

## **Capacitive Sensor MCU**

## QE for Capacitive Touch Advanced Mode Parameter Guide

### 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. However, to optimize touch performance and to mitigate unwanted behavior from environmental effects such as electrical noise, QE for Capacitive Touch supports an "Advanced mode" Tuning.

This application note describes "Advanced mode" Tuning and the CTSU parameters which can be adjusted.

If you are developing a Capacitive Touch for the first time, it is recommended that you read the Capacitive Touch Introduction Guide beforehand.

Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide (R30AN0424)

## **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) 2025-01 or later
- · Renesas QE for Capacitive Touch V4.1.0 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 in tuning.

QE for Capacitive Touch measures the parasitic capacitance of the user's touch sensor and performs autotuning to optimize the parameters. For more information about QE for Capacitive Touch, 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.

| Table 1-1 | Tuning-ad | justable | parameters |
|-----------|-----------|----------|------------|
|           |           |          |            |

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

#### ✓: Supported

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

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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 of auto tuning or CapTouch parameters does not meet the user's 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.

|                                    | Automatic Tuning Processing   |  |
|------------------------------------|---|--|
|                                    | QE is beginning the tuning process.   |  |
| Proparing for                      | During the tuning process, please do not touch the sensors on the target board  |  |
| Preparing for<br>adjustment        | until instructed by the QE Tuning Program.  |  |
| aujustment                         |   |  |
|                                    | Cancel <u>H</u> elp   |  |
| $\mathbf{\nabla}$                  | Automatic Tuning Processing X   |  |
| Macauring                          | QE is measuring the parasitic capacitance for all touch sensors.<br>During this measurement process, please do not touch the sensors on the target  |  |
| Measuring parasitic                | board.  |  |
| capacitance                        |   |  |
| oupuortanto                        | Cancel <u>H</u> elp   |  |
| $\sim$                             | Automatic Tuning Processing X   |  |
|                                    | QE is adjusting offset values for each sensor.(config01)  |  |
| Adjusting                          | During the adjustment process, please do not touch the sensors on the target  |  |
| the offset                         | board. Button00, TS00 35329   |  |
|                                    |   |  |
|                                    |   |  |
|                                    | Cancel <u>H</u> elp   |  |
| •                                  | Automatic Tuning Processing X   |  |
|                                    | QE is now starting sensitivity measurement for each of the touch sensors when not touched.(config01)  |  |
| Measuring                          | During this step, please do not touch the sensors on the target board.  |  |
| sensitivity<br>(while not touched) |   |  |
| (while not touched)                |   |  |
|                                    |   |  |
|                                    | Cancel Help   |  |
| $\sim$                             | Automatic Tuning Processing X   |  |
|                                    | QE will now measure touch sensitivity for (Button00, TS00 @ config01).<br>In this step please use maximum touch pressure on the sensor with a metal |  |
|                                    | conductor. Press any key on the PC keyboard to accept the sensitivity   |  |
| Measuring                          | measurement.  |  |
| sensitivity<br>(while touched)     | Button00, TS00 @ config01: 15265  |  |
| (while touched)                    |   |  |
|                                    | Cancel Help   |  |
|                                    | Automatic Tuning Processing   |  |
| $\sim$                             | The automatic tuning process is now complete. If overflow or warning/errors are   |  |
| •                                  | indicated, those sensors can be retried. If there are continued overflows or  |  |
|                                    | warning/errors, please consult the Renesas application notes for Capacitive Touch<br>for guidance.  |  |
| Result of                          | Select the target Method Kind Name Touch Sensor Threshold Overflow Warning / Error  |  |
| the tuning                         | config01 Button Button00 TS00 65535   |  |
| 3                                  |   |  |
|                                    | Retry Continue the Tuning Process   |  |
|                                    | Cancel Help   |  |
|                                    |   |  |

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

Auto tuning adjusts the sensitivity of touch sensor detection to determine the optimal parameters. 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 of the 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.

|   |    | 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 | Ē  | Write to target board in real time | Toggle button to switch whether the numerical value of the parameter is reflected to<br>the target in real time. |
| 4 | ſ? | 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.

| File name         | Description  |
|-------------------|--|
| qe_touch_config.c | 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 tuning with "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.

|                    | Capacitance<br>Self-Capacit    |                  |                      | <ol> <li>Touc</li> <li>Hardware</li> </ol> | h Judgment    | Offset<br>Auto    |                      | Current<br>Auto | t Range          | Non-measured TS Pin C<br>Auto    | utput Select            | Transmit Po<br>Auto | ower Judgment Type<br>JMM             |         |  |
|--------------------|--------------------------------|------------------|----------------------|--|---------------|-------------------|----------------------|-----------------|------------------|----------------------------------|-------------------------|---------------------|---------------------------------------|---------|--|
|                    | Multi-clock M<br>3 Frequencies |                  | Multiplicatio<br>48  |  | Multiplicatio | on Ratio 2        | Multiplication<br>55 |                 | CCO Cł<br>Hardwa | haracteristics Correction<br>are | Multi-clock<br>Software |                     | Measurement Voltage<br>Normal voltage | Setting |  |
| Method<br>config01 | Kind<br>Button(self)           | Name<br>Button00 | Touch Sensor<br>TS00 | Measure<br>Auto                            |               | Sensor Dr<br>Auto | ive Pulse Freque     | ncy             |                  |                                  |                         |                     |                                       |         |  |
| Start the          | Tuning Process                 |                  |                      |  |               |                   |                      |                 |                  |                                  |                         |                     |                                       |         |  |

Figure 1-5 "Advanced mode" Tuning window

The parameters that can be adjusted in "Advanced mode" Tuning vary depending on the device. For details, 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.

| I able 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" settings

#### 2.1 Sensitivity improvement adjustment flow

Figure 2-1 shows the adjustment steps to improve sensitivity through "Advanced mode" Tuning.



Figure 2-1 Sensitivity 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 parameters displayed in "Advanced mode" and the corresponding table for each capacitive touch sensor.

|    | Parameter  | Purpose  | CTSU2x       | CTSU2        | CTSU1        | Feature Overview  |
|----|--|--|--------------|--------------|--------------|---|
| 1  | <u>Measurement</u><br><u>Count/Measure</u><br><u>ment Time</u> | Improved sensitivity                             | $\checkmark$ | ~            | $\checkmark$ | Set the measurement count and determine the measurement time.<br>The signal value can be improved by integrating the measurement<br>value.  |
| 2  | <u>Offset Tuning</u><br><u>Target</u>                          | Improved sensitivity                             | $\checkmark$ | $\checkmark$ | $\checkmark$ | Set the target value (%) of the offset current so that the measured value at touch OFF becomes the target. Adjust this when the measurement time is changed.  |
| 3  | Base Clock<br>Frequency/Sens<br>or Drive Pulse<br>Frequency    | Improved<br>sensitivity                          | $\checkmark$ | ~            | $\checkmark$ | Sets the frequency division ratio of the frequency output to the touch<br>sensor. The higher Base Clock Frequency/Sensor Drive Pulse<br>Frequency, the better the sensitivity can be seen. However, a<br>measurement error occurs when the parasitic capacitance is large.  |
| 4  | Current Range  | Improved<br>sensitivity                          | $\checkmark$ | $\checkmark$ | -            | Sets the power supply capability from VDC and determines the<br>current mirror ratio between the measured power supply current and<br>the input current of the current-controlled oscillator. Setting a low<br>current range increases the sensitivity. This is because CCO input<br>current at touch ON increases.   |
| 5  | Non-measured<br>TS Pin Output<br>Select                        | Noise<br>Suppression                             | $\checkmark$ | ~            | -            | These bits set the handling of non-measurement pins other than the measurement pins during the measurement interval of the pin s set in TS pin. Noise suppression can be achieved by appropriately processing the non-measured pins.  |
| 6  | <u>Transmit Power</u>  | Pin Setting                                      | $\checkmark$ | $\checkmark$ | $\checkmark$ | Selects I/O power supply of the pins set to the transmit pins when<br>the mutual capacitance method is used or the active-shield is used.<br>This value uses the default setting and should not be changed.   |
| 7  | Judgment Type  | Noise<br>Suppression                             | \$           | \$           | -            | Judgment Type includes Value Majority Mode (VMM) and Judgment<br>Majority Mode (JMM). VMM is a method to judge by adding two<br>measured values which are close in value from the measured result<br>of 3 frequencies. JMM is a method in which the judgment result of<br>each of the 3 frequency measurements is judged by majority<br>decision.   |
| 8  | Multi-clock<br>Measurement/<br>Multiplication<br>Ratio         | Noise<br>Suppression                             | $\checkmark$ | ~            | -            | Set the measurement times to be measured in Multi-clock<br>Measurement and the Multiplication Ratio of multiple types of<br>frequencies to be used for measurement. Multi-clock Measurement<br>allows you to measure multiple drive frequencies to avoid<br>synchronous noise   |
| 9  | Touch Judgment   | Process<br>reduction<br>Low power<br>consumption | \$           | -            | -            | This function sets whether touch judgment is performed by hardware<br>or software. Low-power consumption can be achieved when touch<br>judgment is set to hardware. However, in the case of a<br>microcontroller with a built-in SNOOZE mode sequencer (SMS), this<br>function can be realized by using it together with the SMS. It can be<br>set from Smart Configurator/Touch Interface<br>Configuration/Advanced Mode.  |
| 10 | CCQ<br>Characteristics<br>Correction                           | Process<br>reduction<br>Low power<br>consumption | $\checkmark$ | -            | -            | This function sets whether CCO characteristics correction is<br>performed by hardware or software. It is set to hardware when<br>hardware touch judgment is enabled. Hardware processing<br>eliminates the need for wake-up for each measurement and<br>contributes to lower power consumption. This function is only<br>displayed on CTSU2SL/CTSU2SLa. It cannot be changed by the<br>user because it is automatically set according to "Judgment Type"<br>and "Touch Judgment". |
| 11 | Multi-clock<br>Correction                                      | Process<br>reduction<br>Low power<br>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/CTSU2SLa. It cannot be changed by the user because it is automatically set according to "Judgment Type" and "Touch Judgment".   |
| 12 | Measurement<br>Voltage Setting                                 | Process<br>reduction<br>Low power<br>consumption | ~            | 1            | -            | Set TSCAP voltage to be used. If the microcontroller operating voltage is less than 2.4V, the measurement voltage is automatically set to a lower voltage and the TSCAP voltage is 1.2V. This function is used when VCC/VDD is less than 2.4V during battery operation.   |



#### 3. Overview of each parameter

#### 3.1 Measurement Count/Measurement Time

In "Measurement Count/Measurement Time", set the number of charge/discharge times to perform one measurement, and determine the time for one measurement. Signal value\* can be improved by increasing the Measurement Count. By increasing the Measurement Count, the signal value\* can be increased, leading to improved sensitivity. However, since the measurement time is also extended at the same time, adjustment according to the user's specifications is required. In addition, adjust the target value by the offset tuning target to prevent overflow when the measurement count is changed. 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 shows the default Measurement Count. By CTSU2/CTSU2x, the Measurement Count is fixed at 8. Table 3-1 Default "Measurement Count" Setting

|                                | Base Clock Frequency/<br>Sensor Drive Pulse Frequency | Measurement<br>Count <sup>*1</sup> | Measurement<br>Time [µs] |
|--------------------------------|---|------------------------------------|--------------------------|
| CTSU1                          | 4 MHz   | 8                                  |                          |
| (Sample RX130)                 | 2 MHz   | 4                                  | 526                      |
|                                | 1 MHz   | 2                                  |                          |
|                                | 0.5 MHz   | 1                                  |                          |
| CTSU2/CTSU2x<br>(Sample RX140) | -   | 8                                  | 128 <sup>*2</sup>        |

**Note1:** For details about SNUM, please refer to the hardware manual for each capacitive touch sensor microcontroller.

Note2: The measurement time of one frequency is described.



