RISC-V

# Timer Array Unit (Pulse Interval Measurement: Width)

## Introduction

This application note describes how the timer array unit (TAU) measures the interval of the pulse. This unit detects both the rising and falling edges of the pulse that are input to the timer input pin (TI02) and measures the high-level width and low-level width of the pulse. Then, measurement results are stored in the on-chip RAM.

## Target Device

RISC-V

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 Overview of Specifications

This application note describes the measurement of the high-level width and low-level width of the input pulse by using channel 2 of the timer array unit 0 (TAU0).

Each time a valid edge is detected on the timer input pin (TI02), the count value of the timer is captured to measure the pulse interval. The measurement result is stored in the on-chip RAM. The type of the detected edge is determined by reading the input data in the PCNTR1 register when a valid edge is detected on the timer input pin (TI02).

Table 1.1 shows the required peripheral functions and their uses. Figure 1.1 presents an overview of the pulse interval measurement.

**Table 1.1 Peripheral Function and Use**

| Peripheral Function | Use |
|---|---|
| Timer array unit 0 (TAU0) channel 2 | Measurement of the interval of the pulse input to the timer input pin (TI02) |

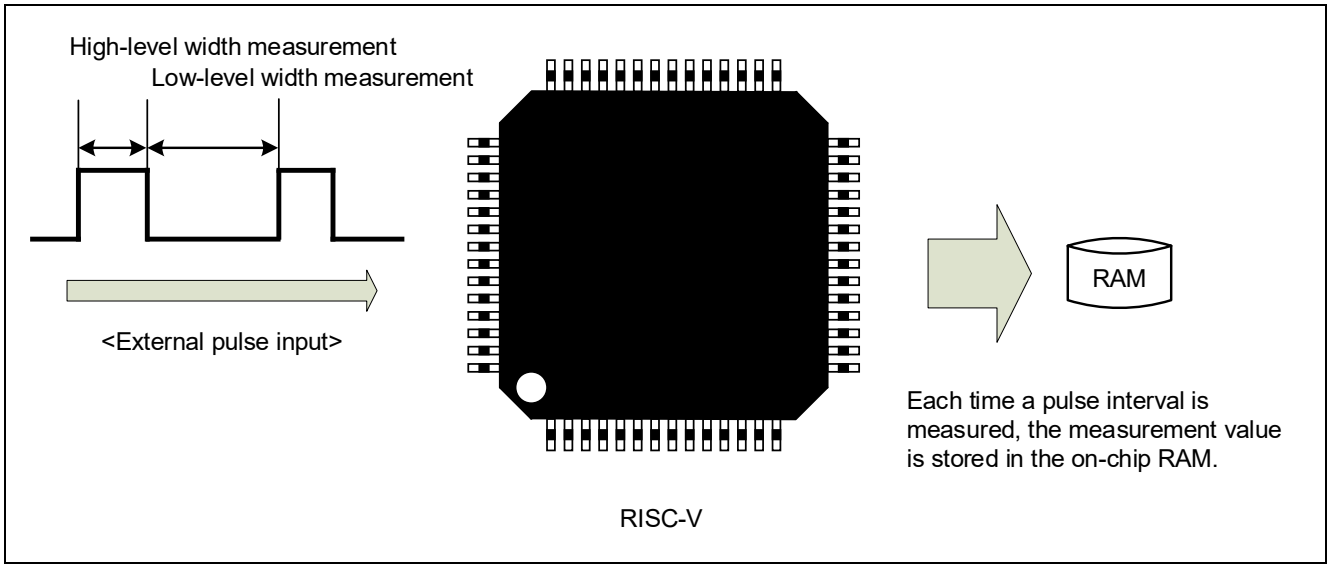


**Figure 1.1 Overview of Pulse Interval Measurement**

## 1.2 Outline of Operation

In this sample code, each time a rising edge or a falling edge is detected on the timer input pin (TI02), the counter value of the timer is captured and a high-level width or a low-level width of the pulse input to the timer input pin (TI02) is measured.

To measure the pulse interval accurately, the capture end interrupts of channel 2 of TAU0 (TAU0_ENDI2) after the first capture end interrupt are used. When capture end interrupts occur after the first capture end interrupt, the type of the detected edge (rising or falling) is determined, and the determination result is reflected in the edge determination flag. Then, according to the edge determination flag, the measured high-level width or low-level width is stored in the appropriate variable in the on-chip RAM.

Note that if a short pulse is detected and a counter value of the timer is captured before the measurement result is stored in the variable in the on-chip RAM, the measurement result is discarded.

