RL78 Family

RL78/G23 Capacitive Touch Low Power Guide (SNOOZE function)

Introduction

This application note explains the electrostatic Capacity Touch measurement that uses the 32-bit Interval Timer (TML32) and the SNOOZE function of CTSU2L installed in RL78/G23.

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.

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1. Specification

1.1 Project description

Sample code that this application note describes is confirmed to operate on the RL78/G23 Capacitive Touch Evaluation System (RTK0EG0030S01001BJ). The setting of this project is adjusted to R7F100GSN2DFB implemented on the RL78/G23 Capacitive Touch Evaluation System. Modify the device setting in the project when you use the other device.

1.2 Used Peripherals

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

Table 1 - 1 Peripherals in the sample code

Used Peripherals	Functions
Capacitive Sensing Unit (CTSU2L)	Measures electrostatic capacitance of the touch sensor.
Data transfer controller (DTC)	- Transfers the set values of the CTSUSO0 and CTSUSO1 registers at the time of touch measurement from RAM to the CTSU register (SFR). - Transfer the count value of the CTSUSC register from the CTSU register (SFR) to RAM.
32-bit interval timer (TML32)	Timer to release STOP mode and transition to SNOOZE mode (measurement cycle: 100 ms).
Logic and event link controller (ELCL)	Interrupt source: Sets INTITL (interval signal detection of 32-bit interval timer) to an event signal and generates an external trigger to transition from STOP mode to SNOOZE mode.

1.3 CPU Operation Mode

Table 1 - 2 lists CPU operation mode used in this sample code.

Table 1 - 2 CPU operation mode

CPU operation mode	Transition condition
STOP mode	In the processing of the RM_TOUCH_ScanStart function, the CAP bit of the CTSUCRAL register is set to "1", the SNZ bit is set to "1", and then the STRT bit is set to "1". After that, transition to the STOP mode by executing the STOP instruction.
SNOOZE mode (touch measurement processing)	When the TML32 interrupt source is generated during STOP mode and the falling edge of the external trigger from ELCL is detected, the MCU transitions to SNOOZE mode.
Normal mode (Touch measurement end processing and Touch On/Off judgment processing)	When the measurement end interrupt occurs, the MCU transitions to the normal mode (CPU processing is executed).

1.4 CTSU Operation Status

Table 1 - 3 lists CTSU operation status used in this sample code.

Table 1 - 3 CTSU operation status

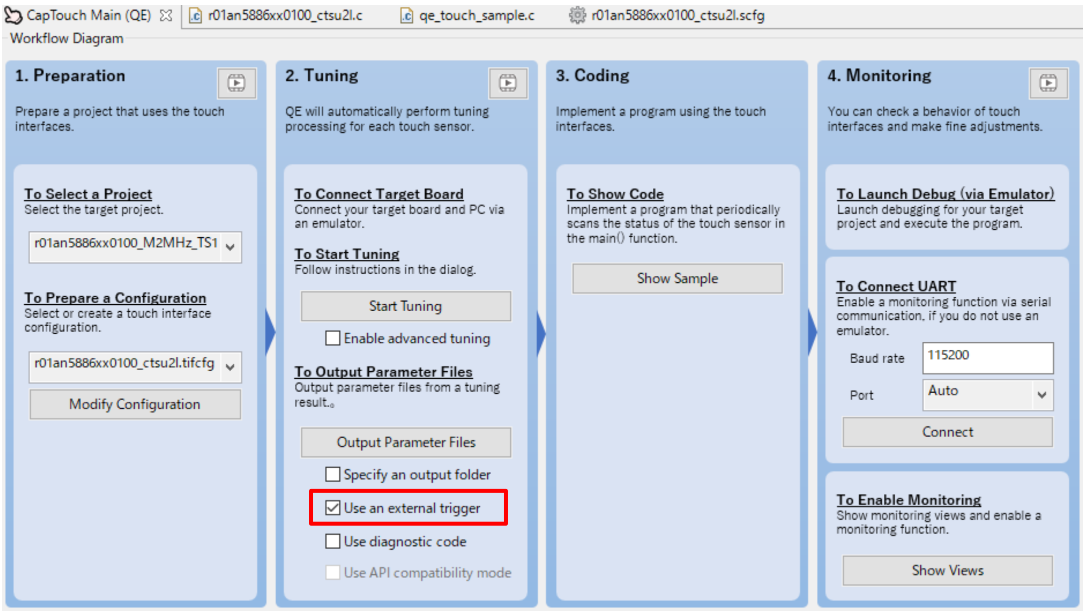
CTSU operation status Note	Transition condition
Operating (during touch measurement in the SNOOZE mode)	Touch measurement start
Suspended (waiting for an external trigger)	Touch measurement stop

Note. For details of the setting conditions, refer to <CTSU hardware state control> in the RL78/G23 User's Manual: Hardware.

1.5 Project Settings

For details on this project setting, check the component configuration in the Smart Configurator.
Also, in this project, "Use an external trigger" is enabled in QE for Capacitive Touch as shown in Figure 1 - 1.

Figure 1 - 1 Setting to select external trigger in QE for Capacitive Touch



1.6 File Configuration

Table 1 - 4 lists the file added or changed in the sample code generated by Smart Configurator and QE for Capacitive Touch.

Table 1 - 4 Files added or changed in the sample code

File name	Outline	Remarks
r01an5886xx0100_ctsu2l.c	Main processing	Changed file
mcu_clocks.c	Clock setting	Changed the setting value of CMC register (Connection of unused pins for P123 and P124)
qe_touch_sample.c	Touch measurement control processing	Changed file

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 check conditions

Item	Description
Microcontroller used	RL78/G23 (R7F100GSN2DFB)
Operating frequency	• Main system clock High-speed on-chip oscillator (f_{IH}) : 32 MHz • CPU/peripheral hardware clock (f_{CLK}) : 32 MHz • Subsystem clock Low-speed on-chip oscillator (f_{IL}) : 32.768 kHz Low-speed peripheral clock frequency (f_{SXP}) : 32.768 kHz
Operating voltage	5.0 V (can be operated at 1.8 V to 5.5 V Note) LVD0 detection voltage: Reset mode At rising edge TYP. 1.69 V (1.64 V to 1.74 V) At falling edge TYP. 1.65 V (1.60 V to 1.70 V)
Target board	RL78/G23 Capacitive Touch Evaluation System (RTK0EG0030S01001BJ)
Integrated Development Environment (e^2 studio)	e^2 studio V2021-07 (21.7.0) from Renesas Electronics Corp.
Smart configurator (SC)	V1.1.0 (version: 21.7.0) from Renesas Electronics Corp.
C compiler (e^2 studio)	CC-RL V1.10.00 from Renesas Electronics Corp.
QE for Capacitive Touch	V2.0.0 from Renesas Electronics Corp.

Note. When using boost power on (PUMPON bit of CTSUCRAL register = 1) and measurement power-supply voltage = 1.2 V (ATUNE0 bit of CTSUCRAL register = 1). Depending on the power supply voltage (V_{DD}), the available boost power on and measurement power-supply voltage settings are different.

This sample code uses the SIS drivers/middleware and Code Generator shown in Figure 2 - 1.

