R32C/100 Series

Using the Self Test and Open-Circuit Detection Assist Functions in the A/D Converter

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Abstract

This document describes using the self test and open-circuit detection assist functions in the A/D converter.

Products

R32C/120 Group
R32C/121 Group
R32C/142 Group
R32C/145 Group
R32C/151 Group
R32C/152 Group
R32C/153 Group
R32C/156 Group
R32C/157 Group
R32C/160 Group
R32C/161 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

This document explains how to perform a self test and detect open-circuit in an analog input pin.

Table 1.1 lists the Peripheral Function and Its Application. Figure 1.1 shows the Block Diagram.

Table 1.1 Peripheral Function and Its Application

Peripheral Function	Application
A/D0	A/D convert input voltage to the AN_0 pin

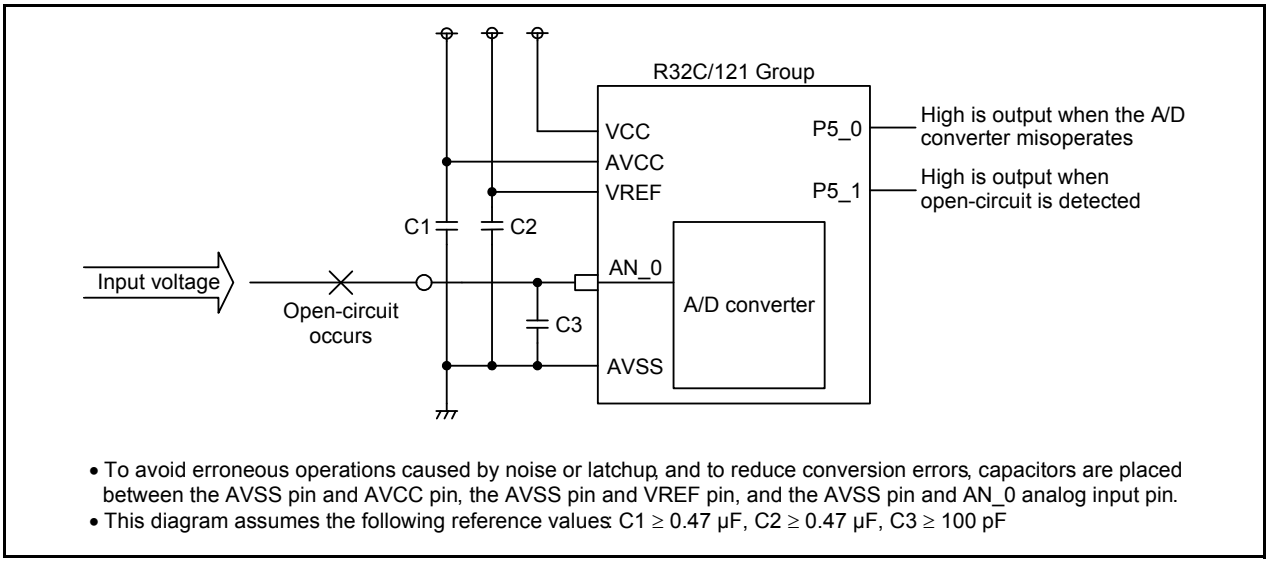


Figure 1.1 Block Diagram

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	R5F64219JFB (R32C/121 Group)
Operating frequencies	• PLL clock: 128 MHz • Base clock: 64 MHz • CPU clock: 64 MHz • Peripheral bus clock: 32 MHz • Peripheral clock: 32 MHz
Operating voltage	5 V
Integrated development environment	Renesas Electronics High-performance Embedded Workshop Version 4.09
C compiler	Renesas Electronics R32C/100 Series C Compiler V.1.02 Release 01
	Compile options -D__STACKSIZE__=0X300 -D__ISTACKSIZE__=0X300 -DVECTOR_ADR=0x0FFFFFBDC -c -finfo -dir “$(CONFIGDIR)” Default setting is used in the integrated development environment.
Operating mode	Single-chip mode
Sample code version	1.00

3. Reference Application Note

The application note associated with this document is listed below. Refer to the following application note for additional information.

• R32C/100 Series A/D Conversion in One-shot Mode (REJ05B1207)

4. Hardware

4.1 Pins Used

Table 4.1 lists the Pins Used and Their Functions.