(1) Initialize TAU0.
   - Use the P103/TI02 pin for inputting capture trigger.
   - Set the operation clock of TAU0 channel 2 to PCLKB.
   - Set TAU0 channel 2 to the capture mode.
   - Set the TI02 pin input valid edge to “Both edge”.
   - Set the capture trigger of TAU0 channel 2 to “Valid edge of the TI02 pin input”.
   - Use the capture end interrupt (TAU0_ENDI2) from TAU0 channel 2.

(2) Set the TS[2] bit of the timer channel start register 0 (TS0) to 1 to enable count operation. This clears the timer count register (TCR02) to 0000H and starts counting.
(3) Switch to a sleep mode and wait for a detection of a valid edge.
(4) When a valid edge is detected, the count value of the TCR02 register is captured to the timer data register (TDR02), at the same time, the TCR02 register is cleared to 0000H, and the capture end interrupt (TAU0_ENDI2) is requested, and then a sleep mode is released. After a sleep mode is released, the capture end interrupt request flag is cleared. The first capture value of the TDR02 register is invalid and cannot be used.
(5) Set the numbers of measurement times of the high-level width and low-level width.
(6) Enable interrupt requests.
(7) Switch to a sleep mode and wait for a detection of a valid edge.
(8) When a valid edge is detected, a sleep mode is released, and in the capture end interrupt processing, the capture value of the TDR02 register is temporarily stored in the on-chip RAM.
(9) Read the data of the PCNTR1 register twice to determine the detected edge.
(10) If a valid edge is not detected during the capture end interrupt processing and the two data of the PCNTR1 register are same, the determination result (00H or 01H) of the PCNTR1 register is set to the edge determination flag. According to the value of the edge determination flag, either a high-level width or a low-level width is selected, and the capture value temporarily stored is stored in the variable in the on- chip RAM appropriately for the selected width type.
    If a valid edge is detected during the capture end interrupt processing or the two data of the PCNTR1 register are not same, the capture value temporarily stored is not stored in the variable in the on-chip RAM, and the capture end interrupt request flag is cleared, and the number of the discarded edge is incremented.
(11) Repeat steps (7) to (10) until high-level widths and low-level widths are measured four times each.
(12) After the measurement of the setting number is finished, set the TT[2] bit of the timer channel stop register 0 (TT0) to 1 to disable count operation, and switch to a sleep mode.

## 2. Operation Confirmation Conditions

The operation of the sample code provided with this application note has been tested under the following conditions.

**Table 2.1 Operation Confirmation Conditions**

| Item | Description |
|---|---|
| MCU used | RISC-V (R9A02G021) |
| Board used | RISC-V-48p Fast Prototyping Board (RTK9FPG021S000W0BJ) |
| Operating frequency | High-speed on-chip oscillator clock: 48 MHz<br>CPU/peripheral hardware clock: 48 MHz |
| Operating voltage | 3.3 V (can be operated at 1.6 V to 5.5 V) |
| Integrated development environment (e$^2$studio) | e$^2$studio V2024-01.1 (24.1.1) from Renesas Electronics Corp. |
| C compiler (e$^2$studio) | LLVM for RISC-V 17.0.2.202401 |
| Smart configurator (SC) | Smart Configurator for RISC-V V24.1.1.v20240125-1623 |
| Board support package (BSP) | V1.00 from Renesas Electronics Corp. |

# 3. Hardware Descriptions

## 3.1 Example of Hardware Configuration

Figure 3.1 shows an example of the hardware configuration used in the application note.

