

# **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 Taring adjustable parameters
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Parameter	Auto tuning	Manually tuning with CapTouch parameters	Tuning with "Advanced mode"
Base Clock Frequency /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 *	-	-	$\checkmark$
Non-measured TS Pin Output Select *1	-	-	$\checkmark$
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 *1	√*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
adjustment	undi instructed by the QE funning Program.
dujustment	Count
	Automatic Tuning Processing X
Measuring	QL is measuring the parasitic capacitance for all touch sensors. During this measurement process, please do not touch the sensors on the target
parasitic	board.
capacitance	
	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 board.
the offset	Button00, TS00 35329
	Cancel Help
$\sim$	
	CE is now starting sensitivity measurement for each of the touch sensors when not
Measuring	touched.(config01)
sensitivity	During this step, please do not touch the sensors on the target board.
(while not touched)	
	Cancel Help
	Automatic Tuning Processing
· · · · · · · · · · · · · · · · · · ·	QE will now measure touch sensitivity for (Button00, TS00 @ config01).
	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	Button00, TS00 @ config01: 15265
(while touched)	
	Carrol Halo
$\sim$	Automatic Tuning Processing X
$\mathbf{V}$	indicated, those sensors can be retried. If there are continued overflows or
	warning/errors, please consult the Renesas application notes for Capacitive Touch
Deput of	Select the target Method Kind Name Touch Sensor Threshold Overflow Warning / Error
the tuning	config01 Button Button00 TS00 65535
the tuning	
	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	围	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	100 EE	Write to target board in real time	Toggle button to switch whether the numerical value of the parameter is reflected to the target in real time.
4	Ĩ	Generate a parameter file	The parameter file is output based on the parameter information adjusted in this view.

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

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

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.

Method Capacitance Type Shield P config01 Self-Capacitance method None		Shield Pin None	<ol> <li>Touc</li> <li>Hardware</li> </ol>	h Judgment	Offset Auto	Tuning Target	Current Auto	t Range	Non-measured TS Pin C Auto	utput Select	Transmit Po Auto	ower Judgment Type JMM			
System	Multi-clock M 3 Frequencies	leasurement	Multiplicatio 48	n Ratio 1	Multiplicatio	on Ratio 2	Multiplication 55	Ratio 3	CCO Cł Hardwa	haracteristics Correction are	Multi-clock Software	Correction	Measurement Voltage Normal voltage	Setting	
Method config01	Kind Button(self)	Name Button00	Touch Sensor TS00	Measure Auto	ment Time	Sensor Dr 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.

		-							
Table	1-4	Source	files	outout	hv the	"Output	Parameter	Files"	hutton
i ubic	1 -	000100	11100	ouipui	by the	Output	i ulumotor	1 1100	Dutton

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

Supported



#### 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/ Sensor Drive Pulse Frequency	Measurement Count <sup>*1</sup>	Measurement Time [µs]
CTSU1	4 MHz	8	
	2 MHz	4	526
	1 MHz	2	
	0.5 MHz	1	
CTSU2/CTSU2x (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 [µs]	Measurement time [µs]	Total (Stabilization wait time + 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 [µs]	Total (Stabilization wait time + Measurement time) [µs]	
8 [(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".

	Select se	etting valu	es for ead	h method	d / touch inte	erface.							
	🔺 lf you	will set these v	alues inadver	tently or witho	out clear understan	ding, it c	ould lead to p	oor tuning res	ults.				
	Method	Capacitance	Туре	Shield Pin	Offset Tuning Targ	get Tran	smit Power						
	config01	Self-Capacit	ance method	None	Auto	Aut	0						
	Method	Kind	Name	Touch Sensor	Measurement C	ount Ba	se Clock Free	quency					
	config01	Button(self)	Button00	TS00	Auto	~ AL	to	¥					
					1								
	Start the T	uning Process	;		3								
					4 5					_			
					6 7	J					Cancel	<u>H</u> elp	
							0114						
						U	301						
Auton	natic Tuning P	rocessing											
Select s	etting val	ues for eac	h method	/ touch in	nterface.								
🔺 lf you	u will set these	values inadver	ently or witho	ut clear under	standing, it could le	ad to poo	rtuning result	s.					
Method	Capacitanc	е Туре	Shield Pin	Offset Tuning	Target Current Ra	inge No	n-measured 1	S Pin Output S	elect Transr	nit Power	Judgment Type		
config0	1 Self-Capaci	tance method	None	Auto	Auto	Au	to		Auto		VMM		
	Multi-clock I	Aeasurement	Multiplicatio	n Ratio 1 Mu	Itiplication Ratio 2	Multiplic	ation Ratio 3	Measuremen	it Voltage Sett	ing			
System	3 Frequencie	s	64	55		73		Normal volta	ige				
Method	Kind	Name	Touch Sensor	Measuremer	nt Time Sender Dr	ive Dulce F	requency						
config0	1 Button(self)	Button00	TS00	Auto	✓ Auto	incruise i	×						
				Auto (STCLK cycle	* 8) * 1								
Start the	Tuning Proces	is		(STCLK cycle (STCLK cycle	* 8) * 2 * 8) * 3								
				(STCLK cycle	* 8) * 5								
				(STCLK cycle	^ 8) ^ 6 * 8) * 7						C	ancel	<u>H</u> elp
						СТ	SU2						
🖬 Automa	tic Tuning Proce	ssing											
elect se	tting values	for each m	ethod / tou	ch interface	2								
A If your	will set these valu	er inach ertentlig	or without clear	understanding is	t could lead to poor tu	ning results							
Method	Canacitance Tvi	ne Shie	ld Pin 🔒 To	uch ludament	Offset Tuning Targe	t Curren	Range Non-	measured TS Pin	Output Select	Transmit Po	wer ludament Tvr	)e	
config01	Self-Capacitance	e method Non	e Hardwa	re	Auto	Auto	Auto		output select	Auto	JMM		
		1								1			
System	Multi-clock Mea B Frequencies	urement Multi	plication Ratio 1	Multiplication	Ratio 2 Multiplicati	on Ratio 3	CCO Characte	ristics Correction	Multi-clock	Correction	Measurement Voltag	ge Setting	
System :	requencies	40		41			. aruware		Sonware				
Method	Kind M	lame Touch	Sensor Measu	rement Time	Sensor Drive Pulse Free	uency							
config01	Button(self) E	utton00 TS00	Auto Auto	✓ A	Auto	~							
			(STCL)	cycle * 8) * 1 cycle * 8) * 2									
Start the T	uning Process		(STCL)	cycle * 8) * 3									
start the h			- I O I CLI										
start the h			(STCL)	cycle * 8) * 5								Cancel	Hale