Table 4.1 Pins Used and Their Functions

Pin Name	I/O	Function
P10_0/AN_0	Input	Analog voltage input for determining open-circuit detection.
P5_0	Output	High is output when the A/D converter misoperates.
P5_1	Output	High is output when open-circuit is detected.

5. Software

5.1 Operation Overview

In the sample code for this document, the self test is performed to determine that the A/D converter is operating normally. If the A/D converter is operating normally, then the open-circuit detection assist is used to detect open-circuit in an analog input pin.
Table 5.1 lists the A/D Converter Settings.

Table 5.1 A/D Converter Settings

Item	Setting
fAD	32 MHz (peripheral clock)
Operating clock (ϕAD)	fAD divided by 2
Resolution	10 bits
Operating mode	One-shot mode
Sample and hold function	Used
DMAC operating mode	Disabled

Figure 5.1 shows the Block Diagram of the Open-Circuit Detection Assist Circuit.

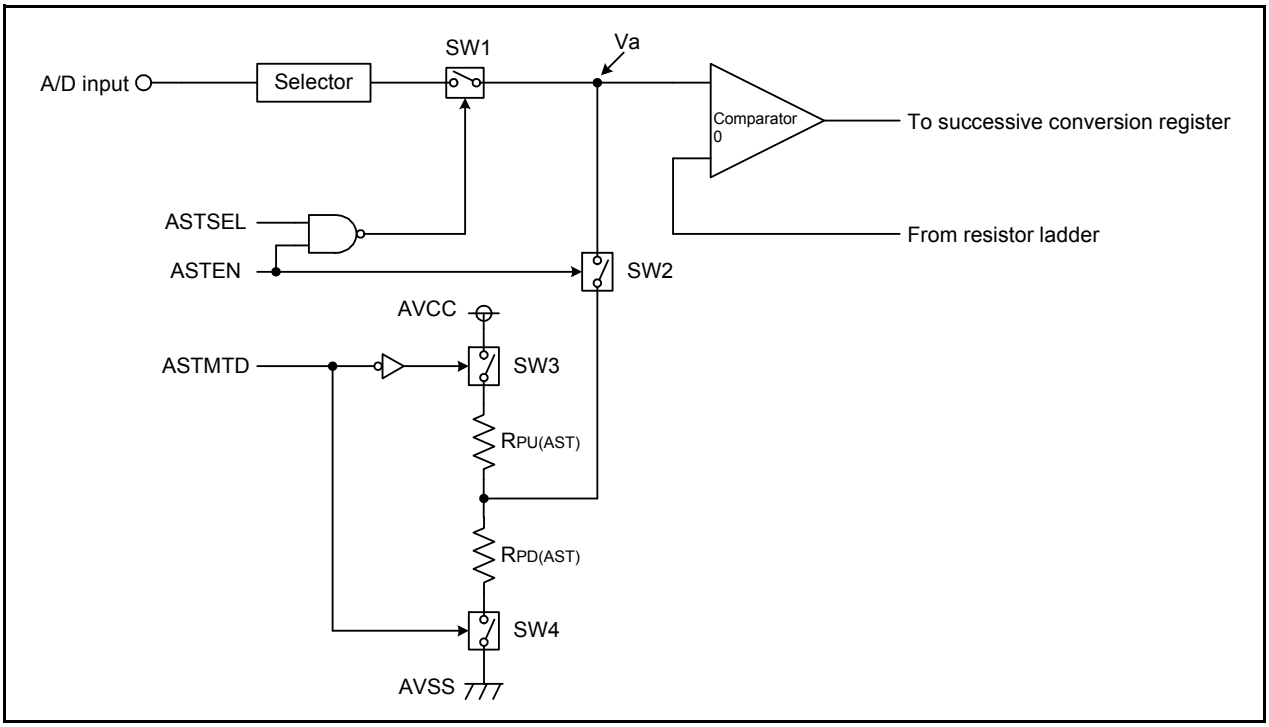


Figure 5.1 Block Diagram of the Open-Circuit Detection Assist Circuit

5.1.1 Self Test Assist

When using the self test assist, perform the following to set SW1 to SW4 in Figure 5.1.

(1) Self test assist in pull-up mode
- SW1 off: Set the ASTSEL bit to 1 (self test assist)
- SW2 on: Set the ASTEN bit to 1 (assist enabled)
- SW3 on: Set the ASTMTD bit to 0 (pull-up)
- SW4 off: Set the ASTMTD bit to 0 (pull-up)

In pull-up mode, the open-circuit detection assist circuit is pulled-up, so Va in Figure 5.1 is almost equal to AVCC.

