R8C/LA5A Group

How to Use the Internal Temperature Sensor of the A/D Converter

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Abstract

This document describes a program to calculate the temperature using the internal temperature sensor of the A/D converter for the R8C/LA5A Group.

Products

R8C/LA5A Group

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

Contents

1. Specifications

The temperature is calculated using an external temperature sensor and internal temperature sensor.
The temperature measured from the external temperature sensor is calculated using the A/D conversion result of the output voltage from the external temperature sensor and the Temperature Characteristics of the External Temperature Sensor Output Voltage listed in Table 4.1. The temperature measured from the internal temperature sensor is calculated using the A/D conversion result of the output voltage from the internal temperature sensor, and the pre-measured reference value of the A/D conversion result and reference temperature.

Table 1.1 lists the Peripheral Functions and Their Applications. Figure 1.1 shows the Function Block Diagram. Figure 1.2 shows the Mode Block Diagram.

Table 1.1 Peripheral Functions and Their Applications

Peripheral Function	Application
A/D converter	Perform A/D conversion on the output voltage from the external temperature sensor or output voltage from the internal temperature sensor.
Timer RJ0	Generate 10 ms period.
$\overline{\text{INT2}}$ interrupt	Change to calibration mode.
$\overline{\text{INT7}}$ interrupt	Change the temperature sensor.
LCD drive control circuit	Display modes, temperature, and A/D conversion results.

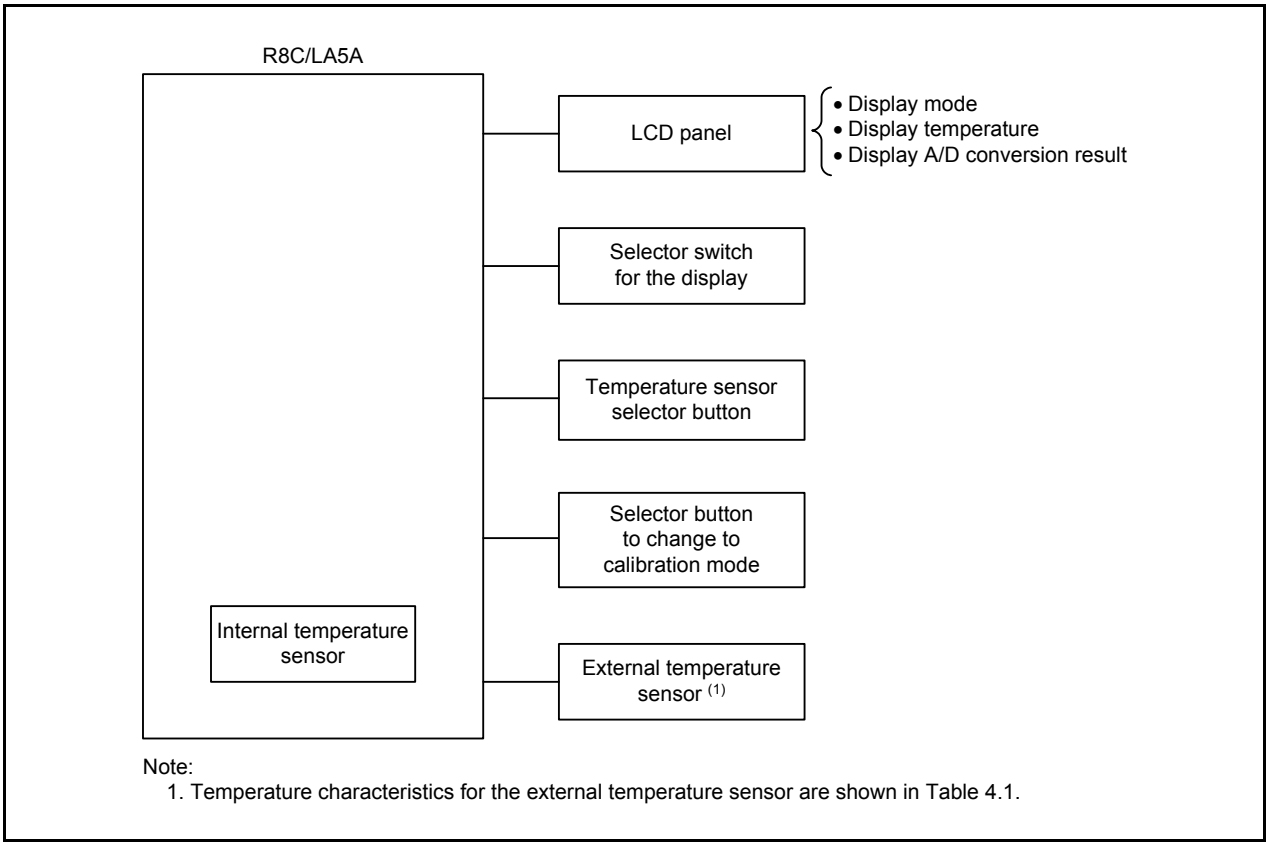

Figure 1.1 Function Block Diagram

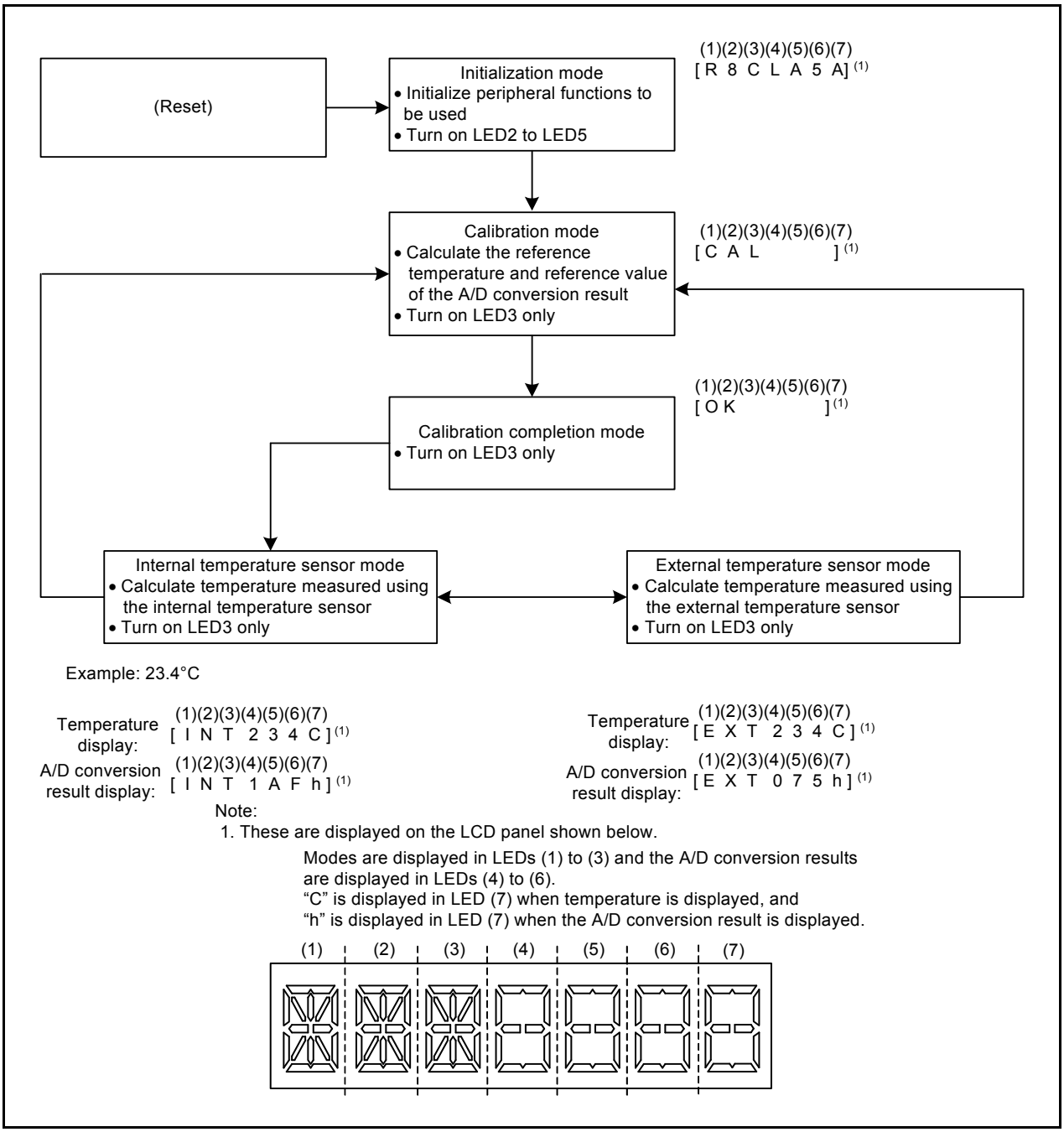

Figure 1.2 Mode Block Diagram

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	R8C/LA5A Group
Operating frequencies	• XIN clock: 8 MHz • System clock: 8 MHz • CPU clock: 8 MHz
Operating voltage	5.0 V (1.8 to 5.5 V)
Integrated development environment	Renesas Electronics Corporation High-performance Embedded Workshop Version 4.09
C compiler	Renesas Electronics Corporation M16C Series, R8C Family C Compiler V.5.45 Release 01
	Compile options -D__UART0__ -c -finfo -dir "$(CONFIGDIR)" -R8C (Default setting is used in the integrated development environment.)

3. Hardware

3.1 Hardware Configuration

Figure 3.1 shows a Connection Example.

