R8C/LA5A Group

Using the Gain Amplifier in the A/D Converter

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Abstract

This document describes the gain amplifier in the R8C/LA5A Group A/D converter.

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

A/D conversion is performed using the A/D converter whether the gain amplifier is used or not.
Each time the gain amplifier selector button is pushed, the gain amplification factor increases in the following order:
Gain amplifier is not used → Gain 1 → Gain 2 → Gain 4 → Gain 6 → Gain 8
The current mode and A/D conversion value are displayed on the LCD.

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 whether the gain amplifier is used or not
Timer RJ0	Count the time to display the initialization mode
$\overline{\text{INT7}}$ interrupt	Detects when the gain amplifier selector button has been pushed
LCD drive control circuit	Display the A/D conversion value and state of the gain amplifier

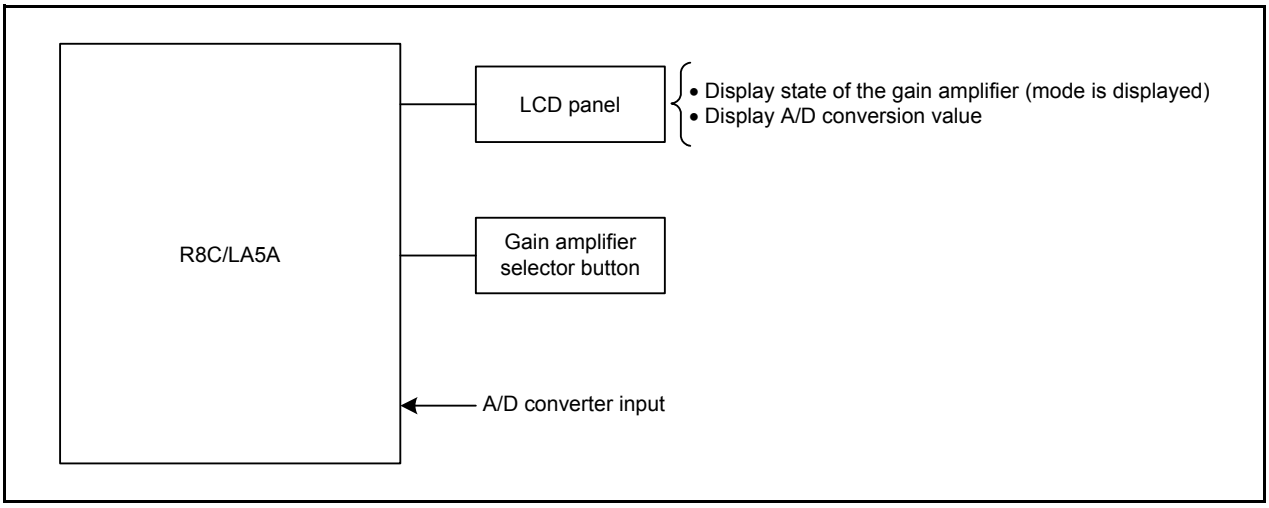

Figure 1.1 Function Block Diagram

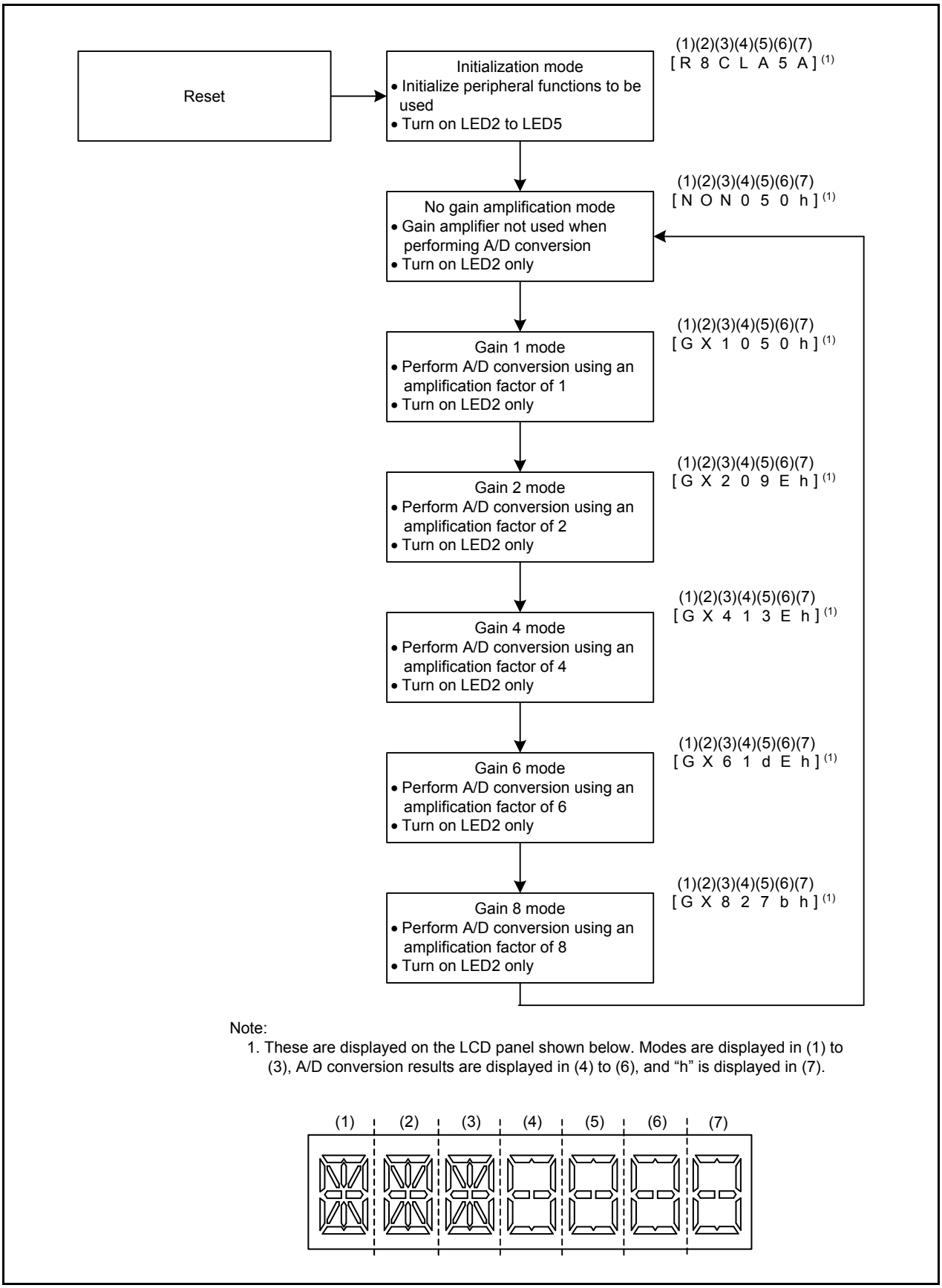