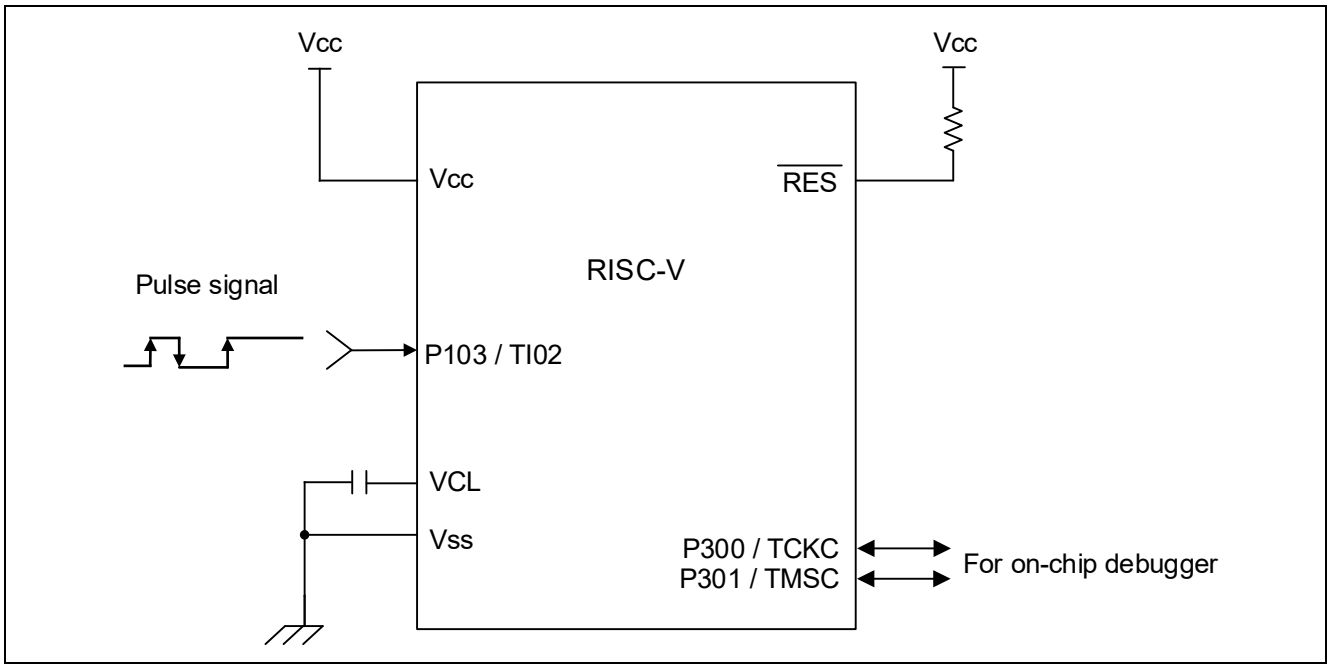


**Figure 3.1 Hardware Configuration**

Note 1. This simplified circuit diagram was created to show an overview of connections only. When actually designing your circuit, make sure the design includes appropriate pin handling and meets electrical characteristic requirements (connect each input-only port to Vcc or Vss through a resistor).

Note 2. Vcc must not be lower than the reset release voltage (VLVD0) that is specified for the LVD0.

## 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 | Function |
|---|---|---|
| P103 / TI02 | Input | Timer input pin of TAU0 channel 2 |

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. Software Explanation

## 4.1 Setting of Option Byte

Table 4.1 shows the option byte settings. Set the values that are most suited to your system as necessary.

**Table 4.1 Option Byte Settings**

| Address | Setting Value | Contents |
|---|---|---|
| 0000_0400H | FFFF_FFFFH | Disables the watchdog timer.<br>(Counting stopped after reset) |
| 0000_0404H | FFFF_CFFFH | High-speed on-chip oscillator clock : 48 MHz |
| 0101_0008H | FFFF_FFFFH | Enables on-chip debugging |

## 4.2 List of Constants

Table 4.2 shows the constants that are used in this sample program.

**Table 4.2 Constants for the Sample Program**

| Constant | Setting | Description |
|---|---|---|
| _0001_TAU_OVERFLOW_OCCURS | 0x0001U | Overflow occurrence is detected |

## 4.3 List of Variables

Table 4.3 lists global variables.

**Table 4.3 Global Variables**

| Type | Variable Name | Description | Function Used |
|---|---|---|---|
| volatile uint8_t | g_count | Number of times to measure pulse interval | main<br>r_Config_TAU0_2_interrupt |
| volatile uint8_t | g_times_high | Number of times to measure high-level width | main<br>r_Config_TAU0_2_interrupt |
| volatile uint8_t | g_times_low | Number of times to measure low-level width | main<br>r_Config_TAU0_2_interrupt |
| volatile uint8_t | g_edge_flag | Edge determination flag | r_Config_TAU0_2_interrupt |
| uint8_t | g_port_data[2] | Storage of input level of P103/TI02 pin | r_Config_TAU0_2_interrupt |
| uint32_t | g_width_high[4] | Storage of measurement value of high-level width | r_Config_TAU0_2_interrupt |
| uint32_t | g_width_low[4] | Storage of measurement value of low-level width | r_Config_TAU0_2_interrupt |
| uint8_t | g_times_invalid | Number of times of discarded measurement value | r_Config_TAU0_2_interrupt |
| volatile uint32_t | g_tau0_ch2_width | Temporary storage of measurement value of pulse interval | r_Config_TAU0_2_interrupt |

## 4.4 List of Functions

Table 4.4 shows a list of functions.