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

• CTSU1 (RX130)

```
Stabilization wait time [µs] = 34 × (1/sensor drive pulse frequency)
```

Measurement time [µs] = 263 × (1/sensor drive pulse frequency) × (Measurement count)

Table 3-2 shows a typical example of the measurement time and stabilization wait time when the self-capacitance method is used in RX130 as a typical CTSU1.

Table 3-2 Stabilization Wait Time and measurement time when using self-capacitance method on RX130

| Base Clock Frequency [MHz] | Measurement count | Stabilization wait time<br>[µs] | Measurement<br>time [µs] | Total (Stabilization wait time +<br>Measurement time) [µs] |
|----------------------------|-------------------|---------------------------------|--------------------------|--|
| 4                          | 8                 | 8.5                             | 526                      | 534.5  |
| 2                          | 4                 | 17                              | 526                      | 543  |
| 1                          | 2                 | 34                              | 526                      | 560  |
| 0.5                        | 1                 | 68                              | 526                      | 594  |

**Note:** Recommended CTSUPRRTIO, CTSUPRMODE are used. Changing this value is deprecated. For details, please refer to the hardware manual for each capacitive touch sensor microcontroller.

#### • CTSU2/CTSU2x (RX140)

#### Stabilization wait time [µs] = (64 × 3 [for 3 frequency measurement])

Measurement time [µs] = (16 × (Measurement count) × 3 [for 3 frequency measurement])

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

Table 3-3 Stabilization wait time and the measurement time when using self-capacitance method with RX140 (3-frequency measurement)

| Measurement count           | Stabilization wait time [µs] | Measurement time<br>[µs] | Total (Stabilization wait time +<br>Measurement time) [µs] |
|-----------------------------|------------------------------|--------------------------|--|
| 8<br>[(STCLK cycle* 8) * 8] | 192 [64 × 3]                 | 384 [128 × 3]            | 576 [192 + 384]  |

**Note:** STCLK cycling is a reference clock for measuring times. It is set to the recommended 0.5MHz (2µs).

The 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 and the following documents.

RX Family QE CTSU Module Using Firmware Integration Technology Rev.3.00 (R01AN4469)



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

|             |                                   | atic Tuning Pro     |                   |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
|-------------|-----------------------------------|---------------------|-------------------|--------------------------------------|-----------------------------|--------------|--------------------------|--------------------|-------------------------|-------------|--------------------------------------|--------------|--------------|
|             | Select se                         | etting valu         | es for ead        | h method                             | d / touch inte              | rface.       |                          |                    |                         |             |                                      |              |              |
|             | 🔺 lf you                          | will set these v    | alues inadver     | tently or witho                      | out clear understan         | ding, it co  | uld lead to p            | oor tuning res     | ults.                   |             |                                      |              |              |
|             | Method                            | Capacitance         | Туре              | Shield Pin                           | Offset Tuning Targ          | jet Tran     | smit Power               |                    |                         |             |                                      |              |              |
|             | config01                          | Self-Capacita       | ance method       | None                                 | Auto                        | Auto         | ,<br>,                   |                    |                         |             |                                      |              |              |
|             |                                   |                     | 1                 |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
|             | Method                            | Kind                | Name              | Touch Sensor                         | Measurement C               |              | se Clock Free            | quency             |                         |             |                                      |              |              |
|             | config01                          | Button(self)        | Button00          | TS00                                 | Auto<br>Auto                | V Au         | to                       | ~                  |                         |             |                                      |              |              |
|             |                                   |                     |                   |                                      | 1                           |              |                          |                    |                         |             |                                      |              |              |
|             | Start the T                       | uning Process       | i                 |                                      | 3                           |              |                          |                    |                         |             |                                      |              |              |
|             |                                   |                     |                   |                                      | 4<br>5                      |              |                          |                    |                         | _           |                                      |              |              |
|             |                                   |                     |                   |                                      | 6<br>7                      | J            |                          |                    |                         |             | Cancel                               | <u>H</u> elp |              |
|             |                                   |                     |                   |                                      |                             | СТ           | SU1                      |                    |                         |             |                                      |              |              |
|             |                                   |                     |                   |                                      |                             |              | 301                      |                    |                         |             |                                      |              |              |
|             | natic Tuning P                    | -                   |                   |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
| Select s    | etting val                        | ues for eac         | h method          | / touch in                           | nterface.                   |              |                          |                    |                         |             |                                      |              |              |
| 🔺 lf you    | u will set these                  | values inadvert     | ently or witho    | ut clear unders                      | standing, it could le       | ad to poor   | tuning result            | s.                 |                         |             |                                      |              |              |
| Method      |                                   |                     |                   | -                                    | Target Current Ra           | -            |                          | S Pin Output S     |                         | nit Power   | Judgment Type                        |              |              |
| config0     | 1 Self-Capaci                     | tance method        | None              | Auto                                 | Auto                        | Aut          | 0                        |                    | Auto                    |             | VMM                                  |              |              |
|             | Multi-clock I                     | /leasurement        | Multiplicatio     | n Ratio 1 Mu                         | Itiplication Ratio 2        | Multiplic    | ation Ratio 3            | Measuremen         | t Voltage Sett          | ting        |                                      |              |              |
| System      | 3 Frequencie                      | 5                   | 64                | 55                                   |                             | 73           |                          | Normal volta       | ge                      |             |                                      |              |              |
| Method      | Kind                              | Name                | Touch Sensor      | Measuremer                           | nt Time Sensor Dri          | ve Pulse F   | requency                 |                    |                         |             |                                      |              |              |
| config0     | 1 Button(self)                    |                     | TS00              | Auto                                 | ✓ Auto                      |              | ~                        |                    |                         |             |                                      |              |              |
|             |                                   |                     |                   | Auto<br>(STCLK cycle<br>(STCLK cycle | * 8) * 1                    |              |                          |                    |                         |             |                                      |              |              |
| Start the   | Tuning Proces                     | s                   |                   | (STCLK cycle                         | * 8) * 3                    |              |                          |                    |                         |             |                                      |              |              |
|             |                                   |                     |                   | (STCLK cycle<br>(STCLK cycle         | * 8) * 5                    |              |                          |                    |                         |             |                                      |              |              |
|             |                                   |                     |                   | (STCLK cycle<br>(STCLK cycle         | *8)*7                       |              |                          |                    |                         |             | C                                    | ancel        | <u>H</u> elp |
|             |                                   |                     |                   |                                      |                             | СТ           | SU2                      |                    |                         |             |                                      |              |              |
| 🔒 Automa    | itic Tuning Proce                 | ssing               |                   |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
| elect se    | tting values                      | for each m          | ethod / tou       | ch interface                         | 2                           |              |                          |                    |                         |             |                                      |              |              |
|             | -                                 |                     |                   |                                      | t could lead to poor tu     | nina results |                          |                    |                         |             |                                      |              |              |
|             | Capacitance Ty                    |                     |                   | uch Judgment                         |                             |              |                          | measured TS Pin (  | Output Select           | Transmit Po | wer Judgment Typ                     | e            |              |
|             |                                   | e method Non        | _                 |                                      | Auto                        | Auto         | Auto                     |                    |                         | Auto        | JMM                                  |              |              |
|             |                                   |                     |                   |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
|             | Multi-clock Mea:<br>3 Frequencies | urement Multi<br>48 | plication Ratio 1 | Multiplication<br>41                 | Ratio 2 Multiplicatio<br>55 | on Ratio 3   | CCO Characte<br>Hardware | ristics Correction | Multi-clock<br>Software |             | Measurement Voltag<br>Normal voltage | je Setting   |              |
| ,           |                                   |                     | 6                 |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
| Method      |                                   | lame Touch          |                   |                                      | Sensor Drive Pulse Freq     | uency        |                          |                    |                         |             |                                      |              |              |
| config01    | Button(self) E                    | utton00 TS00        | Auto<br>Auto      | ✓ A                                  | Auto                        | ~            |                          |                    |                         |             |                                      |              |              |
|             |                                   |                     | (STCL)            | cycle * 8) * 1<br>cycle * 8) * 2     |                             |              |                          |                    |                         |             |                                      |              |              |
| Start the T | uning Process                     |                     | (STCL)            | cycle * 8) * 3<br>cycle * 8) * 4     |                             |              |                          |                    |                         |             |                                      |              |              |
|             |                                   |                     |                   |                                      |                             |              |                          |                    |                         |             |                                      |              |              |
|             |                                   |                     | (STCL)            | cycle * 8) * 5<br>cycle * 8) * 6     |                             |              |                          |                    |                         |             | E E                                  | Cancel       | <u>H</u> elp |

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

For the set value, the value of Measurement Count -1 is reflected to "snum" of the qe\_touch\_config.c. If "(STCLK Cycle\* 8) \* 8" is selected in "Measurement Count/Measurement Time", it is set as "snum = 0x07".

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



# 3.1.1 Effects on sensitivity and precautions due to changes in the Measurement Count/Measurement Time

Table 3-4 shows the measurement values (actual measurement examples) when RX140 mounted capacitance touch evaluation system is used when "Measurement Count/Measurement Time" is changed.

Table 3-4 Measurement values when "Measurement Count/Measurement Time" is changed (actual measurement example)

| Capacitance Touch Evaluation System with CTSU2x(RX140) |                            |                           |                                 |  |                                     |                        |  |
|--|----------------------------|---------------------------|---------------------------------|--|-------------------------------------|------------------------|--|
| Self-capacitance                                       | e method, VM               | M method, Sens            | or Drive Pulse Fre              | equency: 2MHz, Current Rang                              | je: 40µA, button 1                  | ch (averaged five time | es)  |
| Measurement<br>count                                   | Offset<br>tuning<br>target | Avg. at<br>touch OFF<br>A | Avg. at touch<br>ON<br><b>B</b> | Signal value<br>(Difference of touch<br>ON/OFF)<br>B - A | Avg. at touch<br>OFF<br>Noise value | SNR                    | Stabilization wait<br>time<br>+<br>Measurement<br>time |
| 8  | 37.5%                      | 11545                     | 13514                           | 1969   | 17.78                               | 17.85                  | 576 µs   |
| 12   | 25%                        | 11666                     | 14586                           | 2920   | 22.76                               | 20.96                  | 768 µs   |
| 16   | 20%                        | 11435                     | 14994                           | 3559   | 27.12                               | 21.12                  | 912 µs   |

**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".

If the noise has a standard distribution, increasing the measurement count/measurement time will increase the signal value because the number of integrated touch measurements will increase, but the noise will be averaged, thus improving the SNR.

