RL78/G23

Safety Function (A/D Test)

Introduction

This application note explains the sample code for the A/D test function, which is one of the safety functions of the RL78/G23.

The A/D test function performs A/D conversions at three reference voltage points to check the A/D converter for normal operation. The three reference voltage points are the internal 0 V, VDD, and internal reference voltage (1.48 V).

Target Device

RL78/G23

When applying the sample program covered in this application note to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.

Contents

1. Specifications

1.1 Specification Outline

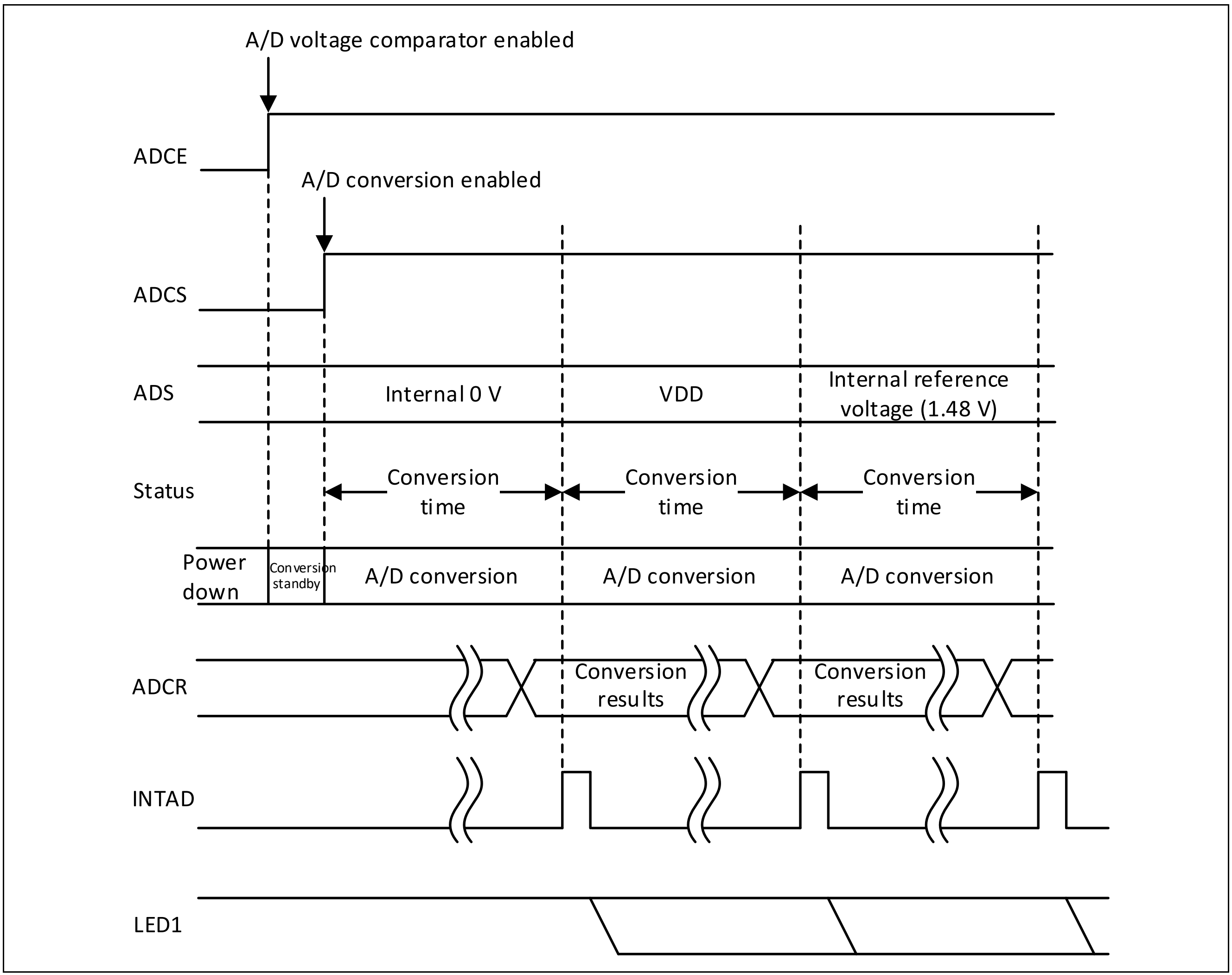
This application note contains an example of using the A/D test function, which is one of the safety functions of the RL78/G23. The sample code covered in this application note converts internal 0 V, VDD, and internal reference voltage (1.48 V) to digital values. Subsequently, it turns on LED1 if the conversion results are within the allowable range and blinks it otherwise.

Table 1 - 1 summarizes peripheral functions to be used. Figure 1.1 shows the outline of the conversion of the A/D converter.

Table 1 - 1 Peripheral Functions to be Used and their Uses

Peripheral Function	Use
A/D converter	Converts analog signal inputs at the levels that are referred to as internal 0 V, VDD, and internal reference voltage (1.48 V) to digital values.
Bit 3 of port 5	Used to output the A/D conversion results to LED1.

Figure 1 - 1 Outline of Conversion of the A/D Converter



1.2 Operation Outline

This sample code performs A/D conversions on the analog voltages at the internal 0 V, VDD, and internal reference voltage (1.48 V) sequentially using the software trigger and sequential conversion modes of the A/D converter. It then waits for the completion of the A/D conversion in HALT mode. After the A/D conversion is finished, the sample code checks to determine if the A/D conversion results are within the allowable range. It turns on LED1 if the conversion results are within the allowable range and blinks it otherwise.

