

Capacitive Sensor Microcontrollers

CTSU Capacitive Touch Introduction Guide

Introduction

This application note is an introduction guide for customers who use the Capacitive Touch Sensor Unit (Capacitive Touch Sensing Unit: hereinafter referred to as CTSU) for the first time.

Target Device

RX Family, RA Family, and RL78 Family MCUs and Renesas Synergy™ embedding the CTSU (CTSU indicates CTSU2, CTSU2L, CTSU2SL, etc.)

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1. Outline

This application note is an introduction guide for customers who use the capacitive touch sensor for the first time.

This chapter introduces the principles and features of capacitive touch detection, MCU lineup, hardware, software, development environment, and evaluation kits (Capacitive Touch Evaluation System).

The first-generation capacitive touch sensor uses a third-party IP(SCU/TSCU) and is used in R8C family (newly adopted is not recommended). From the second-generation, products used Renesas' uniquely developed capacitive touch sensor CTSU were released from the RX family, and are also being deployed in the Renesas Synergy™ and RA families. Today, the functions of CTSU2 are also evolving, as products embedding the third-generation CTSU2 are used in a variety of products, RA family, RL78 family, and RX family.

In the user's manuals of products. etc., the capacitance sensor of the second generation is written as CTSU/CTSUa, but it is written as "CTSU1" in order to distinguish it from CTSU2 of the third generation. This application note discusses the differences between CTSU1 and CTSU2, as well as the characteristics and types of CTSU2.

1.1 Application Product Development Process for Capacitive Touch

Figure 1-1 shows the application product development process for capacitive touch. Refer to the following for details.

- For understanding of capacitive touch, refer to “2.Capacitance Detection” and “3.Capacitive Touch Sensor Type”
- For MCU with Capacitive touch sensor, refer to “4.Capacitive Sensor MCU”
- For H/W, refer to “5.Hardware”
- For S/W, refer to “6.Software”
- For tuning, refer to “7.Tuning”
- For development environment, refer to “8.Development Environment”
- For evaluation kit, refer to “9.Evaluation kit”

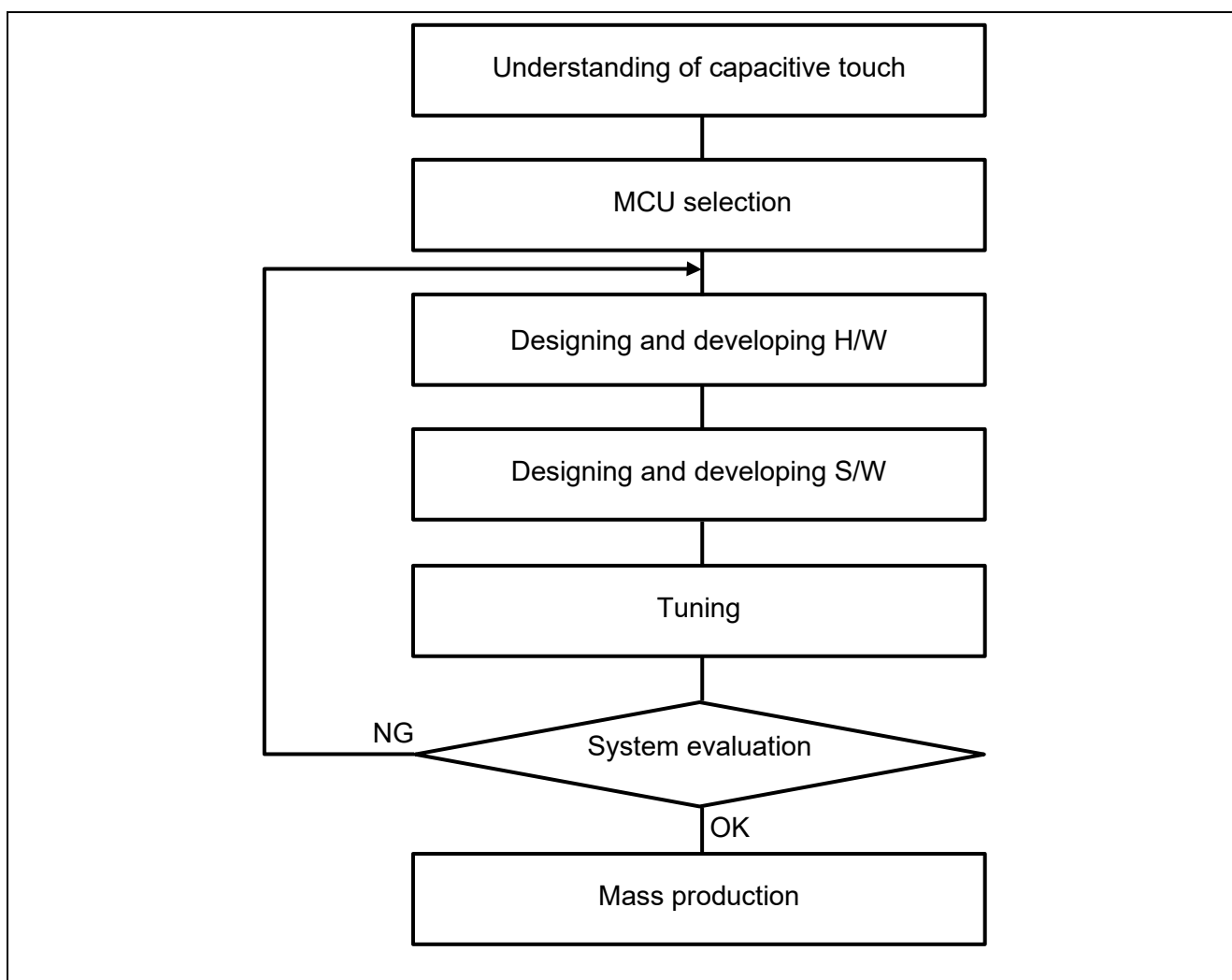


Figure 1.1 Application product development process for capacitive touch

2. Capacitance Detection

2.1 Capacitance Detection Overview

Unlike a typical switch with mechanical contacts, the Capacitance Touch Key captures minute changes in capacitance (a few pF or less) generated between the human body and the electrodes. The change is converted to ON/OFF of the switch.

For this reason, wiring and electrodes for capacitance detection must be designed correctly because they are affected by disturbances such as noise.

CTSU developed by Renesas detects changes in capacitance by converting capacitance into current through a switched-capacitor circuit and then digitizing it. Sensitivity is increased by changing the current range and integrating the number of measurements, and noise immunity is improved by dispersing sensor drive pulses. In addition, CTSU supports the "self-capacitance method" and "mutual-capacitance method" detection methods.

2.2 Self-capacitance Method

Figure 2.1 shows the touch detection principle of self-capacitance method. The left side of the figure shows the capacitance of only the electrode. The right side shows the capacitance where the capacitance has changed (increased) due to human body contact. Capacitance also exists in electrodes and wiring where capacitors are not connected in the circuit. This is called parasitic capacitance. When a finger approaches, capacitance is generated between the electrode and the finger, and the capacitance between the electrode-GND is increased. The self-capacitance method detects changes in the capacitance generated between-GND in this way.

The total capacitance between the electrode and GND can be expressed by the following formula.

$$\text{Total Capacity} = C_p + C_f$$

C_p : Parasitic capacitance

C_f : Capacitance to fingers

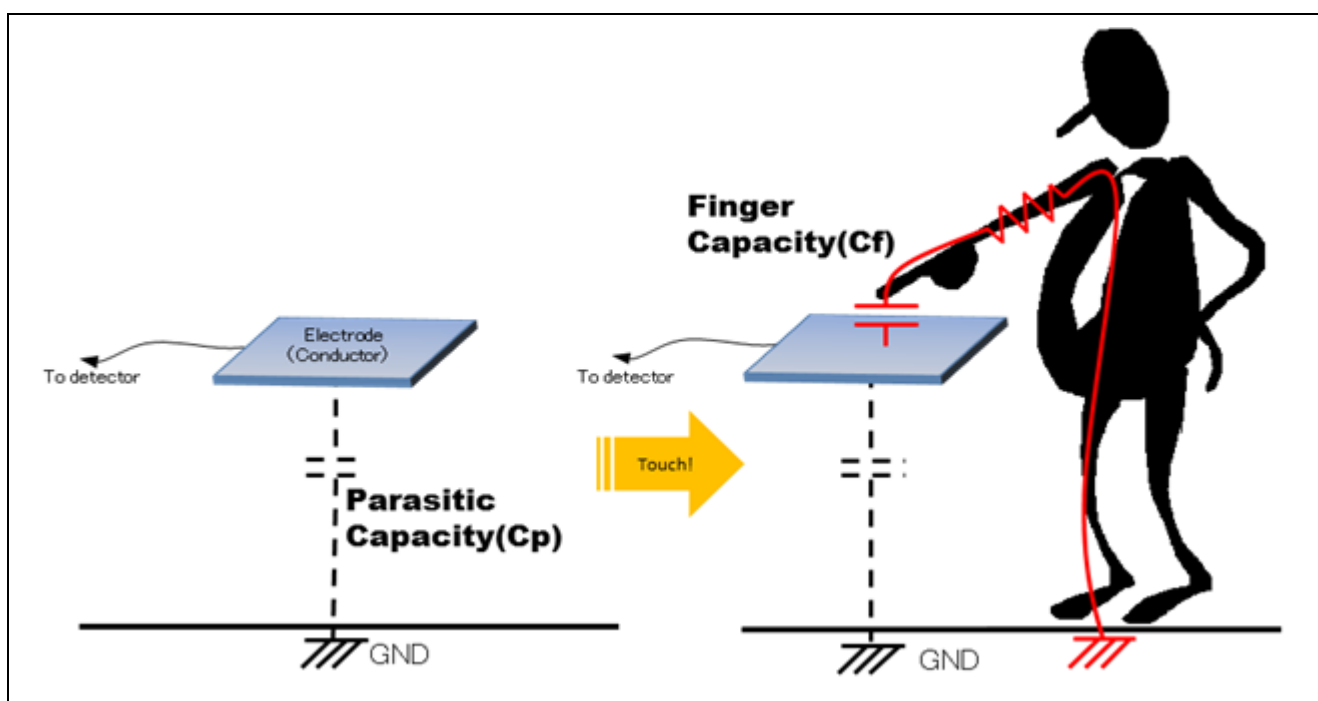


Figure 2.1 Touch detection principle of self-capacitance method

2.2.1 Detection Principle

Figure 2.2 shows the measurement circuit of CTSU.

CTSU measures the capacitance by outputting a sensor drive pulse from TS terminal and measuring the charge/discharge current. The following equation is established when the electrode-side current: I , sensor drive pulse frequency F , and parasitic capacitance are C_p , finger capacitance C_f , and sensor drive pulse voltage V .

$$I = F (C_p + C_f) V$$

The current I is the sum of the current I_1 supplied from VDC (Voltage Down Converter) for measurement and the current I_2 supplied from the offset current (DAC).

For the current I_1 supplied from the measurement VDC, a current I_{OUT} proportional to the current-controlled oscillator (Current Controlled Oscillator: hereinafter CCO) is applied via the current mirror. CCO outputs a pulse-frequency proportional to I_{OUT} . The current I_{OUT} is measured for a fixed period according to the sensor drive pulse output. It is stored in the sensor counter register.

The amount of current (measured value) differs when only the parasitic capacitance C_p is used and when a C_f is applied due to finger-contact. The change of capacitance is detected from the change of this measured value.