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	Self-capacitance method, VMM method, Sensor Drive Pulse Frequency: 2MHz, Current Range: 40µA, button 1ch (averaged five times)						
Measurement count	Offset tuning target	Avg. at touch OFF A	Avg. at touch ON B	Signal value (Difference of touch ON/OFF) B - A	Avg. at touch OFF Noise value	SNR	Stabilization wait time + Measurement 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 with CTSU1(RX130)							
Self-Capacitance System PCI	LKB:32MHz Sensor Drive Pulse I	Frequency: 2MHz Offset Tuning	Target: 37.5% Key 1ch				
Measurement count	Stabilization wait time	Measurement time [µs]	Total (Stable waiting time	Measurement value			
	[µs]		+ Measurement time) [µs]	(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 with CTSU2x(RX140)					
Self-Capacitance System PC	LKB:32MHz Sensor Drive	Pulse Frequency:: 2MHz	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 Voltage	15360 (37.5%)	10240 (25%)	-
CTSU2/ CTSU2x	Value Majority Mode (VMM)	Normal Voltage	11520 (37.5%)	7680 (25%)	4608 (15%)
		Low Voltage	9216 (37.5%)	6144 (25%)	-
	Judgment Majority Mode (JMM)	Normal Voltage	5760 (37.5%)	3840 (25%)	2304 (15%)
		Low Voltage	4608(37.5%)	3072 (25%)	-

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

Offeret Turning Terret	Target value*	Target value*
Onset runing rarget	(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 25.0%								
	Method	Kind	Name	Touch Sense	r 30.0%		: Base Cloc	k Frequency					
	config01	Button(self)	Button00	TS00	37.5%		Auto						
					45.0%		J						
	Start the T	Juning Process	5		50.0%								
											Cancel	<u>H</u> elp	
-							CTSU1						
Automa	tic Tunina Pr	rocessing					5.00						
elect se	tting valu	les for ear	h methor	l / touch i	nterface								
	will set these	values in advert	tently or with	ut clear und-	standing it.	ould lead t	o poor turir -	eculte					
Method	Canacitance		Shield Pip	Offset Tuping	Target	rrent Range	Non-measu	red TS Pip O	itnut Select	Transmit Power	ludament T	(Dē	
config01	Self-Capacit	tance method	None	Auto		o i	v Auto	red 15 Pill Ot	v	Auto	VMM	v v	
				Auto 10.0%									
N Curture 2	Multi-clock N	feasurement	Multiplicat o	15.0% 20.0%	on F	atio 2 Mu	ultiplication Ra	tio 3 Measu	irement Volt	age Setting			
System 3	Frequencies	j	04	25.0% 30.0%		/3		Norm	al voltage				
Method	Kind	Name	Touch Senser	35.0% 37.5%	Se	nsor Drive F	Pulse Frequenc	y					
config01	Button(self)	Button00	TS00	40.0% 45.0%	Au	rto							
			(	50.0%									
Start the Tu	uning Proces	5											
											E	Cancel	<u>H</u> elp
							OTOUC						
							CISU2						
Automati	c Tuning Proce	ssing											
elect sett	ing values	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.						
Method C	apacitance Typ	pe Shie	eld Pin 🕕 To	ouch Judgment	Offset Tur	ing Target	Current Range	Non-measure Auto	d TS Pin Outpu	it Select Transmit	Power Judgme	nt Type	
contigui S	en-Capacitano	e metnoa Nor	ne nardwa		Auto		- 10 V	Auto		✓ Auto	* JIVIIVI	¥	
M	ulti-clock Mea	surement Mult	iplication Ratio	1 Multiplicatio	R 15.0%	F	Ratio 3 CCO Ch	aracteristics Co	prrection Mu	lti-clock Correction	Measurement	Voltage Setting	
System 3 F	requencies	48		41	20.0%	-	Hardwa	re	Sof	tware	Normal voltag	e	
Method K	(ind t	Vame Toucł	Sensor Meas	urement Time	35.0% 35.0%	r					1		
config01 E	utton(self) E	Jutton00 TS00	Auto		40.0%								
					145.0% 50.0%								
	ning Process												
Start the Tur													
Start the Tur													