**Table 4.4 Functions**

| Function name | Outline |
|---|---|
| r_Config_TAU0_2_interrupt() | TAU0 channel 2 capture end interrupt processing (TAU0_ENDI2) |

## 4.5 Specification of Functions

The function specifications of the sample code are shown below.

| r_Config_TAU0_2_interrupt() | |
|---|---|
| Outline | TAU0 channel 2 capture end interrupt processing |
| Header | r_cg_interrupt_handlers.h |
| Declaration | void r_Config_TAU0_2_interrupt(void) |
| Description | Determine the type of the input pulse edge and store the measured pulse interval in the variable in the on-chip RAM according to the detected edge. |
| Argument | None |
| Return Value | None |

## 4.6 Flowcharts

### 4.6.1 Main Processing

Figure 4.1 shows the flowchart of the main processing.

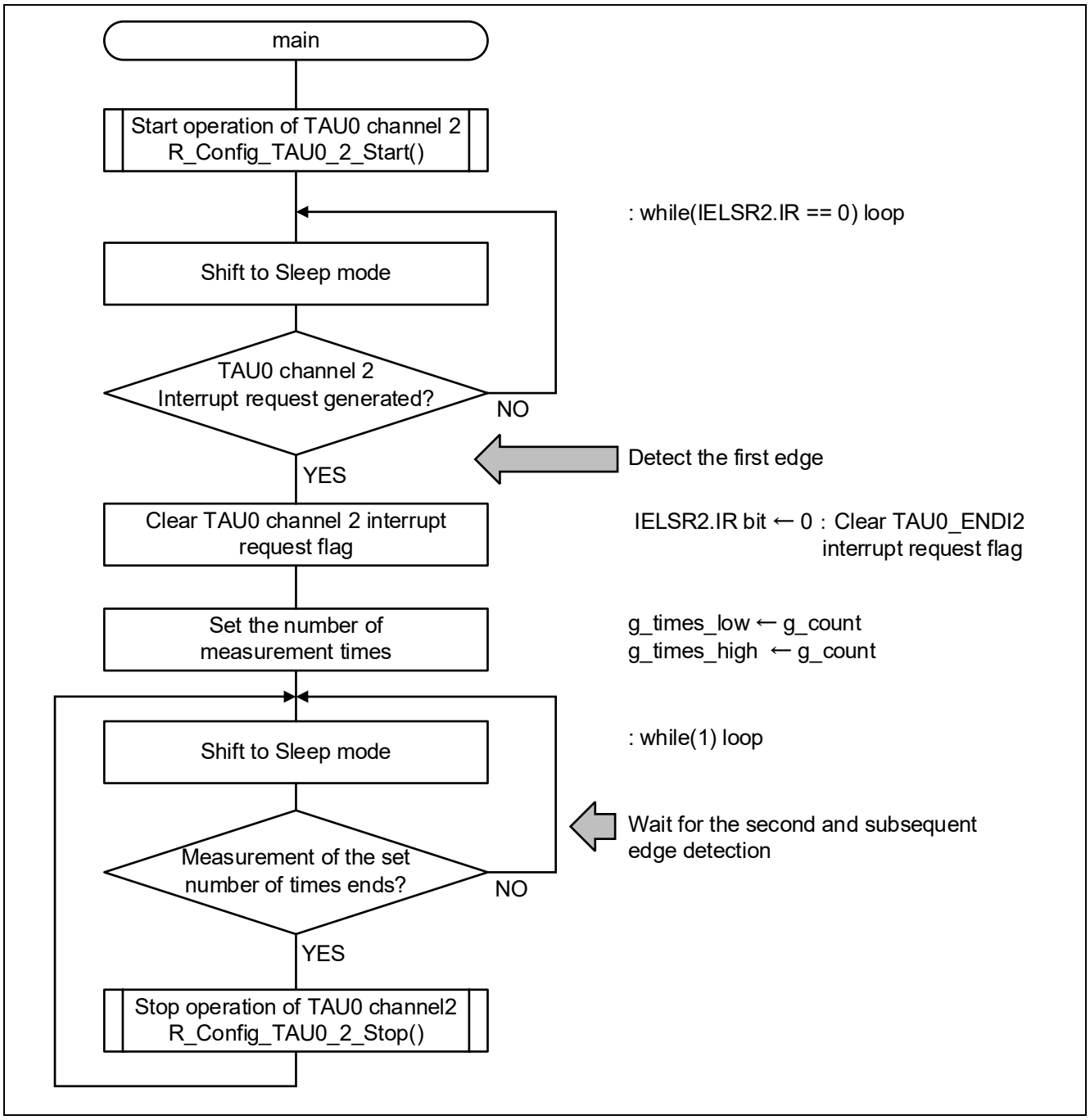


**Figure 4.1 Main Processing**

### 4.6.2 TAU0 Channel 2 Capture End Interrupt Processing

Figure 4.2 and Figure 4.3 show the flowchart of TAU0 channel 2 capture end interrupt processing.