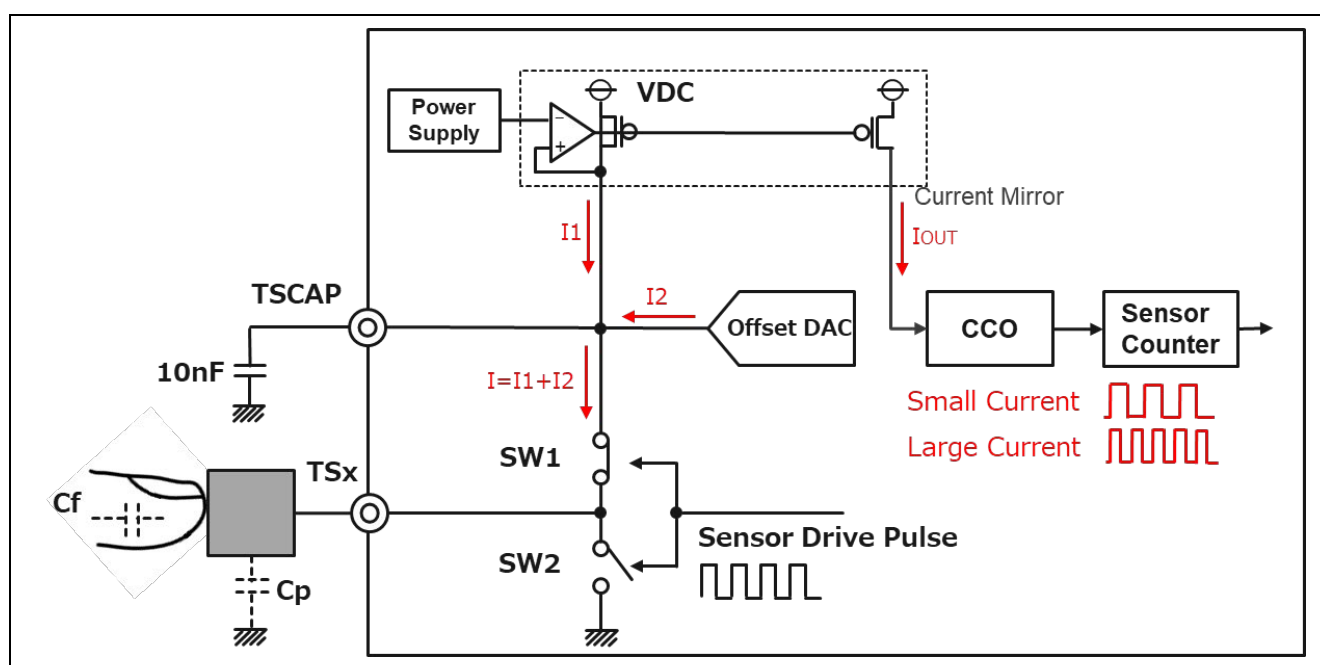


Figure 2.2 Measurement circuit of CTSU

2.2.2 Measurement Range

The sensor counter register ranges from 0 to 65535 for 16bit registers. However, when actually using the sensor counter register, measurement must be performed within the current measurement range (upper limit of the current range: 100% or less). CTSU is equipped with a sensor offset adjusting register, and the offset current can be tuned to control the count of the parasitic capacitance components. Tuning the offset current to bring the count value close to the target value in the measurement range is called the initial offset tuning process. This is done by software-processing after resetting MCU in order to adjust individual differences in hardware.

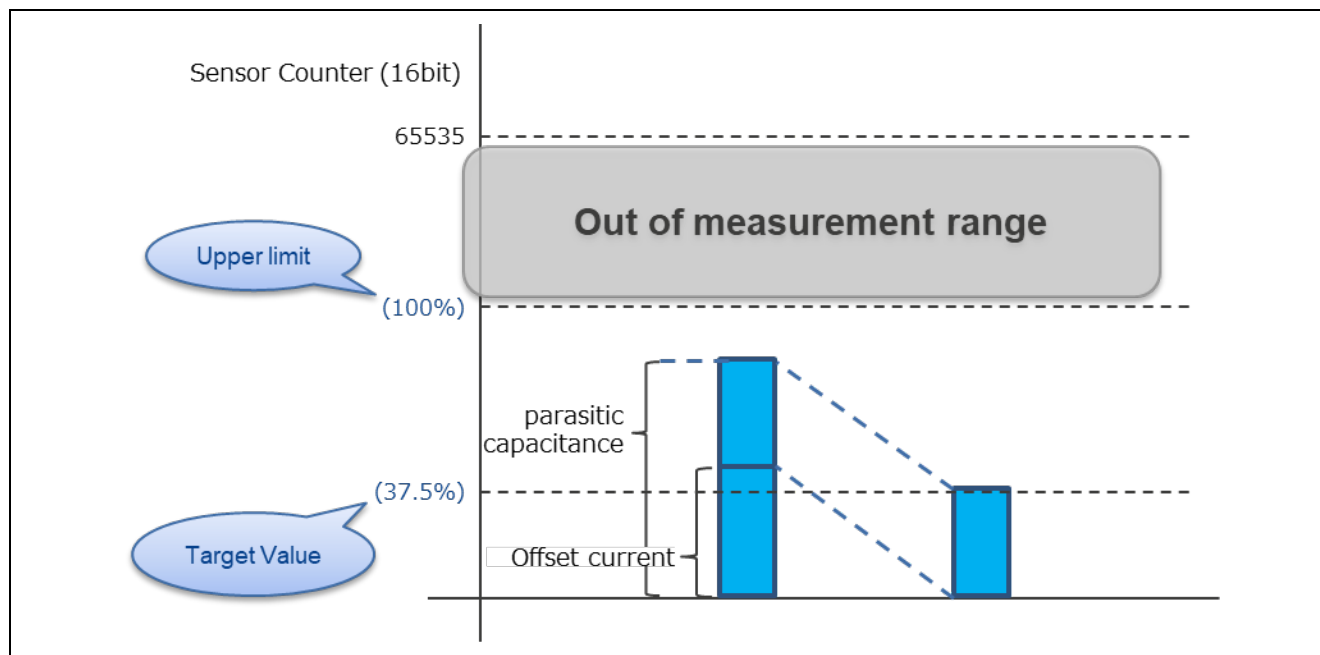


Figure 2.3 Initial offset tuning process of self-capacitance method

Refer to the following for details.

[RL78 Family CTSU Module Software Integration System\(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology\(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTSU \(r_ctsu\)](#)

2.3 Mutual-capacitance Method

In the mutual-capacitance method, the electrostatic capacitance (hereinafter referred to as "inter-electrode capacitance") generated between two electrodes, the transmitting electrode TX (hereinafter referred to as "TX electrode") and the receiving electrode RX (hereinafter referred to as "RX electrode") is measured. When a finger comes close to the electrode, a portion of the electromagnetic field moves to the human body, which is the conductor, causing the capacitance between the electrodes to decrease. By periodically observing the capacitance change between these electrodes, the approaching of the human body is detected.

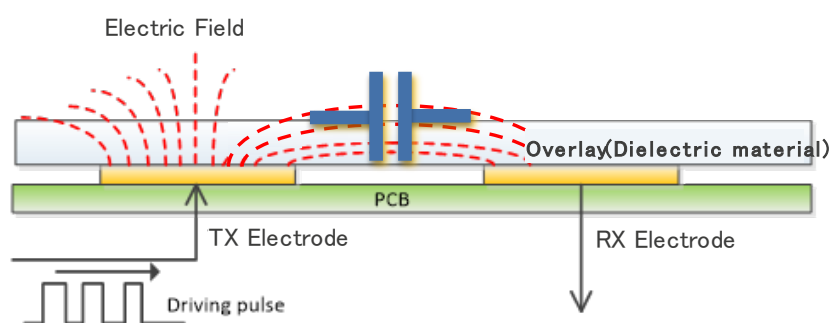


Figure 2.4 The human body is NOT approached

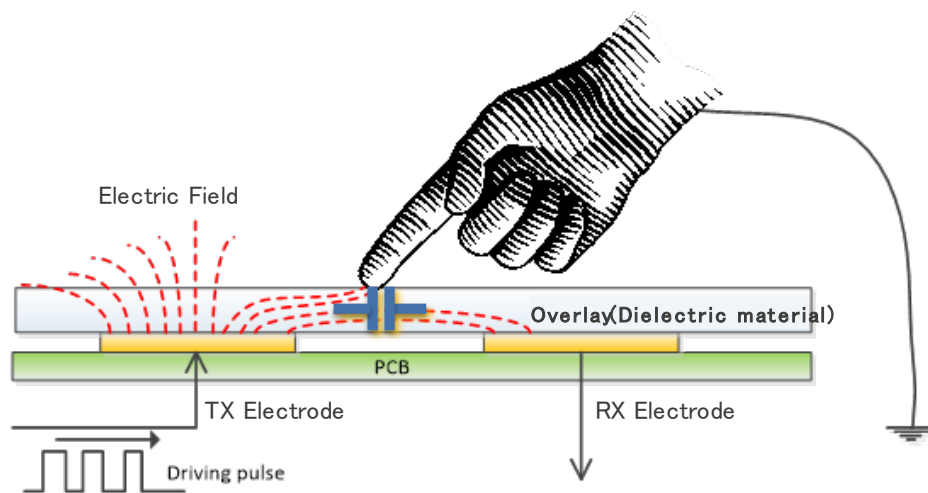


Figure 2.5 Approaching the human body

2.3.1 Detection Principle

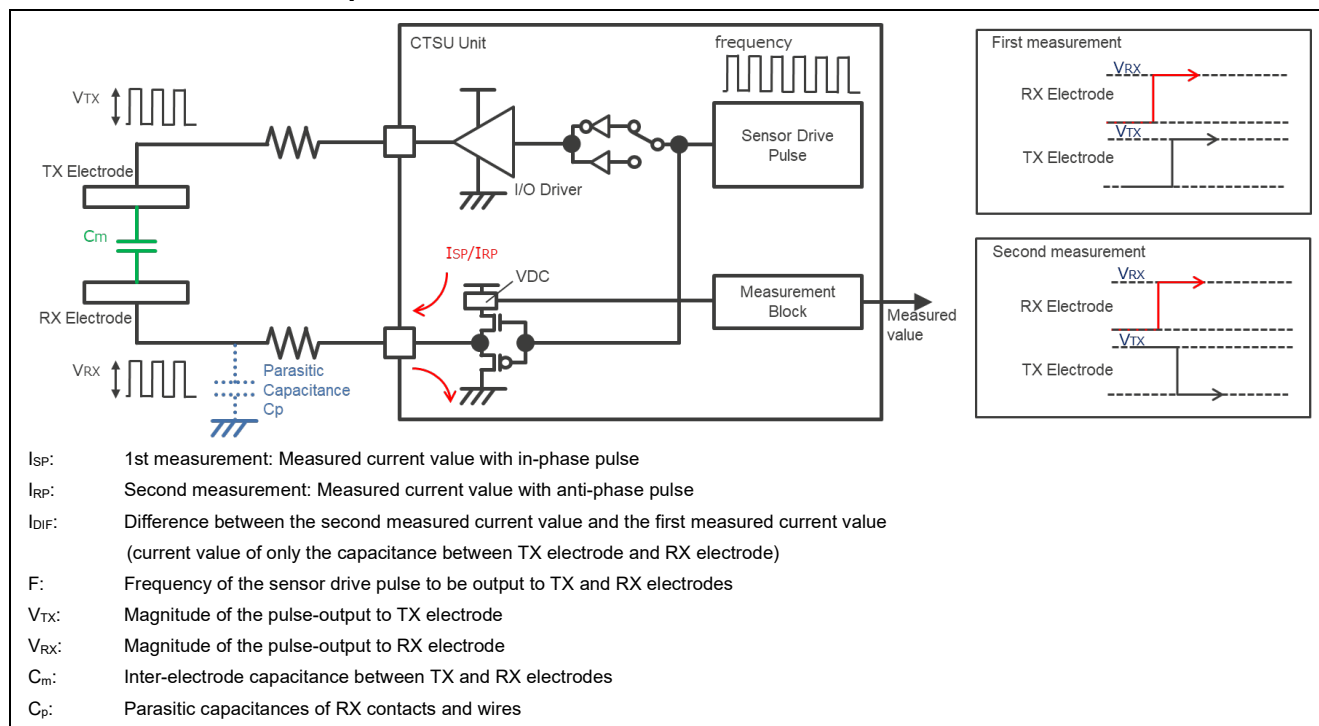


Figure 2.6 Outline of mutual-capacitance method operation

Figure 2.6 shows the configuration of CTSU inside the mutual-capacitance method.

If the frequency F of the sensor drive pulse, the voltage V_{TX} of the voltage V_{TX} , RX electrode side of TX electrode side, the parasitic capacitance is C_p , and the capacitance between electrodes is C_m ,

The current I_{SP} when in-phase pulse-outputting is

$$I_{SP} = F (C_p V_{RX} + C_m (V_{RX} - V_{TX}))$$

For the current I_{RP} when a anti-phase pulse is output

$$I_{RP} = F (C_p V_{RX} + C_m (V_{RX} + V_{TX}))$$

When the difference between the measurement results is calculated,

$$I_{DIF} = I_{RP} - I_{SP} = F C_m 2V_{TX}$$

The current of the capacitance between the electrodes can be measured.

In this mutual-capacitance method, the parasitic capacitance C_p can be canceled by measuring the same-phase pulse and anti-phase pulse, and calculating the difference between the two measurements. Only the inter-electrodes capacitance C_m to be detected can be measured.

V_{TX} is supplied from the mains voltage. Therefore, the measured value varies depending on the power supply voltage of MCU.

2.3.2 Measurement Range

The sensor counter register must be measured within the current measurement range (100% of the upper limit of the current range is 40960 or less) when actually using it, although the range for 16bit register is 0 to 65535. CTSU is equipped with a sensor offset adjustment register, and the offset current is tuned to control the count of the parasitic capacitance components. Tuning the offset current amount to bring the count value closer to the target value in the measurement range is called the initial offset tuning process. This is done by software-processing after resetting MCU in order to adjust individual differences in hardware. Figure 2.7 shows the initial offset tuning process of the mutual-capacitance method. The measured value of the current ISP measured at the time of in-phase pulse output is called the primary counter, and the measured value of the current ISP measured at the time of reverse-phase pulse output is called the secondary counter.