(1) Initialize the A/D converter.

Table 1 - 2 shows the initial Settings for A/D converter.

Table 1 - 2 Initial Settings for A/D converter

Register Name	Setting Value	Content
PER0	20H	Enables supply of an input clock. • The SFRs used by the A/D converter can be read and written.
MK1H	FFH	Interrupt servicing disabled by using the interrupt mask flag (ADMK).
IF1H	00H	Clear the interrupt request flag. • No interrupt request signal is generated.
PR11H	FFH	Priority level selection: Specify level 3 (low priority level)
PR01H	FFH	
ADM0	00H	Conversion time setting Conversion time mode: Normal 1 Conversion time: 2112/f_{CLK} (66 μs) A/D conversion channel selection: Select mode
ADM1	00H	A/D conversion mode: Sequential conversion mode Trigger mode setting: Software trigger no-wait mode f_{CLK} input frequency setting: 4 MHz < f_{CLK} ≤ 32 MHz
ADM2	00H	Resolution setting: 10 bits Selection of the + side reference voltage source: V_{DD} Selection of the - side reference voltage: V_{SS} Conversion result upper / lower bound value setting: Generates an interrupt request (INTAD) when ADLL ≤ ADCRn ≤ ADUL
ADUL	FFH	Upper bound value: FFH
ADLL	00H	Lower bound value: 00H
ADS	81H	A/D channel selection: Internal reference voltage output
-	-	Use A/D interrupt (INTAD)

(2) Switch the test voltage.

Switch the register settings according to the test voltage to be used for A/D conversion.
More specifically, perform the following steps:

- Disable the A/D voltage comparator.

<When the test voltage is internal 0 V>
- Set the A/D test target to the internal 0 V.

< When the test voltage is VDD>

- Set the A/D test target to VDD.

< When the test voltage is internal reference voltage >

- Set the A/D test target to the internal reference voltage.

- Enable the A/D voltage comparator and wait for a stabilization period (1 us).

(3) Start A/D conversion.

Set the ADCS bit in the ADM0 register to 1 (Starts conversion operation) to start A/D conversion.

(4) Execute the HALT instruction to enter the HALT mode and wait for an A/D conversion end interrupt.

When the A/D conversion on the input voltage is finished, the A/D converter transfers the A/D conversion results to the ADCR register and generates an A/D conversion end interrupt.

(5) Check the A/D conversion results.

When the sample code exits the HALT mode on the A/D conversion end interrupt, it reads the A/D conversion results from the ADCR register.

(6) Check to determine if the A/D conversion results are within the allowable range.

<If the A/D conversion results are within the allowable range >

- If the tests on the three types of input voltages are completed, the sample code turns on LED1 and enters an infinite loop.
- If the tests on the three types of input voltages are not completed, the sample code repeats steps (2) to (6).

<If the A/D conversion results are outside the allowable range >

- The sample code enters an infinite loop for blinking LED1.

2. Operation Check Conditions

The sample code contained in this application note has been checked under the conditions listed in the table below.

Table 2 - 1 Operation Confirmation Conditions

Item	Description
Microcontroller used	RL78/G23 (R7F100GLG)
Operating frequency	• High-speed on-chip oscillator (HOCO) clock: 32 MHz • CPU/peripheral hardware clock: 32 MHz
Operating voltage	5.0 V (can be operated at 2.4 V Note to 5.5 V) LVD0 detection voltage: Reset mode At rising edge TYP. 1.90 V (1.84 V to 1.95 V) At falling edge TYP. 1.86 V (1.80 V to 1.91 V)
Integrated development environment (CS+)	CS+ for CC E8.05.00f from Renesas Electronics Corp.
C compiler (CS+)	CC-RL V1.09.00 from Renesas Electronics Corp.
Integrated development environment (e^2 studio)	e^2 studio V2021-01 from Renesas Electronics Corp.
C compiler (e^2 studio)	CC-RL V1.09.00 from Renesas Electronics Corp.
Integrated development environment (IAR)	IAR Embedded Workbench for Renesas RL78 V4.20.1 from IAR Systems
C compiler (IAR)	IAR C/C++ Compiler for Renesas RL78 V4.20.1.2260 from IAR Systems

