R8C/LA5A Group

Method to Correct the A/D Conversion Value Using the On-Chip Reference Voltage

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Abstract

This document describes a method to correct the A/D conversion value using the on-chip reference voltage (hereinafter referred to as OCVREF) for the 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

Since the fixed OCVREF is retained with the same supply voltage, change in the OCVREF A/D conversion value indicates the Vref variation of the A/D conversion reference voltage.
Perform A/D conversion on the OCVREF when Vref is equal to VCC and when Vref is not equal to VCC. Then calculate the rate of variation in the Vref based on the difference.
Using that rate of variation, the A/D conversion value of the analog input voltage when Vref is not equal to Vcc can be corrected to a value close to the A/D conversion value when Vref is equal to Vcc.
However, when Vref is not equal to Vcc, A/D conversion does not comply with the recommended operating conditions, therefore absolute accuracy of the A/D converted value is not guaranteed. The correction value that was calculated using that A/D conversion value is also not guaranteed.

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

Table 1.1 Peripheral Functions and Their Applications

Peripheral Function	Application
A/D converter	Perform A/D conversion on the OCVREF and analog input voltage
Timer RJ0	Count the time to display the initialization mode
$\overline{\text{INT2}}$ interrupt	Detects input for the selector button to change to calibration mode
$\overline{\text{INT7}}$ interrupt	Detects input for the LCD display selector button
LCD drive control circuit	Display mode and the A/D conversion value