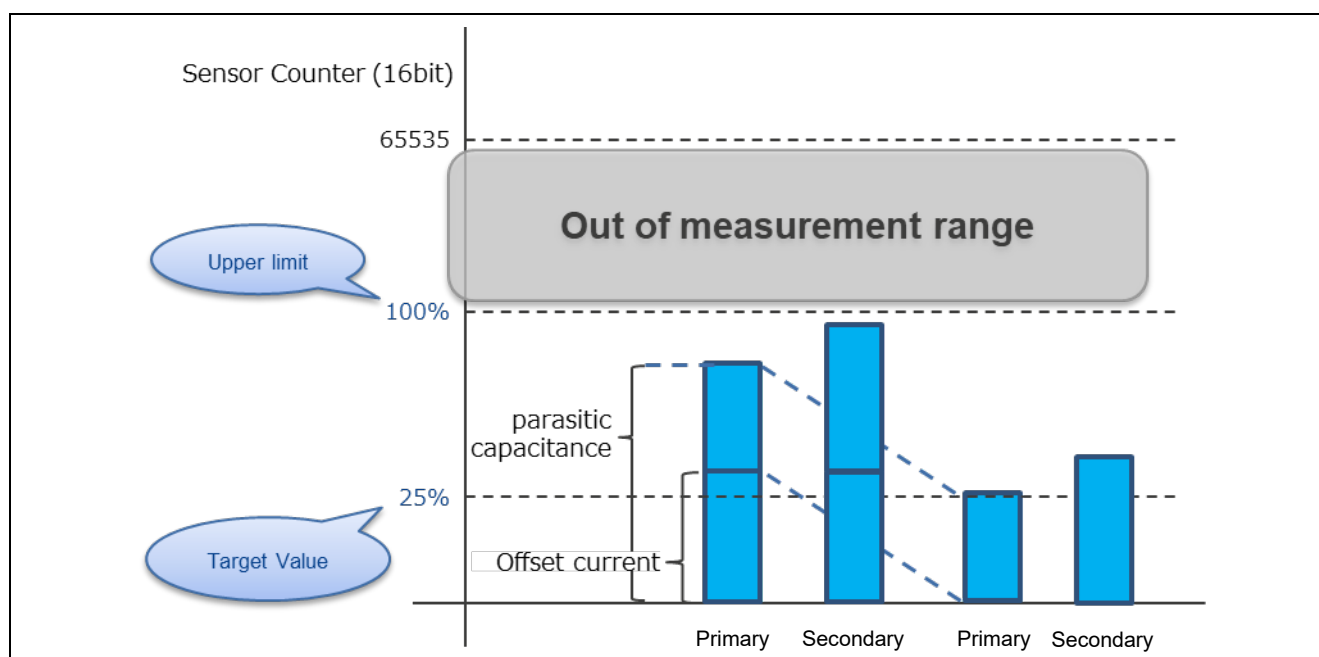


Figure 2.7 Initial offset tuning process of mutual-capacitance method

Refer to the following for details.

[RL78 Family CTSU Module Software Integration System\(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology\(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTSU \(r_ ctsu\)](#)

2.4 Drift Correction Processing and Touch Detection

Figure 2.8 shows an example of a series of operations until a change in the measured value and the reference value and a touch ON are detected.

(1) Drift correction process

Capacitance changes when a finger comes into contact with an electrode placed nearby, or due to changes in capacitance caused by temperature, humidity, aging, etc. To reduce these effects, the standard values are updated periodically through drift correction processing.

(2) Touch detection

The capacitance changes when the human body contacts the overlay on the electrode, and the touch ON is confirmed when the touch threshold is exceeded. Since the mutual-capacitance button reduces the inter-electrode capacitance when touching, the touch threshold is set in the decreasing direction of the measured value to judge the touch ON/OFF.

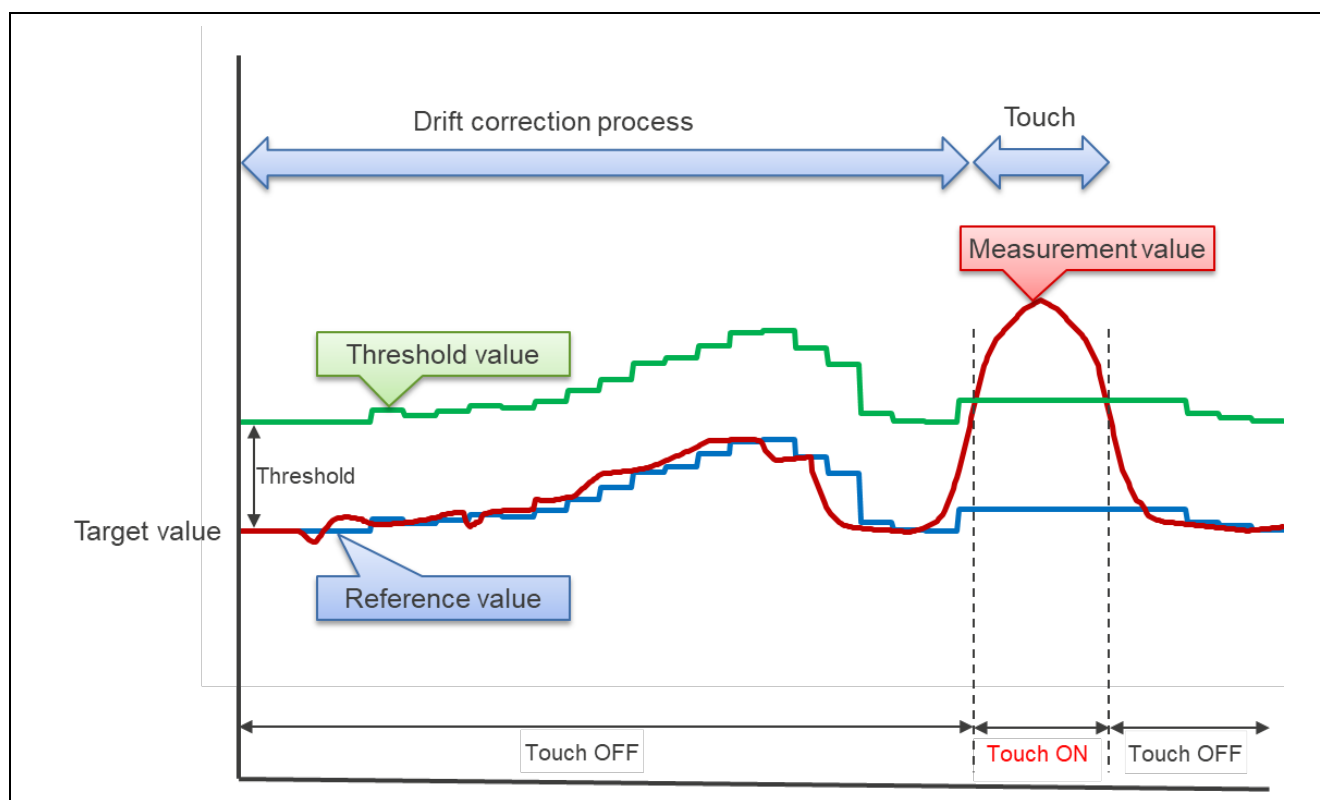


Figure 2.8 Drift correction processing and touch detection

For details of operation, refer to the following application note about the TOUCH module.

[RL78 Family TOUCH Module Software Integration System \(R11AN0485\)](#)

[RX Family QE Touch module Firmware Integration Technology \(R01AN4470\)](#)

[RA Flexible Software Package Documentation: Touch \(rm_touch\)](#)

Refer to "7.Tuning" for details such as touch ON/OFF judgment and drift-correction.

3. Capacitive Touch Sensor Type

3.1 Differences in Capacitive Touch Sensor

Compared with CTSU1, CTSU2 has the following main added function and enhanced features:

- Enhanced noise immunity
 - Synchronous noise avoidance function by multiple sensor drive pulse frequency measurement
 - Improvement of water resistance by the self-capacitance method using an active shield electrode
- Enhanced scan speed
 - Addition of "Capacitance-Frequency Conversion" (CFC) that supports parallel simultaneous scanning
- Reduction of software processing load
 - Addition of automatic judgment function
 - Addition of automatic correction function

Table 3.1 Comparison of the capacitive touch sensor functions

Function	CTSUS1	CTSUS2	CTSUS2L	CTSUS2La	CTSUS2SL
Self-capacitance method	✓	✓	✓	✓	✓
Mutual-capacitance method	✓	✓	✓	✓	✓
Random pulse frequency measurement	✓	△	△	△	△
Multi-frequency measurement		✓	✓	✓	✓
Active shield		✓	✓	✓	✓
Automatic judgment			✓(*1)	✓(*1)	✓
Automatic correction					✓
Multiple Electrode Connection (MEC)				✓	✓
Capacitance-Frequency Conversion (CFC)		✓			
Temperature correction		✓	✓	✓	✓

✓ : Supported

✓(*1) : Achieved when used with SNOOZE-mode programmable controller (SMS)

△ : This function is not supported by the driver because it supports multi-frequency measurement.

3.2 CTSU1

3.2.1 Random Pulse Frequency Measurement

Capacitance is measured by outputting a sensor drive pulse. When noise is mixed in this sensor drive pulse, the measurement result fluctuates. For this reason, CTSU1 reduces the effect of noise by outputting random pulses that are not synchronized with noise by spread spectrum or phase shifting. Figure 3.1 shows the sensor drive pulse output waveform of CTSU1.

[RX Family QE CTSU module Firmware Integration Technology\(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTSU \(r_ctsu\)](#)

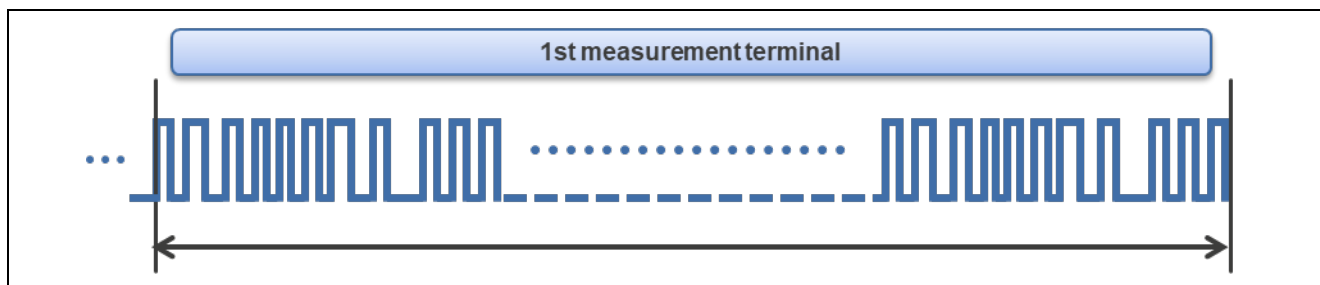


Figure 3.1 Sensor drive pulse output waveform of CTSU1

3.3 CTS2

3.3.1 Multi-frequency Measurement

Capacitance is measured by outputting a sensor drive pulse. When noise is mixed in this sensor drive pulse, the measurement result fluctuates. For this reason, CTS2 is equipped with a multi-frequency measurement function that enables measurement with several clocks with differing frequencies. Figure 3.2 shows an example of the sensor drive pulse waveform when measured at 3 frequencies. Noise immunity is improved by excluding measurement results that may be affected by noise.

Refer to the following for details.

[RL78 Family CTS2 Module Software Integration System\(R11AN0484\)](#)

[RX Family QE CTS2 module Firmware Integration Technology\(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTS2 \(r_cts2\)](#)

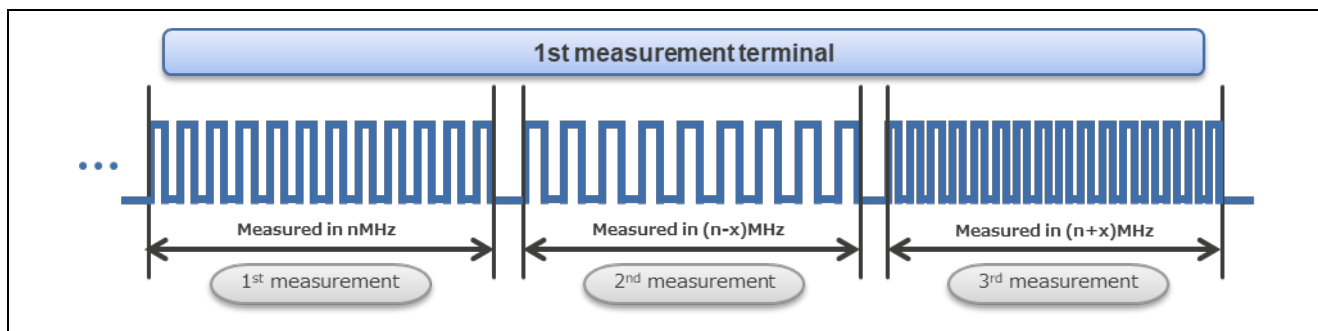


Figure 3.2 Example of the sensor drive pulse waveform when measured at 3 frequencies

3.3.2 Active Shield

This function drives the shield pattern with the same potential and phase as the electrode being measured. When the active shield is used, the capacitive coupling between the electrode and the shield pattern can be reduced compared with GND shield, and further noise-suppressing measures can be taken.