Figure 2 - 1 Components of Smart Configurator

Component	Version	Configuration
Board Support Packages. - v1.12 (r_bsp)	1.12	r_bsp(used)
Capacitive Sensing Unit driver. (r_ctsu)	1.10	r_ctsu(used)
Interval Timer	1.0.0	Config_ITL000(ITL000: used)
Ports	1.0.0	Config_PORT(PORT: used)
Touch middleware. (rm_touch)	1.10	rm_touch(used)

3. Software Description

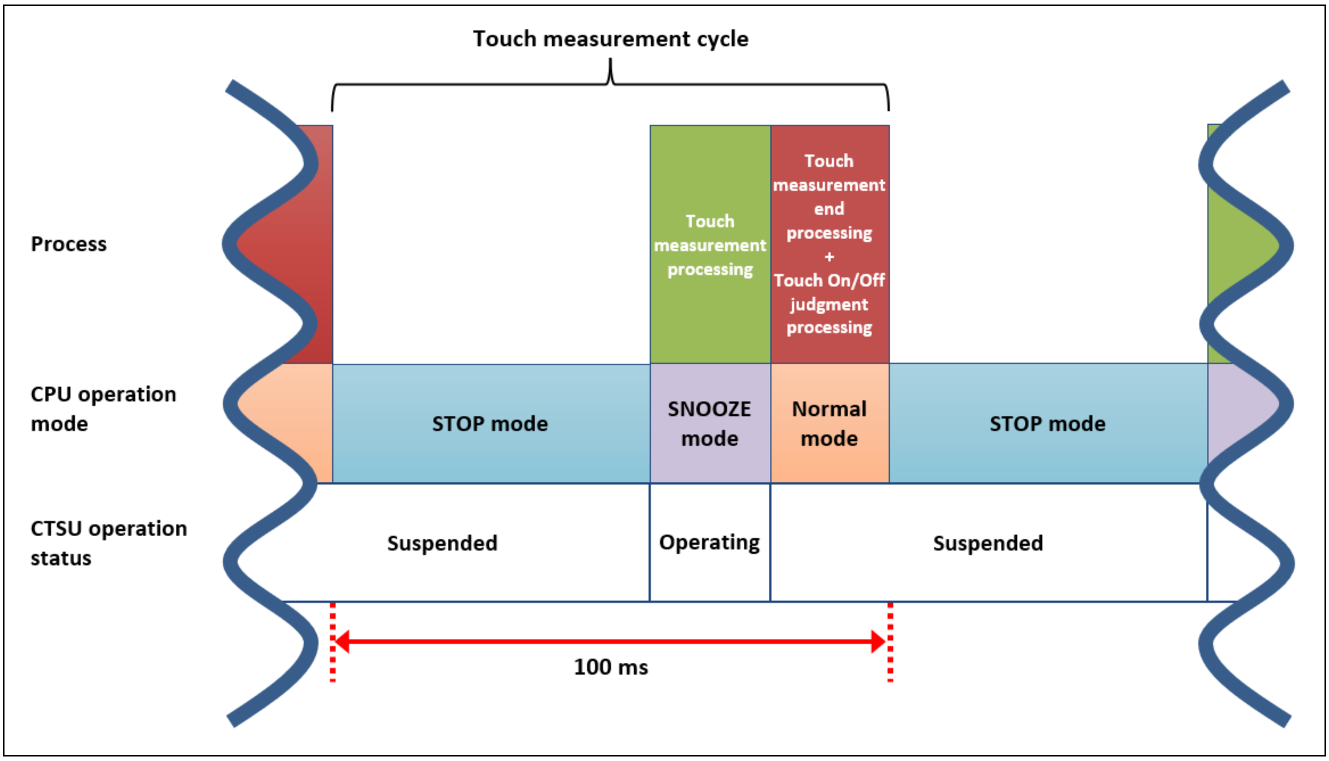
The sample code operates as follows by using the SIS drivers/middleware and Code Generator.

1. After reset release by power-on, RM_TOUCH_Open function is executed to initialize CTSU.
2. Select the event source for the CTSU in the ELCL.
3. By executing the RM_TOUCH_ScanStart function, set the touch measurement setting and SNOOZE function to enable, and then goes to the external trigger wait state.
4. Start the TML32 (measurement cycle: 100 ms).
5. Transition to STOP mode by executing the STOP instruction.
6. When the TML32 interrupt source is generated during STOP mode and the falling edge of the external trigger from ELCL is detected, transition to SNOOZE mode and start touch measurement.
7. When the measurement end interrupt occurs, transition to normal mode to execute CPU processing.
8. Get the measurement results and turn on the LED1 when touch-on is detected. When touch-off is detected, turn off the LED1.
9. Repeat from step 5 to step 8.

3.1 Operation image

Figure 3 - 1 shows CPU operation mode and CTSU operation status according to the process in the sample code.

Figure 3 - 1 Operation image



3.2 List of Variables

Table 3 - 1 lists the global variable that is used by this sample program.

Table 3 - 1 Global variable

Type	Variable name	Description
uint64_t	button_status	Variable to check the button status
uint8_t	g_qe_touch_flag	Measurement completion flag

3.3 List of Functions

The specification for functions added or changed in this sample code are shown below.

3.3.1 main()

main()

Synopsis	Main processing.	
Declaration	void main(void)	
Explanation	Call the qe_touch_main().	
Argument	-	-
Return value	-	

3.3.2 qe_touch_main()

qe_touch_main()

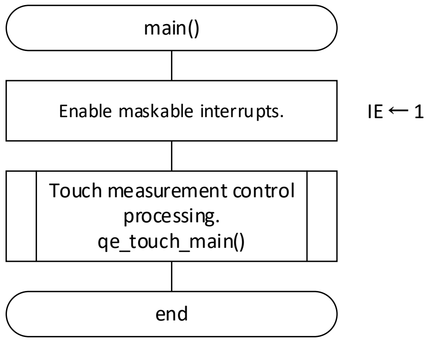
Synopsis	Touch measurement control processing.	
Declaration	void qe_touch_main(void)	
Explanation	Configure the touch measurement settings to use the SNOOZE function, and then control the touch measurement. Touch measurement is repeated, and each time a measurement result is obtained, LED1 is turn on when touch-on is detected, and LED1 is turn off when touch-off is detected.	
Argument	-	-
Return value	-	

4. Flowcharts

4.1 Main Processing

Figure 4 - 1 shows the flowchart for the main processing.

Figure 4 - 1 Main processing



4.2 Touch Measurement Control Processing

Figure 4 - 2, Figure 4 - 3 and Figure 4 - 4 show the flowchart for touch measurement control processing.

Figure 4 - 2 Touch measurement control processing (1/3)