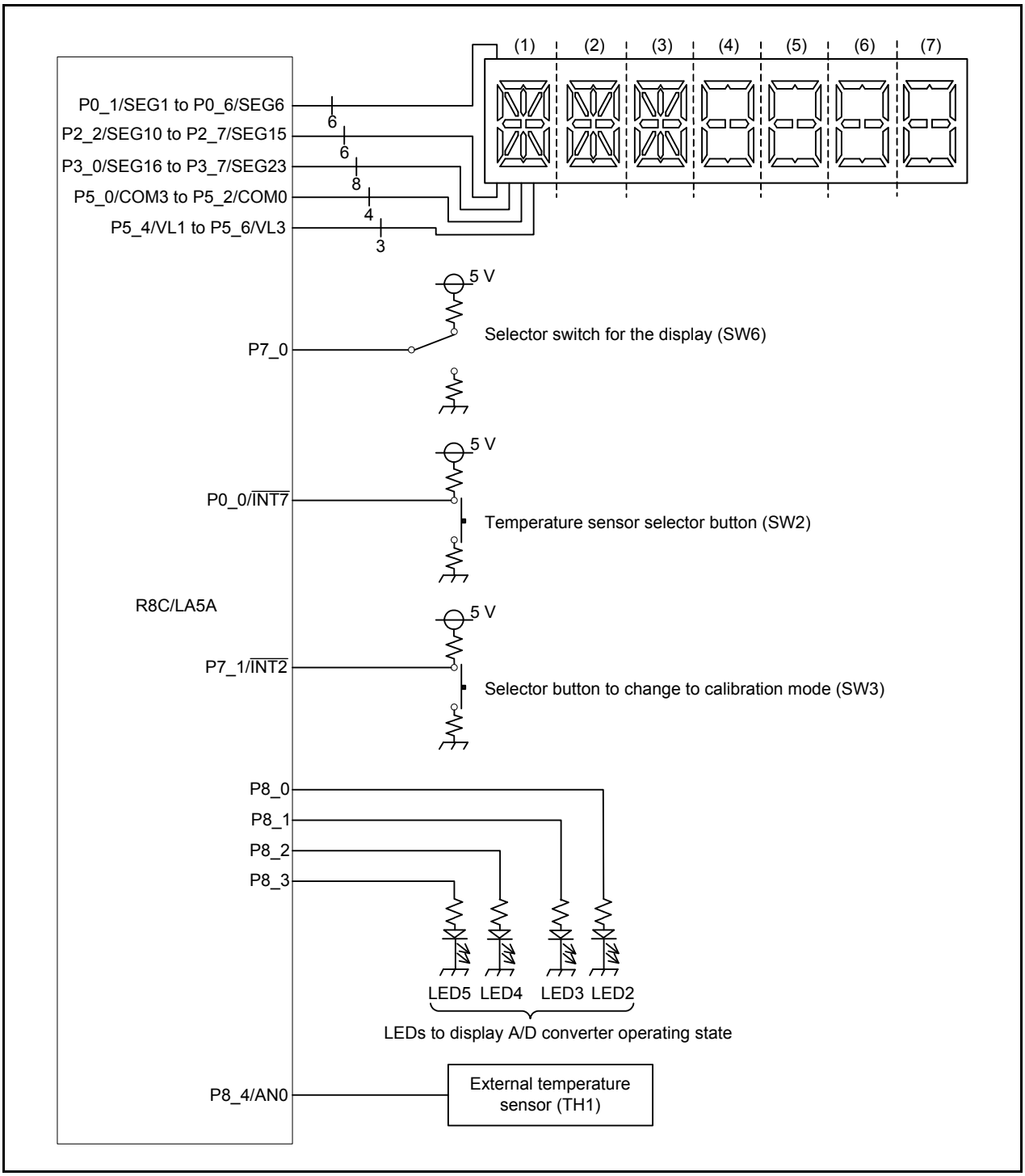

Figure 3.1 Connection Example

3.2 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
P0_1/SEG1 to P0_6/SEG6	Output	SEG output (LCD display)
P2_2/SEG10 to P2_7/SEG15	Output	SEG output (LCD display)
P3_0/SEG16 to P3_7/SEG23	Output	SEG output (LCD display)
P5_0/COM3 to P5_3/COM0	Output	COM output (LCD display)
P5_4/VL1 to P5_6/VL3	Input	VL input (LCD display)
P7_0	Input	Selector switch input for the display (SW6)
P0_0/$\overline{\text{INT7}}$	Input	Input for the temperature sensor selector button (SW2)
P7_1/$\overline{\text{INT2}}$	Input	Input for the selector button to change to calibration mode (SW3)
P8_0	Output	LED2 output
P8_1	Output	LED3 output
P8_2	Output	LED4 output
P8_3	Output	LED5 output
P8_4/AN0	Input	Analog voltage input from external temperature sensor (TH1)

4. Software

4.1 Operation Overview

As shown in Figure 4.1 Mode Transition, this software is configured with initialization mode, calibration mode, calibration completion mode, internal temperature sensor mode, and external temperature sensor mode.

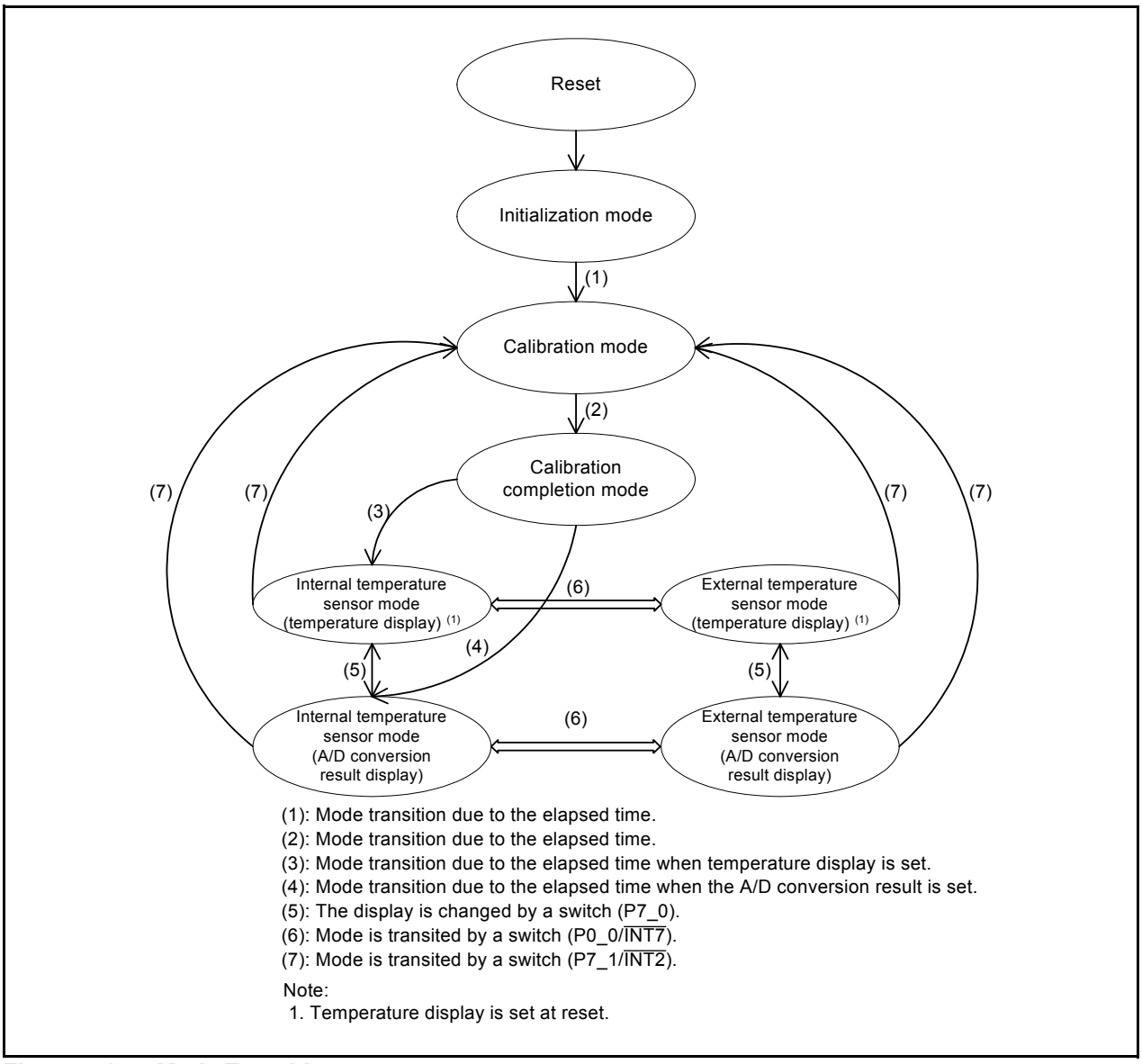

Figure 4.1 Mode Transition

4.1.1 Mode Description

Initialization mode

- After reset starts, the peripheral functions are initialized and the target device name (for this application note, "R8CLA5A") is displayed on the LCD for 2 seconds.
- LED2 to LED5 are turned on.

Calibration mode

- Only LED3 is turned on.
- A/D conversion is performed once on the output voltage from the external temperature sensor and once on the output voltage from the internal temperature sensor.
- The temperature is calculated based on the A/D conversion result of the output voltage from the external temperature sensor and the Temperature Characteristics of the External Temperature Sensor Output Voltage in Table 4.1. Retain the temperature as the reference temperature.
- The A/D conversion result of the output voltage from the internal temperature sensor is retained as the reference value of the A/D conversion result.

Calibration completion mode

- Only LED3 is turned on.
- "OK" is displayed on the LCD for 2 seconds.

Internal temperature sensor mode

- A/D conversion is performed on the output voltage from the internal temperature sensor each second.
- The temperature is calculated based on the A/D conversion result of the output voltage from the internal temperature sensor, and the reference value of the A/D conversion result and reference temperature. (The highest and lowest values of the eight A/D conversion results are excluded, and the average value of the remaining six results is used as the A/D conversion result of the output voltage from the internal temperature sensor.)
- "INT" and the temperature or the A/D conversion result are displayed on the LCD (use a switch to toggle between displaying the temperature and the A/D conversion result).
- LED3 is turned on, and LED5 is turned on when a negative temperature is displayed.