As shown in Figure 3.3, when one button is being measured and another electrode is grounded, if water causes the other electrode to generate capacitance, it can cause malfunction. By using an active shield as shown in Figure 3.4, the influence of the capacitance generated in the other electrode can be reduced, thus preventing malfunction.

The active shield can only be used with the self-capacitance method. It cannot be used in the mutual-capacitance method.

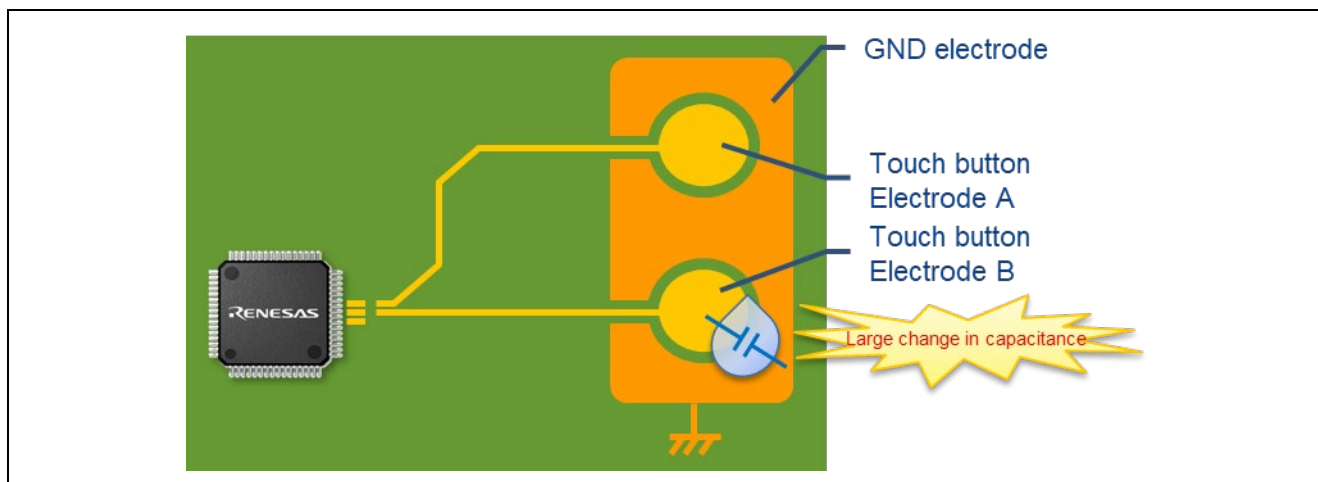


Figure 3.3 GND shield

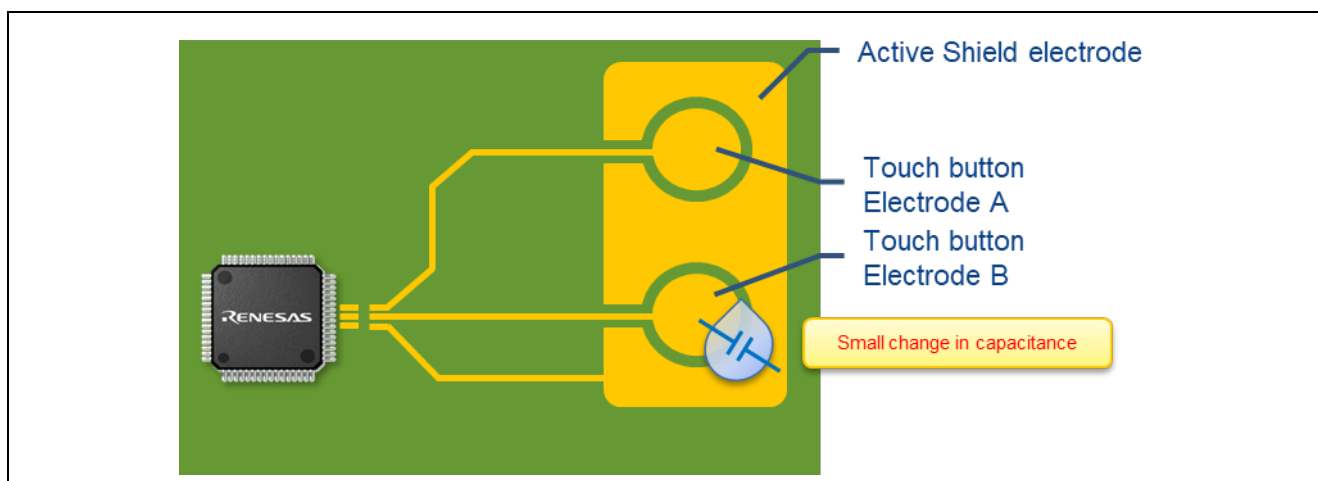


Figure 3.4 Active Shield

Refer to the following for details.

[RL78 Family CTSU Module Software Integration System\(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology\(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTSU \(r_cts\)](#)

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Electrode Design Guide \(R30AN0389\)](#)

3.3.3 Automatic Judgment

This is a function to judge the touch of a button by hardware without activating CPU. Therefore, low power consumption operation can be realized.

To use this function, select the capacitance sensor equipped with the automatic judgment function.

Refer to the following for details.

[RL78 Family CTSU Module Software Integration System\(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology\(R01AN4469\)](#)

3.3.4 Automatic Correction

Auto-correction function to correct sensor CCO(ICO) with hardware. It does not consume the main processor processing time because the hardware handles the correction calculation without using the software's correction calculation processing.

Refer to the following for details.

[RX Family QE CTSU module Firmware Integration Technology\(R01AN4469\)](#)

3.3.5 Multiple Electrode Connection (MEC)

Multiple Electrode Connection (MEC) is a function of connecting self-capacitance type electrodes inside CTSU to measure them as a single electrode. If you use MEC, you can use any key to return from standby mode. In addition, since the number of measurements can be shortened by making multiple measurements into one, the power consumption can be reduced. In addition, multiple electrodes can be used as electrodes for one large proximity sensor.

Figure 3.5 shows operation image of MEC. The diagram on the left shows MEC function disabled, and the diagram on the right shows MEC function enabled, which can be switched by software.

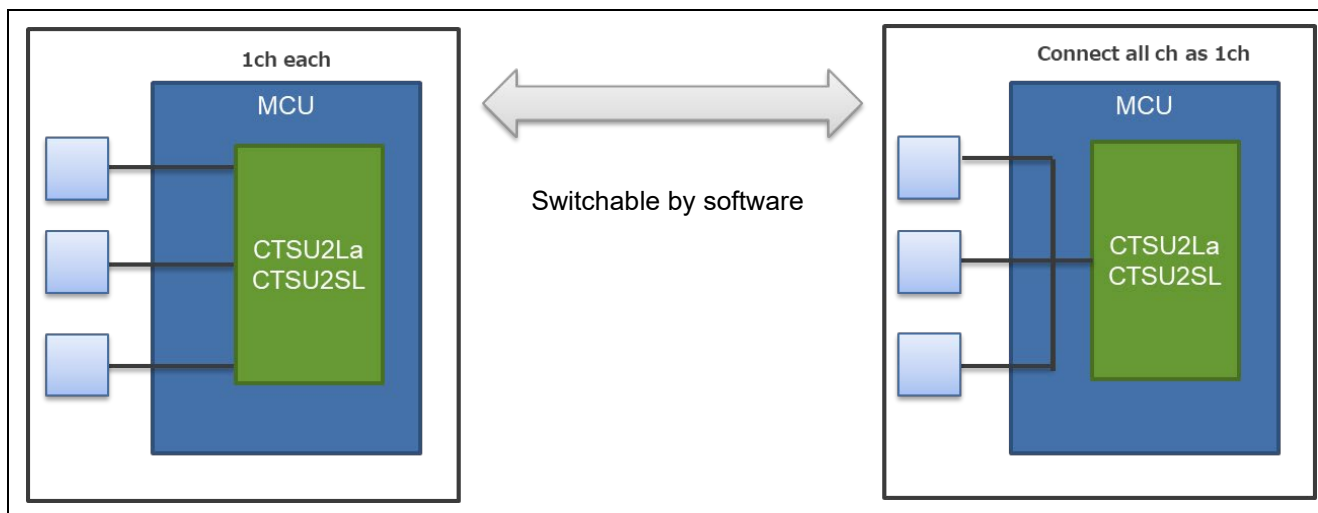


Figure 3.5 Operation image of MEC

To use this function, select a capacitance sensor equipped with a MEC function.

Refer to the following for details.

[RL78 Family CTSU Module Software Integration System \(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology \(R01AN4469\)](#)

[RX140 Group Smart Wakeup Solution \(R11AN0613\)](#)

3.3.6 Capacitance-Frequency Conversion (CFC)

By using CFC pin as the receiving pin and switching to the mutual-capacitance parallel measurement mode, it is possible to simultaneously measure several pins.

Refer to the following for details.

[RA Flexible Software Package Documentation: CTSU \(r_ ctsu\)](#)

3.3.7 Temperature correction

The compensation factor for CCO is updated by connecting an external resistor to TS pin.

Refer to the following for details.

[RL78 Family CTSU Module Software Integration System \(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology \(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTSU \(r_ ctsu\)](#)

4. Capacitive Sensor MCU

4.1 MCU Lineup

Renesas offers a broad lineup of MCU with capacitive sensors for all of RA, RX, RL78 Family MCU, Renesas Synergy™.

Please refer to the following for details and the latest information of each of these families.

- [RA Family of Arm® Cortex®-M based MCUs](#)
- [RX 32-Bit Performance / Efficiency MCUs](#)
- [RL78 Low Power 8 & 16-bit MCUs](#)
- [Renesas Synergy™ Platform MCUs](#)