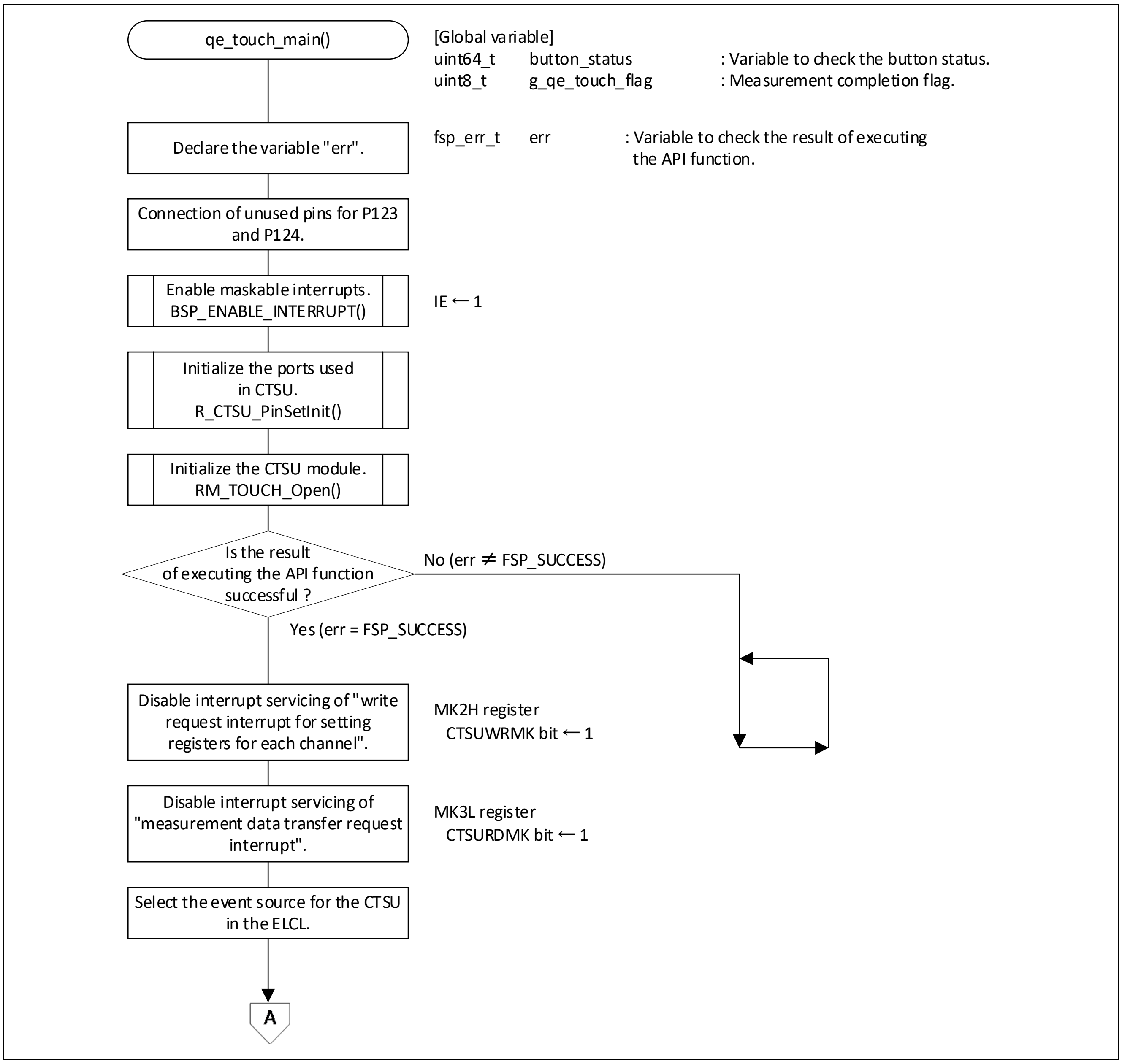


Figure 4 - 3 Touch measurement control processing (2/3)

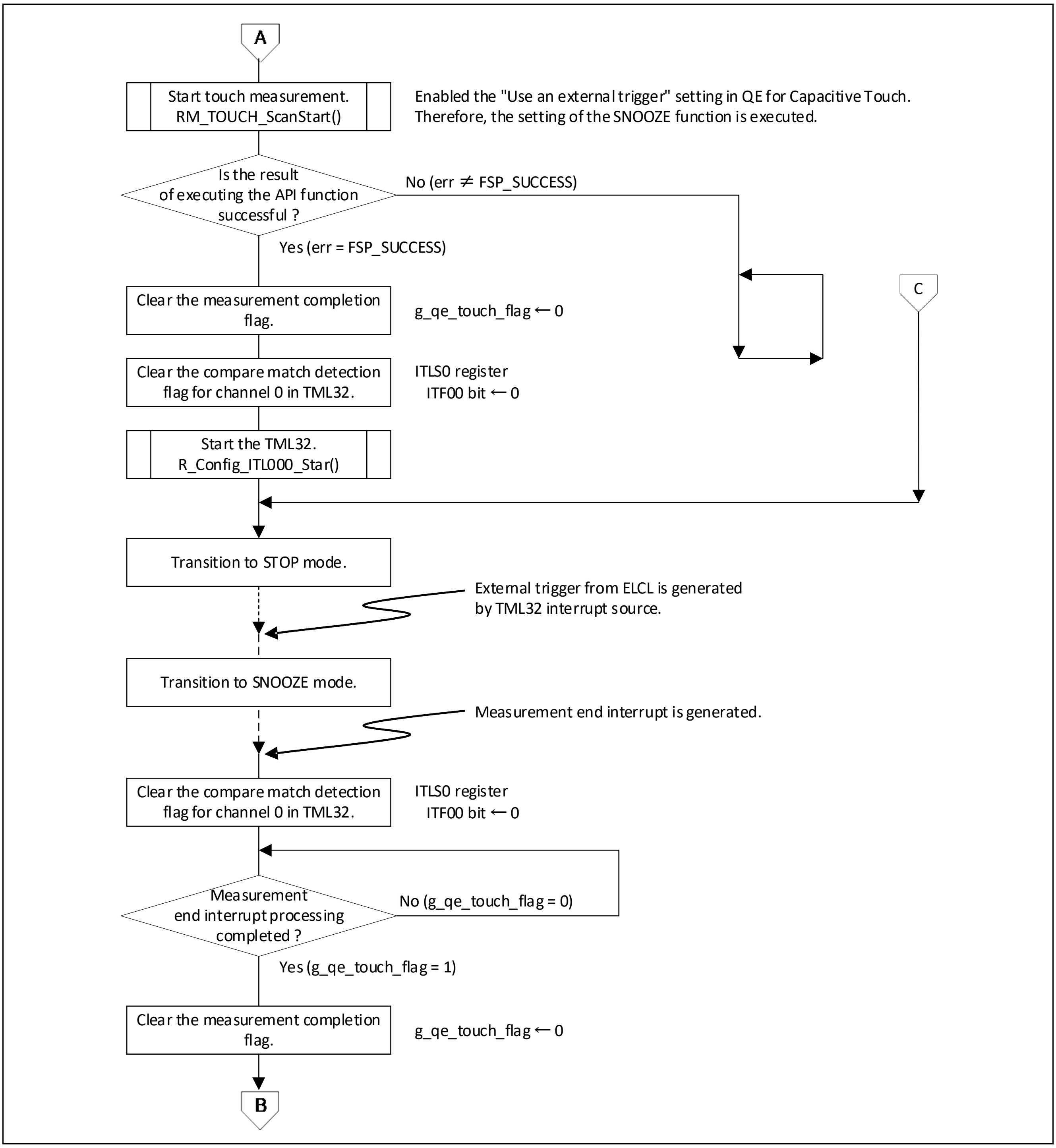
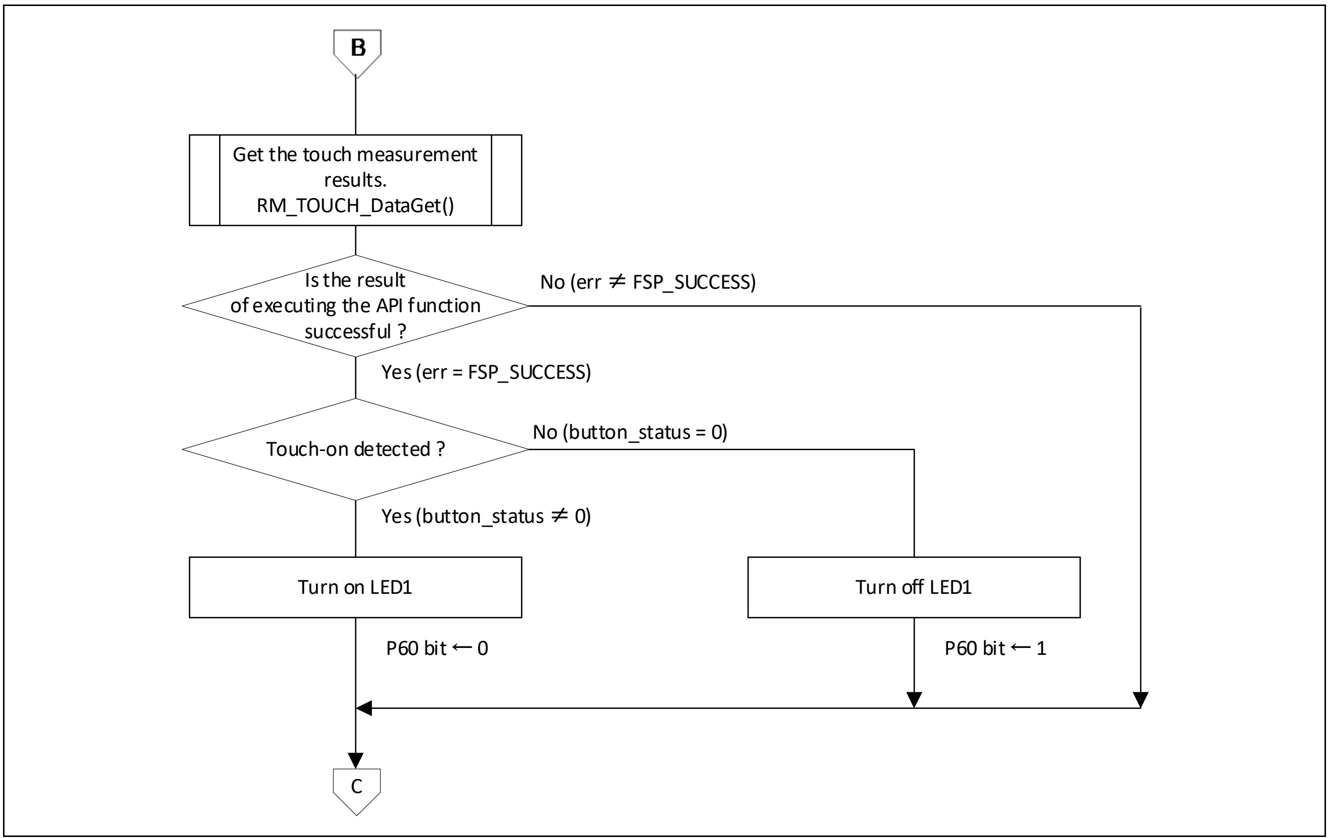


