RX Family

QE CTSU module Firmware Integration Technology

Introduction

This application note describes the CTSU module.

Target Device

- RX113 Group
- RX130 Group
- RX230 Group
- RX231 Group
- RX23W Group
- RX671 Group
- RX140 Group
- RX260 Group
- RX261 Group

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Related Documents

Firmware Integration Technology User's Manual (R01AN1833)
Board Support Package Firmware Integration Technology Module (R01AN1685)
Adding Firmware Integration Technology Module to Projects (R01AN1723)
RX100 Series VDE Certified IEC60730 Self-Test Code (R01AN2061ED)
RX v2 Core VDE Certified IEC60730 Self-Test Code for RX v2 MCU (R01AN3364EG)

Contents

1. Overview

The CTSU module is a CTSU driver for the Touch module. The CTSU module assumes the access from the Touch middleware layer, and it is also accessible from a user application.

The CTSU peripheral has five versions: CTSU, CTSUa, CTSU2L, CTSU2SL, and CTSU2SLa. Each MCU devices are equipped with the following version of CTSU peripherals.

CTSU2SLa ：RX260, RX261
CTSU2SL：RX140-256KB, RX140-128KB
CTSU2L：RX140-64KB
CTSUa：RX130, RX671
CTSU：RX113, RX230, RX231, RX23W

Since there is no difference in the explanation of the difference in function in this document, both CTSU and CTSUa are referred to as CTSU.

CTSU and CTSU2 have different functions, so these are described in this application note as below.

- Common description for CTSU, CTSU2L, CTSU2SL, CTSU2SLa -> CTSU
- Description only for CTSU -> CTSU1
- Common description for CTSU2L, CTSU2SL and CTSU2SLa -> CTSU2L
- Common description for CTSU2SL, CTSU2SLa -> CTSU2SL
- Description only for CTSU2SLa -> CTSU2SLa

1.1 Functions

The CTSU module supports the following functions.

1.1.1 QE for Capacitive Touch Usage

The module provides various capacitive touch measurements based on configuration settings generated by QE for Capacitive Touch.

As a part of the configuration settings, the touch interface configuration displays the combination of pins to be measured (referred to as TS) and the corresponding measurement mode. Multi-touch interface configurations are necessary when the development product has a combination of different measurement modes or when the active shield is used.

1.1.2 Measurements and Obtaining Data

Measurements can be started by a software trigger or by an external event triggered by the Event Link Controller (ELC).

The CTSU module processes interrupts (INTCTSUWR and INTCTSURD) if generated during a measurement. The data transfer controller (DTC) can also be used for these processes.

When the measurement complete interrupt (INTCTSUFN) process is complete, the application is notified in a callback function. Make sure you obtain the measurement results before the next measurement is started as internal processes are also executed when a measurement is completed.

Start the measurement with API function R_CTSU_ScanStart().

Obtain the measurement results with API function R_CTSU_DataGet().

1.1.3 Sensor CCO Correction function

The CTSU peripheral has a built-in correction circuit to handle the potential microvariations related to the manufacturing process of the sensor CCO MCU.

This module uses the correction circuit during initialization after power-on to generate a correction coefficient to ensure accurate sensor measurement values. This correction coefficient is used to correct the measurement value.

When temperature correction is enabled, an external resistor connected to a TS pin is used to periodically update the correction coefficient. By using an external resistor that is not dependent on temperature, you can even correct the temperature drift of the sensor CCO.

1.1.4 Initial Offset Adjustment

The CTSU2L peripheral was designed with a built-in offset current circuit in consideration of the amount of change in current due to touch. The offset current circuit cancels enough of the parasitic capacitance for it to fit within the sensor CCO dynamic range.

This module adjusts the offset current setting. As the adjustment uses the normal measurement process, R_CTSU_ScanStart() and R_CTSU_DataGet() must be repeated several times after startup. Because the ctsu_element_cfg_t member “so” is the starting point for adjustments, you can set the appropriate value for “so” in order to reduce the number of times the two functions must be run to complete the adjustment. Normally, the value used for “so” is a value adjusted by QE for Capacitive Touch.

For CTSU2L, this feature can be turned off in the config.