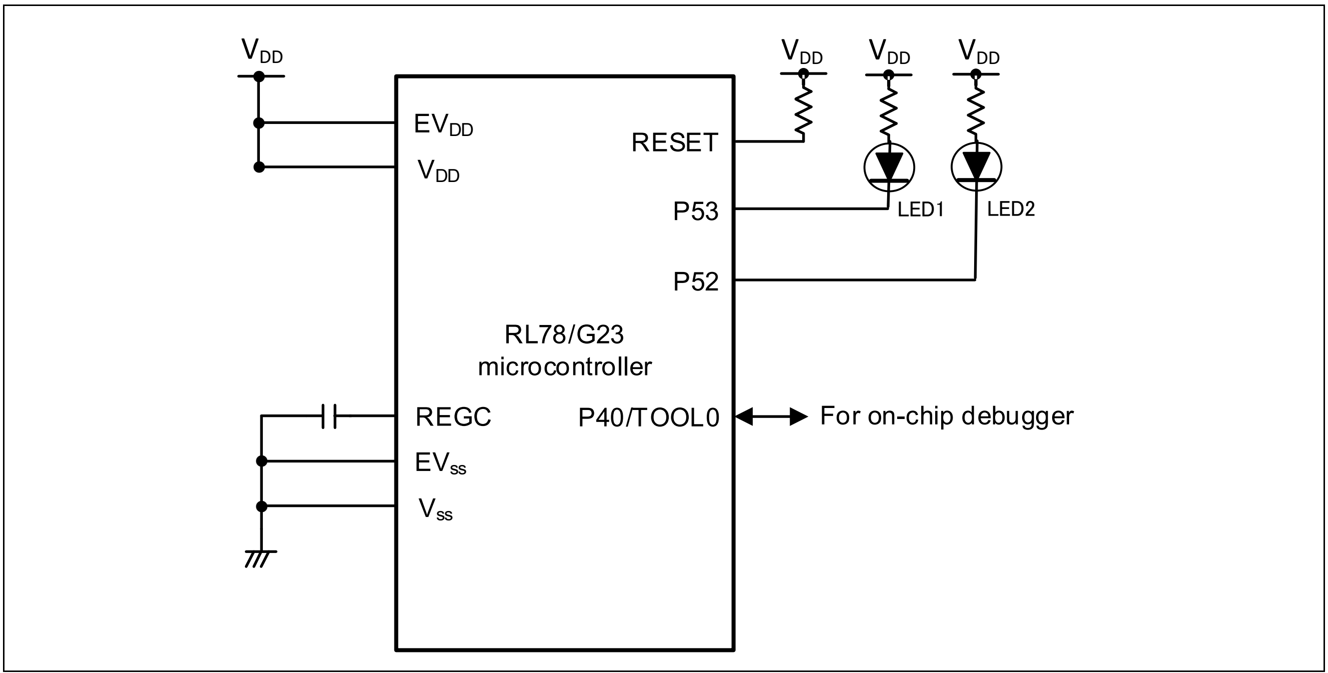
Note. When using normal mode of A/D converter.

3. Description of the Hardware

3.1 Hardware Configuration Example

The example of configuration of the hardware that is used for this application note is shown below.

Figure 3 - 1 Hardware Configuration



Note 1. The purpose of this circuit is only to provide the connection outline and the circuit is simplified accordingly. When designing and implementing an actual circuit, provide proper pin treatment and make sure that the hardware's electrical specifications are met (connect the input-only ports separately to V_{DD} or V_{SS} via a resistor).

Note 2. Connect any pins whose name begins with EV_{SS} to V_{SS} and any pins whose name begins with EV_{DD} to V_{DD}, respectively.

Note 3. V_{DD} must be held at not lower than the reset release voltage (V_{LVD}) that is specified as LVD.

Note 4. LED2 connected to P52 is always off.

3.2 List of Pins to be used

Table 3 - 1 lists the pins to be used and their functions.

Table 3 - 1 Pins to be Used and their Functions

Pin Name	I/O	Description
P53	Output	Outputs the A/D conversion results to LED1.

Caution In this application note, only the used pins are processed. When actually designing your circuit, make sure the design includes sufficient pin processing and meets electrical characteristic requirements.

4. Description of the Software

4.1 List of Option Byte Settings

Table 4 - 1 summarizes the settings of the option bytes.

Table 4 - 1 Option Byte Settings

Address	Value	Description
000C0H / 010C0H	01101110B	Disables the watchdog timer. (Stops counting after the release from the reset status.)
000C1H / 010C1H	11111110B	LVD0 detection voltage: Reset mode At rising edge TYP. 1.90 V (1.84 V to 1.95 V) At falling edge TYP. 1.86 V (1.80 V to 1.91 V)
000C2H / 010C2H	11101000B	HS mode HOCO: 32 MHz
000C3H / 010C3H	10000100B	Enables the on-chip debugger.

4.2 List of Constants

Table 4 - 2 lists the constants that are used in this sample program.

The initial values are listed in Table 4 - 2.

Table 4 - 2 Constants for the Sample Program

Constant	Setting	Description
OVERALL_ERROR_LSB_UNIT	7	Overall A/D converter error ±7 LSB This constant determines the allowable error of the tests.
VSS_RANGE_MAX	7	Upper limit of allowable internal 0 V range Determined by VSS_RANGE_MAX = 0 + OVERALL_ERROR_LSB_UNIT.
AD_RESOLUTION_HEX	0x03FF	A/D conversion resolution = 10 bits
VDD_RANGE_MIN	0x03F8	Lower limit of allowable VDD range Determined by VDD_RANGE_MIN = AD_RESOLUTION_HEX - OVERALL_ERROR_LSB_UNIT.
VDD	5.0	VDD (unit: V)
VBGR_MIN	1.42	Minimum internal reference voltage (1.48 V) (unit: V)
VBGR_MAX	1.54	Maximum internal reference voltage (1.48 V) (unit: V)
VBGR_RANGE_MIN	0x011B	Lower limit of allowable internal reference voltage (1.48 V) Determined by VBGR_RANGE_MIN = (VBGR_MIN / (VDD / 0x03FF)) - OVERALL_ERROR_LSB_UNIT.
VBGR_RANGE_MAX	0x0142	Upper limit of allowable internal reference voltage (1.48 V) Determined by VBGR_RANGE_MAX = (VBGR_MAX / (VDD / 0x03FF)) + OVERALL_ERROR_LSB_UNIT.

Caution 1. The constants listed in Table 4 - 2 are obtained at a power voltage of 5.0 V. Change VDD according to the system.

Caution 2. There are cases in which the results of executing the sample code are outside the allowable range when a power voltage of 5.0 V is supplied and the constants listed in Table 4 - 2 are used. In such a case, replace the power supply with a more stable power supply or determine the allowable range setting while paying attention to the possible errors that may be caused by the power supply (more specifically, adjust OVERALL_ERROR_LSB_UNIT).

