

# Capacitive Sensor MCU

## QE for Capacitive Touch Advanced Mode Parameter Guide

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### Introduction

This application note describes Advanced mode and adjustable CTSU parameters using the Capacitive Touch Sensor Support Tool (QE for Capacitive Touch).

QE for Capacitive Touch is a tool that generates tuning data which is used by Renesas MCU which have the CTSU peripheral (Capacitive Touch Sensing Unit).

By default, QE for Capacitive Touch generates tuning data via "Auto Tuning" mode. Additionally, to optimize touch performance, QE for Capacitive Touch supports an "Advanced mode" Tuning.

If you are developing a Capacitive Touch for the first time, it is recommended that you read the Capacitive Touch Introduction Guide beforehand. For information on the hardware, please refer to the Capacitive Touch Electrode Design Guide.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

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

### Target Device

CTSU mounted RX family, RA family, RL78 family MCU, Renesas Synergy™

(CTSU includes CTSU2, CTSU2L, CTSU2La, CTSU2SL, CTSU2SLa, etc.)

In addition, refer to CTSU2x for CTSU2L/CTSU2La/CTSU2SL/CTSU2SLa after the next page.

### Development Environment Covered in This Document

- Renesas e<sup>2</sup> studio Integrated Development Environment (IDE) 2025-12 or later
- Renesas QE for Capacitive Touch V4.3.0 or later

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### 1. Outline

This chapter describes the flow of parameter generation using QE for Capacitive Touch and the parameters that can be adjusted.

QE for Capacitive Touch measures the parasitic capacitance of the user's touch sensor and performs auto-tuning to optimize the parameters. For more information about QE for Capacitive Touch, please see Web page below.

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

Auto tuning with QE for Capacitive Touch generates basic CapTouch parameters. If the required specifications are not met in evaluations using these parameters, perform manual tuning with CapTouch parameters. If further adjustment is required, perform "Advanced mode" Tuning. Figure 1-1 shows the tuning procedure in QE for Capacitive Touch.

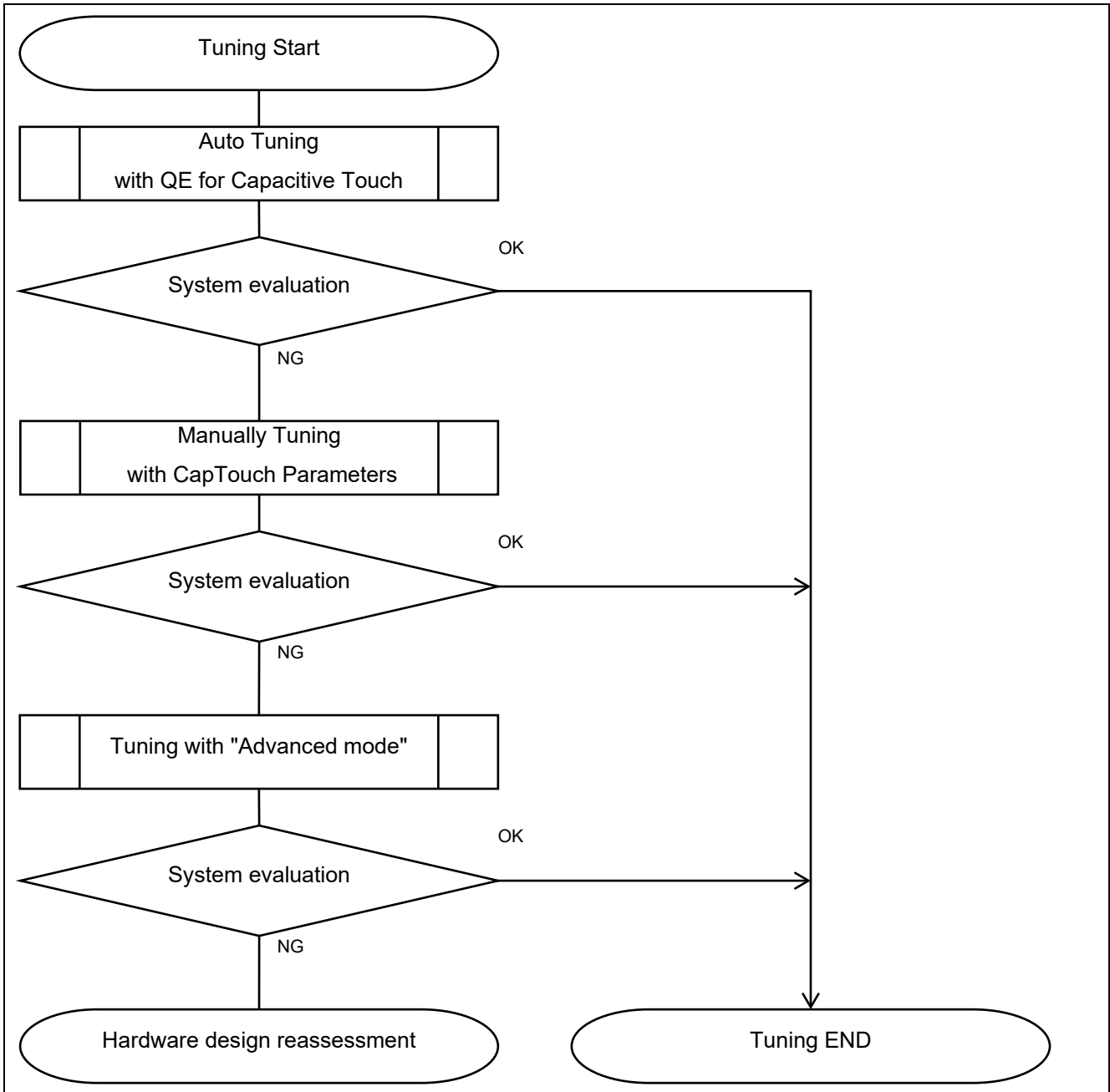


Figure 1-1 Tuning Flowchart

Table 1-1 lists the parameters that can be adjusted with Auto Tuning /Manual tuning with CapTouch parameters /"Advanced mode" Tuning. Please refer to QE CTSU module/QE TOUCH module Application Notes for each device family of parameters.

**Table 1-1 Tuning-adjustable parameters**

Parameter	Auto tuning	Manually tuning with CapTouch parameters	Tuning with "Advanced mode"
Base Clock Frequency /Sensor Drive Pulse Frequency	✓	-	✓
Offset	✓	(Display only)	-
Touch Threshold	✓	✓	-
Hysteresis	✓	✓	-
Sample count for drift correction	-	✓	-
Continuous Touch Cancel Count	-	✓	-
Debouncing count of touch-on filter	-	✓	-
Debouncing count of touch-off filter	-	✓	-
Average sample count for moving average filter	-	✓	-
Measurement Count/Measurement Time	-	-	✓
Offset Tuning Target	-	-	✓
Current Range *1	-	-	✓
Non-measured TS Pin Output Select *1	-	-	✓
Transmit Power	-	-	✓
Judgment Type *1	-	-	✓
Multi-clock Measurement/Multiplication Ratio*1	-	-	✓
Touch Judgment (Software/Hardware) *2	-	-	✓
CCO Characteristics Correction (Software/Hardware) *3	-	-	(Display only)
Multi-clock Correction (Software/Hardware) *3	-	-	(Display only)
Measurement Voltage Setting *1	✓*4	-	✓*4

✓: Supported

**Note1:** This function can be adjusted only for CTSU2/CTSU2L/CTSU2La/CTSU2SL/CTSU2SLa. Please refer to "Capacitance Touch Introduction Guide" for the difference of each capacitance touch sensor and corresponding products.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

**Note2:** Hardware touch judgment (Auto Judgment) is a function available only for CTSU2L/CTSU2La/CTSU2SL/CTSU2SLa. However, for microcontrollers with a built-in SNOOZE mode sequencer (SMS), it can be realized by using it together with the SMS. When the MCU with built-in SMS is used, "SMS" is displayed instead of "Hardware" in Touch Judgment. It can be set from Smart Configurator/Touch Interface Configuration/Advanced mode.

**Note3:** This function is only displayed on CTSU2SL/CTSU2SLa. It cannot be changed by the user because it is automatically set according to "Judgment Type" and "Touch Judgment".

**Note4:** When the microcontroller operating voltage setting is less than 2.4 V, the measurement voltage is automatically set to a lower voltage. 2.4 V or higher, the measurement voltage can still be set to a lower voltage in Advanced mode.

Auto Tune automatically adjusts the parameters using QE for Capacitive Touch, and outputs the adjusted parameters to the source file. For manual tuning of CapTouch parameters, those settings that can be changed using the "CapTouch Parameter List" in QE for Capacitive Touch are shown. For details, please refer to "7.2 Manually Tuning with CapTouch Parameters" in the document below.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

If the manual tuning or auto tuning of CapTouch parameters does not meet the target requirements for sensitivity/noise immunity, you can adjust the parameters in Advanced mode.

### 1.1 Auto Tuning

Figure 1-2 shows the flow of Auto tuning.

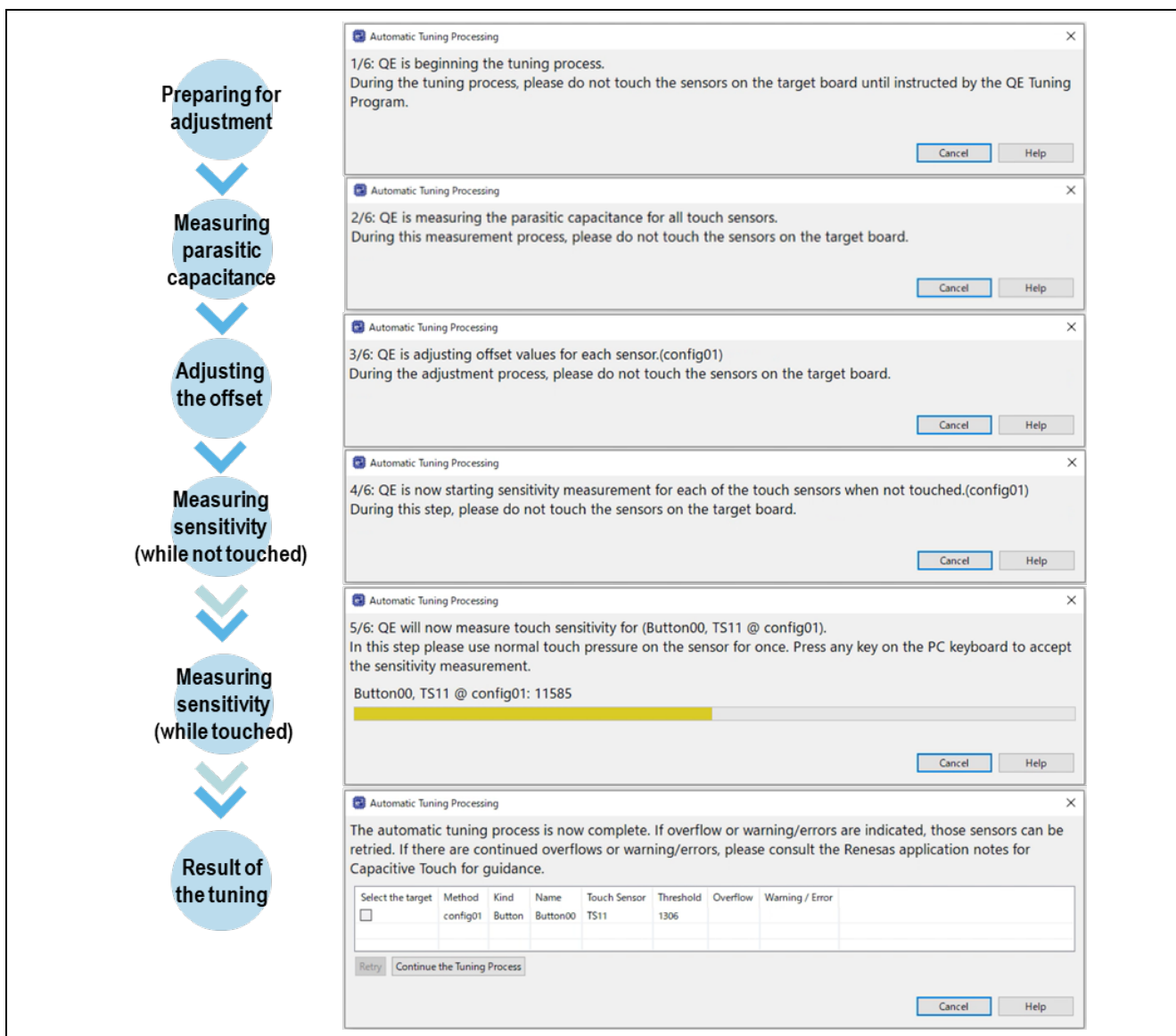


Figure 1-2 Flow of Auto tuning with QE for Capacitive Touch

Auto tuning adjusts the optimal parameters of touch sensor detection. First, the capacitance at touch OFF is measured, and “Base Clock Frequency/Sensor Drive Pulse Frequency” is set according to the measurement result. Also, adjust the offset according to the "Offset Tuning Target.” Then, the capacitance change of touch ON/OFF status is measured, touch thresholds, etc. are set, and the tuning result is output to the source file.

## 1.2 Manual Tuning with CapTouch Parameters

For Manual tuning with CapTouch parameters, software parameters can be changed from "CapTouch Parameters (QE)". The touch behavior and the effect of changing the parameter values can be viewed in real time.

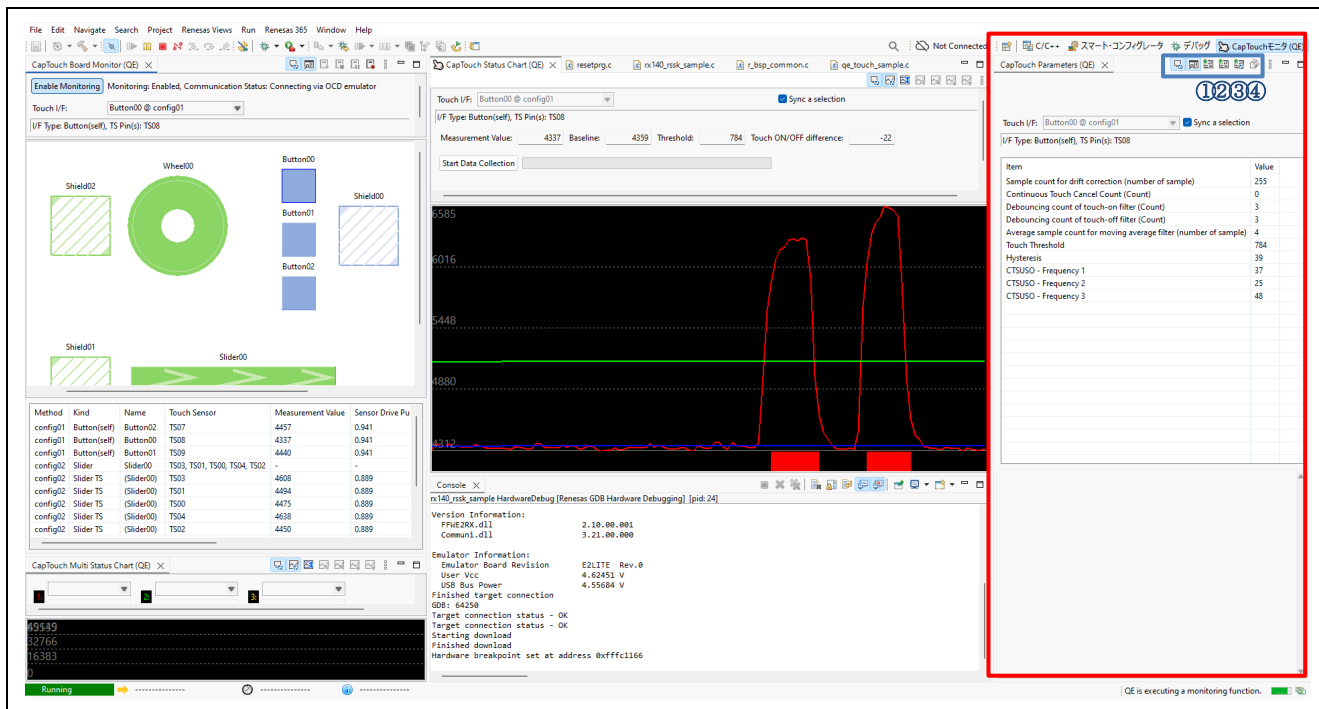


Figure 1-3 Manual Tuning with QE for Capacitive Touch

For Manual tuning, use the "CapTouch Parameters (QE)" in QE for Capacitive Touch (in red box in Figure 1-3). You can change the parameter and check the operation after adjusting it from the "CapTouch Status Chart (QE)" in real time. Parameters adjusted in this view can also be reflected in the source file. Please refer to Table 1-2 for explanations of the functions of the "CapTouch Parameters (QE)" tool bar (in the blue frame in Figure 1-3) used when performing manual tuning. Parameters can be read and written to the application via the CapTouch Parameter icons.

Table 1-2 "CapTouch Parameters (QE)" tool bar function.

	Icon Description	Feature Overview
①	Read from target board	Reads parameter values from the target board.
②	Write to target board	Write the value of the edited parameter to the target board.
③	Write to target board in real time	Toggle button to switch whether the numerical value of the parameter is reflected to the target in real time.
④	Generate a parameter file	The parameter file is output based on the parameter information adjusted in this view.

"Generate parameter file" outputs the source file under the `qe_gen` folder. Table 1-3 shows the output source file. After outputting the source file, the operation of adjusted parameters can be checked by building and debugging.

Table 1-3 Source file output by "Generating a Parameter File"

File name	Description
<code>qe_touch_config.c</code>	File that holds parameter settings for each configuration (method)

Please refer to the QE for Capacitive Touch "Help" for details.

### 1.3 "Advanced Mode" Tuning

In the "Advanced mode" Tuning, it is possible to adjust mainly hardware parameters such as the sensor drive pulse output for measuring capacitance. For details on the parameters that can be adjusted, please refer to the table below 2.3 Correspondence Table for Each Capacitive Touch Sensor.

Figure 1-4 shows the Cap Touch workflow (QE). Tuning can be performed from "2. Tuning Touch Sensors". Tuning by checking the "Advanced mode" checkbox under "Start Tuning".

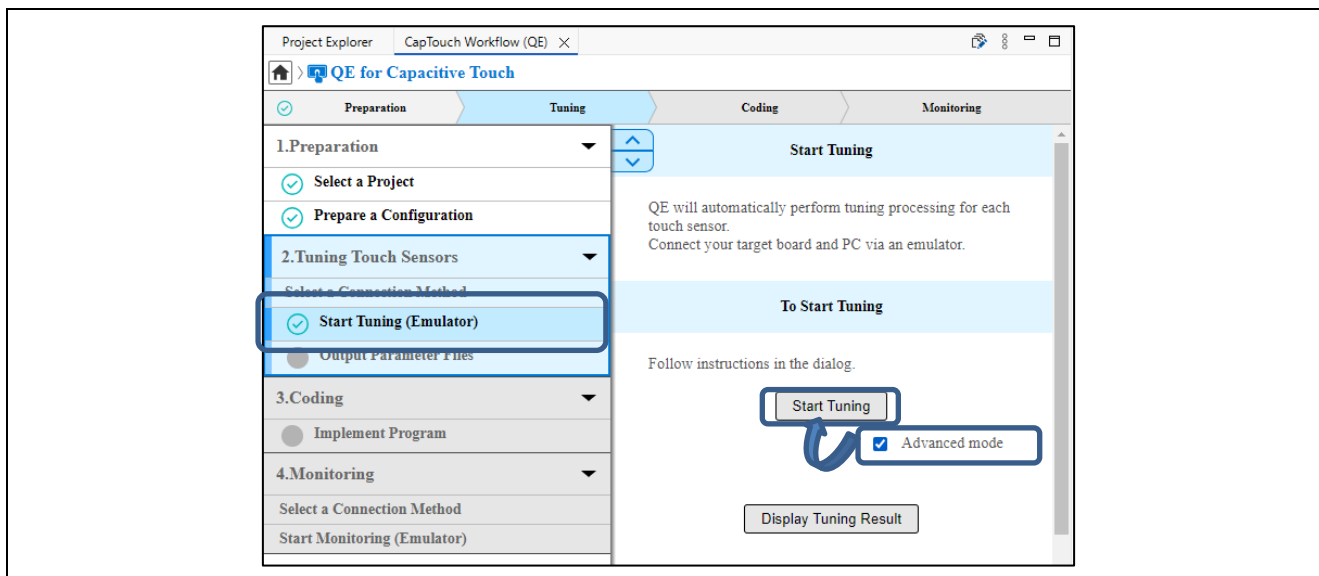
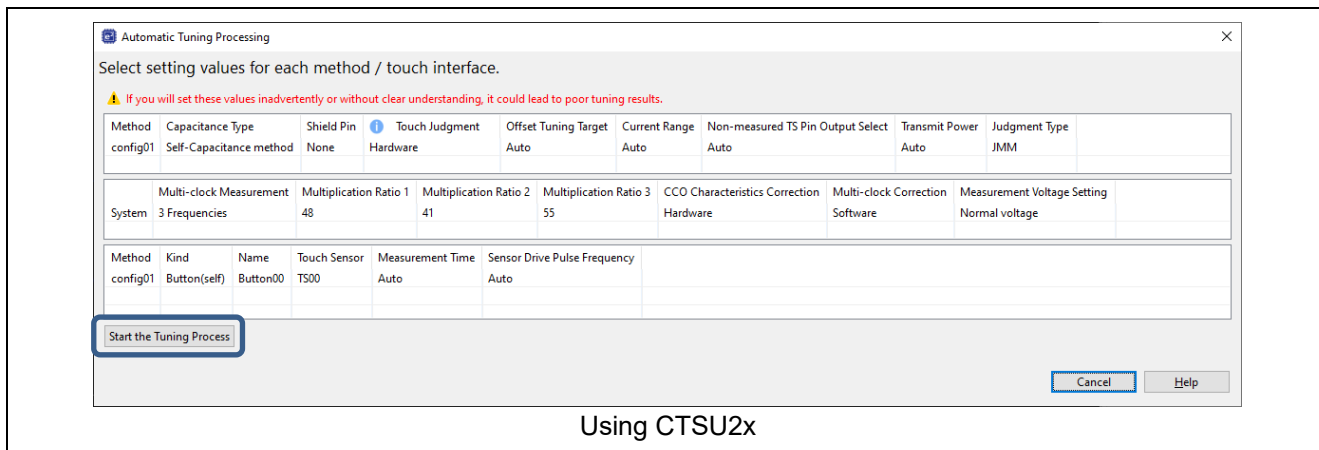


Figure 1-4 Tuning with "Advanced mode"

When "Advanced mode" Tuning is started, a window as shown in Figure 1-5 is displayed and each parameter can be adjusted. After desired parameters are adjusted, click the "Start the Tuning Process" button in the blue frame in Figure 1-5 to start tuning.