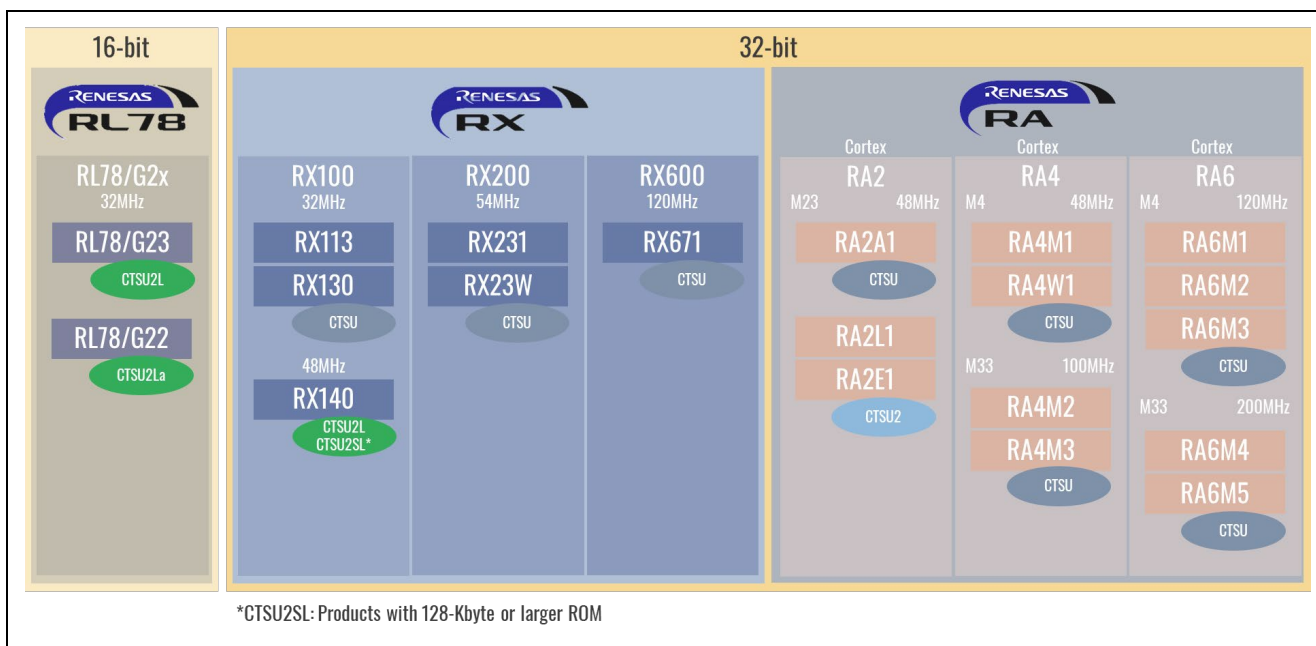


Figure 4.1 Lineup of capacitive sensor MCU

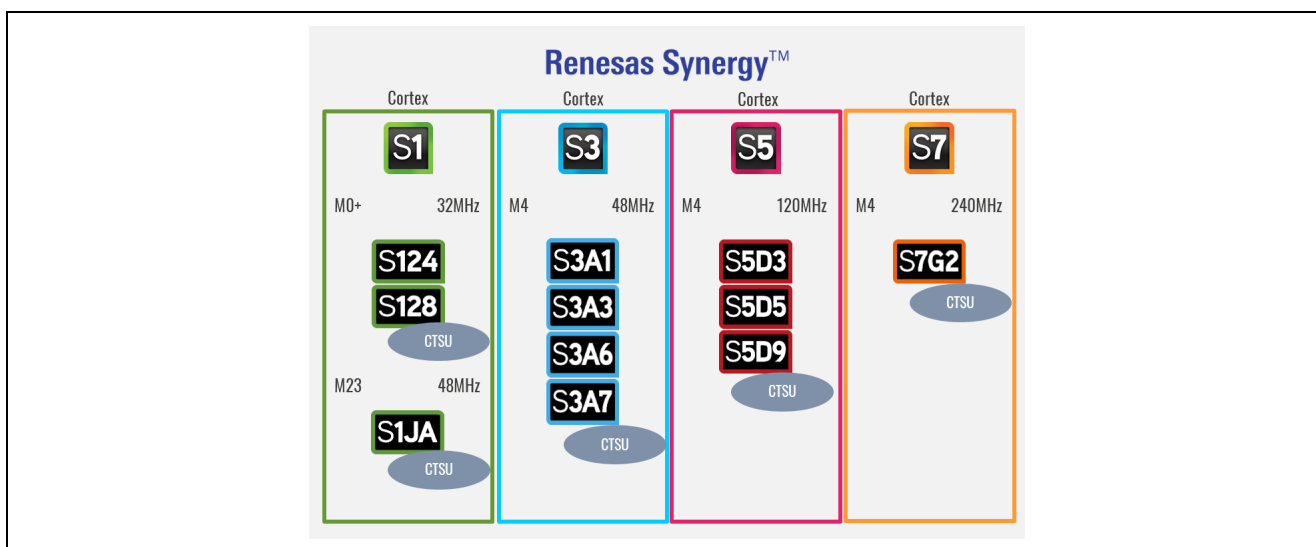


Figure 4.2 Lineup of capacitive sensor MCU (1Renesas Synergy™)

4.2 Points for MCU Selection

Selection of MCU with capacitive touch sensor has several points. First of all, it is important to find out what kind of interface applying the capacitive touch sensor should be used in your product. When the interface is determined, the number of TS terminals required for that interface is determined, and options can be narrowed down. Furthermore, by verifying MCU peripheral functions that are required in addition to the electrostatic capacitance touch sensor, the optimal MCU of mounting the electrostatic capacitance touch sensor for the customer is determined.

4.2.1 Interface

This section introduces the interface in the capacitive touch sensor solution provided by Renesas.

The interface includes a self-capacitance button, a self-capacitance slider, a self-capacitance wheel, and a mutual-capacitance button (keypad). Each feature is as follows.

(1) Self-capacitance button

This interface reacts when a finger is touched and is ideal for replacing mechanical contact switches.

Only the self-capacitance method can be used. It can be configured with one TS pin.

(2) Self-capacitance slider and self-capacitance wheel

The slider detects the position of the finger when it is moved up and down, left and right, and the wheel detects the angle when the finger is moved in a circle. These two interfaces differ from each other in that they do not have both ends of TS terminal (the wheel is applicable) or have both ends (the slider is applicable). Otherwise, they are almost the same interface.

Sliders and wheels can only be used with the self-capacitance method. Sliders can be configured with three to ten TS terminals and wheels with four or eight TS terminals.

(3) Mutual-capacitance button (Keypad)

This is the same as a button, but with a matrix of TS jacks, you can configure many buttons with fewer TS jacks, ranging from 2 buttons (1 x 2) to 64 buttons (8 x 8).

Only the mutual-capacitance method can be used, and two TS pins can be configured.

Table 4.1 Supported interfaces and required numbers of TS pins for each sensing method

Interface	TS number of terminal
Self-capacitance button	1
Self-capacitance wheel	4, 8
Self-capacitance slider	3~10
Mutual-capacitance button (Keypad)	2

Note: Indicates the minimum required TS pin count.

4.2.2 Features of Detection Method

The features of the detection method are shown below.

- Features of self-capacitance method

There are few items that must be considered when wiring on a printed circuit board, making layout easy. In addition, you can configure the electrodes of the sliders and wheels.

Water resistance is not very strong, so if water resistance is required, CTSU2 will make one terminal active-shielded, which will increase water resistance as with the mutual-capacitance method. (See Figure 4.3)

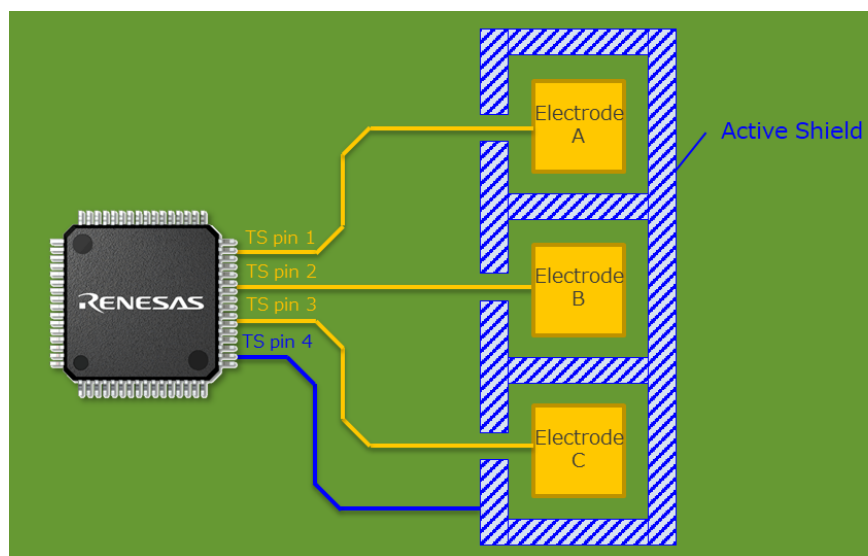


Figure 4.3 Electrode layout of self-capacitance method

- Features of mutual-capacitance method

The keypad can be configured with a matrix of buttons with a small number of terminals, and it is also water resistant. However, there are more items to consider when wiring, such as the limit of the wiring between the transmitting and receiving electrodes and the parasitic capacitance value, compared with the self-capacitance.

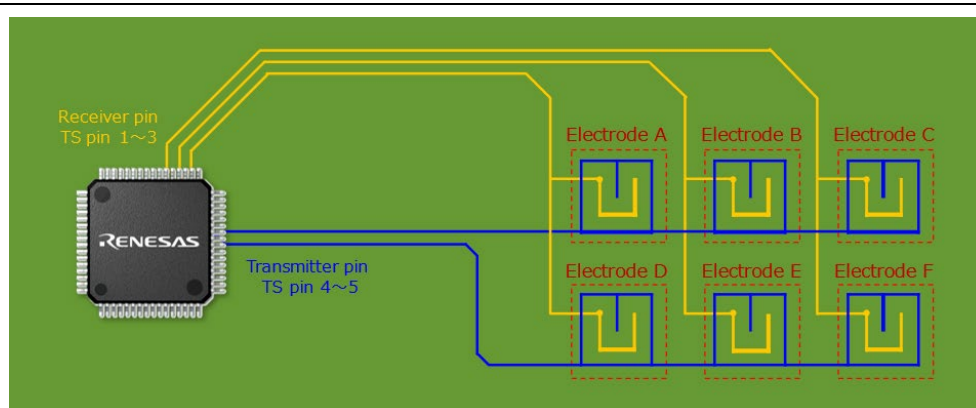


Figure 4.4 Electrode layout of mutual-capacitance method

Refer to the following for details of the electrode layout.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Electrode Design Guide \(R30AN0389\)](#)

- Precautions on detection method and wiring

As shown in Figure 4.3, the self-capacitance method configures one electrode for one TS terminal. However, for the mutual-capacitance method, as shown in Figure 4.4, the self-capacitance method configures several electrodes with one TS terminal. Therefore, there are more restrictions on the wiring between the transmitting and receiving electrodes, parasitic capacitance values, etc. compared to the self-capacitance method.

Refer to the following for details.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Electrode Design Guide \(R30AN0389\)](#)

4.3 MCUs Embedding CTSU1

Table 4.2 to Table 4.8 compare the functions of MCU embedding CTSU1(CTS/CTSUA). Refer to each product introduction page for details of each device.

You can narrow down the product in more detail in the product selection field at the bottom of the product introduction page.

Table 4.2 RA family MCU embedding CTSU1 (1/2)

Name of family product	RA2A1	RA4M1	RA4M2	RA4M3	RA4W1
CPU cores	ARM CM23	ARM CM4	ARM CM33	ARM CM33	ARM CM4
Max. operating frequency (MHz)	48	48	100	100	48
Power supply voltage (V)*1	1.6 - 5.5	1.6 - 5.5	2.7 - 3.6	2.7 - 3.6	1.8 - 3.6
Program Memory (KB)	256	256	256, 384, 512	512, 768, 1024	512
Data Flash (KB)	8	8	8	8	8
RAM (KB)	32	32	128	128	96
Capacitance sensor type	CTS				
TS number of terminal	26	27	12	20	11
Self-capacitance method	✓	✓	✓	✓	✓
Mutual-capacitance method	✓	✓	✓	✓	✓
Random pulse frequency measurement	✓	✓	✓	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.3 RA family MCU embedding CTSU1 (2/2)

Name of family product	RA6M1	RA6M2	RA6M3	RA6M4	RA6M5
CPU cores	ARM CM4	ARM CM4	ARM CM4	ARM CM33	ARM CM33
Max. operating frequency (MHz)	120	120	120	200	200
Power supply voltage (V)*1	2.7 - 3.6	2.7 - 3.6	2.7 - 3.6	2.7 - 3.6	2.7 - 3.6
Program Memory (KB)	512	512, 1024	1024, 2048	512, 768, 1024	1024, 1536, 2048
Data Flash (KB)	8	32	64	8	8
RAM (KB)	256	384	640, 384	256	512
Capacitance sensor type	CTS				
TS number of terminal	19	18	18	20	12
Self-capacitance method	✓	✓	✓	✓	✓
Mutual-capacitance method	✓	✓	✓	✓	✓
Random pulse frequency measurement	✓	✓	✓	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.4 RX family MCU embedding CTSU1 (1/2)

Name of family product	RX113	RX130	RX230	RX231	RX23W
CPU cores	RXv1	RXv1	RXv2	RXv2	RXv2
Max. operating frequency (MHz)	32	32	54	54	54
Power supply voltage (V)*1	1.8 - 3.6	1.8 - 5.5	1.8 - 5.5	1.8 - 5.5	1.8 - 3.6
Program Memory (KB)	128, 256, 384, 512	64, 128, 256, 384, 512	128, 256	128, 256, 384, 512	384, 512
Data Flash (KB)	8	8	8	8	8
RAM (KB)	64, 32	10, 16, 48, 32	32	32, 64	64
Capacitance sensor type	CTSU	CTSUa	CTSU		
TS number of terminal	12	36	24	24	12
Self-capacitance method	✓	✓	✓	✓	✓
Mutual-capacitance method	✓	✓	✓	✓	✓
Random pulse frequency measurement	✓	✓	✓	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.5 RX family MCU embedding CTSU1 (2/2)

Name of family product	RX671
CPU cores	RXv3
Max. operating frequency (MHz)	120
Power supply voltage (V)*1	2.7 - 3.6
Program Memory (KB)	1024, 1536, 2048
Data Flash (KB)	8
RAM (KB)	384
Capacitance sensor type	CTSUa
TS number of terminal	17
Self-capacitance method	✓
Mutual-capacitance method	✓
Random pulse frequency measurement	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.6 Renesas Synergy™ embedding CTSU1 (1/3)

Name of family product	S124	S128	S1JA	S3A1	S3A3
CPU cores	ARM CM0+	ARM CM0+	ARM CM23	ARM CM4	ARM CM4
Max. operating frequency (MHz)	32	32	48	48	48
Power supply voltage (V)*1	1.6 - 5.5	1.6 - 5.5	1.6 - 5.5	1.6 - 5.5	1.6 - 5.5
Program Memory (KB)	64, 128	256	256	1024	512
Data Flash (KB)	4	4	8	8	8
RAM (KB)	16	24	32	192	96
Capacitance sensor type	CTSU				
TS number of terminal	31	28	26	27	27
Self-capacitance method	✓	✓	✓	✓	✓
Mutual-capacitance method	✓	✓	✓	✓	✓
Random pulse frequency measurement	✓	✓	✓	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.7 Renesas Synergy™ embedding CTSU1 (2/3)

Name of family product	S3A6	S3A7	S5D3	S5D5	S5D9
CPU cores	ARM CM4	ARM CM4	ARM CM4	ARM CM4	ARM CM4
Max. operating frequency (MHz)	48	48	120	120	120
Power supply voltage (V)*1	1.6 - 5.5	1.6 - 5.5	2.7 - 3.6	2.7 - 3.6	2.7 - 3.6
Program Memory (KB)	256	1024	512	512, 1024	1024, 2048
Data Flash (KB)	8	16	8	32	64
RAM (KB)	32	192	256	384	640
Capacitance sensor type	CTSU				
TS number of terminal	27	31	12	18	18
Self-capacitance method	✓	✓	✓	✓	✓
Mutual-capacitance method	✓	✓	✓	✓	✓
Random pulse frequency measurement	✓	✓	✓	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.8 Renesas Synergy™ embedding CTSU1 (3/3)

Name of family product	S7G2
CPU cores	ARM CM4
Max. operating frequency (MHz)	240
Power supply voltage (V)*1	2.7 - 3.6
Program Memory (KB)	3072, 4096
Data Flash (KB)	64
RAM (KB)	640
Capacitance sensor type	CTSU
TS number of terminal	18
Self-capacitance method	✓
Mutual-capacitance method	✓
Random pulse frequency measurement	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

4.4 MCUs Embedding CTSU2

CTSUS2(CTSUS2, CTSUS2L, CTSUS2La, CTSUS2SL) Table 4.9 to Table 4.11 compare the function outline of the installed MCU. The power supply voltage (V) in this table may differ from the operating voltage of the capacitive touch sensor.