Figure 1.2 Mode Block Diagram

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.

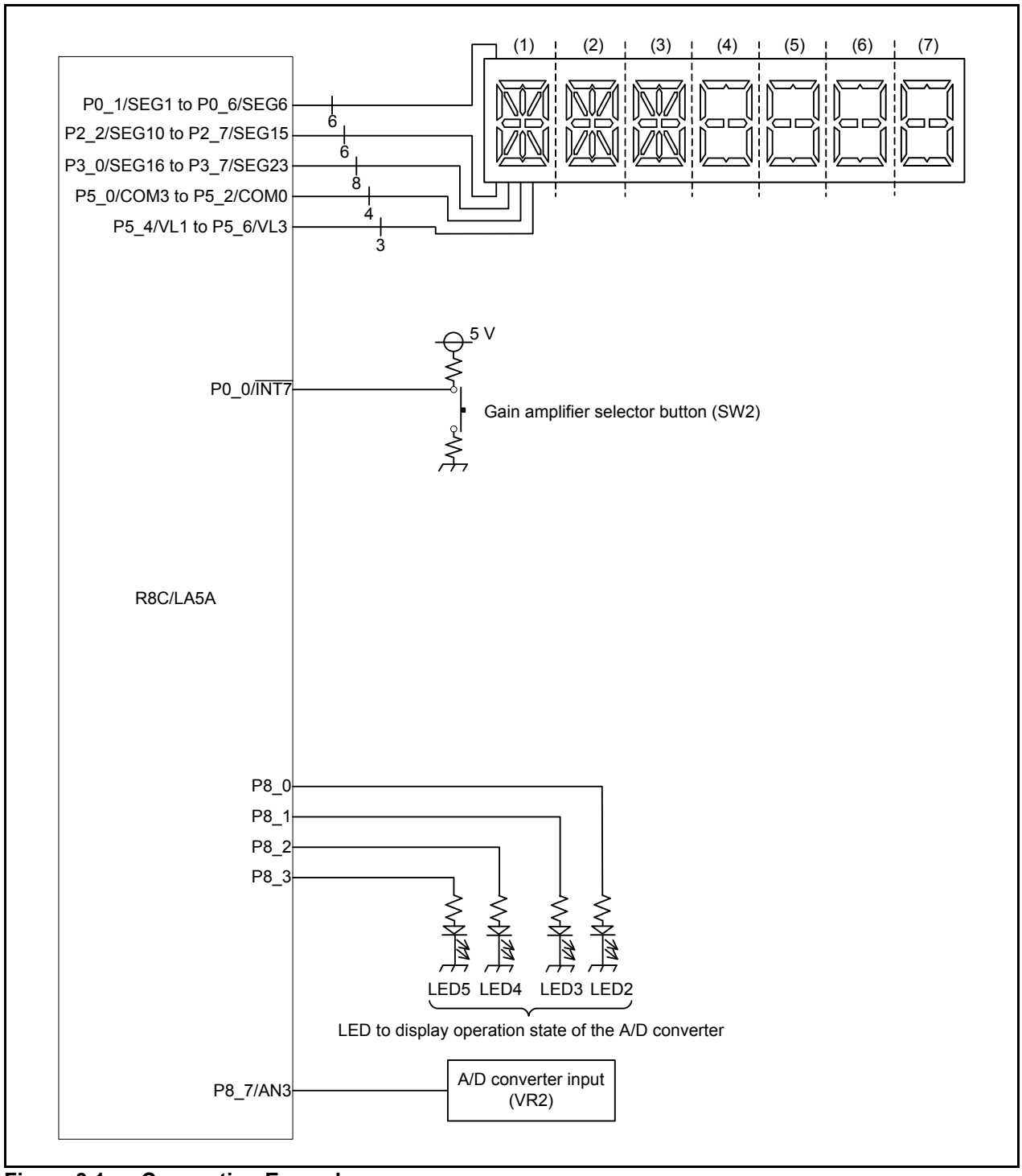

Figure 3.1 Connection Example

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_0/$\overline{\text{INT7}}$	Input	Gain amplifier selector button
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)
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)

4. Software

4.1 Operation Overview

A/D conversions are repeated every second and the current mode and A/D conversion value are displayed on the LCD. Each time the gain amplifier selector button is pushed, the gain amplification factor increases in the following order:
Gain amplifier is not used → Gain 1 → Gain 2 → Gain 4 → Gain 6 → Gain 8

In this application note, transit between modes using the gain amplifier selector button (as shown in Figure 4.1). The LED displays the gain amplifier setting that corresponds to each mode. The highest and lowest values of the eight A/D conversion results are excluded, and the average value of the remaining six results is obtained.
Figure 4.1 shows Mode Transition.