Accumulation of the measurement count increases the signal value. At the same time, however, the measurement value may overflow or the measurement time may not satisfy the user's required specifications. In such cases, please consider adjusting the target value of offset adjustment, reducing the measurement count, or changing the current range or frequency. These can be adjusted individually. Also, increasing the measurement count can cause CTSU to consume more power during low-power operation. Please adjust the measurement count after thorough evaluation according to the specifications required by the user.



#### 3.1.2 Necessity of Offset Tuning Adjustment when Changing Measurement Count

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

Table 3-5 and Figure 3-3 show the measurements of "Measurement Count/Measurement Time" in RX130 as a typical CTSU1.

| Capacitance Touch         | Evaluation System wit           | h CTSU1(RX130)                  |  |                                       |
|---------------------------|---------------------------------|---------------------------------|--|---------------------------------------|
| Self-Capacitance System F | CLKB:32MHz Sensor Drive Puls    | e Frequency: 2MHz Offset Tuning | Target: 37.5% Key 1ch                                  |                                       |
| Measurement count         | Stabilization wait time<br>[µs] | Measurement time [µs]           | Total (Stable waiting time<br>+ Measurement time) [µs] | Measurement value (theoretical value) |
| 1                         | 17                              | 131.5                           | 148.5  | 3840                                  |
| 2                         | 17                              | 263                             | 280  | 7680                                  |
| 3                         | 17                              | 394.5                           | 411.5  | 11520                                 |
| 4                         | 17                              | 526                             | 543  | 15360                                 |
| 5                         | 17                              | 657.5                           | 674.5  | 19200                                 |
| 6                         | 17                              | 789                             | 806  | 23040                                 |
| :                         | :                               | :                               | :  | :                                     |

Table 3-5 Measurement value for "Measurement Count/Measurement Time" with RX130 (theoretical value)



Figure 3-3 Measurement value (theoretical value) for "Measurement Count/Measurement Time" 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. Increasing the measurement count may cause overflow of measurements during touch ON. The offset tuning target must be adjusted so that the measurement value is within the range of good output-linearity characteristics of the current-controlled oscillator (CCO).



Table 3-6 and Figure 3-4 show typical measurements for "Measurement Count/Measurement Time" in RX140 as a CTSU2/CTSU2x.

Table 3-6 measurement value for "Measurement Count/Measurement Time" with RX140 (theoretical value)

| Capacitance Touch          | Evaluation System     | m with CTSU2x(F         | RX140)                               |                               |
|----------------------------|-----------------------|-------------------------|--------------------------------------|-------------------------------|
| Self-Capacitance System PC | LKB:32MHz Sensor Driv | ve Pulse Frequency:: 2M | Hz Offset Tuning Target: 37.5% Key 1 | ch                            |
| Measurement count          | Stabilization         | Measurement             | Total (Stable waiting time +         | Measured value per            |
|                            | wait time [µs]        | time [µs]               | Measurement time) [µs]               | frequency (theoretical value) |
| 1 [(STCLK cycle* 8) * 1]   | 192                   | 48                      | 240                                  | 720                           |
| 2 [(STCLK cycle* 8) * 2]   | 192                   | 96                      | 288                                  | 1440                          |
| 3 [(STCLK cycle* 8) * 3]   | 192                   | 144                     | 336                                  | 2880                          |
| :                          | :                     | :                       | :                                    | :                             |
| 8 [(STCLK cycle* 8) * 8]   | 192                   | 384                     | 576                                  | 5760                          |
| :                          | :                     | :                       | :                                    | :                             |
| 16 [(STCLK cycle* 8) * 16] | 192                   | 768                     | 960                                  | 11520                         |
| :                          | :                     | :                       | :                                    | :                             |



Figure 3-4 Measurement value (theoretical value) for "Measurement Count/Measurement Time" with RX140

For instance, if the measurement count is increased to 16 when using the self-capacitance method, the measurement value at touch OFF will be around 11520. Increasing the measurement count may cause overflow of measurements during touch ON. It is necessary to adjust the offset tuning target so that the measurement value fits within the good range of the output linearity characteristic of the current controlled oscillator (CCO).



## 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 16bit 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 3-7 shows the target values for the default "Measurement Count". For the default "Measurement Count" see Table 3-1 setting.

Table 3-7 Default "Offset Tuning Target" Setting for Each measurement

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

**Note:** VMM is used, the total value  $(128 + 128 = 256 \ \mu s)$  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  $\mu$ s).



Target values are shown in Table 3-8 for setting the target value during offset-tuning in CTSU1.

Table 3-8 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/CTSU2x differ depending on the version of QE for Capacitive Touch. Table3-9 shows the target values when the offset tuning target are changed by CTSU2/CTSU2x when QE for Capacitive Touch prior to v3.5.0 is used after v4.0.0 and Table3-10.

Table3-9 Target value for "Offset Tuning Target" CTSU2/CTSU2x (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 μs) of the 3-frequency measurement. When JMM is used, it is equivalent to one frequency (128 μs).

| Table3-10 Target value for "Offset Tuning Target" CTSU2/CTSU2x |
|--|
| (QE for Capacitive Touch v3.5.0 or earlier)                    |

| Offect Tuning Torget | Target value*                               | Target value*                    |
|----------------------|---|----------------------------------|
| Offset Tuning Target | (QE for Capacitive Touch v3.3.0 or earlier) | (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 µs) 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 Table3-9. It is recommended that the latest QE for Capacitive Touch be used in the evaluation.



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

|               | Select se         | etting valu       | ies for ea                | ch metho       | d / touc                   | n interfa        | ace.             |                     |                |                              |               |                 |              |
|---------------|-------------------|-------------------|---------------------------|----------------|----------------------------|------------------|------------------|---------------------|----------------|------------------------------|---------------|-----------------|--------------|
|               | 🔺 If you          | will set these v  | values inadve             | tently or with | out clear un               | derstandin       | g, it could lea  | d to poor tur       | ing results.   |                              |               |                 |              |
|               | Method            | Capacitance       | Туре                      | Shield Pin     | Offset Tun                 | ing Target       | Transmit Po      | wer                 |                |                              |               |                 |              |
|               | config01          | Self-Capacit      | ance method               | None           | Auto                       | ~                | Auto             | ~                   |                |                              |               |                 |              |
|               |                   |                   |                           |                | Auto<br>25.0%              |                  |                  |                     |                |                              |               |                 |              |
|               | Method            | Kind              | Name                      | Touch Sense    | r 30.0%<br>35.0%           |                  |                  | k Frequency         |                |                              |               |                 |              |
|               | config01          | Button(self)      | Button00                  | TS00           | 37.5%<br>40.0%             |                  | Auto             |                     |                |                              |               |                 |              |
|               |                   |                   |                           |                | 45.0%                      |                  | J                |                     |                |                              |               |                 |              |
|               | Start the T       | Funing Process    | 5                         |                | 50.0%                      |                  |                  |                     |                |                              |               |                 |              |
|               |                   |                   |                           |                |                            |                  |                  |                     |                |                              |               |                 |              |
|               |                   |                   |                           |                |                            |                  |                  |                     |                |                              | Cancel        | <u>H</u> elp    |              |
| -             |                   |                   |                           |                |                            |                  | CTSU1            |                     |                |                              |               |                 |              |
| Automa        | itic Tuning Pr    | rocessing         |                           |                |                            |                  | 5.00             |                     |                |                              |               |                 |              |
|               |                   | ues for eac       | h methor                  | l / touch i    | nterface                   |                  |                  |                     |                |                              |               |                 |              |
|               |                   | values inadvert   |                           |                |                            |                  | o poor turir -   | eculte              |                |                              |               |                 |              |
|               | Capacitance       |                   |                           | Offset Tuning  |                            |                  |                  |                     | itnut Select   | Transmit Powe                | ludament T    | (De             |              |
|               |                   | tance method      |                           | Auto           |                            |                  | v Auto           | red 15 Pill Ot      |                |                              | VMM           | v<br>v          |              |
|               |                   |                   |                           | Auto<br>10.0%  |                            |                  |                  |                     |                |                              |               |                 |              |
|               |                   | Aeasurement       | Multiplicat o<br>64       | 15.0%<br>20.0% | on F                       | Ratio 2 Mu<br>73 | ultiplication Ra |                     |                | age Setting                  |               |                 |              |
| System 3      | 3 Frequencies     | j                 |                           | 25.0%<br>30.0% |                            | /3               |                  | Norm                | al voltage     |                              |               |                 |              |
| Method        | Kind              | Name              | <b>T</b> 1 0              | 35.0%<br>37.5% | Se                         | nsor Drive F     | Pulse Frequenc   | y                   |                |                              |               |                 |              |
| config01      | Button(self)      | Button00          |                           | 40.0%<br>45.0% | Au                         | ıto              |                  |                     |                |                              |               |                 |              |
|               |                   |                   | (                         | 50.0%          |                            |                  |                  |                     |                |                              |               |                 |              |
| Start the Tu  | uning Proces      | 5                 |                           |                |                            |                  |                  |                     |                |                              |               |                 |              |
|               |                   |                   |                           |                |                            |                  |                  |                     |                |                              | E             | Cancel          | <u>H</u> elp |
|               |                   |                   |                           |                |                            |                  | OTOUC            |                     |                |                              |               |                 |              |
|               |                   |                   |                           |                |                            |                  | CTSU2            |                     |                |                              |               |                 |              |
| Automati      | c Tuning Proce    | ssing             |                           |                |                            |                  |                  |                     |                |                              |               |                 |              |
| elect sett    | ing values        | s for each m      | nethod / to               | uch interfac   | e.                         |                  |                  |                     |                |                              |               |                 |              |
| 🛕 lf you wil  | ll set these valu | ues inadvertently | or without clear          | understanding, | it could lead t            | o poor tuning    | g results.       |                     |                |                              |               |                 |              |
|               | Capacitance Typ   |                   | eld Pin 🌖 To<br>ne Hardwa |                | Offset Tur<br>Auto         | ning Target      |                  | Non-measure<br>Auto | d TS Pin Outpu | it Select Transmit<br>v Auto | Power Judgme  | nt Type         |              |
| contigui S    | en-Capacitano     | ce method Nor     | ne nardwa                 |                | Auto                       |                  | - 10 V           | Auto                |                | ✓ Auto                       | * JIVIIVI     | ¥               |              |
| M             | ulti-clock Mea    | surement Mult     | iplication Ratio          |                | 10.0%<br>R 15.0%           | F                |                  |                     | prrection Mu   | lti-clock Correctior         | Measurement   | Voltage Setting |              |
| System 3 F    | requencies        | 48                |                           | 41             | 20.0%<br>25.0%<br>30.0%    | -                | Hardwa           | re                  | Sof            | tware                        | Normal voltag | e               |              |
| Method K      | (ind t            | Name Touch        | Sensor Meas               | urement Time   | 30.0%<br>35.0%<br>et 37.5% | r                |                  |                     |                |                              | 1             |                 |              |
|               |                   | Button00 TS00     | Auto                      |                | Au 40.0%<br>45.0%          |                  |                  |                     |                |                              |               |                 |              |
|               |                   |                   |                           |                | 45.0%<br>50.0%             |                  |                  |                     |                |                              |               |                 |              |
|               | ning Process      |                   |                           |                |                            |                  |                  |                     |                |                              |               |                 |              |
| Start the Tur |                   |                   |                           |                |                            |                  |                  |                     |                |                              |               |                 |              |
| Start the Tur |                   |                   |                           |                |                            |                  |                  |                     |                |                              |               | Cancel          | Help         |

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



# 3.2.1 Effects on Offset Tuning Target and Measurement Count Change on Measurement Value

The measured value changes depending on the measurement count. If the measurement count is set to twice the default setting, the measured value also doubles.