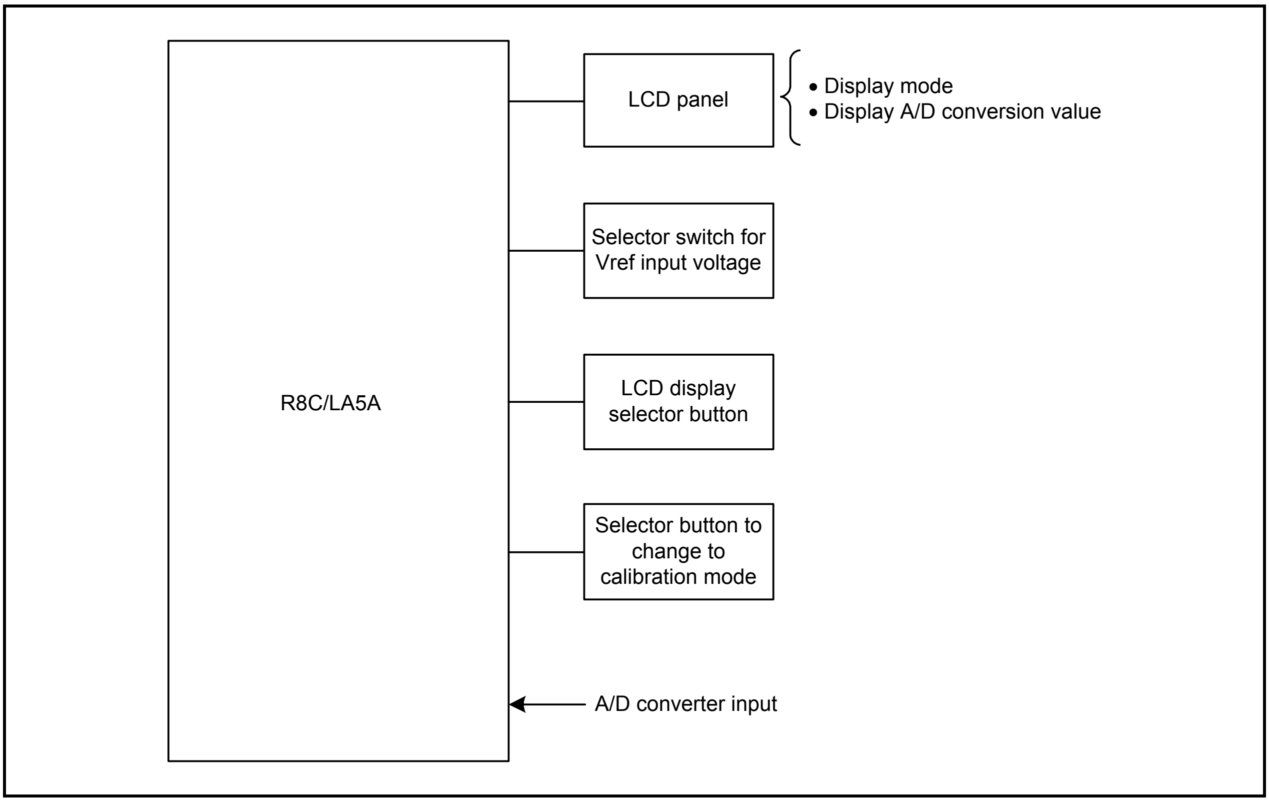

Figure 1.1 Function Block Diagram

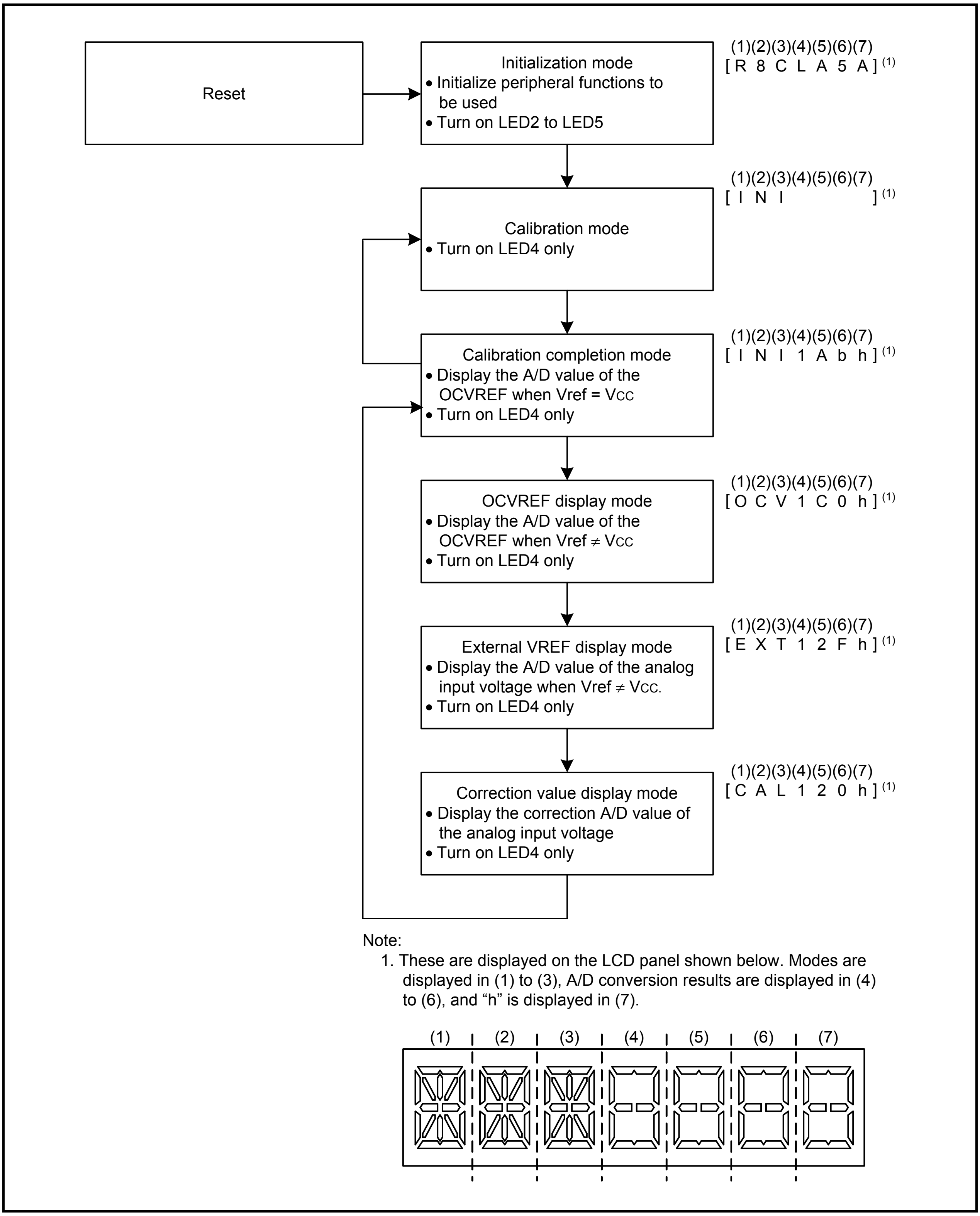

Figure 1.2 Mode Block Diagram

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.)

The fixed OCVREF is retained with the same supply in this application note. Also, when Vref is not equal to Vcc, A/D conversion does not comply with the recommended operating conditions, therefore absolute accuracy of the A/D converted value is not guaranteed.

3. Hardware

3.1 Hardware Configuration

Figure 3.1 shows a Connection Example.

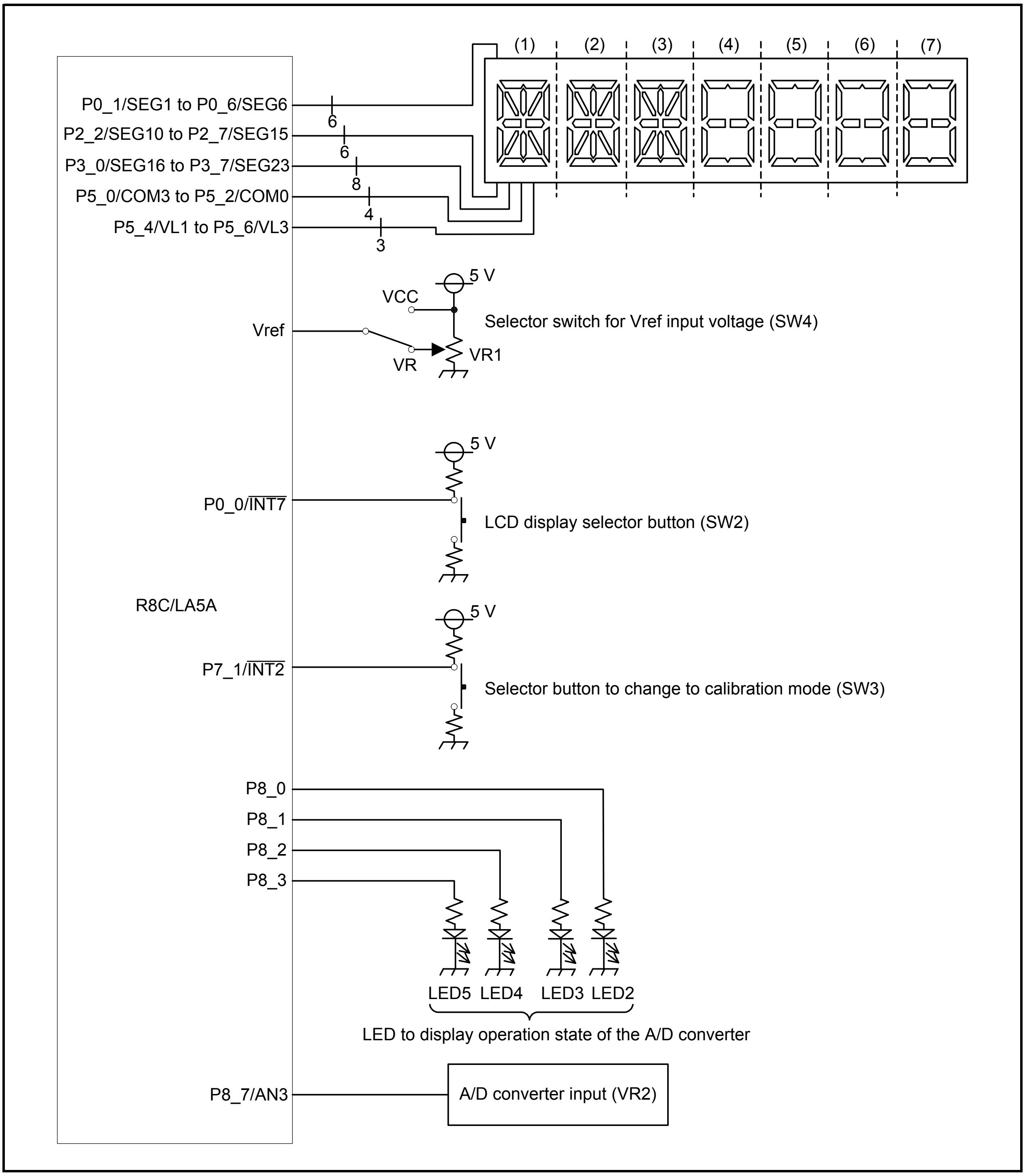

Figure 3.1 Connection Example

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	Output	VL input (LCD display)
P0_0/$\overline{\text{INT7}}$	Input	Input for the LCD display 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_7/AN3	Input	A/D converter input (AN3)
Vref	Input	Selector switch input for Vref input voltage (SW4)

4. Software

4.1 Operation Overview

The OCVREF is A/D converted when Vref is equal to VCC and Vref is not equal to VCC, and the rate of variation in the Vref is calculated based on each A/D conversion value. The A/D conversion value of the analog input voltage when Vref is not equal to VCC is corrected to a value close to the A/D conversion value when Vref is equal to VCC using the the rate of variation in the Vref.

In this application note, the software is configured with the six modes shown in Figure 4.1 Mode Transition. Modes are transited using the LCD display selector button or selector button to change to calibration mode to correct the A/D conversion value.
Processing in each mode and content displayed on the LCDs are described in Figure 4.1 Mode Transition. The highest and lowest values of the eight conversion results are excluded, and the average value of the remaining six results is obtained.

Figure 4.1 shows the Mode Transition.