External temperature sensor mode

- A/D conversion is performed on the output voltage from the external temperature sensor each second.
- The temperature is calculated based on the A/D conversion result of the output voltage from the external temperature sensor, and the Temperature Characteristics of the External Temperature Sensor Output Voltage in Table 4.1.
  (The highest and lowest values of the eight A/D conversion results are excluded, and the average value of the remaining six results is used as the A/D conversion result of the output voltage from the external temperature sensor.)
- "EXT" and the temperature or the A/D conversion result are displayed on the LCD (use a switch to toggle between displaying the temperature and the A/D conversion result).
- LED3 is turned on, and LED5 is turned on when a negative temperature is displayed.

4.1.2 Setting the A/D Converter When the Output Voltage from the Internal Temperature Sensor is A/D Converted

The A/D converter setting when the output voltage from the internal temperature sensor is described below.

Settings
- Use the A/D converter in repeat mode 1.
- Use 10-bit resolution.
- Use f1 as the clock source of fAD.
- Use fAD divided by 8 for operating clock ϕAD.
- Use a software trigger for the A/D conversion start condition.
- Use a gain of 4 in the gain amplifier.
- Disable the A/D open-circuit detection assist function.

4.1.3 Setting the A/D Converter When the Output Voltage from the External Temperature Sensor is A/D Converted

The A/D converter setting when the output voltage from the external temperature sensor is described below.

Settings
- Use the P8_4/AN0 pin for analog input of the output voltage from the external temperature sensor.
- Use the A/D converter in repeat mode 1.
- Use 10-bit resolution.
- Use f1 as the clock source of fAD.
- Use fAD divided by 8 for operating clock ϕAD.
- Use a software trigger for the A/D conversion start condition.
- Use a gain of 1 in the gain amplifier.
- Disable the A/D open-circuit detection assist function.

Table 4.1 lists the Temperature Characteristics of the External Temperature Sensor Output Voltage used in this application note.

Table 4.1 Temperature Characteristics of the External Temperature Sensor Output Voltage

Temperature (°C)	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11
A/D value (HEX)	1A	1B	1D	1E	20	22	23	25	27	29
Temperature (°C)	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1
A/D value (HEX)	2B	2D	2F	31	34	36	38	3B	3E	40
Temperature (°C)	0	1	2	3	4	5	6	7	8	9
A/D value (HEX)	43	46	49	4C	4F	53	56	5A	5D	61
Temperature (°C)	10	11	12	13	14	15	16	17	18	19
A/D value (HEX)	65	69	6D	71	75	79	7E	82	87	8B
Temperature (°C)	20	21	22	23	24	25	26	27	28	29
A/D value (HEX)	90	95	9A	9F	A5	AA	AF	B5	BB	C0
Temperature (°C)	30	31	32	33	34	35	36	37	38	39
A/D value (HEX)	C6	CC	D2	D8	DF	E5	EB	F2	F8	FF
Temperature (°C)	40	41	42	43	44	45	46	47	48	49
A/D value (HEX)	105	10C	113	11A	121	128	12F	136	13D	144
Temperature (°C)	50	51	52	53	54	55	56	57	58	59
A/D value (HEX)	14C	153	15A	162	169	170	178	17F	187	18E
Temperature (°C)	60	61	62	63	64	65	66	67	68	69
A/D value (HEX)	196	19D	1A4	1AC	1B3	1BB	1C2	1CA	1D1	1D8
Temperature (°C)	70	71	72	73	74	75	76	77	78	79
A/D value (HEX)	1E0	1E7	1EE	1F5	1FD	204	20B	212	219	220
Temperature (°C)	80	81	82	83	84	85				
A/D value (HEX)	227	22E	235	23B	242	249				

4.1.4 Using the Internal Temperature Sensor to Calculate the Temperature

The method for calculating the temperature based on the A/D conversion result of the output voltage from the internal temperature sensor is described below.

Calibration mode

(1) Perform A/D conversion on the output voltage from the external temperature sensor, calculate the temperature using its A/D conversion result and the Temperature Characteristics of the External Temperature Sensor Output Voltage in Table 4.1, and retain the temperature as the reference temperature (EXT_TEMP_BASE).

(2) Perform A/D conversion on the output voltage from the internal temperature sensor and retain its A/D conversion result as the reference value of the A/D conversion result (INT_AD_BASE).

Internal Temperature Sensor Mode

(3) Perform A/D conversion on the output voltage from the internal temperature sensor and obtain the A/D conversion result (INT_AD_VALUE).

(4) Calculate the difference of the output voltage (INT_VOL_DIF) using the reference value of the A/D conversion result (INT_AD_BASE) and the A/D conversion result (INT_AD_VALUE).

Vref /1023 = 4.88 mV/bit
(Vref: A/D converter reference voltage (5000 mV), A/D resolution: 10 bits)

INT_VOL_DIF = (INT_AD_BASE - INT_AD_VALUE) × (Vref / 1023)
= (INT_AD_BASE - INT_AD_VALUE) × (4.88 mV/bit)

(5) Obtain the temperature difference from the reference temperature (TEMP_DIF) based on the difference of the output voltage (INT_VOL_DIF) and the temperature coefficient of the output voltage from the internal temperature sensor (TEMP_C = -2.1 mV/°C). Calculate the temperature (INT_TEMP_VALUE) using the reference temperature (EXT_TEMP_BASE) and temperature difference from the reference temperature (TEMP_DIF).

The temperature coefficient of the output voltage from the internal temperature sensor when a gain of 4 is selected = -2.1 mV/°C × 4 (gain of 4) = -8.4 mV/°C

TEMP_DIF = (INT_VOL_DIF / -8.4 mV/°C)
INT_TEMP_VALUE = EXT_TEMP_BASE - TEMP_DIF

Note that the temperature coefficient of the output voltage from the internal temperature sensor is described in the manual.

4.2 Required Memory Size

Table 4.2 lists the Required Memory Size.

Table 4.2 Required Memory Size

Memory Used	Size	Remarks
ROM	3685 bytes	In the r01an1155_src.c module
RAM	38 bytes	In the r01an1155_src.c module
Maximum user stack usage	38 bytes	
Maximum interrupt stack usage	20 bytes	

The required memory size varies depending on the C compiler version and compile options.

4.3 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
TEMP_minus20	-200	-20°C
TEMP_85	850	85°C
EXT_TBL_SIZE	106	Size of data table in the temperature characteristics for the external temperature sensor
TEMP_2_1mv	-84	The temperature coefficient of the output voltage from the internal temperature sensor (gain of 4)
VOLT_VAL_AD1bit	488	Voltage value per bit of the A/D value
CALIB	0	Calibration mode
CALIB_COMP	1	Calibration completion mode
INT_TEMP_SENSR	2	Internal temperature sensor mode
EXT_TEMP_SENSR	3	External temperature sensor mode
INITIAL	255	Initialization mode
AD_INT_TEMP_SENSR	0	Internal temperature sensor mode of the A/D converter
AD_EXT_TEMP_SENSR	1	External temperature sensor mode of the A/D converter
TEMP_DSP	0	LCD temperature display mode
OK_CHNG	1	LCD display mode can be changed
NO_CHNG	0	LCD display mode cannot be changed
SLIDE_SW1	P7_0	Slide switch input (Selector switch for the display)
SLIDE_SW1_D	PD7_0	Slide switch I/O bit
LED2	P8_0	LED2 output
LED2_D	PD8_0	LED2 I/O bit
LED3	P8_1	LED3 output
LED3_D	PD8_1	LED3 I/O bit
LED4	P8_2	LED4 output
LED4_D	PD8_2	LED4 I/O bit
LED5	P8_3	LED5 output
LED5_D	PD8_3	LED5 I/O bit
SW_ON	1	Switch input ON
SW_OFF	0	Switch input OFF
TM_1sec	100	1 second counter value
TM_2sec	200	2 seconds counter value
NUM0_ADDRESS	LRA20L	Display register address of the third digit for the full segment of the LCD
NUM1_ADDRESS	LRA16L	Display register address of the second digit for the full segment of the LCD
NUM2_ADDRESS	LRA12L	Display register address of the first digit for the full segment of the LCD
NUM3_ADDRESS	LRA10L	Display register address of the fourth digit for the 7 segments of the LCD
NUM4_ADDRESS	LRA5L	Display register address of the third digit for the 7 segments of the LCD
NUM5_ADDRESS	LRA3L	Display register address of the second digit for the 7 segments of the LCD
NUM6_ADDRESS	LRA1L	Display register address of the first digit for the 7 segments of the LCD

4.4 Structure/Union List

Figure 4.2 shows the Structure/Union Used in the Sample Code.

```
typedef union
  struct{
     unsigned char First :8;
     unsigned char Second :8;
     unsigned char Third :8;
     unsigned char Fourth :8;
   }data;
   long int All;
}LONG_INT;

typedef union{
   struct{
      unsigned char First   :4;
      unsigned char Second  :4;
      unsigned char Third   :4;
      unsigned char Fourth  :4;
   }data;
   unsigned short All;
}DATA;

typedef union{
   struct{
      unsigned char Low   :8;
      unsigned char High  :8;
   }data;
   unsigned short All;
}DATA16;

typedef struct{
   signed long    temp;
   unsigned short ad_val;
}EXT_TMP;

typedef union{
   struct{
      unsigned char b0  :1;
      unsigned char b1  :1;
      unsigned char b2  :1;
      unsigned char b3  :1;
      unsigned char b4  :1;
      unsigned char b5  :1;
      unsigned char b6  :1;
      unsigned char b7  :1;
   }bit;
   unsigned char All;
}FLAG;
```

Figure 4.2 Structure/Union Used in the Sample Code

4.5 Variables

Table 4.4 lists the Global Variables and Table 4.5 lists the static Variable.