Using CTSU2x

Figure 1-5 "Advanced mode" Tuning window

The parameters that can be adjusted in "Advanced mode" Tuning vary depending on the device. For details, please see 2.3 Correspondence Table for Each Capacitive Touch Sensor.

After tuning in the "Advanced mode", you can reflect the results of parameter adjustment in the source file by clicking the "Output Parameter Files" button shown in Figure 1-6 from the "To Output Parameter Files" menu.

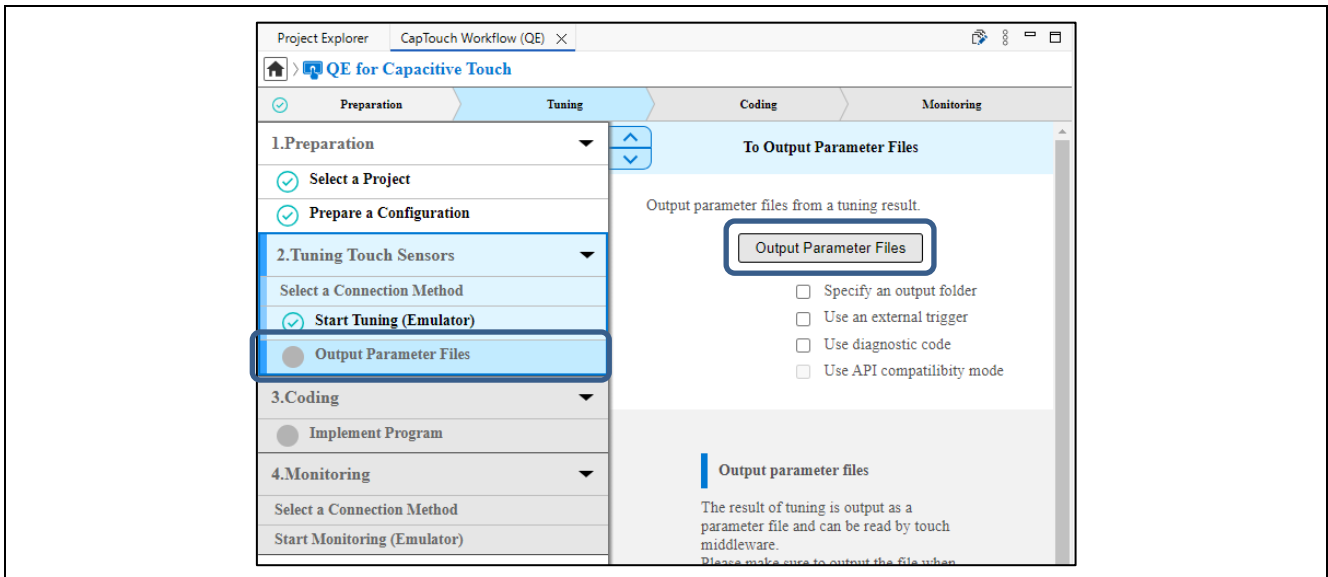


Figure 1-6 To Output Parameter Files

Click the Output File button to output the source file under the “qe\_gen” folder. Table 1-4 shows the source files that are output.

Table 1-4 Source files output by the "Output Parameter Files" button

File name	Description
qe_touch_define.h	Macro information file used by the touch middleware
qe_touch_config.h	Files to include from user programs
qe_touch_config.c	File that holds parameter settings for each configuration (method)

After outputting the source file, the operation of adjusted parameters can be checked by building and debugging.

Setting these values incorrectly or without a clear understanding may result in poor adjustment results. Adjust the value after sufficiently evaluating it to suit the environment in which it is used.

## 2. "Advanced Mode" Tuning Flow

This section describes the adjustment process in Advanced mode and the adjustable parameters.

### 2.1 Signal Value Improvement Adjustment Flow

Figure 2-1 shows the adjustment steps to improve signal value, which represents the measurement difference between touch ON and OFF states, through "Advanced mode" Tuning.

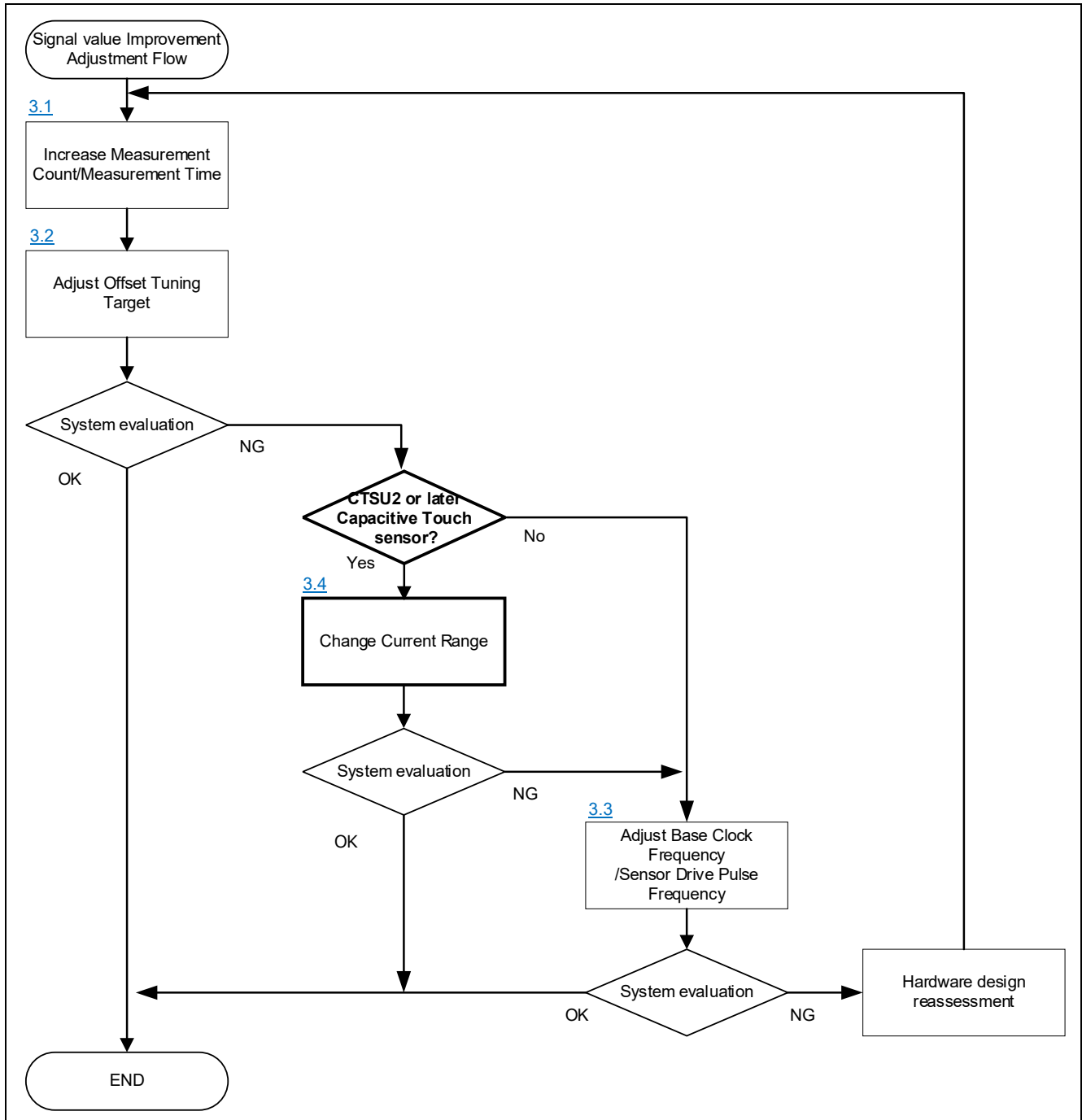


Figure 2-1 Signal value improvement adjustment flow

## 2.2 Noise Suppression Adjustment Flow

Figure 2-2 shows the adjustment steps for improving noise immunity through "Advanced mode" Tuning.

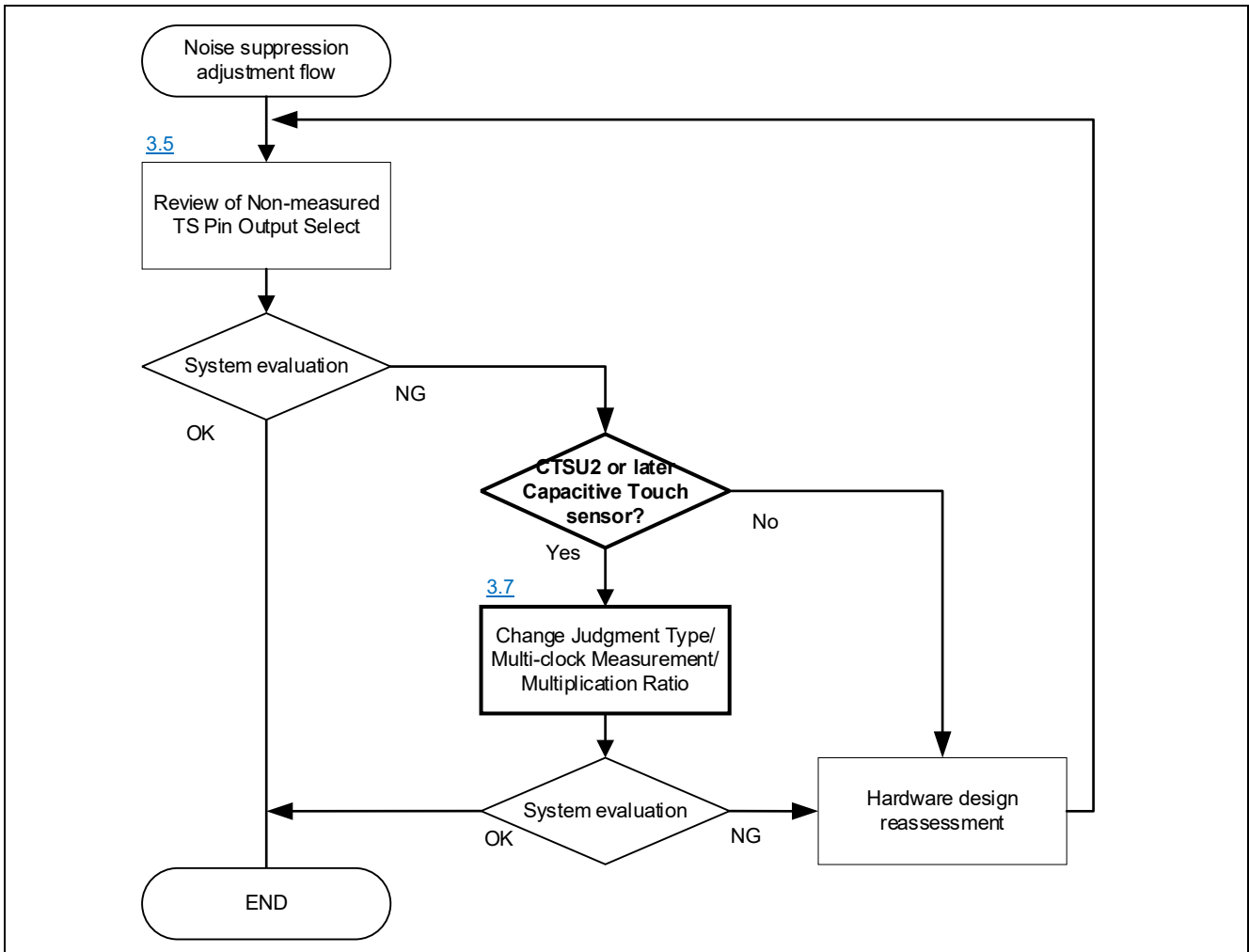


Figure 2-2 Noise suppression adjustment flow

## 2.3 Correspondence Table for Each Capacitive Touch Sensor

Table 2-1 shows the purpose and functional overview of the parameters that can be configured in Advanced mode, along with their applicability to each capacitive touch sensor.

**Table 2-1 Parameters configurable in Advanced mode, their purposes, and their correspondence to capacitive touch sensors**

	Parameter	Purpose	CTS2x	CTS2	CTS1	Feature Overview
1	<a href="#">Measurement Count/Measurement Time</a>	Improved signal value	✓	✓	✓	Set the Measurement Count and determine the Measurement Time. The signal value can be improved by integrating the measurement value.
2	<a href="#">Offset Tuning Target</a>	Improved signal value	✓	✓	✓	Set the Offset Tuning target (%) so that the measurement value at touch OFF becomes the target value. The offset value is adjusted automatically. Adjust this when the measurement time is changed.
3	<a href="#">Base Clock Frequency/Sensor Drive Pulse Frequency</a>	Improved signal value	✓	✓	✓	Set the division ratio of the clock/pulse frequency output to the touch sensor section. The higher Base Clock Frequency/Sensor Drive Pulse Frequency, the better the signal value can be seen. However, a measurement error occurs when the parasitic capacitance is large. For details, please see Figure 3-8 to Figure 3-13.
4	<a href="#">Current Range</a>	Improved signal value	✓	✓	-	Sets the current supply capability from VDC and determines the current mirror ratio between the measured power supply current and the input current of the current-controlled oscillator. Setting a low current range increases the signal value. This is because CCO input current at touch ON increases.
5	<a href="#">Non-measured TS Pin Output Select</a>	Pin Setting	✓	✓	-	For each method in the touch interface configuration, you can specify how to handle TS pins that are not being measured, excluding the active shield pins during scanning.
6	<a href="#">Transmit Power</a>	Pin Setting	✓	✓	✓	Selects I/O power supply of the pins set to the transmit pins when the mutual capacitance method is used or the active-shield is used. Use the default setting for this value.
7	<a href="#">Judgment Type</a>	Noise Suppression	✓	✓	-	Judgment Type includes Value Majority Mode (VMM) and Judgment Majority Mode (JMM). VMM is a method to judge by adding two measured values which are close in value from the measured results of 3-frequency. JMM is a method in which the judgment result of each of the 3-frequency measurements is judged by majority decision.
8	<a href="#">Multi-clock Measurement/Multiplication Ratio</a>	Noise Suppression	✓	✓	-	Set the measurement times to be measured in Multi-clock Measurement and the Multiplication Ratio of multiple types of frequencies to be used for measurement. Multi-clock Measurement allows you to measure multiple drive frequencies to avoid synchronous noise. Measuring with multiple sensor drive pulse frequencies makes it possible to exclude measurement results that may have been affected by noise. If the default multiplication ratio settings cause the measurement values to be influenced by synchronous noise, adjust the multiplication ratio as needed.
9	<a href="#">Touch Judgment</a>	Process reduction Low power consumption	✓	-	-	This function sets whether touch judgment is performed by hardware or software. When touch detection is handled by hardware, or when touch detection is configured to use SNOOZE Mode Sequencer (SMS) on microcontrollers that incorporate SMS, low-power operation can be achieved. It can be set from Smart Configurator/Touch Interface Configuration/Advanced mode.
10	<a href="#">CCO Characteristics Correction</a>	Process reduction Low power consumption	✓	-	-	This function sets whether CCO characteristics correction is performed by hardware or software. It is set to hardware when hardware touch judgment is enabled. Hardware processing eliminates the need for wake-up for each measurement and contributes to lower power consumption. This function is only displayed on CTSU2SL/CTS2SLa. It cannot be changed by the user because it is automatically set according to Judgment Type and Touch Judgment.
11	<a href="#">Multi-clock Correction</a>	Process reduction Low power consumption	✓	-	-	This function sets whether Multi-clock Correction is performed in hardware or software. It is set to hardware when VMM is used and hardware touch judgment is enabled. This function is only displayed on CTSU2SL/CTS2SLa. It cannot be changed by the user because it is automatically set according to Judgment Type and Touch Judgment.
12	<a href="#">Measurement Voltage Setting</a>	Process reduction Low power consumption	✓	✓	-	Set TSCAP voltage to be used. If the microcontroller operating voltage is less than 2.4 V, the measurement voltage is automatically set to a lower voltage and the TSCAP voltage is 1.2 V. This function is used when the microcontroller operating voltage is less than 2.4 V during battery operation.

✓: Supported

### 3. Explanation of Each Parameter

#### 3.1 Measurement Count/Measurement Time

In "Measurement Count/Measurement Time" setting, the measurement time is determined by configuring the measurement count. In CTSU1, it is displayed as "Measurement Count" and in CTSU2, it is displayed as "Measurement Time".

1. CTSU1: The measurement time for a single cycle is determined by CTSUPRMODE, CTSUPRRATIO, and the base clock cycle. The "Measurement Count" is determined by the following formula. For details on CTSUSNUM, CTSUPRMODE, and CTSUPRRATIO, please refer to the hardware manual for each capacitive touch sensor microcontroller.  
Measurement Count = (CTSUSNUM + 1)

2. CTSU2/CTSUX: "Measurement time" is configured based on (STCLK cycle × 8). The measurement time is determined by the following formula. The STCLK cycle is 2 μs (0.5 MHz). For details on the STCLK cycle (STCLK period) and SNUM, please refer to the hardware manual for each capacitive touch sensor microcontroller.

$$\text{Measurement time } [\mu\text{s}] = [(\text{STCLK cycle} * 8) * (\text{SNUM} + 1)]$$

Signal value\* can be improved by increasing "Measurement Count/Measurement Time". However, since the time required for measurement is also extended at the same time, adjustment according to the target requirements is required. Also, when changing "Measurement Count/Measurement Time", please adjust the offset tuning target using the "Offset Tuning Target" to prevent overflow. Please refer to 3.2 Offset Tuning Target for details of offset tuning target adjustment.

**Note:** The signal value indicates the difference value at touch ON/OFF.

Figure 3-1 shows the image of the measurement times by the measurement count and the measured value at the time of touch ON/OFF.

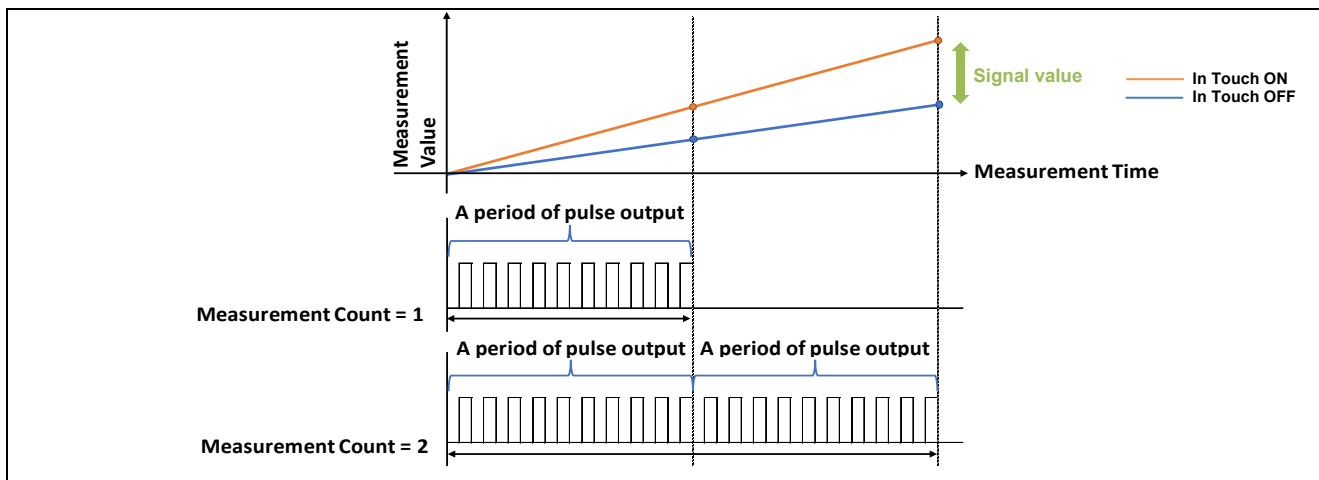


Figure 3-1 Image of Measurement Time and measurement value based on Measurement Count

Table 3-1 and Table 3-2 show the default "Measurement Count/Measurement Time" when using the self-capacitance method for CTSU1 and CTSU2/CTS2x, respectively. In CTSU1, Measurement Count is determined based on the "Base Clock Frequency" so that Measurement Time is fixed at 526  $\mu$ s. In CTSU2/CTS2x, SNUM is set to 7 to ensure the Measurement Time of 128  $\mu$ s.

**Table 3-1 CTSU1 Default "Measurement Count" Setting**

	Base Clock Frequency [MHz]	CTSUSNUM	Measurement Count	Measurement Time [ $\mu$ s]
CTSU1 (Sample RX130)	4	7	8	526
	2	3	4	
	1	1	2	
	0.5	0	1	

**Note:** This indicates the measurement time when using the recommended settings for CTSUPRRATIO and CTSUPRMODE. Changing these values is deprecated. For details, please refer to the hardware manual for each capacitive touch sensor microcontroller.

**Table 3-2 CTSU2 Default "Measurement Time" Setting**

	SNUM	Measurement Time [ $\mu$ s]	Measurement Time for one frequency [ $\mu$ s]
CTS2/CTS2x (Sample RX140)	7	$[(\text{STCLK cycle} * 8) * 8]$	128

**Note:** STCLK is the reference clock used for determining the measurement time. The measurement time shown corresponds to the recommended STCLK value of 0.5 MHz (STCLK cycle: 2  $\mu$ s). For further details, please refer to the hardware manual for each capacitive touch sensor microcontroller.

This section describes the Time Required for Measurement for each touch sensor. The Time Required for Measurement represents the time required to perform a touch measurement for each electrode of each touch sensor, and is defined as the sum of the Sensor Stabilization Wait Time and the measurement time. The Sensor Stabilization Wait Time refers to the time from the start of supplying the sensor drive pulses until the voltage at the TSCAP pin reaches a stable state. For details on the Sensor Stabilization Wait Time (CTSUSST/SST), refer to the hardware manual for each capacitive touch sensor microcontroller.

The formulas for calculating the stabilization wait time and the measurement time for CTSU1, CTSU2/CTSU2x are shown below.

- CTSU1 (RX130)

$$\text{Sensor Stabilization wait time } [\mu\text{s}] = 34 \cdot \frac{1}{\text{Base Clock Frequency}}$$

$$\text{Measurement time } [\mu\text{s}] = 263 \cdot \frac{1}{\text{Base Clock Frequency}} \cdot (\text{CTSUSNUM} + 1)$$

For the detailed information on the “Base Clock Frequency,” please refer to 3.3 Base Clock Frequency/Sensor Drive Pulse Frequency.