Default target value (CTSU)

Mode	CTSU1 target value	CTSU2L target value
Self-capacitance	15360 (37.5%)	11520 (37.5%)
Self-capacitance using active shield	-	4608 (15%)
Mutual-capacitance	10240 (25%)	7680 (25%)

The percentage is based on 100% being the maximum input current applied to the CCO.
CTSU1 : 100% is the measured value 40960 when the measurement time is 526us(base time).
CTSU2L : 100% is the measured value 30720 when the measurement time is 256us(base time).
When the measurement time is changed, the target value is adjusted by the ratio with the base time.

Example of target value in combination of CTSUSNUM and CTSUSDPA

CTSU1 (CTSU clock = 32MHz、Self-capacitance mode)

Target value	CTSUSNUM	CTSUSDPA	Measurement time
15360	0x3	0x7	526us
30720	0x7	0x7	1052us
30720	0x3	0xF	1052us
7680	0x1	0x7	263us
7680	0x3	0x3	263us

The measurement time changes depending on the combination of CTSUSNUM and CTSUSDPA. Recommended CTSUPRRTIO, CTSUPRMODE are used. Changing this value is deprecated. For details, refer to the hardware manual of each capacitive touch sensor.

・CTSU2L (Self-capacitance mode)

Target value	Target value (multi-clock)	CTSUSNUM	Measurement time
5760	11520 (128us + 128us)	0x7	128us
11520	23040 (256us + 256us)	0xF	256us
2880	5760 (64us + 64us)	0x3	64us

The measurement time changes depending on CTSUSNUM. If STCLK cannot be set to 0.5MHz, it will not support the table above. Regarding STCLK, refer to the hardware manual.

1.1.5 Random Pulse Frequency Measurement (CTSU1)

The CTSU1 peripheral measures at one drive pulse frequency.

The drive pulse frequency determines the amperage to the electrode and generally uses the value tuned with QE for Capacitive Touch.

The actual drive pulse is phase-shifted and frequency-spread with respect to the base clock as a measure against external environmental noise. This module is fixed at initialization and sets the following.

CTSUSOFF = 0, CTSUSSMOD = 0, CTSUSSCNT = 3

The base clock is calculated as below.

It is determined by PCLK frequency input to CTSU, CTSU Count Source Select bit(CTSUCLK), and CTSU Sensor Drive pulse Division Control bit(CTSUSDPA). For example, If it is set PCLK =32MHz, CTSUCLK = PLCK/2, and CTSUSDPA = 1/16, then base clock is 0.5MHz. CTSUSDPA can change for each TS port.

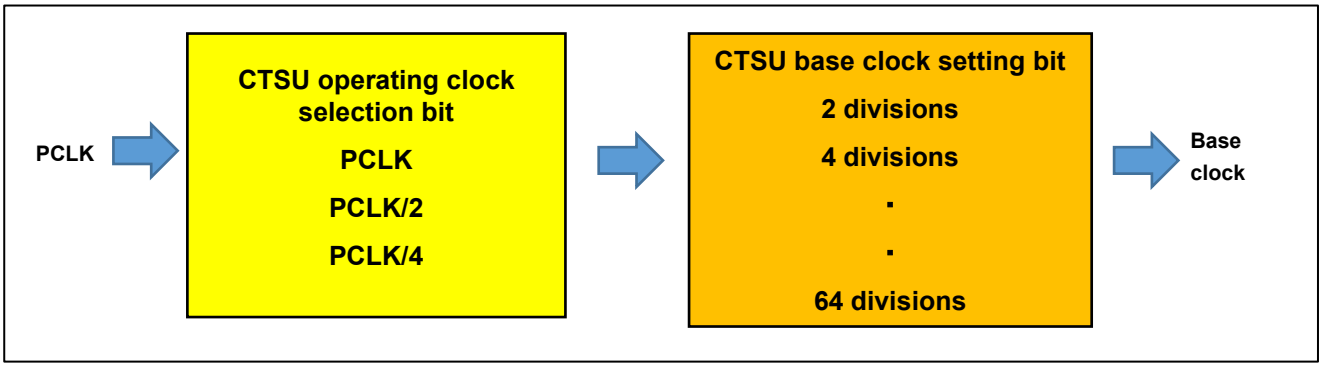

Figure 1 Base clock settings

1.1.6 Multi-clock Measurements (CTSU2L)

The CTSU2L peripheral can measure in one of four drive frequencies to avoid synchronous noise.