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%.

CTSU2:

When using VMM:

Measurement Voltage Setting: Normal Voltage

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

Note: 30720 is the value when the offset tuning target is 100% at the measurement time of 256  $\mu s.$ 

Measurement Voltage Setting: Low Voltage

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

Note: 24576 is the value when the offset tuning target is 100% at the measurement time of 256  $\mu s.$ 

When using JMM:

Measurement Voltage Setting: Normal Voltage

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

Note: 15360 is the value when the offset tuning target is 100% at the measurement time of 128  $\mu s.$ 

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  $\mu$ s.



Indicates the measured value (theoretical value) at touch OFF when VMM is used with respect to the setting of the offset tuning target when the measurement count in Table 3-11 and Figure 3-7 show CTSU2/CTSU2x is changed.

Table 3-11 Measurement values for "Offset Tuning Target " when the measurement count is changed (theoretical values)

| Offset Tuning Target | Target value when using<br>VMM* | Measured value (theoretica used in touch OFF* | l value) when VMM is  |
|----------------------|---------------------------------|---|-----------------------|
|                      | VIVIVI                          | Measurement Count: 8 (default)                | Measurement Count: 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 value (theoretical value) with respect to "Offset Tuning Target" when the Measurement Count is changed

Changing the Offset Tuning Target may cause the count value to overflow. Set the target value and the measurement time so that the measurement value at the maximum capacitance-added state\* assumed when the system (product) is operating falls within the good range of output linearity characteristics of the current-controlled oscillator (CCO). 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 3-7.

If the measurement value differs from the expected value, refer to Table 3-11 to set the offset tuning target. Set the offset tuning taeget 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 sensitivity 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.

Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide (R30AN0424)

"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. 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 1.6V) is shown below.

| ρFQ | 10 | 12        | 15 | 18 | 22 | 27 | 33 | 39  | 47 | 56 | 68 | 82  | 100   | 150 | 200 | 220 | 240 | 270 | 300 | 330 | 360 | 390 | 430 | 470 | 510 | 560 | 620 | 680 | 750 | 820 | 910 | 1000 |
|-----|----|-----------|----|----|----|----|----|-----|----|----|----|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 10  | -  | <b>4M</b> | Hz |    |    | -  |    |     |    |    |    |     |       | ·   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 12  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 15  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 22  |    |           |    |    |    |    | 21 | /Hz |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 22  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 33  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 39  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 42  |    |           |    |    |    |    |    |     |    |    |    | 1.0 | ИНz   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 47  |    |           |    |    |    |    |    |     |    |    |    | -11 | VITIZ |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 51  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 56  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 62  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 68  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     | •   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 75  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     | υ.  | 5MF | 12  |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 91  |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |
| 100 |    |           |    |    |    |    |    |     |    |    |    |     |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |

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 1.18V) 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.

| pF_Q     | 10 1 | 2 15 | 18 | 22 | 27 | 33  | 39  | 47  | 56 | 68 | 82 | 100 | 150 | 200 | 220 | 240 | 270 | 300 | 330 | 360 | 390 | 430 | 470 | 510 | 560 | 620 | 680 | 750 | 820 | 910 1 | .000 |
|----------|------|------|----|----|----|-----|-----|-----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|------|
| 10       | 3.7  | 75МН | z  |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 15       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 18       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 27       |      |      |    |    |    | 1.8 | 75N | IHz |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 33       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 42       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 47       |      |      |    |    |    |     |     |     |    |    | 1N | IHz |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 51<br>56 |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 62       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 68<br>75 |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 82       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     | 0.5 | 5МН | Z   |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 91       |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     | -   |     |     |     |     |     |     |     |     |     |     |     |       |      |
| 100      |      |      |    |    |    |     |     |     |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |      |

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



Figure 3-10 shows the relation between the parasitic capacitance/damping resistor of RX140 and the Sensor Drive Pulse Frequency. A typical example of CTSU2/CTSU2x is shown below.

| ρF_Q     | 10 | 12  | 15 | 18 | 22 | 27 | 33 | 39  | 47 | 56 | 68 | 82 | 100 | 150 | 200 | 220 | 240 | 270 | 300 | 330 | 360 | 390 | 430 | 470 | 510 | 560 | 620 | 680 | 750 | 820 | 910 1 | 000 |
|----------|----|-----|----|----|----|----|----|-----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|-----|
| 10       |    |     |    |    | ł  |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 12       |    | 4МН | z  |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 15       |    |     | -  |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 18       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 27       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 33       |    |     |    |    |    |    | 21 | 1Hz |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 39       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 42       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 47       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 51<br>56 |    |     |    |    |    |    |    |     |    |    |    | 1N | /Hz |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 62       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 68       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 75       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 82       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     | 0.5 | бМН | z   |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 91       |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     | _   |     |     |     |     |     |     |     |     |     |     |     |       |     |
| 100      |    |     |    |    |    |    |    |     |    |    |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |       |     |

Figure 3-10 Parasitic capacitance/damping resistance of RX140 (receiving electrode 1.5V) vs. Sensor Drive Pulse 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. In Auto-tuning sets the optimum frequency where no measurement error occurs.

In addition, in CTSU2/CTSU2x, the frequency set in "Sensor Drive Pulse Frequency" is determined as the 1st frequency in Multi-clock Measurement. Please refer to 3.7 Judgment Type/Multi-clock Measurement/Multiplication Ratio for the setting method of the 2nd/3rd Frequency.



Figure 3-11 shows a window example for setting "Base Clock Frequency/Sensor Drive Pulse Frequency" with "Advanced mode".

|             |                          | atic Tuning P  |                      |                |  |                            |                   |                                |                       |                      |           |              |
|-------------|--------------------------|----------------|----------------------|----------------|--|----------------------------|-------------------|--------------------------------|-----------------------|----------------------|-----------|--------------|
|             | Select se                | etting valu    | ues for ead          | ch metho       | d / touch int  | erface.                    |                   |                                |                       |                      |           |              |
|             | 🔺 lf you                 | will set these | values inadver       | tently or with | iout clear understa  | nding, it coul             | d lead to po      | oor tuning resul               | ts.                   |                      |           |              |
|             | Method                   | Capacitanc     | е Туре               | Shield Pin     | Offset Tuning Ta   | rget Transn                | nit Power         |                                |                       |                      |           |              |
|             | config01                 |                | tance method         | None           | Auto   | Auto                       |                   |                                |                       |                      |           |              |
|             |                          |                |                      |                |  |                            |                   |                                |                       |                      |           |              |
|             | Method                   | Kind           | Name                 | Touch Senso    | r Measurement (  | Count Base                 | Clock Frequ       | uency                          |                       |                      |           |              |
|             | config01                 | Button(self)   | ) Button00           | TS00           | Auto   | N Auto                     |                   | ~                              | _                     |                      |           |              |
|             |                          |                |                      |                |  | Auto                       | ating clock       | divided by 2                   | •                     |                      |           | _            |
|             | Ctart the T              | Tuning Proces  |                      |                |  | Oper                       | ating clock       | divided by 4                   |                       |                      |           |              |
|             | start the                | uning Proces   | 5                    |                |  | Oper                       | ating clock       | divided by 6<br>divided by 8   |                       |                      |           |              |
|             |                          |                |                      |                |  |                            |                   | divided by 10<br>divided by 12 |                       | Cancel               | Help      |              |
|             |                          |                |                      |                |  |                            |                   | divided by 12                  |                       | Cancel               | Пер       |              |
|             |                          |                |                      |                |  | CTS                        | 111               |                                |                       |                      |           |              |
|             |                          |                |                      |                |  | 013                        | 51                |                                |                       |                      |           |              |
| 🔄 Auto      | matic Tuning Pr          | ocessing       |                      |                |  |                            |                   |                                |                       |                      |           |              |
| Select      | setting valu             | les for eac    | ch method            | / touch i      | nterface.  |                            |                   |                                |                       |                      |           |              |
| 🔺 If yo     | u will set these         | values inadver | tently or witho      | ut clear under | standing, it could le  | ad to poor tu              | ning results.     |                                |                       |                      |           |              |
| Method      | d Capacitance            | : Туре         | Shield Pin           | Offset Tuning  | Target Current Ra  | ange Non-r                 | neasured TS       | Pin Output Sele                | ct Transmit Pow       |                      |           |              |
| config0     | 1 Self-Capacit           | ance method    | None                 | Auto           | Auto   | Auto                       |                   |                                | Auto                  | VMM                  |           |              |
|             | Multi-clock N            | Acocurament    | Multiplication       | Patia 1 M      | Itiplication Ratio 2   | Multiplicatio              | on Patio 2        | Measurement V                  | oltago Sotting        |                      |           |              |
| System      | 3 Frequencies            |                | 64                   | 55             | intiplication Natio 2  | 73                         |                   | Normal voltage                 |                       |                      |           |              |
|             |                          |                |                      |                |  |                            |                   |                                |                       |                      |           |              |
| Method      |                          |                | Touch Sensor         | Measureme      | nt Time Sensor Dr  | ive Pulse Freq             | luency            |                                |                       |                      |           |              |
| config0     | 1 Button(self)           | Button00       | TS00                 | Auto           | Auto   |                            | ~                 |                                |                       |                      |           |              |
|             |                          |                |                      |                | SUCLK div<br>SUCLK div   | ided by 4                  |                   |                                |                       |                      |           |              |
| Start the   | e Tuning Proces          | 5              |                      |                | SUCLK div<br>SUCLK div   | ided by 8                  |                   |                                |                       |                      |           |              |
|             |                          |                |                      |                | SUCLK div  | rided by 10<br>rided by 12 |                   |                                |                       | C                    | ancel     | Help         |
|             |                          |                |                      |                | SUCLK div  | rided by 14                |                   |                                |                       |                      |           |              |
|             |                          |                |                      |                |  | CTS                        | U2                |                                |                       |                      |           |              |
| Autom       | atic Tuning Proces       | ssing          |                      |                |  |                            |                   |                                |                       |                      |           |              |
|             | -                        | -              | othed (tou           | ch interfac    |  |                            |                   |                                |                       |                      |           |              |
|             | etting values            |                |                      |                |  |                            |                   |                                |                       |                      |           |              |
|             | 1                        | -              |                      |                | it could lead to poor tu   | -                          |                   |                                |                       |                      |           |              |
|             | Capacitance Typ          |                |                      | ich Judgment   | Offset Tuning Targ   | et Current Ra<br>Auto      | nge Non-m<br>Auto | easured TS Pin Out             | put Select Transmi    | t Power Judgment Typ | e         |              |
| coningor    | Self-Capacitance         | emethod Nor    | ie narowai           | e              | Auto   | Auto                       | Auto              |                                | Auto                  | JIVIIVI              |           |              |
|             | Multi-clock Meas         | urement Mult   | iplication Ratio 1   | Multiplication | n Ratio 2 Multiplicati   | on Ratio 3 CC              | O Characteris     | stics Correction               | Aulti-clock Correctio | n Measurement Voltag | e Setting |              |
| System      | 3 Frequencies            | 48             |                      | 41             | 55   | Ha                         | ardware           | 5                              | oftware               | Normal voltage       |           |              |
|             |                          |                |                      |                |  |                            |                   |                                |                       |                      |           |              |
| Method      | Kind N<br>Button(self) B |                | Sensor Measu<br>Auto |                | Sensor Drive Pulse Free<br>Auto                                  | quency                     |                   |                                |                       |                      |           |              |
| conngol     | Dutton(Sell) D           | 1300           | 1000                 |                | Auto   | ^                          |                   |                                |                       |                      |           |              |
|             |                          |                |                      |                | SUCLK divided by 2<br>SUCLK divided by 4                         |                            |                   |                                |                       |                      |           |              |
|             |                          |                |                      |                | SUCLK divided by 6   |                            |                   |                                |                       |                      |           |              |
| Start the 1 | Funing Process           |                |                      |                | SUCLK divided by 8   |                            |                   |                                |                       |                      |           |              |
| Start the T | Funing Process           |                |                      |                | SUCLK divided by 8<br>SUCLK divided by 10<br>SUCLK divided by 12 |                            |                   |                                |                       | Г                    | Cancel    | <u>H</u> elp |