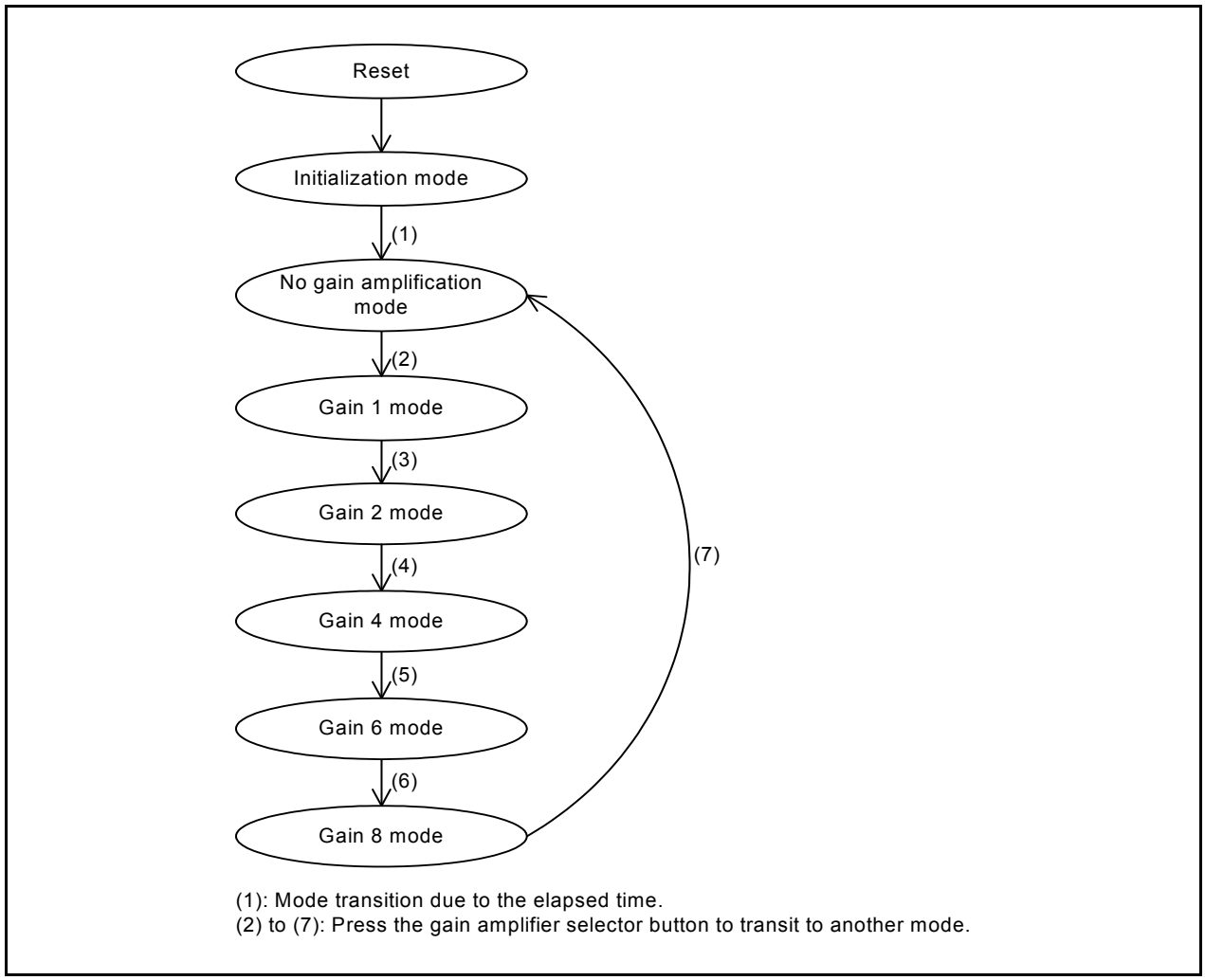

Figure 4.1 Mode Transition

4.2 Setting the Gain Amplifier

The analog input voltage can be increased by the specified amplification factor using the gain amplifier. The A/D conversion values below show the calculated values when the gain amplifier is not used and when a gain amplification factor of 2 is used.

Conditions:
V_{CC} = Vref = 5.0 V
A/D converter: Same as the setting used in this application note
Voltage per LSB: 0.0049 V ≈ 5.0 V ÷ 1023
Analog input voltage = 1.0 V

A/D conversion value when the gain amplifier is not used:
1.0 V ÷ 0.0049 V ≈ 204

A/D conversion value when using a gain amplification factor of 2:
(1.0 V * 2) ÷ 0.0049 V ≈ 408

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 8 for operating clock ϕAD.
- Use a software trigger for the A/D conversion start condition.
- Disable the A/D open-circuit detection assist function.

4.3 Required Memory Size

Table 4.1 lists the Required Memory Size.