By default, this module measures at three different frequencies and makes a majority judgement on the three measurement results obtained.

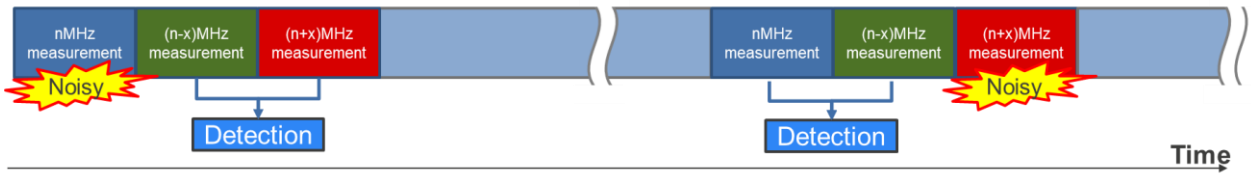

Figure 2 Multi-clock Measurements

There are two types of majority judgement modes for the three measurement results: JMM (Judgement Majority Mode) and VMM (Value Majority Mode). JMM only supports self-capacitance buttons and mutual-capacitance buttons.

Figure 3 shows the flowchart of JMM and VMM with the Touch module.

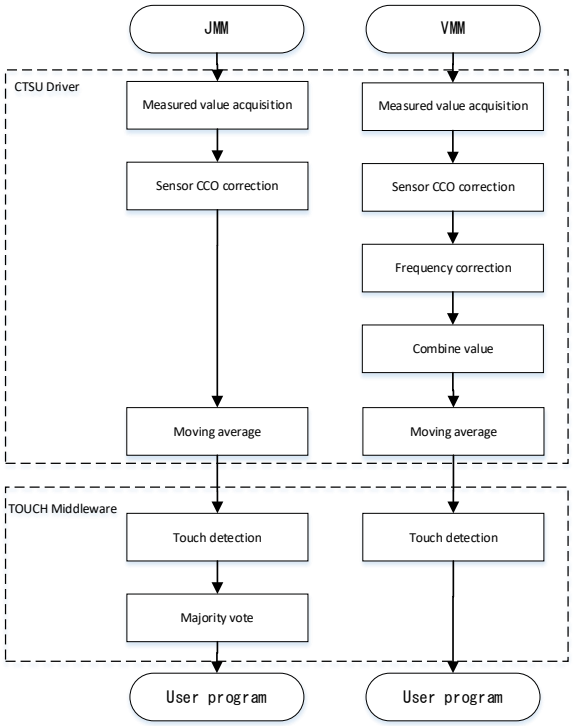

Figure 3 Flowchart of JMM and VMM

JMM makes a final touch judgment by using majority touch judgment results for each of the three CCO-corrected measurement values.

VMM performs frequency correction to standardize the three CCO-corrected measurements to the measured values at the first frequency, and adds two measurements with similar values. This results in a measurement value that doubles the measurement time. Touch judgment is made with this measured value.

Example VMM Calculations

From the frequency-corrected values 1, 2, and 3, the difference values 1, 2, and 3 for each pair are calculated, and the smaller pair is selected by comparing the absolute values of the difference values. To prevent chattering, a combination of value 1 and value 2 is given a weight to be selected. When comparing value 3, multiply the difference value 2 by 2 and multiply the difference value 3 by 1.5.

Value 1	Value 2	Value 3	Difference value 1	Difference value 2	Difference value 3	Result	Added Value
7734	7734	7663	0	71	71	Value 1+2	15468
7689	7739	7666	50	23	73	Value 1+3	15355
7734	7679	7664	55	70	15	Value 2+3	15343
7721	7719	7694	2	27	25	Value 1+2	15440
7716	7747	7693	31	23	54	Value 1+2	15463

You can set JMM or VMM for each touch interface configuration. If the ctsu_cfg_t member "majority_mode" is set to 1, it works in JMM, and if it is set to 0, it works in VMM.

R_CTSU_DataGet () can get the data after conducting the moving average. To retrieve the data for each of the previous processes R_CTSU_SpecificDataGet use (). These data can also be used to determine the data with its own noise filter in the Touch module. See Chapters 3.8 and 3.9 for more information.