Table 4 - 3 lists the A/D test voltages and the upper and lower limit of their allowable ranges.

The values listed in the table are obtained when the constants listed in Table 4 - 2 are used.

Table 4 - 3 A/D Test Voltages and their Allowable Ranges

A/D Test Voltage	Lower Limit of Allowable Range	Upper Limit of Allowable Range
Internal 0 V	-	7 (VSS_RANGE_MAX)
VDD	0x03F8 (VDD_RANGE_MIN)	-
Internal reference voltage (1.48 V)	0x011B (VBGR_RANGE_MIN)	0x0142 (VBGR_RANGE_MAX)

4.3 List of Functions

Table 4 - 4 lists the functions that are used in this sample program.

Table 4 - 4 Functions

Function Name	Outline
R_ADC_Set_TestVoltage	Sets test voltage.
R_ADC_Set_Vss	Sets test voltage to internal 0 V.
R_ADC_Set_Vdd	Sets test voltage to VDD.
R_ADC_Set_Vbgr	Sets test voltage to internal reference voltage.
R_Main_Check_AD_Data	Checks A/D conversion results.
R_Main_Blink_Led	Blinks LED.

4.4 Function Specifications

This section describes the specifications for the functions that are used in the sample code.

[Function Name]] R_ADC_Set_TestVoltage

Synopsis	Sets test voltage.
Header	r_cg_macrodriver.h r_cg_adc.h r_cg_userdefine.h
Declaration	void R_ADC_Set_TestVoltage(uint8_t testVoltageIndex)
Explanation	Selects the voltage to be used for A/D tests.
Arguments	• testVoltageIndex : Voltage to be used for A/D tests (0, 1, or 2) 0: Internal 0V 1: VDD 2: Internal reference voltage (1.48 V)
Return value	None
Remarks	If voltage is set to a value greater than 2, 2 is assumed.

[Function Name] R_ADC_Set_Vss

Synopsis	Sets test voltage to internal 0 V.
Header	r_cg_macrodriver.h r_cg_adc.h r_cg_userdefine.h
Declaration	void R_ADC_Set_Vss(void)
Explanation	Sets the A/D test voltage to internal 0 V.
Arguments	None
Return value	None
Remarks	None

[Function Name] R_ADC_Set_Vdd

Synopsis	Sets A/D test voltage to VDD.
Header	r_cg_macrodriver.h r_cg_adc.h r_cg_userdefine.h
Declaration	void R_ADC_Set_Vdd(void)
Explanation	Sets the A/D test voltage to VDD.
Arguments	None
Return value	None
Remarks	None

[Function Name] R_ADC_Set_Vbgr

Synopsis	Sets A/D test voltage to internal reference voltage.
Header	r_cg_macrodriver.h r_cg_adc.h r_cg_userdefine.h
Declaration	void R_ADC_Set_Vbgr(void)
Explanation	Sets the A/D test voltage to internal reference voltage (1.48 V).
Arguments	None
Return value	None
Remarks	None

[Function Name] R_Main_Check_AD_Data

Synopsis	Checks A/D conversion results.
Header	r_cg_macrodriver.h r_cg_adc.h r_cg_userdefine.h
Declaration	uint8_t R_ADC_Check_AD_Data (uint8_t testVoltageIndex)
Explanation	Returns the A/D conversion results.
Arguments	• testVoltageIndex : Voltage to be used for the A/D test (0, 1, or 2) 0: Internal 0 V 1: VDD 2: Internal reference voltage (1.48 V)
Return value	• When the A/D conversion results are within the allowable range: 0x00 • When the A/D conversion results are outside the allowable range: 0x01
Remarks	If voltage is set to a value greater than 2, 2 is assumed.

[Function Name] R_Main_Blink_Led

Synopsis	Blinks LED.
Header	r_cg_macrodriver.h r_cg_cgc.h r_cg_port.h r_cg_adc.h
Declaration	void R_Main_Blink_Led(void)
Explanation	Blinks LED at intervals of one second. This function forms an infinite loop and control will never be returned to the calling function.
Arguments	None
Return value	None
Remarks	None

4.5 Flowcharts

4.5.1 Main Processing

Figure 4 - 1 and Figure 4 - 2 show the flowchart for the main processing.

Figure 4 - 1 Main Processing (1/2)

