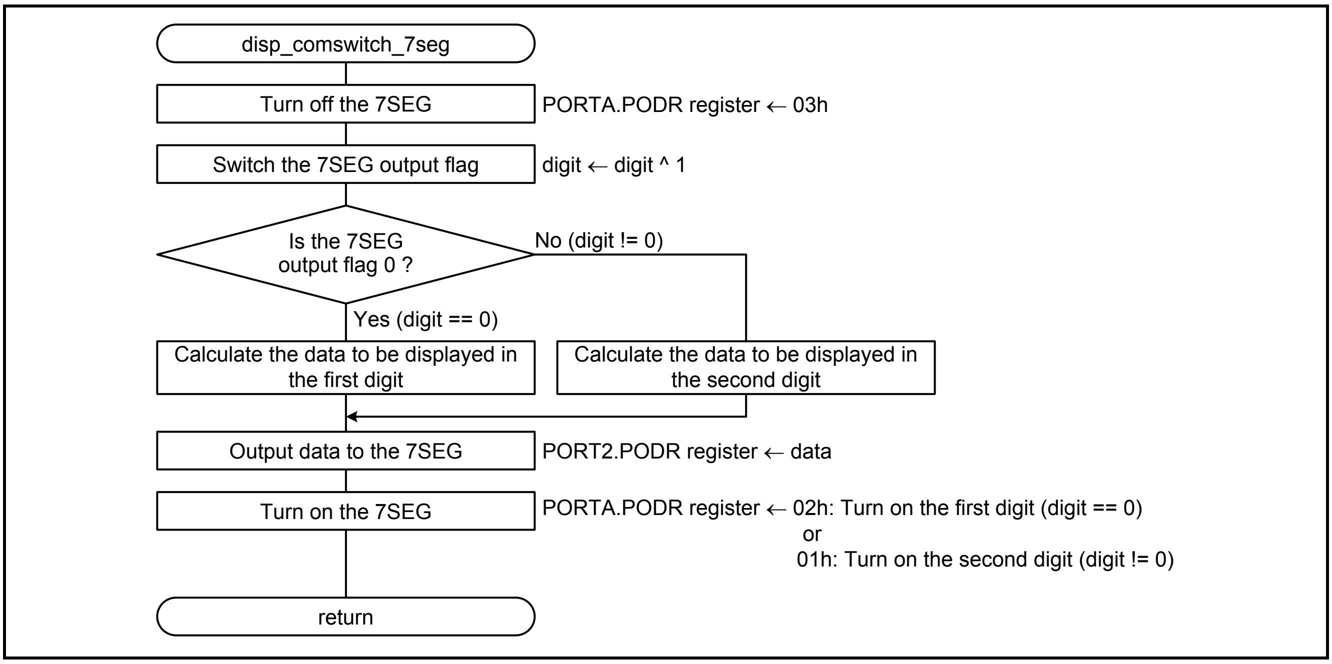


Figure 5.8 Processing to Switch the 7SEG Select Output

5.8.8 Processing to Display a Dash on the 7SEG

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

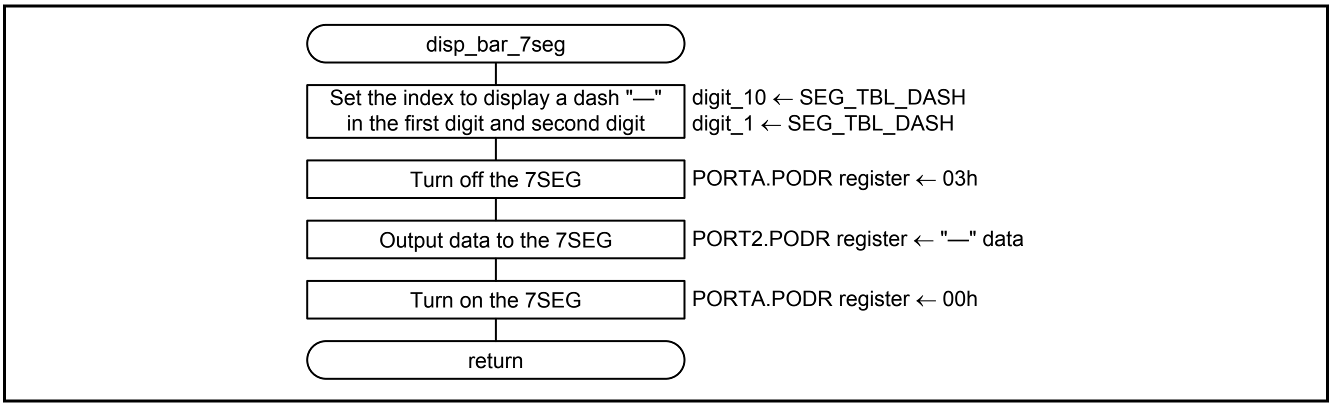


Figure 5.9 Processing to Display a Dash on the 7SEG

5.8.9 Compare Match Interrupt Handling

Figure 5.10 shows the Compare Match Interrupt Handling.