Drive pulse frequency is determined based on the config settings. The module sets registers according to the config settings, and sets the three drive frequencies.

Drive pulse frequency is calculated in the following equation:

(PCLKB frequency / CLK / STCLK) x SUMULTIn / SDPA : n = 0, 1, 2

The figure below shows the settings for generating a 2MHz drive pulse frequency when the PCLKB frequency is 32MHz. SDPA can be set for each touch interface configuration.

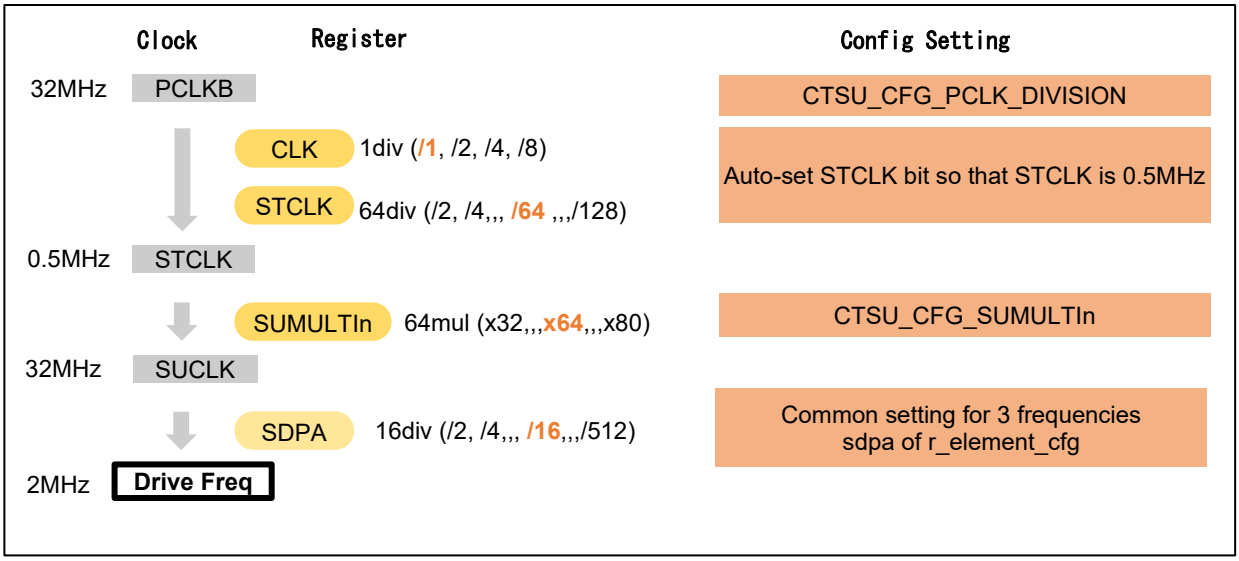

Figure 4 Drive Pulse Frequency Settings

1.1.7 Shield Function (CTSU2L)

The CTSU2L peripheral has a built-in function that outputs a shield signal in phase with the drive pulse from the shield pin and the non-measurement pin in order to shield against external influences while suppressing any increase in parasitic capacitance. This function can only be used during self-capacitance measurements.

This module allows the user to set a shield for each touch interface configuration.

For example, for the electrode configuration shown in Figure 5, the members of ctsu_cfg_t should be set as follows. Other members have been omitted for the example.

```
.txvsel      = CTSU_TXVSEL_INTERNAL_POWER,
.txvsel2     = CTSU_TXVSEL_MODE,
.md          = CTSU_MODE_SELF_MULTI_SCAN,
.posel       = CTSU_POSEL_SAME_PULSE,
.ctsuchac0   = 0x0F,
.ctsuchtrc0 = 0x08,
```

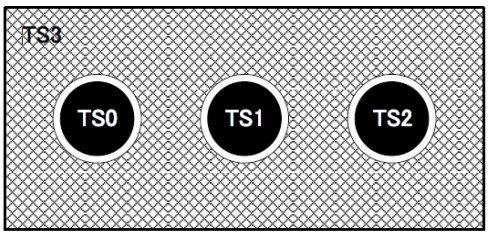

Figure 5 Example of Shield Electrode Structure

1.1.8 Measurement Error Message

When the CTSU2L peripheral detects an abnormal measurement, it sets the status register bit to 1.