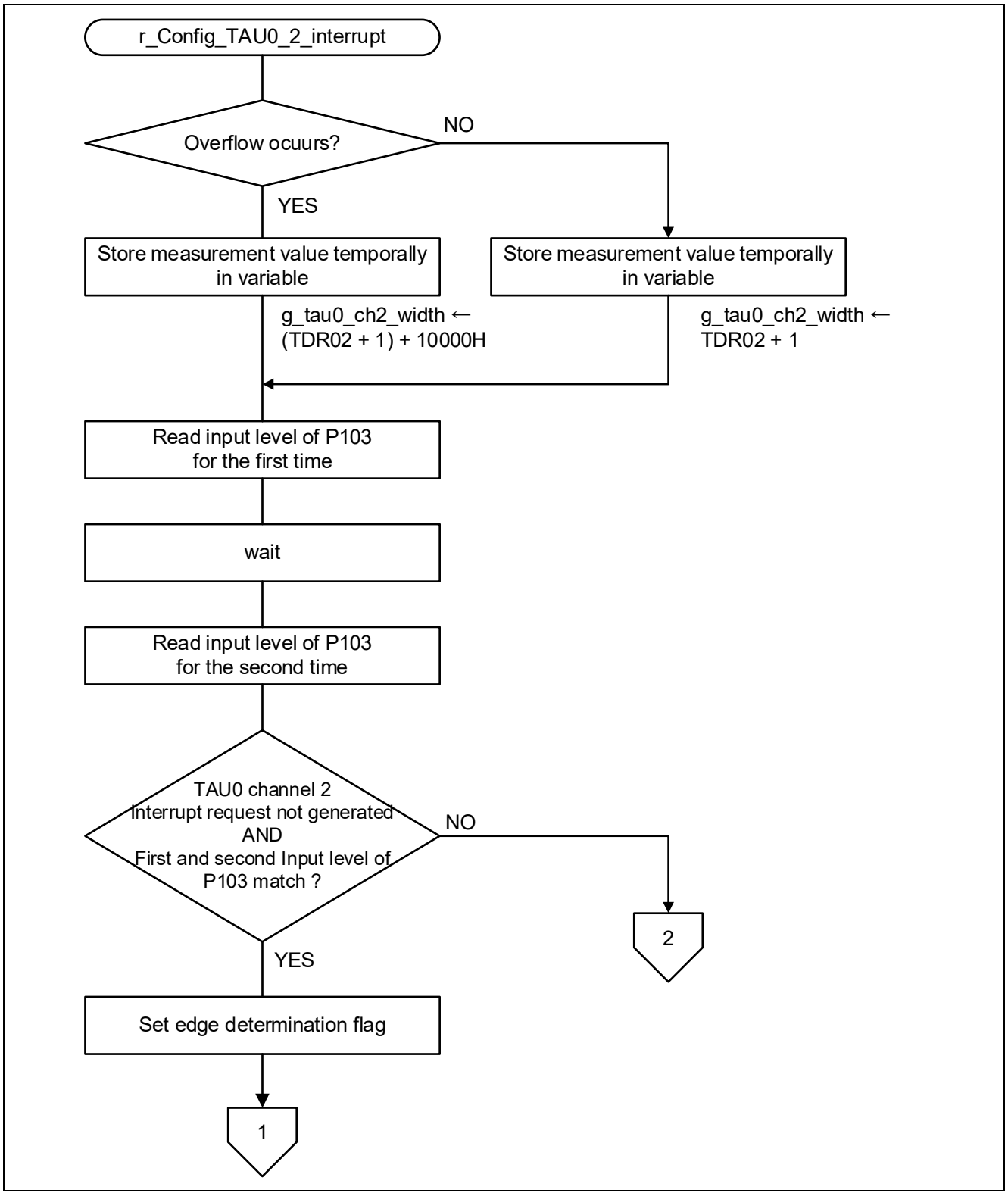


**Figure 4.2 TAU0 Channel 2 Capture End Interrupt Processing (1/2)**

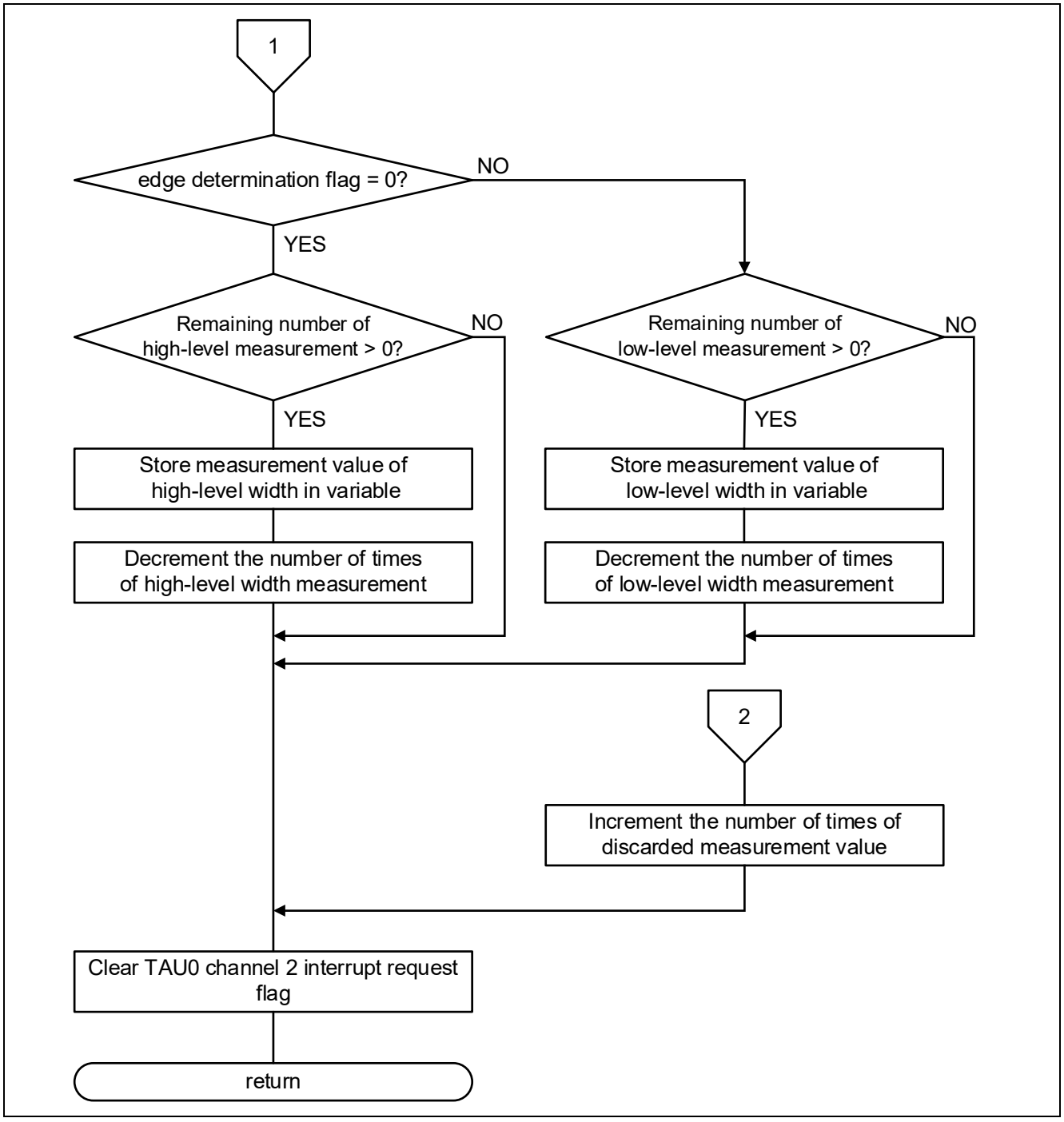


**Figure 4.3 TAU0 Channel 0 Capture End Interrupt Processing (2/2)**

## 5. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

## 6. Reference Documents

RISC-V User's Manual: Hardware (R01UH1036EJ)

The latest versions can be downloaded from the Renesas Electronics website.

Technical update

The latest versions can be downloaded from the Renesas Electronics website.

## Revision History

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 1.00 | Mar.18.24 | — | Initial release |

# 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

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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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