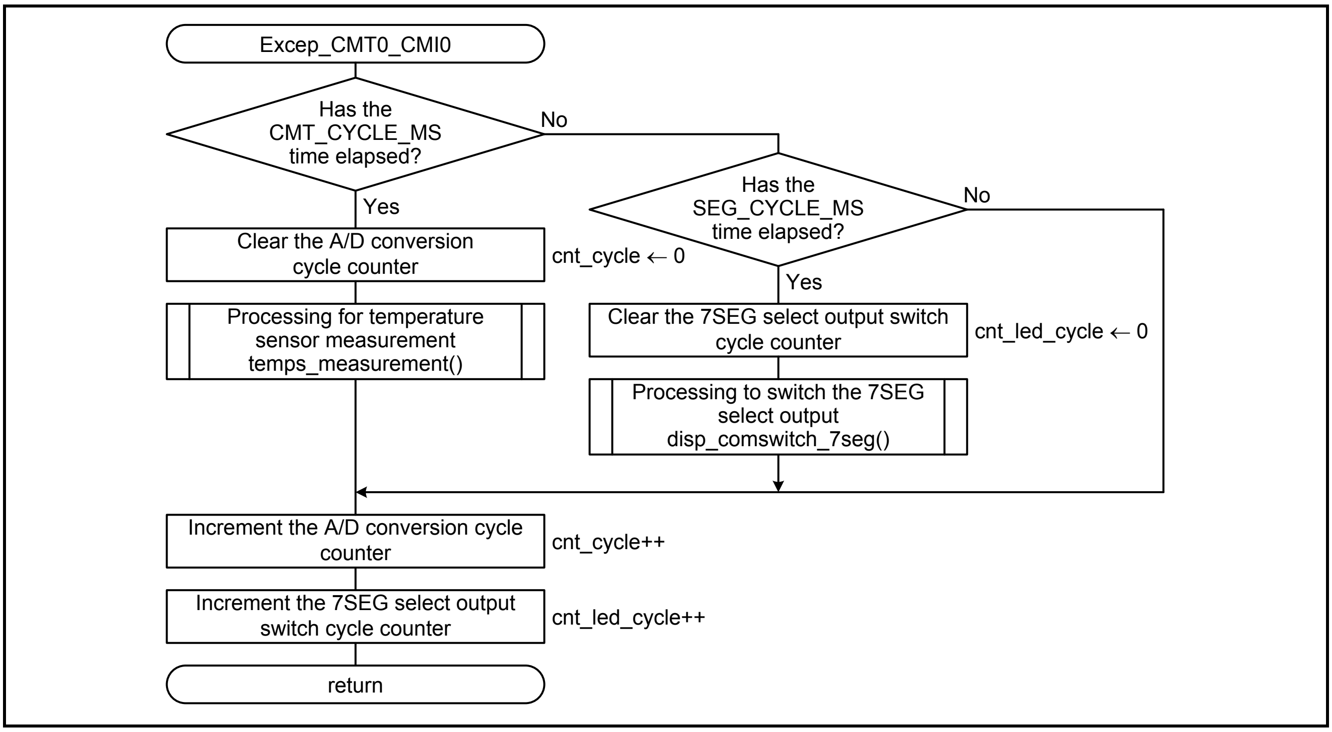
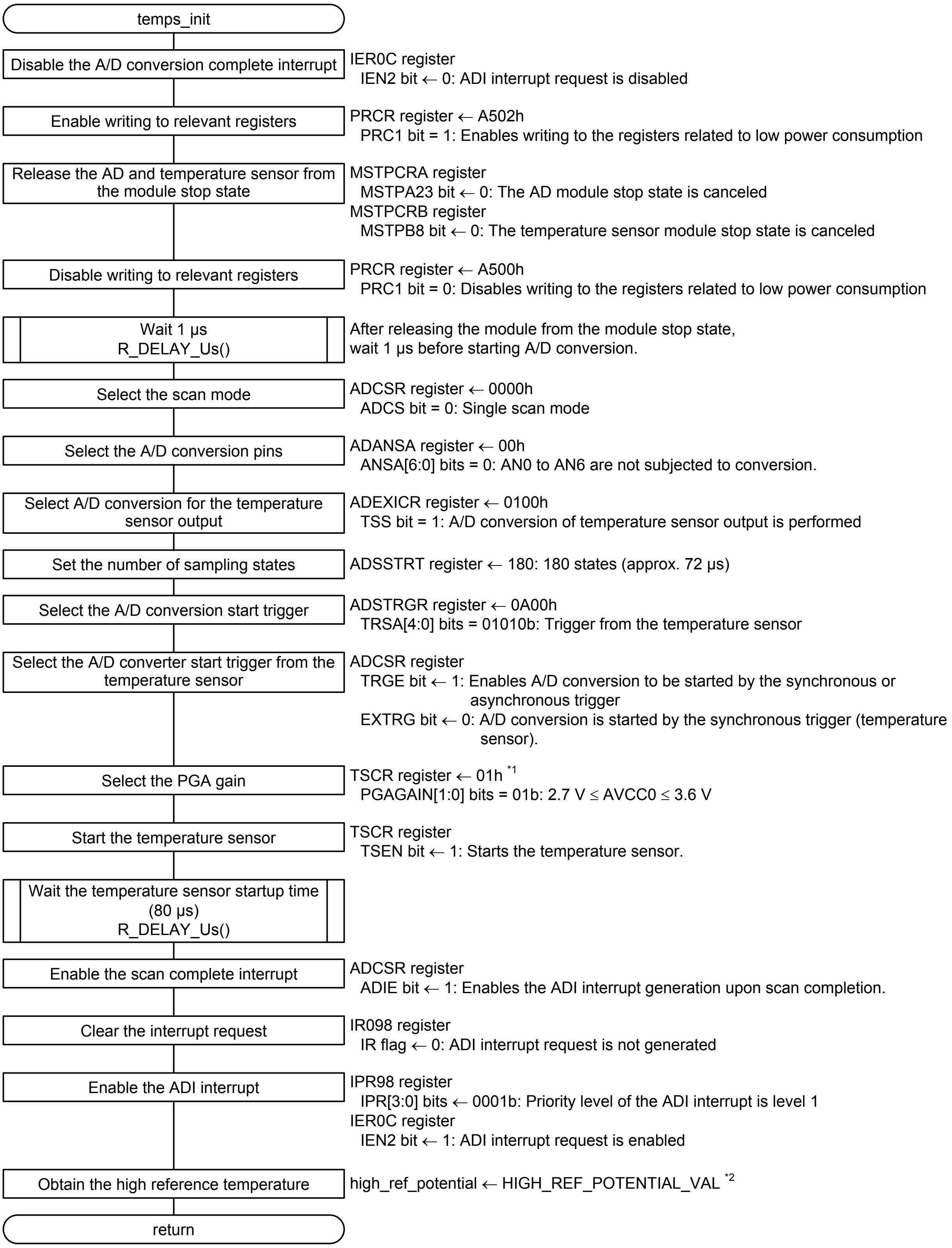


Figure 5.10 Compare Match Interrupt Handling

5.8.10 AD and Temperature Sensor Initialization

Figure 5.11 shows the AD and Temperature Sensor Initialization.



