# RL78/G22

Capacitive Touch Low Power Guide (SMS / MEC function)

## Introduction

This application note describes how to use SNOOZE Mode Sequencer (SMS) and Multiple Electrode Connection (MEC) function to achieve low power consumption when measuring capacitance touch.

## Target Device

RL78/G22

When applying the contents of this application note to other MCUs, please change them according to the specifications of the MCUs and perform a thorough evaluation.

## Contents

## 1. Outline

This application note shows the reference current when the capacitive touch measurement using SNOOZE Mode Sequencer (SMS) function and MEC function of RL78/G22 is operated intermittently in 100ms cycles. By using SMS function and Multiple Electrode Connection (MEC) function, the touch on/off status of several electrodes can be determined during SNOOZE mode, enabling low power consumption.

※ SNOOZE Mode Sequencer (SMS)

This function sequentially executes up to 32 processes from 21 types of processing such as arithmetic processing, branch processing, and control of peripheral functions (timer, serial communication, etc.). SMS is activated by the interrupt-request signal of the peripheral function or the output signal of ELC, and the process can be executed independently of CPU. Therefore, SMS can operate even when CPU is in stand-by. In addition, since the operating current of SMS is smaller than that of CPU, CPU can be replaced by a process to reduce power consumption.

※Multiple Electrode Connection (MEC) Function

This function connects multiple electrodes and measures them as a single electrode. This function is only available in self-capacitance mode.

This sample program measures three buttons (consisting of three electrodes) and one slider (consisting of five electrodes) in the normal mode and measures eight electrodes as one electrode using MEC function in the low power consumption mode.

## 2. Used Peripherals

Table 2-1 lists the used peripherals in the sample code.

**Table 2-1 Peripherals in the sample code**

| Used Peripherals | Functions |
|---|---|
| Capacitive Sensing Unit (CTSU2La) | Measures electrostatic capacitance of the touch sensor. |
| 32-bit interval timer (TML32) | Timer to release STOP mode and transition to SNOOZE mode (measurement cycle: 100 ms). |
| Data transfer controller (DTC) | Port output using DTC from CTSU2La. An interrupt signal is generated using the signal output from the port.<br>An interrupt signal triggers the ELC to start SMS processing. |
| Port | |
| Interrupt Controller (INTP) | |
| Event Link Controller (ELC) | |
| SNOOZE Mode Sequencer (SMS) | |

# 3. Operation Environment / Conditions

Table 3-1 lists the operating conditions, Table 3-2 lists the operating conditions, and Figure 3-1 shows CTSU measurement touch sensor, sensor drive pulse frequency, and CTSU measurement times, Table 3-3 lists the option byte setting.

**Table 3-1 Operation environment**

| Item | Contents |
|---|---|
| MCU | RL78/G22 (R7F102GGE2DFB) |
| Operating voltage | 5.0 V<br>VD0 detection voltage: Reset mode<br>At rising edge TYP. 2.67V (2.59 V～2.75 V)<br>At falling edge TYP. 2.62V (2.54 V～2.70 V) |
| Target board | RL78/G22 capacitive touch evaluation system (RTK0EG0042S01001BJ) |
| Integrated development environment | e$^2$ studio (2023-04) |
| Smart Configurator | V23.4.0 |
| C compiler | CC-RL V1.12.00<br>Compile options of optimization: -Odefault |
| QE for Capacitive Touch | V3.3.0 |
| Debugger | E2 emulator Lite |

**Table 3-2 Operation conditions**

| Item | Contents |
|---|---|
| High-speed on-chip oscillator clock (fIH) | 6MHz *Note |
| CPU/peripheral hardware clock (fCLK) | 6MHz *Note |
| Low-speed on-chip oscillator clock (fIL) | 32.768 kHz |
| Low-speed peripheral clock (fSXP) | 32.768 kHz |
| Capacitive Touch measurement cycle | 20 ms (Normal mode)/100 ms (Low power consumption mode) |
| Measurement Mode Select 1 [MD1] | Self-capacitance method (single measurement) |
| Measurement Mode Select 0 [MD0] | Multi-scan mode |
| Measurement Start Trigger Select [CAP] | External trigger (ELC) |
| SNOOZE Enable [SNZ] | Enables the SNOOZE mode |
| Analog Adjustment 0 [ATUNE0] | Measurement power-supply voltage = 1.5 V (Normal voltage operating mode) |
| Analog Adjustment 1 [ATUNE1] | 40 μA |
| Sensor Stabilization Wait Time Setting | 64 μs (Recommended value) |
| Multi-clock x Enable [MCAx] | 3 frequencies (MCA0, MCA1, MCA2: Available) |

Note : Operation is not supported when fIH or fCLK is set to 4 MHz or lower.

| Method | Kind | Name | Touch Sensor | Parasitic Capacitance[pF] | Sensor Drive Pulse Frequency[MHz] | Threshold | Scan Time[ms] | Overflow |
|---|---|---|---|---|---|---|---|---|
| config01 | Button(self) | Button00 | TS28 | 20.188 | 2.0 | 1279 | 0.576 | None |
| config01 | Button(self) | Button01 | TS18 | 18.826 | 2.0 | 1186 | 0.576 | None |
| config01 | Button(self) | Button02 | TS00 | 19.104 | 2.0 | 1269 | 0.576 | None |
| config01 | Slider | Slider00 | TS04, TS05, TS06, TS07, TS01 | - | - | 929 | - | None |
| config01 | Slider TS | (Slider00) | TS04 | 16.139 | 2.0 | - | 0.576 | - |
| config01 | Slider TS | (Slider00) | TS05 | 17.604 | 2.0 | - | 0.576 | - |
| config01 | Slider TS | (Slider00) | TS06 | 18.167 | 2.0 | - | 0.576 | - |
| config01 | Slider TS | (Slider00) | TS07 | 18.639 | 2.0 | - | 0.576 | - |
| config01 | Slider TS | (Slider00) | TS01 | 20.493 | 2.0 | - | 0.576 | - |
| config02 | Button(self) | Mec00 | TS00 | 100.389 | 0.5 | 596 | 0.576 | None |

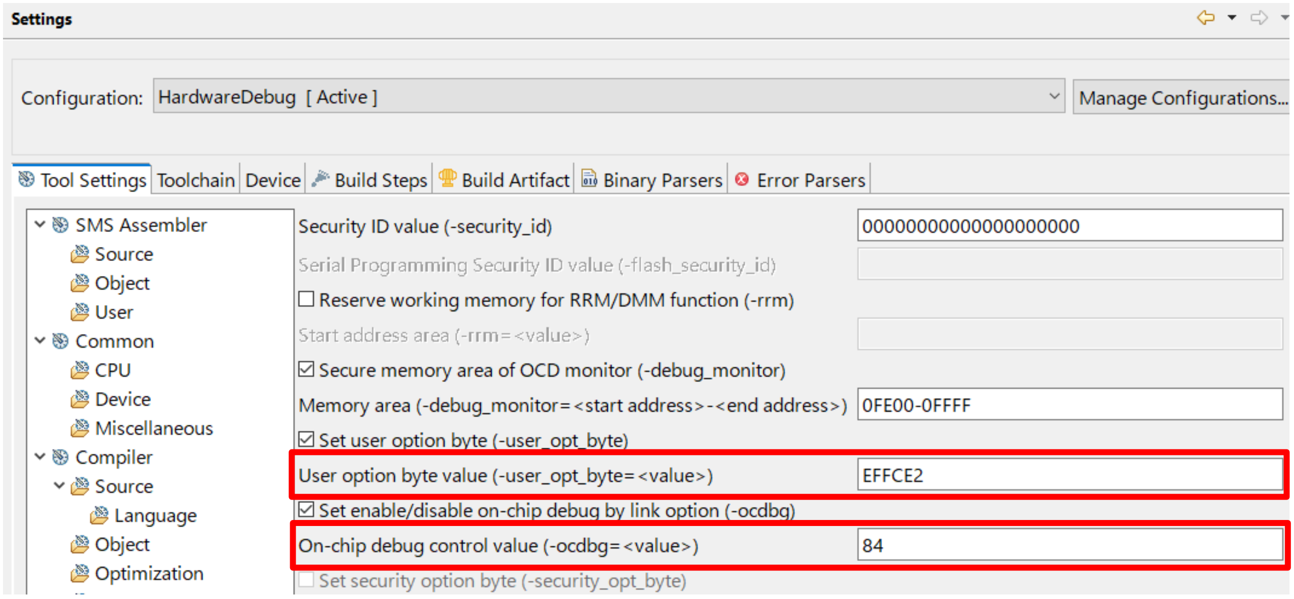
**Figure 3-1 CTSU measurement Touch sensor and Sensor Drive Pulse Frequency and CTSU Scan Time**