Table 4.1 Required Memory Size

Memory Used	Size	Remarks
ROM	1705 bytes	In the r01an1156_src.c module
RAM	38 bytes	In the r01an1156_src.c module
Maximum user stack usage	17 bytes	
Maximum interrupt stack usage	20 bytes	

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

4.4 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
GAIN_STOP	0	Gain amplifier is not used
GAIN_1	1	Gain 1
GAIN_2	2	Gain 2
GAIN_4	3	Gain 4
GAIN_6	4	Gain 6
GAIN_8	5	Gain 8
INITIAL	255	Initialization mode
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_1sec	100	1 second counter value
TM_2sec	200	2 seconds 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

4.5 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

4.6 Variables

Table 4.3 lists the Global Variables.

Table 4.3 Global Variables (1/2)

Type	Variable Name	Contents	Function Used
unsigned char	gain_mode	Gain mode	ad_init, gain_operation, lcd_dsp, trj0_interrupt
unsigned char	req_gain_mode	Request gain mode	gain_operation, int7_interrupt, trj0_interrupt
unsigned char	cnt_1sec	1 second counter	gain_operation trj0_interrupt
FLAG	flags	flg_adc: A/D conversion completion flag	gain_operation, ad_value_get, ad_interrupt
unsigned short	ad_buf[8]	Buffer to obtain the A/D conversion result	ad_value_get, ad_interrupt
union DATA	V_result	Store A/D conversion result (main processing)	ad_value_get, lcd_dsp

4.7 Functions

Table 4.4 lists the Functions.

Table 4.4 Functions

Function Name	Outline
mcu_init	System clock setting
port_init	Port setting (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
gain_operation	Gain amplifier operation
ad_value_get	Obtaining the A/D conversion result
ad_average_get	Obtaining the A/D average value
lcd_dsp	LCD display processing (1)
lcd_full_seg	Display processing of the full segment of the LCD (1)
lcd_7seg LCD7	Display processing of the 7 segments of the LCD (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.

4.8 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 LED pin to display the A/D converter operating mode.
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 when the gain amplifier selector button is pushed. $\overline{\text{INT7}}$ 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 time to display the 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	Perform the initial setting to A/D convert using repeat mode 1 whether the gain amplifier is used or not.
Argument	None
Returned value	None
Remarks	—

gain_operation	
Outline	Gain amplifier operation
Header	None
Declaration	void gain_operation(void)
Description	Perform processing when the gain amplifier is not used or the amplification factor of the gain amplifier 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 the A/D conversion result. • Turn on the LED2 only. • Display the A/D conversion value and state of the gain amplifier on the LCD.
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	—

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 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.

int7_interrupt	
Outline	$\overline{\text{INT7}}$ interrupt handling
Header	None
Declaration	void int7_interrupt(void)
Description	• Change the gain amplifier mode in the order shown in Figure 4.1: (2) → (3) → (4) → (5) → (6) → (7) → (2) • Disable the $\overline{\text{INT7}}$ and timer RJ interrupts.
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 result. • 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 every second. • Enable the A/D interrupt.
Argument	None
Returned value	None
Remarks	This flowchart is omitted.

4.9 Flowcharts

4.9.1 Main Processing

Figure 4.3 shows the Main Processing.