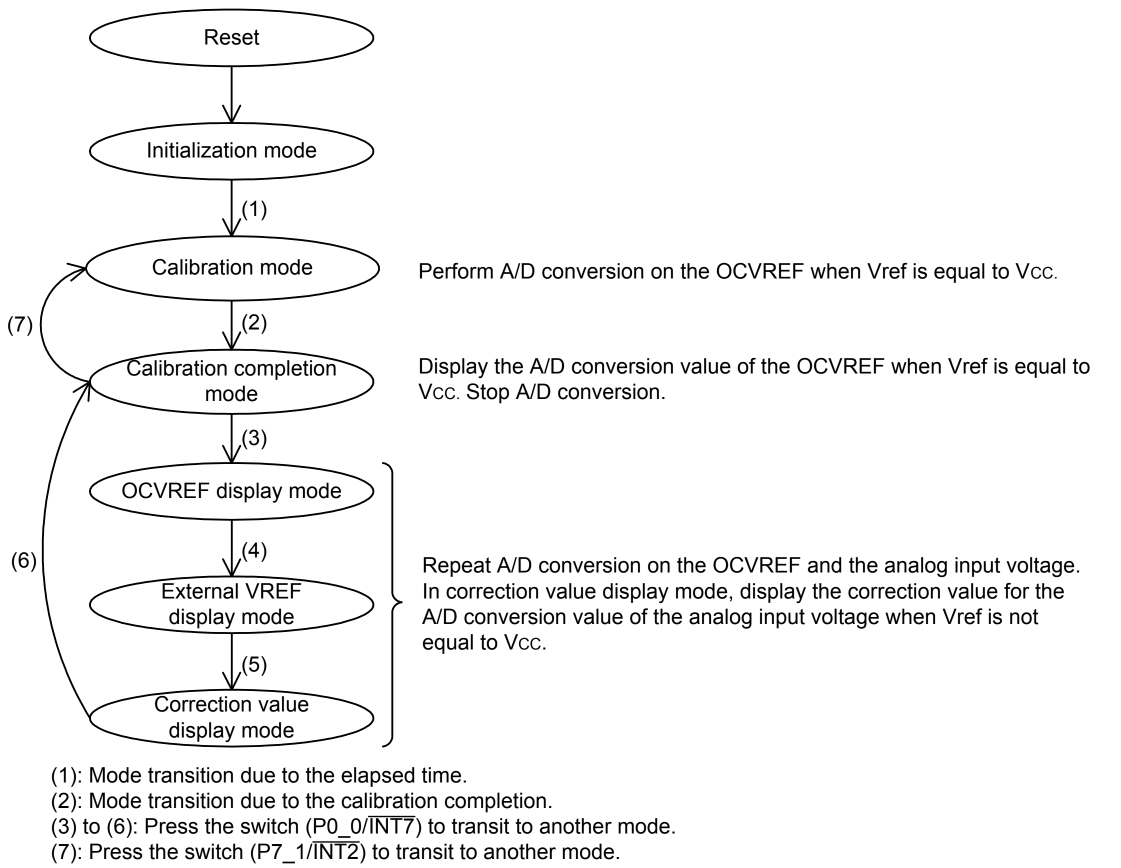

Figure 4.1 Mode Transition

4.1.1 Setting the On-Chip Reference Voltage

The value of the OCVREF is A/D converted using itself as the analog input. The A/D converter setting when performing A/D conversion on the OCVREF is shown below.

Setting:

- Use the A/D converter in repeat mode 1.
- Use 10 bits for the resolution.
- Use f1 as the clock source of fAD.
- Use fAD divided by 2 for operating clock ϕAD.
- Use a software trigger for the A/D conversion start condition.
- Disable the A/D open-circuit detection assist function.

In repeat mode 1, the A/D conversion result of the OCVREF is stored each time A/D conversion is completed in the following order:
AD0 → AD1 → …→ AD7

Reference: Calculation method of the A/D conversion value
The calculation method of the A/D conversion value based on the analog input voltage using the typical value of the OCVREF standard value is shown below.

Conditions: VCC = Vref = 5.0 V, A/D converter is in 10-bit mode
OCVREF: 1.70 V (Typ.)
VCC = Vref = 1.8 to 5.5 V, OCVREF: min 1.53 V, typ. 1.70 V, max. 1.87 V
Voltage per LSB: 5.0 V ÷ 1023 ≈ 0.0049 = 4.9 mV
A/D conversion value: 1.70 V ÷ 0.0049 ≈ 346.94 ≈ 15Bh

4.1.2 Method to Correct the A/D Conversion Value of the Analog Input Voltage

This section describes a method of using the OCVREF to correct the A/D conversion value of the analog input voltage when Vref is not equal to Vcc to a value that is close to the A/D conversion value when Vref is equal to Vcc.

Based on the A/D converter function when A/D resolution is 10 bits, (1) and (2) below are related equations when Vref is equal to Vcc.

(1) Perform A/D conversion on the OCVREF when Vref is equal to VCC and retain the result.

ADOCVREF_VCC: A/D conversion value of OCVREF when Vref is equal to VCC

(2) Perform A/D conversion on the OCVREF when Vref is not equal to VCC and retain the result.

ADOCVREF_NOVCC: A/D conversion value of OCVREF when Vref is not equal to VCC

(3) Compared to when Vref is not equal to VCC, the percentage of the A/D conversion result when Vref is equal to VCC can be calculated using the following formula and its percentage is assumed as the correction value.

ADJUST_Percentage = ADOCVREF_Vcc ÷ ADOCVREF_NOVcc
ADJUST_Percentage: Comparison to when Vref is not equal to VCC, the percentage of the A/D conversion result when Vref is equal to VCC.

(4) Correct the A/D conversion value of the external input voltage when Vref is not equal to VCC using the value calculated in step (3). Then the closest A/D conversion value when Vref is equal to VCC can be obtained.

ADEXT_Adjust = ADEXT_NOVcc × ADJUST_Percentage
ADEXT_Adjust: A/D conversion value of the external input voltage after correction
ADEXT_NOVCC: A/D conversion value of the external input voltage when Vref is not equal to VCC

4.2 Required Memory Size

Table 4.1 lists the Required Memory Size.

Table 4.1 Required Memory Size

Memory Used	Size	Remarks
ROM	2272 bytes	In the r01an1246_src.c module
RAM	44 bytes	In the r01an1246_src.c module
Maximum user stack usage	34 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 4.2 lists the Constants Used in the Sample Code.