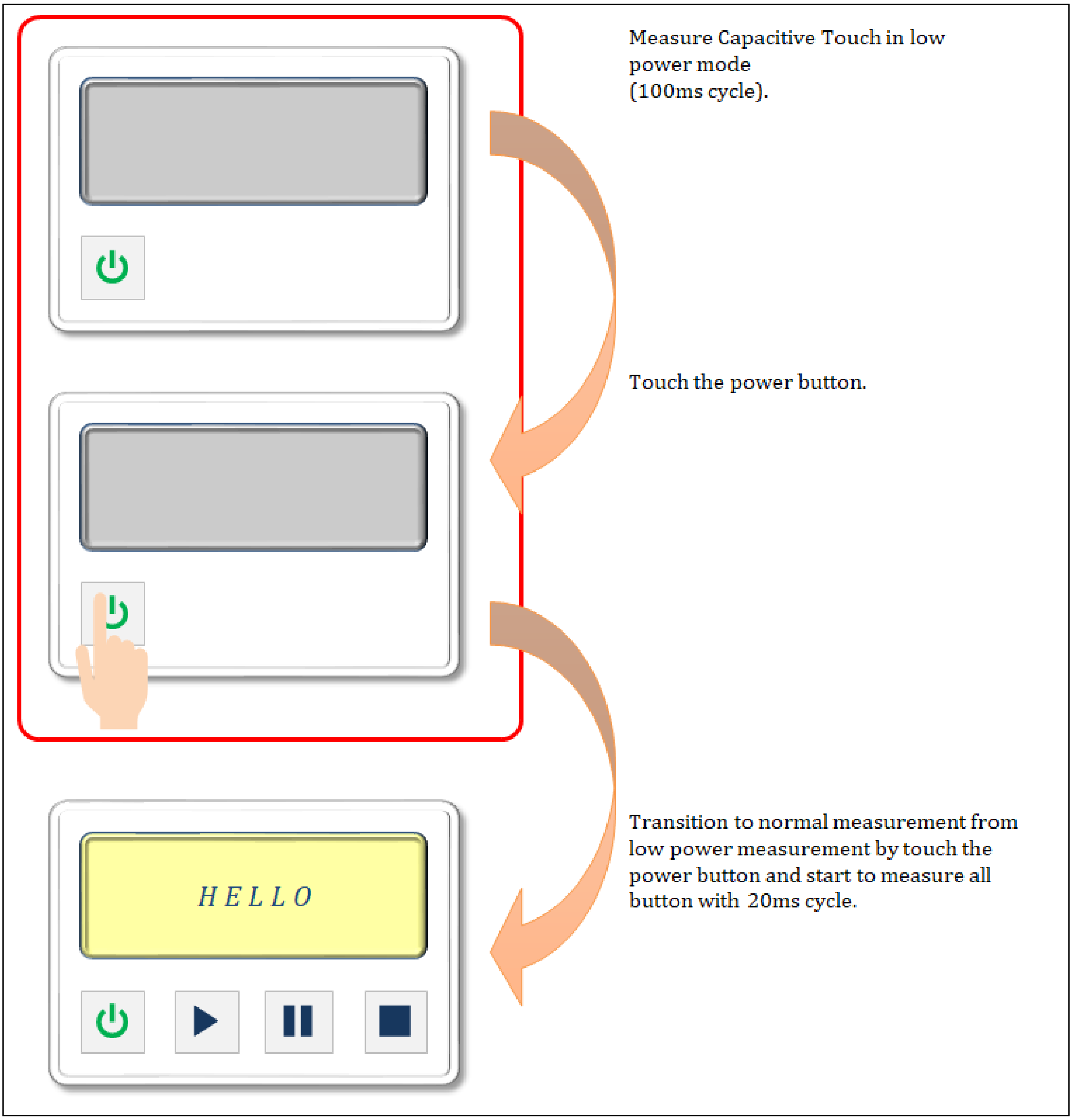
Figure 4 - 4 Touch measurement control processing (3/3)



5. Current consumption

The system configuration in the following red box shows a model of the electrostatic capacitive touch low power consumption operation described in this application note.

Figure 5 - 1 Model of the electrostatic capacitive touch low power consumption operation



5.1 Operation Conditions

Table 5 - 1 shows operation conditions.