**Table 3-3 Option Byte Settings**

| Address | Setting Value | Contents |
|---|---|---|
| 000C0H/020C0H | 11101111B (0xEF) | Disables the watchdog timer.<br>(Counting stopped after reset) |
| 000C1H/020C1H | 11111100B (0xFC) | LVD0 detection voltage: reset mode<br>At rising edge TYP. 2.67V (2.59 V～2.75 V)<br>At falling edge TYP. 2.62V (2.54 V～2.70 V) |
| 000C2H/020C2H | 11100010B (0xE2) | HS mode,<br>High-speed on-chip oscillator clock (fIH): 6 MHz |
| 000C3H/020C3H | 10000100B (0x84) | Enables on-chip debugging |

To set the option byte, open the project properties after code generation,

"C/C++ Build" -> "Settings" -> "Tool Settings" -> "Linker" -> "Device" -> "User option byte value" and "On-chip debug control value".



# 4. Capacitive touch settings

## 4.1 Touch interface configuration

Figure 4-1 shows the touch interface configuration.

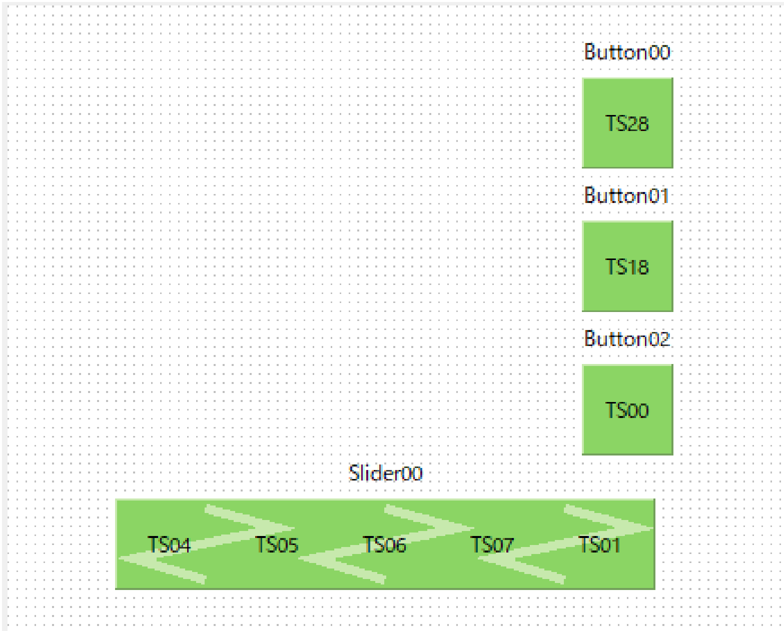



**Figure 4-1 Touch interface configuration**

## 4.2 Method settings

Figure 4-2 shows the touch interface configuration method settings. MEC function is used by enabling multi-electrode connection.

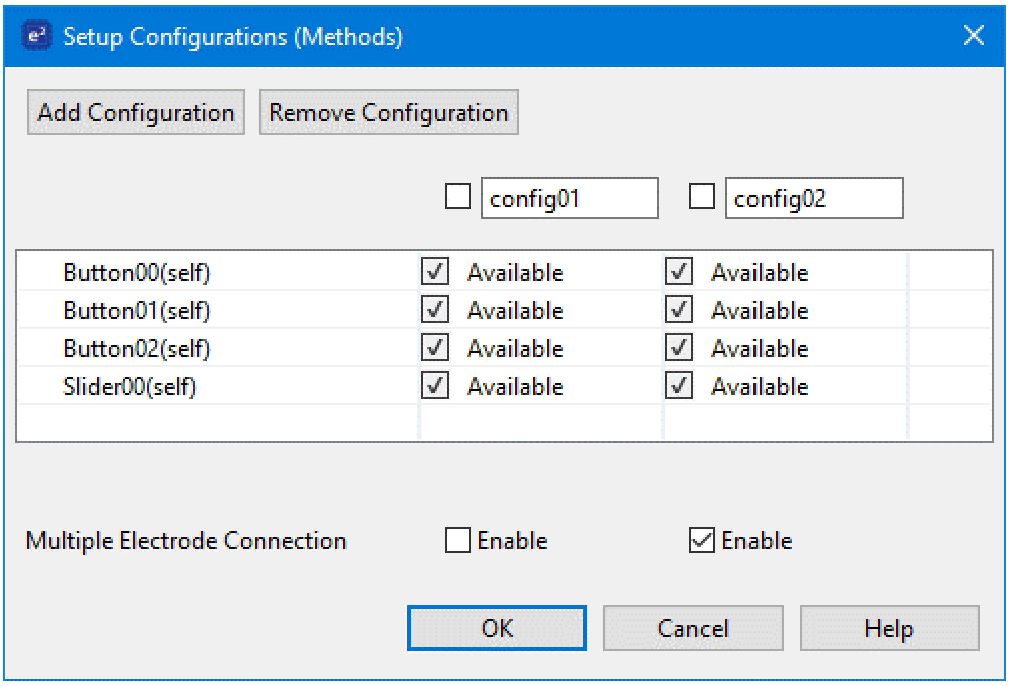



**Figure 4-2 Method settings**

## 5. Used components

Figure 5-1 shows the components used in Smart Configurator.

| Component | Version | Configuration |
|---|---|---|
| Board Support Packages. - v1.60 (r_bsp) | 1.60 | r_bsp(used) |
| Capacitive Sensing Unit driver. (r_ctsu) | 1.40 | r_ctsu(used) |
| Interrupt Controller | 1.4.0 | Config_INTC(INTC: used) |
| Interval Timer | 1.4.0 | Config_ITL000(ITL000: used), Config_TAU0_1(TAU0_1: used) |
| Ports | 1.4.0 | Config_PORT(PORT: used) |
| Touch middleware. (rm_touch) | 1.40 | rm_touch(used) |
| Voltage Detector | 1.3.0 | Config_LVD0(LVD0: used) |

**Figure 5-1 Components**

## 6. Touch measurement software operation

This section describes the sample project operation overview.

===== Up to initial offset tuning ====================================================

1. Executes RM_TOUCH_Open function. After the reset is released by power-on, CTSU is initialized.
2. ELC sets CTSU as the link destination for the compare match of the event source 32-bit interval timer 0.
3. Execute RM_TOUCH_ScanStart to set the touch measurement and wait for external trigger.
4. TML32 timer counting starts (measurement cycle: 20 ms).
5. When STOP instruction is executed, the unit transits to STOP.
6. When an interrupt of TML32 is generated, touch measurement is started by entering SNOOZE mode by an external trigger from ELC.
7. By the measurement end interrupt, the mode transitions to normal mode and touch on/off judgment is performed. Touch-Measurement Using SMS, MEC (Low Power Consumption Mode Use)

===== Touch-Measurement Using SMS, MEC (Low Power Consumption Mode Use) ===========

8. After initial offset tuning, set SMS by executing RM_TOUCH_SmsSet.
9. The touch measurement setting and SNOOZE function are enabled by executing RM_TOUCH_ScanStart function. Then, the external trigger wait status is set.
10. Starts counting of TML32 timer (measurement cycle: 100 ms).
11. When STOP instruction is executed, the unit transits to STOP.
12. When an interrupt of TML32 is generated, touch measurement is started by entering SNOOZE mode by an external trigger from ELC.
13. When a measurement end interrupt is generated, touch on/off judgment is made by SMS while in SNOOZE mode.
14. Transits to normal mode at touch-on judgment. When touch-off judgment is made, the display returns to 11.

===== Touch measurement of buttons/sliders (normal mode) =============================

15. Execute RM_TOUCH_ScanStart to wait for an external trigger.
16. TML32 timer counting starts (measurement cycle: 20 ms).
17. Touch-measurement is performed by an external trigger from ELC after TML32 timer count has elapsed 20ms.
18. After the touch measurement is finished, the touch on/off judgment and LED lighting are executed from the slider touch position.
19. When touch-on judgment or slider touch position is detected, repeats from 17 to 18. When touch-on judgment and detection of slider touch position are not performed for 3 seconds, transition to 8.