Table 4.2 Constants Used in the Sample Code

Constant Name	Setting Value	Contents
CALIB_COMP	0	Calibration completion mode
OC_VREF	1	OCVREF display mode
EXE_VREF	2	External VREF display mode
CORRECT	3	Correction value display mode
CALIB	4	Calibration mode
INITIAL	255	Initialization mode
OC_VREF_AD	0	A/D conversion mode of the OCVREF
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
TM_2sec	200	2 second counter value
NUM0_ADDRESS	0x227	Display register address of the third digit for the full segment of the LCD
NUM1_ADDRESS	0x223	Display register address of the second digit for the full segment of the LCD
NUM2_ADDRESS	0x21F	Display register address of the first digit for the full segment of the LCD
NUM3_ADDRESS	0x21B	Display register address of the fourth digit for the 7 segments of the LCD
NUM4_ADDRESS	0x216	Display register address of the third digit for the 7 segments of the LCD
NUM5_ADDRESS	0x214	Display register address of the second digit for the 7 segments of the LCD
NUM6_ADDRESS	0x212	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      :4;
        unsigned char Second  :4;
        unsigned char Third      :4;
        unsigned char Fourth    :4;
    }data;
    unsigned short All;
}DATA;

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 4.3 lists the Global Variables.

Table 4.3 Global Variables

Type	Variable Name	Contents	Function Used
unsigned char	proc_mode	Processing mode	mode_proc, ocrvf_operation, lcd_dsp, int2_interrupt, int7_interrupt
unsigned char	req_mode	Request mode	mode_proc, ocrvf_operation, int2_interrupt, int7_interrupt
unsigned char	ad_cnv_mode	A/D conversion mode	ad_init, mode_proc, ocrvf_operation
union DATA	ADOCVREF_Vcc	Store the A/D conversion value of OCVREF when Vref = VCC	ocrvf_operation, calib_correct, lcd_dsp
union DATA	ADOCVREF_NOVcc	Store the A/D conversion value of OCVREF when Vref ≠ VCC	ocrvf_operation, calib_correct, lcd_dsp
union DATA	ADEXT_NOVcc	Store the A/D conversion value of the analog input voltage when Vref ≠ VCC	ocrvf_operation, calib_correct, lcd_dsp
union DATA	ADEXT_Adjust	Store the A/D conversion value of the correction input voltage	calib_correct, lcd_dsp
FLAG	flags	flg_adc: A/D conversion completion flag flg_lcd_dsp: LCD display request flag	mode_proc, ocrvf_operation, ad_interrupt, lcd_dsp
unsigned short	ad_buf[8]	Buffer to obtain the A/D conversion result	ad_average_get, ad_interrupt

4.6 Functions

Table 4.4 lists the Functions.

Table 4.4 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)
initial_wait	Initialization wait processing (1)
ad_init	Initial setting of the A/D converter
mode_proc	Mode processing (1)
ocrvf_operation	On-chip reference voltage processing
ad_average_get	Obtaining the average A/D value
calib_correct	Calculation for correction value
lcd_dsp	LCD display processing (1)
lcd_full_seg	Display processing for the full segment of the LCD (1)
lcd_7seg	Display processing of the 7 segments of the LCD (1)
int2_interrupt	$\overline{\text{INT2}}$ interrupt handling (1)
int7_interrupt	$\overline{\text{INT7}}$ interrupt handling (1)
ad_interrupt	A/D interrupt handling

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 A/D converter operating mode.
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 for the selector button to change to calibration mode. $\overline{\text{INT2}}$ 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 $\overline{INT7}$ interrupt
Header	None
Declaration	void int7_init(void)
Description	Perform the initial setting of the $\overline{INT7}$ interrupt to detect input to the LCD display selector button. $\overline{INT7}$ 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.

initial_wait	
Outline	Initialization wait processing
Header	None
Declaration	void initial_wait(void)
Description	Use 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.

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 OCVREF or analog input voltage.
Argument	None
Returned value	None
Remarks	—

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

ocrvf_operation	
Outline	On-chip reference voltage processing
Header	None
Declaration	void ocrvf_operation(void)
Description	• Obtain the A/D conversion result for the OCVREF or analog input voltage. • Start A/D conversion for the OCVREF or analog input voltage.
Argument	None
Returned value	None
Remarks	—

ad_average_get	
Outline	Obtaining the average A/D 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	None

calib_correct	
Outline	Calculation for correction value
Header	None
Declaration	voidocrvf_operation(void)
Description	The A/D conversion value of the analog input voltage when Vref is not equal to VCC is corrected to the A/D conversion value when Vref is equal to VCC using the A/D conversion values of OCVREF when Vref is equal to VCC and the OCVREF when Vref is not equal to VCC.
Argument	None
Returned value	None
Remarks	—

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_full_seg	
Outline	Display processing for 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.

int2_interrupt	
Outline	$\overline{\text{INT2}}$ interrupt handling
Header	None
Declaration	void int2_interrupt(void)
Description	• Change to calibration mode. • Disable the $\overline{\text{INT2}}$ interrupt.
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 processing mode every time an interrupt is generated in the order shown in Figure 4.1: (3) → (4) → (5) → (6) → (3) … • Disable the $\overline{\text{INT7}}$ interrupt.
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	—

4.8 Flowcharts

4.8.1 Main Processing

Figure 4.3 shows the Main Processing.