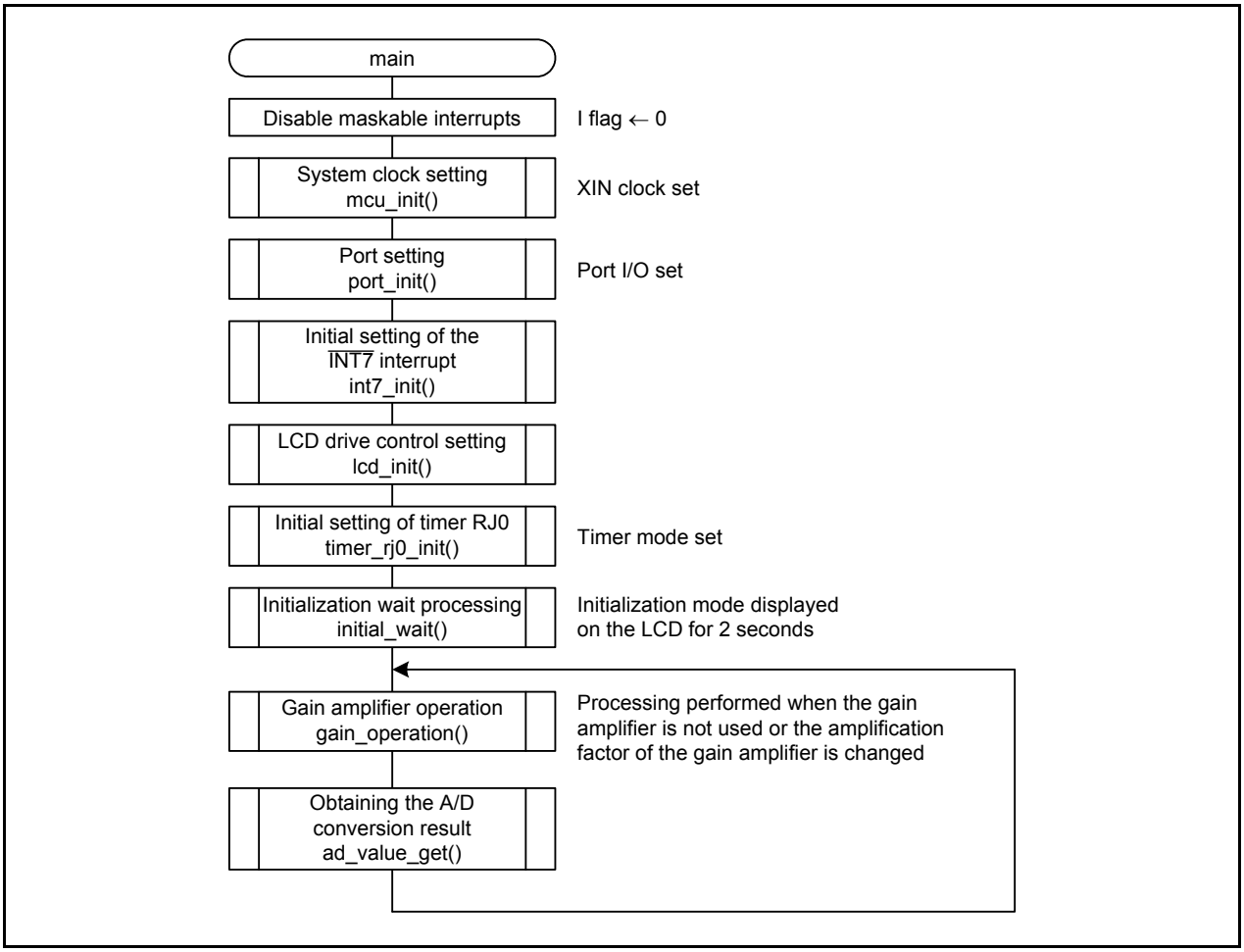

Figure 4.3 Main Processing

4.9.2 System Clock Setting

Figure 4.4 shows the System Clock Setting.

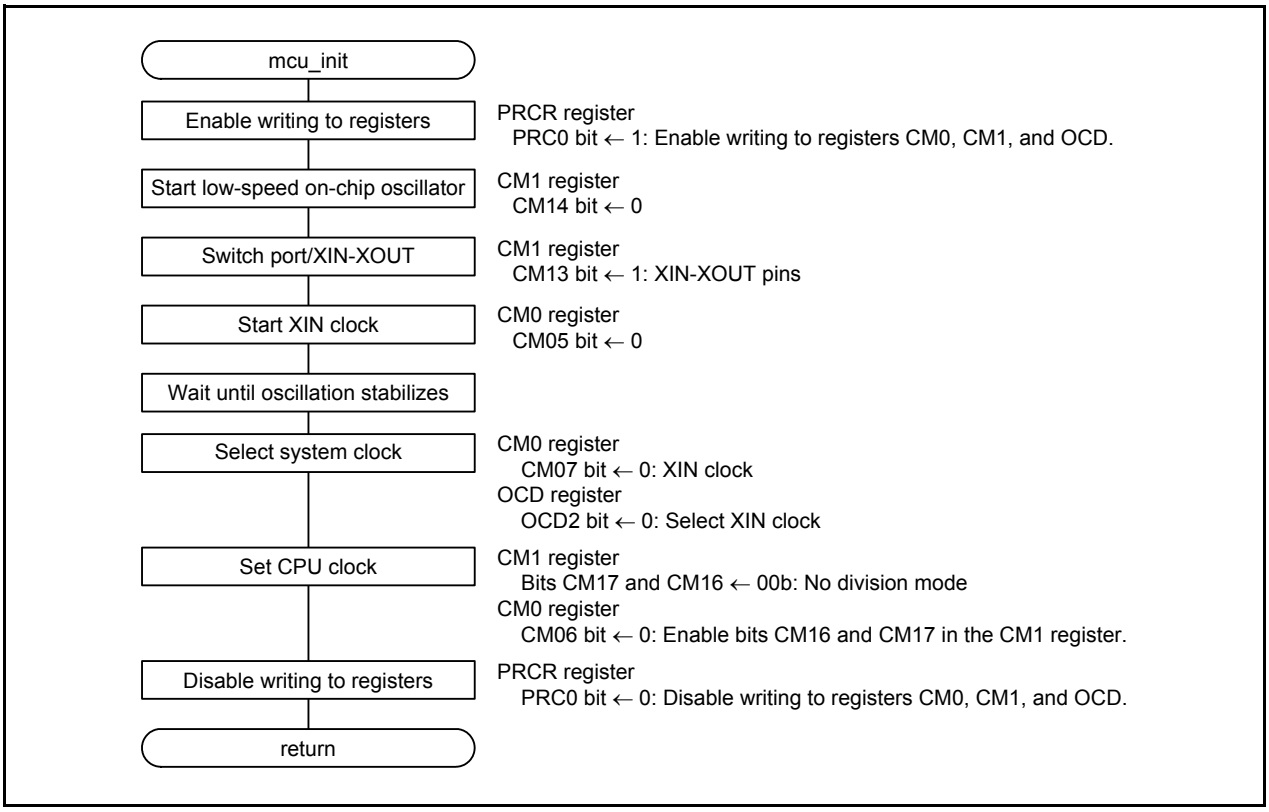

Figure 4.4 System Clock Setting

4.9.3 Initial Setting of the A/D Converter

Figure 4.5 shows the Initial Setting of the A/D Converter.