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	Measured value (theoretic used in touch OFF*	al value) when VMM is
	VIVIIVI	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.

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	1000
10		4	Hz		·									·									·					·				
12																																
15																																
18							21	ЛНт																								
22																																
27																																
33																																
39																																
42												1	ИНz																			
47																																
51																																
56																																
62																																
68																	_															
75																	0.	5MF	z													
82																																
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	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	1000
10	3.	75MF	Iz																												
15			-																												
18																															
27						1.8	75N	IHz																							
33																															
39																															
47											1M	IHz																			
51																															
62																															
68																															
75																0 1	мн	7													
91																0	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	-													
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												1N	1Hz																			
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".

	Select s	etting val	ues for eac	ch metho	d / touch inter	rface.					
	🔥 If you	will set these	values inadver	tently or with	out clear understand	ling, it could le	ad to poor tuning re	sults.			
	Method	Capacitanc	е Туре	Shield Pin	Offset Tuning Targe	et Transmit I	ower				
	config0	Self-Capac	itance method	None	Auto	Auto					
	Method	Kind	Name	Touch Sensor	Measurement Co	ount Base Clo	ock Frequency				
	config0	Button(self	) Button00	TS00	Auto	Auto	¥				
						Operatir	g clock divided by 2				
	Start the	Tuning Proce	55			Operatir Operatir Operatir Operatir Operatir	ig clock divided by 4 ig clock divided by 8 ig clock divided by 8 ig clock divided by 10 ig clock divided by 12 ig clock divided by 14			Cancel	<u>H</u> elp
						CTSU	1				
Autor	matic Tuning P	rocessing									
elect (	setting val	ues for ea	ch method	/ touch i	oterface						
A Ifuo	u will set these	walues inadva	rtently or witho	y couch in	tanding, it could lead	I to poor tunin	a seculte				
Methor	Canacitan	e Type	Shield Pin	Offset Tuning	Target Current Ran	ge Non-mea	sured TS Pin Output S	elect Transn	nit Power In	dament Type	
config0	1 Self-Capac	itance method	None	Auto	Auto	Auto	saled 15 Fill Output 5	Auto	VN	иgment iype ИМ	
							1				
Sustam	Multi-clock	Measurement	Multiplication	Ratio 1 Mu	tiplication Ratio 2	Multiplication I	Ratio 3 Measuremen	t Voltage Setti	ing		
System	STrequencie							90			
Method	I Kind	Name	Touch Sensor	Measuremen	nt Time Sensor Drive	e Pulse Freque	icy				
config0	1 Button(self	) Button00	TS00	Auto	Auto		~				
		_			SUCLK divid	led by 2 led by 4					
Start the	E Tuning Proce	ss			SUCLK divid	led by 6 led by 8					
					SUCLK divid	led by 10 led by 12	J			Canc	el <u>H</u> elp
					SUCLK divid	led by 14					
						CTSU	2				
Autom	atic Tuning Proc	essing									
elect se	etting value	s for each m	nethod / tou	ch interface	e.						
If you	will set these val	ues inadvertently	or without clear	understanding, i	could lead to poor tuni	na results.					
Method	Capacitance Ty	rpe Shi	eld Pin 🕕 Tor	uch Judgment	Offset Tuning Target	Current Range	Non-measured TS Pin	Output Select	Transmit Power	Judgment Type	
config01	Self-Capacitan	ce method No	ne Hardwar	re	Auto	Auto	Auto		Auto	JMM	
1									1		
System	Multi-clock Mea	surement Mult	tiplication Ratio 1	Multiplication	Ratio 2 Multiplication	Ratio 3 CCO C	haracteristics Correction	Multi-clock C	Correction Mea	asurement Voltage Se mal voltage	tting
system	- requencies	40				Tardw		Sortware	1401		
Method	Kind	Name Toucl	h Sensor Measu	rement Tim = 3	ensor Drive Pulse Freque	ency					
config01	Button(self)	Button00 TS00	Auto	× 4	uto	~					
				S	UCLK divided by 2 UCLK divided by 4						
	<b>Funing Process</b>			S	UCLK divided by 6						
Start the I				3	o cert united by o						
Start the I				S	UCLK divided by 10						

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.