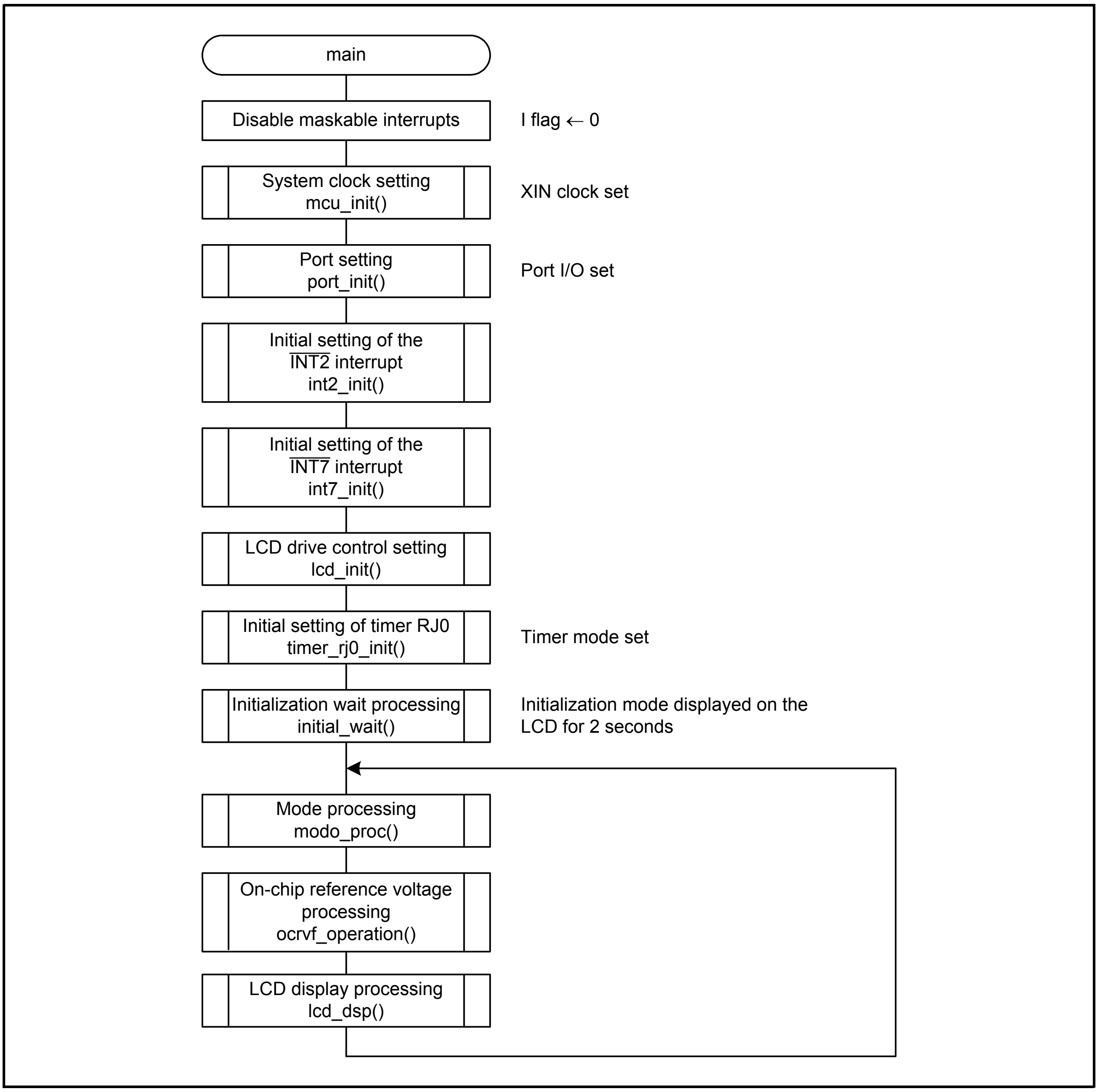

Figure 4.3 Main Processing

4.8.2 System Clock Setting

Figure 4.4 shows the System Clock Setting.

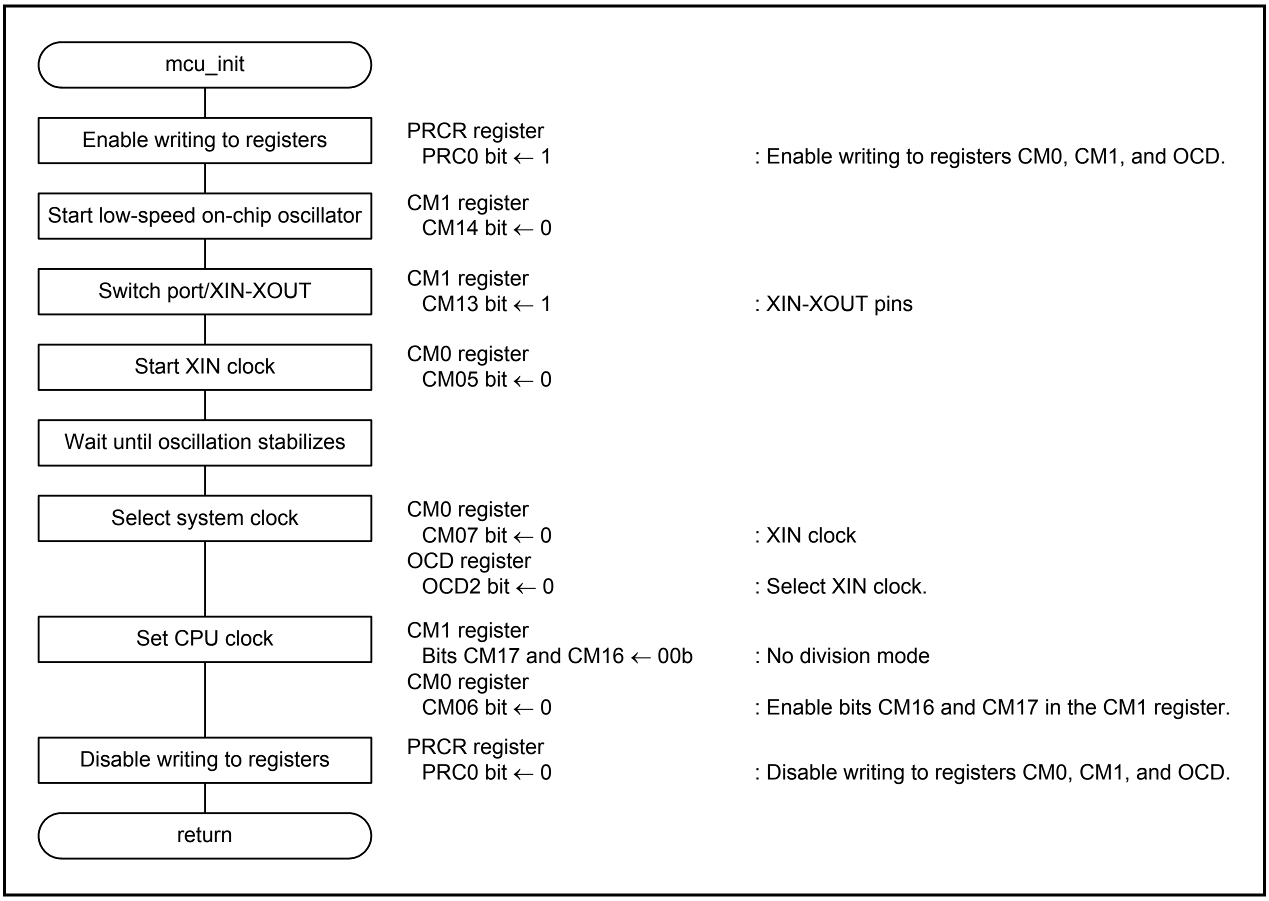

Figure 4.4 System Clock Setting

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.