Note 1. Change the constants to accommodate the user system.
Note 2. The setting value will differ according to the PGA gain selected in the constants.

Figure 5.11 AD and Temperature Sensor Initialization

5.8.11 Obtain the A/D Conversion Status

Figure 5.12 shows Obtain the A/D Conversion Status.

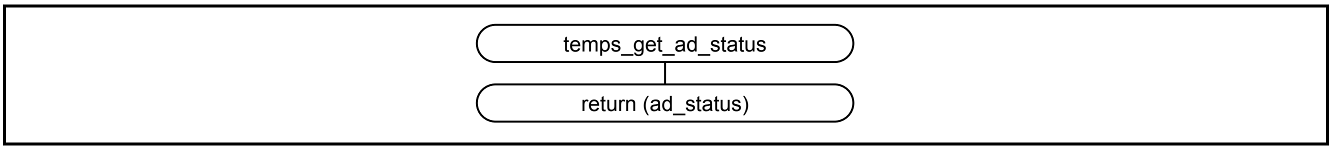


Figure 5.12 Obtain the A/D Conversion Status

5.8.12 Obtain the Temperature Sensor Measurement Result

Figure 5.13 shows Obtain the Temperature Sensor Measurement Result.

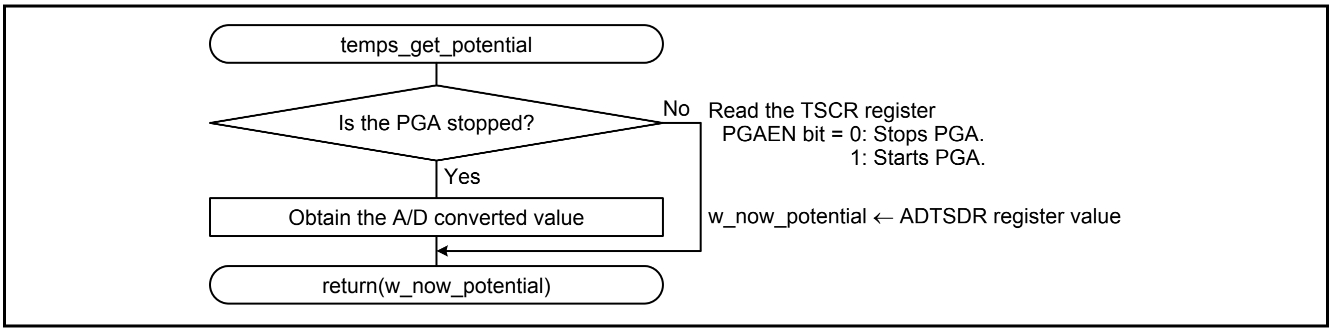


Figure 5.13 Obtain the Temperature Sensor Measurement Result

5.8.13 Obtain the Current Temperature

Figure 5.14 shows Obtain the Current Temperature.

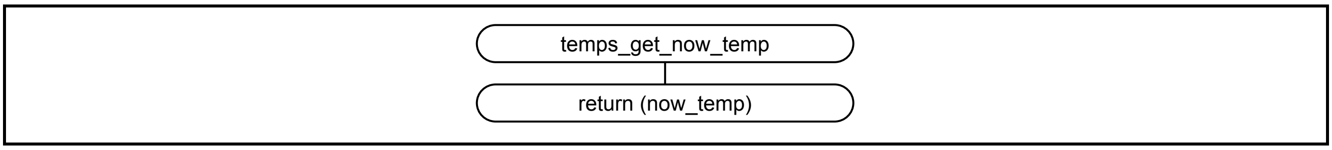


Figure 5.14 Obtain the Current Temperature

5.8.14 Processing for Temperature Sensor Calibration

Figure 5.15 shows the Processing for Temperature Sensor Calibration.