## 6.1 Operation Image of CPU and CTSU

Figure 6-1 shows an image of CPU operation and CTSU operation status during touch measurement using SMS.

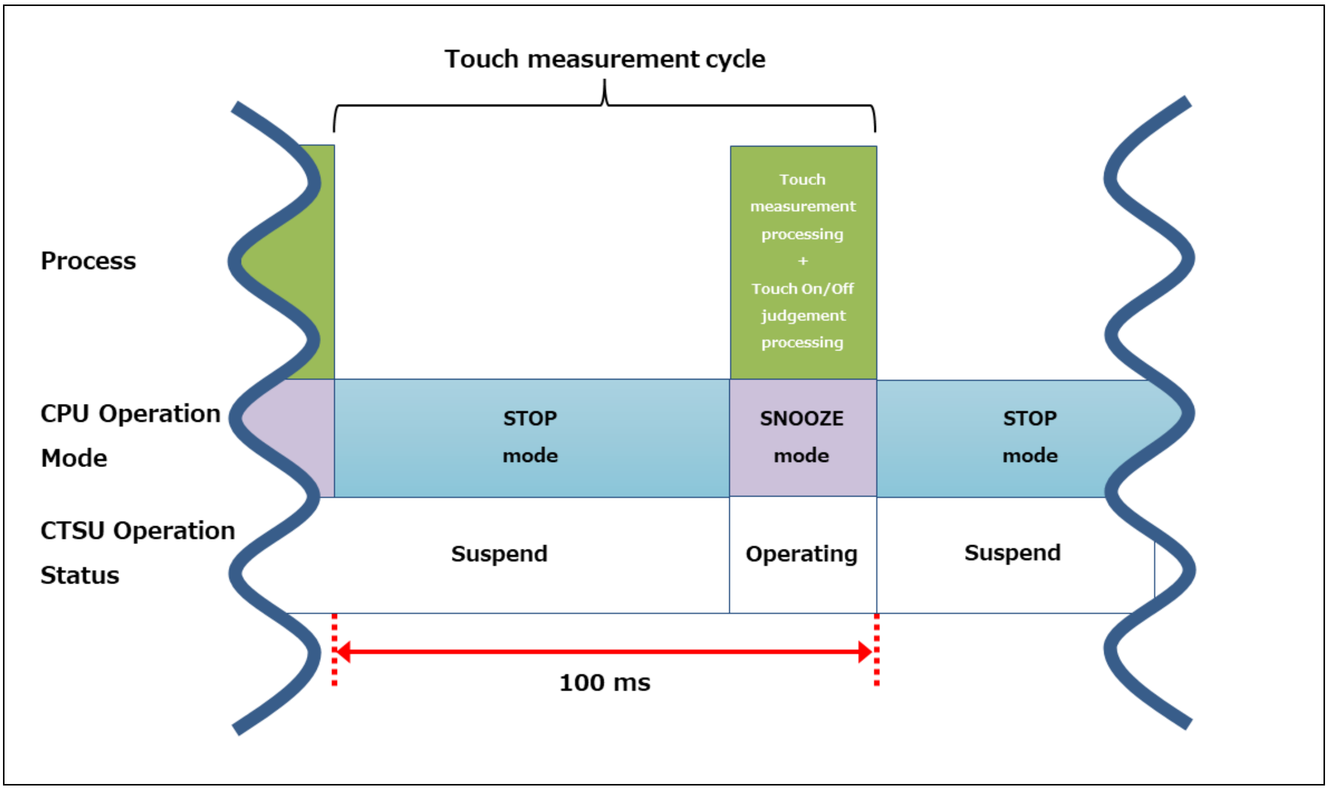



**Figure 6-1** When using SMS for touch-measurement (operation image)

# 7. Sample Project flow chart

The flow chart of the sample project is described below.

## 7.1 Main processing

Figure 7-1 shows the flowchart of main processing.

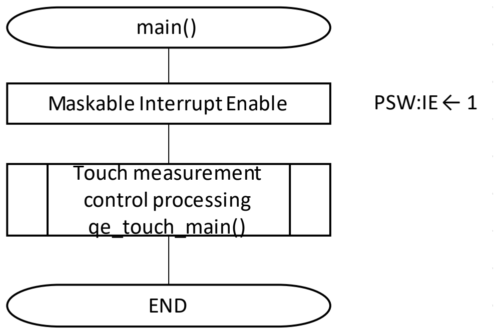



**Figure 7-1 Flowchart of main processing**

## 7.2 Touch measurement initial processing

Figure 7-2, Figure 7-3, and Figure 7-4 show the flowchart of touch measurement initial processing.