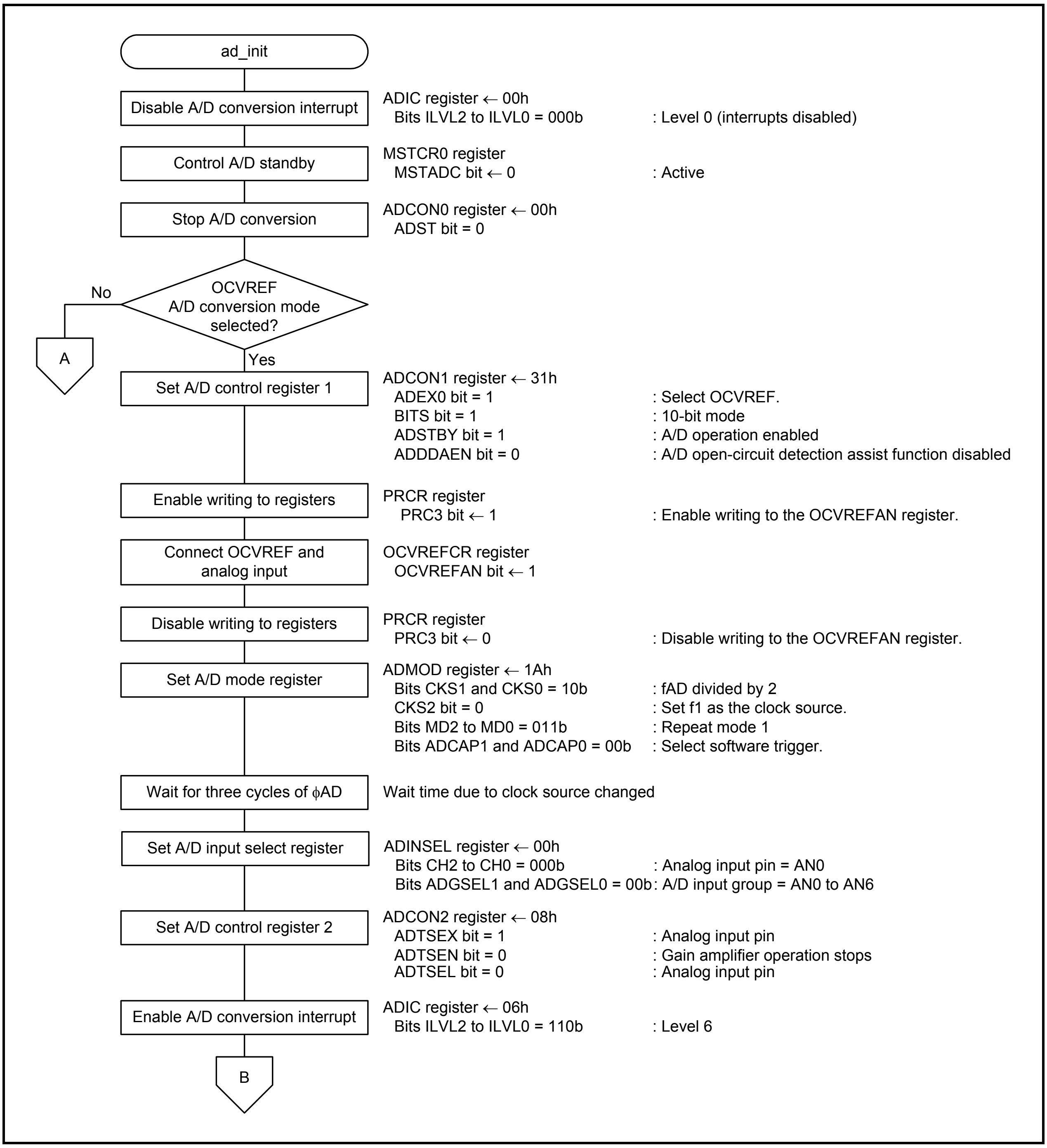

Figure 4.5 Initial Setting of the A/D Converter (1/2)

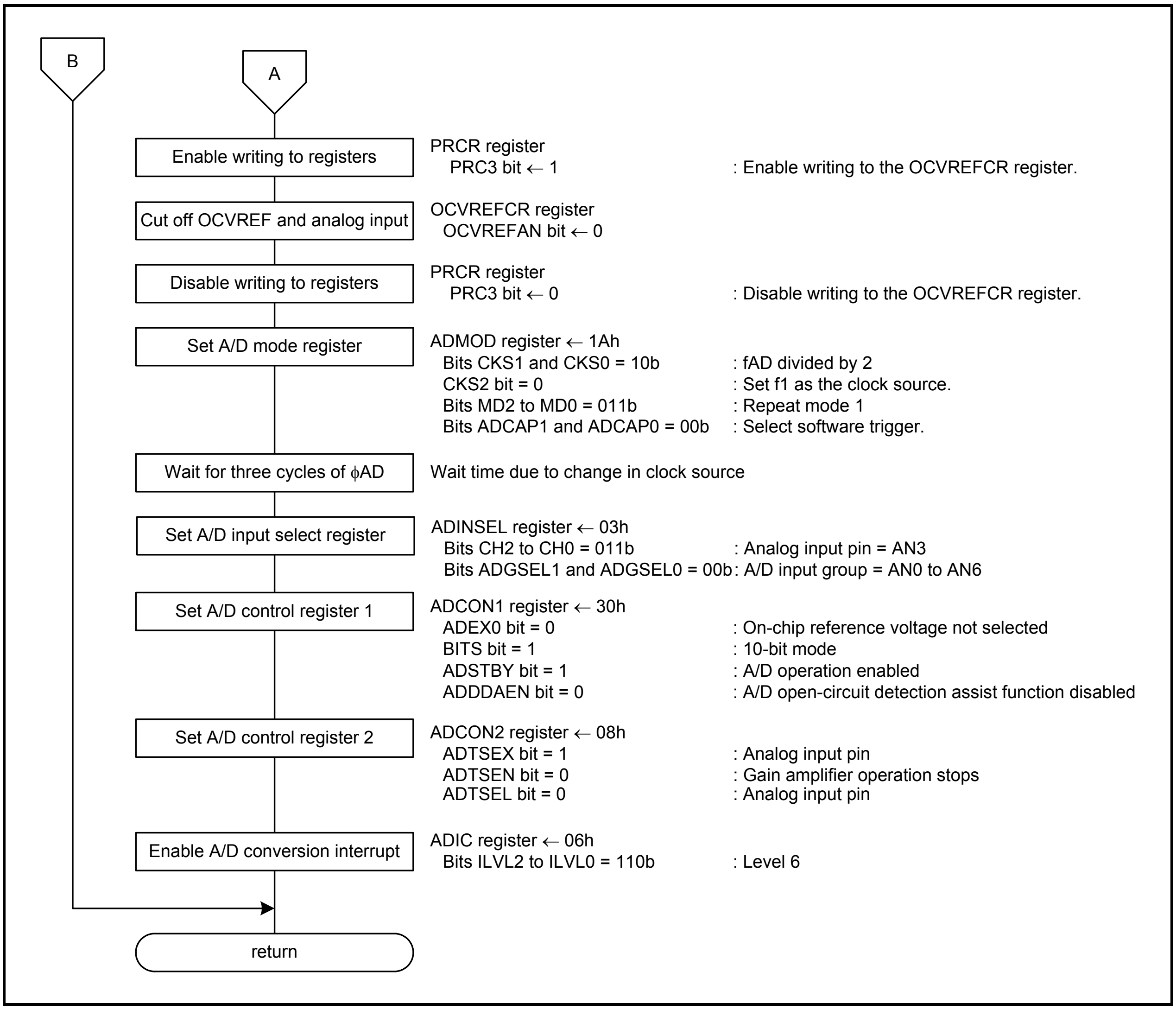

Figure 4.6 Initial Setting of the A/D Converter (2/2)

4.8.4 On-Chip Reference Voltage Processing

Figure 4.7 and Figure 4.8 show the On-Chip Reference Voltage Processing.