Figure 3-11 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.

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



#### 3.3.1 Effects on Sensitivity by Changing Base Clock Frequency/Sensor Drive Pulse Frequency

Table 3-12 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 3-12 Measurement values when Sensor Drive Pulse Frequency is changed (actual measurement example)

| Capacitan                          | ce Touch Evaluation       | n System with CTSU          | 2x(RX140)  |                                     |             |
|------------------------------------|---------------------------|-----------------------------|--|-------------------------------------|-------------|
| Self-capacitance                   | ce method, VMM method, M  | easurement Count: 8, Currer | t Range: 40μΑ, Offset Tuning                             | Target: 37.5% (averaged             | five times) |
| Sensor Drive<br>Pulse<br>Frequency | Avg. at touch<br>OFF<br>A | Avg. at touch<br>ON<br>B    | Signal value<br>(Difference of touch<br>ON/OFF)<br>B - A | Avg. at touch<br>OFF<br>Noise value | SNR         |
| 4MHz                               | 11674                     | 15322                       | 3648   | 26.1                                | 23.29       |
| 2MHz                               | 11540                     | 13376                       | 1836   | 17.7                                | 16.22       |
| 1MHz                               | 11580                     | 12513                       | 932  | 13                                  | 11.29       |
| 0.5MHz                             | 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 the 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. If the frequency is increased forcibly when the parasitic capacitance is large, a measurement error may occur.

Figure 3-12 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 3-12 Image of CTSU measurement

When set to 0.5MHz, 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.

In addition, considering that the charge/discharge times should be sufficiently secured, set Base Clock Frequency/Sensor Drive Pulse Frequency to be less than 4MHz.

Please adjust Base Clock Frequency/Sensor Drive Pulse Frequency after sufficiently evaluating it in accordance with the specifications required by the user.



#### 3.3.2 How to adjust the Base Clock Frequency/Sensor Drive Pulse Frequency using Advanced Mode

Automatic 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, 4MHz, 2MHz, 1MHz, 0.5MHz by the parasitic capacitance, 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 3-13 shows the relation between parasitic capacitance and SDPA when a damping resistor of 560  $\Omega$  is used in RX130 that is CTSU1.



Figure 3-13 Parasitic capacitance that can be measured when RX130 is used

When the parasitic capacitance is 30pF and the operating clocks (CTSUCLK) are 32MHz, the optimal SDPA is 11. Base Clock Frequency is calculated by the following formula. Base Clock Frequency = CTSUCLK / ((SDPA + 1) × 2)

When the operating clock (CTSUCLK) is 32MHz and SDPA is 11, Base Clock Frequency is as follows. Base Clock Frequency:  $32[MHz] / ((11 + 1) \times 2) = 1.333MHz$ 

In RX130, the measurement time is set to be 526µs 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 3-14 shows the relation between SDPA and the measurement count when the operating clock 32MHz is used when the value is set to around 526µs.



Figure 3-14 SDPA and Measurement Count when 526µs equivalent Measurement Times are set when RX130 (operation clock 32MHz) is used

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



Figure 3-15 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  $\Omega$  is used.



Figure 3-15 Parasitic capacitance that can be measured when RX140 is used

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

**Note:** SUCLK = STCLK[0.5MHz] × 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 [MHz] / 2) / (9 + 1) = 1.6MHz Sensor Drive Pulse Frequency (multiplied by 55) : (27.5[MHz] / 2) / (9 + 1) = 1.38MHz Sensor Drive Pulse Frequency (multiplied by 73) : (36.5[MHz] / 2) / (9 + 1) = 1.83MHz

Please adjust after sufficiently evaluating it in accordance with the specifications required by the user.



### 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 sensitivity. 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 (Cp + Cf) 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.

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A current IOUT proportional to CCO is applied to the current 11 supplied from the measurement VDC through the current mirror. Set the power supply capability from VDC and the current mirror ratio is automatically determined according to the setting. Increasing the current range increases the current 11 supplied from VDC for measurement.

Figure 3-16 shows an image of the measurement when using normal current (40 µA).



Figure 3-16 Measurement image when normal current (40µA) is used

Table 3-13 shows the default settings.

Table 3-13 Default "Current Range" settings

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

In addition to the defaults, CTSU2/CTSU2x can be set to low current (20µA) or very high current (160µA).



Figure 3-17 shows an example window for setting "Current Range" with "Advanced mode".

| config01                                   | Capacitance<br>Self-Capacita  | •••  |   | Offset Tuning<br>Auto                  | Target Current F  | Range Non-measured   |                                     |                              | Judgment Type<br>VMM ✓ |       |              |
|--|---|--|---|--|---|--|-------------------------------------|------------------------------|------------------------|-------|--------------|
| System                                     | Multi-clock M<br>3 Frequencies  |  | Multiplication<br>64  | Ratio 1 Mul<br>55                      | Itiplica i Normal o<br>High-cur                             | ent output(20uA)<br>output(40uA)<br>rent output(80uA)<br>current output(160uA) | Neasurement Volta<br>Vormal voltage | ge Setting                   |                        |       |              |
| Method<br>config01                         | Kind<br>Button(self)  | Name<br>Button00                                     | Touch Sensor<br>TS00  | Measuremer<br>Auto                     | nt Time Sensor D<br>Auto                                    | Drive Pulse Frequency  |                                     |                              |                        |       |              |
|  |   |  |   |  |   |  |                                     |                              | Ca                     | incel | <u>H</u> elp |
|  | tic Tuning Proces   | -  | method / tou  | ich interface                          | e.  | CTSU2  |                                     |                              | Ca                     | ncel  | <u>H</u> elp |
| elect se<br>If you v<br>Method             | tting values  | for each r<br>es inadvertentl<br>e Sh                | ly or without clear<br>nield Pin 🚺 To                                   | understanding, i<br>uch Judgment       | ie.<br>it could lead to poor<br>Offset Tuning Tar<br>v Auto | tuning results.<br>get Current Range No<br>Auto - Aut<br>Auto - Aut            |                                     | Select Transmit I<br>v Auto  | Yower Judgment Type    |       | <u>H</u> elp |
| elect se<br>If you v<br>Method<br>config01 | tting values<br>vill set these value<br>Capacitance Typ<br>Self-Capacitance | for each r<br>es inadvertentl<br>e Sh<br>e method No | ly or without clear<br>nield Pin<br>one Hardwa<br>ultiplication Ratio 1 | understanding, i<br>uch Judgment<br>re | it could lead to poor                                       | tuning results.<br>get Current Range No<br>Auto - Aut<br>Low-current output(   | 0uA)<br>ion Mult<br>80uA) Soft      | ✓ Auto<br>i-clock Correction | lower Judgment Type    |       | <u>H</u> elp |

Figure 3-17 Setting of "Current Range"

The setting is reflected in the qe\_touch\_config.c. Normal current (40µA) 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 Sensitivity by Changing the Current Range

Table 3-14 shows the measurement values (actual measurement examples) when RX140 mounted capacitance touch evaluation system is used when the Current Range is changed.

Table 3-14 Measurement values when the Current Range is changed (actual measurement example)

| Capacitance                                 | Fouch Evaluati            | on System with CTS          | J2x(RX140)   |                                     |        |
|---|---------------------------|-----------------------------|--|-------------------------------------|--------|
| Self-capacitance me<br>(averaged five times |                           | Sensor Drive Pulse Frequenc | y: 2MHz, Measurement Coun                                | t: 8, Offset Tuning Target: 3       | 37.5%  |
| Current Range                               | Avg. at touch<br>OFF<br>A | Avg. at touch<br>ON<br>B    | Signal value<br>(Difference of touch<br>ON/OFF)<br>B - A | Avg. at touch<br>OFF<br>Noise value | SNR    |
| 20µA  | 11653                     | 15508                       | 3855   | 38.32                               | 16.216 |
| 40µA  | 11566                     | 13513                       | 1947   | 16.96                               | 17.672 |
| 80µA  | 11513                     | 12484                       | 970  | 11.46                               | 14.288 |
| 160µA                                       | 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 the 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-mode 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 3-18 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 ( $40\mu$ A) / very high current ( $160\mu$ A) when the Sensor Drive Pulse Frequency is 2MHz and an electrode with a parasitic capacitance of approximately 18.8pF is used. current I2 supplied from the current (DAC) and the current value lout flowing in the CCO are shown below.



Figure 3-18 Current value when the offset tuning taeget and current range are changed

The current flowing through the CCO is  $2.5 \sim 20\mu$ A, and  $20\mu$ A flows when the offset tuning target is 100%. When the normal current (40µA) is used, 11 = approx. 15µA, 12 = approx. 41µA when the offset-tuning target is 37.5%. The current IOUT flowing through CCO is determined by the current mirror rate with the current 11 supplied from VDC for measurement and is therefore calculated as IOUT = 11 / 2 = 7.5µA.