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

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



#### 3.3.1 Effects on 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	e method, VMM method, M	leasurement Count: 8, Currer	t Range: 40µA, Offset Tuning	Target: 37.5% (averaged	five times)
Sensor Drive Pulse Frequency	Avg. at touch OFF A	Avg. at touch ON B	Signal value (Difference of touch ON/OFF) B - A	Avg. at touch OFF Noise value	SNR
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".

Method	Capacitance Ty	oe	Shield Pin C	Offset Tuning Tar	get Current Range Non-m	easured TS Ain Output Select	t Transmit Power	Judgment Type	
config01	Self-Capacitanc	e method	None A	iuto	Auto ✓ Auto Auto		v Auto v	VMM ¥	
System	Multi-clock Mea 3 Frequencies	surement M	Vultiplication 34	Ratio 1 Multipl 55	Low-current output(20u lica i Normal output(40uA) High-current output(80u Very high-current output	A) IA) t(160uA)	ltage Setting		
Method config01	Kind N Button(self) E	Name To Sutton00 TS	ouch Sensor	Measurement Ti Auto	ime Sensor Drive Pulse Freq Auto	uency			
Autor	tic Tuning Processie				CTS	U2			
elect se	etting values fo	<sup>9</sup> r each me nadvertently or	thod / touc	ch interface.	ould lead to poor tuning results.				~
				uch Judament	Offset Tuning Target Current Rat	nge Non-measured TS Pin Outr	out Select Transmit Po	wer Judgment Type	
Method config01	Capacitance Type Self-Capacitance m	shield ethod None	Hardware	e v /	Auto Auto	✓ Auto	✓ Auto	✓ JMM ✓	
Method config01 System	Capacitance Type Self-Capacitance m Multi-clock Measure 3 Frequencies	ment Multip	Ication Ratio 1	e v / Multiplication Ra 41	Auto Auto Auto Low-curren tio 2 Multiplicatio S5 Very high-curren Very high-curren	Auto t output(20uA) put(40uA) it output(80uA) urrent output(160uA)	✓ Auto ulti-clock Correction oftware	JMM     V Measurement Voltage Normal voltage	etting

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 To	ouch Evaluatio	on System with CTSI	J2x(RX140)		
Self-capacitance meth (averaged five times)	od, VMM method,	Sensor Drive Pulse Frequenc	y: 2MHz, Measurement Coun	t: 8, Offset Tuning Target: 3	37.5%
Current Range	Avg. at touch OFF A	Avg. at touch ON B	Signal value (Difference of touch ON/OFF) B - A	Avg. at touch OFF Noise value	SNR
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 channel through the power setting	This setting outputs a shield signal in phase with the sensor drive pulse from the non-measurement pin during the measurement period.

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

	Capacitan	се Туре	Shield	Pin Offset Tu	ning Target	Current Rai	nge Non	n-measure	ed TS Pin Output Se	ect Transm	it Power	Judgment T	ype	
config01	Self-Capac	itance meth	od None	Auto	~	Auto	✓ Auto Auto	to to		✓ Auto	~	/MM	~	
System	Multi-clock 3 Frequenci	Measuremer es	nt Multipli 64	ication Ratio 1	Multiplicatio	on Ratio 2	MutHi-Z 73 Sam	tput low th Z tput low th ne phase pr	nrough GPIO nrough the power se pulse output as trans	tting (prohibi mission char	ited item) inel throug	h the power	/ setting	
Method config01	Kind 1 Button(sel	Name f) Button0	Touch Se ) TS00	ensor Measure Auto	ement Time	Sensor Driv Auto	ve Pulse Fr	Frequency						
							CTS	SU2				[	Cancel	<u>H</u> elp
Automa	atic Tuning Prov Stting value will set these va	cessing ?s for each lues inadverter	method ,	/ touch inter t clear understand	face. ing, it could lea	id to poor tun	CT:	SU2				[	Cancel	Help
Automa elect se I If you v Method	atic Tuning Proc tting value will set these va Capacitance T	cessing es for each lues inadverter ype	method , itly or withour ihield Pin	/ touch inter t clear understand Touch Judgmo	face. ing, it could lea ent Offset	id to poor tun Tuning Target	CT:	SU2	on-measured TS Pin O	tput Select T	ransmit Pow	er Judgmer	Cancel It Type	<u>H</u> elp ×
Automa elect se I If you w Method config01	atic Tuning Proc tting value vill set these va Capacitance T Self-Capacitar	cessing 25 for each lues inadverter ype 2 1ce method	method , ntly or withour Shield Pin H None H	/ touch inter t clear understand Touch Judgmu ardware	face. ing, it could lea ent Offset " v Auto	ad to poor tun Tuning Target	CT:	s. t Range No Aut	on-measured TS Pin O ato	ıtput Select T V A	ransmit Pow uto	er Judgmer v JMM	Cancel It Type	<u>H</u> еlp ×
Automa elect se I If you w Method config01	atic Tuning Prod Stting Value will set these va Capacitance T Self-Capacitan Multi-clock Me 3 Frequencies	cessing 25 for each lues inadverter Sype a nce method asurement A 4	method , ttly or withou Shield Pin ( None H fultiplication 3	/ touch inter t clear understand Touch Judgmr ardware Ratio 1 Multiplic 41	face. ing, it could lea ent Offset Auto ation Ratio 2	id to poor tun Tuning Target Multiplicatio 55	CT: ing results. t Current I v Auto n Ratio 3	s. t Range No Aut CCO ( Hi Hardw Sar	on-measured TS Pin O ito ito ito ito ito ito ito ito ito ito	itput Select T V A ) iower setting (p as transmissio	ransmit Pow uto rohibited it: <u>1 channel th</u>	er Judgmer v JMM	Cancel It Type V	<u>Неір</u>
Automa elect se I If you v Method config01 System	stic Tuning Prov etting value will set these va Capacitance 1 Self-Capacitar Multi-clock Me 3 Frequencies Kind Button(self)	cessing 25 for each ype for each ype asurement N asurement N A Name To Button00	method , tty or withou Shield Pin None H fultiplication 3 uch Sensor 20	/ touch inter t clear understand Touch Judgmu ardware Ratio 1 Multiplic 41 Measurement Tin Auto	face. ing, it could lea ent Offset " v Auto intio 2 intio 2 intiota intio 2 intiota intiota	id to poor tur Tuning Target Multiplicatio 55 ve Pulse Frequ	CT: ing results. t Current I v Auto in Ratio 3 (1) uency	s. Range No Aut CCO O Hi- Hardy Sar	on-measured TS Pin O ito ito ito ito thow through GPI -Z itput low through the me phase pulse outpu	rtput Select T	ransmit Pow uto rrohibited itu	er Judgmer v JMM m) rough the por	Cancel It Type v	Help ×