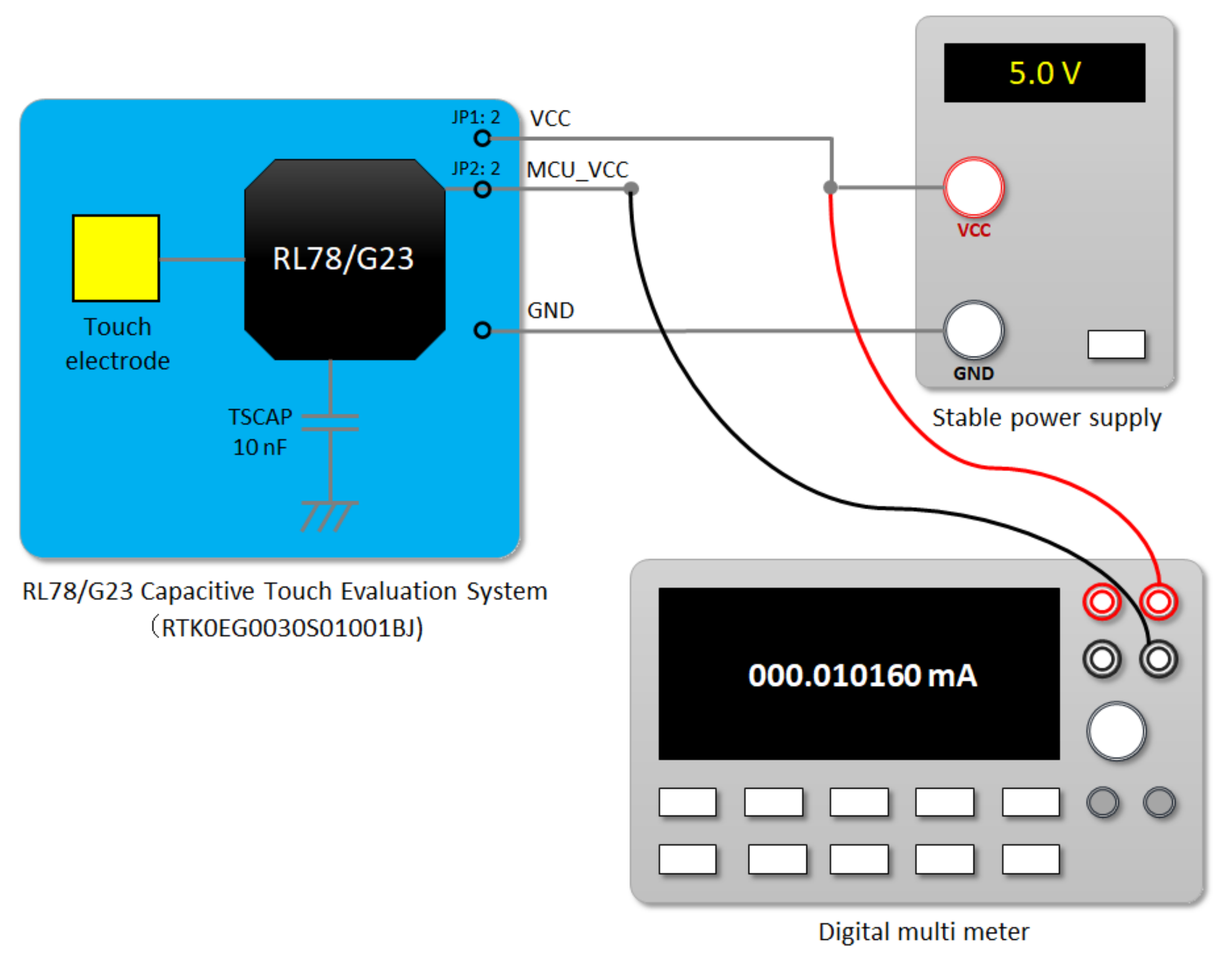
Table 5 - 1 Operation conditions

Item	Description
Touch measurement cycle	100 ms
Sensor drive pulse frequency	2.0 MHz
Touch Sensor (TS pin)	TS06
Measurement mode	Self-capacitance method (MD1 bit of CTSUCRAL register = 0)
Scan mode	Multi-scan mode (MD0 bit of CTSUCRAL register = 1)
Measurement start trigger	External trigger (ELCL) (CAP bit of CTSUCRAL register = 1)
Enables/Disables the SNOOZE function	Enables the SNOOZE function (SNZ bit of CTSUCRAL register = 1)
Boost power	Boost power on (PUMPON bit of CTSUCRAL register = 1)
Measurement power-supply	Measurement power-supply voltage = 1.2 V (ATUNE0 bit of CTSUCRAL register = 1)
Measurement power-supply current adjustment	40 µA (ATUNE1 bit of CTSUCRAL register = 1)
Non-measured pin output select	Low-level output (POSEL[1:0] bits of CTSUCRAH register = 00b)
Sensor drive pulse select	Sensor unit clock (SUCLK) mode (SDPSEL bit of CTSUCRAH register = 1, FCMODE bit of CTSUCRAH register = 1)
Sensor stabilization wait time	32 cycles (SST[7:0] bits CTSUCRBL register = 0x1f)
Measurement count setting	7 (SNUM[7:6] bits CTSUSO1 register = 00b, SNUM[5:0] bits CTSUSO0 register = 00111b)

5.2 Environment to measure current consumption

Figure 5 - 2shows environment to measure current consumption.

Figure 5 - 2 Environment to measure current consumption



5.3 Equipment and Software

Table 5 - 2 shows equipment and software used in current consumption measurement.

Table 5 - 2 Equipment and software

Type	Name	Use
Digital multi meter	Keithley DMM7510	Measure current consumption.
Stable power supply	KENWOOD PWR18-2TP	Supply power to RL78/G23 Capacitive Touch Evaluation System (RTK0EG0030S01001BJ) CPU board.
Software	Keithley KickStart Software	Get result of current consumption measurement from Keithley DMM7510 and output the result to log-file.

5.4 CPU board jumper settings

Table 5 - 3 shows jumper settings of RL78/G23 Capacitive Touch Evaluation System (RTK0EG0030S01001BJ) CPU board to measure current consumption.

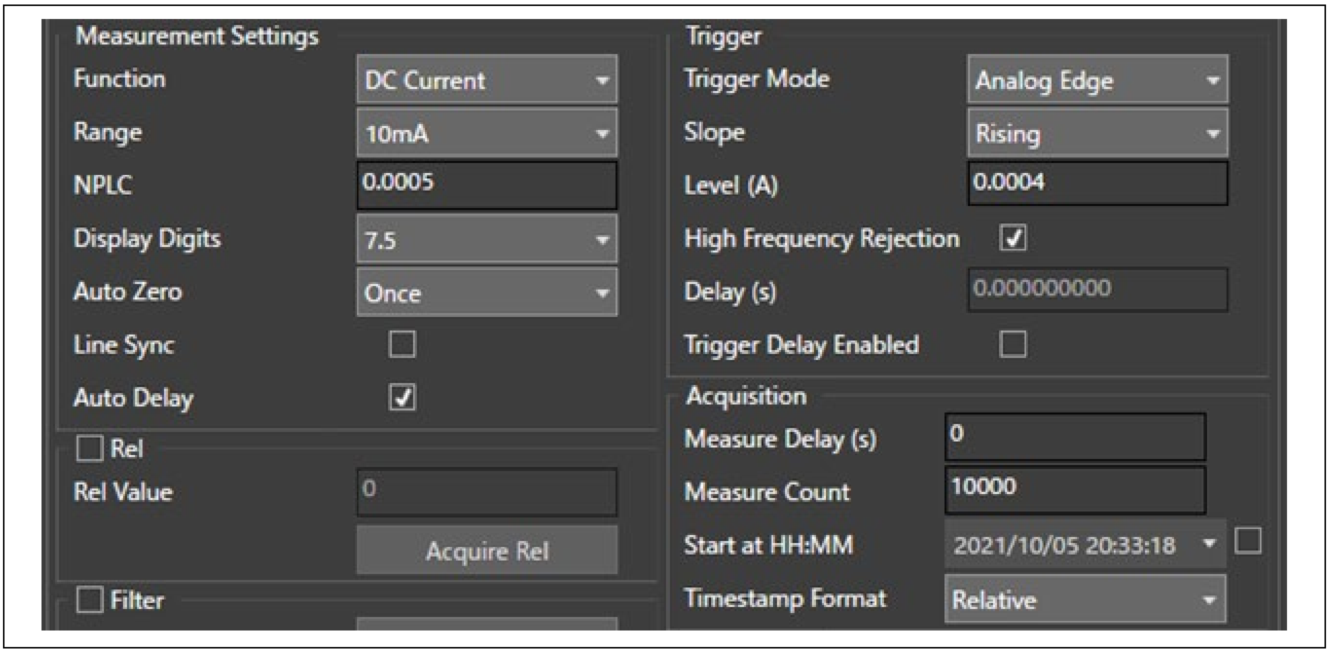
Table 5 - 3 CPU board jumper settings

Position	Circuit group	Jumper	Use
JP1	VCC power	Open	Power supply from JP1: 2
JP2	MCU_VCC power	Open	Measure current consumption
JP3	power supply jumper	Shorted pin 1-2	-
JP4	power supply jumper	Shorted pin 1-2	-

5.5 Setting to measure current consumption

Figure 5 - 3 shows settings of Keithley KickStart to measure current consumption.

Figure 5 - 3 Settings of Keithley KickStart to measure current consumption



5.6 Current Consumption Measurement Results

Figure 5 - 4 to Figure 5 - 7 show the current consumption waveforms for a series of operations in which the CPU operation mode transitions to STOP mode, SNOOZE mode (touch measurement processing), and Normal mode (Touch measurement end processing and Touch On/Off judgment processing).