Table 3-3 shows a typical example of the measurement time and Sensor stabilization wait time when the self-capacitance method is used in RX130 as a typical CTSU1.

**Table 3-3 Sensor stabilization wait time and measurement time when using self-capacitance method on RX130**

Base Clock Frequency [MHz]	SNUM	Measurement count	Sensor stabilization wait time [μs]	Measurement time [μs]*	Time Required for Measurement [μs]
4	7	8	8.5	526	534.5
2	3	4	17.0	526	543.0
1	1	2	34.0	526	560.0
0.5	0	1	68.0	526	594.0

**Note:** This indicates the measurement time when using the recommended settings for CTSUPRRATIO and CTSUPRMODE. Changing these values is deprecated. For details, please refer to the hardware manual for each capacitive touch sensor microcontroller.

- CTSU2/CTSU2x (RX140)

Sensor stabilization wait time [ $\mu\text{s}$ ] =  $64 \cdot 3$  [for 3-frequency measurement]

Measurement time [ $\mu\text{s}$ ] =  $16 \cdot (\text{SNUM} + 1) \cdot 3$  [for 3-frequency measurement]

Table 3-4 shows a typical CTSU2/CTSU2x for the measurement time and Sensor stabilization wait time when the self-capacitance method is used in RX140.

**Table 3-4 Sensor stabilization wait time and the measurement time when using self-capacitance method on RX140 (3-frequency measurement)**

SNUM	Measurement time	Sensor stabilization wait time for 3-frequency measurement [ $\mu\text{s}$ ]	Measurement time for 3-frequency measurement [ $\mu\text{s}$ ]*	Time Required for Measurement [ $\mu\text{s}$ ]
7	$[(\text{STCLK cycle} \cdot 8) \cdot 8]$	192 [ $64 \times 3$ ]	384 [ $128 \times 3$ ]	576 [ $192 + 384$ ]

**Note:** STCLK is the reference clock used for determining the measurement time. The measurement time shown corresponds to the recommended STCLK value of 0.5 MHz (STCLK cycle: 2  $\mu\text{s}$ ).

The Sensor stabilization wait time and the measurement time when each capacitive touch sensor is used vary depending on the operation clock. Please refer to the hardware manual of each capacitive touch sensor. When using the mutual-capacitance method, the time required for measurement is twice that of the self-capacitance method.

Figure 3-2 shows an example when setting "Measurement Count/Measurement Time" with "Advanced mode".

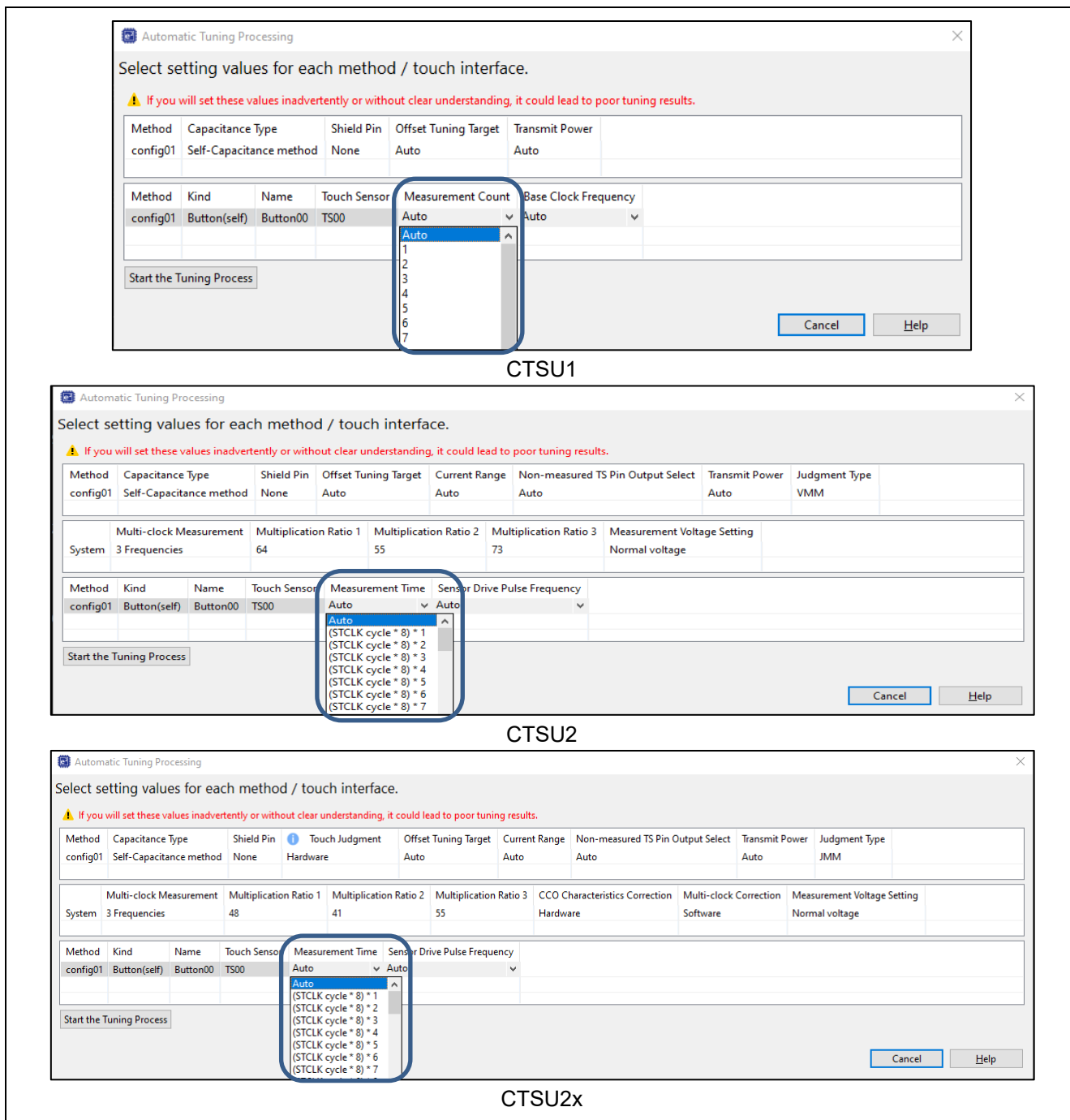


Figure 3-2 Setting of "Measurement Count/Measurement Time"

The set value is reflected to "snum" of the qe\_touch\_config.c. For example, if "(STCLK Cycle\* 8) \* 8" is selected in "Measurement Count/Measurement Time" for RX140, it is set as "snum = 0x07".

```
const ctsu_element_cfg_t g_qe_ctsu_element_cfg_config01[] =
{
    { .ssdiv = CTSU_SSDIV_4000, .so = 0x12B, .snum = 0x07, .sdpa = 0x07 },
};
```

**Note:** For details about SNUM, please refer to the hardware manual for each capacitive touch sensor microcontroller.

### 3.1.1 Effects on Signal Value / SNR and Precautions due to Changes in the Measurement Count/Measurement Time

Table 3-5 shows the measurement values (actual measurement examples) when RX140 mounted capacitance touch evaluation system is used when "Measurement Count/Measurement Time" is changed.

**Table 3-5 Measurement values when "Measurement Count/Measurement Time" is changed (actual measurement example)**

Capacitance Touch Evaluation System with CTSU2x(RX140)								
Self-capacitance method, VMM method, Sensor Drive Pulse Frequency: 2 MHz, Current Range: 40 $\mu$ A, Button 1 ch (averaged five times)								
SNUM	Measurement time for 3-frequency measurement [ $\mu$ s]	Time Required for Measurement [ $\mu$ s]	Offset tuning target [%]	Avg. at touch OFF A	Avg. at touch ON B	Signal value (Difference of touch ON/OFF) B - A	Avg. at touch OFF Noise value	SNR
7	384	576	37.5	11545	13514	1969	17.78	17.85
11	576	768	25.0	11666	14586	2920	22.76	20.96
15	768	912	20.0	11435	14994	3559	27.12	21.12

**Note:** The actual measurement was obtained from QE for Capacitive Touch's "CapTouch Status Chart (QE) View" function. For more information, refer to e<sup>2</sup> studio "Help".

Increasing the "Measurement Count/Measurement Time" raises the accumulation count for touch measurements, resulting in an increased signal value. If the noise follows a normal distribution, the noise is averaged out, thereby improving the SNR.

On the other hand, increasing the "Measurement Count/Measurement Time" may cause the measurement value to overflow. If the "Measurement Count/Measurement Time" exceeds the upper limit, an error will occur when configuring the settings in Advanced mode. In such cases, consider reducing the "Measurement Count/Measurement Time." Furthermore, increasing the "Measurement Count/Measurement Time" may cause the Time Required for Measurement to fail to meet the target requirement, and if the CTSU is operated in low-power mode, increasing "Measurement Count/Measurement Time" may also lead to higher power consumption. Ensure that the "Measurement Count/Measurement Time" is thoroughly evaluated and configured to meet the target system requirements.

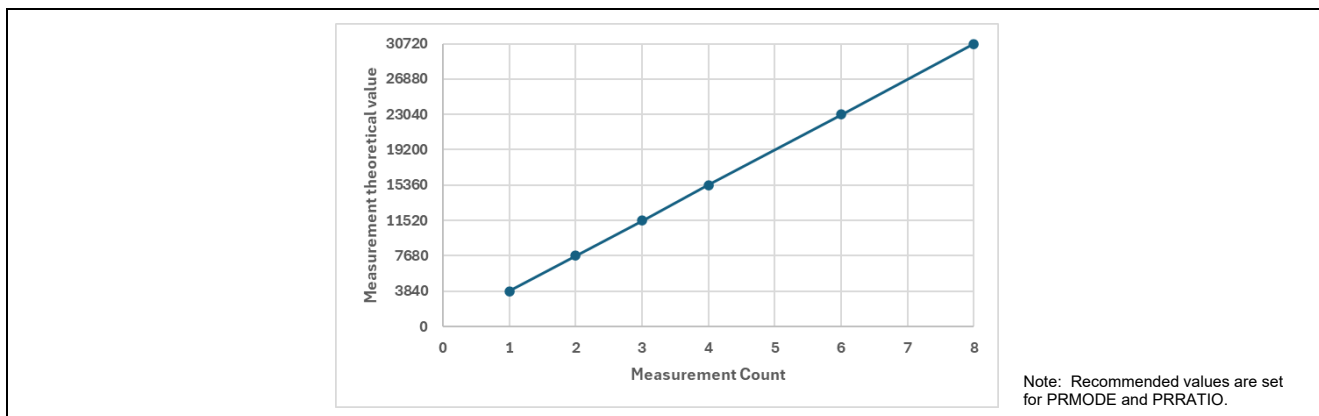
### 3.1.2 Necessity of Offset Tuning Target Adjustment when Changing Measurement Count/Measurement Time

If you change the "Measurement Count/Measurement Time", you need to adjust the "Offset Tuning Target" to prevent the measurement value from exceeding the maximum value of 65535 and overflowing. In order to prevent overflow, "Offset Tuning Target" must be adjusted and the measurement value adjusted. Please refer to 3.2 Offset Tuning Target for offset tuning adjustment.

Table 3-6 and Figure 3-3 show the measurements of "Measurement Count/Measurement Time" in RX130 as a typical CTSU1.

**Table 3-6 Measurement theoretical value for "Measurement Count " with RX130**

<b>RX130 (CTSU1)</b>				
Self-Capacitance System, PCLKB:32 MHz, Sensor Drive Pulse Frequency: 2 MHz, Offset Tuning Target: 37.5%, Key 1ch				
Measurement count	Sensor stabilization wait time [μs]	Measurement time [μs]	Time Required for Measurement [μs]	Measurement theoretical value
1	17	131.5	148.5	3840
2	17	263.0	280.0	7680
3	17	394.5	411.5	11520
4	17	526.0	543.0	15360
5	17	657.5	674.5	19200
6	17	789.0	806.0	23040
:	:	:	:	:



**Figure 3-3 Measurement theoretical value for "Measurement Count " with RX130**

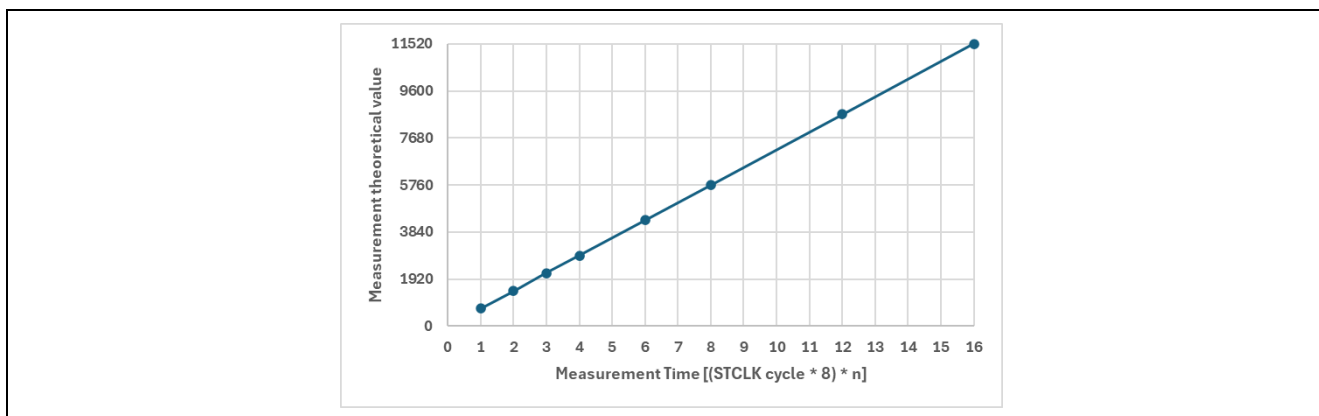
For instance, if the "Measurement Count" is increased to eight by the self-capacitance method, the measurement value at touch OFF will be around 30720. The "Offset Tuning Target" should be adjust so that the measurement value stays in the range where the CCO exhibits good output linearity

Table 3-7 and Figure 3-4 show typical measurements for "Measurement Time" in RX140 as a CTSU2/CTSUX.

**Table 3-7 Measurement theoretical value for "Measurement Time" with RX140**

<b>RX140 (CTSUX/CTSUX)</b>				
Self-Capacitance System, PCLKB: 32 MHz, Sensor Drive Pulse Frequency: 2 MHz, Offset Tuning Target: 37.5%, Key 1 ch				
Measurement time [ $\mu$ s] *	Sensor stabilization wait time [ $\mu$ s]	Measurement time for one frequency [ $\mu$ s]	Time Required for Measurement [ $\mu$ s]	Measurement theoretical value per frequency
[(STCLK cycle * 8) * 1]	192	48	240	720
[(STCLK cycle * 8) * 2]	192	96	288	1440
[(STCLK cycle * 8) * 3]	192	144	336	2880
:	:	:	:	:
[(STCLK cycle * 8) * 8]	192	384	576	5760
:	:	:	:	:
[(STCLK cycle * 8) * 16]	192	768	960	11520
:	:	:	:	:

**Note:** STCLK is the reference clock used for determining the measurement time. The measurement time shown corresponds to the recommended STCLK value of 0.5 MHz (STCLK cycle: 2  $\mu$ s).



**Figure 3-4 Measurement theoretical value for " Measurement Time" with RX140**

For instance, if the "Measurement Time" is increased to [(STCLK cycle \* 8) \* 16] when using the self-capacitance method, the measurement value at touch OFF per frequency will be around 11520. The "Offset Tuning Target" should be adjusted so that the measurement value stays in the range where the CCO exhibits good output linearity.

### 3.2 Offset Tuning Target

In "Offset Tuning Target", adjust the offset current setting for each method so that the measurement value at touch OFF becomes the target value. This adjustment is made when the measurement time is changed and the measurement value overflows, or when the parasitic capacitance is large and the measurement value does not reach the target value for measurement value when the active shield is used. For details, please refer to "2.2.2 Measurement Range" in the following document.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

Figure 3-5 shows an image of offset-tuning when using the self-capacitance method in RX130. The sensor counter register ranges from 0 to 65535 for 16 bit registers. However, when using the sensor counter register, measurement must be performed within the current measurement range (100% or less of the upper limit of the current range). CTSU is equipped with a sensor offset adjustment register. By tuning the offset current, the measured value of the parasitic capacitance component can be controlled and adjusted to the targeted value.

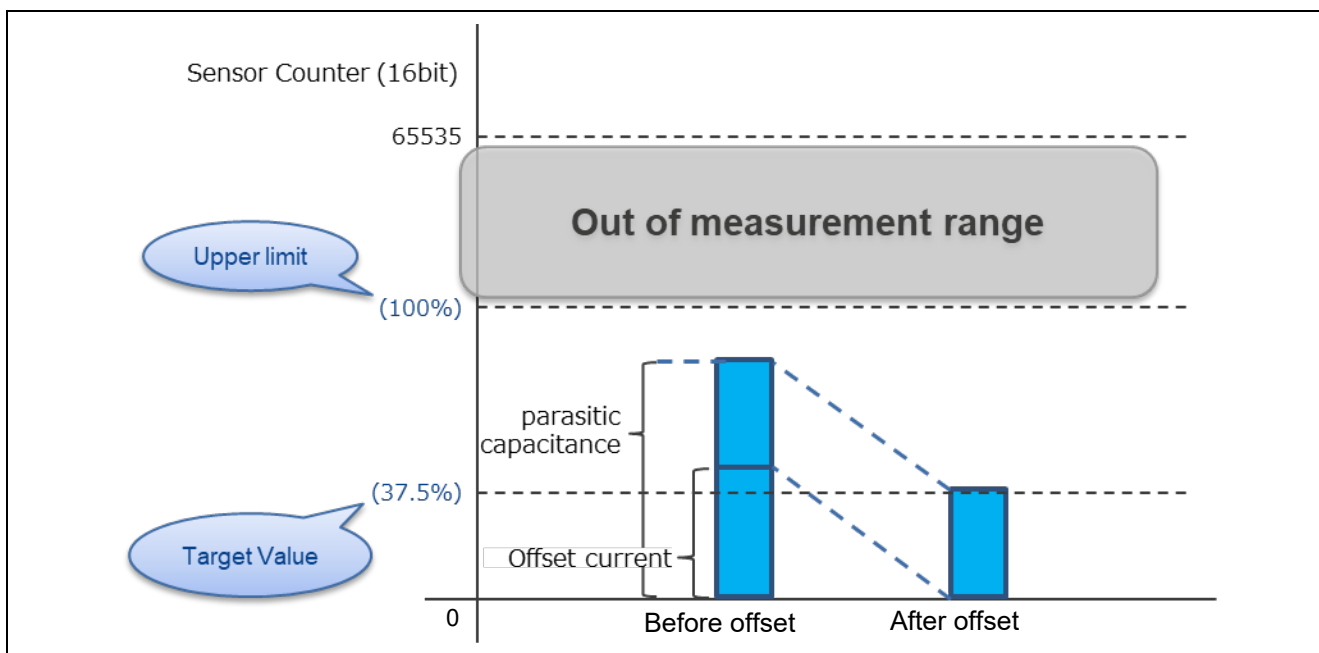


Figure 3-5 Offset Tuning Process of Self-Capacitance Method

Table 3-8 shows the target values for the default "Measurement Count/Measurement Time". For the default "Measurement Count/Measurement Time", please see Table 3-1 CTSU1 Default "Measurement Count" Setting and Table 3-2 CTSU2 Default "Measurement Time" Setting.

**Table 3-8 Default "Offset Tuning Target" Setting for Each measurement**

	Judgment Type *	ATUNE0	Target Value *		
			Self-capacitance method	Mutual capacitance system	Active shield
CTSU1	-	Normal Voltage	15360 (37.5%)	10240 (25%)	-
CTSU2/ CTSU2x	Value Majority Mode (VMM)	Normal Voltage	11520 (37.5%)	7680 (25%)	4608 (15%)
		Low Voltage	9216 (37.5%)	6144 (25%)	-
	Judgment Majority Mode (JMM)	Normal Voltage	5760 (37.5%)	3840 (25%)	2304 (15%)
		Low Voltage	4608 (37.5%)	3072 (25%)	-

**Note:** VMM is used, the total value ( $128 + 128 = 256 \mu\text{s}$ ) of the selected 2-frequency measurement result from the 3-frequency measurement result is used as the final measurement result. When JMM is used, the measured value is one frequency ( $128 \mu\text{s}$ ).

Target values are shown in Table 3-9 for setting the target value during offset-tuning in CTSU1.

**Table 3-9 Target value for "Offset Tuning Target" in CTSU1**

Offset Tuning Target [%]	Target value
25.0	10240
30.0	12288
35.0	14336
37.5	15360
40.0	16384
45.0	18432
50.0	20480

Target values for CTSU2/CTS2x differ depending on the version of QE for Capacitive Touch. Table3-10 shows the target values when the "Offset Tuning Target" are changed by CTSU2/CTS2x when QE for Capacitive Touch prior to v3.5.0 is used after v4.0.0 and Table3-11.

**Table3-10 Target value for "Offset Tuning Target" in CTSU2/CTS2x  
(QE for Capacitive Touch v4.0.0 or later)**

Offset Tuning Target [%]	JMM target value*		VMM target value*	
	Normal Voltage	Low Voltage	Normal Voltage	Low Voltage
10.0	1536	1229	3072	2458
15.0	2304	1843	4608	3686
20.0	3072	2458	6144	4915
25.0	3840	3072	7680	6144
30.0	4608	3686	9216	7373
35.0	5376	4301	10752	8602
37.5	5760	4608	11520	9216
40.0	6144	4915	12288	9830
45.0	6912	5530	13824	11059
50.0	7680	6144	15360	12288

**Note:** When VMM is used, it is the sum of two frequencies (256  $\mu$ s) of the 3-frequency measurement. When JMM is used, it is equivalent to one frequency (128  $\mu$ s).

**Table3-11 Target value for "Offset Tuning Target" CTSU2/CTS2x  
(QE for Capacitive Touch v3.5.0 or earlier)**

Offset Tuning Target [%]	Target value* (QE for Capacitive Touch v3.3.0 or earlier)	Target value* (QE for Capacitive Touch v3.5.0)
10.0	4096	3072
15.0	6144	4608
20.0	8192	6144
25.0	10240	7680
30.0	12288	9216
35.0	14336	10752
37.5	15360	11520
40.0	16384	12288
45.0	18432	13824
50.0	20480	15360

**Note:** The value after the sum of two frequencies (256  $\mu$ s) of the 3-frequency measurement result.

The target value depends on the version of QE for Capacitive Touch at tuning. This application note uses the target values in Table3-10. It is recommended that the latest QE for Capacitive Touch be used in the evaluation.