Refer to each product introduction page for details of each device.

You can narrow down the product in more detail in the product selection field at the bottom of the product introduction page.

Table 4.9 RA family MCU embedding CTSU2

Name of family product	RA2E1	RA2L1
CPU cores	ARM CM23	ARM CM23
Max. operating frequency (MHz)	48	48
Power supply voltage (V)*1	1.6 - 5.5	1.6 - 5.5
Program Memory(KB)	32, 64, 128	128, 256
Data Flash(KB)	4	8
RAM(KB)	16	32
Capacitance sensor type	CTSUS2	
TS number of terminal	30	32
Self-capacitance method	✓	✓
Mutual-capacitance method	✓	✓
Multi-frequency measurement	✓	✓
Active shield	✓	✓
Automatic judgment		
Automatic correction		
Multiple Electrode Connection: MEC		
Capacitance-Frequency Conversion: CFC	18	20
Temperature correction	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.10 RX family MCU embedding CTSU2

Name of family product	RX140	
CPU cores	RXv2	
Max. operating frequency (MHz)	48	
Power supply voltage (V)*1	1.8 - 5.5	
Program Memory(KB)	64	128, 256
Data Flash(KB)	4	8
RAM(KB)	16	32, 64
Capacitance sensor type	CTSU2L	CTSU2SL
TS number of terminal	12	36
Self-capacitance method	✓	✓
Mutual-capacitance method	✓	✓
Multi-frequency measurement	✓	✓
Active shield	✓	✓
Automatic judgment	✓	✓
Automatic correction	✓	✓
Multiple Electrode Connection: MEC		✓
Capacitance-Frequency Conversion: CFC		
Temperature correction	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

Table 4.11 RL78 family MCU embedding CTSU2

Name of family product	RL78/G23	RL78/G22
CPU cores	RL78	RL78
Max. operating frequency (MHz)	32	32
Power supply voltage (V)*1	1.6 - 5.5 *1	1.6 - 5.5 *1
Program Memory(KB)	96, 128, 192, 256, 384, 512, 768	32, 64
Data Flash(KB)	8	2
RAM(KB)	16, 12, 48, 32, 24, 20	4
Capacitance sensor type	CTSU2L	CTSU2La
TS number of terminal	32	29
Self-capacitance method	✓	✓
Mutual-capacitance method	✓	✓
Multi-frequency measurement	✓	✓
Active shield	✓	✓
Automatic judgment	✓	✓
Automatic correction	✓	✓
Multiple Electrode Connection: MEC		✓
Capacitance-Frequency Conversion: CFC		
Temperature correction	✓	✓

✓ : Supported

*1 : The power supply voltage (V) may differ from the operating voltage of the capacitive touch sensor.

5. Hardware

5.1 Electrode design guide

Electrode layout patterns and characteristic data of the self-capacitance method and the mutual-capacitance method are listed. Please refer to the following application notes for MCU design and design examples.

[Capacitive Touch Electrode Design Guide \(R30AN0389\)](#)

6. Software

6.1 Software Configuration

Renesas provides drivers (CTSU Modules) and middleware (TOUCH Modules) to MCU family for the construction of programs that apply capacitive touch sensors. Drivers and middleware are used in conjunction with QE for Capacitive Touch and other developers described below. The tuning result by QE for Capacitive Touch is incorporated into the program as a parameter file, and the definition of the parameter file is reflected in the program by referring to TOUCH module and CTSU module. Figure 6.1 shows the software configuration of a typical program including CTSU module, TOUCH module, and application.

This chapter describes the software of programs applying capacitive touch sensors, including CTSU modules and TOUCH modules.

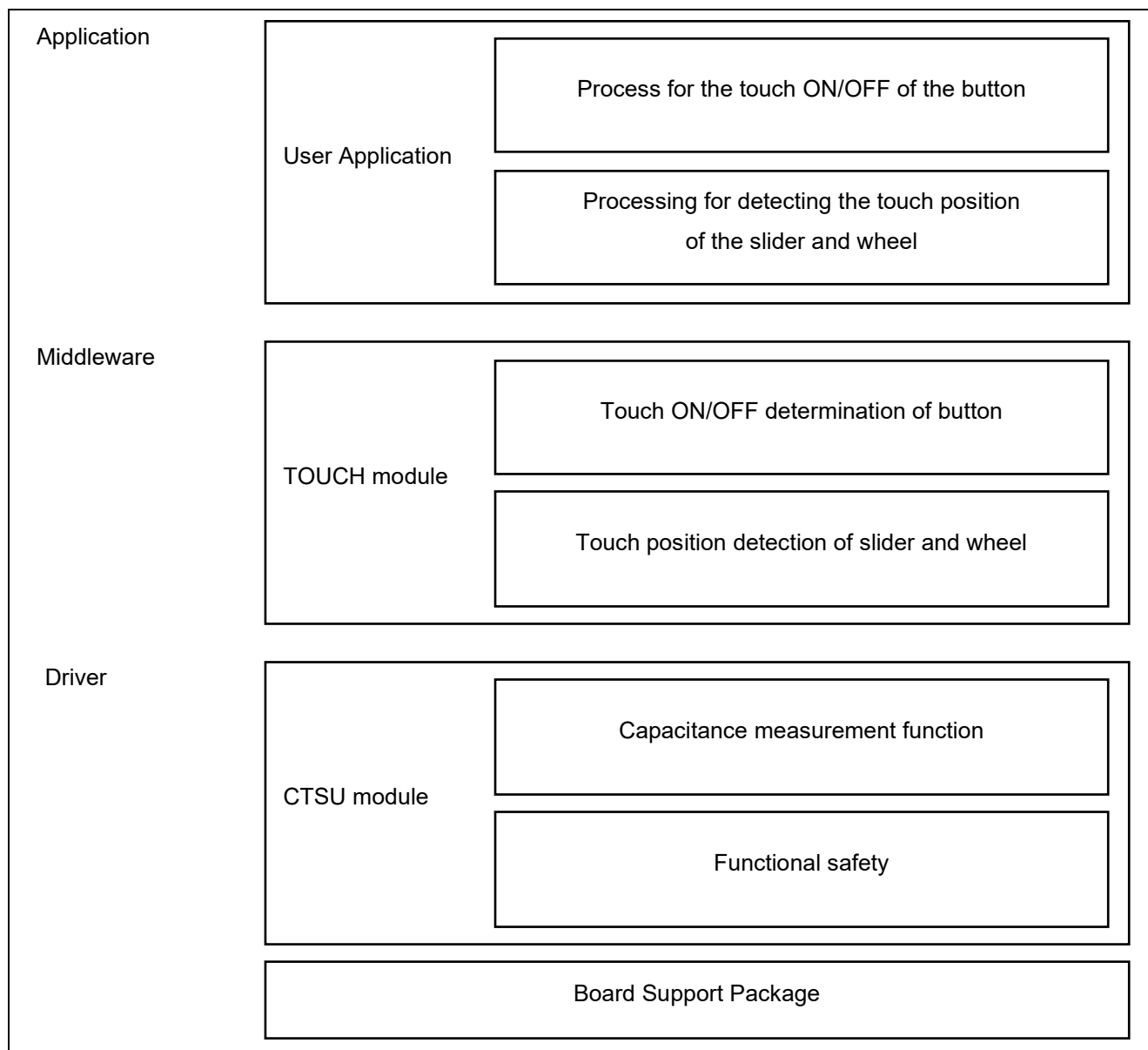


Figure 6.1 Typical software configuration

6.1.1 CTSU Module

CTSU modules are CTSU drivers for TOUCH modules. CTSU register settings, etc. tuned by QE for Capacitive Touch are entered from the parameter file into the module and used.

The capacitance measurement function provided by this module is shown below.

- ICO compensation control
- Initial offset tuning
- Random pulse frequency measurement
- Multi-frequency measurement
- Active shield control
- Automatic judgment control
- Automatic correction control
- MEC control
- CFC control
- Temperature correction control
- Functional safety

Refer to the following for more information on CTSU Modules.

[RL78 Family CTSU Module Software Integration System \(R11AN0484\)](#)

[RX Family QE CTSU module Firmware Integration Technology \(R01AN4469\)](#)

[RA Flexible Software Package Documentation: CTSU \(r_ctsu\)](#)

[Renesas Synergy™ Software Package \(SSP\)](#)

6.1.2 TOUCH Module

TOUCH modules are middleware that use CTSU modules to provide capacitive touch-detection. Parameter setpoints tuned by QE for Capacitive Touch are entered from the parameter file to the module and used.

The main functions provided by this module are as follows.

- Touch ON/OFF determination of button
- Touch position detection of slider and wheel

Refer to the following for more information on TOUCH Modules.

[RL78 Family TOUCH Module Software Integration System \(R11AN0485\)](#)

[RX Family QE Touch module Firmware Integration Technology \(R01AN4470\)](#)

[RA Flexible Software Package Documentation: Touch \(rm_touch\)](#)

[Renesas Synergy™ Software Package \(SSP\)](#)

6.2 Functional Safety

Renesas's capacitive touch keys (CTSU1 and CTSU2) allow the self-test software to diagnose its own circuitry. For details on functional safety, refer to Web page-below.

<https://www.renesas.com/application/industrial/building-home-automation/functional-safety-solution-capacitive-touch-sensor>

6.3 Low Power Guide

An example of setting when using a capacitive touch for low-power applications is provided. Refer to APN below for the low-power guidelines using capacitive touch.

[RA2L1 Group Capacitive Touch Low Power Guide \(R01AN6266\)](#)

[RA6M2 Group Capacitive Touch Low Power Guide \(R01AN6473\)](#)

[RL78 Family RL78/G23 Capacitive Touch Low Power Guide \(SNOOZE function\) \(R01AN5886\)](#)

[RL78/G23 Group RL78/G23 Capacitive Touch Low Power Guide \(SMS function\) \(R01AN6670\)](#)

The application notes that use MEC function are as follows.

[RX140 Group Smart Wakeup Solution \(R11AN0613\)](#)

7. Tuning

Auto-tuning with QE for Capacitive Touch generates basic CapTouch parameters. If the required specifications are not met when evaluating using this parameter, perform Manual tuning of “7.2 Manually Tuning with CapTouch Parameters”. If further adjustment is required, you are preparing “7.3 Tuning with advanced setting”.