Figure 5 - 4 and Figure 5 - 5 show the touch measurement at TS pin 1 channel.

Figure 5 - 6 and Figure 5 - 7 show the touch measurement at TS pin 32 channels.

However, the measurement time is short and the measurement error is large for one channel touch measurement. Therefore, in the program used to calculate the current consumption, the touch measurement is set to 32 channels and the touch measurement cycle is set to 1 second for the current consumption measurement.

Table 5 - 4 shows the results of current consumption measurement at TS pin 32 channels.

Figure 5 - 4 Current consumption waveform: TS pin 1ch measurement (1/2)

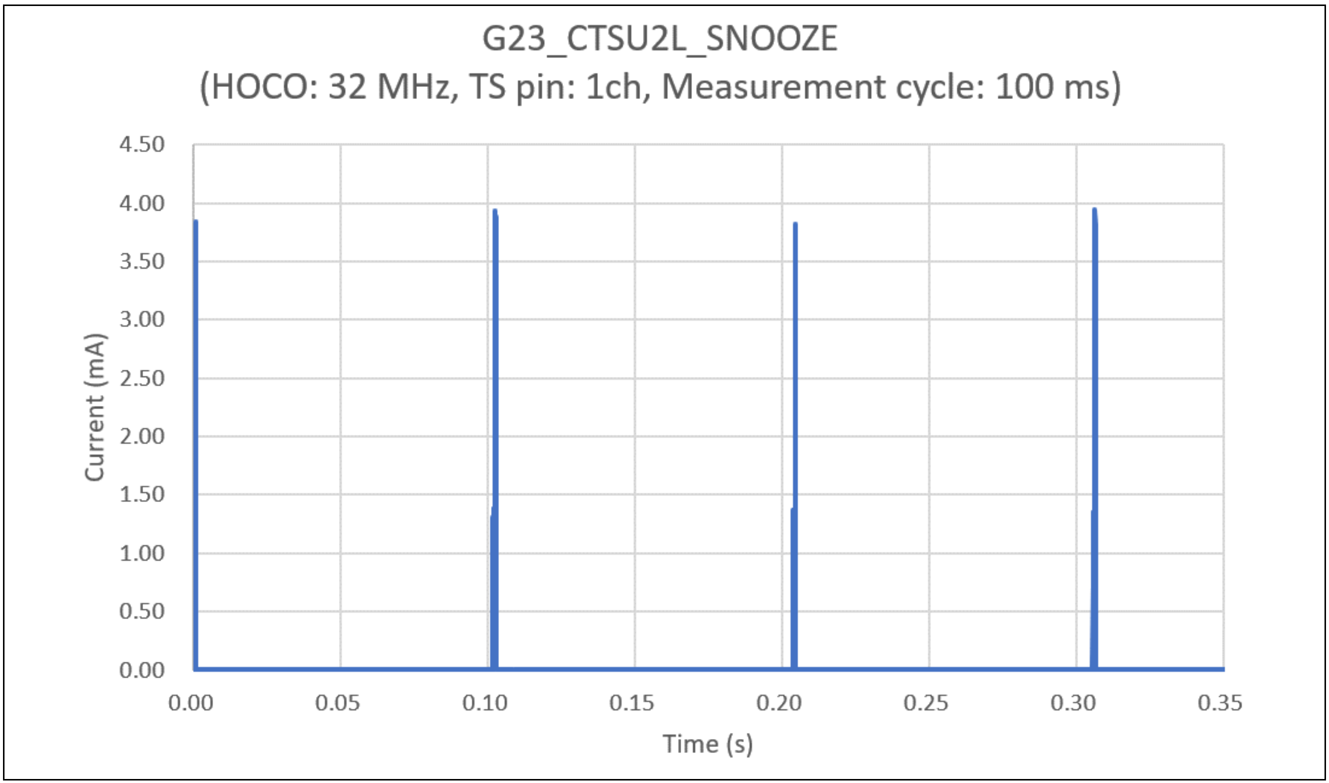


Figure 5 - 5 Current consumption waveform: TS pin 1ch measurement (2/2)

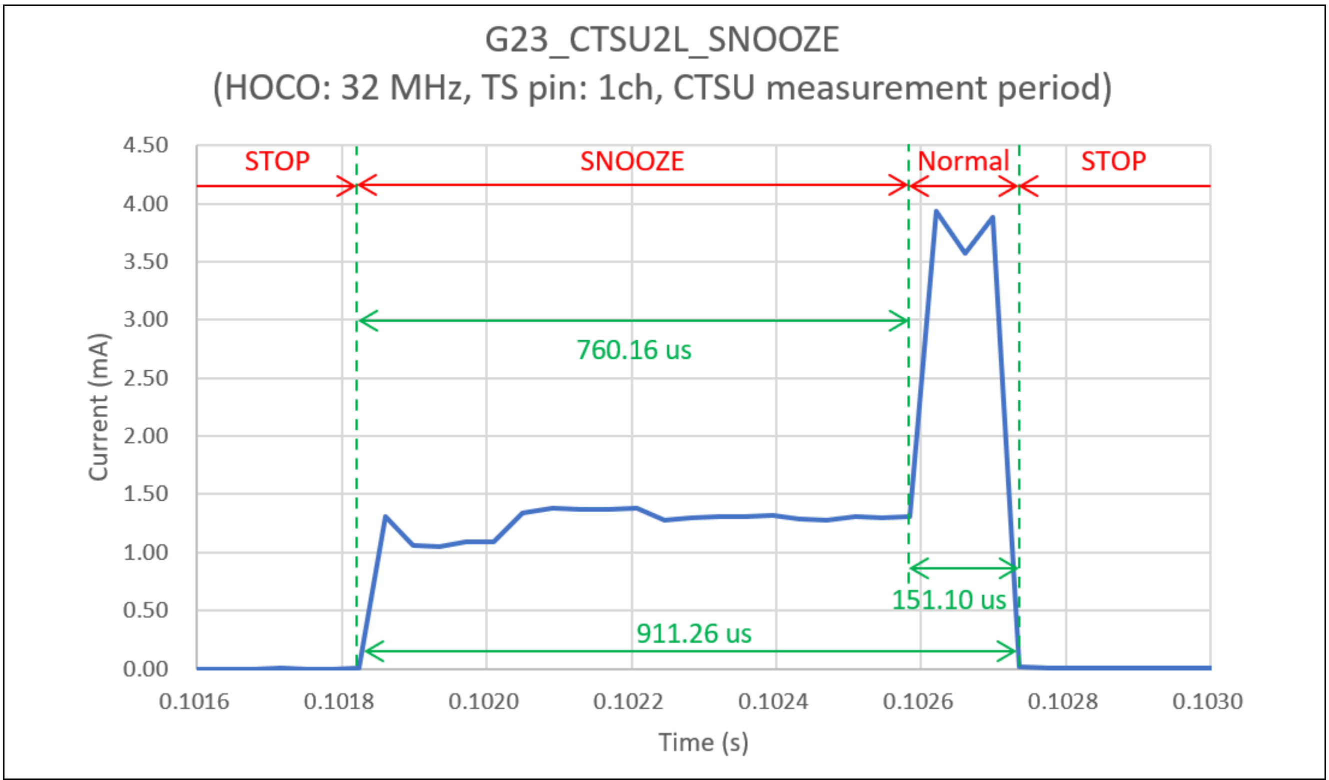


Figure 5 - 6 Current consumption waveform: TS pin 32ch measurement (1/2)