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 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 method is used	VCC	0	Only the receive pin is used during measurement and the transmit 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 changes depending on the voltage of the transmission pin. The 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 the transmit pin is not used. The receiving pin uses TSCAP power supply.
When using mutual capacitance method	VCC (private)	0 / 1	1	The transmission pin is also used during measurement. Sensitivity changes depending on the voltage of the transmission pin. The receiving pin uses TSCAP power supply.
When using active shield	Internal logic power supply (Power supply for active shield) RX,RA:VCL RL:REGC	1	0	The transmit pin is used for the output of the shield pulse. It can act as a shield by outputting pulses of the same phase and potential as the receiving pin from the transmitting pin. The receiving pin uses TSCAP power 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.							
	a server se	, g vale												
	🔺 lf you	will set these	values inadve	tently or wit	hout clear	understandir	ng, it could lead to	poor tuning res	ults.					_
	Method	Capacitance	: Туре	Shield Pin	Offset	Tuning Target	Transmit Power							
	config01	Self-Capacit	ance method	None	Auto		Auto	·						_
							VCC							
	Method	Kind	Name	Touch Sense	or Meas	urement Cou	tInternal logic po	wer supply						
	config01	Button(self)	Button00	TS00	Auto		Auto							-
	Start the T	uning Proces	s											
											Cancel		<u>H</u> elp	
							OTOUR							
							CISU1							
🗿 Auto	matic Tuning Pr	ocessing												
elect	setting valu	les for eac	h method	/ touch	interfa	ce.								
A In	a sector governe	-co ioi cue				it and the st		14-						
🔺 It yo	u will set these	/aiues inadver	tently or witho	ut clear unde	erstanding	it could lead	to poor tuning resu	its.	-					
Metho	d Capacitance	: Type	Shield Pin	Offset Tunin	g Target	Current Rang	e Non-measured	TS Pin Output Se	elect Transm	it Power	Judgment VMM	Type		
contig	Sen-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	VCC Vol a Internal	logic pov	ver supply (F	ower sup	oply for activ	e shield)
System	3 Frequencies	;	64	55	5	73	3	Normal voltag	ge VCC(pri	vate)				
Metho	d Kind	Name	Touch Sensor	Measurem	ent Time	Sensor Drive	Pulse Frequency							
config	01 Button(self)	Button00	TS00	Auto		Auto								
Start th	e Tuning Proces	s												
												Can	cel	<u>H</u> elp
							CT9112							
							01302							
	atic Tuning Proce	sing												
Autom		for each m	ethod / tou	ich interfa	ce.									
Autom	etting values		or without clear	understanding	it could lea	d to noor tunin	a results.							
Autom	etting values will set these valu	inadvertently			Offerst	Tuning Target	Current Ronge Mar	measured TC Dia (	Dutnut Salar	Transmit D -	war huden	ent Time		
Autom elect so	etting values will set these valu	es inadvertently	ld Dia \Lambda T-	uch ludana	Unset	THORE AND A LANDER	Current Kange Nor	-measured to Pin C	Juiput select	ansmit Po Auto	v JMM	ent iype		
Autom elect so If you Method config01	etting values will set these valu Capacitance Typ Self-Capacitance	e Shie	ld Pin 🚺 To ie Hardwa	uch Judgment re	✓ Auto	· • • •	Auto v Auto	)						
Autom elect so If you Method config01	etting values will set these valu Capacitance Typ Self-Capacitanc	es inadvertently e Shie e method Non	ld Pin 🚺 To ie Hardwa	uch Judgment re	✓ Auto	×	Auto v Auto	)		Auto				
Autom elect si I If you Method config01	etting values will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas	es inadvertently e Shie e method Non urement Multi	Id Pin () To e Hardwa	uch Judgment re Multiplicatio	✓ Auto on Ratio 2	Multiplication I	Auto v Auto	eristics Correction	Multi-cloc	Auto /CC nternal log	ic power supp	oly (Power	supply for acti	ve shield)
Autom elect so i If you Method config01 System	will set these values will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas 3 Frequencies	e Shie e Shie e method Non urement Multi 48	Id Pin <b>()</b> To Hardwa	uch Judgment re Multiplicatio 41	✓ Auto on Ratio 2	Multiplication I	Auto v Auto Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto /CC nternal log /CC(private	ic power supp	oly (Power	supply for acti	ve shield)
Autom elect so t If you Method config01 System	etting values will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas 3 Frequencies	es inadvertently e Shie e method Non urement Multi 48	Id Pin <b>()</b> To Hardwa	uch Judgment re Multiplicatio 41	✓ Auto on Ratio 2	Multiplication I	Auto V Auto Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto /CC nternal log /CC(private	ic power supp 	bly (Power	supply for acti	ve shield)