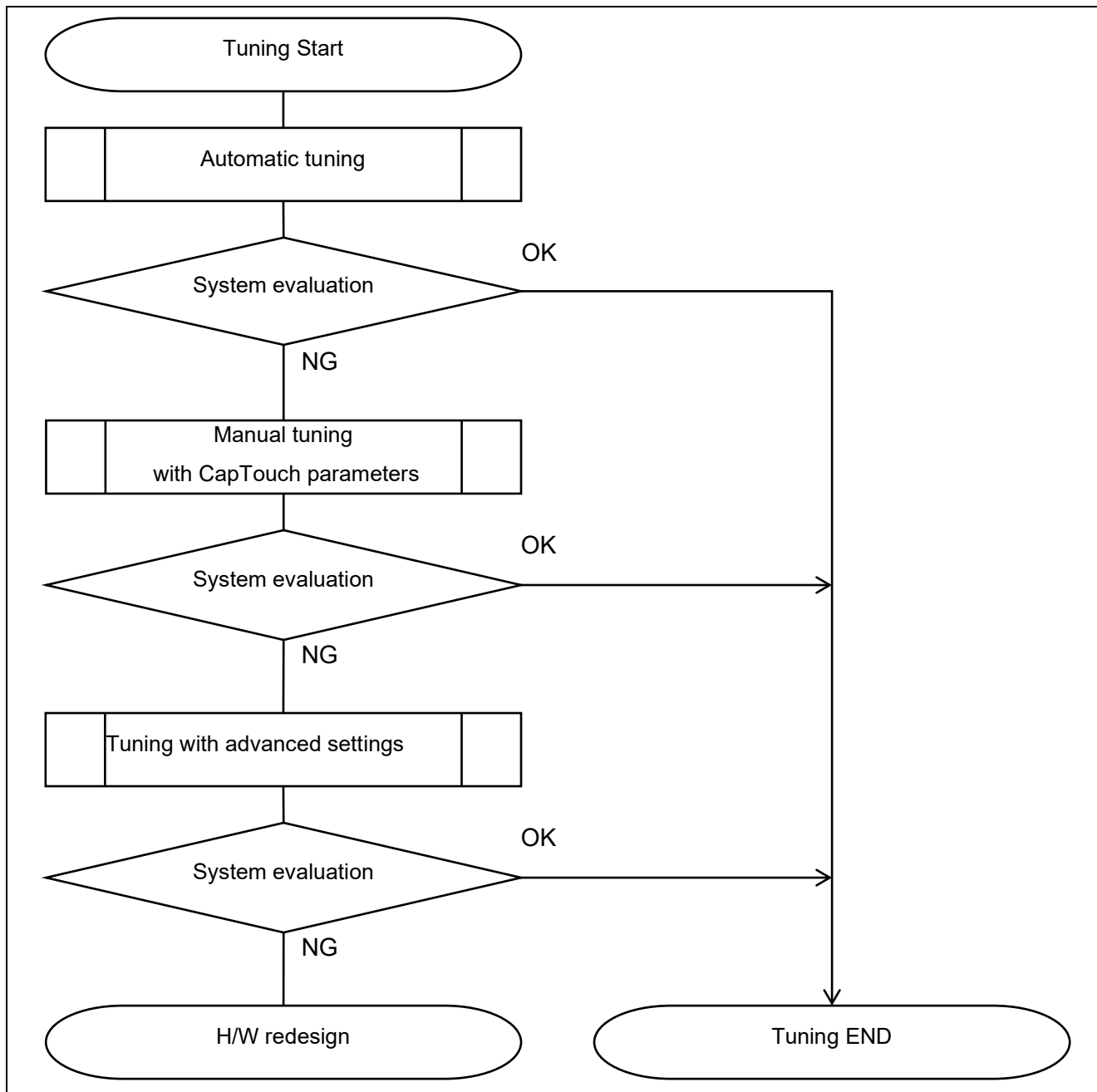


Figure 7.1 Tuning flow chart

7.1 Auto Tuning with QE for Capacitive Touch

Figure 7.2 shows the auto tuning using QE for Capacitive Touch, and the tuning parameters are created by the following process. After resetting MCU, the operation starts based on this parameter.

- Parasitic capacitance measurement

Determine the sensor drive pulse frequency that can be charged and discharged from the parasitic capacitance and resistance value.

- Offset adjustment

By tuning the offset current, the count value is brought close to the target value within the measurement range.

- Sensitivity measurement (Not touched)

The reference value is determined by measuring the capacitance value in a non-contact state.

- Sensitivity measurement (Touched)

Capacitance change of the finger is calculated by measuring the capacitance value with the finger in contact and calculating the difference from the measurement result in the non-contact state. From this result, the threshold and hysteresis are determined.

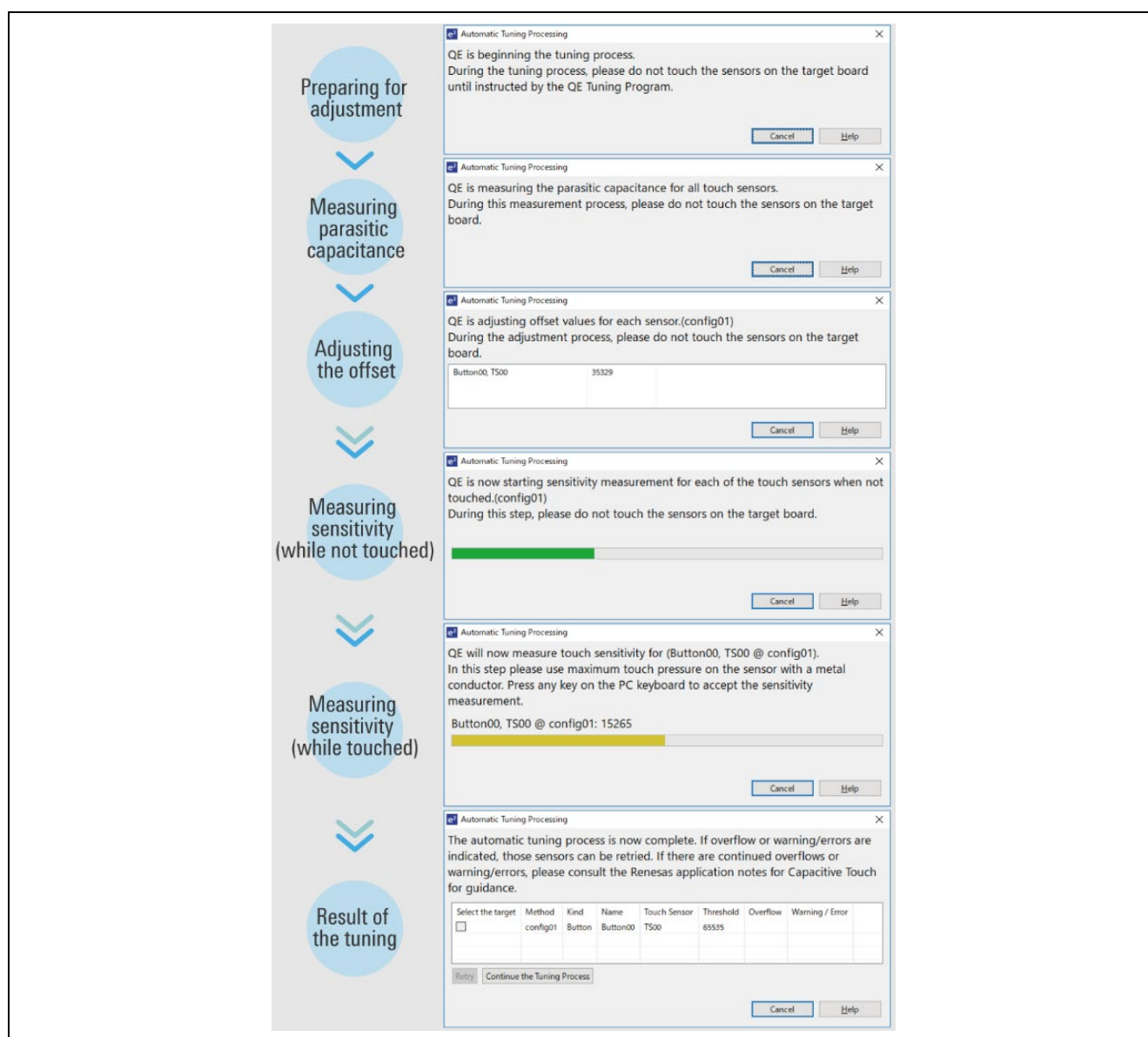


Figure 7.2 Auto tuning using QE for Capacitive Touch

7.2 Manually Tuning with CapTouch Parameters

Manual tuning means that the user changes the parameters as appropriate for auto tuning by QE for Capacitive Touch.

Table 7.1 shows the CapTouch parameters to be manually tuned.

Table 7.1 CapTouch parameters

CapTouch parameter	Overview
Depth of the moving average filter	A moving average filter is used to reduce the effects of noise and specifies the number of moving average operations.
Touch threshold	This value is used to judge the touch ON, and the change required until the measured value is judged from the reference value to the touch ON is specified.
Hysteresis	This value is used to judge the touch OFF, and the change required for the measured value to judge the touch OFF from the touch threshold is specified.
Drift correction processing interval	This function updates the reference value at a fixed cycle to follow changes in parasitic capacitance. The period for updating the reference value can be specified.
Positive noise filter cycles	This is a chattering-proof process to determine the touch ON. You can specify the duration for touch ON to be confirmed when the touch ON status continues for a certain number of times.
Cycle of the negative noise filter	This is a chattering-proof process to determine the touch OFF. You can specify the duration for touch OFF to be confirmed when the touch OFF status continues for a certain number of times.
Long press cancel cycle	This function forcibly turns touch OFF after a certain period of time when something touches ON. You can specify the duration for the force-to-touch OFF function to be activated.

The following is a detailed explanation of the capacitance measurement function related to CapTouch parameters.

(1) Moving average

This filter is applied when calculating the count value.

CapTouch parameter is the depth (hereafter referred to as depth) of the moving averaging filter. Decreasing the depth increases the speed at which the measured value is reflected in the counted value, thus improving the response speed of the button. As a cost of this, the count value responds sensitively when the measurement value suddenly increases and decreases against noise, etc. On the other hand, if the depth increases, the resistance to noise, such as sudden changes in measured values, may be improved, but the response may be slowed down.

(2) Touch judgment

This function determines the touch ON/OFF of the self-capacitance button and mutual-capacitance button (keypad).

The following CapTouch parameters are available.

- Touch threshold

Parameter used for judgment when the button/keypad switches from touch OFF to touch ON.

Reducing the touch threshold makes touch ON easier, while increasing the touch threshold makes touch ON less difficult.

- Hysteresis

This parameter is applied to the touch threshold when the button/keypad changes from touch ON to touch OFF. This parameter functions as a countermeasure against chattering, and touch OFF is judged when the value falls below the touch threshold by the amount of hysteresis.

Increasing the hysteresis will increase the effectiveness of the anti-chattering measures, but be aware that touch ON will make it harder to become touch OFF and may result in poor button response.

- Positive noise filter

This parameter sets the duration from when the count value of the button/keypad exceeds the touch threshold to when it is actually judged to be a touch ON. This parameter acts as a anti-chattering measure and confirms the touch ON when the count value exceeds the touch threshold for a specified period.

Increasing the positive noise filter will increase the effectiveness of the chattering countermeasure, but be aware that the button response may be degraded.

- Negative noise filter

This parameter sets the duration from when the count value of the button/keypad falls below the touch threshold to when it is actually judged to be a touch OFF. This parameter functions as a anti-chattering measure and confirms the touch OFF when the count value falls below the touch threshold for a specified period.

Increasing the negative noise filter will increase the effectiveness of the anti-chattering measures, but be aware that the button response may be degraded.

(3) Drift correction

This function updates the reference value of the button/keypad according to the surrounding environment. This function works in touch OFF, averaging the counted value in touch OFF in a specified period, and updating the reference value with the averaged value.

There is a drift-correction interval as CapTouch parameter, and you can specify the duration for updating the reference. Increasing this parameter slows the update of the reference value, while decreasing it accelerates the update of the reference value. Note that if you set it too small, it will immediately follow the count value when you touch the button. Consequently, it will be difficult to ON the touch.

(4) Press and hold to cancel

This function is used to turn the touch OFF when the touch ON period of the button/keypad exceeds a specified period. Due to sudden environmental changes such as strong noises, it may not be possible to recover from the touch ON status because the drift-correction process does not update the reference. To recover from this state, touch OFF is forced when touch ON continues for a certain period, and drift-correction is activated.

CapTouch parameter is a long press cancel cycle. You can specify the duration of the long press cancel.

Manual tuning can also be done by directly editing the program's source code, but here we'll describe manual tuning using QE for Capacitive Touch.

For manual tuning, use the "List of CapTouch Parameters" in QE for Capacitive Touch (inside the red frame in Figure 7.3). For example, to make the buttons more responsive, reduce the Touch Threshold value. Here, Figure 7.3 lowers the touch threshold from 3000 to 1000. The red line in Figure 7.3 represents the count value, the blue line represents the reference value, and the green line represents the touch threshold. You can see the count value that does not ON touch at the touch threshold of 3000 and the touch ON at the touch threshold of 1000.