Figure 3-6 shows an example when setting "Offset Tuning Target" with "Advanced mode".

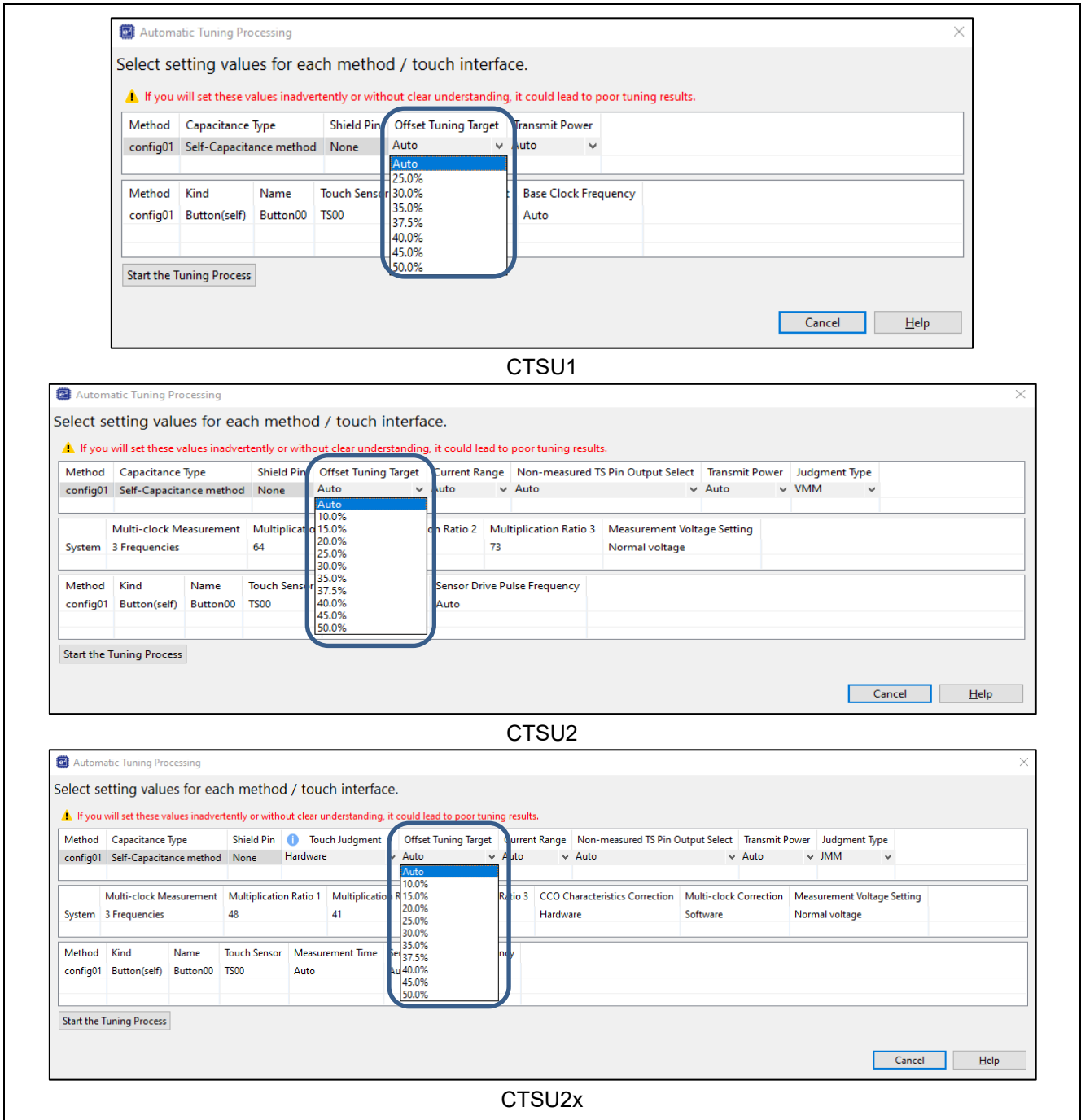


Figure 3-6 Setting of "Offset Tuning Target"

The setting is reflected in the `qe_touch_config.c`. The following is an example of target values for the self capacitance method/mutual capacitance method when RX130 is used. It is not recommended to rewrite this value directly.

```
#if (CTS_TARGET_VALUE_CONFIG_SUPPORT == 1)
    .tuning_self_target_value = 15360,
    .tuning_mutual_target_value = 10240,
#endif
```

### 3.2.1 Effects on Measurement Values due to Changes in Offset Tuning Target and Measurement Count/Measurement Time

The measured value changes depending on the “Measurement Count/Measurement Time”. If the “Measurement Count/Measurement Time” is set to twice the default setting, the measured value also doubles.

#### 1. CTSU1:

Measured value = (Offset tuning target [%] × 40960\*)/100 × (Measurement Count/Default Measurement Count)

**Note:** 40960 is the value when the offset tuning target is 100%.

#### 2. CTSU2:

- When using VMM:

Measurement Voltage Setting: Normal Voltage

Measured value = (Offset tuning target [%] × 30720\*)/100 × (Measurement Time/default Measurement Time)

**Note:** 30720 is the value when the offset tuning target is 100% at the measurement time of 256 μs.

Measurement Voltage Setting: Low Voltage

Measured value = (Offset tuning Target [%] × 24576\*)/100 × (Measurement Time/default Measurement Time)

**Note:** 24576 is the value when the offset tuning target is 100% at the measurement time of 256 μs.

- When using JMM:

Measurement Voltage Setting: Normal Voltage

Measured value = (Offset tuning target [%] × 15360\*)/100 × (Measurement Time/default Measurement Time)

**Note:** 15360 is the value when the offset tuning target is 100% at the measurement time of 128 μs.

Measurement Voltage Setting: Low Voltage

Measured value = (Offset tuning Target [%] × 12288\*)/100 × (Measurement count/default Measurement count)

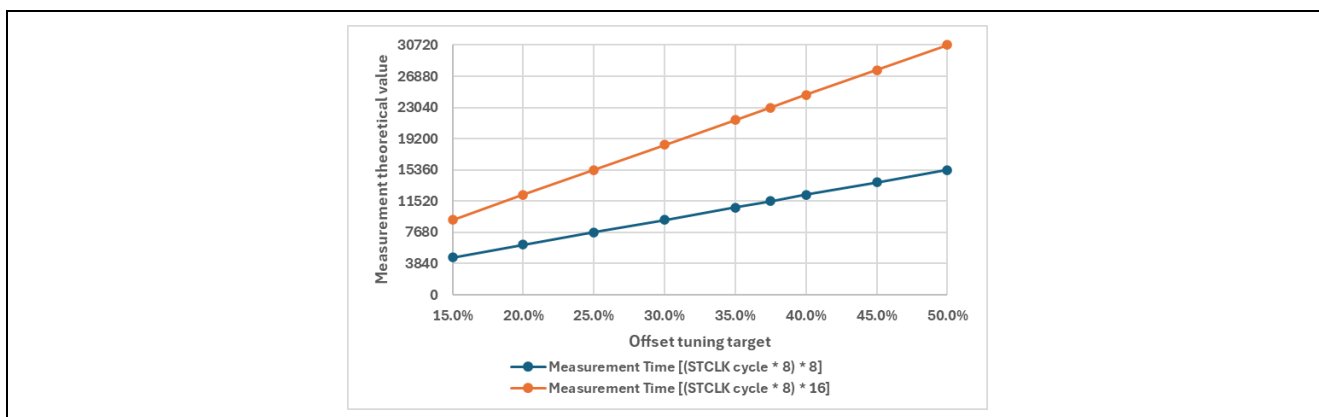
**Note:** 12288 is the value when the offset tuning target is 100% at the measurement time of 128 μs.

Table 3-12 and Figure 3-7 show the measurement theoretical values at touch OFF in VMM for the “Offset Tuning Target” when the “Measurement Time” is changed on CTSU2/CTSU2x.

**Table 3-12 Measurement theoretical values for "Offset Tuning Target " when the “Measurement Time” is changed**

Offset Tuning Target [%]	Target value when using VMM*	Measured theoretical value when VMM is used in touch OFF*	
		Measurement Time (default) [(STCLK cycle * 8) * 8]	Measurement Time [(STCLK cycle * 8) * 16]
10.0	3072	3072	6144
15.0	4608	4608	9216
20.0	6144	6144	12288
25.0	7680	7680	15360
30.0	9216	9216	18432
35.0	10752	10752	21504
37.5	11520	11520	23040
40.0	12288	12288	24576
45.0	13824	13824	27648
50.0	15360	15360	30720

**Note:** The value after the 2-frequency sum of the 3-frequency measurement results.



**Figure 3-7 Measurement theoretical value with respect to "Offset Tuning Target" when the “Measurement Time” is changed**

Changing the “Offset Tuning Target” may cause the measurement value to overflow. Please set the target value and measurement count so that the measured values do not overflow during the system (product) operation under the maximum capacitance-added state\*. If there is no need to change, set the target value and the “Measurement Time” for offset tuning to the target value for each method, referring to Table 3-8.

If the measurement value differs from the expected value due to the changes in the “Measurement Time,” refer to Table 3-12 to set the “Offset Tuning Target.” Set the “Offset Tuning Target” lower than the default setting when the measurement value is larger than the target value, and higher than the default setting when the measurement value is smaller than the target value. When the parasitic capacitance of the electrode is small or the active shield is used, set these target values again when measurement value does not reach the target value set by the offset tuning process.

**Note:** As an example, assume the maximum possible added capacitance, including non-normal operation, when water is spilled over the touch buttons.

### 3.3 Base Clock Frequency/Sensor Drive Pulse Frequency

"Base Clock Frequency/Sensor Drive Pulse Frequency" sets the frequency division of the frequency output to the touch sensor. In CTSU1, it is displayed as "Base Clock Frequency," and in CTSU2, it is displayed as "Sensor Drive Pulse Frequency." For details, please refer to the hardware manual of each capacitive touch sensor.

The higher "Base Clock Frequency/Sensor Drive Pulse Frequency," the better the signal value will be.

However, measurement errors will occur if the parasitic capacitance is large.

CTSU outputs a sensor drive pulse from TS pin and measures the capacitance from the charge current. For details, please refer to the following document.

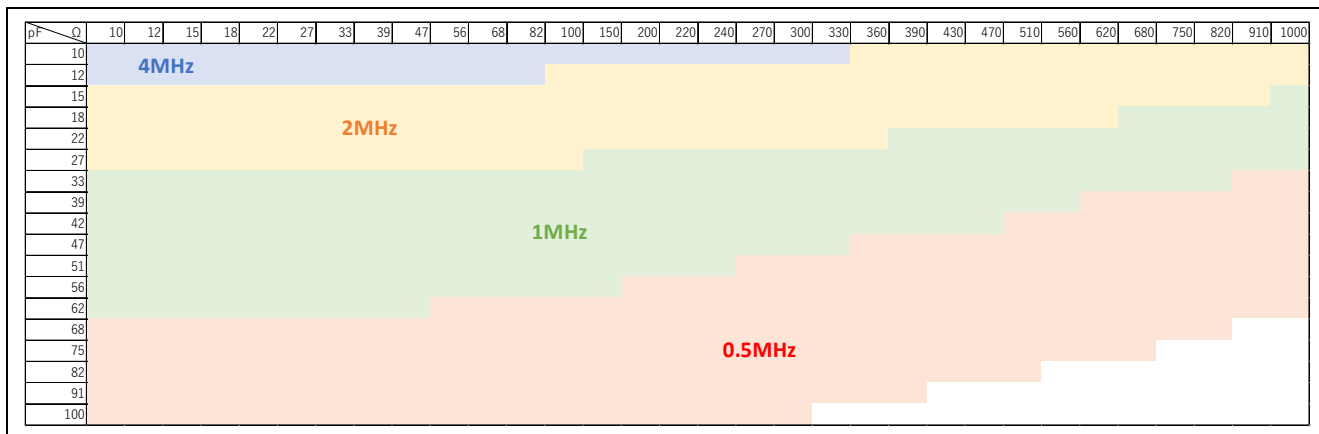
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"Base Clock Frequency/Sensor Drive Pulse Frequency" is set to an appropriate frequency in Auto tuning by the parasitic capacitance and the set damping resistance. In addition, "Base Clock Frequency/Sensor Drive Pulse Frequency" varies depending on the operation clock. For details, please refer to the hardware manual of each capacitive touch sensor. For details about damping resistance, please refer to "Electrode Damping Resistance Value and Sensitivity Characteristics" in the following document.

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

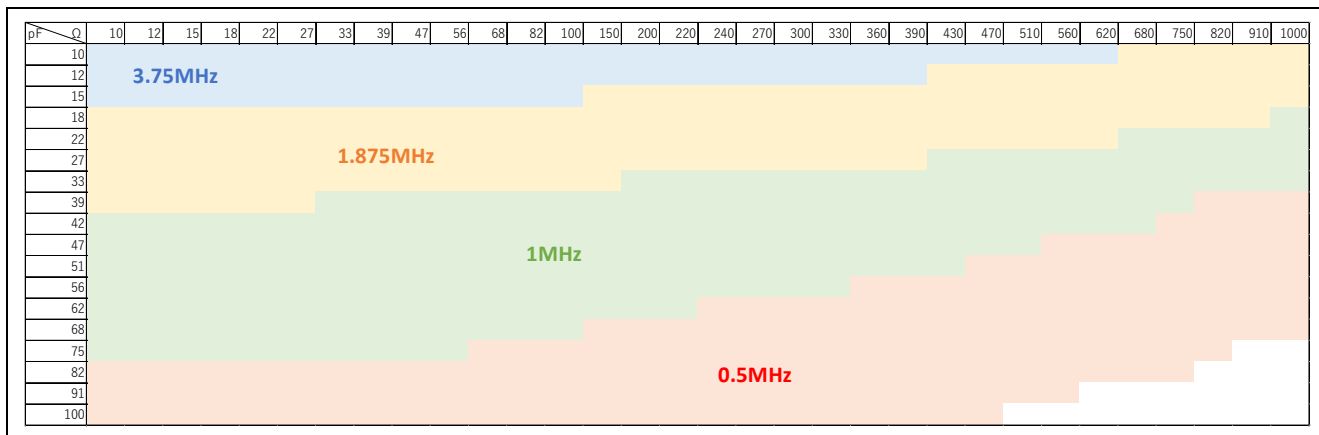
CTSU1 uses a parasitic capacitance/damping resistor to determine the final frequency from four different frequency 4 / 2 / 1 / 0.5 MHz.

Figure 3-8 shows the relation between the parasitic capacitance/damping resistor of RX130 set by Auto tuning and "Base Clock Frequency." A typical example of CTSU1 (TSCAP voltage 1.6 V) is shown below.



**Figure 3-8 Parasitic capacitance/damping resistance of RX130 (receiving electrode 1.6V) vs. Base Clock Frequency**

Figure 3-9 shows a typical CTSU1 (TSCAP voltage 1.18 V) between the parasitic capacitance/damping resistor of RX671 and "Base Clock Frequency" set by Auto tuning. The figure below shows 30 MHz of the operation clocks.



**Figure 3-9 Parasitic capacitance/damping resistance of RX671 (receiving electrode 1.18 V) vs. Base Clock Frequency**

The optimal upper limit of the sensor drive pulse frequency for CTSU2/CTSU2x is determined by the parasitic capacitance and damping resistor. Within this range, the highest of the 3-frequency is selected so that it remains below the upper frequency limit. Figure 3-10 to Figure 3-13 illustrate examples of the 1st frequency. For the first frequency among the 3-frequency measurements, please refer to section “3.7 Judgment Type/Multi-clock Measurement/Multiplication Ratio”.

Figure 3-10 shows the relation between the parasitic capacitance/damping resistor and the sensor drive pulse frequency (1st frequency) under normal voltage conditions set by Auto tuning, using RX140 (SUCLK upper limit: 40 MHz) as a representative example of CTSU2/CTSU2x.

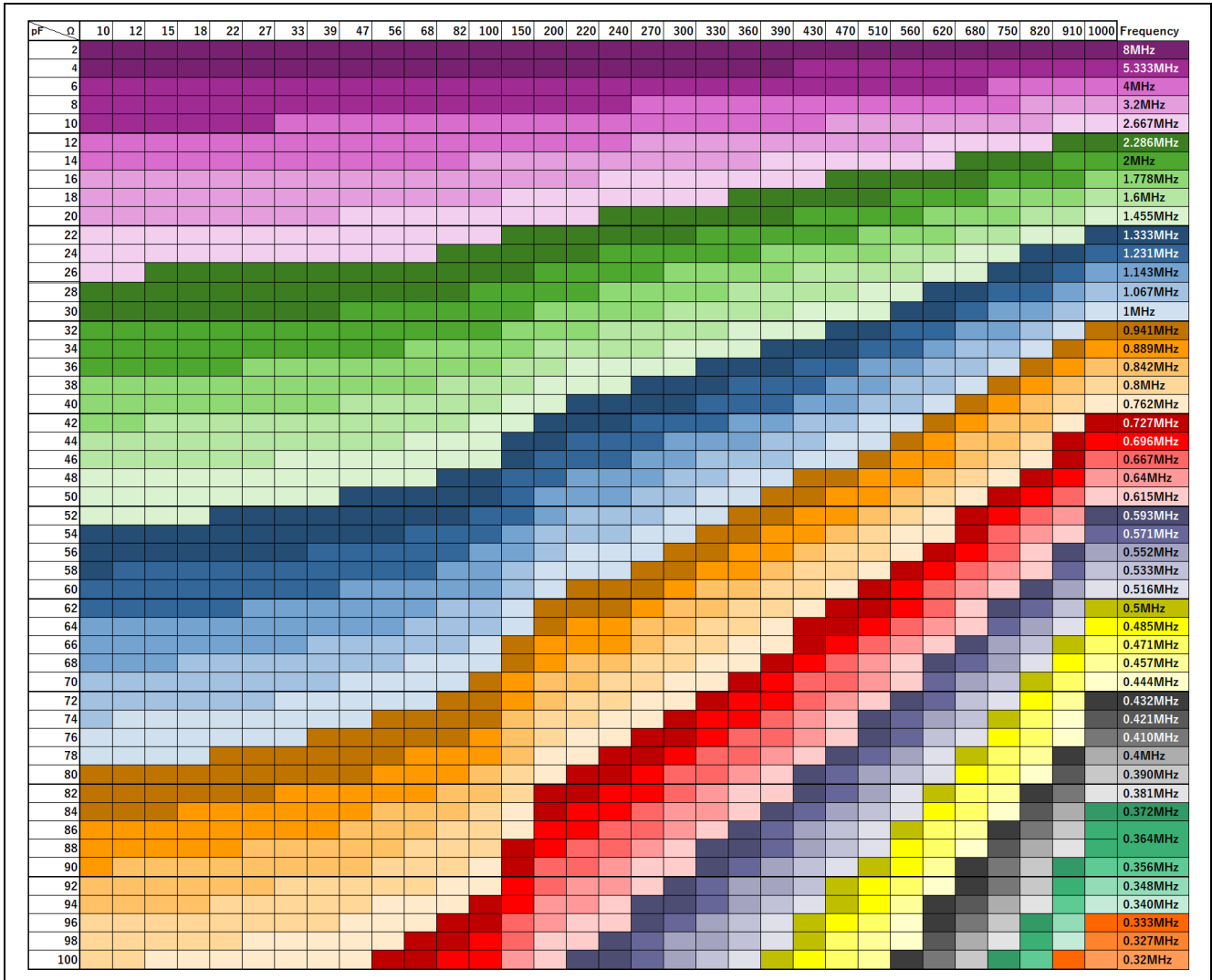


Figure 3-10 Relation between the parasitic capacitance/damping resistor of RX140 (Measurement Voltage Setting: Normal Voltage) and the sensor drive pulse frequency (1st frequency)

Figure 3-11 shows the relation between the parasitic capacitance/damping resistor and the sensor drive pulse frequency (1st frequency) under low voltage conditions set by Auto tuning, using RX140 (SUCLK upper limit: 40 MHz) as a representative example of CTSU2/CTSU2x.

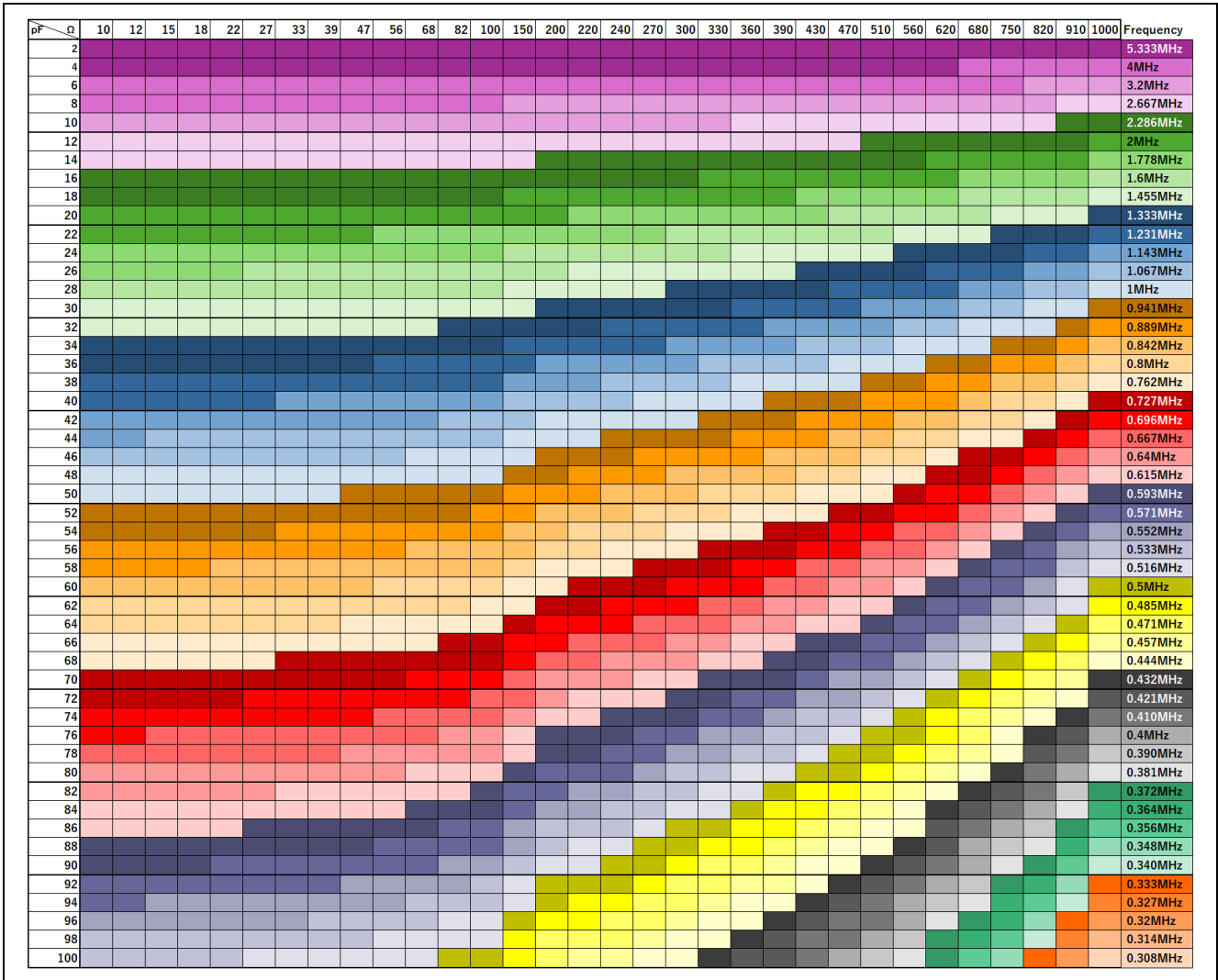


Figure 3-11 Relation between the parasitic capacitance/damping resistor of RX140 (Measurement Voltage Setting: Low Voltage) and the sensor drive pulse frequency (1st frequency)

Figure 3-12 shows the relation between the parasitic capacitance/damping resistor and the sensor drive pulse frequency (1st frequency) under normal voltage conditions set by Auto tuning, using RL78/G23 (SUCCLK upper limit: 32 MHz) as a representative example of CTSU2/CTSU2x.