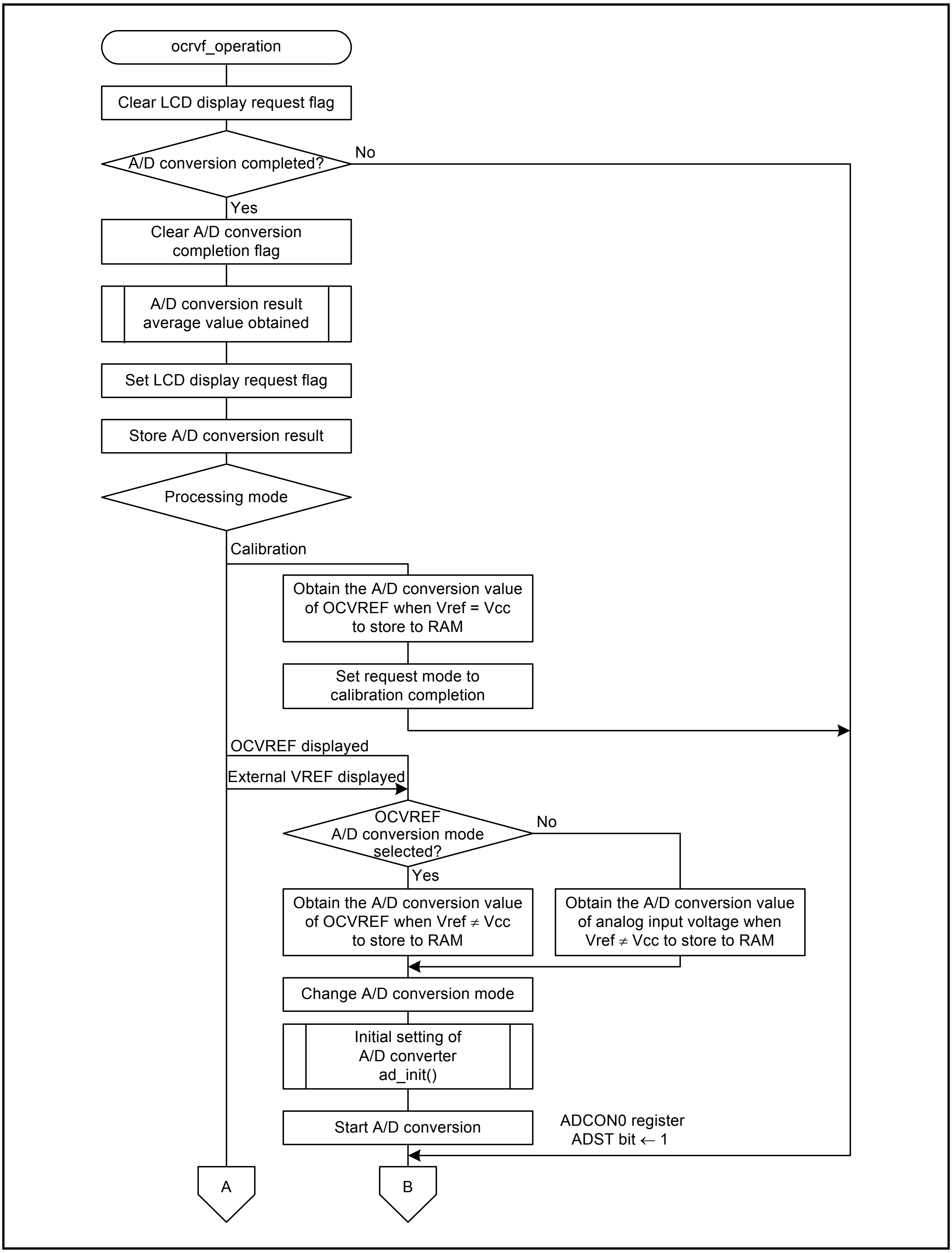

Figure 4.7 On-Chip Reference Voltage Processing (1/2)

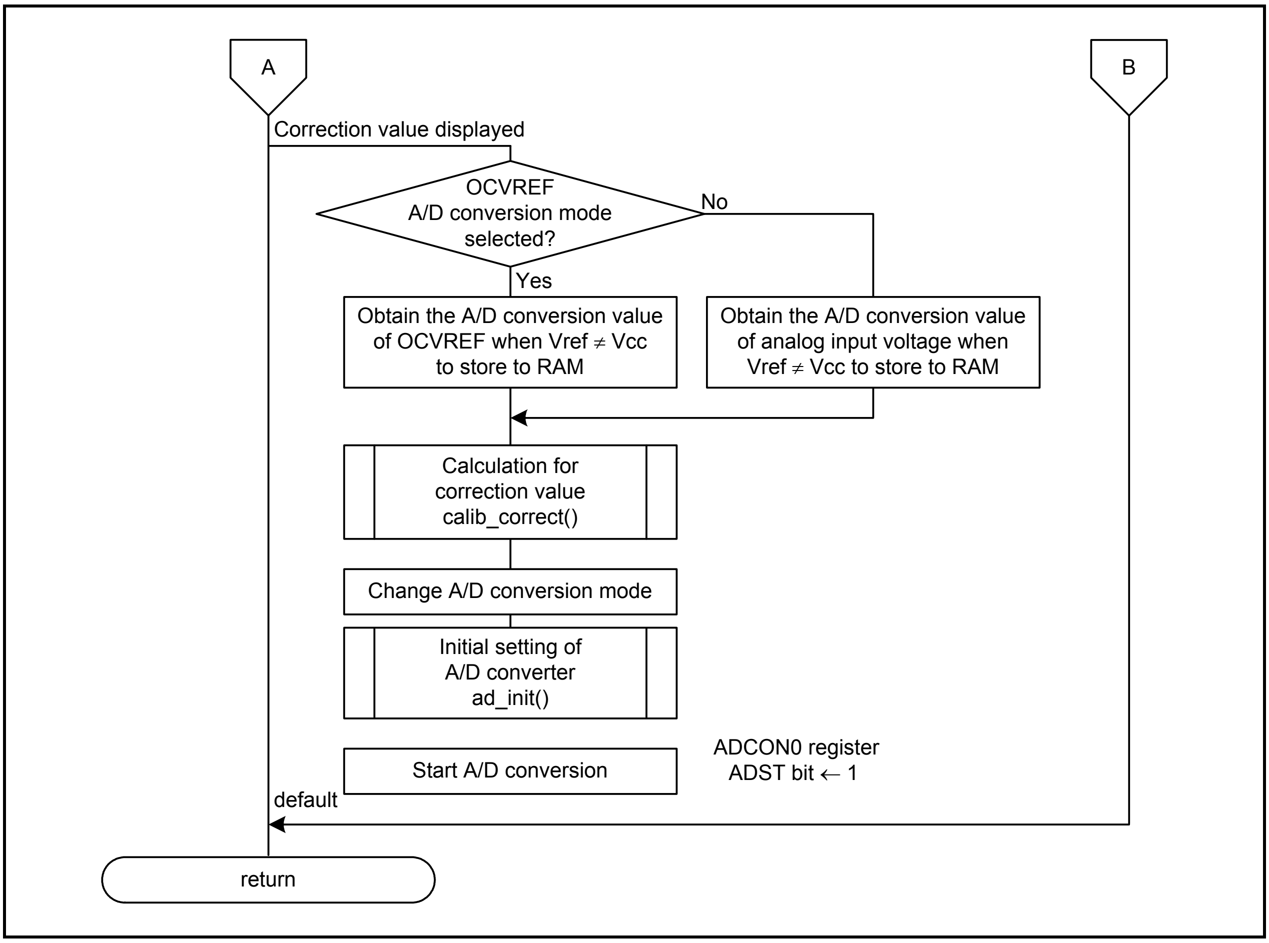

Figure 4.8 On-Chip Reference Voltage Processing (2/2)

4.8.5 Obtaining the Average A/D Value

Figure 4.9 shows Obtaining the Average A/D Value.