(2) Self test assist in pull-down mode
- SW1 off: Set the ASTSEL bit to 1 (self test assist)
- SW2 on: Set the ASTEN bit to 1 (assist enabled)
- SW3 off: Set the ASTMTD bit to 1 (pull-down)
- SW4 on: Set the ASTMTD bit to 1 (pull-down)

In pull-down mode, the open-circuit detection assist circuit is pulled-down, so Va in Figure 5.1 is almost equal to AVSS.
If the result value of A/D conversion is almost the maximum or minimum voltage in each bit setting, the A/D converter is considered to be functioning normally.

5.1.2 Open-Circuit Detection Assist

When using the open-circuit detection assist, perform the following to set SW1 to SW4 in Figure 5.1.

(1) Open-circuit detection assist in pull-up
- SW1 off: Set the ASTSEL bit to 0 (open-circuit detection assist)
- SW2 on: Set the ASTEN bit to 1 (assist enabled)
- SW3 on: Set the ASTMTD bit to 0 (pull-up)
- SW4 off: Set the ASTMTD bit to 0 (pull-up)

In pull-up mode, the open-circuit detection assist circuit is pulled-up, so Va in Figure 5.1 is between AVCC and the A/D applied voltage.

(2) Open-circuit detection assist in pull-down mode
- SW1 off: Set the ASTSEL bit to 0 (open-circuit detection assist)
- SW2 on: Set the ASTEN bit to 1 (assist enabled)
- SW3 off: Set the ASTMTD bit to 1 (pull-down)
- SW4 on: Set the ASTMTD bit to 1 (pull-down)

In pull-down mode, the open-circuit detection assist circuit is pulled-down, so Va in Figure 5.1 is between AVSS and the A/D applied voltage.
The A/D input pin is considered open if the result value of A/D conversion is constantly almost always the maximum or minimum voltage.
When using the open-circuit detection assist, detection accuracy can be increased by performing A/D conversion several times until the internal voltage is stable. Set the open-circuit detection threshold to comply with the user system.

5.2 Constants

Table 5.2 lists the Constants Used in the Sample Code.

Table 5.2 Constants Used in the Sample Code

Constant Name	Setting Value	Contents
AD_DETECTION_MAX	(0x398) (1)	Open-circuit detection (pull-up) threshold (4.5 V)
AD_DETECTION_MIN	(0x06C) (1)	Open-circuit detection (pull-down) threshold (0.5 V)
AD_SELFTEST_MAX	(0x333) (1)	Self test (pull-up) threshold (4.0 V)
AD_SELFTEST_MIN	(0x0D3) (1)	Self test (pull-down) threshold (1.0 V)
OK	(0)	Self test: A/D converter is operating normally Open-circuit detection: Analog input pin is not open-circuit
NG	(1)	Self test: A/D converter is misoperating Open-circuit detection: Analog input pin is open-circuit
CHECK_TIMES	(3)	Number of determination processes for open-circuit detection

Note:

1. The threshold is the value when confirming operation in the sample code for this document. In the sample code, when the A/D converter is operating normally (i.e. the analog input pin is not open-circuit), the A/D conversion range is assumed to be 0.0 to 5.0 V. When performing open-circuit detection or self test using the sample code for this document, set the threshold to comply with the user system.

5.3 Functions

Table 5.3 lists the Functions.

Table 5.3 Functions

Function Name	Outline
main	Main processing
AD_init	A/D converter initialization
AD_conversion	A/D conversion start
AD_selftest	A/D converter self test
AD_detection_assist	Detect open-circuit in an analog input pin

5.4 Function Specifications

The following tables list the sample code function specifications.

main	
Outline	Main processing
Header	None
Declaration	void main(void)
Description	The system clock and A/D converter are initialized, ports used when the A/D converter misoperates are initialized, and a self test is performed. When the A/D converter operates normally, open-circuit detection is performed. When the A/D converter misoperates, high is output from the P5_0 pin. When open-circuit is detected, high is output from the P5_1 pin.
Argument	None
Returned value	None

AD_init	
Outline	A/D converter initialization
Header	None
Declaration	static void AD_init(void)
Description	The A/D0 interrupt is disabled, and A/D0 is set to one-shot mode.
Argument	None
Returned value	None