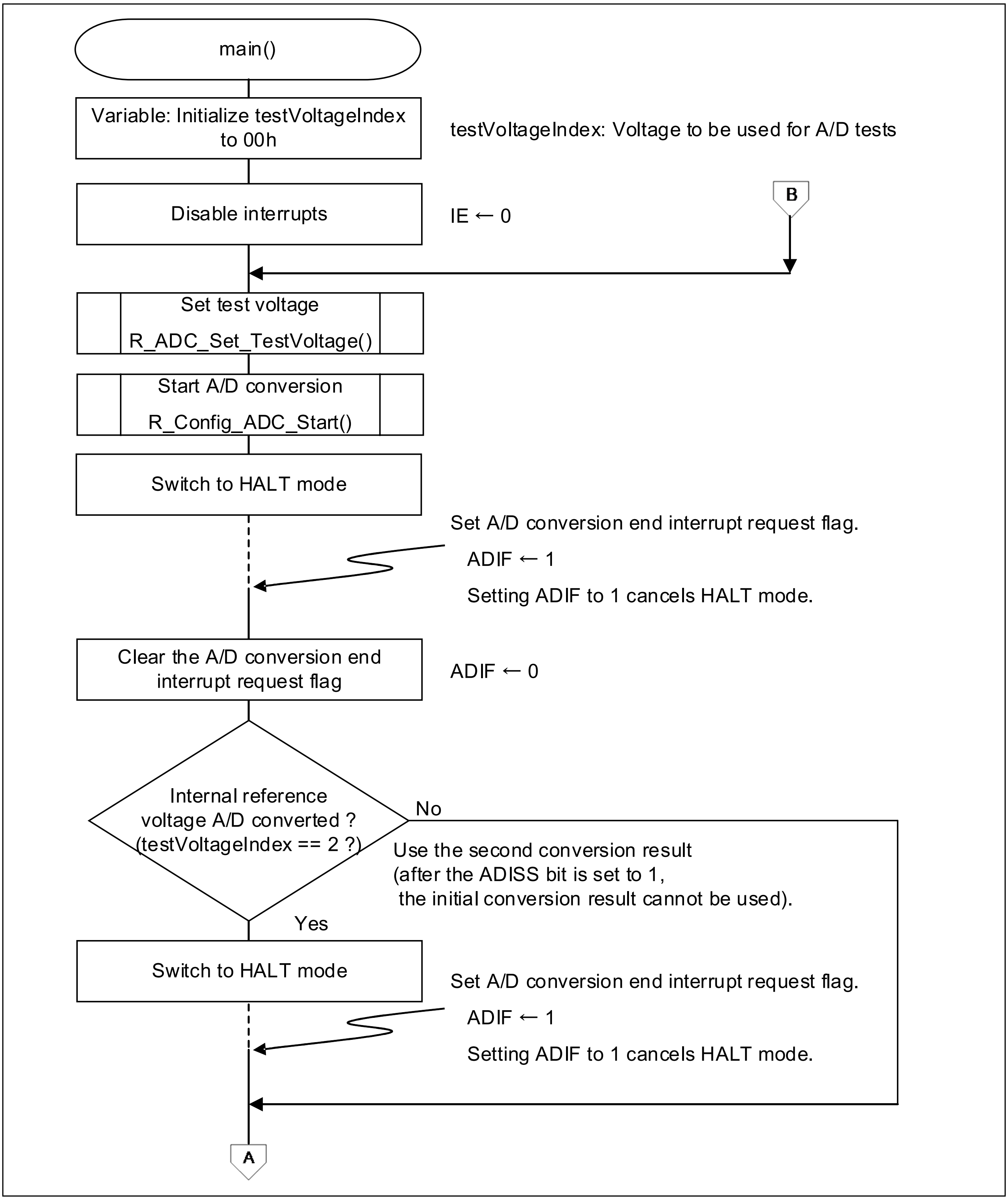
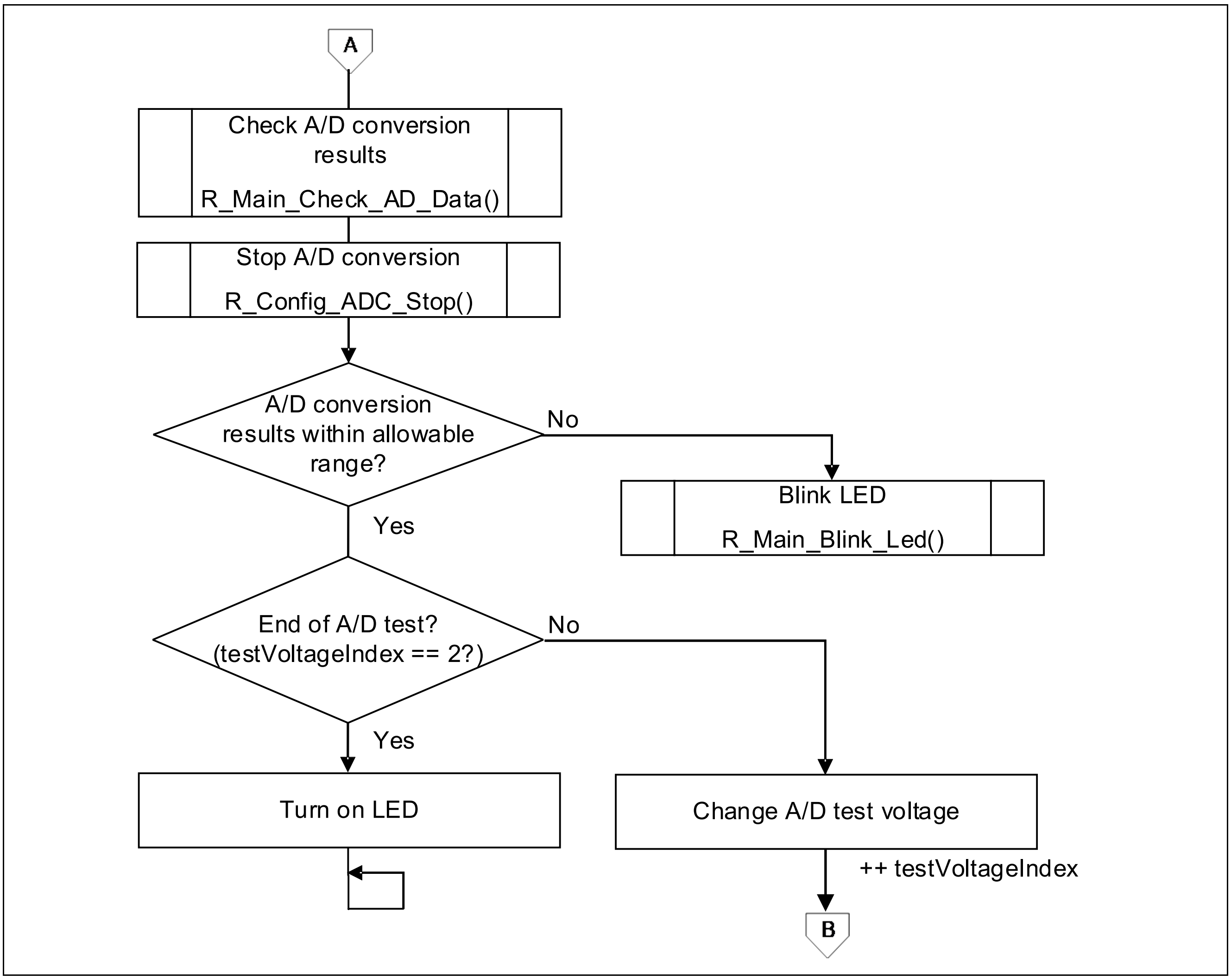