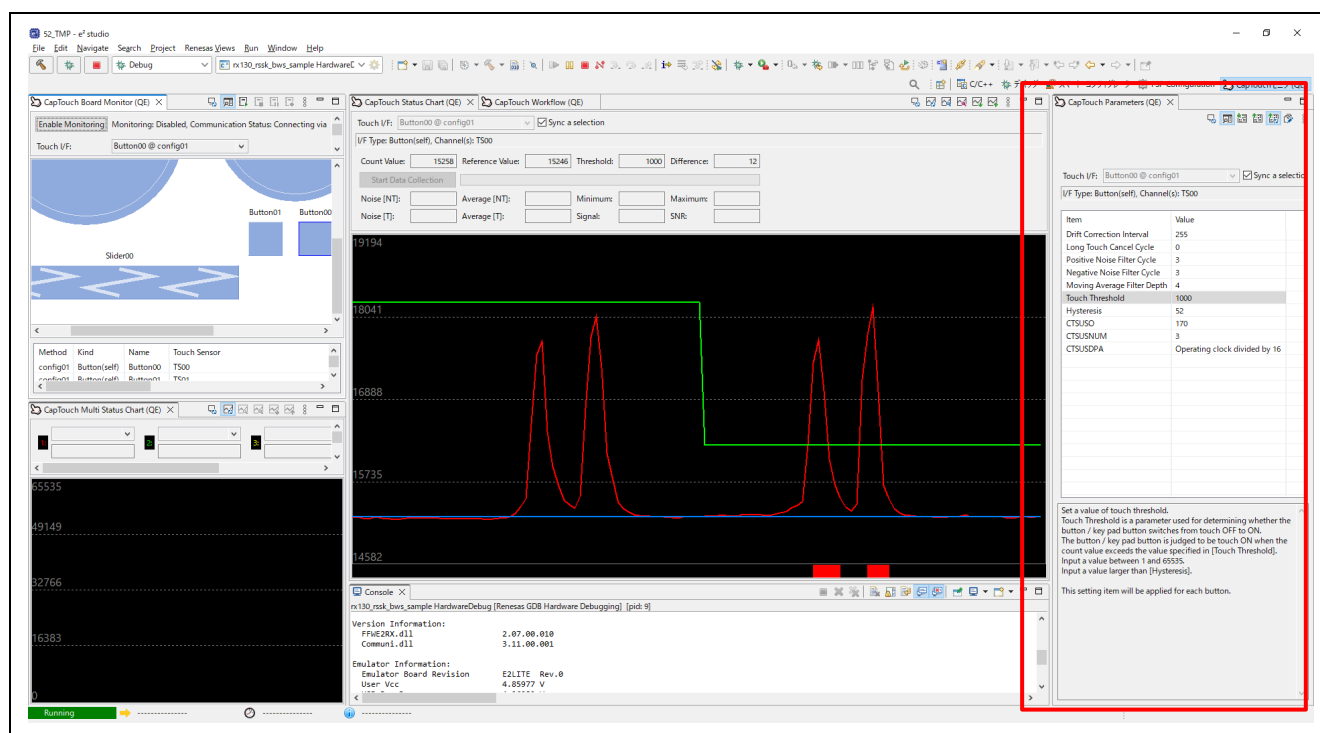


Figure 7.3 Manually Tuning with QE for Capacitive Touch

Please also refer to APN below for parameters.

[RL78 Family CTSU Module Software Integration System \(R11AN0484\)](#)

[RL78 Family TOUCH Module Software Integration System \(R11AN0485\)](#)

[RX Family QE CTSU module Firmware Integration Technology \(R01AN4469\)](#)

[RX Family QE Touch module Firmware Integration Technology \(R01AN4470\)](#)

7.3 Tuning with advanced setting

Advanced tuning allows you to adjust individual parameters such as drive pulse frequency and measurement time. We plan to release this guide in 2Q of 2023 in order to improve the sensitivity/noise immunity.

8. Development Environment

For more information on downloading QE for Capacitive Touch, please refer to URL below to introduce the Capacitive Touch Sensor Support Tool QE for Capacitive Touch. Multiple built-in system development, tuning guide, and tutorial videos are available. A standalone version is also included in the same package.

[QE for Capacitive Touch: Development Assistance Tool for Capacitive Touch Sensors](#)

8.1 Capacitive Touch Sensor Development Support Tool “QE for Capacitive Touch”

The Capacitive Touch Sensor Development Support Tool QE for Capacitive Touch is a solution toolkit that runs on an integrated development environment e²studio. It supports the initial setting and sensitivity tuning of the touch interface required for the development of embedded systems that use a capacitive touch sensor, thus shortening the development period.

It can be developed with a simple GUI according to the workflow. Figure 8.1 shows the operation QE for Capacitive Touch.

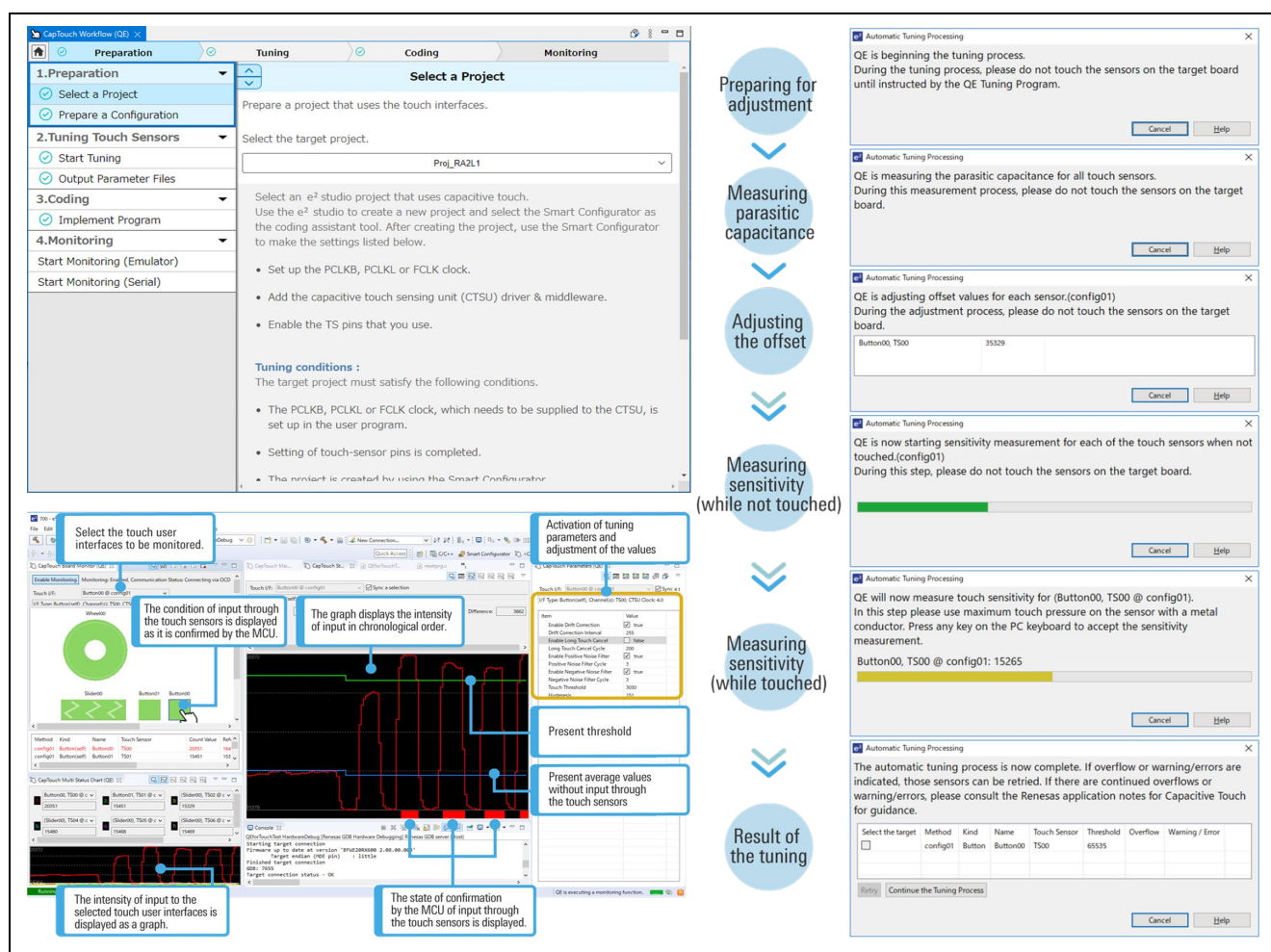


Figure 8.1 Operation display of QE for Capacitive Touch

8.2 Stand-alone Version of QE for Capacitive Touch

For customers who use CS + and IAR integrated development-environment, a stand-alone version of QE for Capacitive Touch (hereafter, a stand-alone version of QE) is available. The stand-alone version of QE acquires measurements through the serial port for tuning and monitoring functions. Figure 8.2 shows the operation of the stand-alone QE.

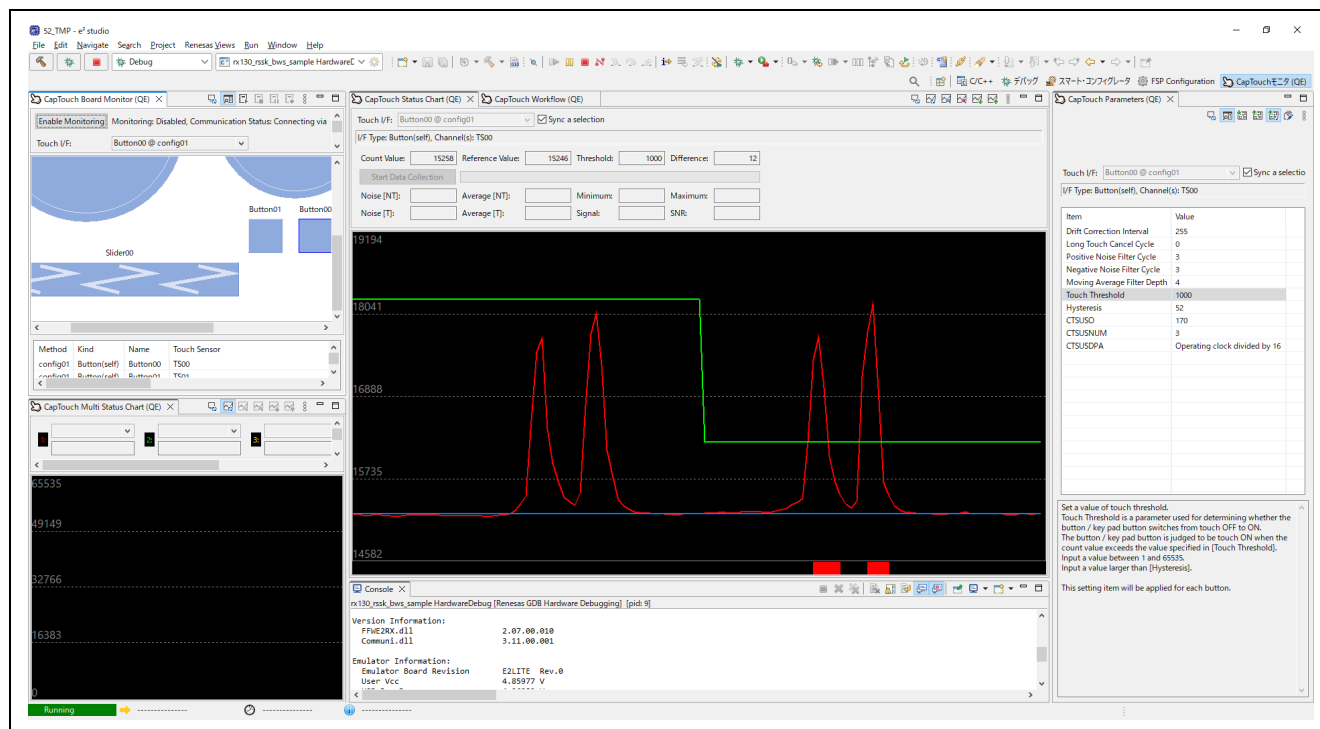


Figure 8.2 Stand-alone version of QE

9. Evaluation kit

9.1 Capacitive Touch Evaluation System

The Capacitive Touch Evaluation System is a kit that can easily evaluate the touch key solutions provided by Renesas. Using the boards and software included in the kit, you can start the evaluation immediately after purchasing the kit.

Refer to the following for details.

<https://www.renesas.com/solutions/touch-key>



Figure 9.1 Capacitive Touch Evaluation System

10. Other

10.1 Term

Term	Description
CCO	CCO (Current Control oscillator) refers to the current-controlled oscillator used by the capacitive touch sensor. Some application notes are referred to as ICO.
ICO	Same as CCO.
TSCAP	This capacitor is used to stabilize the internal-voltage of CTSU.
Damping resistance	This resistor is used to reduce the influence of terminal breakdown and noise from external noise. Refer to the Capacitive Touch Electrode Design Guide (R30AN0389) for more information.
VDC	VDC (Voltage Down Converter) is the power supply for the capacitance sensor built in CTSU.
Multi-frequency measurement	This function measures using multiple sensor unit clocks with different frequencies. It refers to the multi-clock measurement function.

10.2 Technical inquiries

Contact to Technical Support or search for a KnowledgeBase common question (FAQ) or community forum.

<https://www.renesas.com/us/en/contact-us>

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Mar.31.23	-	First edition issued
1.10	Apr.04.23	20	Updated Figure 4.1

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

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