AD_conversion	
Outline	A/D conversion start
Header	None
Declaration	static void AD_conversion(void)
Description	Start A/D conversion and wait until A/D conversion is completed.
Argument	None
Returned value	None

AD_selftest	
Outline	A/D converter self test
Header	None
Declaration	static uint8_t AD_selftest(void)
Description	Set the ASTSEL bit to 1 (self test assist) and the ASTEN bit to 1 (assist enabled) to perform the self test. The self test can be performed using the following: (1) Set the self test assist in pull-up mode and start A/D conversion. If the converted result is a value less than or equal to the threshold, the A/D converter is determined to be misoperating, the return value is NG, and A/D conversion is completed. If the converted value is greater than the threshold, then processing for number (2) is performed. (2) Set the self test assist in pull-down mode and start A/D conversion. If the converted value is a value greater than or equal to the threshold, the A/D converter is determined to be misoperating, the return value is NG, and A/D conversation is completed. If the converted value is less than the threshold, the A/D converter is determined to be operating normally, the return value is OK, and A/D conversion is completed.
Argument	None
Returned value	Self test results OK: A/D converter is operating normally NG: A/D converter is misoperating

AD_detection_assist	
Outline	Detect open-circuit in an analog input pin
Header	None
Declaration	static uint8_t AD_detection_assist(void)
Description	Set the ASTSEL bit to 0 (open-circuit detection assist) and the ASTEN bit to 1 (assist enabled) for open-circuit detection. Open-circuit detection be performed using the methods below. (At this point the initial value for the open-circuit detection flag [automatic variable] is 00h.) (1) Set the open-circuit detection assist in pull-up mode and perform A/D conversion three times. If at least one of the three converted results is a value greater than the threshold, bit 0 of the open-circuit detection flag is set to 1. After the determination processing is performed three times, if 01h is set to the open-circuit detection flag, the processing for number (2) is performed. If 00h is set to the open-circuit detection flag, the processing for number (3) is performed. (2) Set the open-circuit detection assist in pull-down mode and perform A/D conversion three times. If at least one of the three converted results is a value less than the threshold, bit 1 of the open-circuit detection flag is set to 1. After the determination processing is performed three times, the processing for number (3) is performed. (3) This open-circuit detection assist is disabled. If 03h is set to the open-circuit detection flag, the return value is NG (analog input pin is open-circuit); for all other values, the return value is OK (analog input pin is not open-circuit).
Argument	None
Returned value	Open-circuit detection results OK: Analog input pin is not open-circuit NG: Analog input pin is open-circuit

5.5 Flowcharts

5.5.1 Main Processing

Figure 5.2 shows the Main Processing.