Autom elect so I If you Method config01 System Method	will set these values will set these value Capacitance Typ Self-Capacitance Multi-clock Mease 3 Frequencies Kind N	es inadvertently re Shie e method Non urement Multi 48 ame Touch	Id Pin 1 To re Hardwa	uch Judgment re Multiplicatio 41 urement Time	✓ Auto on Ratio 2 Sensor Dri	Multiplication I 55 ve Pulse Frequen	Auto Aut Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto /CC nternal log /CC(private	ic power supp 	bly (Power	supply for acti	ve shield)
Autom elect so i If you Method config01 System Method config01	will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas 3 Frequencies Kind N Button(self) B	es inadvertently re Shie e method Non urement Multi 48 ame Touch utton00 TS00	Id Pin 1 To ne Hardwa	uch Judgment re Multiplicatio 41 urement Time	<ul> <li>✓ Auto</li> <li>on Ratio 2</li> <li>Sensor Dri Auto</li> </ul>	Multiplication I 55 ve Pulse Frequen	Auto V Aut Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto VCC nternal log VCC(private	ic power supp	bly (Power	supply for acti	ve shield)
Autom elect so i If you Method config01 System Method config01	will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas 3 Frequencies Kind N Button(self) B	es inadvertently e Shie e method Non urement Multi 48 ame Touch utton00 TS00	Id Pin 1 To Hardwa Iplication Ratio 1 Sensor Meas Auto	uch Judgment re Multiplicatio 41 urement Time	<ul> <li>✓ Auto</li> <li>on Ratio 2</li> <li>Sensor Dri Auto</li> </ul>	Multiplication I 55 ve Pulse Frequen	Auto v Aut Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto /CC nternal log /CC(private	ic power supp 	oly (Power	supply for acti	ve shield)
Autom elect so f If you Method config01 System Method config01	will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas 3 Frequencies Kind N Button(self) B	es inadvertently re Shie e method Nor urement Multi 48 ame Touch utton00 TS00	Id Pin 1 To Hardwa Iplication Ratio 1 Sensor Meass Auto	uch Judgment re Multiplicatio 41 urement Time	<ul> <li>Auto</li> <li>on Ratio 2</li> <li>Sensor Dri Auto</li> </ul>	Multiplication I 55 ve Pulse Frequen	Auto v Aut Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto /CC nternal log /CC(private	ic power supp	bly (Power	supply for acti	ve shield)
Autom elect so i If you Method config01 System Method config01	will set these valu Capacitance Typ Self-Capacitanc Multi-clock Meas 3 Frequencies Kind N Button(self) B	es inadvertently re method Nor urement Multi 48 ame Touch utton00 TS00	Id Pin 1 To Hardwa	uch Judgment re Multiplicatio 41 urement Time	v Auto on Ratio 2 Sensor Dri Auto	Multiplication I 55 ve Pulse Frequen	Auto v Aut Ratio 3 CCO Charac Hardware	eristics Correction	Multi-cloc Software	Auto /CC nternal log /CC(private	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	Multiplicati	on Ratio 2	Multiplication Ratio 3
System	3 Frequencies		48		41		55
Method	Kind	Name	Touch Sensor	Measur	ement Time	Sensor Dr	ive Pulse Frequency
config0	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 *1	Multiplication Ratio *2	Multiplication Ratio <sup>*2</sup>
RL78/G22 RL78/G23	48	41 [32~60]	Normal Voltage:55 [32~60] Low Voltage:46 [32~60]
RX260 RX261	48	41 [32~64]	Normal Voltage:55 [32~64] Low Voltage:46 [32~64]
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 Self-Capacit	: Type ance method	Shield Pin None	Offset Tuni Auto	ng Target	Current Rar Auto	nge Non-mea Auto	ured TS Pin Output Se	lect Transn Auto	nit Power Ju Vi	udgment Type MM	
System	Multi-clock M 3 Frequencies	leasurement	Multiplicatio	n Ratio 1 1	Multiplicati 55	ion Ratio 2	Multiplication F 73	atio 3 Measurement Normal voltag	Voltage Sett ge	ing		
Method config01	Kind Button(self)	Name Button00	Touch Sensor TS00	Measurer Auto	nent Time	Sensor Driv Auto	ve Pulse Frequer	cy				
											Cancel	<u>H</u> elp
							CTSU	2				
Automatel lect set	tic Tuning Proce tting values vill set these valu	ssing for each n es inadvertently	nethod / too	uch interf	ace. Ig, it could le	ead to poor tur	CTSU:	2				;
Automatel Automa	tic Tuning Proce tting values vill set these valu Capacitance Typ Self-Capacitanc	for each n es inadvertently pe Shi e method No	nethod / to or without clear eld Pin 1 Tr ne Hardw	uch interf r <mark>understandir</mark> ouch Judgmer are	ace. Ig, it could le Int Offse Auto	<del>ead to poor tur</del> t Tuning Target	CTSU ning results. t Current Range Auto	2 Non-measured TS Pin C Auto	Dutput Select	Transmit Powe Auto	Judgment Type JMM	;
Automatelect set	tic Tuning Proce tting values vill set these valu Capacitance Typ Self-Capacitanc Aulti-clock Meas Frequencies	for each n es inadvertently re Shi e method No urement Mul 48	nethod / to or without clea eld Pin ne Hardw tiplication Ratio	uch interf r understandir buch Judgmer are	aCe. Int Offse Auto	ad to poor tur t Tuning Target Multiplicatio 55	CTSU ing results. t Current Range Auto In Ratio 3 CCO C Hardw	2 Non-measured TS Pin C Auto haracteristics Correction are	Dutput Select Multi-clock ( Software	Transmit Powe Auto Correction Me	Judgment Type JMM easurement Voltage Setting prmal voltage	;