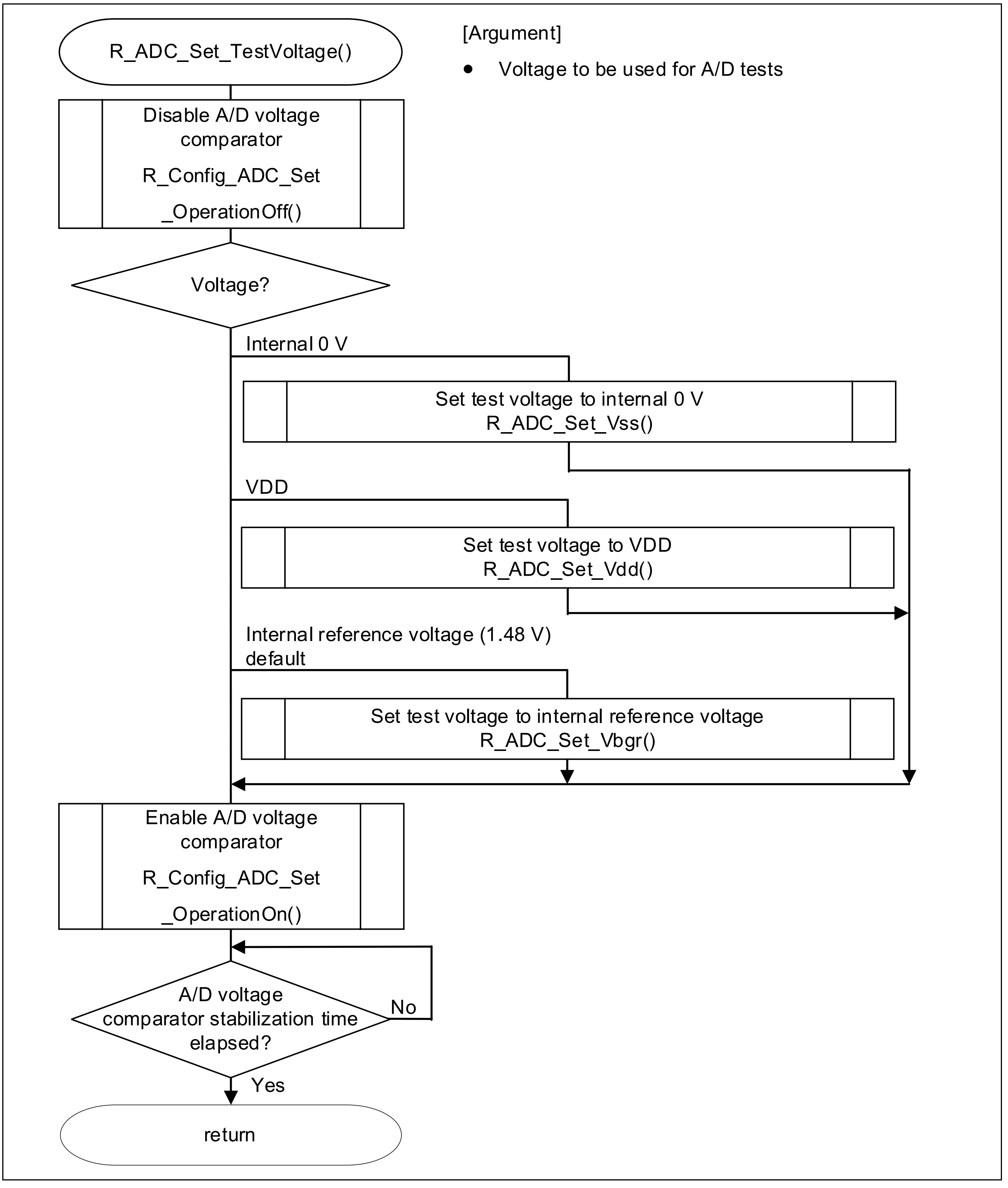
Figure 4 - 2 Main Processing (2/2)



4.5.2 Setting the Test Voltage

Figure 4 - 3 shows the flowchart for setting the test voltage.