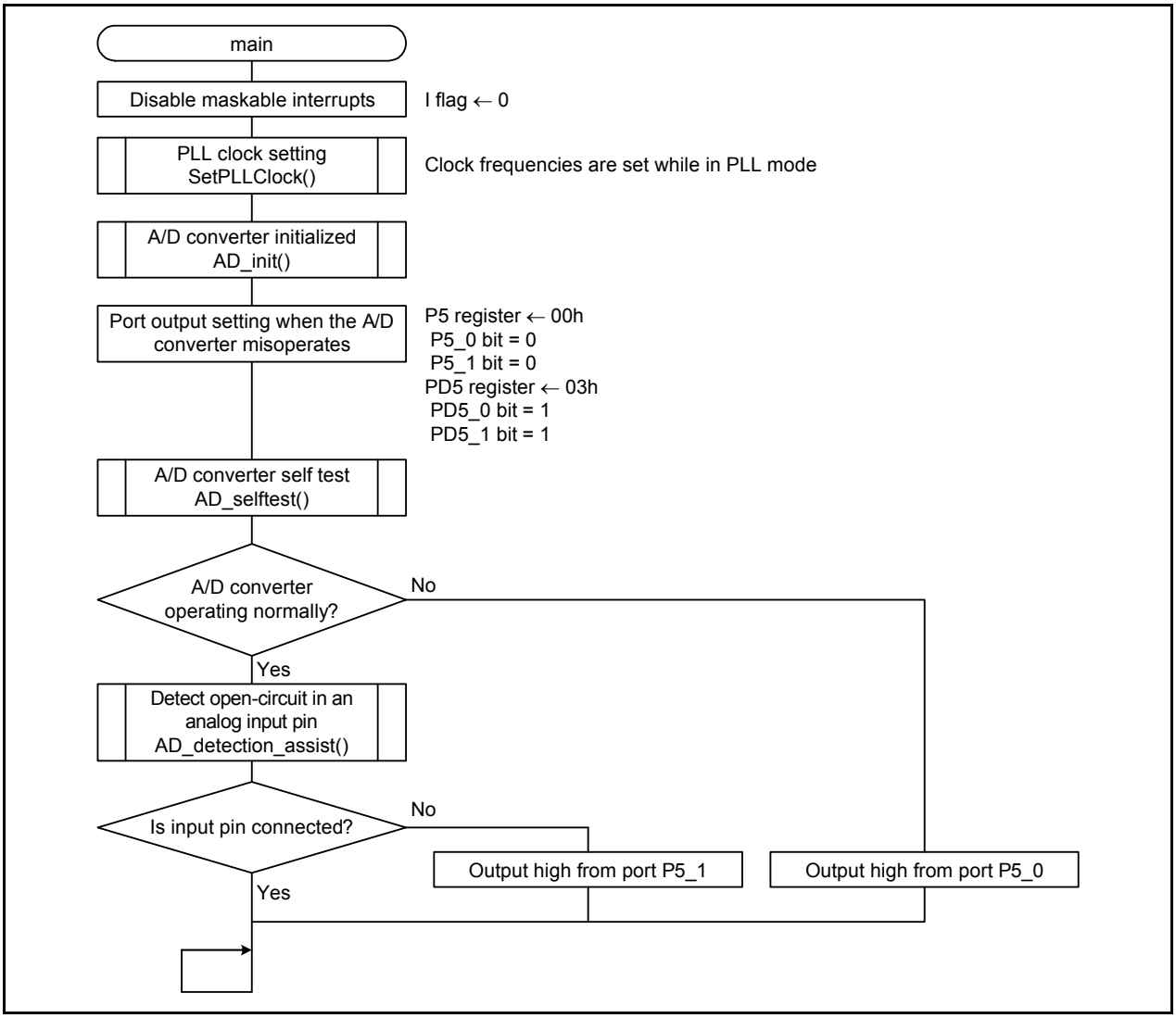
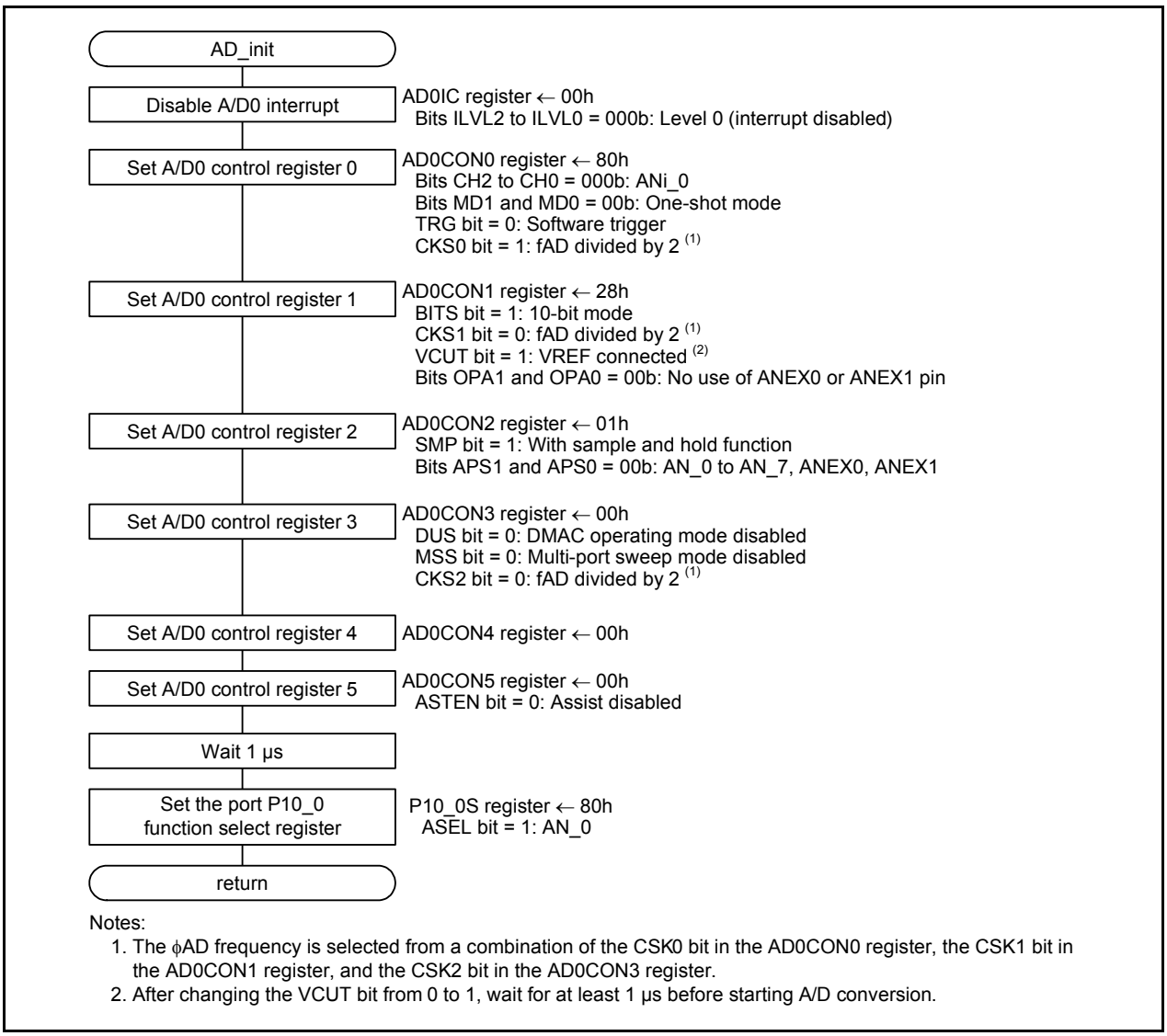