Table 4.4 Global Variables

Type	Variable Name	Contents	Function Used
unsigned char	proc_mode	Processing mode	ad_init, mode_proc, ad_value_get, delay_proc, lcd_dsp, lcd_dsp_chg_sw, int7_interrupt, trj0_interrupt
unsigned char	req_mode	Request processing mode	mode_proc, delay_proc, int2_interrupt, int7_interrupt, trj0_interrupt
unsigned char	int_temp_dsp_mode	Internal temperature sensor display mode	lcd_dsp, int7_interrupt
unsigned char	ext_temp_dsp_mode	External temperature sensor display mode	lcd_dsp, int7_interrupt
unsigned char	ad_conv_mode	A/D conversion mode	ad_init, mode_proc, ad_value_get
unsigned char	counter_1sec	1 second counter	mode_proc, trj0_interrupt
FLAG	flags	flg_adc: A/D conversion completion flag minus_temp: Negative temperature state	mode_proc, ad_value_get, ad_interrupt
DATA16	int_AD_val	A/D conversion result of the output voltage from the internal temperature sensor	ad_value_get, calib_correct, calib_int_temp
DATA16	ext_AD_val	A/D conversion result of the output voltage from the external temperature sensor	ad_value_get, calib_ext_temp
DATA16	int_AD_base_val	Reference value of the A/D conversion result	ad_value_get, calib_int_temp
unsigned short	wait_counter	Wait counter	mode_proc, ad_value_get, delay_proc
int	int_temp_value	Temperature value of the internal temperature sensor	ad_value_get, calib_int_temp
int	ext_temp_value	Temperature value of the external temperature sensor	ad_value_get, calib_correct, calib_ext_temp
int	ext_temp_base	Reference temperature of the external temperature sensor	ad_value_get, calib_int_temp
unsigned short	ad_buf[8]	Buffer to obtain the A/D conversion result	ad_average_get, ad_interrupt

Table 4.5 static Variable

Type	Variable Name	Contents	Function Used
static unsigned char	last_sw	Previous switch input	lcd_dsp_chg_sw

4.6 Functions

Table 4.6 lists the Functions.

Table 4.6 Functions

Function Name	Outline
mcu_init	System clock setting
port_init	Port setting (1)
int2_init	Initial setting of the $\overline{\text{INT2}}$ interrupt (1)
int7_init	Initial setting of the $\overline{\text{INT7}}$ interrupt (1)
lcd_init	LCD drive control setting (1)
timer_rj0_init	Initial setting of timer RJ0 (1)
ad_init	Initial setting of the A/D converter
initial_wait	Initialization wait processing (1)
mode_proc	Mode processing (1)
ad_value_get	Obtaining the A/D conversion result
ad_average_get	Obtaining the A/D average value
calib_int_temp	Temperature calculation of the internal temperature sensor
calib_ext_temp	Temperature calculation of the external temperature sensor
lcd_conv_temp	Temperature data conversion to display on LCD (1)
Bin2Bcd	Conversion from binary to BCD (1)
lcd_dsp	LCD display processing (1)
lcd_dsp_chg_sw	Selector switch processing for the display (1)
lcd_full_seg	Display processing of the full segment of the LCD (1)
lcd_7seg	Display processing of the 7 segments of the LCD (1)
delay_proc	Mode transition delay processing (1)
int2_interrupt	$\overline{\text{INT2}}$ interrupt handling (1)
int7_interrupt	$\overline{\text{INT7}}$ interrupt handling (1)
ad_interrupt	A/D interrupt handling
trj0_interrupt	Timer RJ0 interrupt handling (1)

Note:
1. These flowcharts are omitted.

4.7 Function Specifications

The following tables list the sample code function specifications.

mcu_init	
Outline	System clock setting
Header	None
Declaration	void mcu_init(void)
Description	Set the XIN clock (no division mode) used as the CPU clock and system clock.
Argument	None
Returned value	None
Remarks	—

port_init	
Outline	Port setting
Header	None
Declaration	void port_init(void)
Description	Set the pin for the analog input voltage and set the LED pin to display the A/D converter operating state.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

int2_init	
Outline	Initial setting of the $\overline{\text{INT2}}$ interrupt
Header	None
Declaration	void int2_init(void)
Description	Perform the initial setting of the $\overline{\text{INT2}}$ interrupt to detect input to the calibration mode selector button. $\overline{\text{INT2}}$ pin setting Assigned pin: P7_1 Active edge: Falling edge INT input filter: Filter with f8 sampling
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

int7_init	
Outline	Initial setting of the $\overline{\text{INT7}}$ interrupt
Header	None
Declaration	void int7_init(void)
Description	Perform the initial setting of the $\overline{\text{INT7}}$ interrupt to detect input to the selector button of the temperature sensor. $\overline{\text{INT7}}$ pin setting Assigned pin: P0_0 Active edge: Falling edge INT input filter: Filter with f8 sampling
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

lcd_init	
Outline	LCD drive control setting
Header	None
Declaration	void lcd_init(void)
Description	Set the LCD drive control circuit to display information on the LCD. “R8CLA5A” is displayed on the LCD as initialization mode. LCD drive control circuit setting LCD clock source division ratio: Divide by 16 LCD clock source: f32 Duty: 1/4 Bias: 1/3
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

timer_rj0_init	
Outline	Initial setting of timer RJ0
Header	None
Declaration	void timer_rj0_init(void)
Description	Set timer RJ0 to timer mode to count the display time of initialization mode on the LCD. Timer RJ0 setting Count source: f8 Underflow period: 10 ms = {1 / (8 MHz / 8)} × 10000
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

ad_init	
Outline	Initial setting of the A/D converter
Header	None
Declaration	void ad_init(void)
Description	Using repeat mode 1, perform the initial setting to A/D convert the analog input voltage or output voltage from the on-chip temperature sensor.
Argument	None
Returned value	None
Remarks	—

initial_wait	
Outline	Initialization wait processing
Header	None
Declaration	void initial_wait(void)
Description	Using timer RJ0 to wait for 2 seconds to display the initialization mode on the LCD.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

mode_proc	
Outline	Mode processing
Header	None
Declaration	void mode_proc(void)
Description	Perform processing when the mode is changed.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

ad_value_get	
Outline	Obtaining the A/D conversion result
Header	None
Declaration	void ad_value_get(void)
Description	• Obtain and retain the reference temperature and reference value of the A/D conversion result in calibration mode. • Obtain the A/D conversion result of the output voltage from the internal temperature sensor and temperature in internal temperature sensor mode. • Obtain the A/D conversion result of the output voltage from the external temperature sensor and temperature in external temperature sensor mode.
Argument	None
Returned value	None
Remarks	—

ad_average_get	
Outline	Obtaining the A/D average value
Header	None
Declaration	unsigned int ad_average_get(void)
Description	Exclude the highest and lowest values of the eight A/D conversion results, and obtain the average value of the remaining six results.
Argument	None
Returned value	ret_val
Remarks	—

calib_int_temp	
Outline	Temperature calculation of the internal temperature sensor
Header	None
Declaration	void calib_int_temp(void)
Description	Calculate the temperature using the A/D conversion result of the output voltage from the internal temperature sensor, A/D conversion reference value, and reference temperature.
Argument	None
Returned value	ret_temp
Remarks	—

calib_ext_temp	
Outline	Temperature calculation of the external temperature sensor
Header	None
Declaration	void calib_ext_temp(void)
Description	Calculate the temperature using the A/D conversion result of the output voltage from the external temperature sensor, and data table in the temperature characteristics for the external temperature sensor.
Argument	None
Returned value	ret_temp
Remarks	—

lcd_conv_temp	
Outline	Temperature data conversion to display on the LCD
Header	None
Declaration	void lcd_conv_temp(int lcd_temp_data,unsigned char *temp_T, unsigned char *temp_F,unsigned char *temp_D)
Description	Divide temperature data into tens place, ones place, and tenths place to perform BCD conversion to display on the LCD.
Argument	• First argument: lcd_temp_data: Temperature data • Second argument: temp_T: Address of area to store the display data for tens place after conversion • Third argument: temp_F: Address of area to store the display data for ones place after conversion • Fourth argument: temp_D: Address of area to store the display data for decimal after conversion
Returned value	None
Remarks	This flowchart is omitted.