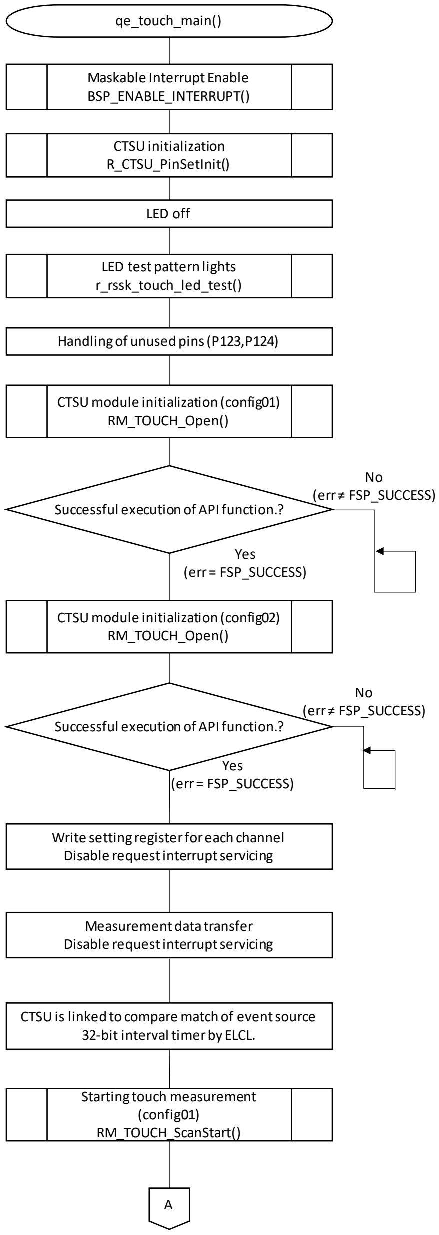



**Figure 7-2** Touch measurement initial processing (1/3)

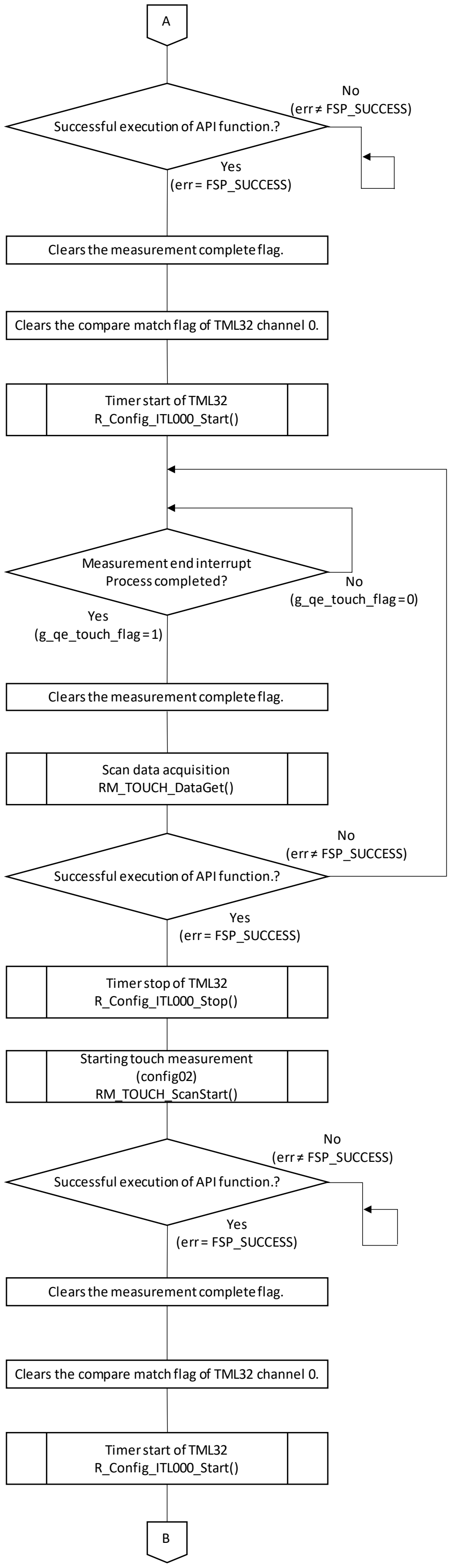



**Figure 7-3** Touch measurement initial processing (2/3)

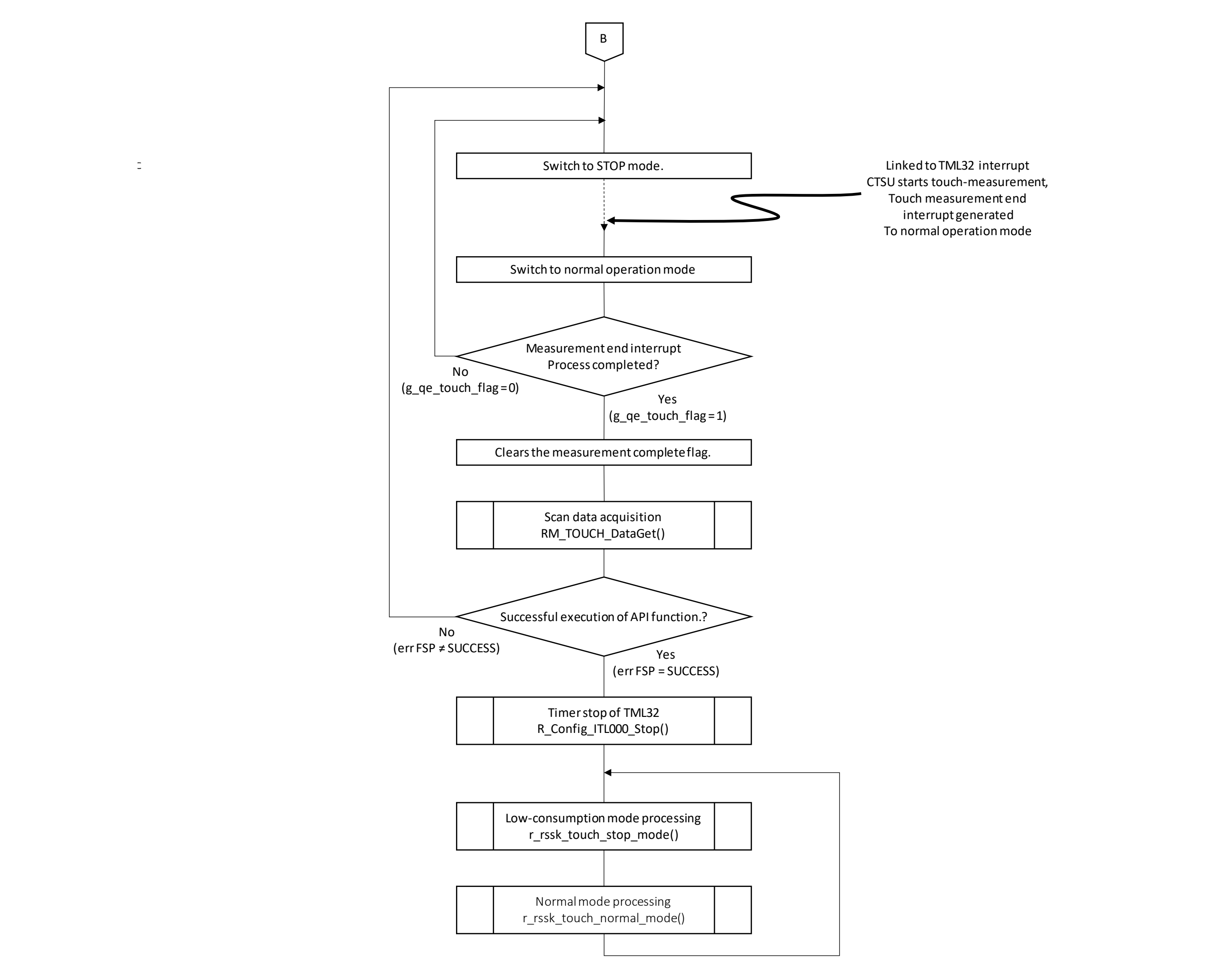



**Figure 7-4** Touch measurement initial processing (3/3)

## 7.3 Touch Measurement Control Processing in Low power consumption mode

Figure 7-5 and Figure 7-6 show the flowchart of touch measurement control processing in low power consumption mode.