Figure 5.2 Main Processing

5.5.2 A/D Converter Initialization

Figure 5.3 shows A/D Converter Initialization.



Notes:
1. The ϕAD frequency is selected from a combination of the CSK0 bit in the AD0CON0 register, the CSK1 bit in the AD0CON1 register, and the CSK2 bit in the AD0CON3 register.
2. After changing the VCUT bit from 0 to 1, wait for at least 1 µs before starting A/D conversion.

Figure 5.3 A/D Converter Initialization

5.5.3 A/D Conversion Execution

Figure 5.4 shows A/D Conversion Execution.

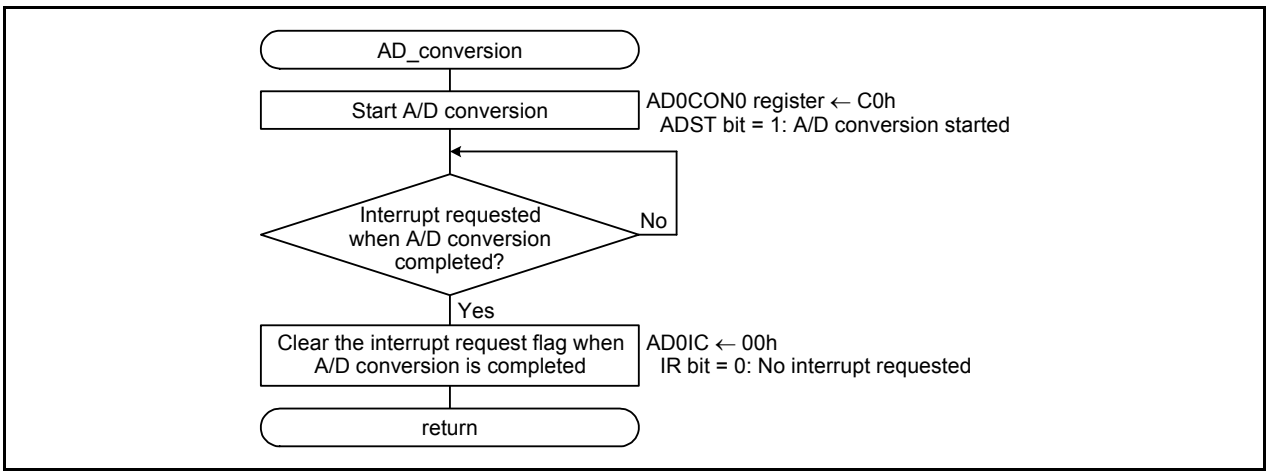


Figure 5.4 A/D Conversion Execution

5.5.4 A/D Converter Self Test

Figure 5.5 shows the A/D Converter Self Test.