Bin2Bcd	
Outline	Conversion from binary to BCD
Header	None
Declaration	void Bin2Bcd(unsigned short data , DATA* buf)
Description	Convert the binary data to BCD code.
Argument	data: Binary data (0000 to 9999) buf: Address of area to store the BCD conversion data
Returned value	None
Remarks	This flowchart is omitted.

lcd_dsp	
Outline	LCD display processing
Header	None
Declaration	void lcd_dsp(void)
Description	LCD displays content for the corresponding mode.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

lcd_dsp_chg_sw	
Outline	Selector switch processing for the display
Header	None
Declaration	unsigned char lcd_dsp_chg_sw(void)
Description	Determine the input of the selector switch for the display and return the result.
Argument	None
Returned value	• Display can be changed: OK_CHNG(1) • Display cannot be changed: NO_CHNG(0)
Remarks	This flowchart is omitted.

lcd_full_seg	
Outline	Display processing of the full segment of the LCD
Header	None
Declaration	void lcd_full_seg(unsigned int address, unsigned char data)
Description	Set the display data to the full segment.
Argument	• First argument: point: LCD display RAM start address • Second argument: display_data: Display data
Returned value	None
Remarks	This flowchart is omitted.

lcd_7seg	
Outline	Display processing of the 7 segments of the LCD
Header	None
Declaration	void lcd_7seg(unsigned int address, unsigned char data)
Description	Set the display data to the 7 segments.
Argument	• First argument: point: LCD display RAM start address • Second argument: display_data: Display data
Returned value	None
Remarks	This flowchart is omitted.

delay_proc	
Outline	Mode transition delay processing
Header	None
Declaration	void delay_proc(void)
Description	Delay the transition of processing mode during a given time.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

int2_interrupt	
Outline	$\overline{\text{INT2}}$ interrupt handling
Header	None
Declaration	void int2_interrupt(void)
Description	Change to calibration mode and disable the $\overline{\text{INT2}}$, $\overline{\text{INT7}}$, and timer RJ0 interrupts.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

int7_interrupt	
Outline	$\overline{\text{INT7}}$ interrupt handling
Header	None
Declaration	void int7_interrupt(void)
Description	• Change to external temperature sensor mode and disable the $\overline{\text{INT7}}$ and timer RJ0 interrupts in internal temperature sensor mode. • Change to internal temperature sensor mode and disable the $\overline{\text{INT7}}$ and timer RJ0 interrupts in external temperature sensor mode.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

ad_interrupt	
Outline	A/D interrupt handling
Header	None
Declaration	void ad_interrupt(void)
Description	• Set the A/D conversion completion flag. • Calculate the sum of the A/D conversion results. • Stop A/D conversion. • Disable the A/D interrupt.
Argument	None
Returned value	None
Remarks	—

trj0_interrupt	
Outline	Timer RJ0 interrupt handling
Header	None
Declaration	void trj0_interrupt(void)
Description	• Start A/D conversion each second in internal temperature sensor mode or external temperature sensor mode. • Enable the A/D interrupt.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

4.8 Flowcharts

4.8.1 Main Processing

Figure 4.3 shows the Main Processing.

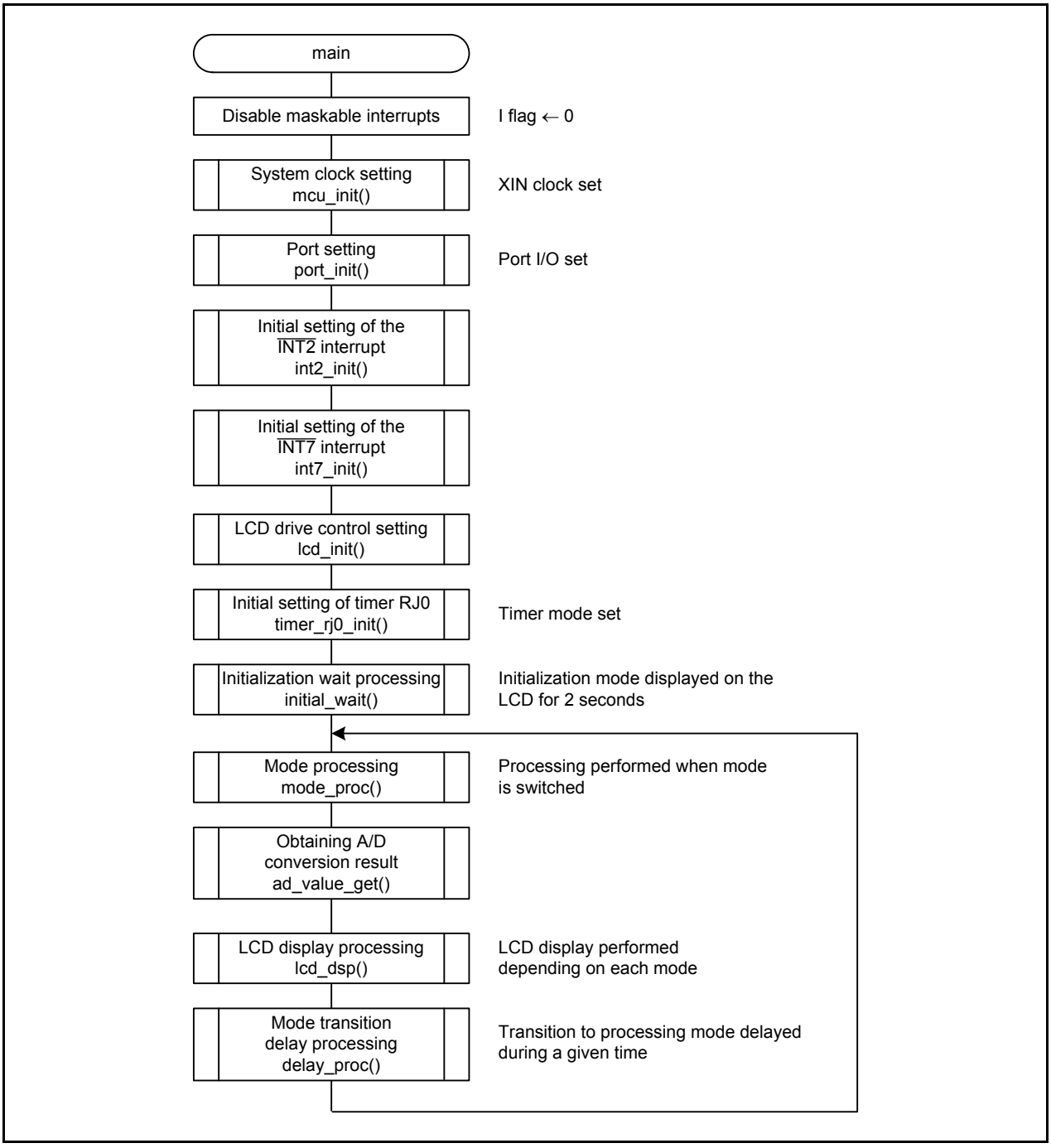

Figure 4.3 Main Processing

4.8.2 System Clock Setting

Figure 4.4 shows the System Clock Setting.

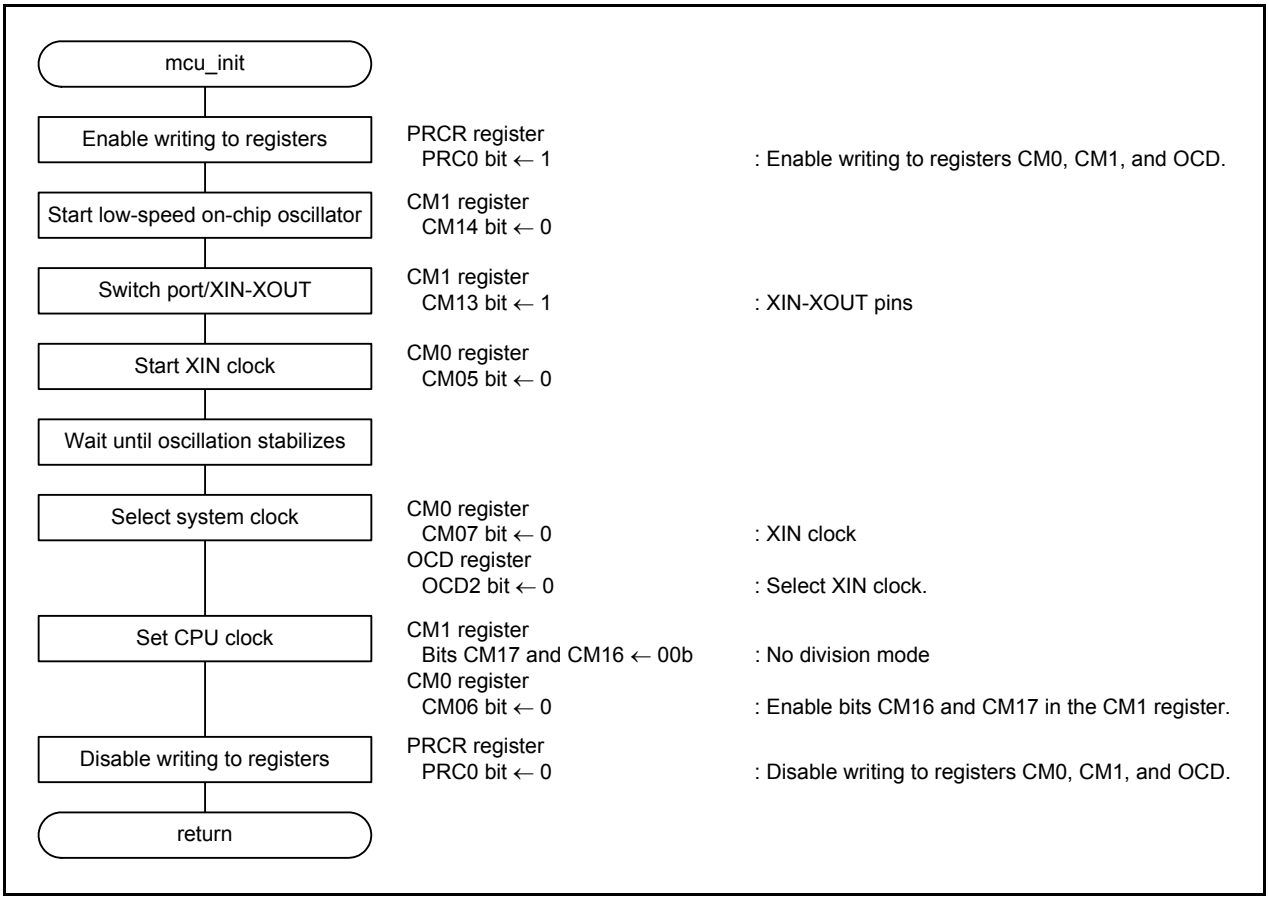

Figure 4.4 System Clock Setting

4.8.3 Initial Setting of the A/D Converter

Figure 4.5 and Figure 4.6 show the Initial Setting of the A/D Converter.