When high current (160 $\mu$ A) is used, I1 = approx. 56 $\mu$ A, I2 = 0 $\mu$ A 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, IOUT = I1/8 is approximately 7 $\mu$ A.

If the current mode 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 user's required specifications.

#### 3.5 Non-measured TS Pin Output Select

The setting of "Non-measured TS Pin Output Select" can be changed only with CTSU2/CTSU2x.

In "Non-measured TS Pin Output Select", the processing of non-measurement pins other than the measurement pins during the measurement period is set for each method.

Noise suppression is possible by appropriately processing non-measurement pins. It is recommended to set TS pin which is not measured to GPIO Low output for noise-suppression. To shield the external influence while suppressing the increase of the parasitic capacitance when using the active shield, set the non-measurement pin to the common-mode pulse output which is the setting to output the shield signal in the same phase as the sensor drive pulse during the measurement period. Table 3-15 shows the default settings.

Table 3-15 Default "Non-measured TS Pin Output Select" setting.

|              | When self-capacitance method is used | When using mutual capacitance method | When using active shield  |
|--------------|--------------------------------------|--------------------------------------|---|
| CTSU2/CTSU2x | Output low thorough GPIO             | Output low thorough GPIO             | Same phase pulse output as transmission channel through the power setting |

Figure 3-20 shows an image of TS pin measurement in a touch interface configuration as shown in Figure 3-19. 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 3-19 Example touch interface configuration



Figure 3-20 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 (CTSU2L) Operation Explanation Rev.1.00 (R01AN5744)



Table 3-16 shows an overview of each process setting.

#### Table 3-16 Overview of processing settings

| Non-measured TS Pin Output Select setting                                    | Overview   |
|--|--|
| Output low thorough 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<br>channel through the power setting | This setting outputs a shield signal in phase with the sensor drive pulse from the non-measurement<br>pin during the measurement period. |

## Figure 3-21 shows an example window for setting "Non-measured TS Pin Output Select" with "Advanced mode".

|  | Capacitano  | се Туре   | Shield   | Pin Offset Tu   | ning Target  | Current Ra                      | nge Nor   | n-measure  | ed TS Pin Output S  | Select Tran           | ismit Powe               | Judgm              | ent Type            |   |              |
|--|---|---|--|---|--|---------------------------------|---|--|---|-----------------------|--------------------------|--------------------|---------------------|---|--------------|
| config01   | 1 Self-Capac  | itance meth   | od None  | Auto  | ¥ 4  | Auto                            | ✓ Auto<br>Auto  |  |   | ✓ Aut                 |                          | VMM                | ~                   |   |              |
| System   | Multi-clock<br>3 Frequencie   | Measuremer<br>es  | nt Multipl<br>64   | lication Ratio 1  | Multiplicatio  | on Ratio 2                      | Out<br>MutHi-Z  | tput low th<br>Z<br>tput low th                      | nrough GPIO<br>nrough the power<br>oulse output as tra            |                       |                          |                    | ower setting        | J |              |
| Method<br>config01                                     |   | Name<br>f) Button00   | Touch Se<br>0 TS00                                       | ensor Measure<br>Auto   | ement Time   | Sensor Driv<br>Auto             | ve Pulse Fr   | Frequency  |   |                       |                          |                    |                     |   |              |
|  |   |   |  |   |  |                                 | CTS   | SU2  |   |                       |                          |                    | Cance               | 2 | <u>H</u> elp |
| elect se   | 9   | es for each   |  | / touch inter   |  | 3d to poor tur                  | _   | SU2  |   |                       |                          |                    | Cance               |   | <u>H</u> elp |
| elect set  | etting value  | es for each   |  | it clear understand   | ing, it could lea  | ad to poor tur<br>Tuning Target | ning results.   | s.   | on-measured TS Pin  | Output Selec          | t Transmit F             | ower Jud           | Cance<br>gment Type |   | Help         |
| elect set<br>1 If you w<br>Method                      | etting value  | es for each<br>lues inadverter  | ntly or withou<br>Shield Pin                             | it clear understand   | ing, it could lea  | Tuning Target                   | ning results.   | s.<br>t Range No<br>Aut                              | uto<br>uto  |                       | t Transmit F<br>✓ Auto   | Power Jud<br>V JMN | gment Type          |   | <u>H</u> elp |
| elect set<br>If you w<br>Method<br>config01            | etting value<br>will set these val<br>Capacitance Ty<br>Self-Capacitar                                    | es for each<br>lues inadverter<br>Type 9<br>nce method 1<br>asurement M | ntly or withou<br>Shield Pin<br>None H                   | t clear understand  | ing, it could lea<br>ent Offset<br>V Auto                  | Tuning Target                   | ning results.<br>tt Current I<br>v Auto<br>on Ratio 3 | s.<br>t Range No<br>Aut<br>CCO ( Hi-<br>Uardio - Our | uto<br>uto<br>utput low through Gl                                | PIO<br>ne power setti | ✓ Auto<br>ng (prohibite) | y JMN              | gment Type<br>1 V   |   | Help         |
| A lf you w<br>Method<br>config01<br>System 3<br>Method | etting value<br>will set these val<br>Capacitance T<br>Self-Capacitar<br>Multi-clock Med<br>3 Frequencies | es for each<br>lues inadverter<br>5ype s<br>asurement A<br>4<br>Name To | ntly or withou<br>Shield Pin<br>None H<br>Aultiplication | t clear understand<br>Touch Judgmo<br>lardware<br>Ratio 1 Multiplic | ing, it could lea<br>ent Offset<br>V Auto<br>ation Ratio 2 | Tuning Target<br>Multiplicatio  | ning results.<br>tt Current<br>v Auto                 | s.<br>t Range No<br>Aut<br>CCO ( Hi-<br>Uardio - Our | uto<br>uto<br>utput low through Gl<br>i-Z<br>utput low through th | PIO<br>ne power setti | ✓ Auto<br>ng (prohibite) | y JMN              | gment Type<br>1 V   |   | <u>Н</u> еір |

Figure 3-21 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.

.posel = 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.

This value uses the default setting and should not be changed. For details, please refer to the following document.

RL78 Family Capacitive Touch Sensing Unit (CTSU2L) Operation Explanation Rev.1.00 (R01AN5744)

Table 3-17 lists the default settings.

#### Table 3-17 Default "Transmit Power" settings

|              | When self-capacitance method is used | When using mutual<br>capacitance method | When using active shield                                     |
|--------------|--------------------------------------|---|--|
| CTSU1        | VCC                                  | VCC                                     | -  |
| CTSU2/CTSU2x | VCC                                  | VCC (private)                           | Internal logic power supply (Power supply for active shield) |

Table 3-18 outlines the settings in CTSU1.

#### Table 3-18 Overview of "Transmit Power" settings for CTSU1

|   | Power setting of transmit pin | TXVSEL | Overview   |
|---|-------------------------------|--------|--|
| When self-capacitance<br>method is used | VCC                           | 0      | Only the receive pin is used during measurement and the transmit<br>pin is not used. The receiving pin uses TSCAP power supply.  |
| When using mutual capacitance method    | VCC                           | 0      | The transmission pin is also used during measurement. Sensitivity<br>changes depending on the voltage of the transmission pin. The<br>receiving pin uses TSCAP power supply. |

When using CTSU1, do not set TXVSEL = 1.

Table 3-19 outlines the settings in CTSU2/CTSU2x.

#### Table 3-19 Overview of "Transmit Power" settings for CTSU2/CTSU2x

|                                      | Power setting of transmit pin   | TXVSEL | TXVSEL2 | Overview  |
|--------------------------------------|---|--------|---------|---|
| When self-capacitance method is used | VCC   | 0      | 0       | Only the receive pin is used during measurement and<br>the transmit pin is not used. The receiving pin uses<br>TSCAP power supply.  |
| When using mutual capacitance method | VCC (private)   | 0 / 1  | 1       | The transmission pin is also used during measurement.<br>Sensitivity changes depending on the voltage of the<br>transmission pin. The receiving pin uses TSCAP power<br>supply.   |
| When using active shield             | Internal logic power supply<br>(Power supply for active shield)<br>RX,RA:VCL<br>RL:REGC | 1      | 0       | The transmit pin is used for the output of the shield<br>pulse. It can act as a shield by outputting pulses of the<br>same phase and potential as the receiving pin from the<br>transmitting pin. The receiving pin uses TSCAP power<br>supply. |

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

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Figure 3-22 shows an example window for setting "Transmit Power" with "Advanced mode".