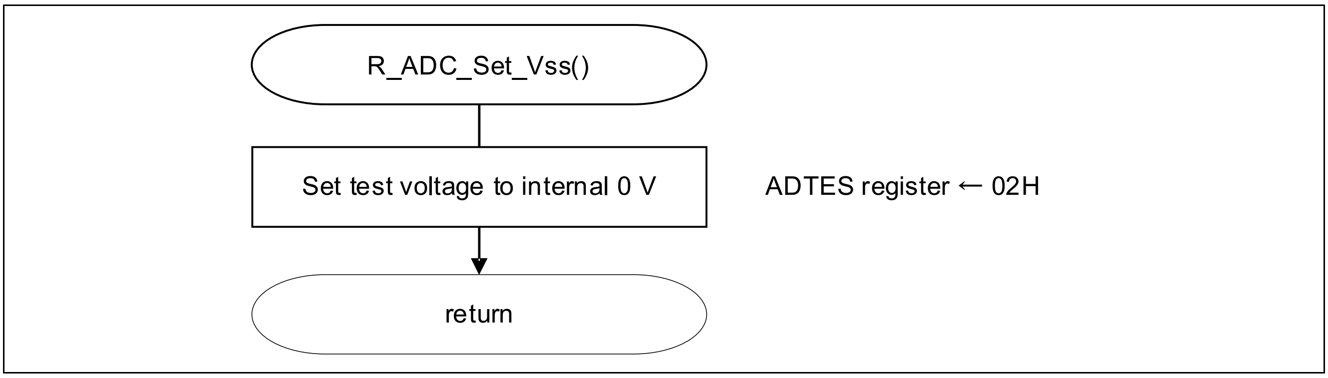
Figure 4 - 3 Setting the Test Voltage



4.5.3 Setting the Test Voltage to Internal 0 V

Figure 4 - 4 shows the flowchart for setting the test voltage to internal 0 V.

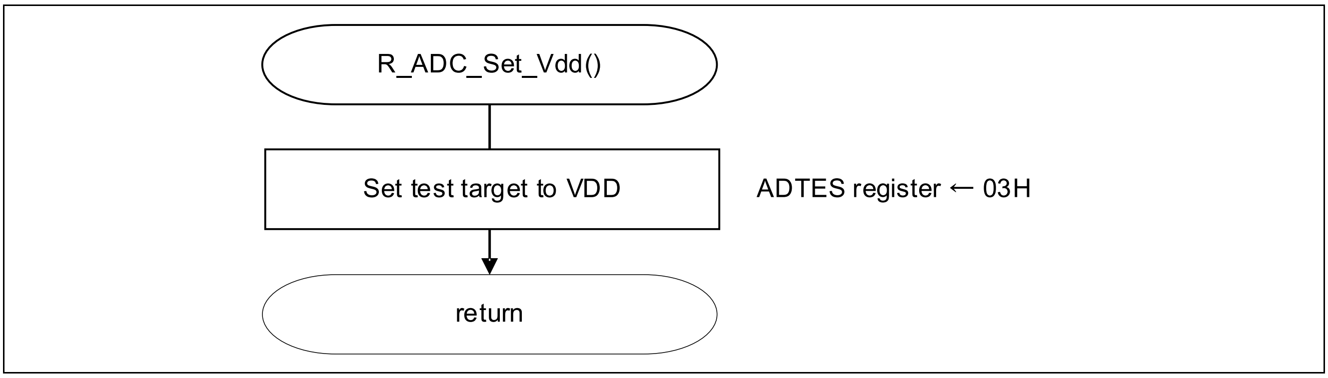
Figure 4 - 4 Setting the Test Voltage to Internal 0 V



4.5.4 Setting the Test Voltage to VDD

Figure 4 - 5 shows the flowchart for setting the test voltage to VDD.

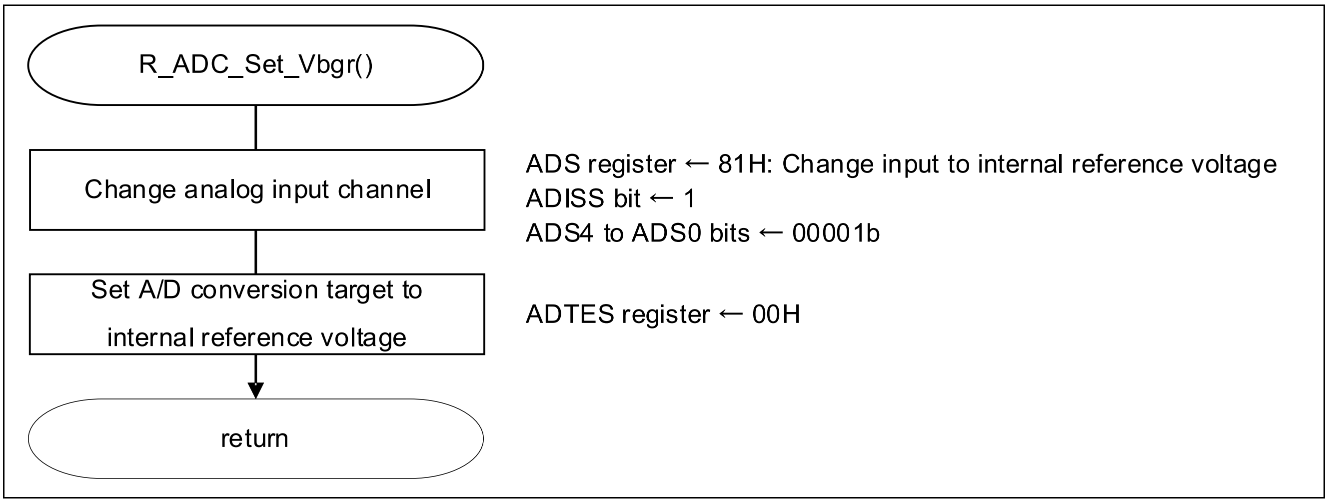
Figure 4 - 5 Setting the Test Voltage to VDD



4.5.5 Setting the Test Voltage to Internal Reference Voltage

Figure 4 - 6 shows the flowchart for setting the test voltage to internal reference voltage.