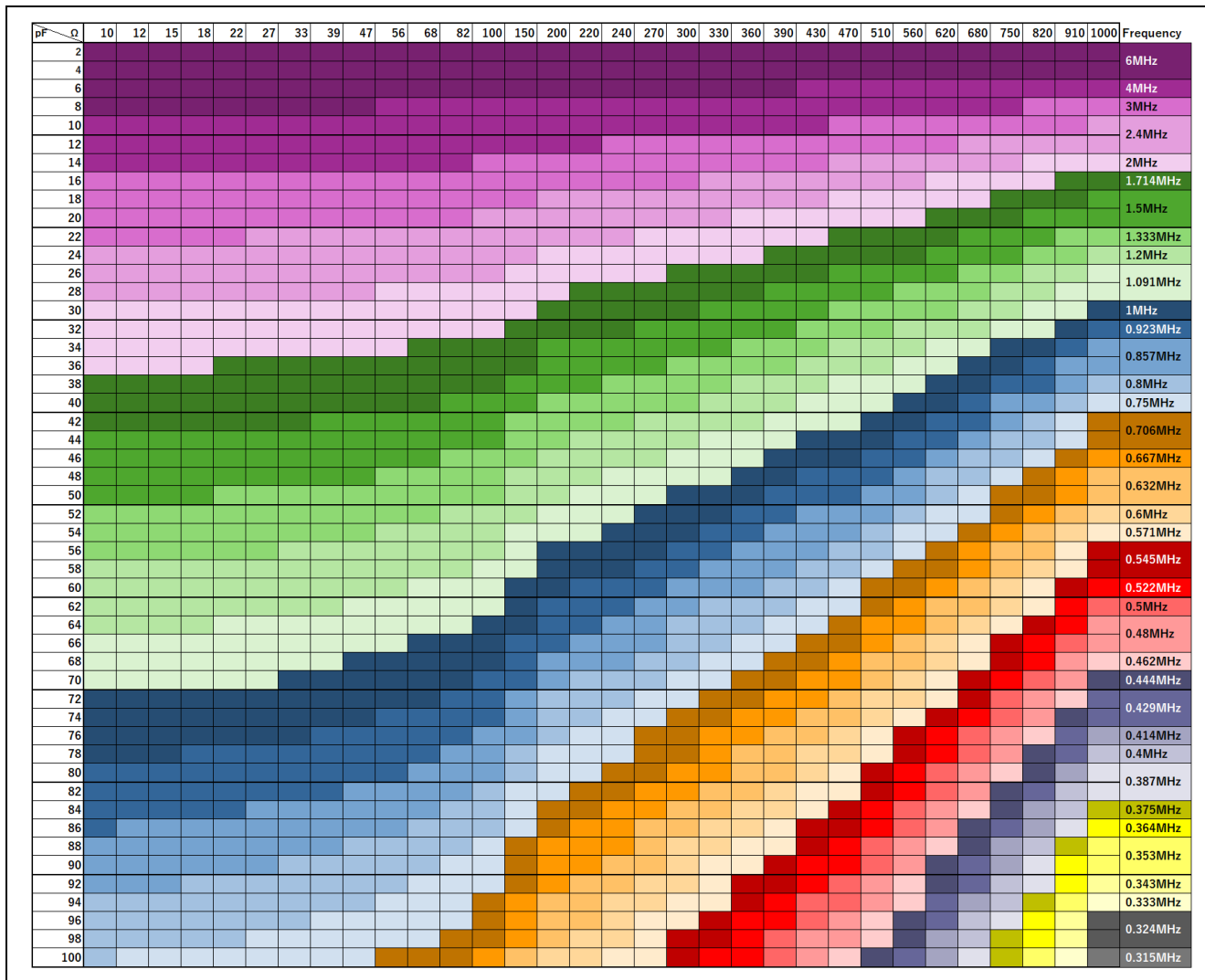
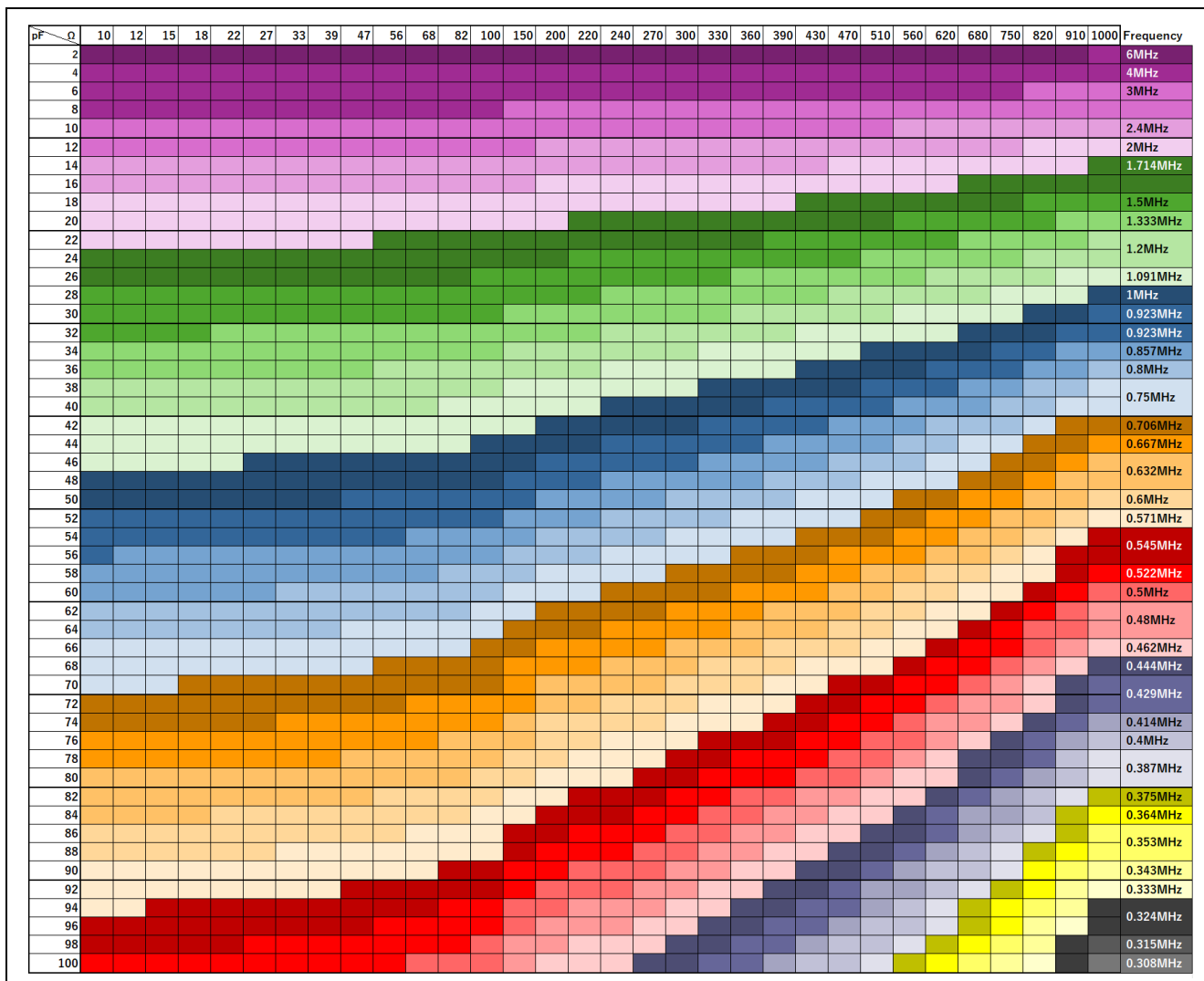


Figure 3-12 Relation between the parasitic capacitance/damping resistor of RL78/G23 (Measurement Voltage Setting: Normal Voltage) and the sensor drive pulse frequency (1st frequency)

Figure 3-13 shows the relation between the parasitic capacitance/damping resistor and the sensor drive pulse frequency (1st frequency) under low voltage conditions set by Auto tuning, using RL78/G23 (SUCLK upper limit: 32 MHz) as a representative example of CTSU2/CTSU2x.



**Figure 3-13 Relation between the parasitic capacitance/damping resistor of RL78/G23 (Measurement Voltage Setting: Low Voltage) and the sensor drive pulse frequency (1st frequency)**

The higher the parasitic capacitance, the lower “Base Clock Frequency/Sensor Drive Pulse Frequency” is set. If “Base Clock Frequency/Sensor Drive Pulse Frequency” is set to a high value when the parasitic capacitance is large, the charge/discharge may not be satisfactorily performed, and measurement error may occur when outputting sensor drive pulses from TS pin. Therefore, in Auto tuning sets the optimum frequency where no measurement error occurs.

If the Base-Clock Frequency/Sensor-Drive Pulse Frequency differs for each electrode, the amount of change during touch will vary. If this variation affects system behavior, align the frequencies to the lowest frequency. If aligning them to the lowest frequency causes the measurement value to fail to reach the target value, adjust the “Offset Tuning Target” and thoroughly evaluate the system to ensure it meets the target requirements.

When using sliders or wheels, all TS pins are set to the same sensor drive pulse frequency, aligned to the lowest frequency among the configured TS pins.

Figure 3-14 shows an example when setting "Base Clock Frequency/Sensor Drive Pulse Frequency" with "Advanced mode".

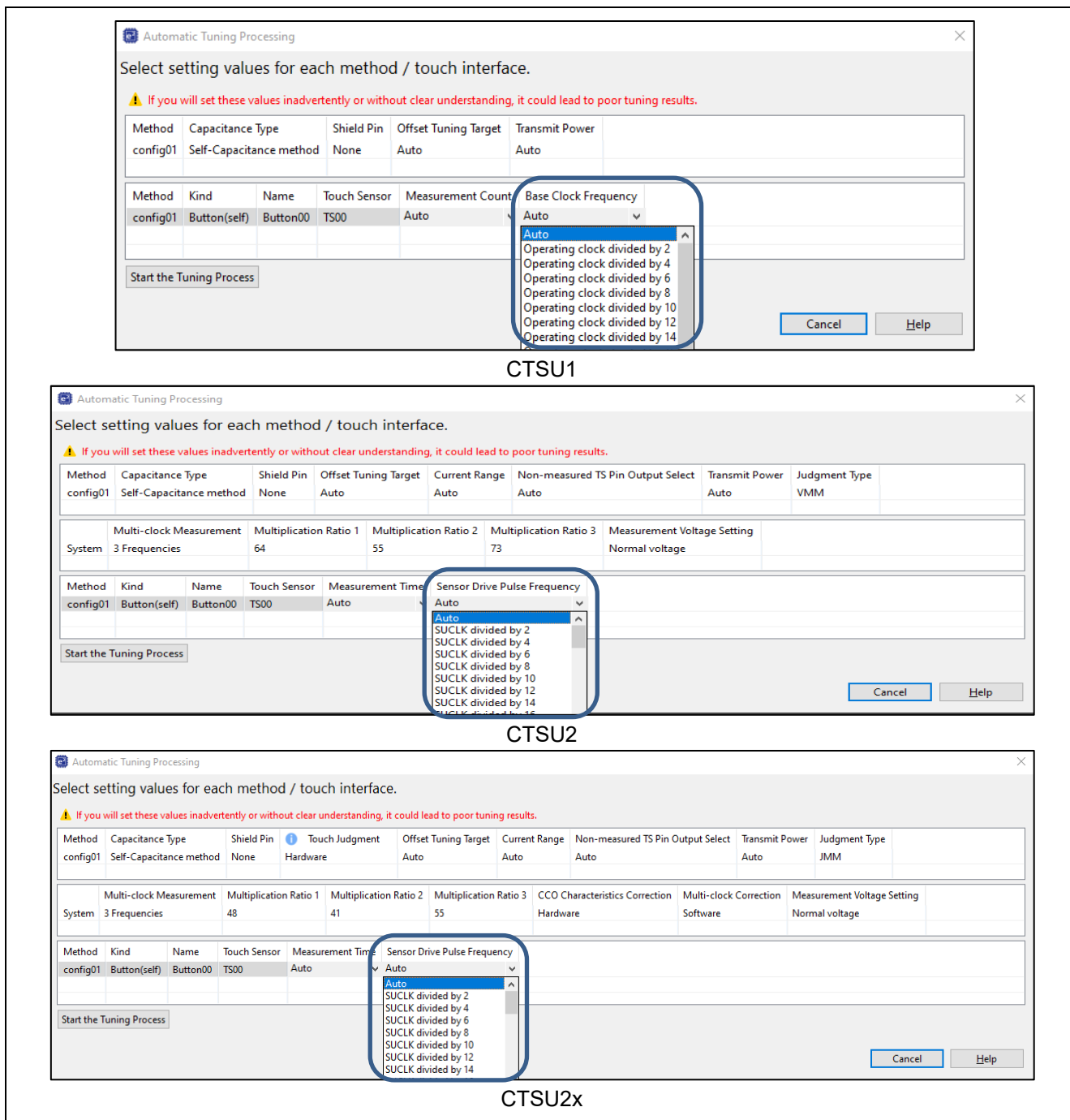


Figure 3-14 Setting of "Base Clock Frequency/Sensor Drive Pulse Frequency"

The setting is reflected in "sdpa" of the qe\_touch\_config.c. For instance, when the Capacitance Touch Evaluation System with RX140 is used, if "SUCLK divided by 16" is selected for "Base Clock Frequency/Sensor Drive Pulse Frequency," "sdpa = 0x07" is set.

```
const ctsu_element_cfg_t g_qe_ctsu_element_cfg_config01[] =
{
    { .ssdiv = CTSU_SSDIV_4000, .so = 0x12B, .snum = 0x07, .sdpa = 0x07 },
};
```

**Note:** For details about SDPA, please refer to the hardware manual for each capacitive touch sensor microcontroller.

### 3.3.1 Effects on Signal value / SNR due to Changes in Base Clock Frequency/Sensor Drive Pulse Frequency

Table 3-13 shows the measurement values (actual measurement examples) when RX140 mounted capacitance touch evaluation system is used when the “Sensor Drive Pulse Frequency” is changed.

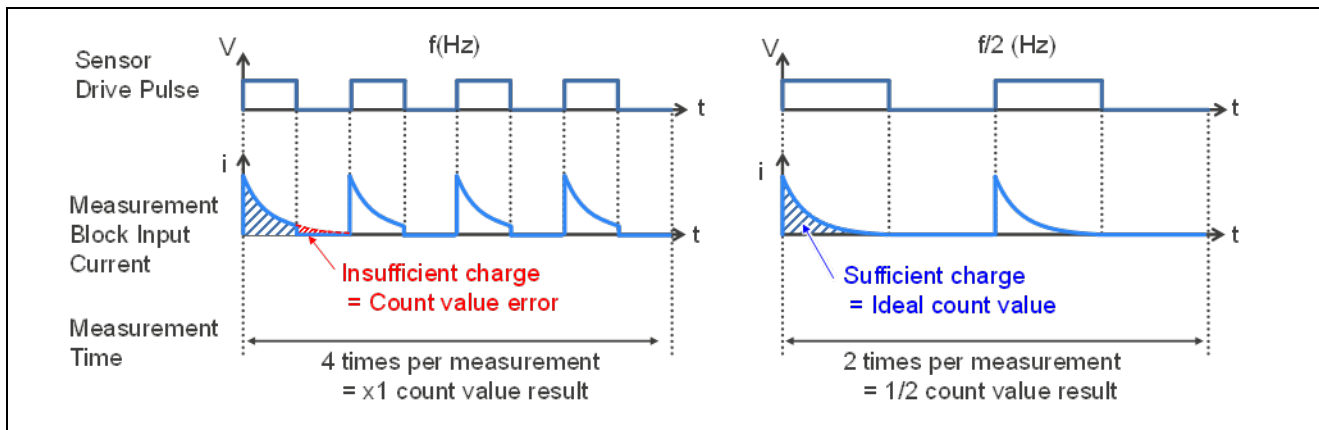
**Table 3-13 Measurement values when Sensor Drive Pulse Frequency is changed (actual measurement example)**

Capacitance Touch Evaluation System with CTSU2x(RX140)					
Self-capacitance method, VMM method, Measurement Time: [STCLK cycle * 8] *8, Current Range: 40 μA, Offset Tuning Target: 37.5% (averaged five times)					
Sensor Drive Pulse Frequency [MHz]	Avg. at touch OFF	Avg. at touch ON	Signal value (Difference of touch ON/OFF) B - A	Avg. at touch OFF Noise value	SNR
4	11674	15322	3648	26.1	23.29
2	11540	13376	1836	17.7	16.22
1	11580	12513	932	13.0	11.29
0.5	11550	12021	471	13.8	5.40

**Note:** The actual measurement was obtained from QE for Capacitive Touch's "CapTouch Status Chart (QE) View" function. For more information, refer to e<sup>2</sup> studio “Help”.

When “Base Clock Frequency/Sensor Drive Pulse Frequency” is increased, the difference in touch ON/OFF can be seen to be large. However, when the frequency is increased, overflow of the measurement counter may occur during touch ON. The “Offset Tuning Target” should be adjusted so that the measurement value at touch ON stays in the range where the CCO exhibits good output linearity.

If the frequency is increased forcibly when the parasitic capacitance is large, a measurement error may occur. Figure 3-15 shows the image of CTSU measurement when the parasitic capacitance is large and “Base Clock Frequency/Sensor Drive Pulse Frequency” is increased. If the output of the pulse is faster than the charging time and the parasitic capacitance is large at a higher frequency, charging/discharging may not be performed sufficiently. As a result, measurement errors may occur. Therefore, it is necessary to set the frequency to match the parasitic capacitance.



**Figure 3-15 Image of CTSU measurement**

When set to 0.5 MHz, if the parasitic capacitance is small, the average value at touch OFF may not be set near the “Offset Tuning Target.” The reason is that the measurement value does not reach the target value because the current supplied from VDC is small because the parasitic capacitance is small, and the current supplied to the current mirror circuit is also small. In this case, increase “Base Clock Frequency/Sensor Drive Pulse Frequency” or decrease the “Offset Tuning Target.”

Also, considering to ensure enough charge/discharge times, set the “Base Clock Frequency/Sensor Drive Pulse Frequency” by referring Figure 3-8 to Figure 3-13.

Please adjust “Base Clock Frequency/Sensor Drive Pulse Frequency” after sufficiently evaluating it in accordance with the target requirements.

### 3.3.2 How to Adjust the Base Clock Frequency/Sensor Drive Pulse Frequency Using Advanced Mode

Auto tuning sets the optimum “Base Clock Frequency/Sensor Drive Pulse Frequency” where no measurement error occurs. Although the final frequency is determined from the default 4 measurement frequencies, 4 MHz, 2 MHz, 1 MHz, 0.5 MHz by the parasitic capacitance in CTSU1, the margin of the frequency set for the parasitic capacitance may be too large. In such a case, it is possible to change to a more detailed frequency by using Advanced mode. Figure 3-16 shows the relation between parasitic capacitance and SDPA when a damping resistor of 560 Ω is used in RX130 that is CTSU1.

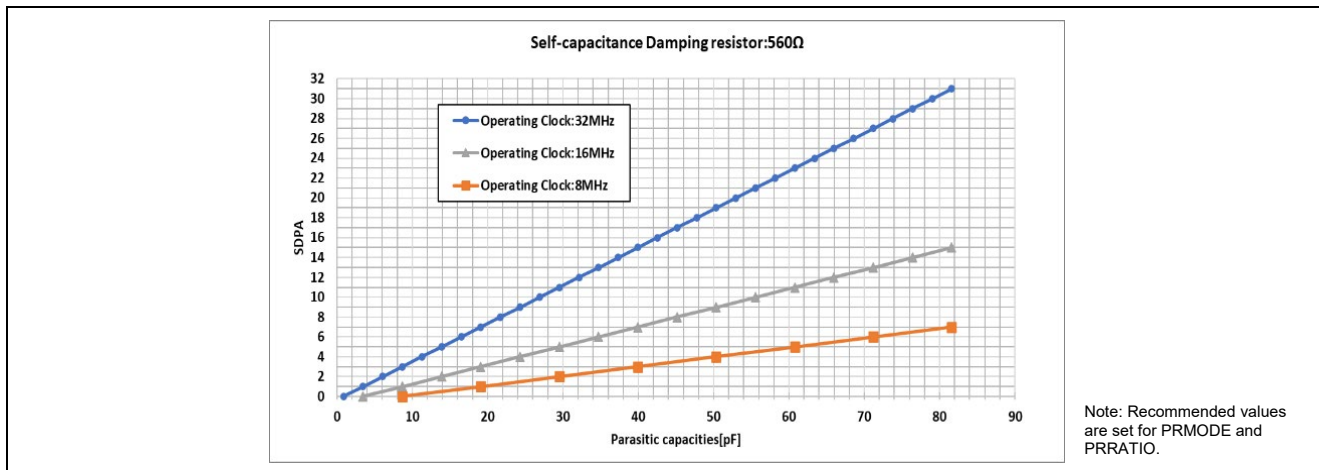


Figure 3-16 Parasitic capacitance that can be measured when RX130 is used

When the parasitic capacitance is 30 pF and the operating clocks (CTSUCLK) are 32 MHz, the optimal SDPA is 11. “Base Clock Frequency” is calculated by the following formula.

$$\text{Base Clock Frequency} = \text{CTSUCLK} / ((\text{SDPA} + 1) \times 2)$$

When the operating clock (CTSUCLK) is 32 MHz and SDPA is 11, “Base Clock Frequency” is as follows.

$$\text{Base Clock Frequency: } 32[\text{MHz}] / ((11 + 1) \times 2) = 1.333 \text{ MHz}$$

In RX130, the measurement time is set to be 526 μs as the result of Auto tuning. However, if “Base Clock Frequency” is manually changed using this Advanced mode, the measurement time also changes. For details, please see 3.1 Measurement Count/Measurement Time. Figure 3-17 shows the relation between SDPA and the measurement count when the operating clock 32 MHz is used when the value is set to around 526 μs.