|  | Select se  | etting valu                             | les for ea               | ch metho             | od / to                            | uch interf                  | ace.                           |                    |                |                     |                   |            |                 |              |
|--|--|---|--------------------------|----------------------|------------------------------------|-----------------------------|--------------------------------|--------------------|----------------|---------------------|-------------------|------------|-----------------|--------------|
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
|  | 🔺 lf you   | will set these                          | values inadve            | tently or wit        | hout clear                         | understandir                | ng, it could lead to           | poor tuning res    | ults.          |                     |                   |            |                 | _            |
|  |  | Capacitance                             |                          |                      |                                    | Tuning Target               |                                |                    |                |                     |                   |            |                 |              |
|  | config01   | Self-Capacit                            | ance method              | None                 | Auto                               |                             | Auto Auto                      | ·                  |                |                     |                   |            |                 | _            |
|  |  |   |                          |                      |                                    |                             | VCC                            |                    |                |                     |                   |            |                 |              |
|  | Method   | Kind                                    | Name                     | Touch Sense          |                                    | urement Cou                 | <u> </u>                       | wer supply         |                |                     |                   |            |                 |              |
|  | config01   | Button(self)                            | Button00                 | TS00                 | Auto                               |                             | Auto                           |                    |                |                     |                   |            |                 | -            |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
|  | Start the T  | funing Proces                           | s                        |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     | Cancel            |            | <u>H</u> elp    |              |
|  |  |   |                          |                      |                                    |                             | OTOUR                          |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             | CTSU1                          |                    |                |                     |                   |            |                 |              |
| 🗿 Auto   | matic Tuning Pi  | ocessing                                |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
| elect  | setting valu   | les for eac                             | h method                 | / touch              | interfa                            | ce.                         |                                |                    |                |                     |                   |            |                 |              |
|  | -  |   |                          |                      |                                    |                             |                                | 14-                |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             | to poor tuning resu            |                    | -              |                     |                   |            |                 |              |
|  | d Capacitance  |   |                          | Offset Tunin<br>Auto |                                    |                             | e Non-measured<br>∨ Auto       | TS Pin Output Se   | elect Transm   |                     | Judgment<br>VMM   | Туре       |                 |              |
| contig   | )1 Self-Capaci   | ance method                             | None                     | Adto                 | ~                                  | Adto                        | Auto                           |                    | Auto           | ~                   | +141141           | *          |                 |              |
|  | Multi-clock N  | leasurement                             | Multiplicatio            | n Ratio 1 M          | lultiplicatio                      | on Ratio 2 M                | Iultiplication Ratio           | Measurement        | Vol a Internal | logic pov           | ver supply (F     | ower sup   | oply for activ  | e shield)    |
| System   | 3 Frequencies  |   | 64                       | 55                   |                                    | 73                          |                                | Normal voltag      | VCCI           | vate)               |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
| Metho  |  |   | Touch Sensor             | Measurem             | ent Time                           |                             | Pulse Frequency                |                    |                |                     |                   |            |                 |              |
| config   | 01 Button(self)  | Button00                                | TS00                     | Auto                 |                                    | Auto                        |                                |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
| Start th   | e Tuning Proces  | s                                       |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             |                                |                    |                |                     |                   | Can        | cel             | <u>H</u> elp |
|  |  |   |                          |                      |                                    |                             | CTSU2                          |                    |                |                     |                   |            |                 |              |
|  |  |   |                          |                      |                                    |                             | 01302                          |                    |                |                     |                   |            |                 |              |
|  | atic Tuning Proce  | sing                                    |                          |                      |                                    |                             |                                |                    |                |                     |                   |            |                 |              |
| Autom  |  | for each m                              | ethod / tou              | ich interfa          | ce.                                |                             |                                |                    |                |                     |                   |            |                 |              |
|  | etting values  |   | or without clear         | understanding        | it could lea                       | d to noor tunin             | a results.                     |                    |                |                     |                   |            |                 |              |
| elect s  |  | inadvertently                           |                          |                      |                                    |                             |                                | measured TC Dia (  | Dutnut Salar   | Transmit D -        | ower Judgm        | ent Time   |                 |              |
| elect s  | will set these valu  |   | ld Dia \Lambda T-        |                      | Unset                              |                             | Current Range Nor              | -measured to Pin C |                | Iransmit Po<br>Auto | v JMM             | ient iype  |                 |              |
| elect s<br>L If you<br>Method                                  | will set these valu<br>Capacitance Typ   | e Shie                                  | ld Pin 🚺 To<br>ie Hardwa | -                    | ✓ Auto                             |                             | Auto v Auto                    |                    |                |                     |                   |            |                 |              |
| elect s<br>L If you<br>Method                                  | will set these valu  | e Shie                                  | -                        | -                    |                                    |                             | Auto v Auto                    |                    |                | Auto                |                   |            |                 |              |
| elect s<br>L If you<br>Method                                  | will set these valu<br>Capacitance Typ   | e Shie<br>e method Non                  | e Hardwa                 | re                   | ✓ Auto                             | ~                           | Auto v Auto                    | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp     | oly (Power | supply for acti | ve shield)   |
| elect so<br>If you<br>Method<br>config01                       | will set these valu<br>Capacitance Typ<br>Self-Capacitanc  | e Shie<br>e method Non                  | e Hardwa                 | re                   | ✓ Auto                             | ~                           |                                | )                  | Multi-cloc (   | /CC                 | ic power supp     | oly (Power | supply for acti | ve shield)   |
| elect so<br>If you<br>Method<br>config01                       | will set these valu<br>Capacitance Typ<br>Self-Capacitanc<br>Multi-clock Meas  | e method Non<br>urement Multi           | e Hardwa                 | Multiplicatio        | ✓ Auto                             | ✓<br>Multiplication I       | Ratio 3 CCO Charac             | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp<br> | bly (Power | supply for acti | ve shield)   |
| elect so<br>If you<br>Method<br>config01<br>System<br>Method   | will set these valu<br>Capacitance Typ<br>Self-Capacitanc<br>Multi-clock Meas<br>3 Frequencies<br>Kind N                   | e method Non urement Multi 48 ame Touch | e Hardwa                 | Multiplication       | ✓ Auto<br>on Ratio 2<br>Sensor Dri | ✓<br>Multiplication I       | Ratio 3 CCO Charac<br>Hardware | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp<br> | bly (Power | supply for acti | ve shield)   |
| elect so<br>If you<br>Method<br>config01<br>System<br>Method   | will set these valu<br>Capacitance Typ<br>Self-Capacitanc<br>Multi-clock Meas<br>3 Frequencies                             | e method Non urement Multi 48 ame Touch | Hardwa                   | Multiplication       | ✓ Auto<br>on Ratio 2               | V<br>Multiplication I<br>55 | Ratio 3 CCO Charac<br>Hardware | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp     | bly (Power | supply for acti | ve shield)   |
| elect so<br>If you<br>Method<br>config01<br>System<br>Method   | will set these valu<br>Capacitance Typ<br>Self-Capacitanc<br>Multi-clock Meas<br>3 Frequencies<br>Kind N                   | e method Non urement Multi 48 ame Touch | e Hardwa                 | Multiplication       | ✓ Auto<br>on Ratio 2<br>Sensor Dri | V<br>Multiplication I<br>55 | Ratio 3 CCO Charac<br>Hardware | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp<br> | oly (Power | supply for acti | ve shield)   |
| elect so<br>Method<br>config01<br>System<br>Method<br>config01 | will set these valu<br>Capacitance Typ<br>Self-Capacitanc<br>Multi-clock Meas<br>3 Frequencies<br>Kind N                   | e method Non urement Multi 48 ame Touch | e Hardwa                 | Multiplication       | ✓ Auto<br>on Ratio 2<br>Sensor Dri | V<br>Multiplication I<br>55 | Ratio 3 CCO Charac<br>Hardware | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp     | bly (Power | supply for acti | ve shield)   |
| elect so<br>Method<br>config01<br>System<br>Method<br>config01 | will set these valu<br>Capacitance Typ<br>Self-Capacitanc<br>Multi-clock Meas<br>3 Frequencies<br>Kind N<br>Button(self) B | e method Non urement Multi 48 ame Touch | e Hardwa                 | Multiplication       | ✓ Auto<br>on Ratio 2<br>Sensor Dri | V<br>Multiplication I<br>55 | Ratio 3 CCO Charac<br>Hardware | )                  | Multi-cloc (   | /CC<br>nternal log  | ic power supp     | bly (Power | supply for acti | ve shield)   |

Figure 3-22 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 used

 txvsel = CTSU\_TXVSEL\_VCC,

Below is a sample of CTSU2/CTSU2x.

- When self-capacitance method is used
  - .txvsel = CTSU\_TXVSEL\_VCC,
  - .txvsel2= CTSU\_TXVSEL\_MODE,
- When mutual capacitance method is used
   . txvsel = CTSU\_TXVSEL\_VCC,
  - .txvsel2= CTSU\_TXVSEL\_VCC\_PRIVATE,
- When active shield is used
   txvsel = CTSU\_TXVSEL\_INTERNAL\_POWER,
  - .txvsel2= CTSU\_TXVSEL\_MODE,



#### 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 frequencies 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 touch judgment method 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. Figure3-23 shows the operation image when VMM is used.



Figure 3-23 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 3-24 shows the operation image when JMM is used.



Figure 3-24 Image of operation when JMM is used

Please refer to the following document for details of the touch judgment method. <u>Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide (R30AN0424)</u>

Table3-20 shows examples of default settings for "Judgment Type" and "Multi-clock Measurement" when buttons are used.

Table3-20 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 3-25.

|         | Multi-clock M  | easurement | Multiplication | Ratio 1 | Multiplication | on Ratio 2 | Multiplication Ratio 3  |
|---------|----------------|------------|----------------|---------|----------------|------------|-------------------------|
| System  | 3 Frequencies  |            | 48             |         | 41             |            | 55                      |
|         |                |            |                |         |                |            |                         |
| Method  | Kind           | Name       | Touch Sensor   | Measur  | ement Time     | Sensor Dri | ive Pulse Frequency     |
| config0 | 1 Button(self) | Button00   | TS00           | 0.128 m | s              | 2.000 MH:  | z, 1.708 MHz, 2.292 MHz |

Figure 3-25 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 3-21 shows the default setting of "Multiplication Ratio" and the lower and upper limits that can be set.

Table 3-21 Default "Multiplication Ratio" settings

| Device               | 1st frequency                      | 2nd frequency                      | 3rd frequency   |
|----------------------|------------------------------------|------------------------------------|---|
|                      | Multiplication Ratio <sup>*1</sup> | Multiplication Ratio <sup>*2</sup> | Multiplication Ratio <sup>*2</sup>                      |
| RL78/G22<br>RL78/G23 | 48                                 | 41 [32~60]                         | Normal Voltage : 55 [32~60]<br>Low Voltage : 46 [32~60] |
| RX260<br>RX261       | 48                                 | 41 [32~64]                         | Normal Voltage : 55 [32~64]<br>Low Voltage : 46 [32~64] |
| Other                | 64                                 | Normal Voltage:55 [32~80]          | Normal Voltage : 73 [32~80]                             |
| Device               |                                    | Low Voltage:55 [32~64]             | Low Voltage : 46 [32~64]                                |

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

Note2: For details on the Measurement Voltage Setting, 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.

## Sensor Drive Pulse Frequency [2nd frequency] = Sensor Drive Pulse Frequency [1st frequency] × Multiplication Ratio [2nd frequency]/Multiplication Ratio [1st frequency]

## Sensor Drive Pulse Frequency [3rd frequency] = Sensor Drive Pulse Frequency [1st frequency] × Multiplication Ratio [3rd frequency]/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 3-26 shows an example window for setting the "Judgment Type/Multi-clock Measurement/Multiplication Ratio" in "Advanced mode".

| config01                                    | Capacitance<br>Self-Capacit                            | 21  | Shield Pin<br>None   | Offset Tuni<br>Auto                    | ng Target   | Current Rar<br>Auto | nge Non-mea<br>Auto                      | ured TS Pin Output Se                                      | lect Transn<br>Auto |                       | udgment Type<br>MM   |              |
|---|--|---|----------------------|--|---|---------------------|--|--|---------------------|-----------------------|----------------------|--------------|
| System                                      | Multi-clock M<br>3 Frequencies                         |   | Multiplicatio<br>64  |  | Multiplicati<br>55                                |                     | Multiplication F<br>73                   | atio 3 Measurement<br>Normal voltag                        | -                   | ing                   |                      |              |
| Method<br>config01                          | Kind<br>Button(self)                                   | Name<br>Button00  | Touch Sensor<br>TS00 | Measurer<br>Auto                       | nent Time   | Sensor Driv<br>Auto | ve Pulse Frequer                         | cy   |                     |                       |                      |              |
|   |  |   |                      |  |   |                     |  |  |                     |                       | Cancel               | <u>H</u> elp |
|   |  |   |                      |  |   |                     | CTSU                                     | 2  |                     |                       |                      |              |
| lect set                                    |  | for each n  | nethod / to          |  |   | ead to poor tur     |  | 2  |                     |                       |                      | ;            |
| elect set<br>If you w<br>Method             | tting values   | for each n<br>es inadvertently<br>be Shi                | y or without clear   | r understandir<br>ouch Judgmer         | ıg, it could le                                   |                     |  |  | Dutput Select       | Transmit Powe<br>Auto | Judgment Type<br>JMM | ;            |
| elect set<br>If you w<br>Method<br>config01 | tting values<br>vill set these valu<br>Capacitance Typ | for each n<br>es inadvertently<br>be Shi<br>e method No | y or without clear   | r understandir<br>ouch Judgmer<br>vare | n <mark>g, it could le</mark><br>nt Offse<br>Auto |                     | ning results.<br>t Current Range<br>Auto | Non-measured TS Pin C<br>Auto<br>haracteristics Correction |                     | Auto<br>Correction Me |                      |              |

Figure 3-26 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 40MHz.