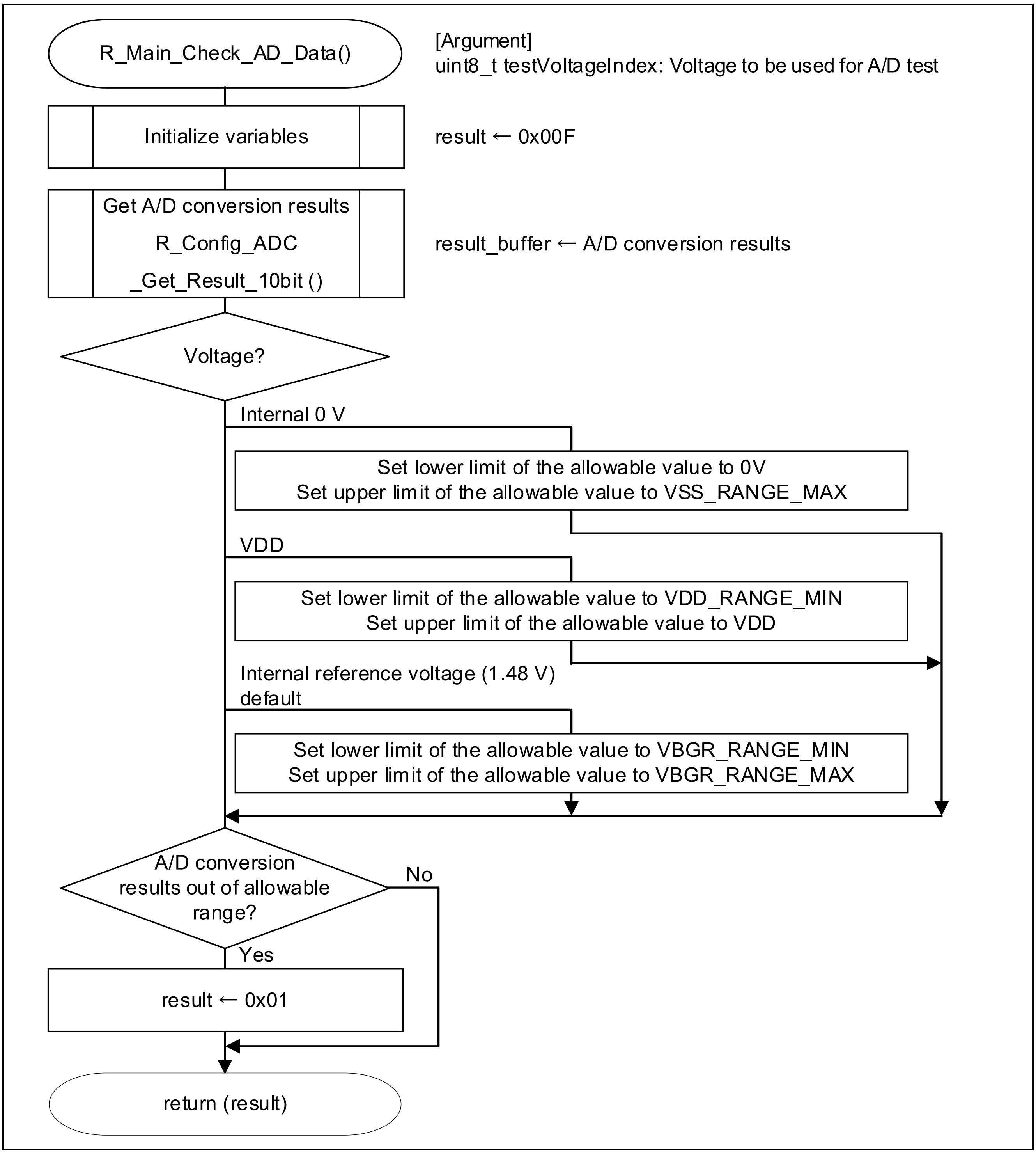
Figure 4 - 6 Setting The Test Voltage to Internal Reference Voltage



4.5.6 Checking the A/D Conversion Results

Figure 4 - 7 shows the flowchart for checking the A/D conversion results.

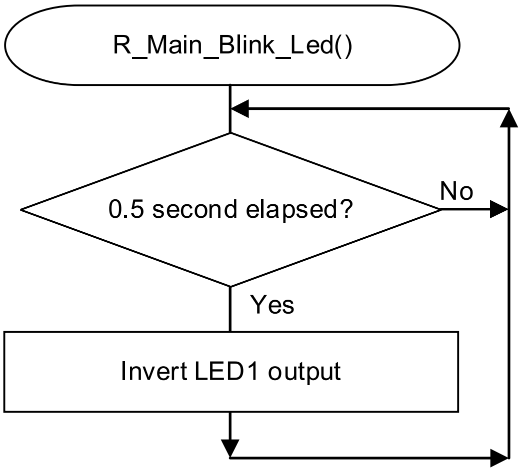
Figure 4 - 7 Checking the A/D Conversion Results



4.5.7 Blinking the LED

Figure 4 - 8 shows the flowchart for blinking the LED.

Figure 4 - 8 Blinking the LED



5. Sample Code

The sample code is available on the Renesas Electronics Website.

6. Documents for Reference

RL78/G23 User's Manual: Hardware (R01UH0896)

RL78 Family User's Manual: Software (R01US0015)

(The latest versions of the documents are available on the Renesas Electronics Website.)

Technical Updates/Technical Brochures

(The latest versions of the documents are available on the Renesas Electronics Website.)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Apr.13.21	-	First edition issued

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

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

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time 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 time 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 time 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 time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the 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.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is 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. Additionally, 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.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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