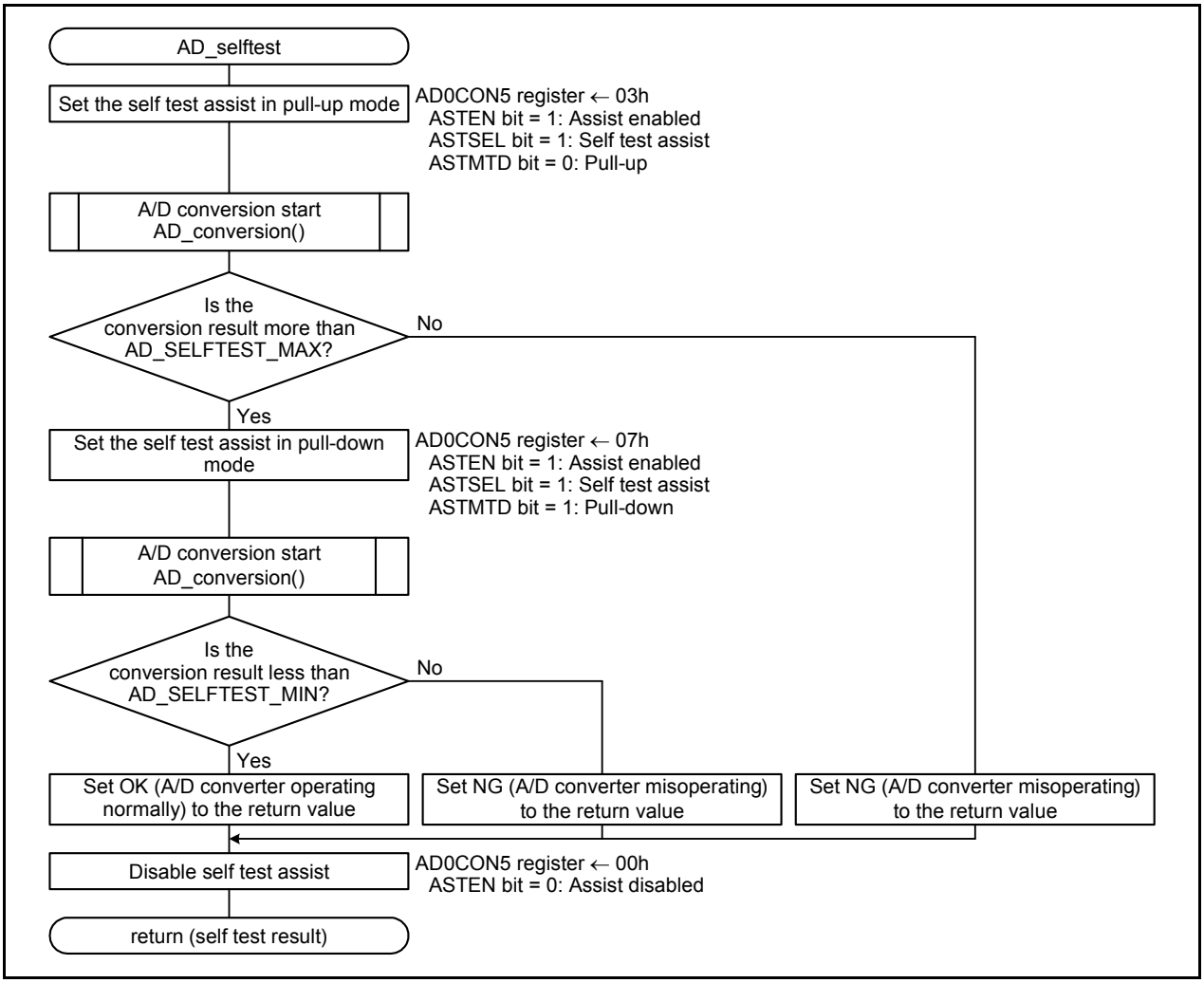


Figure 5.5 A/D Converter Self Test

5.5.5 Detect Open-Circuit in an Analog Input Pin

Figure 5.6 shows detecting open-circuit in an analog input pin.