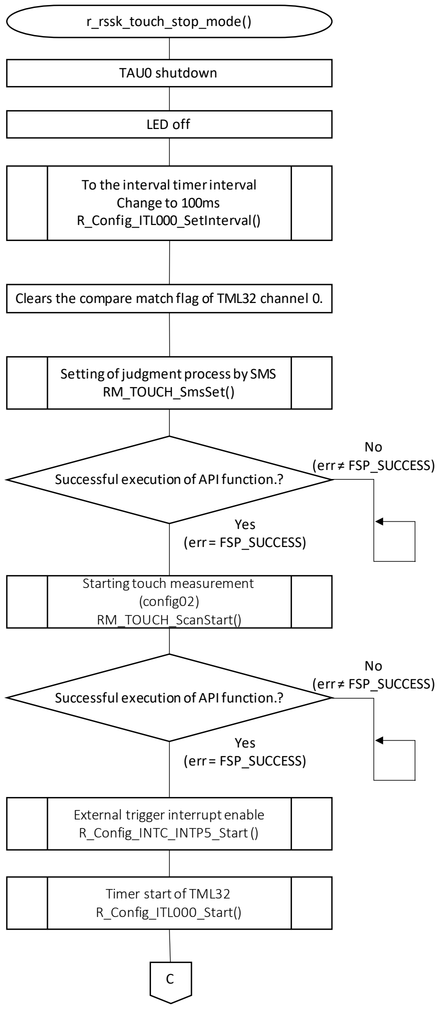



**Figure 7-5** Touch Measurement Control Processing in Low Power Consumption Mode (1/2)

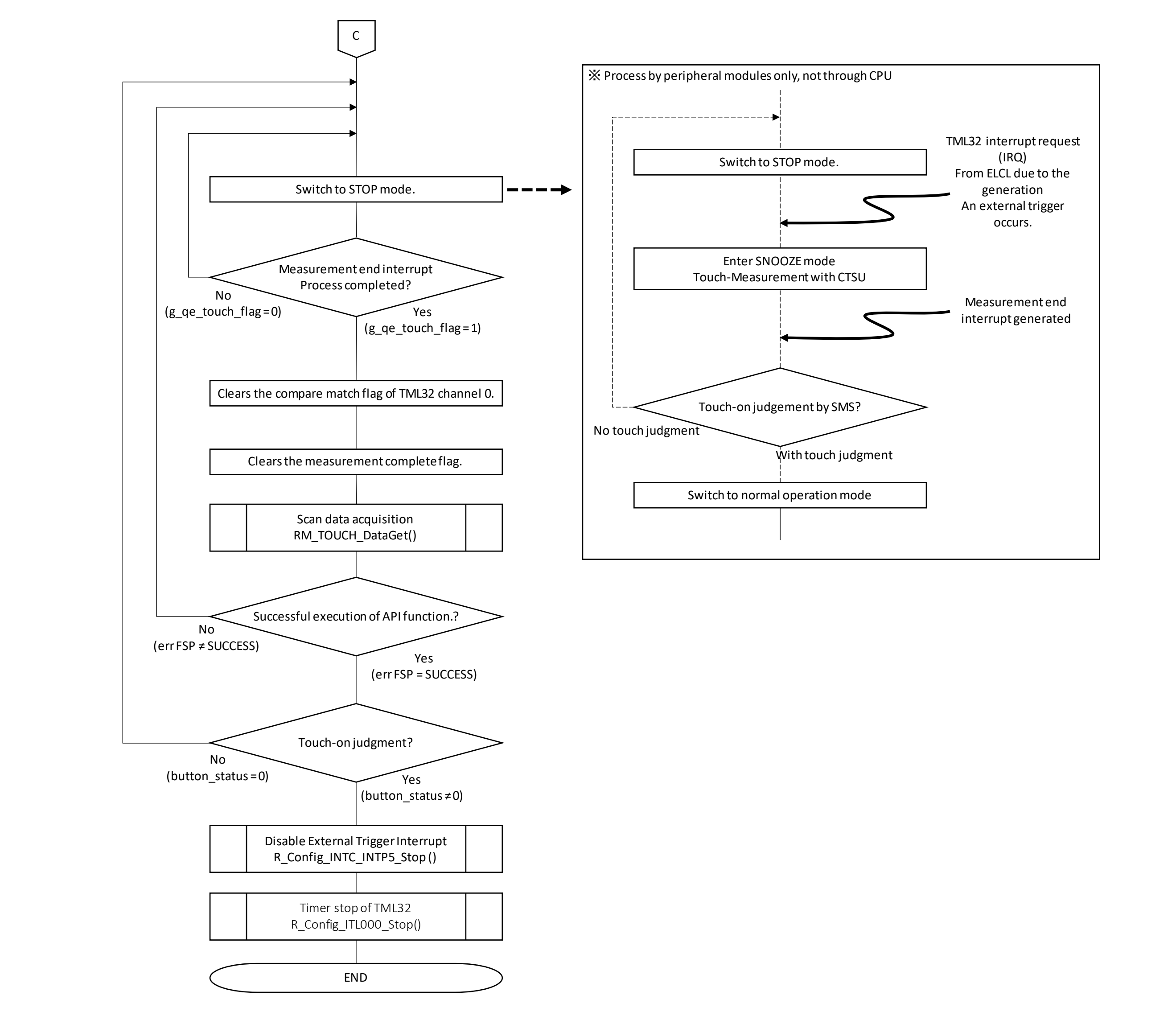



**Figure 7-6** Touch Measurement Control Processing in Low Consumption Mode (2/2)

## 7.4 Touch Measurement Control Processing in Normal Mode

Figure 7-7 and Figure 7-8 show the flowchart of touch measurement control processing in normal mode.

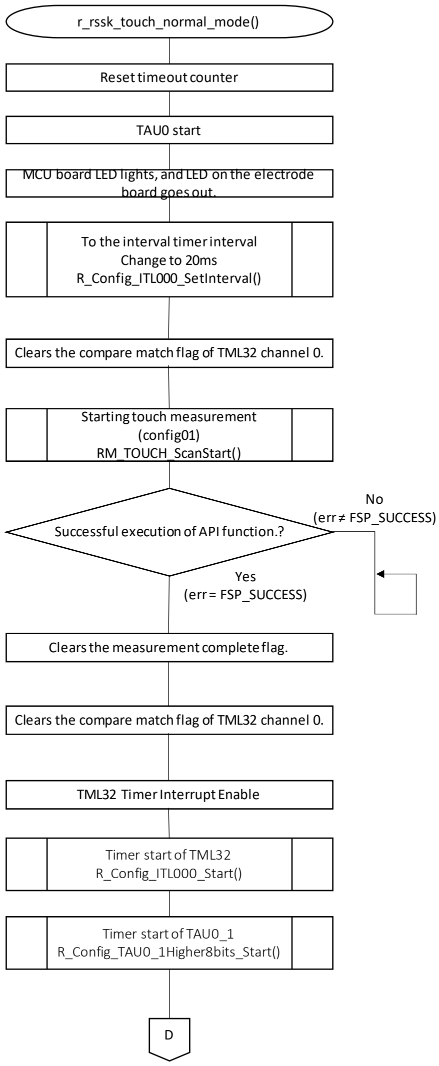



**Figure 7-7** Touch Measurement Control Processing in Normal Mode (1/2)

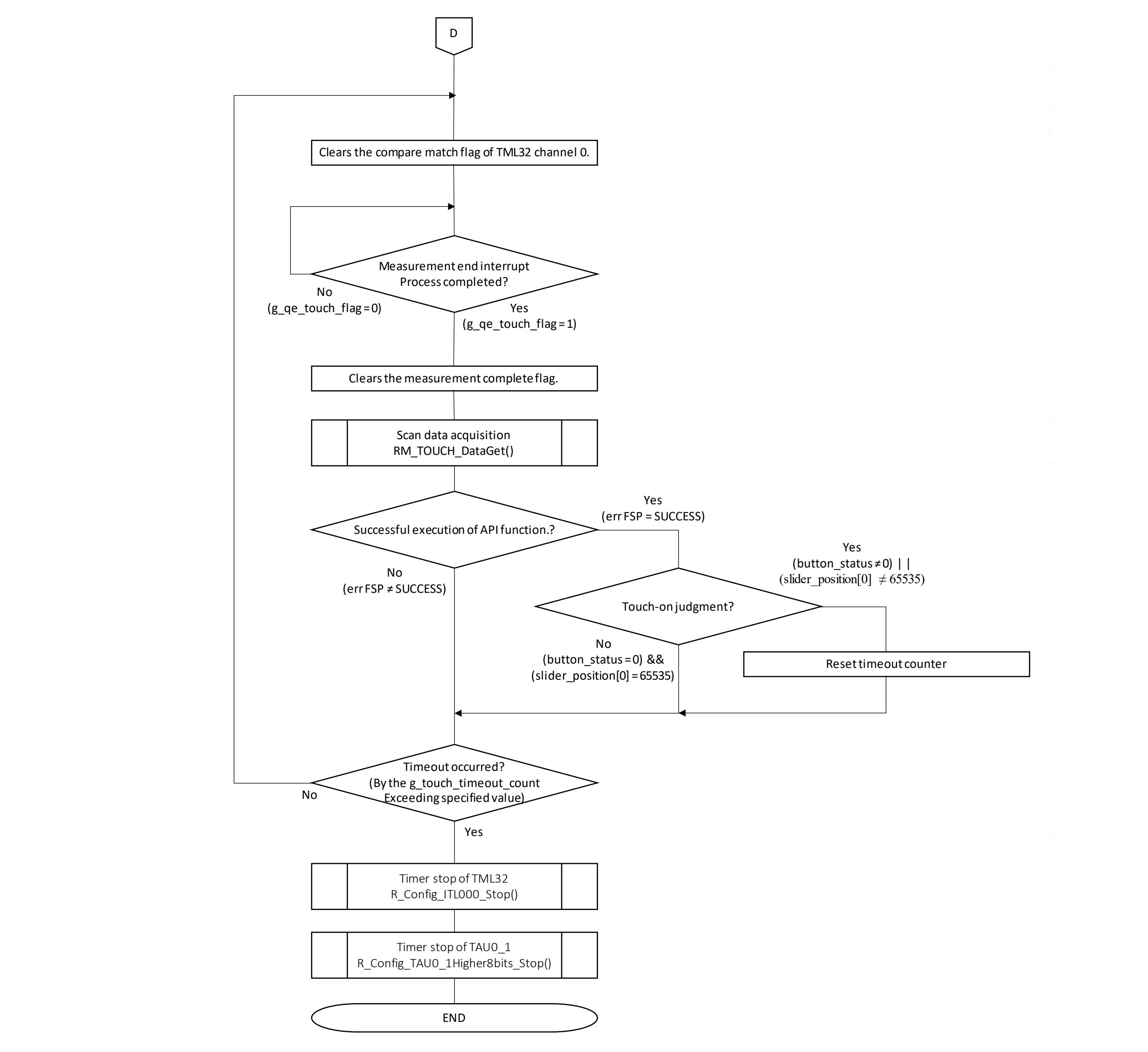



**Figure 7-8** Touch Measurement Control Processing in Normal Mode (2/2)

# 8. How to measure current consumption

## 8.1 Environment to Measure Current Consumption

Figure 8-1 shows environment to measure current consumption.