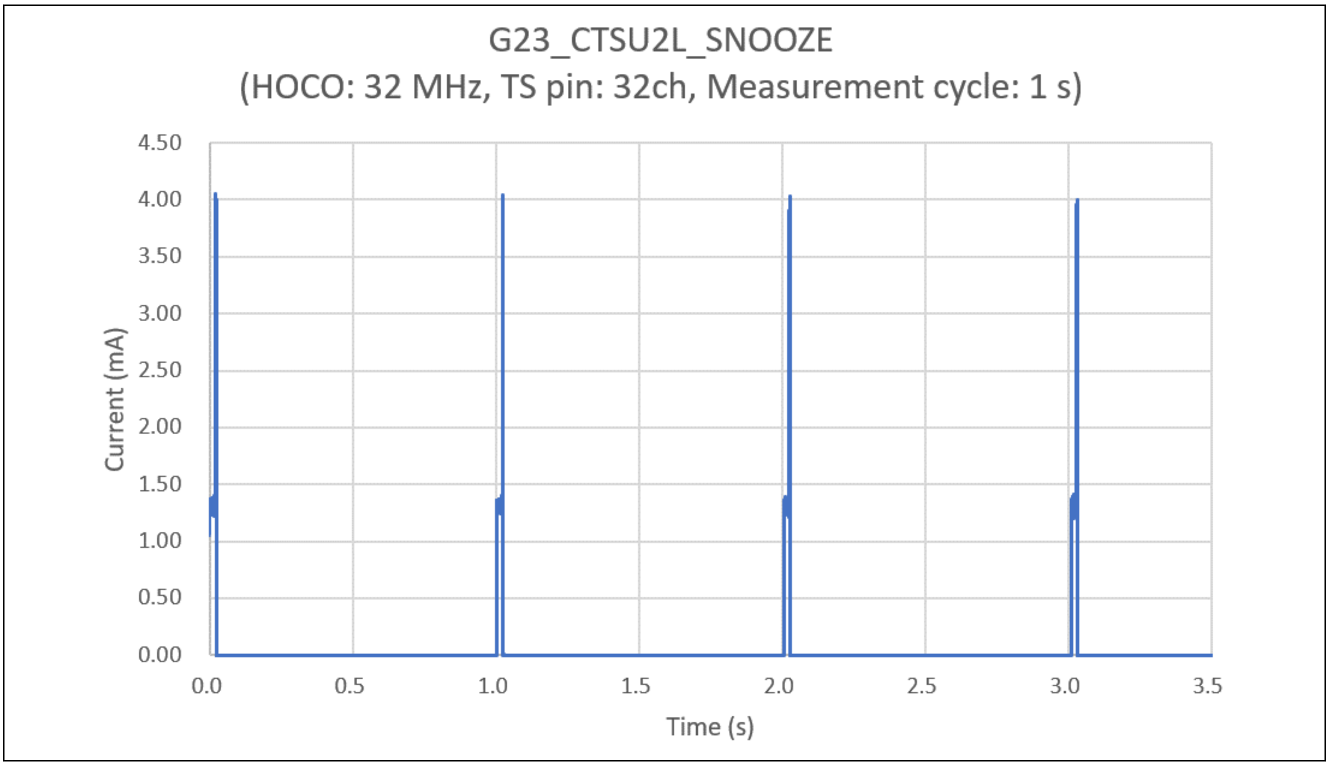


Figure 5 - 7 Current consumption waveform: TS pin 32ch measurement (2/2)

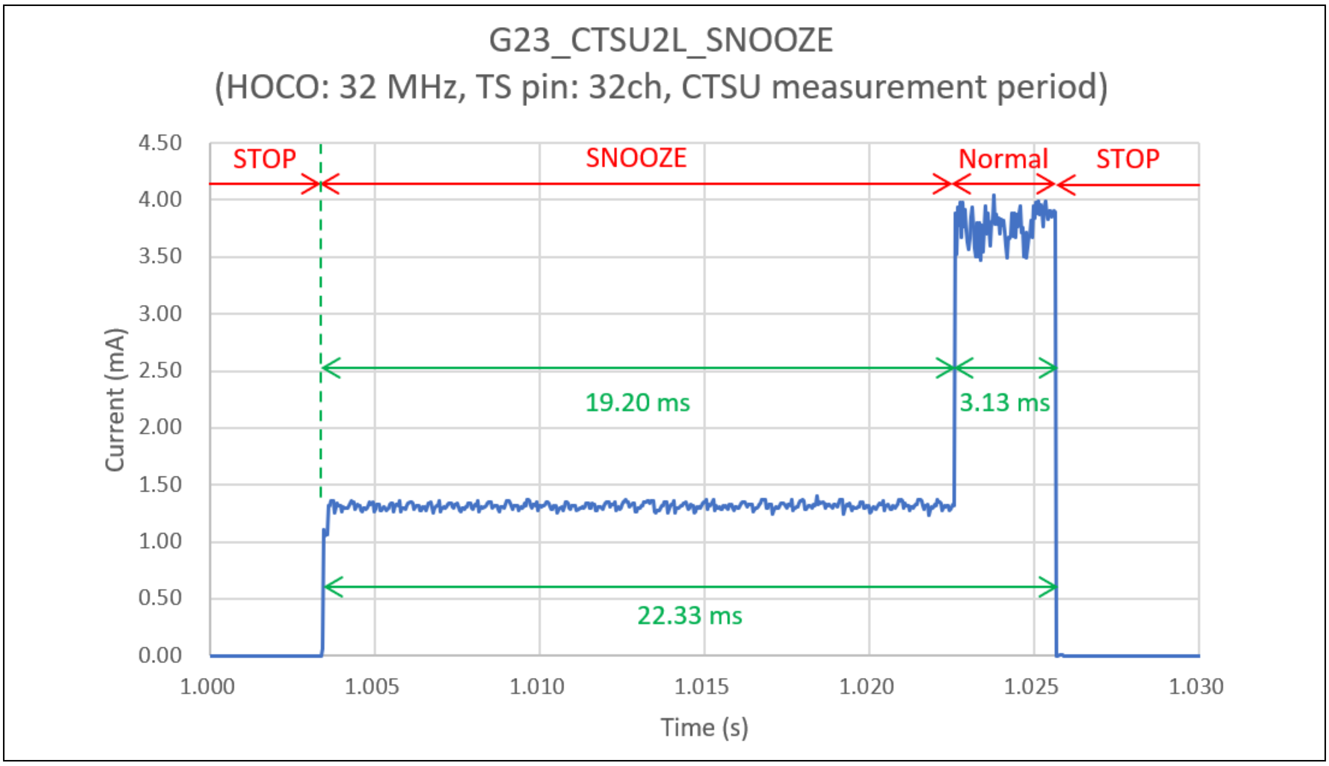


Table 5 - 4 Current consumption measurement results (TS pin 32ch measurement)

CPU operation mode	Time (ms)	Average current consumption (mA)
STOP mode	977.67	0.00084
SNOOZE mode (touch measurement processing) (32ch measurement)	19.20	1.31
Normal mode (Touch measurement end processing and Touch On/Off judgment processing) (32ch measurement)	3.13	3.71

5.7 Current Consumption Calculation Results

Using the measurement values in "Table 5 - 4 Current consumption measurement results (TS pin 32ch measurement)" and converting the TS pin to one channel and the touch measurement cycle to 100 ms, the " average current consumption of 100 ms cycle" is as shown below.