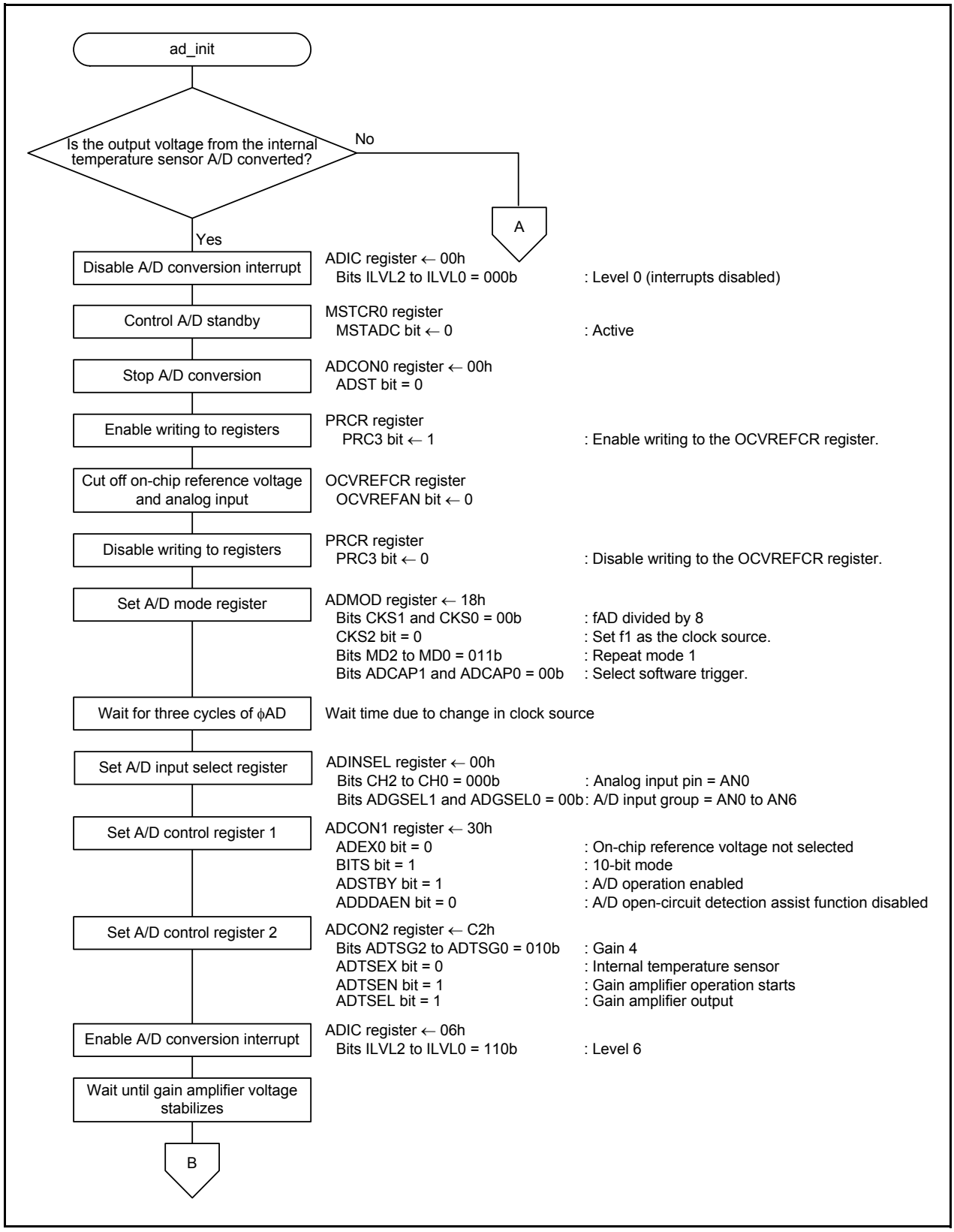

Figure 4.5 Initial Setting of the A/D Converter (1/2)

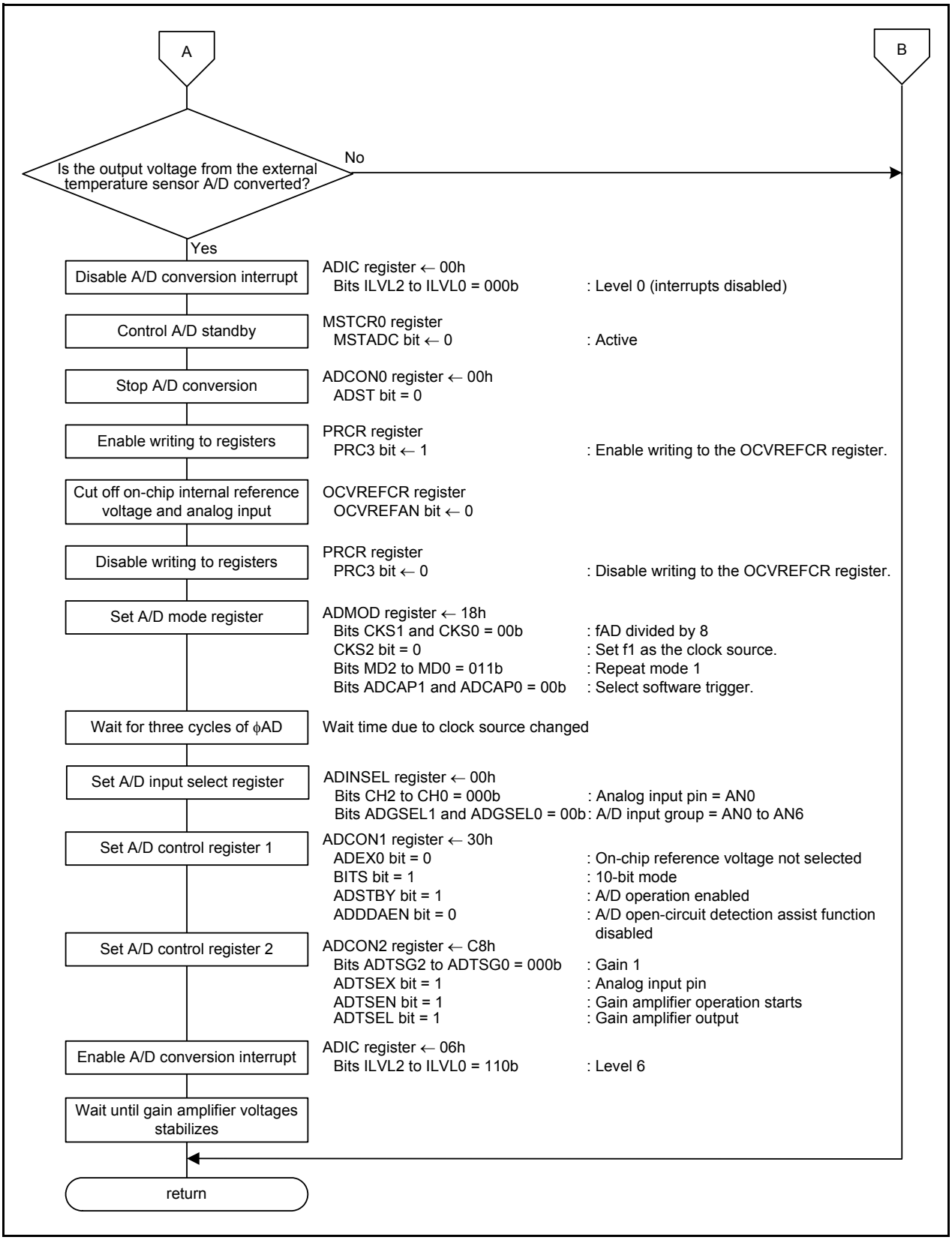

Figure 4.6 Initial Setting of the A/D Converter (2/2)

4.8.4 Obtaining the A/D Conversion Result

Figure 4.7 and Figure 4.8 show how to obtain the A/D conversion result.