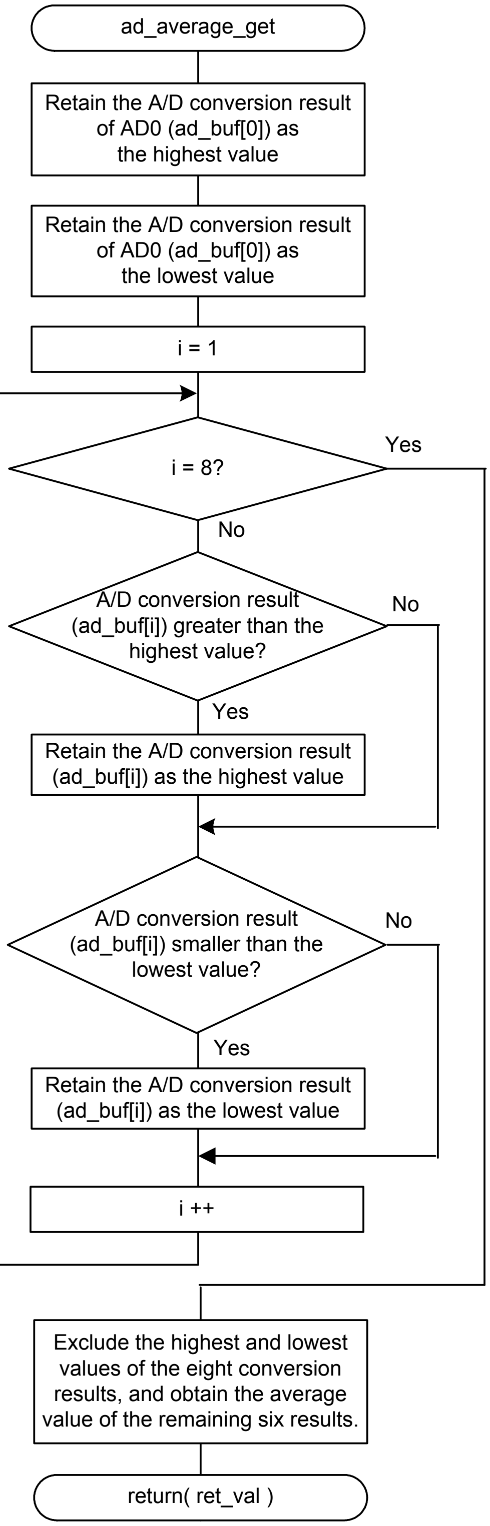

Figure 4.9 Obtaining the Average A/D Value

4.8.6 Calculating the Correction Value

Figure 4.10 shows Calculating the Correction Value.

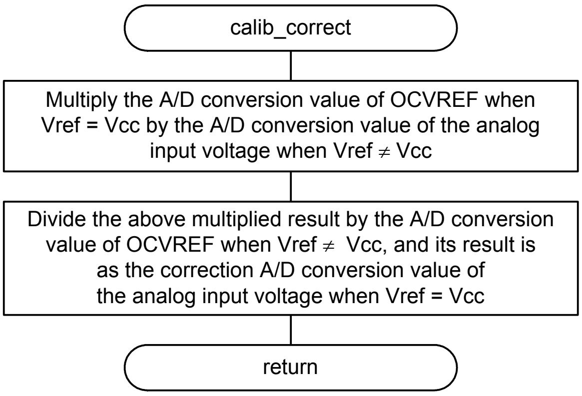

Figure 4.10 Calculating the Correction Value

4.8.7 A/D Interrupt Handling

Figure 4.11 shows the A/D Interrupt Handling.

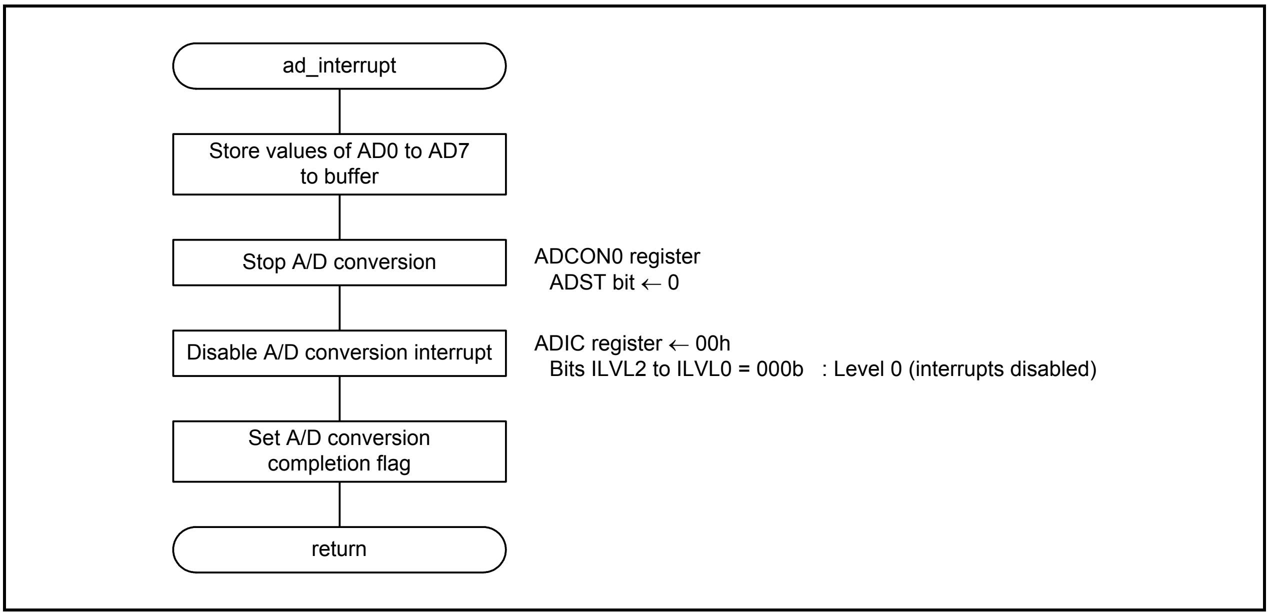

Figure 4.11 A/D Interrupt Handling

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.

Website and Support

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

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

Revision History	R8C/LA5A Group Method to Correct the A/D Conversion Value Using the On-Chip Reference Voltage

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

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