In the measurement complete interrupt process, the module reads ICOMP1, ICOMP0, and SENSOVF of the status register and notifies the results in the callback function. The status register is reset after the contents are read. For more details on abnormal measurements, refer to “member event” in the ctsu_callback_args_t callback function argument.

1.1.9 Moving Average

This function calculates the moving average of the measured results.

Set the number of times the moving average should be calculated in the config settings.

1.1.10 Diagnosis Function

The CTSU peripheral has a built-in function that diagnoses its own inner circuit. This diagnosis function provides the API for diagnosing the inner circuit.

The diagnostic requirements are different for CTSU1 and CTSU2L providing 5 types of diagnosis for CTSU1 and 9 types for CTSU2L.

The diagnosis function is executed by calling the API function. This is executed independently from the other measurements.

To enable the diagnosis function, set CTSU_CFG_DIAG_SUPPORT_ENABLE to 1.

For CTSU1, 27pF condenser should be connected externally. After diagnostic function measurement, wait about 1ms before starting touch scanning.

For CTSU2L, use ADC FIT (r_s12ad_rx). If an error occurs in the ADC module used for Diagnosis mode, return FSP_ERR_ABORTED as the return value of R_CTSU_DataGet().For ADC module errors, see ADC FIT (r_s12ad_rx).

Consider the following three points when using the diagnostic function of CTSU2L.

1. When using the CTSU2L diagnostic function, CTSU driver must measure ADC. Therefore, when using ADC FIT on an application, be sure to close ADC FIT before using the diagnostic function.
2. If you did not close the ADC FIT, CTSU driver return value of FSP_ERR_ABORTED. Please refer to the sample below and close the ADC FIT so that the ADC measurement in the CTSU driver can be performed when the next diagnostic function is executed.

```
R_CTSU_ScanStart(g_qe_ctsu_instance_diagnosis.p_ctrl);
while (0 == g_qe_touch_flag) {}
g_qe_touch_flag = 0;

err = R_CTSU_DataGet(g_qe_ctsu_instance_diagnosis.p_ctrl, &dummyD);
if (FSP_SUCCESS == err)
{
    diag_err = R_CTSU_Diagnosis(g_qe_ctsu_instance_diagnosis.p_ctrl);
    if ( FSP_SUCCESS == diag_err )
    {
        /* TODO: Add your own code here. */
    }
}
else if (FSP_ERR_ABORTED == err)
{
    adc_err = R_ADC_Close(0);
    if (ADC_SUCCESS != adc_err)
    {
        while (true) {}
    }
}
```

3. When creating an RTOS application, consider the scheduling of diagnostic functions tasks for the CTSU module and tasks for the ADC module.

1.1.11 MEC Function (CTSU2SL)

The CTSU2SL peripheral has MEC (Multiple Electrode Connection) function that connects multiple electrodes and measures them as a single electrode. This feature is only available in self capacitance mode.

This is an example when using three electrodes. In normal times, normal measurement is performed, and 3 channels are measured to get each measured value. In power saving, MEC measurement is performed, and one channel is measured by combining three channels to acquire one measured value.

Figure 6 shows a compare of time of normal measurement and MEC measurement. Since multi channels are measured at the same time, the measurement time is shortened.