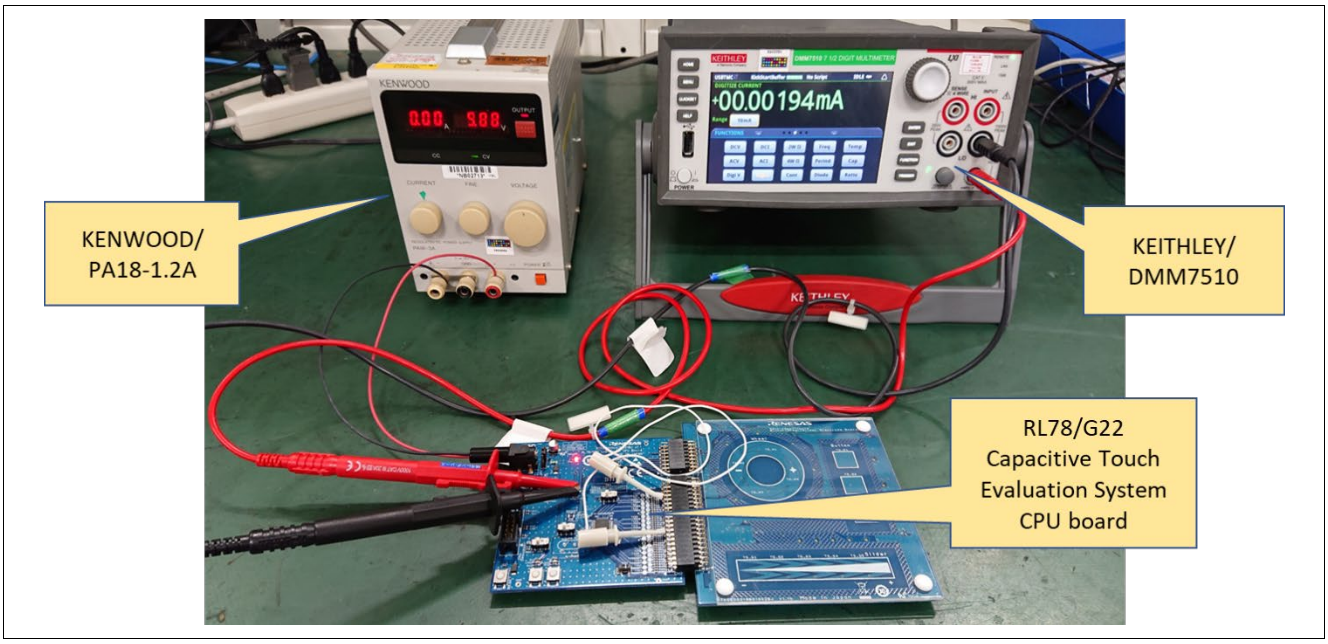



**Figure 8-1 Environment to measure current consumption**

## 8.2 Equipment and Software

Table 8-1 shows equipment and software used in current consumption measurement.

**Table 8-1 Current measuring equipment and Software**

| Type | Name | Use |
|---|---|---|
| Digital multi meter | KEITHLEY/DMM7510 | Measure current consumption. |
| DC power supply | KENWOOD/PA18-1.2A | Supply power to RL78/G22 Capacitive Touch Evaluation System CPU board(RTK0EG0042S01001BJ). |
| Software | KEITHLEY/KickStart Software | Get result of current consumption measurement from Keithley DMM7510 and output the result to log-file. |

## 8.3 How to connect the target board and each equipment

Figure 8-2 shows how to connect the RL78/G22 capacitive touch evaluation system CPU board and each equipment, and Figure 8-3 shows the power supply system diagram for the RL78/G22 capacitive touch evaluation system CPU board.