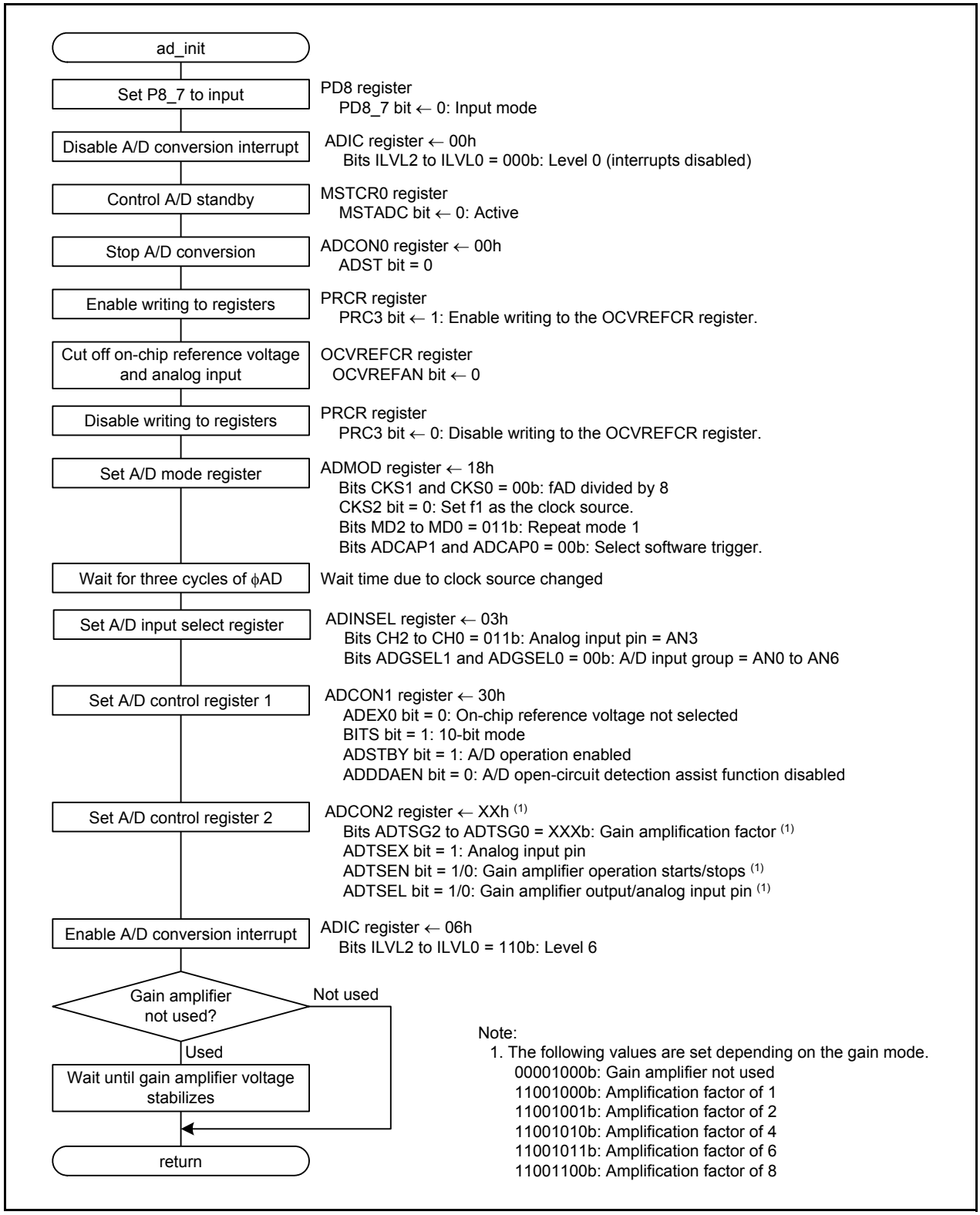

Figure 4.5 Initial Setting of the A/D Converter

4.9.4 Operation of the Gain Amplifier

Figure 4.6 shows the Gain Amplifier Operation.