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

Figure 3-27 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 Correct	ction/Multi-clock Correction"
---	-------------------------------

Touch Judgment	CCO Characteristics Correction	Multi-clock Correction
Hardware	Hardware	When using VMM: Hardware 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".

Method config01	Capacitance Self-Capacita	Type ince method	Shield Pin None	1 Touch SMS	Judgment	Offset Auto	Tuning Target	Current Range Auto	Non-measured TS Pin O Auto	utput Select Tr	ansmit Power uto	Judgment Type JMM		
System	Multi-clock Me 3 Frequencies	easurement	Multiplicatio	n Ratio 1 M	Multiplicatio 41	n Ratio 2	Multiplication 55	Ratio 3 Measu Norma	rement Voltage Setting Il voltage					
Method config01	Kind Button(self)	Name Button00	Touch Sensor TS00	Measuren Auto	nent Time	Sensor Driv Auto	ve Pulse Freque	ncy						
Start the T	Funing Process						СТЯ	3U2L/C	TSU2La				Cancel	<u>H</u> elp
Autom Autom elect se I if you Method	atic Tuning Process atic Tuning Pro atting valu will set these v Capacitance	ocessing les for ea alues inadv Type	ach methc ertently or with Shield Pin	od / touc	:h interfa nderstandin :h Judgmen	aCe. g, it could t Offsi	CTS lead to poor tu et Tuning Targe	SU2L/C	TSU2La	n Output Select	Transmit Po	wer Judgment 1	Cancel	Help ×
Autom Autom elect se If you Method config01	atic Tuning Process atic Tuning Pro etting valu will set these v Capacitance Self-Capacit	ocessing les for ea ralues inadv Type ance metho	ach metho ertently or with Shield Pin d None	od / touc hout clear un Touc Hardware	:h interfa nderstandin :h Judgmen	aCe. g, it could t Offsa Auto	CTS lead to poor tu et Tuning Targe	SU2L/C	TSU2La ge Non-measured TS Pi Auto	n Output Select	Transmit Po Auto	wer Judgment 1 JMM	Cancel /pe	<u>Help</u>
Autom elect se I If you Method config01 System	atic Tuning Process atic Tuning Pro- etting valu will set these v Capacitance Self-Capacit Multi-clock M 3 Frequencies	ocessing les for ea ralues inadv Type ance metho leasurement	ach metho ertently or with Shield Pin d None : Multiplicat 48	od / touc hout clear ur Date Hardware ion Ratio 1	:h interfa nderstandin ch Judgmen : Multiplicat 41	aCe. g. it could t Offs Auto ion Ratio 2	CTS lead to poor tu et Tuning Targe 2 2 3 3 3	SU2L/C ning results. tt Current Ran Auto 2n Ratio 3 CCC Har	TSU2La ge Non-measured TS Pi Auto O Characteristics Correctio dware	n Output Select n Multi-cloc Software	Transmit Po Auto : Correction	wer Judgment 1 JMM Veasurement Volt Vormal voltage	ype age Setting	Help X