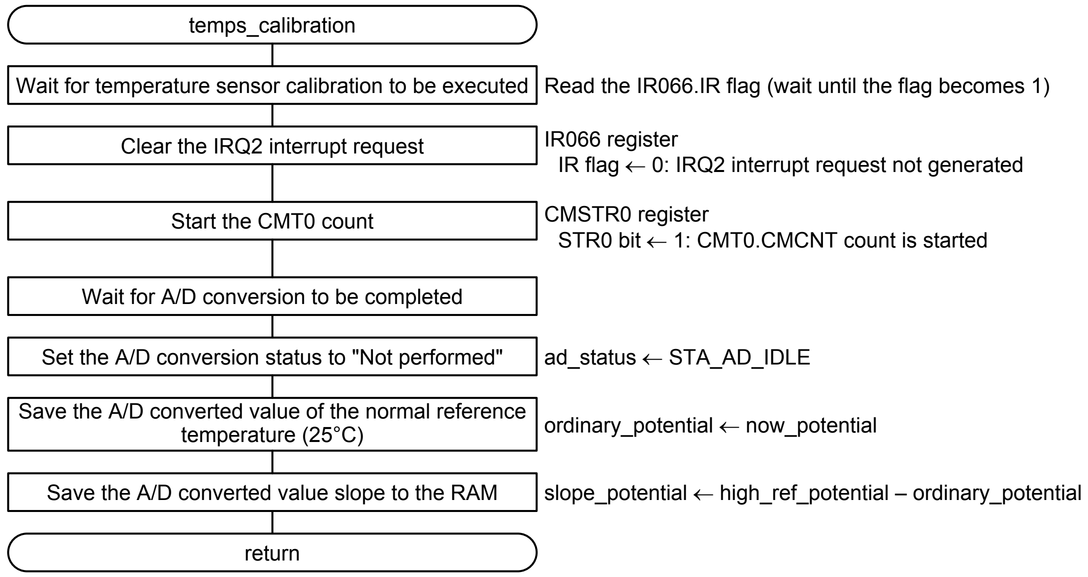


Figure 5.15 Processing for Temperature Sensor Calibration

5.8.15 Processing for Temperature Sensor Measurement

Figure 5.16 shows the Processing for Temperature Sensor Measurement.

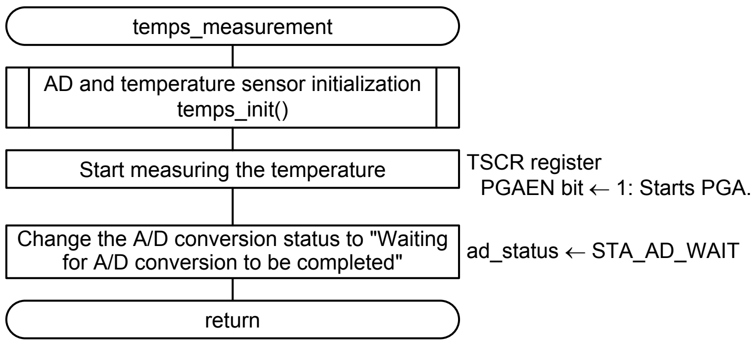
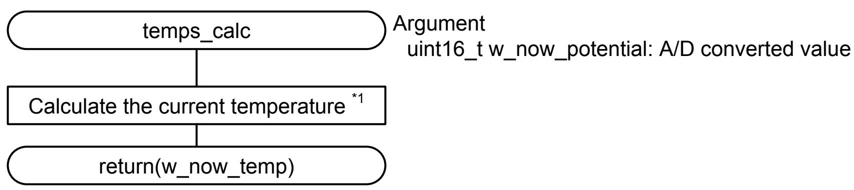


Figure 5.16 Processing for Temperature Sensor Measurement

5.8.16 Processing to Calculate the Current Temperature

Figure 5.17 shows the Processing to Calculate the Current Temperature.



Note 1. Refer to section 5.1.1 Formula for the Temperature Characteristic for details on the formula.

Figure 5.17 Processing to Calculate the Current Temperature

5.8.17 A/D Conversion Complete Interrupt Handling

Figure 5.18 shows the A/D Conversion Complete Interrupt Handling.