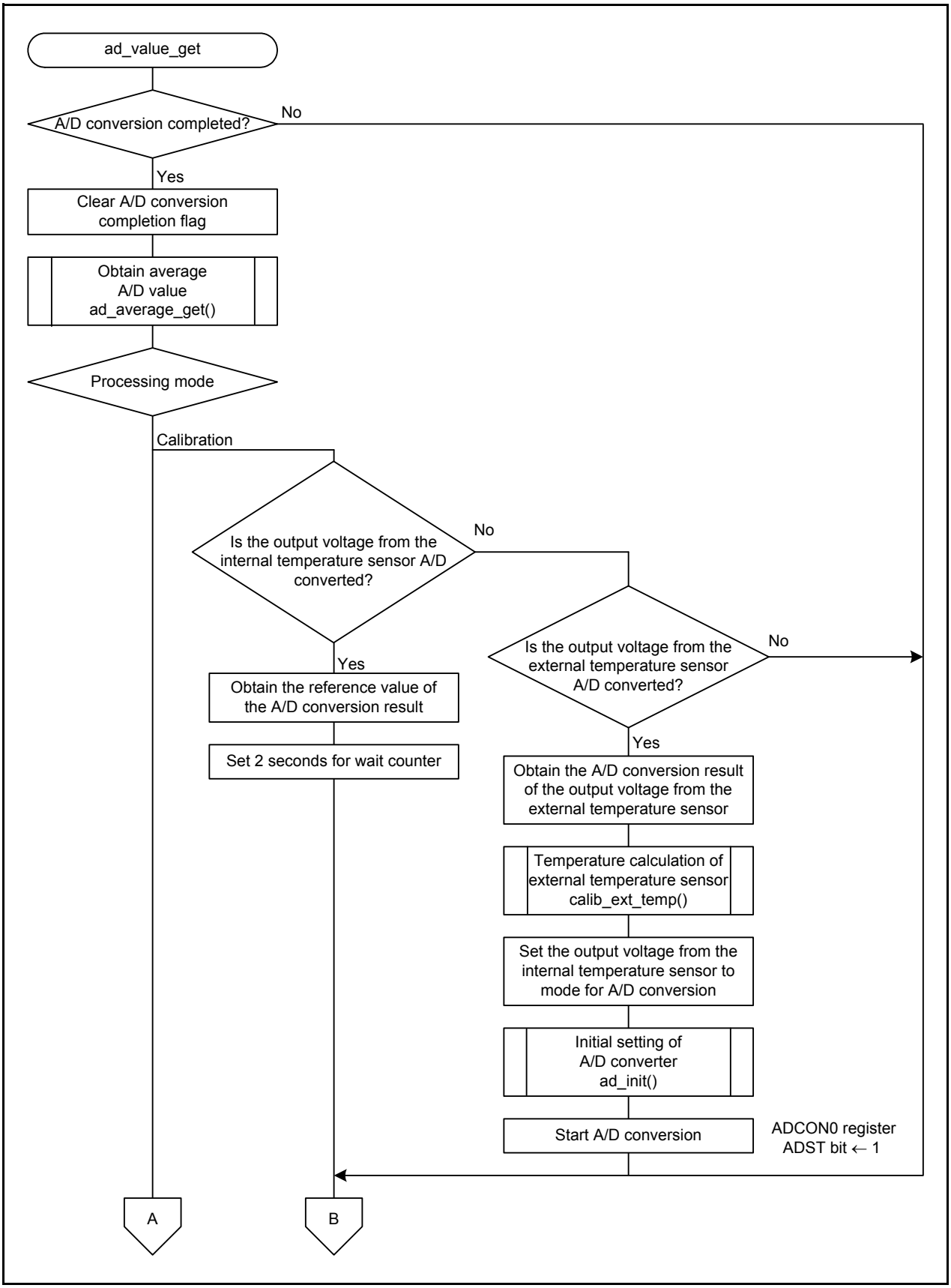

Figure 4.7 Obtaining the A/D Conversion Result (1/2)

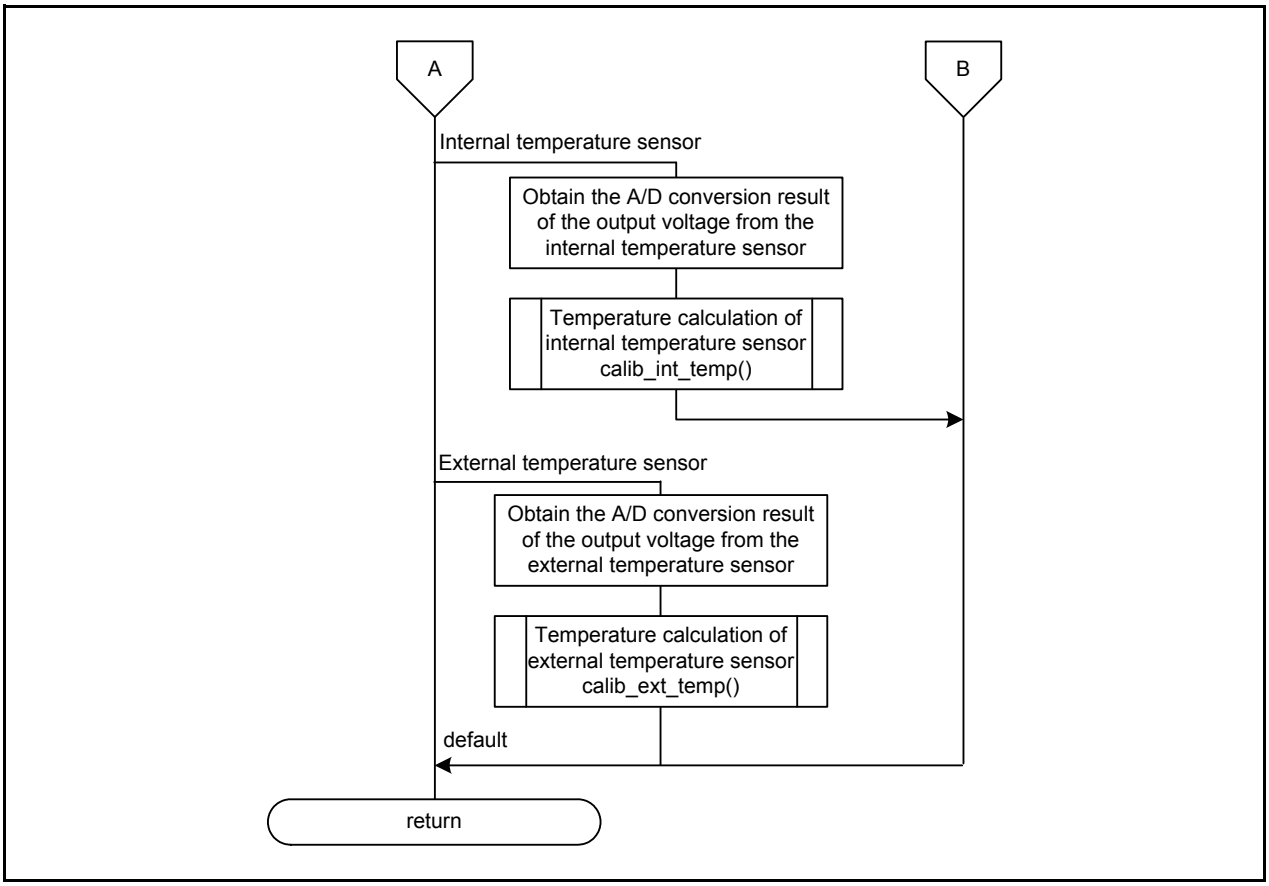

Figure 4.8 Obtaining the A/D Conversion Result (2/2)

4.8.5 Obtaining the Average A/D Value

Figure 4.9 shows the Obtaining the Average A/D Value.

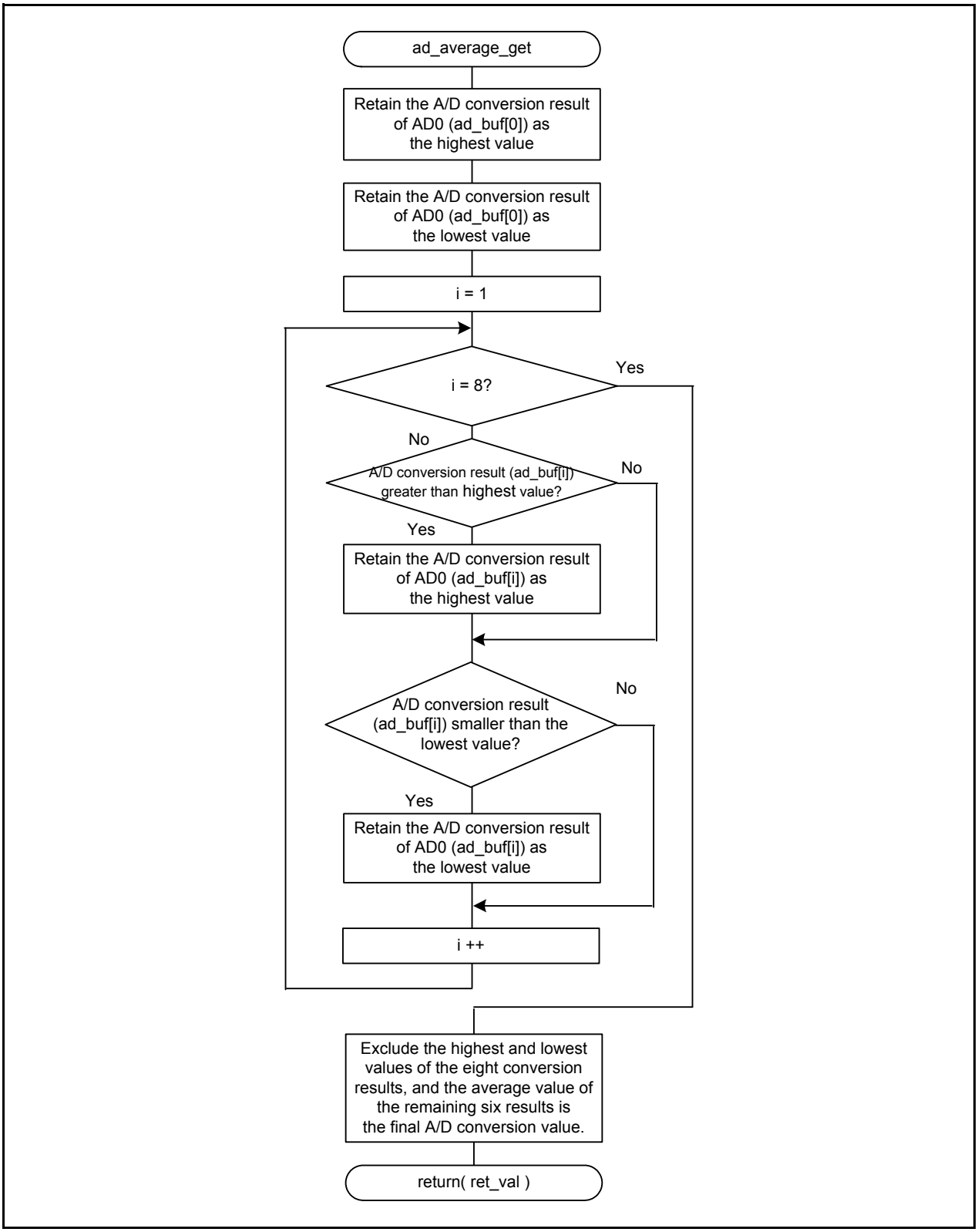

Figure 4.9 Obtaining the Average A/D Value

4.8.6 Temperature Calculation of the Internal Temperature Sensor

Figure 4.10 shows the Temperature Calculation of the Internal Temperature Sensor.