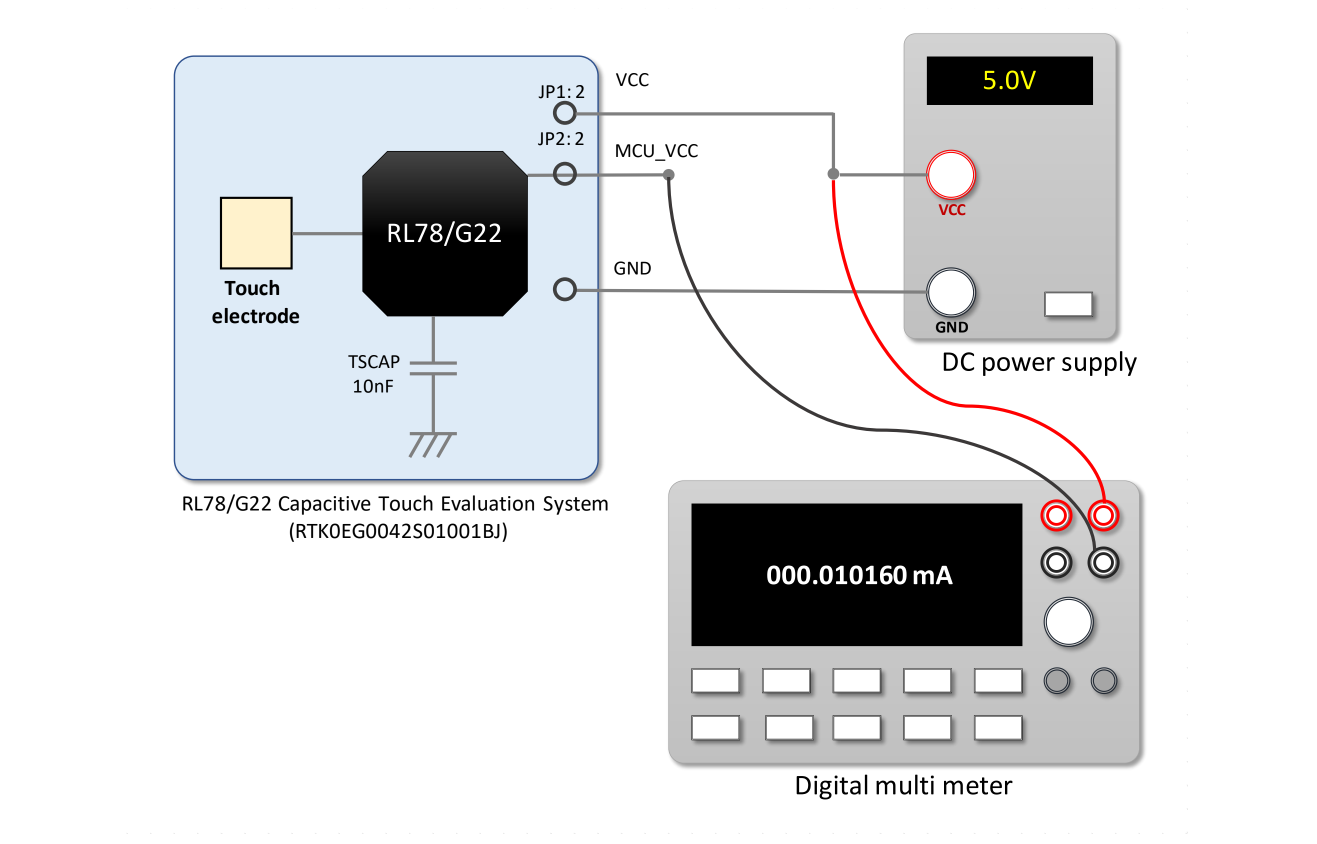



**Figure 8-2 Connect the RL78/G22 capacitive touch evaluation system CPU board and each equipment**

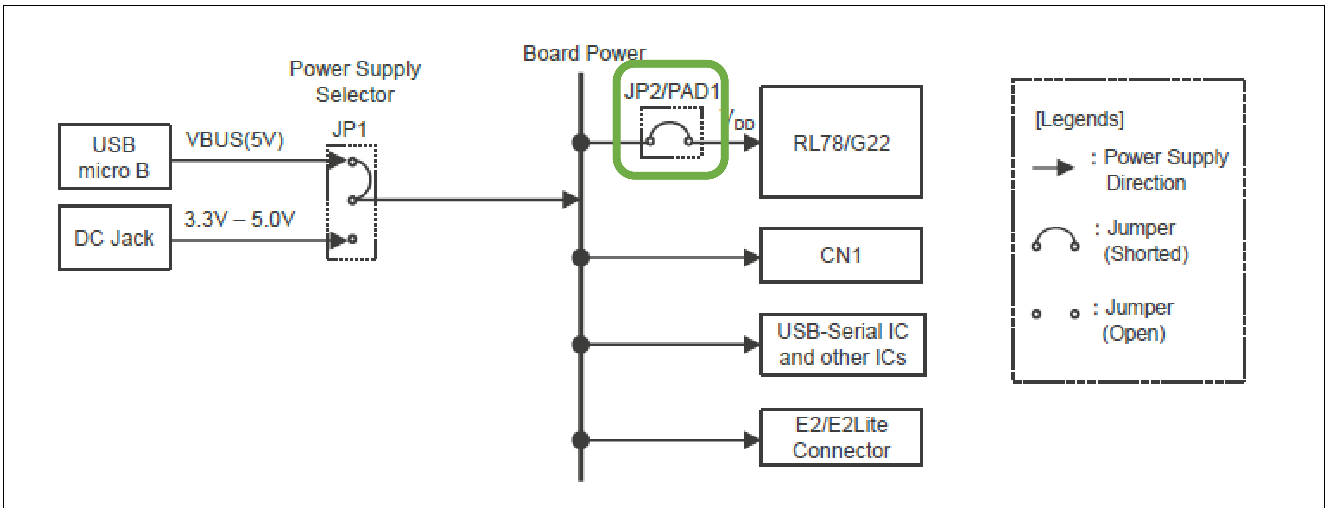



**Figure 8-3 Power supply system diagram for the RL78/G22 capacitive touch evaluation system CPU board**

## 8.4 RL78/G22 Capacitive Touch Evaluation System CPU Board

Figure 8-4 shows the pins of RL78/G22 Capacitive Touch Evaluation System CPU Board to be connected to the digital multimeter and the 16-pin and 32-pin wires of the Application Header (CN2). Table 8-2 shows the jumper settings on RL78/G22 Capacitive Touch Evaluation System CPU Board.

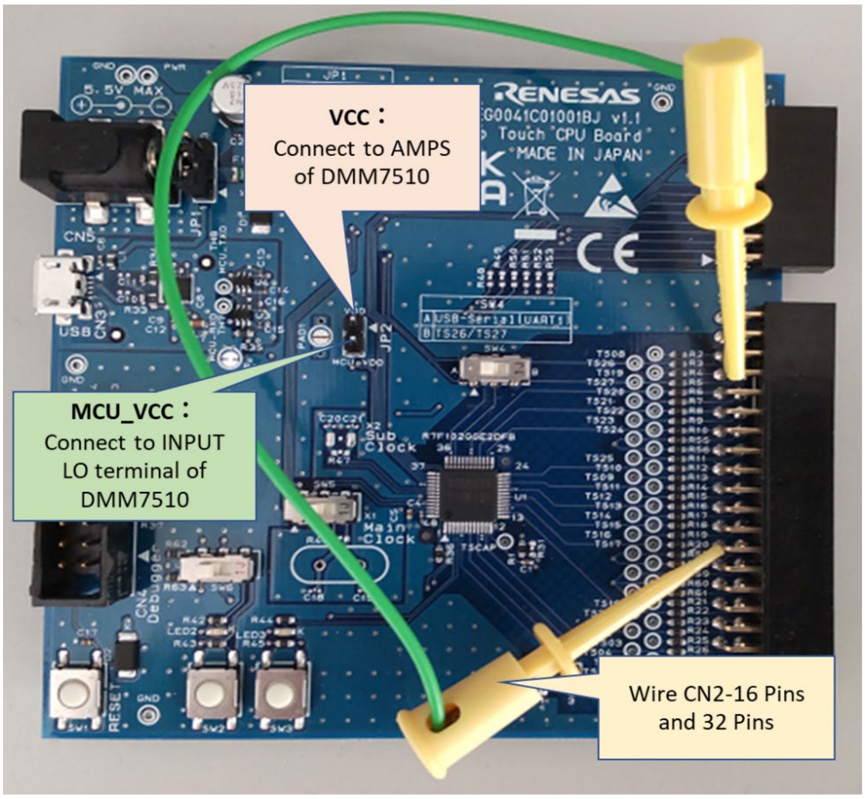



**Figure 8-4 Pins of CPU board connected to the digital multimeter**

**Table 8-2 CPU board jumper settings**

| Position | Circuit group | Jumper setting | Use |
|---|---|---|---|
| JP1 | VCC power | Shorted pin 2-3 | Power supply from CN5 |
| JP2 | MCU_VCC_power | Open | Measure current consumption |
| SW4 | USB-Serial Conversion/Application Header (CN2) | OFF | Using P00/TS26/TxD1, P01/TS27/RxD1 as a serial communication terminal |
| SW5 | Clock Circuit/Application Header (CN1) | OFF | Use P121/X1, P122/X2 as GPIO (CN1) |
| SW6 | Push-Switch LED/ Application Headers (CN1) | OFF | Use P61, P62 as GPIO (CN1) |
| SW7 | Capacitance touch | OFF | Using TS01 as Normal CTSU Pin |

## 8.5 Settings of current measuring software

Figure 8-5 shows settings of KEITHLEY/KickStart software to measure current consumption.

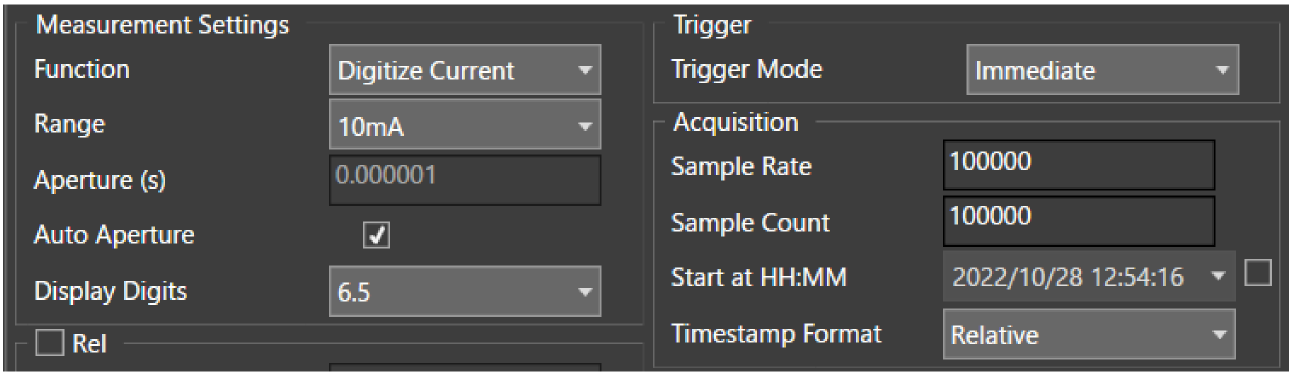



**Figure 8-5 Settings of KEITHLEY/KickStart software**

# 9. Current consumption measurement result

## 9.1 Current consumption waveform in intermittent operation

Figure 9-1 shows the Current consumption waveform in intermittent operation with touch measurement every 100 ms.

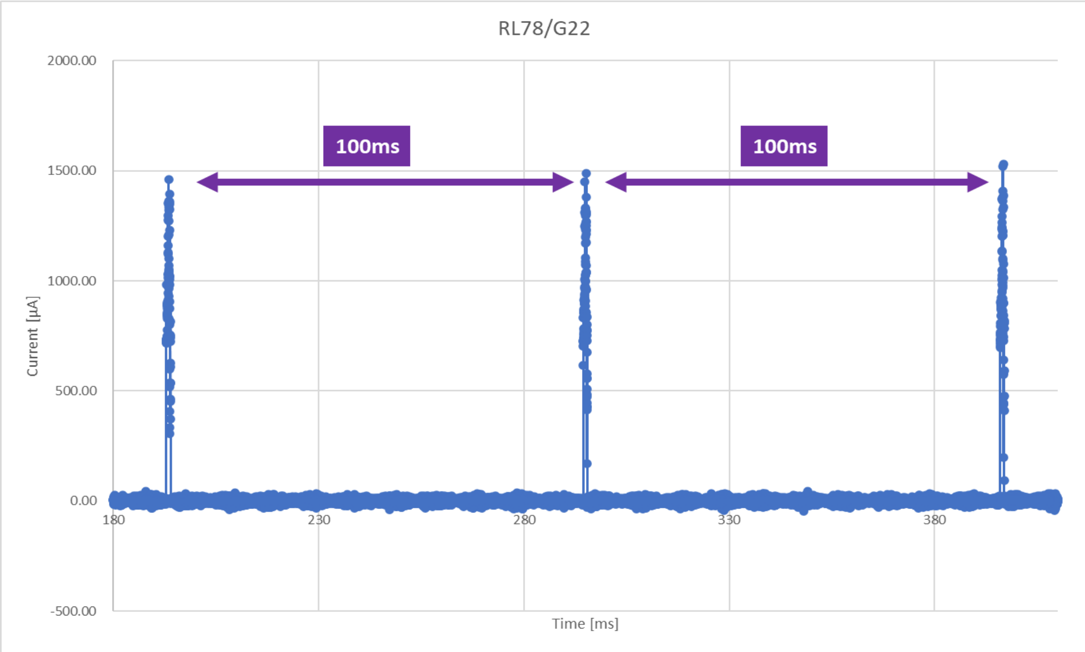



**Figure 9-1 Current waveform in intermittent operation with touch measurement every 100 ms**

## 9.2 Current Consumption When Transiting to CPU (Touch Measurement Using SMS/MEC)

Figure 9-2 shows the current consumption waveform when the CPU operation mode transitions to STOP mode and SNOOZE mode (touch measurement processing + touch on/off determination processing).