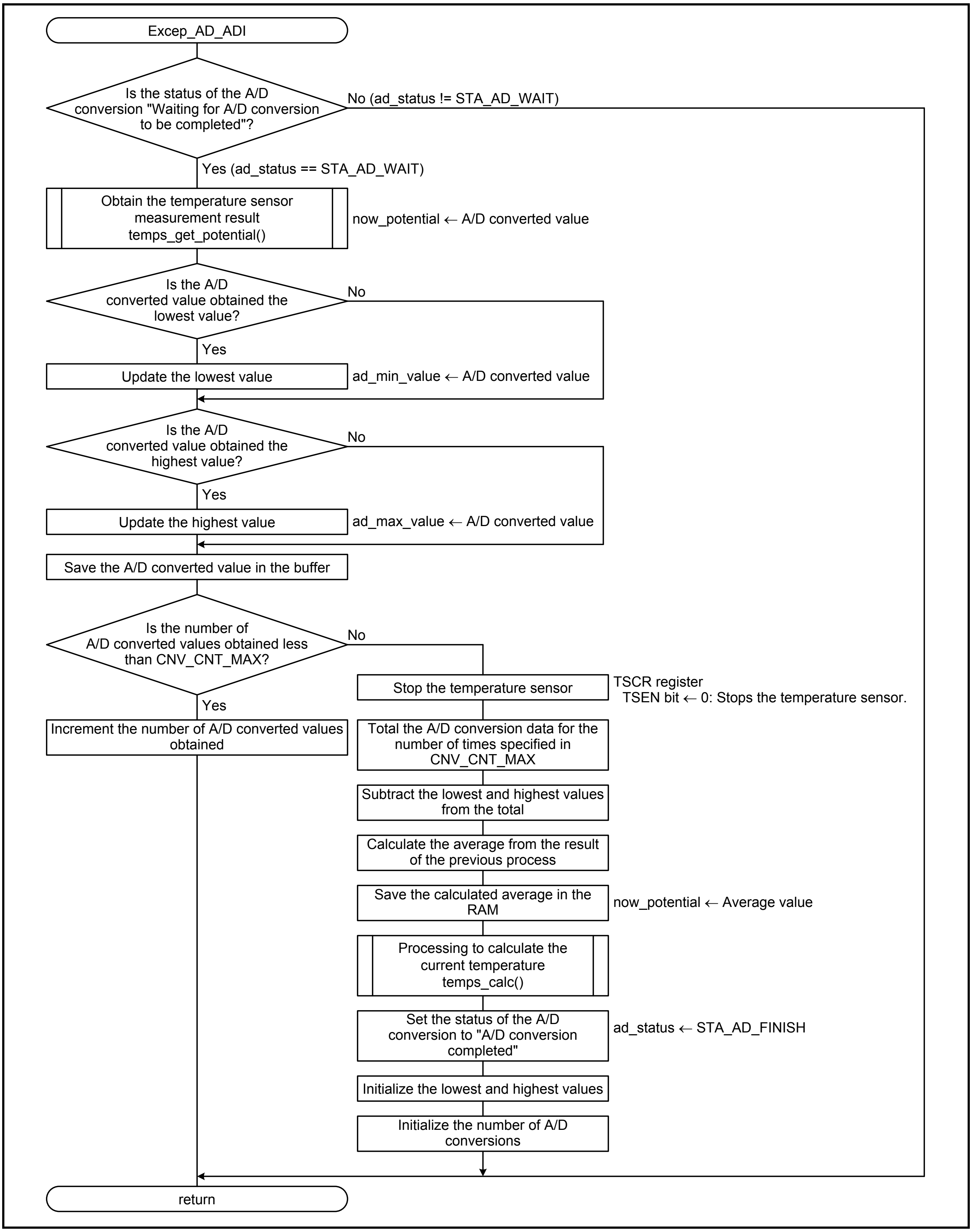


Figure 5.18 A/D Conversion Complete Interrupt Handling

6. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

7. Reference Documents

User's Manual: Hardware
RX21A Group User's Manual: Hardware Rev.1.00 (R01UH0025EJ)
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	RX21A Group Application Note Using the Temperature Sensor to Calculate the Ambient Temperature

Rev.	**Date**	**Description**	
		Page	**Summary**
1.00	Sep. 1, 2014	—	First edition issued

General Precautions in the Handling of MPU/MCU Products

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

1. Handling of Unused Pins

   Handle unused pins in accordance with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

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

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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

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