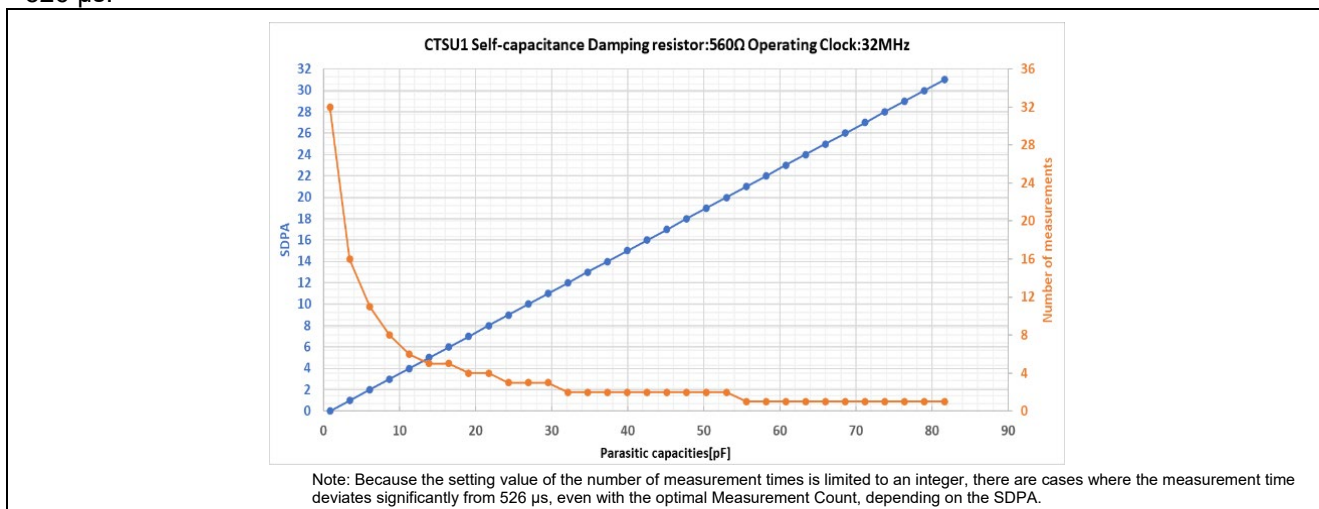
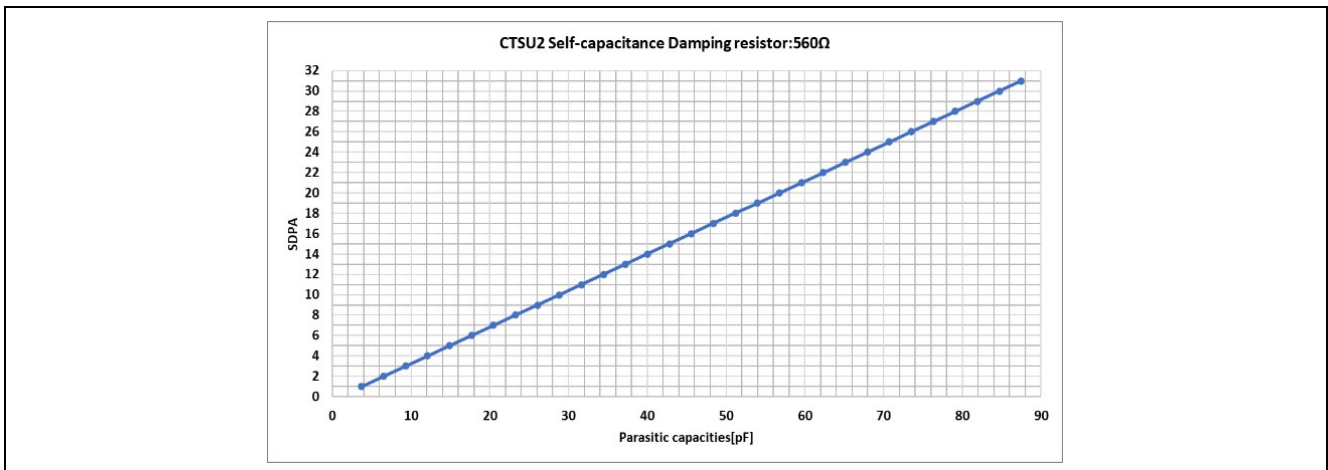


Figure 3-17 SDPA and Measurement Count when 526 μs equivalent measurement times are set when RX130 (operation clock 32 MHz) is used

When changing the measurement time, adjust it to the target requirements to prevent an overflow error from occurring. Depending on the operation clock, the setting may be set to other than 4/2/1/0.5 MHz depending on the Auto tuning. For instance, if the operating clocks are 30 MHz, they cannot be set to 4/2 MHz because of the frequency division relation. In such cases, 4/2 MHz is set to a lower 3.75/1.875 MHz.

Figure 3-18 shows the parasitic capacitance versus SDPA when the default setting of "Multi-clock measurement/ Multiplication Ratio" is used in RX140 that is CTSU2 and the damping resistor 560 Ω is used.



**Figure 3-18 Parasitic capacitance that can be measured when RX140 is used**

When the parasitic capacitance is 25 pF, the optimal SDPA is 9.  
 The "Sensor Drive Pulse Frequency" is calculated by the following formula.  
 Sensor Drive Pulse Frequency =  $(\text{SUCLK}^* / 2) / (\text{SDPA} + 1)$

**Note:**  $\text{SUCLK} = \text{STCLK}[0.5\text{MHz}] \times \text{SUMULTI}$  is shown. For details on STCLK and SUMULTI, please refer to the hardware manual for each capacitive touch sensor.

When SDPA is 9, the frequency at 3-frequency measurement is as follows.  
 Sensor Drive Pulse Frequency (multiplied by 64) :  $(32 [\text{MHz}] / 2) / (9 + 1) = 1.6 \text{ MHz}$   
 Sensor Drive Pulse Frequency (multiplied by 55) :  $(27.5[\text{MHz}] / 2) / (9 + 1) = 1.38 \text{ MHz}$   
 Sensor Drive Pulse Frequency (multiplied by 73) :  $(36.5[\text{MHz}] / 2) / (9 + 1) = 1.83 \text{ MHz}$

Please adjust after sufficiently evaluating it in accordance with the target requirements.

### 3.4 Current Range

The "Current Range" setting can be changed only with CTSU2/CTSU2x.

In "Current Range", the current mirror ratio between the current supplied from the measurement VDC and the current flowing through the current controlled oscillator (CCO) via the current mirror circuit is set for each method. Setting a low "Current Range" increases the signal value. This is because CCO input current at the time of touch ON increases.

CTSU measures the capacitance by outputting a sensor drive pulse from TS pin 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 Cp, finger capacitance Cf, and sensor drive pulse voltage V.

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

Here, the current I is the sum of the current I1 supplied from the measurement VDC and the current I2 supplied from the offset current (DAC). For details, please refer to "2.2.1 Detection Principle" in the following document.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

A current IOUT proportional to I1 supplied from the measurement VDC is applied to the CCO through the current mirror. Set the current supply capability from VDC and the current mirror ratio is automatically determined according to the setting. Increasing the "Current Range" increases the current I1 supplied from VDC for measurement.

Figure 3-19 shows an image of the measurement when using normal current (40 μA).

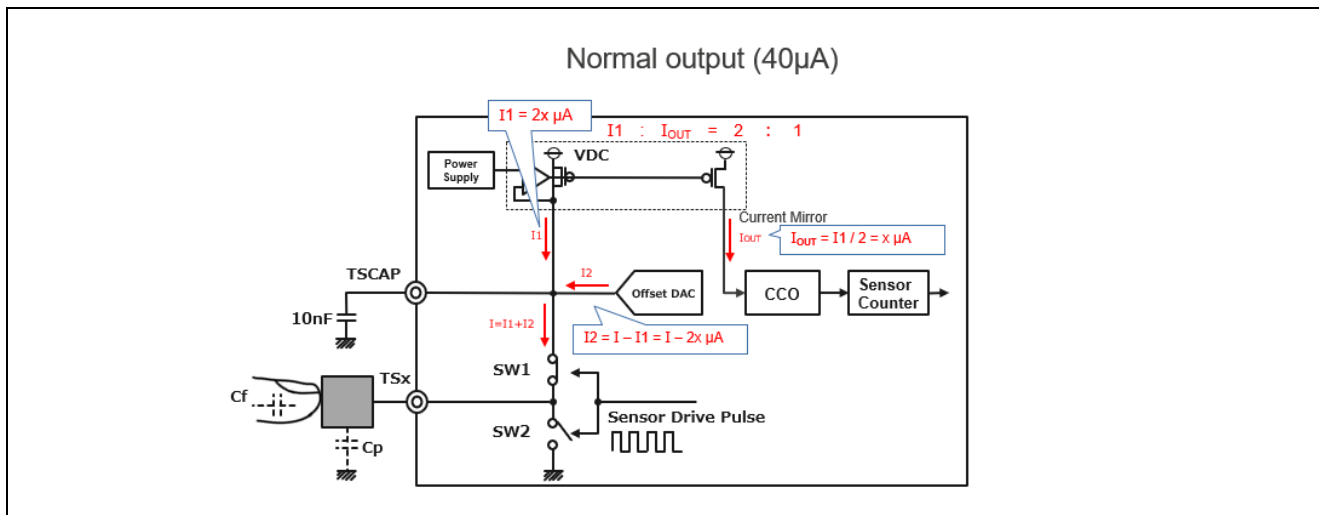


Figure 3-19 Measurement image when normal current (40 μA) is used

Table 3-14 shows the default settings.

Table 3-14 Default "Current Range" settings

	When self-capacitance method is used	When using mutual capacitance method
CTSU2/CTSU2x	Normal current output (40 μA)	High-current output (80 μA)

Table 3-15 outlines the settings in CTSU2/CTSU2x.

Table 3-15 Overview of "Current Range" settings for CTSU2/CTSU2x

Current Range	ATUNE1	ATUNE2	Current mirror ratio
Low-current output (20 μA)	0	1	1
Normal current output (40 μA)	1	0	2
High-current output (80 μA)	0	0	4
Very high-current output (160 μA)	1	1	8

Figure 3-20 shows an example when setting "Current Range" with "Advanced mode".

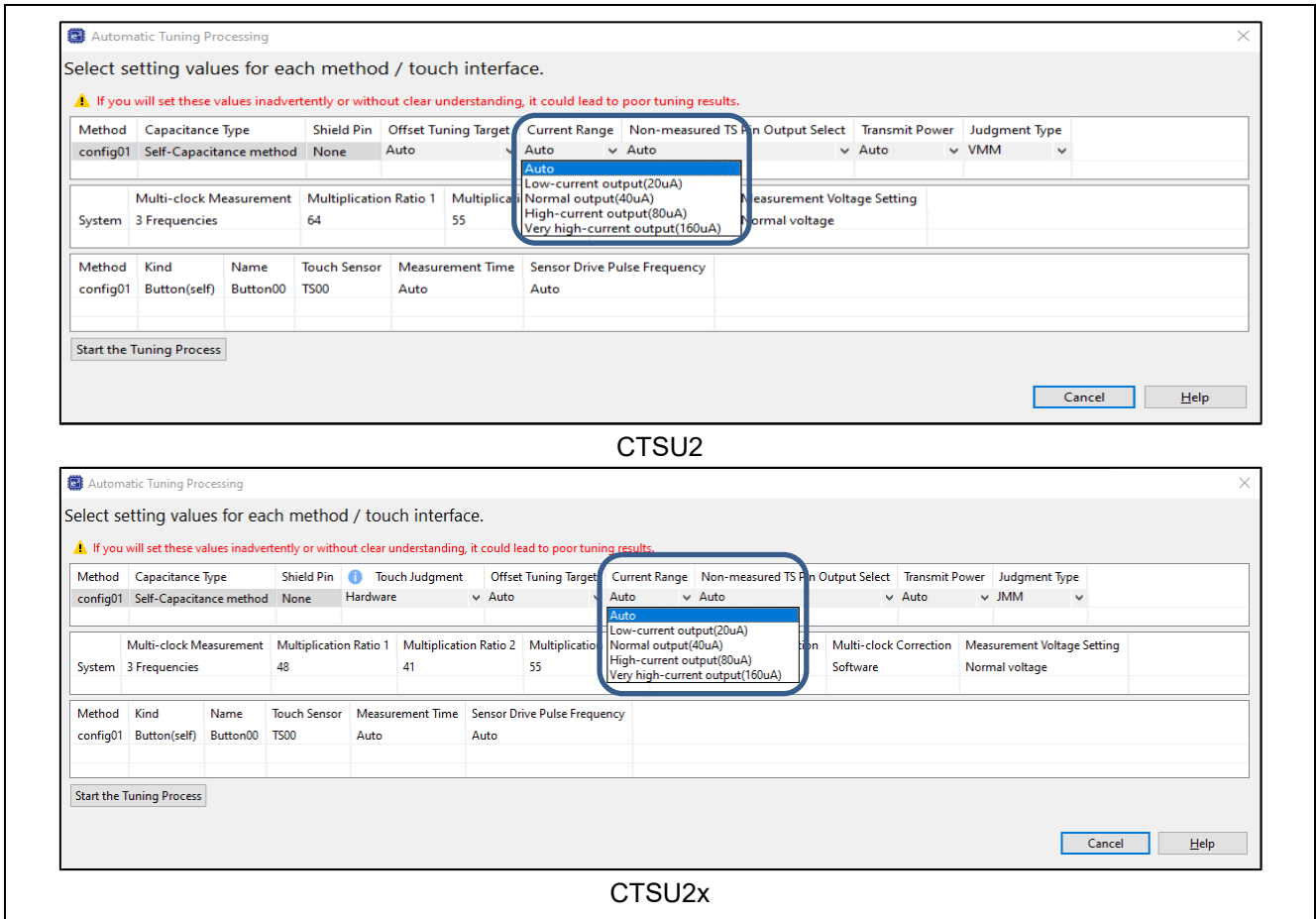


Figure 3-20 Setting of "Current Range"

The setting is reflected in the `qe_touch_config.c`. Normal current output (40  $\mu$ A) is shown below.

```
.atune12= CTSU_ATUNE12_40UA,
```

**Note:** For details about ATUNE, please refer to the hardware manual for each capacitive touch sensor microcontroller.

### 3.4.1 Effects on Signal Value / SNR due to Changes in the Current Range

Table 3-16 shows the measurement values (actual measurement examples) when RX140 mounted capacitance touch evaluation system is used when the “Current Range” is changed.

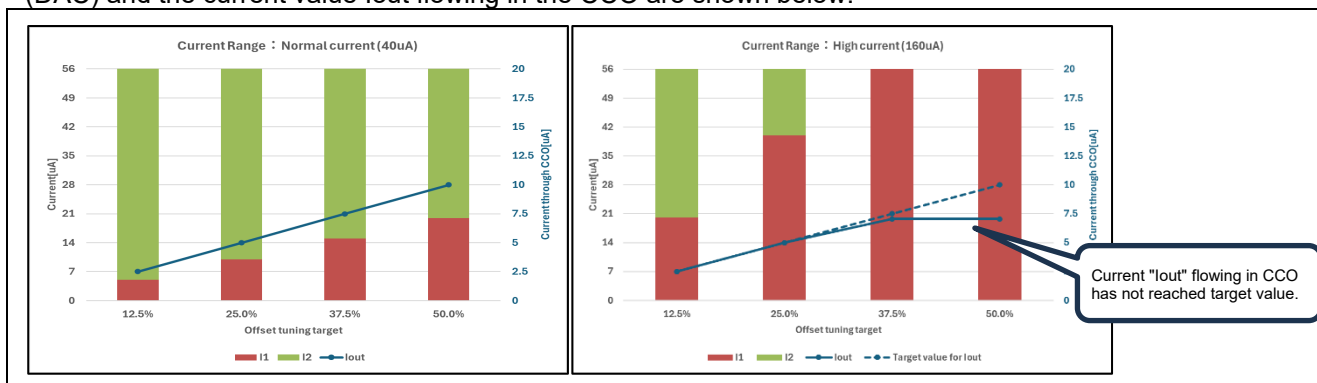
**Table 3-16 Measurement values when the Current Range is changed (actual measurement example)**

Capacitance Touch Evaluation System with CTSU2x(RX140)					
Self-capacitance method, VMM method, Sensor Drive Pulse Frequency: 2 MHz, Measurement Time: [(STCLK cycle * 8) * 8] Offset Tuning Target: 37.5% (averaged five times)					
Current Range [μA]	Avg. at touch OFF A	Avg. at touch ON B	Signal value (Difference of touch ON/OFF) B - A	Avg. at touch OFF Noise value	SNR
20	11653	15508	3855	38.32	16.29
40	11566	13513	1947	16.96	17.67
80	11513	12484	970	11.46	14.29
160	11360	11840	480	9.94	7.49

**Note:** The actual measurement was obtained from QE for Capacitive Touch's "CapTouch Status Chart (QE) View" function. For more information, refer to e<sup>2</sup> studio "Help".

When the “Current Range” is low, the difference in touch ON/OFF can be seen to be large, but when the “Current Range” is low, overflow may occur during touch ON. Perform adjustment after sufficiently evaluating the offset tuning to meet the user's required specifications. Also, if the “Current Range” is too large when the parasitic capacitance is small, the mean value at touch OFF may not be set near the “Offset Tuning Target.” The reason is that the measurement value does not reach the target value because the current supplied from VDC is small because the parasitic capacitance is small and the current supplied to the current mirror circuit is also small. In this case, lower the “Current Range” or decrease the target value of the measurement value.

Figure 3-21 shows, as an example, the current I1 supplied from the VDC for measurement and the current I2 supplied from the offset current (DAC) to the “Offset Tuning Target” when the “Current Range” is normal current (40 μA) / very high current (160 μA) when the “Sensor Drive Pulse Frequency” is 2 MHz and an electrode with a parasitic capacitance of approximately 18.8pF is used. current I2 supplied from the current (DAC) and the current value Iout flowing in the CCO are shown below.



**Figure 3-21 Current value when the offset tuning target and “Current Range” are changed**

The current flowing through the CCO is 2.5-20 μA, and 20 μA flows when the offset tuning target is 100%. When the normal current (40 μA) is used, I1 = approx. 15 μA, I2 = approx. 41 μA when the offset-tuning target is 37.5%. The current IOUT flowing through CCO is determined by the current mirror rate with the current I1 supplied from VDC for measurement and is therefore calculated as  $I_{OUT} = I1 / 2 = 7.5 \mu A$ .

When high current (160 μA) is used, I1 = approx. 56 μA, I2 = 0 μA when the offset tuning target is 37.5%. Since the current IOUT flowing through CCO is determined by the current mirror rate with the current I1 supplied from the measurement VDC,  $I_{OUT} = I1/8$  is approximately 7 μA.

If the “Current Range” is too large when the parasitic capacitance is small, the current supplied to the current mirror circuit will also be small and the measurement value will not reach the target value.

Adjust the target value for “Current Range” and offset tuning after fully evaluating the target requirements.

### 3.5 Non-measured TS Pin Output Select

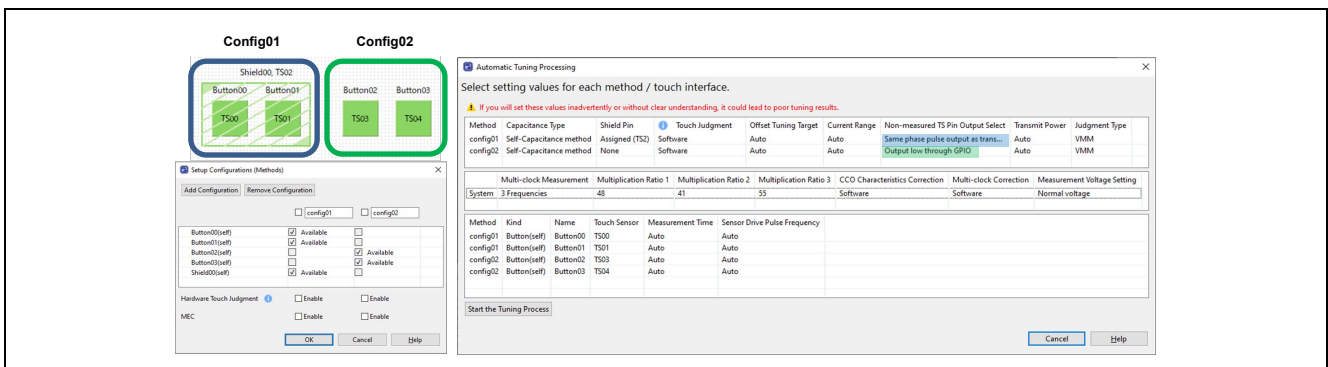
The setting of "Non-measured TS Pin Output Select" can be changed only with CTSU2/CTS2Ux.

In the "Non-measured TS Pin Output Select" setting, you configure how to handle TS pins that are not being measured for each method in the touch interface configuration, excluding active shield pins during scanning. Table 3-17 shows the default settings.