Figure 5 - 8 Operation timing of CTSU

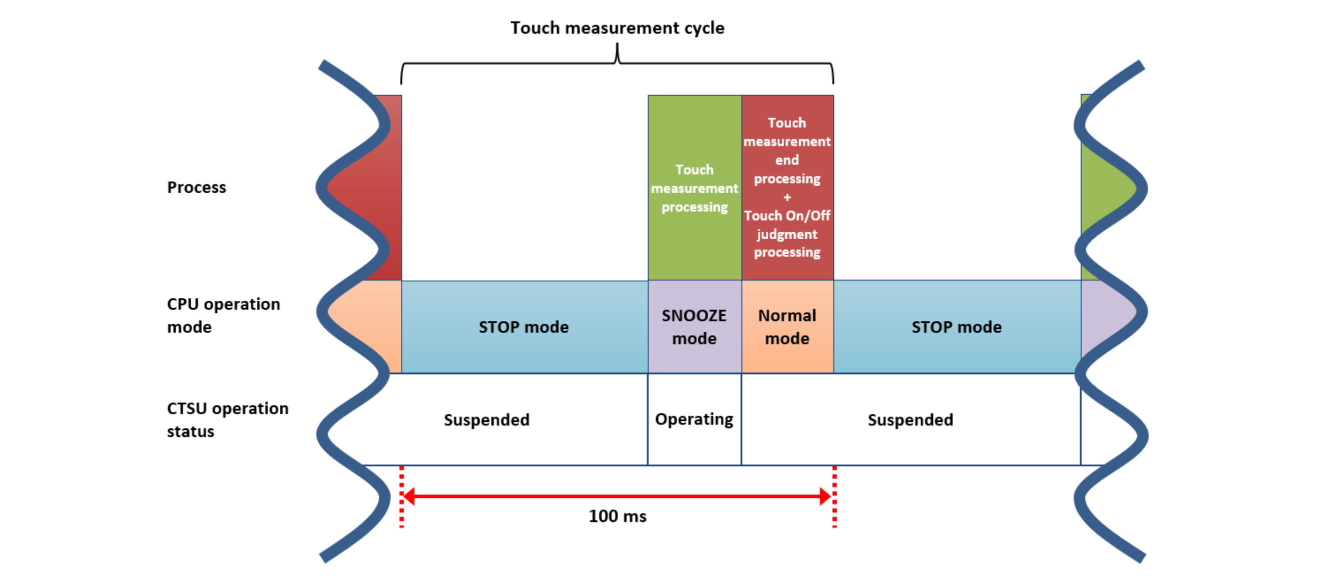


Table 5 - 5 Current consumption calculation results (TS pin 1ch measurement)

CPU operation mode	Time (ms)	Current consumption (uA)
STOP mode	100 – 0.60 – 0.10 = 99.30	$(0.00084 \times 10^3) \times 99.30$ ≈ 83.41
SNOOZE mode (touch measurement processing) (1ch measurement)	19.20 / 32 = 0.60	$(1.31 \times 10^3) \times 0.60$ ≈ 786.00
Normal mode (Touch measurement end processing and Touch On/Off judgment processing) (1ch measurement)	3.13 / 32 ≈ 0.10	$(3.71 \times 10^3) \times 0.10$ = 371.00
Total	100	1240.41

Average current consumption of 100 ms cycle = 1240.41 / 100

≈ 12.40 uA

6. Sample Code

The sample code is available on the Renesas Electronics Website.

7. Points for Caution when Using the Sample Code

7.1 The timing when the touch measurement result is determined

(1) Effect of Positive/Negative Noise Filter

The timing when the touch measurement result is determined depends on the setting of the positive noise filter/negative noise filter. In the sample code, the positive noise filter/negative noise filter cycle is set to "3". Therefore, the RM_TOUCH_DataGet function is called every touch measurement cycle to get the measurement result, and the touch measurement result is determined to be ON/OFF when the ON/OFF status is three times consecutively.

For details about positive noise filter /negative noise filter and how to change the setting value, see the application Note RL78 Family TOUCH Module Software Integration System (R11AN0485).

(2) Effect of moving average

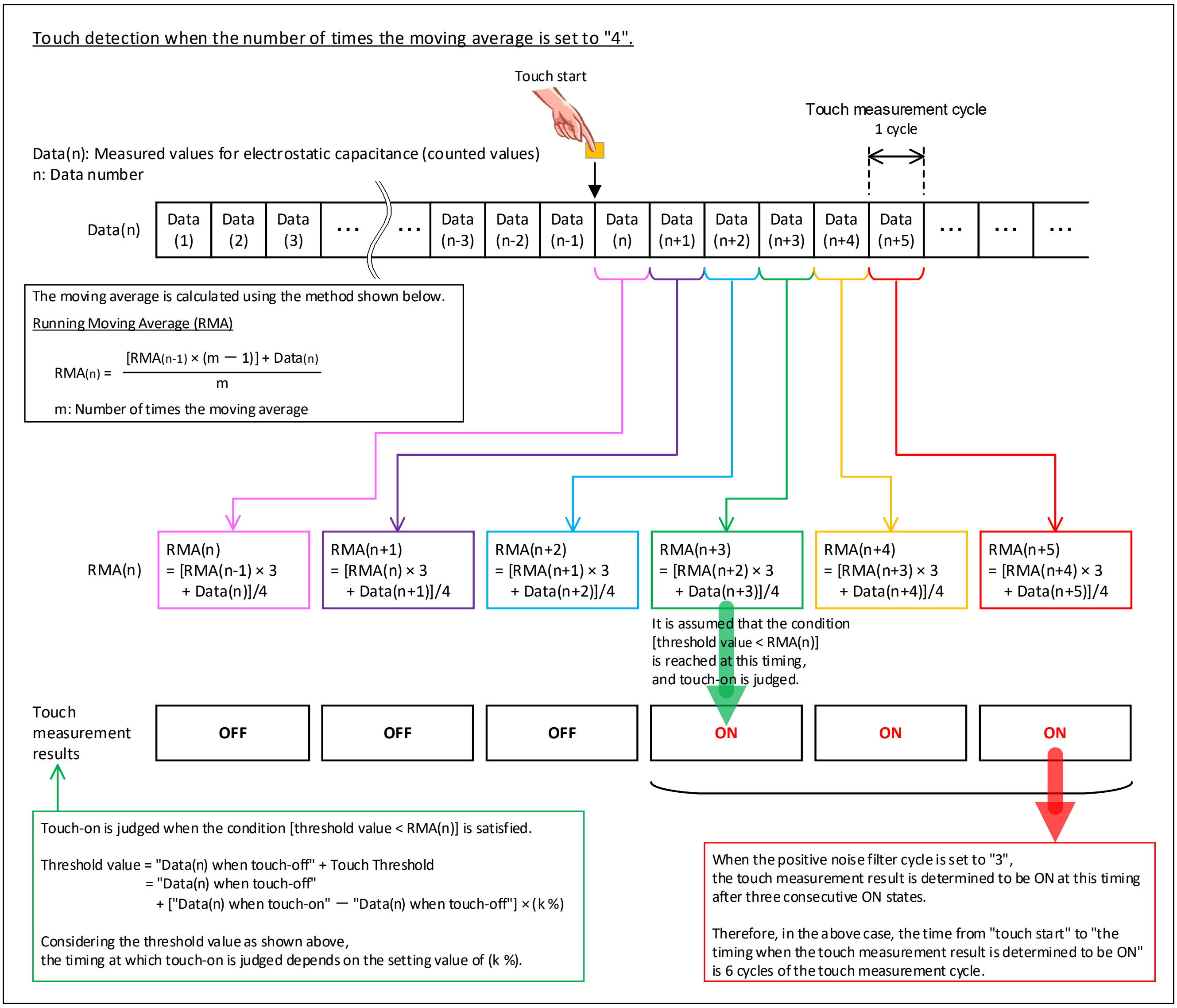
The timing when the touch measurement result is determined depends on the setting of the moving average.

In the sample code, the number of times the moving average is set to "4".

The number of times the moving average is set by the variable "num_moving_average" in the qe_touch_config.c file.

Figure 7 - 1 shows the example of moving average processing operation.

Figure 7 - 1 Example of moving average processing operation



8. Documents for Reference

RL78/Gxx User's Manual: Hardware

- 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.)

User's Manual: Development Tools

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

User's Manual: RL78/G23 Capacitive Touch Evaluation System (RTK0EG0030S01001BJ)

(The latest versions of the documents are available on 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 versions of the documents are available on 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	Nov.20.21	-	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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