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.

config01	Capacitano	ce Type itance meth	Shield Pi od None	n Offset Tu Auto	ning Target	Current Range Auto	e Nor Aut	n-measu to	red TS Pin	Output Selec	t Transr Auto	nit Power	Judgment Ty VMM	pe			
System	Multi-clock Measurement Multiplystem 3 Frequencies 64		nt Multiplica 64	olication Ratio 1 Multiplication Ratio 55		ion Ratio 2 M v 73	Ratio 2 Multiplication Ratio 3 Measurement Vo 73 Normal voltage Normal voltage			oltage Sett	ing V						
Method config01	Kind Button(self	Name f) Button00	Touch Sen 0 TS00	sor Measur Auto	ement Time	Sensor Drive Auto	Pulse F	requency	Lov	v voltage							
														Canc	el	H	elp
Automa lect set	itic Tuning Proc tting value vill set these val	essing is for each	1 method /	touch inte	rface. ding, it could l	ead to poor tuning	CT g results	SU2						Canc	el	H	elp >
Automa lect set If you w Method :onfig01	ttic Tuning Proc tting value will set these val Capacitance T Self-Capacitar	essing to for each lues inadverter ype toce method	n method / ntly or without o Shield Pin None Har	touch inte :lear understan Touch Judgn rdware	rface. ding, it could l nent Offse Auto	ead to poor tuning tr Tuning Target	CT g results Current Auto	SU2	Non-measi Auto	ured TS Pin Out	tput Select	Transmit Po Auto	wer Judgmer JMM	Canc it Type	el	H	2 <b> p</b>
Automa lect set lf you w Method config01	itic Tuning Proc tting value will set these val Capacitance T Self-Capacitar Multi-clock Me 3 Frequencies	ressing is for each lues inadverter ype acce method asurement A 4	n method / ntly or without of Shield Pin None Multiplication Ra 18	touch inte lear understan Touch Judgn rdware tio 1 Multipl 41	rface. ding, it could I ding, it could I ding, it could I offse Auto cation Ratio 2 v	ead to poor tuning tr Tuning Target Multiplication F 55	CT g results Current Auto Ratio 3	s. t Range	Non-mease Auto aracteristics e	ured TS Pin Out	iput Select Multi-clock ioftware	Transmit Po Auto Correction	wer Judgmer JMM Measurement V Normal voltage Normal voltage	Canc it Type foltage Se	el etting	H	2 <b> p</b>
Automa elect set If you w Method config01	tic Tuning Proc tting value vill set these val Capacitance T Self-Capacitan Self-Capacitan Vulti-clock Me 3 Frequencies	essing ess for each use inadverter ype acce method asurement N 4 Name To	n method / ntly or without a Shield Pin None Multiplication Ra 18	touch inte lear understan Touch Judgn dware tio 1 Multipl 41	rface. ding, it could I ment Offse Auto cation Ratio 2 ~ ma Sense: D	ead to poor tuning tt Tuning Target Multiplication F 55	CT g results Current Auto Ratio 3	s. tt Range	Non-mease Auto aracteristics e	ured TS Pin Out Correction 1	iput Select Vulti-clock ioftware	Transmit Po Auto Correction	wer Judgmer JMM Measurement V Normal voltage Low voltage	Canc it Type foltage Se	el etting	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 LOW VOLTAGE MODE	(1)

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



# **Revision History**

		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	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 Capacitive Touch v4.0.0
		P18	Corrected with offset-tuning target value updated in QE for Capacitive Touch v4.0.0
		P19	Table3-10 lists QE for Capacitive Touch v3.3.0 and v3.5.0 tuning targets
		P23	Added a chart of the relation between parasitic capacitance/damping resistor and measurement frequency, taking RX671 as an example.
		P29	Corrected the rated current value flowing through the Current Control oscillator (CCO).
		P34	Replace chapters 3.6 and 3.7 from the previous edition
		P37	Modified the title of chapter 3.7
		P40	Added explanation of Auto Judgement and Automatic Multi- Frequency Correction (Hardware)
		P43	Added explanation of Low Voltage Operating Mode
3.10	Feb.19.25	-	Terms have been revised in accordance with the terminology corrections in QE for Capacitive Touch v4.1.0.
		-	Figures have been updated in accordance with the terminology corrections in QE for Capacitive Touch v4.1.0.
		-	The text regarding usage restrictions has been removed as hardware judgment using VMM has become possible from QE for Capacitive Touch v4.1.0.
		P15	The text in section 3.1.1 has been updated.



# 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 reseting 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 systemevaluation test for the given product.

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