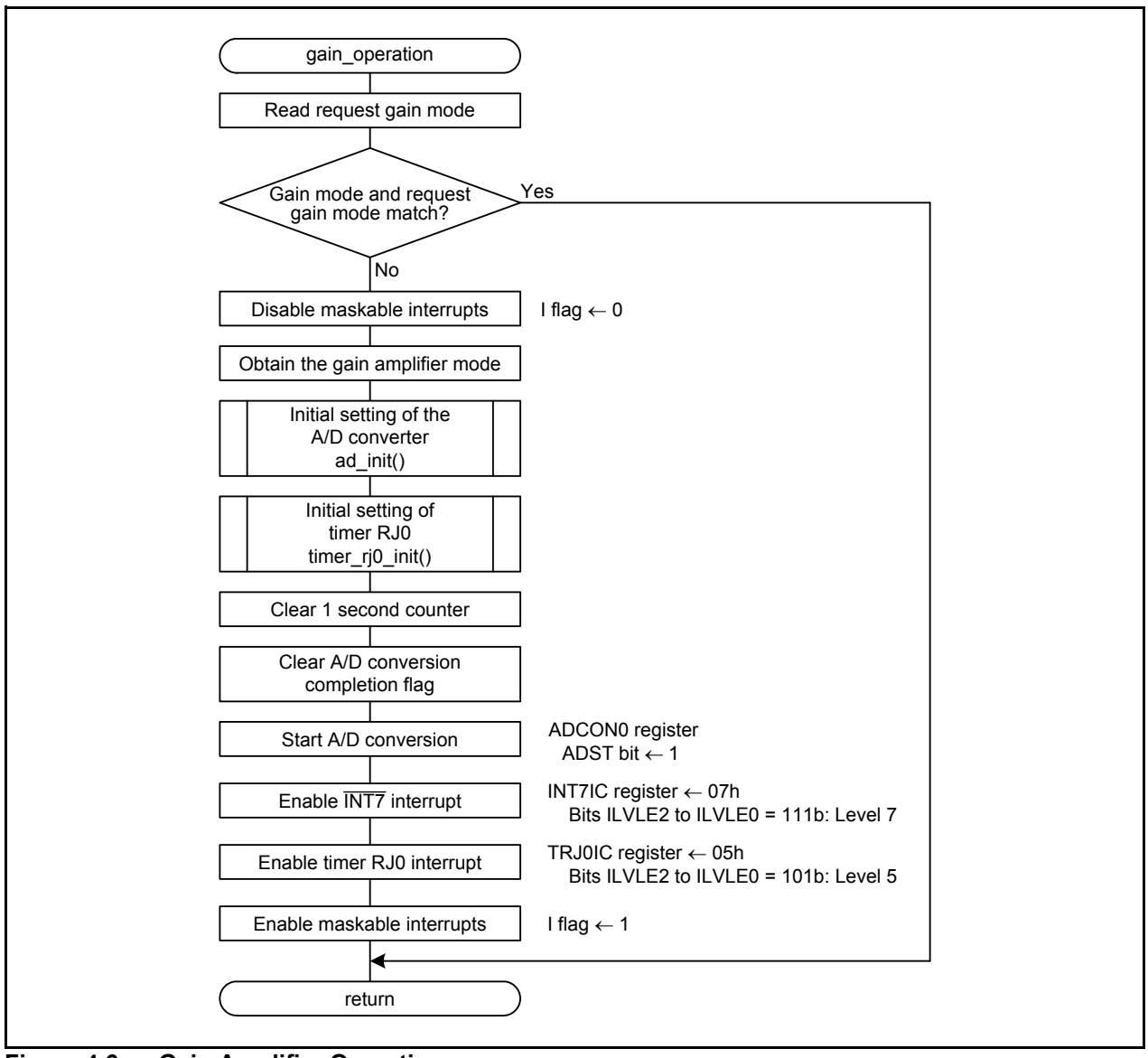

Figure 4.6 Gain Amplifier Operation

4.9.5 Obtaining the A/D Conversion Result

Figure 4.7 shows the Obtaining the A/D Conversion Result.

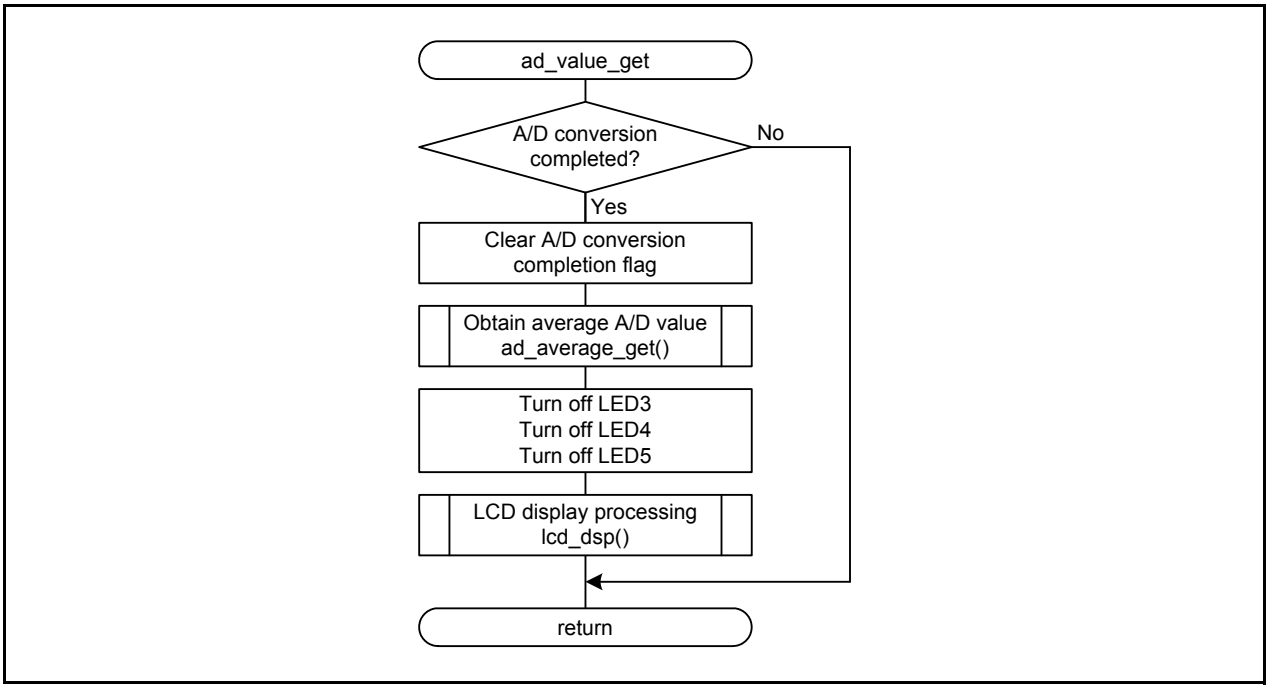

Figure 4.7 Obtaining the A/D Conversion Result

4.9.6 Obtaining the Average A/D Value

Figure 4.8 shows the Obtaining the Average A/D Value.