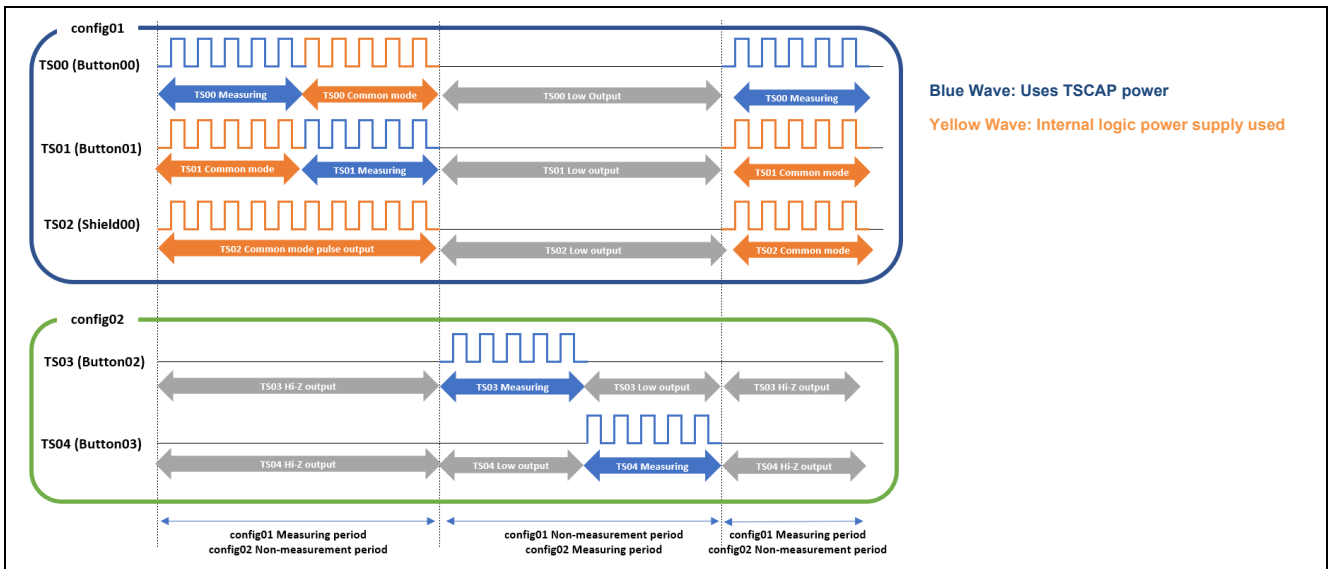
**Table 3-17 Default "Non-measured TS Pin Output Select" setting.**

	When self-capacitance method is used	When using mutual capacitance method	When using active shield
CTS2U/CTS2Ux	Output low through GPIO	Output low through GPIO	Same phase pulse output as transmission channel through the power setting

Figure 3-23 shows an image of TS pin measurement in a touch interface configuration as shown in Figure 3-22. Since the active shield is set for the behavior of TS pin during config01 measurement period, the other pin TS01, TS02 is in-phase pulsing while TS00 is being measured. During config02 measurement, TS04 that TS03 is being measured is turned Low.



**Figure 3-22 Example touch interface configuration**



**Figure 3-23 Image of TS pin measurement**

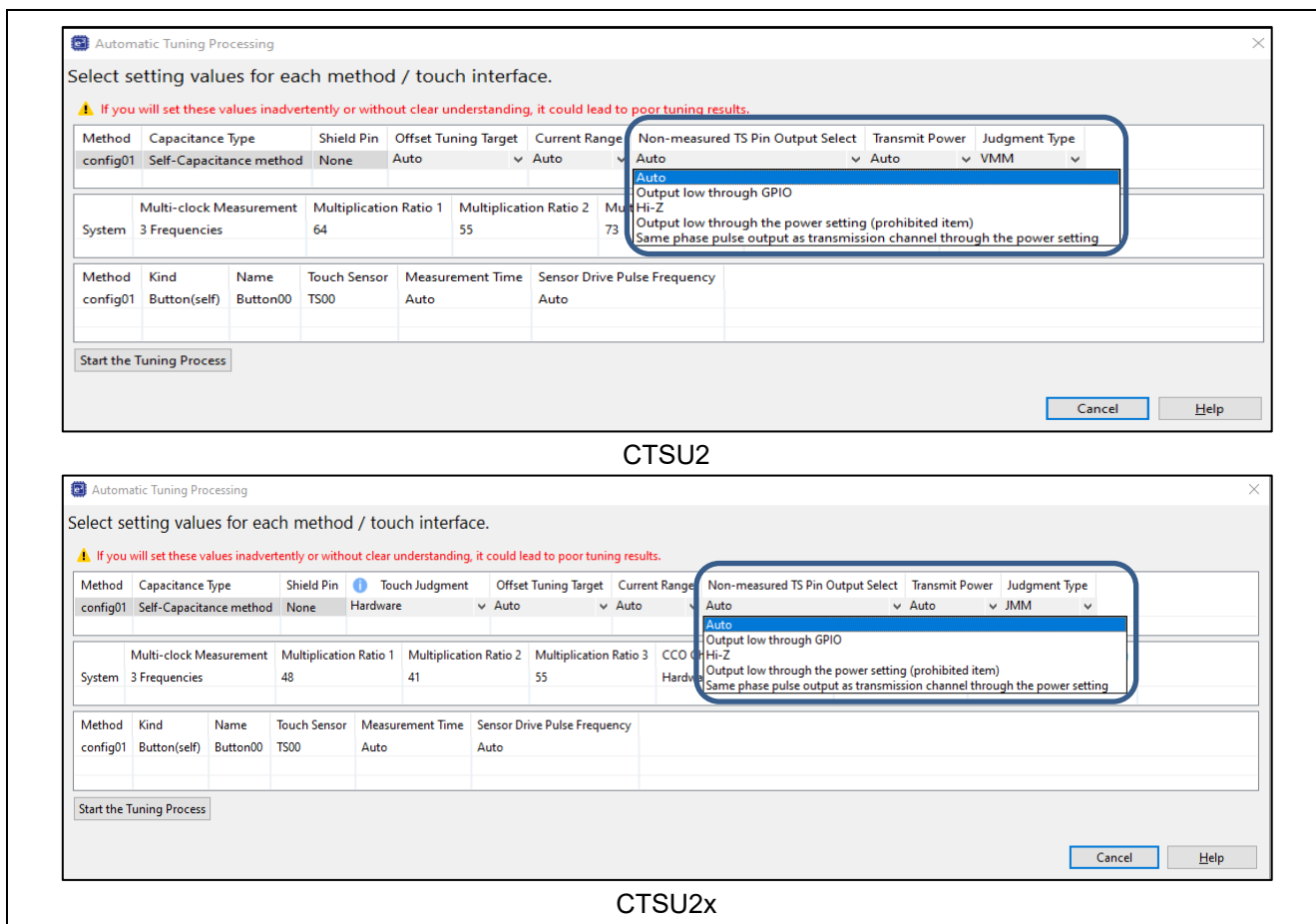
This is an example of a "Non-measured TS Pin Output Select". Please refer to the following documents.  
[RL78 Family Capacitive Touch Sensing Unit \(CTS2U2L\) Operation Explanation \(R01AN5744\)](#)

Table 3-18 shows an overview of each process setting.

**Table 3-18 Overview of processing settings**

Non-measured TS Pin Output Select setting	Overview
Output low through GPIO	This setting is used to output a Low from the non-measurement pin during measurement.
Hi-Z	This setting is used to output a Hi-Z from the non-measurement pin during measurement.
Same phase pulse output as transmission channel through the power setting	This setting outputs a shield signal in phase with the sensor drive pulse from the non-measurement pin during the measurement period.

Figure 3-24 shows an example when setting "Non-measured TS Pin Output Select" with "Advanced mode".



**Figure 3-24 Setting of "Non-measured TS Pin Output Select"**

The setting is reflected in the `qe_touch_config.c`. Below is an example of setting from GPIO to L-output.

```
.pose1 = CTSU_POSEL_LOW_GPIO,
```

**Note:** For details about POSEL, please refer to the hardware manual for each capacitive touch sensor microcontroller.

### 3.6 Transmit Power

When the mutual capacitance method is used, I/O power supply of the pins set in the transmit pin is selected for each method in the "Transmit Power". The selected power supply is also used for the self-capacitance active shield electrode.

Use the default setting for this value. For details, please refer to the following document.

[RL78 Family Capacitive Touch Sensing Unit \(CTS2U2L\) Operation Explanation \(R01AN5744\)](#)

Table 3-19 lists the default settings.

**Table 3-19 Default "Transmit Power" settings**

	When using self-capacitance method	When using mutual capacitance method	When using active shield
CTS1	RL78: VDD/EVDD RX: VCC RA, Synergy: VCC/AVCC	VCC	-
CTS2/CTS2x	Internal logic power supply (Power supply for active shield)	VCC (private)	Internal logic power supply (Power supply for active shield)

Table 3-20 shows the settings in CTS1.

**Table 3-20 "Transmit Power" settings in CTS1**

	Power setting of transmit pin	TXVSEL	Overview
When using self-capacitance method	RL78: VDD/EVDD RX: VCC	0	Only the receive pin is used during measurement and the transmit pin is not used.
When using mutual capacitance method	RA, Synergy: VCC/AVCC	0	The transmission pin is also used during measurement. Signal value changes depending on the voltage of the transmission pin.

When using CTS1, do not set TXVSEL = 1.

Table 3-21 shows the settings in CTS2/CTS2x.

**Table 3-21 "Transmit Power" settings in CTS2/CTS2x**

	Power setting of transmit pin	TXVSEL	TXVSEL2	Overview
When self-capacitance method is used (including when using active shield)	Internal logic power supply (power supply for active shield) RX, RA: VCL RL: REGC	1	0	The transmit pin is used for the output of shield pulse. It can act as a shield by outputting the pulses with the same phase and potential as the receiving pin.
When using mutual capacitance method	VCC (private)	0 / 1	1	The transmission pin is also used during measurement. Signal value changes depending on the voltage of the transmission pin.

**Note:** For details, please refer to "2.3.1 Detection Principle" in the following document.

[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

Figure 3-25 shows an example when setting "Transmit Power" with "Advanced mode".

The figure consists of three screenshots of the 'Automatic Tuning Processing' dialog box, each showing the 'Transmit Power' dropdown menu open. The dialog box title is 'Automatic Tuning Processing' and it contains the instruction 'Select setting values for each method / touch interface.' and a warning: 'If you will set these values inadvertently or without clear understanding, it could lead to poor tuning results.'

**CTSU1 (RX130)**  
 The first screenshot shows the 'Transmit Power' dropdown menu with options: Auto, VCC, and Internal logic power supply. The 'Auto' option is selected.

**CTSU2 (RA2L1)**  
 The second screenshot shows the 'Transmit Power' dropdown menu with options: Auto, VCC/AVCC, Internal logic power supply (Power supply for active shield), and VCC(private). The 'Auto' option is selected.

**CTSU2x (RL78/F25)**  
 The third screenshot shows the 'Transmit Power' dropdown menu with options: Auto, VDD/EVDD, Internal logic power supply (Power supply for active shield), and VCC(private). The 'Auto' option is selected.

Figure 3-25 Setting of "Transmit Power"

The setting is reflected in the `qe_touch_config.c`.

Below is a sample of CTSU1.

- When self-capacitance method/mutual capacitance method is used

```
.txvsel = CTSU_TXVSEL_VCC,
```

Below is a sample of CTSU2/CTSUX.

- When self-capacitance method is used (including when the active shield is used)

```
.txvsel = CTSU_TXVSEL_INTERNAL_POWER,  
.txvsel2= CTSU_TXVSEL_MODE,
```

- When mutual capacitance method is used

```
.txvsel = CTSU_TXVSEL_VCC,  
.txvsel2= CTSU_TXVSEL_VCC_PRIVATE,
```

### 3.7 Judgment Type/Multi-clock Measurement/Multiplication Ratio

The settings for "Judgment Type" and "Multi-clock Measurement" and "Multiplication Ratio" can be changed only with CTSU2/CTSU2x.

"Multi-clock Measurement" can be performed with multiple sensor drive pulse frequencies to avoid synchronous noise. By default, it measures at 3 different frequencies and uses the results of measurements at each of the 3-frequency to make touch judgments. "Judgment Type" can be set for each method, and "Multi-clock Measurement" and "Multiplication Ratio" can be set for each system.

The "Judgment Type" is shown below.

1. Value Majority Mode (VMM)

VMM is the result of two measurements that are close to the measured value of three frequencies. Touch judgment is performed with the value obtained by adding. Figure3-26 shows the operation image when VMM is used.

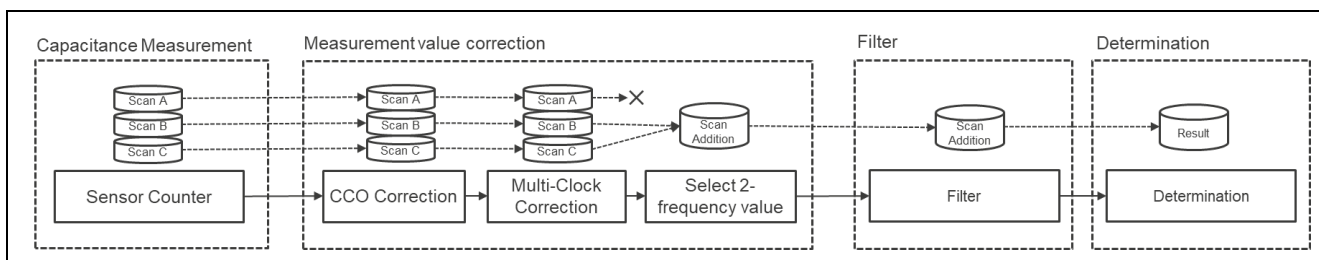


Figure3-26 Image of operation when VMM is used

2. Judgment Majority Mode (JMM)

JMM is a method to make the final touch judgment by majority decision based on the judgment result of each of the 3-frequency measurements. Only the self-capacitance and mutual capacitance buttons are supported. Figure 3-27 shows the operation image when JMM is used.

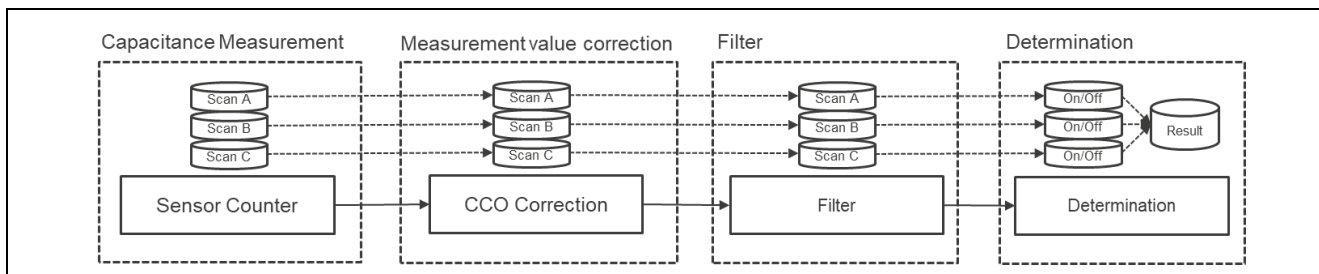


Figure 3-27 Image of operation when JMM is used

Please refer to the following document for details of the "Judgment Type."  
[Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide \(R30AN0424\)](#)

Table3-22 shows examples of default settings for "Judgment Type" and "Multi-clock Measurement" when buttons are used.

Table3-22 Default "Judgment Type/Multi-clock measurement" settings

	Touch Judgment	Judgment Type	Multi-clock Measurement
CTSU2	-	VMM	3-frequency
CTSU2x	Hardware	JMM	3-frequency
	Software	VMM	3-frequency

The “Sensor Drive Pulse Frequency” according to the set Multiplication Ratio is displayed as shown in Figure 3-28.

Multi-clock Measurement		Multiplication Ratio 1	Multiplication Ratio 2	Multiplication Ratio 3	
System	3 Frequencies	48	41	55	
Method	Kind	Name	Touch Sensor	Measurement Time	Sensor Drive Pulse Frequency
config01	Button(self)	Button00	TS00	0.128 ms	2,000 MHz, 1,708 MHz, 2,292 MHz

Figure 3-28 “Sensor Drive Pulse Frequency” by Setting the Multiplication Ratio

In Advanced mode setting, “Multi-clock Measurement” is measured by three sensor drive pulse frequencies respectively. The 1st frequency is the value set by “Sensor Drive Pulse Frequency”. Its Multiplication Ratio is fixed to 48 or 64 by the device. Multiplication Ratio of the 2nd and 3rd frequencies can be changed to an arbitrary value.

Table 3-23 shows the default setting of “Multiplication Ratio” and the lower and upper limits that can be set.

Table 3-23 Default “Multiplication Ratio” settings

Device	1st frequency Multiplication Ratio <sup>1</sup>	2nd frequency Multiplication Ratio <sup>2</sup> [Configurable range]	3rd frequency Multiplication Ratio <sup>2</sup> [Configurable range]
RL78/G22 RL78/G23 RL78/L23 RA0L1	48	41 [32~60]	Normal Voltage : 55 [32~60] Low Voltage : 46 [32~60]
RX260 RX261	48	41 [32~64]	Normal Voltage : 55 [32~64] Low Voltage : 46 [32~64]
RL78/F22 RL78/F25	64	55 [32~76]	73 [32~76]
Other Device	64	Normal Voltage : 55 [32~80] Low Voltage : 55 [32~64]	Normal Voltage : 73 [32~80] Low Voltage : 46 [32~64]

**Note1:** The multiplication factor of the 1st frequency differs depending on the upper limit of SUCCLK. For more information on SUCCLK, please refer to the hardware manual for each capacitive touch sensor microcontroller.

**Note2:** For details on the Measurement Voltage Setting, please see “3.9 Measurement Voltage Setting”.

The formulas for calculating “Sensor Drive Pulse Frequency” of the 2nd and 3rd frequencies when the Multiplication Ratio is changed are shown below.

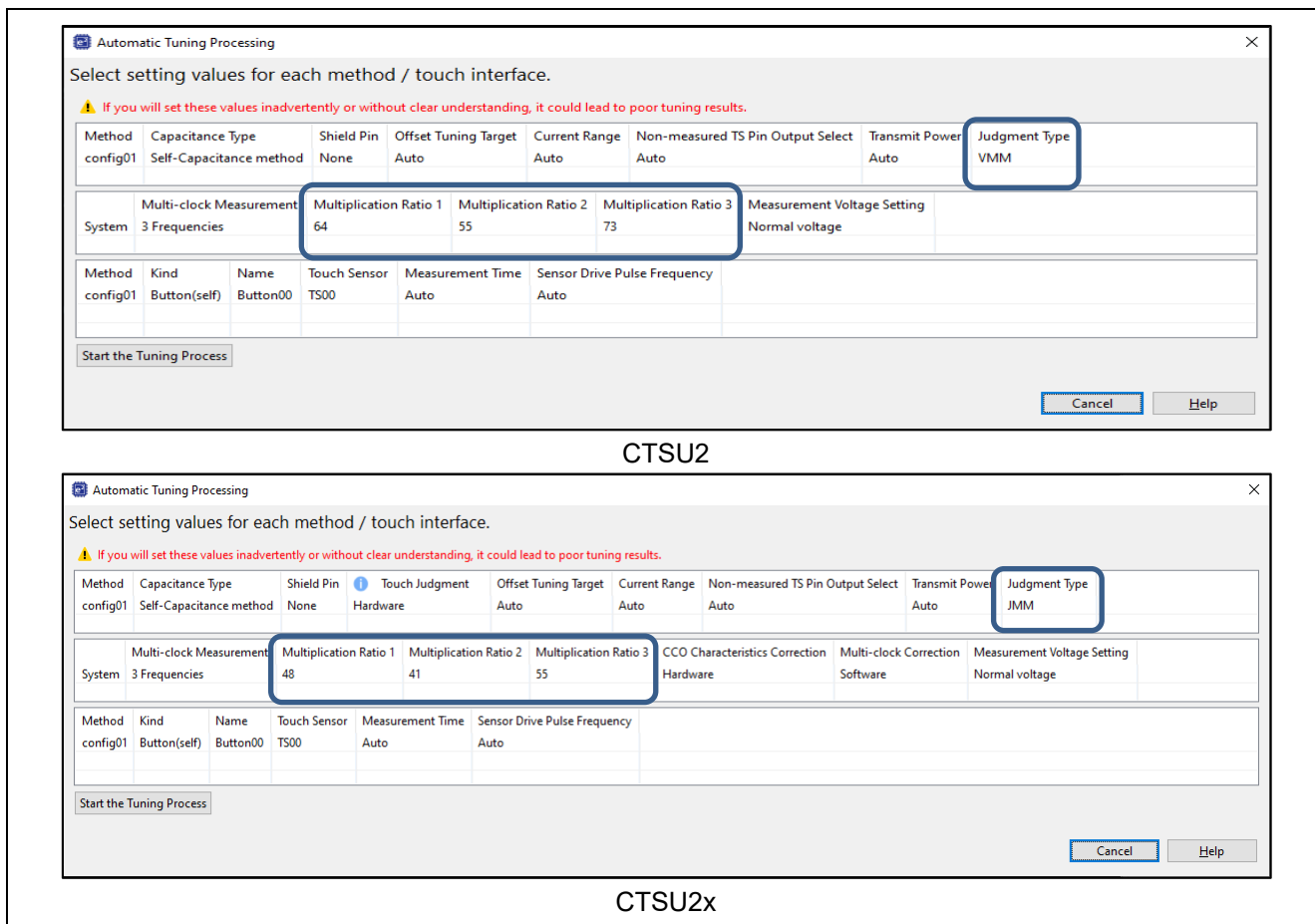
$$\text{Sensor Drive Pulse Frequency [2nd frequency]} = \text{Sensor Drive Pulse Frequency [1st frequency]} \times \frac{\text{Multiplication Ratio [2nd frequency]}}{\text{Multiplication Ratio [1st frequency]}}$$

$$\text{Sensor Drive Pulse Frequency [3rd frequency]} = \text{Sensor Drive Pulse Frequency [1st frequency]} \times \frac{\text{Multiplication Ratio [3rd frequency]}}{\text{Multiplication Ratio [1st frequency]}}$$

Increasing the frequency difference for 3-frequency measurement tends to increase the dispersion of the measurement value.

In addition, Multiplication Ratio should be set so that the measurement value does not overflow. Multiplication Ratio should be set after thorough evaluation.

Figure 3-29 shows an example when setting the "Judgment Type/Multi-clock Measurement/Multiplication Ratio" in "Advanced mode".



**Figure 3-29 Setting of "Judgment Type/Multi-clock Measurement/Multiplication Ratio"**

The setting of "Judgment Type" is reflected in the `qe_touch_define.h`. The following is a sample setting when VMM is used.

```
#define CTSU_CFG_MAJORITY_MODE (1)
```

The setting of "Multi-clock Measurement/Multiplication Ratio" is reflected on the `qe_touch_define.h`. Below is an example of setting when the upper limit of `SUCLK` is 40 MHz.

```
#define CTSU_CFG_NUM_SUMULTI (3)
#define CTSU_CFG_SUMULTI0 (0x3F)
#define CTSU_CFG_SUMULTI1 (0x36)
#define CTSU_CFG_SUMULTI2 (0x48)
```

**Note:** For details about `SUMULTI`, please refer to the hardware manual for each capacitive touch sensor microcontroller.