#define CTSU\_CFG\_NUM\_SUMULTI(3)#define CTSU\_CFG\_SUMULTIO(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. Table 3-22 shows the description of each function.

Table3-22 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<br>software. Hardware touch judgment (Auto judgment) is available only<br>for buttons. However, if your microcontroller has a built-in SNOOZE<br>mode sequencer (SMS), you can use this function together with SMS.<br>When SMS is used, only the majority decision mode (JMM) can be<br>used.   |
| CCO Characteristics Correction | This function sets whether CCO characteristics correction is performed<br>by hardware or software. This function is only displayed on<br>CTSU2SL/CTSU2SLa. It cannot be changed by the user because it is<br>automatically set according to "Judgment Type" and "Touch Judgment".  |
| Multi-clock Correction         | This function sets whether multi-clock correction is performed in<br>hardware or software. Multi-clock correction process after 3-frequency<br>measurement and the results of 2 frequencies with close values from<br>the 3-frequency measurement are selected for the final measurement<br>result. Available only when VMM is used. This function is only displayed<br>on CTSU2SL/CTSU2SLa. It cannot be changed by the user because it<br>is automatically set according to "Judgment Type" and "Touch<br>Judgment". |

Figure 3-27 shows the operation image of the functions when VMM is used.



Figure 3-27 Image of operation when VMM is used

Figure 3-28 shows the operation image of the functions when JMM is used. Multi-clock Correction is not available when JMM is used.



Figure 3-28 Image of operation when JMM is used



Table3-23 shows examples of default settings for each function when Touch Judgment is Hardware or Software.

| Table3-23 Default Settings for "CCO Characteristics C | Correction/Multi-clock Correction" |
|---|------------------------------------|
|---|------------------------------------|

| Touch Judgment | CCO Characteristics Correction | Multi-clock Correction                                   |
|----------------|--------------------------------|--|
| Hardware       | Hardware                       | When using VMM: Hardware<br>When JMM is used: Software * |
| Software       | Software                       | Software *   |

Note: Includes when Multi-clock Correction is disabled.

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 3-29 shows the flow for determining the "Touch Judgment/CCO Characteristics Correction/Multi-clock Correction" setting.



Figure 3-29 Flowchart for Determining "Touch Judgment/CCO Characteristics Correction/ Multi-clock Correction"



Figure3-30 shows a window example when setting "Touch Judgment/CCO Characteristics Correction/Multiclock Correction" in Advanced Mode. When the MCU with built-in SMS is used, "SMS" is displayed instead of "Hardware" in " Touch Judgment".

|   | Capacitance<br>Self-Capacita                                       |   | Shield Pin<br>None                       | 1 Touch<br>SMS     | n Judgment                     | Offset<br>Auto                     | Tuning Target                      | Current Range<br>Auto                                     | Non-measured TS Pin O<br>Auto        |                 | ansmit Power<br>uto | Judgment Type<br>JMM  |        |              |
|---|--|---|--|--------------------|--------------------------------|------------------------------------|------------------------------------|---|--------------------------------------|-----------------|---------------------|-----------------------|--------|--------------|
|   | Multi-clock Me<br>3 Frequencies                                    | easurement  | Multiplicatio                            |                    | Multiplicatio<br>41            |                                    | Multiplication<br>55               |   | rement Voltage Setting<br>Il voltage |                 |                     |                       |        |              |
| Method<br>config01                                  | Kind<br>Button(self)   | Name<br>Button00  | Touch Sensor<br>TS00                     | r Measuren<br>Auto |                                | Sensor Driv<br>Auto                | ve Pulse Freque                    | ncy   |                                      |                 |                     |                       |        |              |
| Start the T   | Funing Process   |   |  |                    |                                |                                    | СТЯ                                | 3U2L/C  | TSU2La                               |                 |                     |                       | Cancel | <u>H</u> elp |
| Autom<br>elect se<br>If you<br>Method               | natic Tuning Pro<br>etting valu<br>will set these v<br>Capacitance | ocessing<br>les for ea<br>values inadv                                      | ertently or witl<br>Shield Pin           | hout clear ur      | nderstandin<br>ch Judgmen      | <mark>g, it could</mark><br>t Offs | lead to poor tu<br>et Tuning Targe | ning results.   | ge Non-measured TS Pi                | n Output Select |                     |                       |        | Help ×       |
| Autom<br>elect se<br>If you<br>Method               | natic Tuning Pro<br>etting valu<br>will set these v                | ocessing<br>les for ea<br>values inadv                                      | ertently or witl<br>Shield Pin           | hout clear ur      | nderstandin<br>ch Judgmen      | g, it could                        | lead to poor tu<br>et Tuning Targe | ining results.  |                                      | n Output Select | Transmit Po<br>Auto | wer Judgment 1<br>JMM |        |              |
| Autom<br>elect se<br>I If you<br>Method<br>config01 | natic Tuning Pro<br>etting valu<br>will set these v<br>Capacitance | ocessing<br>les for ea<br>values inadv<br>Type<br>ance metho<br>leasurement | ertently or with<br>Shield Pin<br>d None | hout clear ur      | nderstandin<br>ch Judgmen<br>e | g, it could<br>t Offs<br>Auto      | lead to poor tu<br>et Tuning Targe | ning results.<br>et Current Ran<br>Auto<br>on Ratio 3 CCC | ge Non-measured TS Pi                |                 | Auto                |                       | ype    |              |

Figure3-30 Setting of "Touch Judgment/CCO Characteristics Correction/Multi-clock Correction"

The setting of "Touch Judgment" is reflected in the r\_ctsu\_qe\_config.h. The following is an example when Touch Judgment is 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/CTSU2x.

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 2.4V, "Measurement Voltage Setting" is automatically set to a lower voltage and TSCAP voltage is 1.2V. This function is used when the microcontroller operating voltage becomes less than 2.4V 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 3-24 shows an example of the default settings for "Measurement Voltage Setting" with operating voltage.

Table 3-24 Default Settings for "Measurement Voltage Setting" with Operating Voltage

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

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

Figure 3-31 shows an example window for setting "Measurement Voltage Setting" in Advanced Mode.

| Method<br>config01                         | Capacitano  |   | Shield Pi<br>od None  | n Offset Tu<br>Auto  | ning Target  | Current Range<br>Auto                | e Nor<br>Aut                            |               | red TS Pin                         | Output Selec                               | t Transr<br>Auto | nit Power           | Judgment Ty<br>VMM                                       | pe                    |       |   |             |
|--|---|---|---|--|--|--------------------------------------|---|---------------|------------------------------------|--|------------------|---------------------|--|-----------------------|-------|---|-------------|
| System                                     | Multi-clock<br>3 Frequencie   |   | nt Multiplica<br>64   | ation Ratio 1  | Multiplicat<br>55  | ion Ratio 2 M<br>v 73                |   | ation Rat     | V Nor                              | asurement Vo<br>mal voltage<br>mal voltage | oltage Sett      | ing<br>V            |  |                       |       |   |             |
| Method<br>config01                         |   | Name<br>f) Button00   | Touch Sen<br>0 TS00   | sor Measur<br>Auto   | ement Time   | Sensor Drive A                       | Pulse F                                 | requency      | Lov                                | v voltage                                  |                  |                     |  |                       |       |   |             |
|  |   |   |   |  |  |                                      |   |               |                                    |  |                  |                     |  | Canc                  | el    | H | elp         |
| lect set                                   | vill set these va   | s for each  | -   | lear understan   | ding, it could l   | ead to poor tuning                   | g results                               |               |                                    |  |                  |                     |  |                       | el    | H | elp<br>>    |
| lect set<br>If you w<br>Method             | tting value   | s for each<br>lues inadverter   | ntly or without of Shield Pin   |  | ding, it could l   | t Tuning Target                      | g results                               | s.<br>t Range |                                    | ured TS Pin Out                            | tput Select      | Transmit Po<br>Auto | wer Judgmer<br>JMM                                       |                       | el    | H | 2 <b> p</b> |
| lect set<br>If you w<br>Method<br>config01 | tting value<br>vill set these val<br>Capacitance T<br>Self-Capacitar                                    | is for each<br>lues inadverter<br>ype<br>ince method                    | ntly or without of<br>Shield Pin<br>None Han                            | i <mark>lear understan</mark><br>Touch Judgn<br>rdware           | ding, it could l<br>nent Offse<br>Auto<br>cation Ratio 2 | t Tuning Target                      | g results<br>Current<br>Auto<br>Ratio 3 | 5.<br>t Range | Non-measi<br>Auto<br>aracterístics | Correction 1                               |                  | Auto<br>Correction  | JMM<br>Measurement V<br>Normal voltage<br>Normal voltage | it Type<br>′oltage Se |       | H | 2 <b> p</b> |
| Hect set<br>If you w<br>Method<br>config01 | tting value<br>vill set these val<br>Capacitance T<br>Self-Capacitar<br>Multi-clock Me<br>3 Frequencies | s for each<br>lues inadverter<br>ype<br>acce method<br>asurement A<br>4 | ntly or without of<br>Shield Pin<br>None Hau<br>Multiplication Ra<br>18 | tiear understan<br>Touch Judgn<br>rdware<br>ttio 1 Multipl<br>41 | ding, it could I<br>nent Offse<br>Auto<br>cation Ratio 2 | tt Tuning Target<br>Multiplication F | g results<br>Current<br>Auto<br>Ratio 3 | s.<br>t Range | Non-measi<br>Auto<br>aracterístics | Correction 1                               | /lulti-clock     | Auto<br>Correction  | JMM<br>Measurement V<br>Normal voltage                   | it Type<br>′oltage Se | tting | H | elp         |

Figure 3-31 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: 1.5V) The microcontroller operating voltage 5.0V

#define CTSU\_CFG\_VCC\_MV (5000)

#define CTSU\_CFG\_LOW\_VOLTAGE\_MODE (0)

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

#define CTSU\_CFG\_VCC\_MV (5000)
#define CTSU\_CFG\_LOW\_VOLTAGE\_MODE (1)

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

| #define | CTSU_CFG | _VCC_MV |           | (1800) |  |
|---------|----------|---------|-----------|--------|--|
| #define | CTSU CEG |         | TAGE 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**

|      |           | Description | 1   |
|------|-----------|-------------|---|
| Rev. | Date      | 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   |
|      |           |             | • Judgement Type  |
|      |           |             | • Auto Judgement/Automatic Multi-Frequency Correction   |
|      |           |             | (Hardware)  |
|      |           |             | Low Voltage Operating Mode  |
|      |           | -           | 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  |
|      |           | F 13,20,31  | Capacitive Touch v4.0.0   |
|      |           | P18         | Corrected with offset-tuning target value updated in QE for   |
|      |           | 1.10        | 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.   |



# 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 is supplied until the 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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