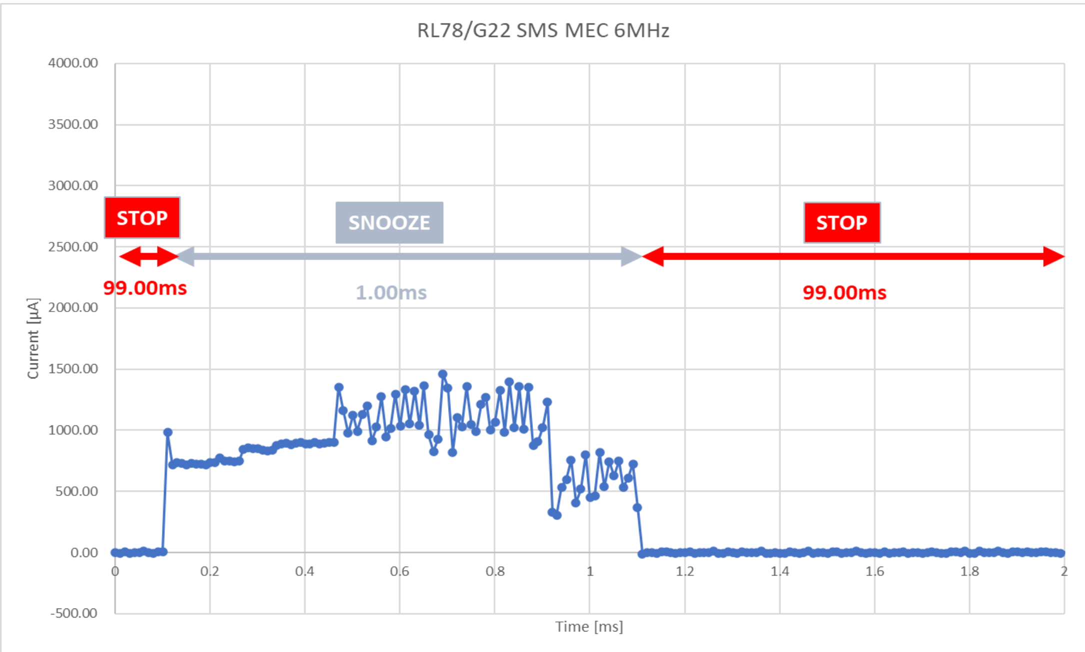
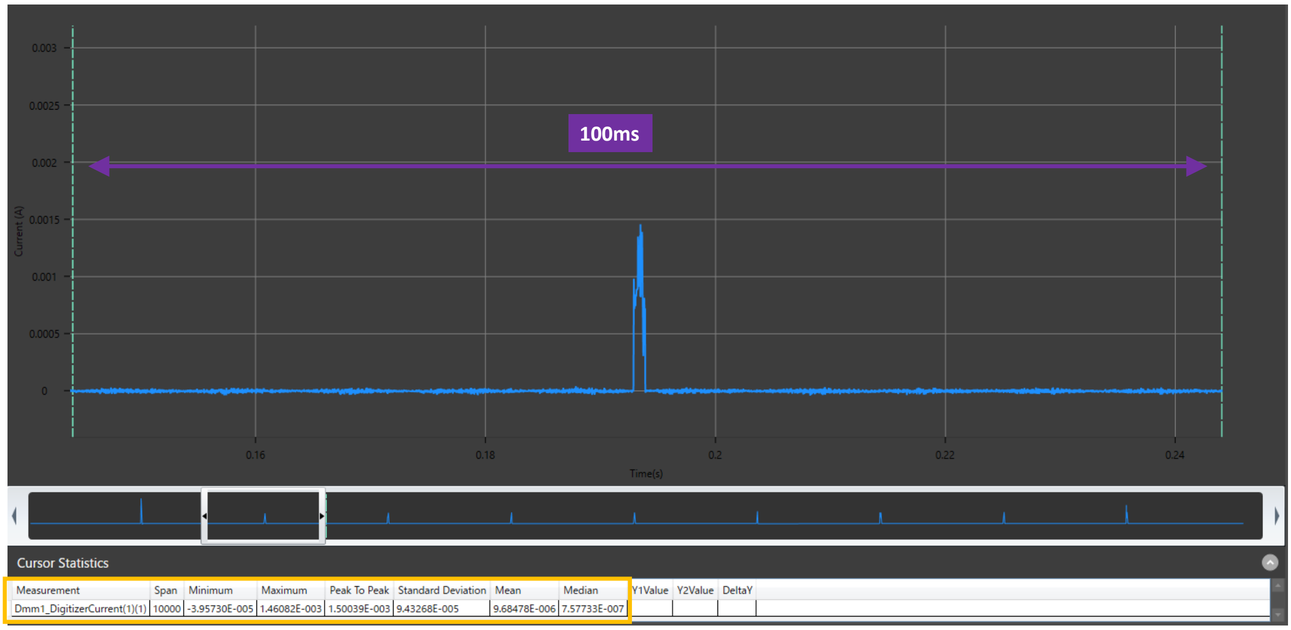



**Figure 9-2** MEC Measurement of Current Consumption (Touch-Measurement Using SMS/MEC)

## 9.3 Current Consumption Calculation (Touch-Measurement Using SMS/MEC)

Figure 9-3 shows the average current consumption of 100 ms cycle by the KEITHLEY/KickStart software.




| Measurement | Span | Minimum | Maximum | Peak To Peak | Standard Deviation | Mean | Median |
|---|---|---|---|---|---|---|---|
| Dmm1_DigitizerCurrent(1)(1) | 10000 | -3.95730E-005 | 1.46082E-003 | 1.50039E-003 | 9.43268E-005 | 9.68478E-006 | 7.57733E-007 |

**Figure 9-3** Current Consumption (Touch-measurement using SMS/MEC)

Current consumption (touch measurement cycle of 100 ms) = **9.6848 μA**

## 10. Related Document

RL78/Gxx User’s Manual: Hardware
- RL78/G22 User’s Manual: Hardware (R01UH0978)

RL78 Family User's Manual: Software (R01US0015)
(The latest version can be downloaded from the Renesas Electronics website.)

Technical Update/Technical News
(The latest version can be downloaded from the Renesas Electronics website.)

User's Manual：Development Environments
(The latest version can be downloaded from the Renesas Electronics website.)

User's Manual：RL78/G22 Capacitive Touch Evaluation System（RTK0EG0042S01001BJ)
(The latest version can be downloaded from the Renesas Electronics website.)

Application Note RL78 Family Capacitive Touch Sensing Unit (CTSU2L) Operation Explanation (R01AN5744)
Application Note RL78 Family
Using QE and SIS to Develop Capacitive Touch Applications (R01AN5512)
Application Note RL78 Family CTSU Module Software Integration System (R11AN0484)
Application Note RL78 Family TOUCH Module Software Integration System (R11AN0485)
Application Note Capacitive Sensor Microcontrollers CTSU Capacitive Touch Electrode Design Guide (R30AN0389)
(The latest version can be downloaded from the Renesas Electronics website.)

## Website and Support

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

Capacitive Sensing Unit related page
https://www.renesas.com/solutions/touch-key
https://www.renesas.com/qe-capacitive-touch

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

## Revision History

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 1.00 | Mar.14.23 | - | First edition issued |
| 1.10 | Jul.19.23 | 4 | Table 3-1 Operation environment, updated |
| | | 5 | Table 3-3 Option Byte Settings, added |
| | | 7 | Figure 5-1 Components, updated |
| | | 10 | Renamed “7.Current measurement software flow chart” to “7.Sample Project flow chart” |

# 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.

## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
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## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

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