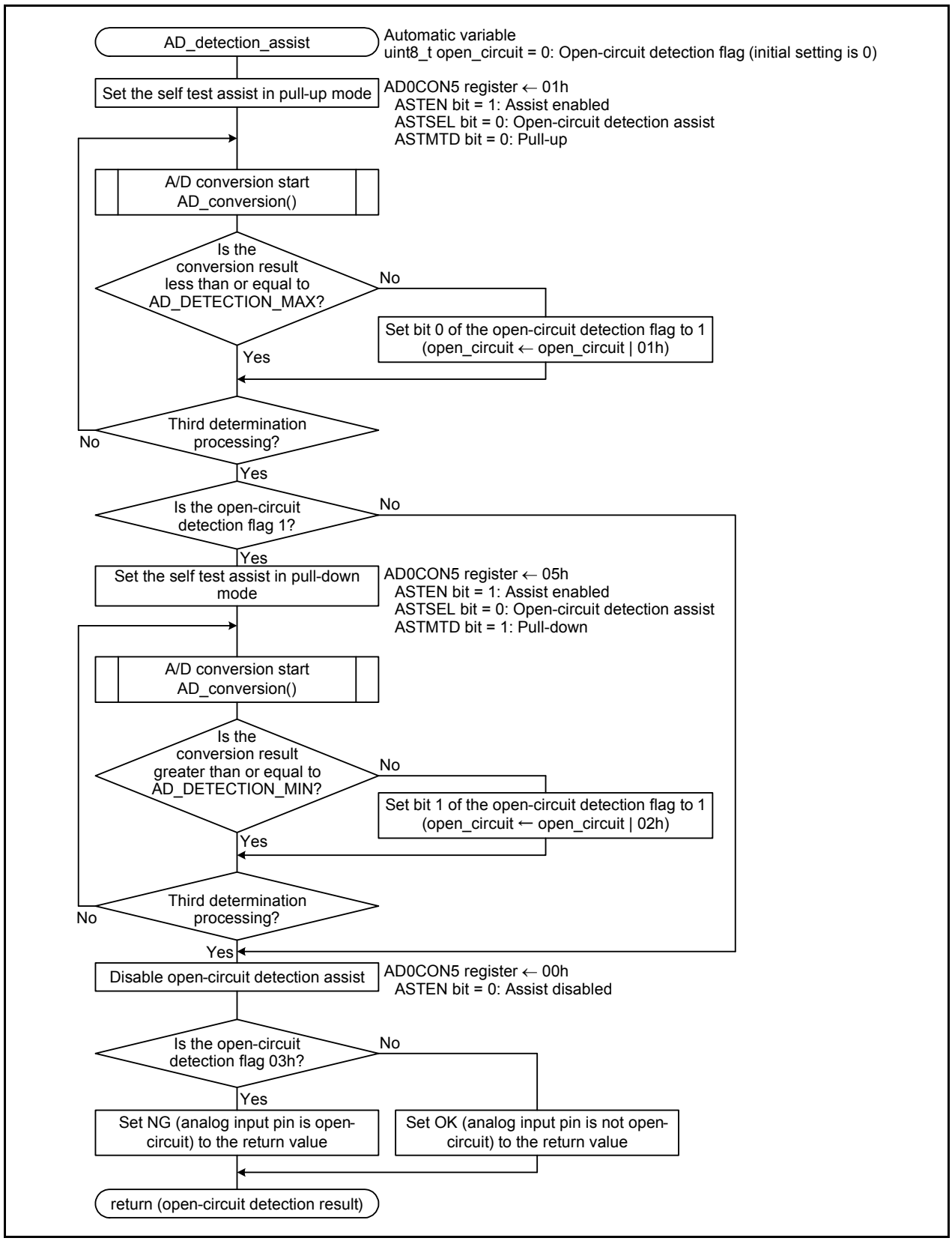


Figure 5.6 Detecting Open-Circuit in an Analog Input Pin

6. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

7. Reference Documents

R32C/120 Group User's Manual: Hardware Rev.1.20
R32C/121 Group User's Manual: Hardware Rev.1.20
R32C/142 Group User's Manual: Hardware Rev.1.10
R32C/145 Group User's Manual: Hardware Rev.1.10
R32C/151 Group User's Manual: Hardware Rev.1.10
R32C/152 Group User's Manual: Hardware Rev.1.10
R32C/153 Group User's Manual: Hardware Rev.1.10
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Revision History	R32C/100 Series Using the Self Test and Open-Circuit Detection Assist Functions in the A/D Converter

Rev.	Date	Description	
		Page	Summary
1.00	Jan. 18, 2013	—	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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