### 3.8 Touch Judgment/CCO Characteristics Correction/Multi-clock Correction

The "Touch Judgment" and "CCO Characteristics Correction" and "Multi-clock Correction" settings are applicable to CTSU2x.

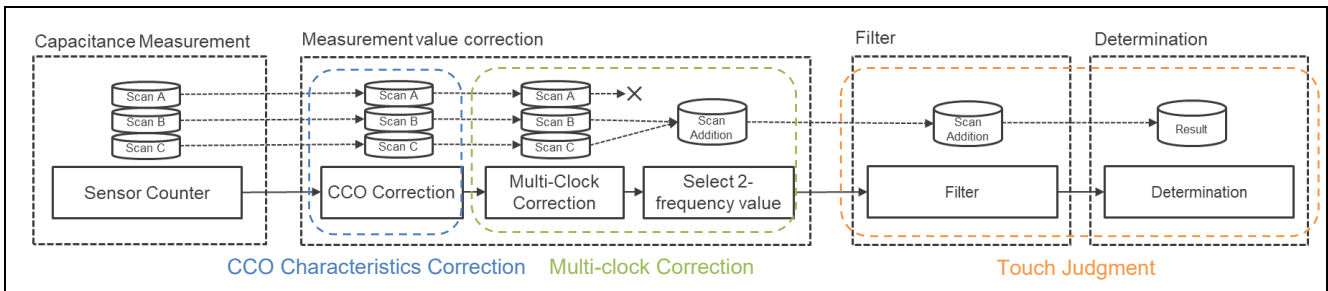
These settings determine whether each process is performed in hardware or software. When processed by hardware, software processing is not required, resulting in low power consumption and reduced processing time for the main processor. In Advanced mode, the "CCO Characteristics Correction" and "Multi-clock Correction" settings are set automatically by referring to "Touch Judgment" settings.

Table3-24 shows the description of each function.

**Table3-24 Function overview of "Touch Judgment/Multi-clock Correction/CCO Characteristics Correction"**

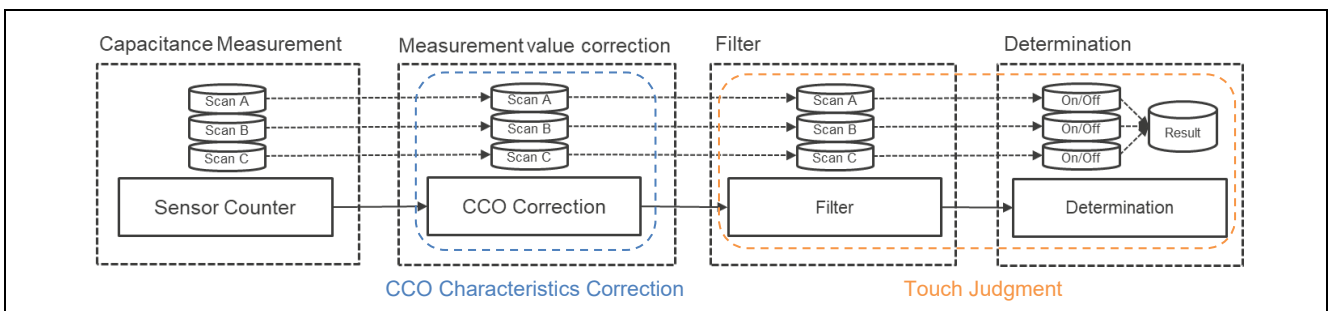
Function	Function overview
Touch Judgment	This function sets whether "Touch Judgment" is performed by hardware or software. Hardware touch judgment (Auto judgment) is available only for buttons. However, if your microcontroller has a built-in SNOOZE mode sequencer (SMS), you can use this function together with SMS. When SMS is used, only the majority decision mode (JMM) can be used.
CCO Characteristics Correction	This function sets whether "CCO characteristics correction" is performed by hardware or software. This function is only displayed on CTSU2SL/CTSU2SLa. It cannot be changed by the user because it is automatically set according to "Judgment Type" and "Touch Judgment".
Multi-clock Correction	This function sets whether "Multi-clock Correction" is performed in hardware or software. "Multi-clock correction" process after 3-frequency measurement and the results of 2 frequencies with close values from the 3-frequency measurement are selected for the final measurement result. Available only when VMM is used. This function is only displayed on CTSU2SL/CTSU2SLa. It cannot be changed by the user because it is automatically set according to "Judgment Type" and "Touch Judgment".

Figure 3-30 shows the operation image of the functions when VMM is used.



**Figure 3-30 Image of operation when VMM is used**

Figure 3-31 shows the operation image of the functions when JMM is used. "Multi-clock Correction" is not available when JMM is used.



**Figure 3-31 Image of operation when JMM is used**

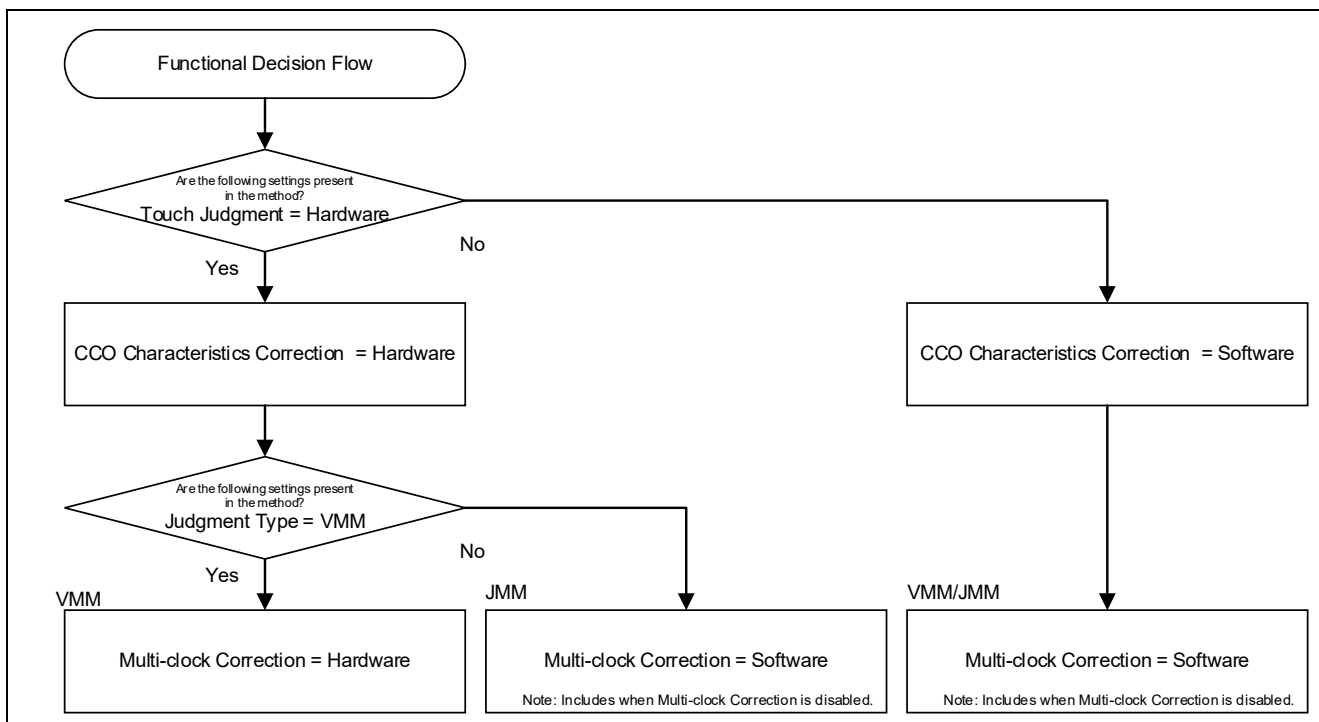
Table3-25 shows examples of default settings for each function when “Touch Judgment” is Hardware or Software.

**Table3-25 Default Settings for "CCO Characteristics Correction/Multi-clock Correction"**

Touch Judgment	CCO Characteristics Correction	Multi-clock Correction
Hardware	Hardware	When any method is set to VMM: Hardware Otherwise: Software *
Software	Software	Software *

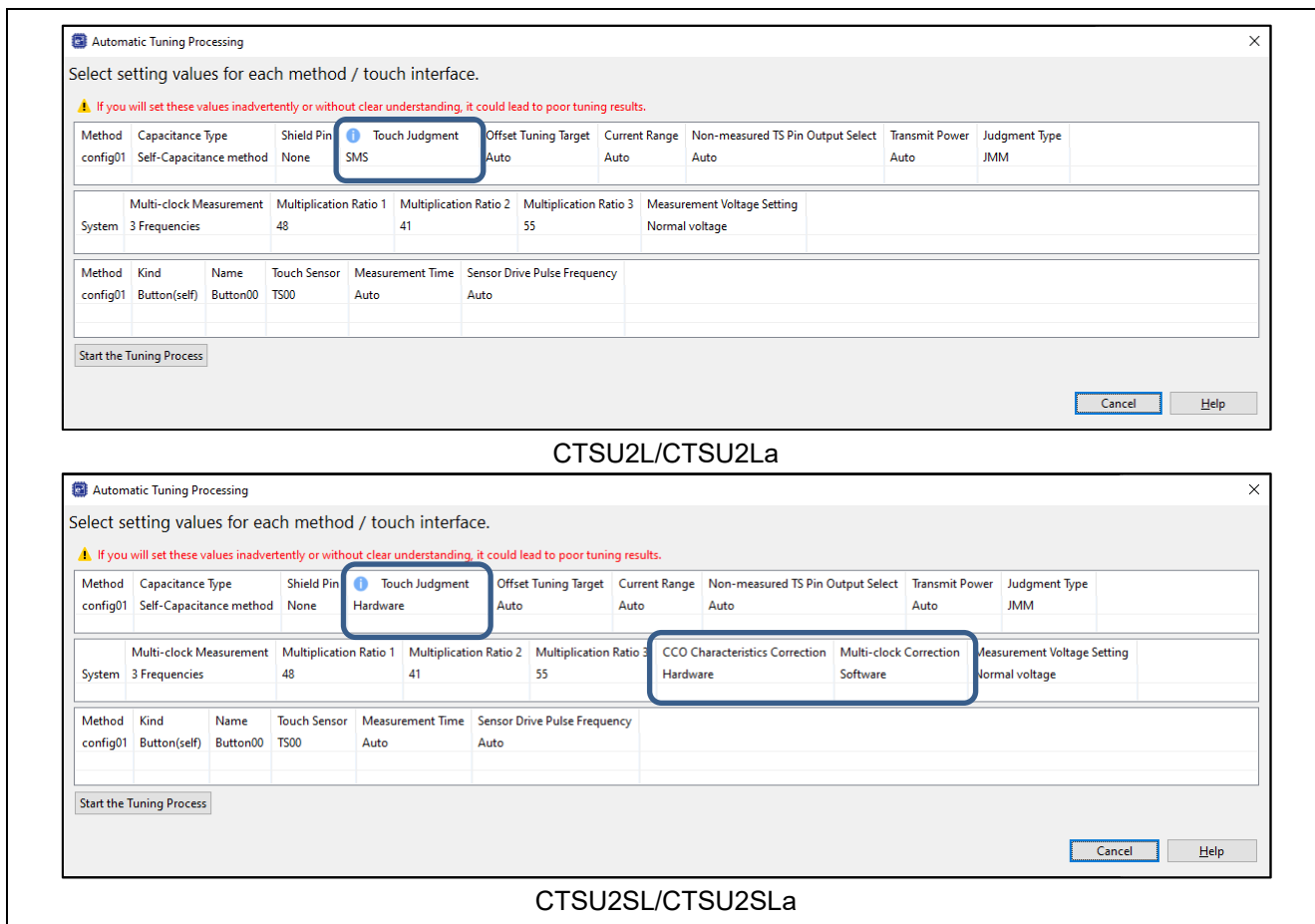
**Note:** When no method is set to VMM, “Multi-clock Correction” does not operate and is disabled. In Advanced mode, it is displayed as “Software” in the user interface.

If the “Touch Judgment” is Hardware for any method in the system, “CCO Characteristics Correction” is Hardware as the system. If VMM is used when “Touch Judgment” is Hardware, the “Multi-clock Correction” is also Hardware. Figure 3-32 shows the flow for determining the "Touch Judgment/CCO Characteristics Correction/Multi-clock Correction" setting.



**Figure 3-32 Flowchart for Determining "Touch Judgment/CCO Characteristics Correction/Multi-clock Correction"**

Figure3-33 shows an example when setting "Touch Judgment/CCO Characteristics Correction/Multi-clock Correction" in Advanced mode. When the MCU with built-in SMS is used, "SMS" is displayed instead of "Hardware" in "Touch Judgment".



**Figure3-33 Setting of "Touch Judgment/CCO Characteristics Correction/Multi-clock Correction"**

The setting of "Touch Judgment" is reflected in the r\_ctsu\_qe\_config.h or r\_ctsu\_config.h. The following is an example when "Touch Judgment" is set to hardware.

```
#define CTSU_CFG_AUTO_JUDGE_ENABLE (1)
```

The setting of "CCO Characteristics Correction/Multi-clock Correction" is reflected in the qe\_touch\_define.h. The following is an example of when "Touch Judgment" is hardware when JMM is used.

```
#define CTSU_CFG_AUTO_CORRECTION_ENABLE (1)
#define CTSU_CFG_AUTO_MULTI_CLOCK_CORRECTION_ENABLE (0)
```

**Note:** For details of each function, please refer to the hardware manual for each capacitive touch sensor microcontroller.

### 3.9 Measurement Voltage Setting

The "Measurement Voltage Setting" setting can be changed only with CTSU2/CTSUX.

In "Measurement Voltage Setting", TSCAP voltage to be used can be set for each system. When the operating voltage of the microcontroller is less than 2.4 V, "Measurement Voltage Setting" is automatically set to a lower voltage and TSCAP voltage is 1.2 V. This function is used when the microcontroller operating voltage becomes less than 2.4 V during battery operation. In addition, "Measurement Voltage Setting" can be used only when buttons, sliders and wheels are used. Switching TSCAP voltage during MCU operation is not supported.

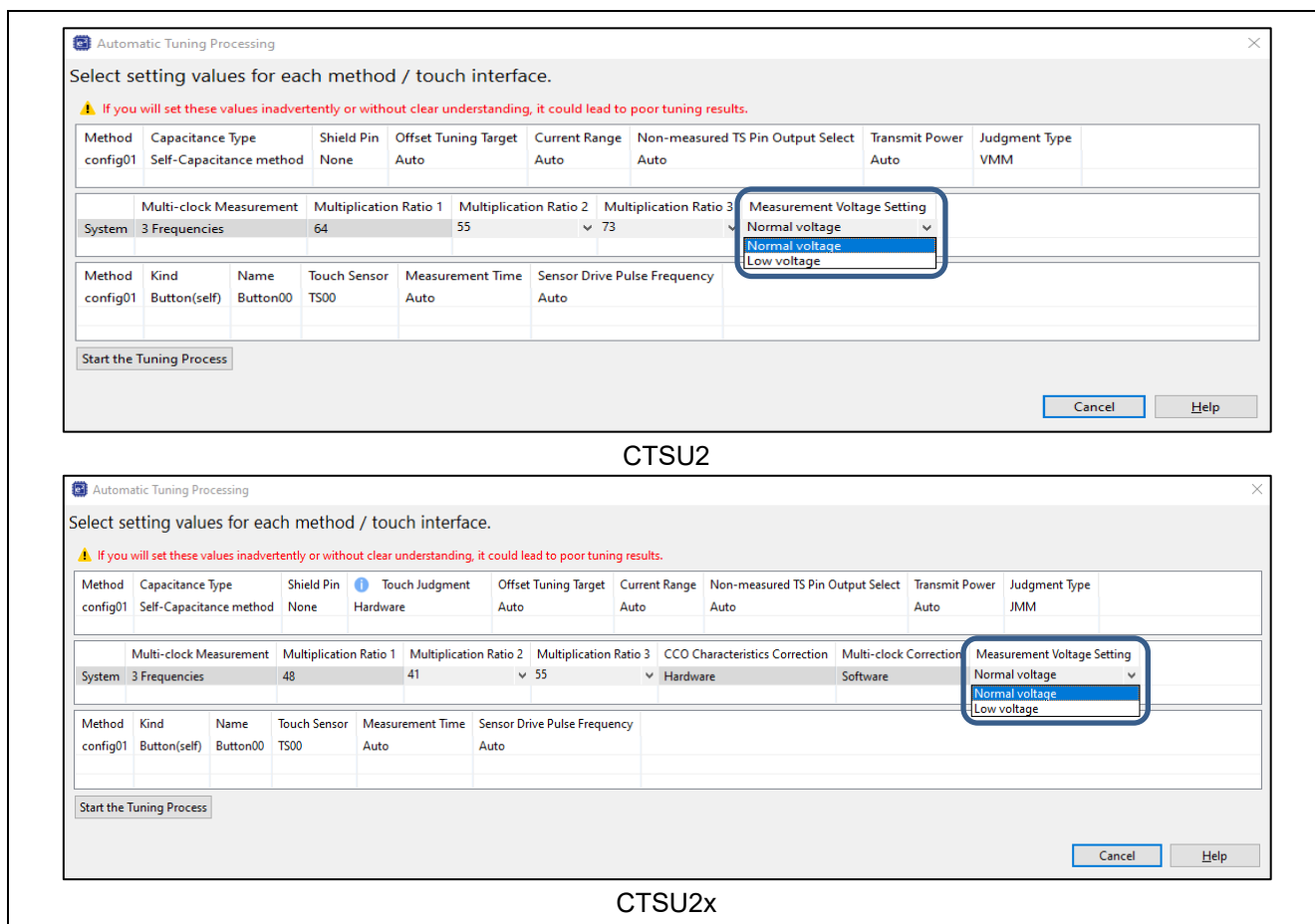
Table 3-26 shows an example of the default settings for "Measurement Voltage Setting" with operating voltage.

**Table 3-26 Default Settings for "Measurement Voltage Setting" with Operating Voltage**

Operating voltage *	Measurement Voltage Setting	TSCAP voltage [V]
More than 2.4V	Normal Voltage	1.5
Less than 2.4V	Low Voltage	1.2

**Note:** For configurable operating voltage, please refer to the hardware manual for each capacitive touch sensor microcontroller.

Figure3-34 shows an example when setting "Measurement Voltage Setting" in Advanced mode.



**Figure3-34 Setting of "Measurement Voltage Setting"**

The setting is reflected in the `qe_touch_define.h`. An example is shown below.

- Measurement Voltage Setting : Normal Voltage (TSCAP voltage: 1.5 V)  
The microcontroller operating voltage 5.0 V

```
#define CTSU_CFG_VCC_MV          (5000)
#define CTSU_CFG_LOW_VOLTAGE_MODE (0)
```

- Measurement Voltage Setting : Low Voltage (TSCAP voltage: 1.2 V)  
The microcontroller operating voltage 5.0 V

```
#define CTSU_CFG_VCC_MV          (5000)
#define CTSU_CFG_LOW_VOLTAGE_MODE (1)
```

- Measurement Voltage Setting : Low Voltage (TSCAP voltage: 1.2 V)  
The microcontroller operating voltage 1.8 V

```
#define CTSU_CFG_VCC_MV          (1800)
#define CTSU_CFG_LOW_VOLTAGE_MODE (1)
```

**Note:** For details on the low voltage operating mode, please refer to the hardware manual for each capacitive touch sensor microcontroller.

## Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jun.20.23	-	First edition issued
2.00	Dec.25.23	P26	Added explanation on how to adjust measurement frequency
		P30	Added an image diagram of the amount of current change relative to the offset target value when the measured current range is changed.
		P38	Added image diagrams when Automatic Correction (Hardware) is enabled/disabled.
3.00	Oct.22.24	-	New feature information added <ul style="list-style-type: none"> <li>• Judgement Type</li> <li>• Auto Judgement/Automatic Multi-Frequency Correction (Hardware)</li> <li>• Low Voltage Operating Mode</li> </ul>
		-	The diagram was changed with the change of the workflow after QE for Capacitive Touch v4.0.0 and the view design for monitoring.
		-	Changed figures because the available items have been renamed for the advanced dialogs from QE for Capacitive Touch v4.0.0 onwards.
		P1	Add CTSU2La, CTSU2SLa to the operation check device.
		P11	Updated Capacitive Touch Sensor Correspondence Table
		P15,26,31	Updated data as offset-tuning target value-updated in QE for Capacitive Touch v4.0.0
		P18	Corrected with offset-tuning target value updated in QE for Capacitive Touch v4.0.0
		P19	Table3-10 lists QE for Capacitive Touch v3.3.0 and v3.5.0 tuning targets
		P23	Added a chart of the relation between parasitic capacitance/damping resistor and measurement frequency, taking RX671 as an example.
		P29	Corrected the rated current value flowing through the Current Control oscillator (CCO).
		P34	Replace chapters 3.6 and 3.7 from the previous edition
		P37	Modified the title of chapter 3.7
		P40	Added explanation of Auto Judgement and Automatic Multi-Frequency Correction (Hardware)
P43	Added explanation of Low Voltage Operating Mode		
3.10	Feb.19.25	-	Terms have been revised in accordance with the terminology corrections in QE for Capacitive Touch v4.1.0.
		-	Figures have been updated in accordance with the terminology corrections in QE for Capacitive Touch v4.1.0.
		-	The text regarding usage restrictions has been removed as hardware judgment using VMM has become possible from QE for Capacitive Touch v4.1.0.
		P15	The text in section 3.1.1 has been updated.
3.20	Sep.24.25	-	The diagram was changed with the change of the workflow after QE for Capacitive Touch v4.2.0 and the view design for monitoring.
		P11	Corrected parameter description
		P12	Revised the explanation regarding "Measurement Count/Measurement Time."

		P23	Corrected the explanation and figure with the change of the adjustment method of sensor drive pulse frequency.
		P32	Added a table for Current Range and current mirror ratio.
		P41	RL78/L23, RA0L1, RL78/F25, RL78/F22 was added to the description of the multiplication ratio setting.
3.30	Mar.24.26	P1	Added a link to the design guide to Introduction.
		P9	Revised the title of section 2 to 2. "Advanced mode" tuning flow.
		P9,10	Modified the flowchart
		P11	Revised the description of Feature Overview in Table 2-1 Correspondence table of capacitive touch sensor.
		P12,13,14,15	Revised the description of Measurement Count/Measurement Time.
		P17	Added the explanation of SNUM upper limit check in Advanced mode.
		P18,19,32	Revised the description of overflow.
		P30	Add the description of the same sensor drive pulse frequency set to all TS pins configuring sliders/wheels.
		P35	Revised the description of current range.
		P40,41,42	Revised the description of setting names for Transmit Power and changes in default settings.

# 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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