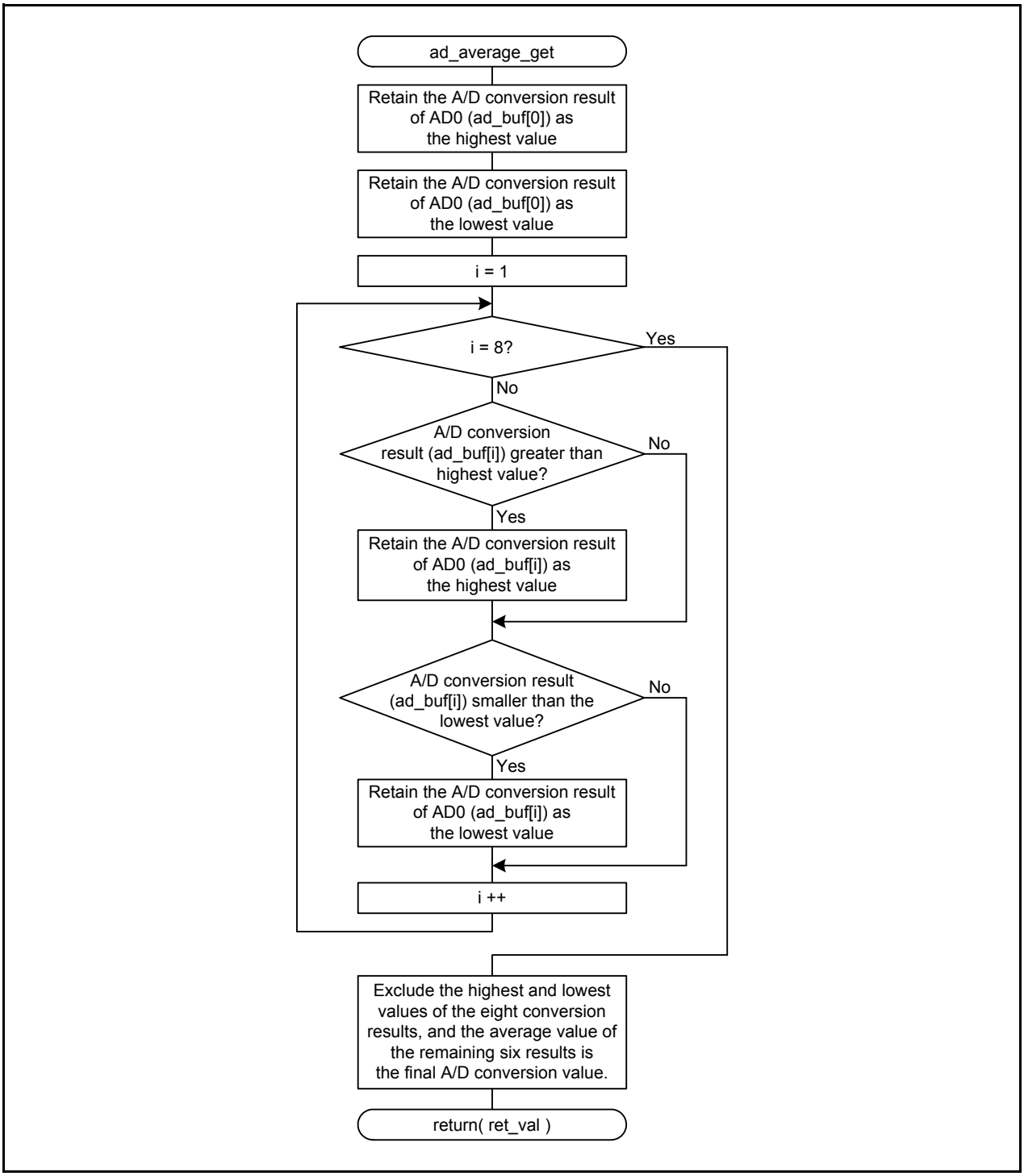

Figure 4.8 Obtaining the Average A/D Value

4.9.7 A/D Interrupt Handling

Figure 4.9 shows the A/D Interrupt Handling.

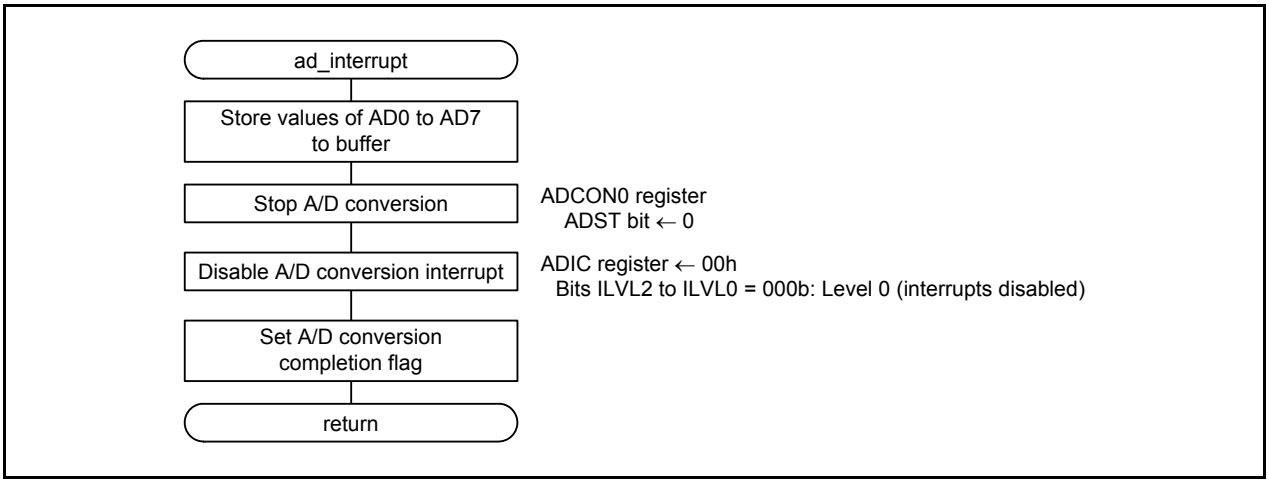

Figure 4.9 A/D Interrupt Handling

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 Using the Gain Amplifier in 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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