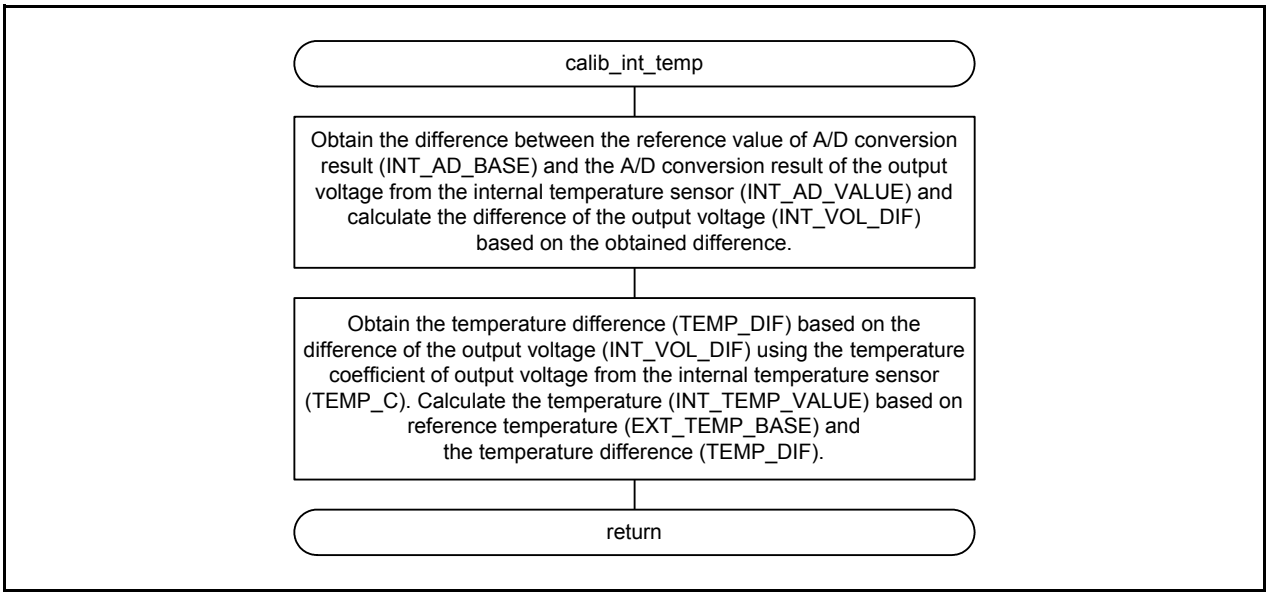

Figure 4.10 Temperature Calculation of the Internal Temperature Sensor

4.8.7 Temperature Calculation of the External Temperature Sensor

Figure 4.11 shows the Temperature Calculation of the External Temperature Sensor.

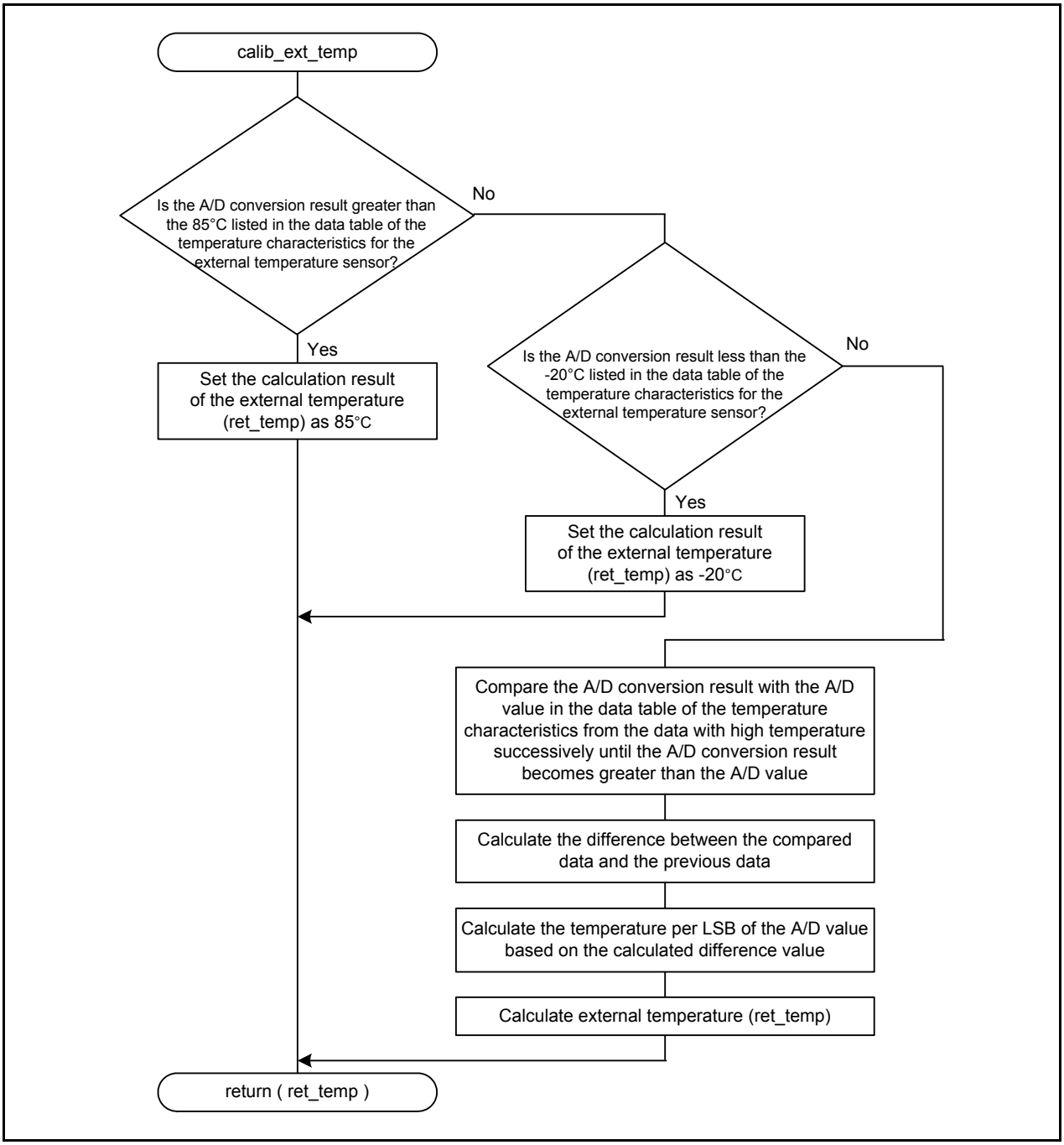

Figure 4.11 Temperature Calculation of the External Temperature Sensor

4.8.8 A/D Interrupt Handling

Figure 4.12 shows the A/D Interrupt Handling.

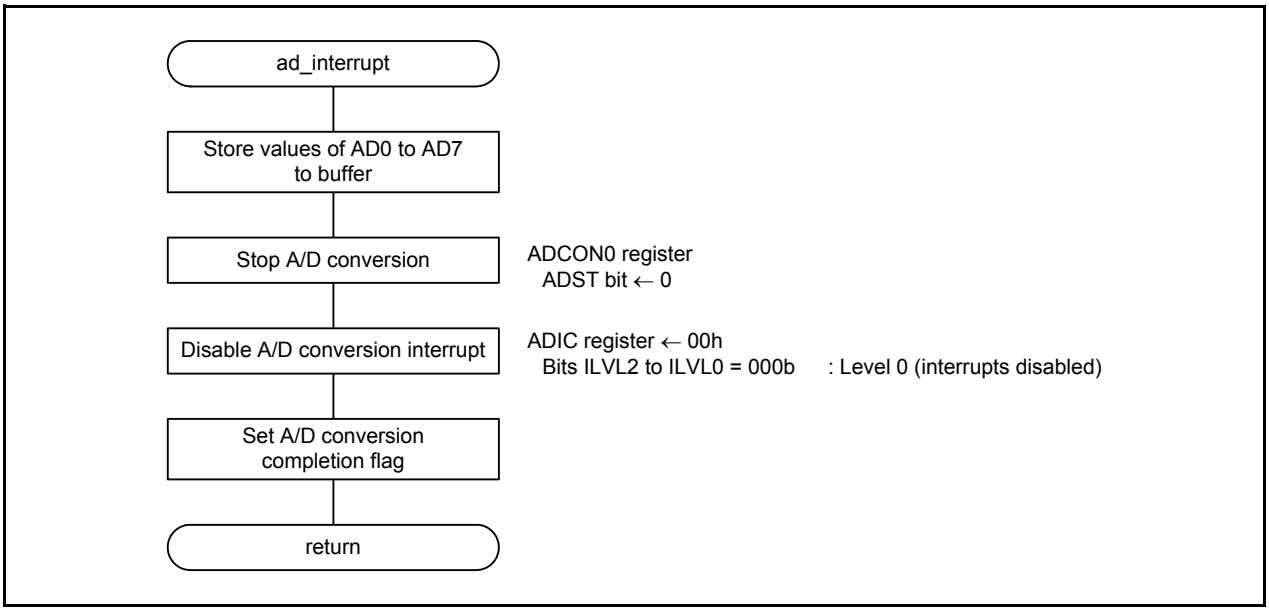

Figure 4.12 A/D Interrupt Handling

5. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

6. Reference Documents

User's Manual

R8C/LA3A Group, R8C/LA5A Group User's Manual: Hardware Rev. 1.00
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.

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Revision History	R8C/LA5A Group How to Use the Internal Temperature Sensor of the A/D Converter

Rev.	Date	Description	
		Page	Summary
1.00	June 25, 2012	—	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 manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

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 one with a different part number, confirm that the change will not lead to problems.

   — The characteristics of MPU/MCU in the same group but having different part numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different part numbers, implement a system-evaluation test for each of the products.

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