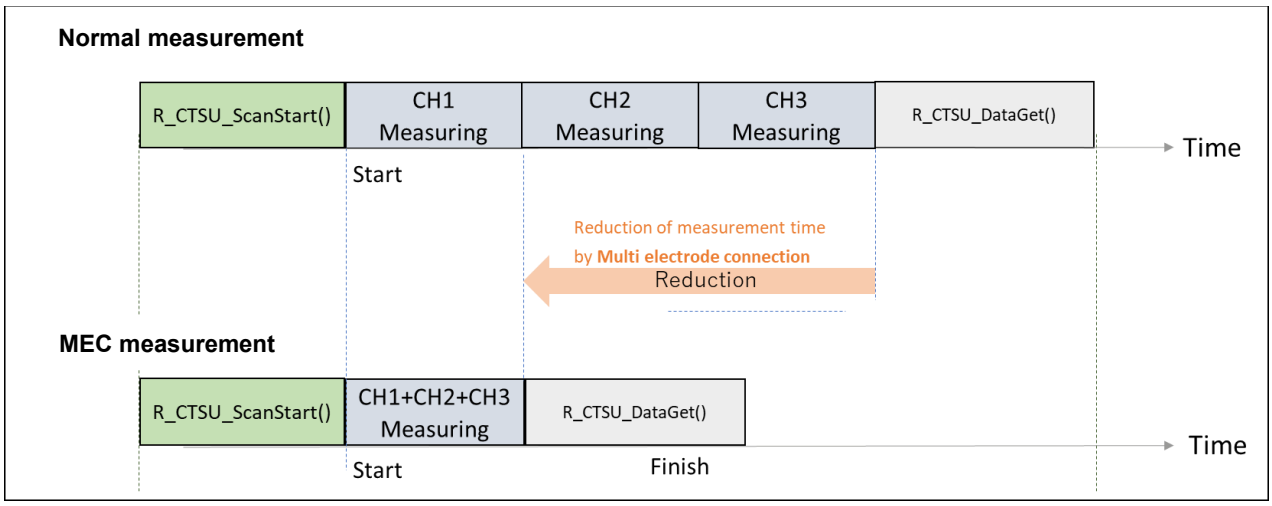

Figure 6 Compare of time between normal measurement and MEC measurement

To enable the code for the MEC feature, set CTSU_CFG_MULTIPLE_ELECTRODE_CONNECTION_ENABLE to 1.

When using MEC, create a touch interface configuration different from the normal touch interface configuration for the same TS. The following settings are required for the touch interface configuration for MEC measurement.

To enable MEC for touch interface configurations by setting tsod in ctsu_cfg_t to 1.

Set mec_ts of ctsu_cfg_t to one of the TS numbers to be measured.

If you want to use the shield function at the same time, set the TS number of the shield pin in mec_shield_ts of ctsu_cfg_t. In this case, only one TS can be used as a shield pin.

Set num_rx of ctsu_cfg_t to 1.

For example, in the case of the electrode configuration shown in Figure 7, set the members of ctsu_cfg_t as shown below. Other members are omitted here.

```
    .tsod = 1,
    .mec_ts = 0,
    .mec_shield_ts = 3,
    .num_rx = 1,
```

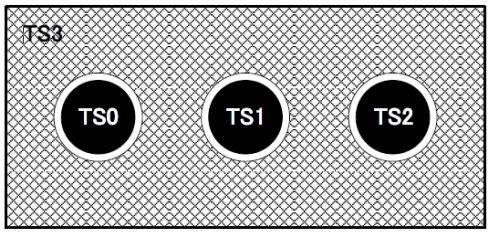

Figure 7 Example of MEC and shield electrode configuration

1.1.12 Automatic CCO Correction (CTSU2SL)

CTSU2SL peripheral has an automatic correction that correct the sensor CCO by hardware. Refer to Section 1.1.3 for more information on sensor CCO correction.

CTSU2SL peripheral processes the correction calculation. CCO correction data can be calculated without using the correction calculation processing of the software. The processing time of the main processor is not consumed.

Set CTSU_CFG_AUTO_CORRECTION_ENABLE to 1 to enable this feature.

1.1.13 Automatic Frequency Correction (CTSU2SLa)

CTSU2SLa peripheral has an automatic frequency correction that correct the calculation by hardware.

CTSU2SLa peripheral processes the correction calculation. Frequency correction data can be calculated without using the correction calculation processing of the software. The processing time of the main processor is not consumed.

Set CTSU_CFG_AUTO_MULTI_CLOCK_CORRECTION_ENABLE to 1 to enable this feature.

1.1.14 Automatic Judgement (CTSU2SL)

CTSU2SL peripheral has an automatic judgement that judges the touch of a button by hardware.

CTSU2SL peripheral processes the touch judgment of the button. The processing time of the main processor is not consumed.

Measurements and Judgements can be initiated either by software triggers or external events triggered by the Event Link Controller (ELC). Please use the API function R_CTSU_ScanStart ().

This module processes INTCTSUWR and INTCTSURD generated during measurement. Since DTC is used for these processes, DTC is required.

A callback function notifies the application when the processing of INTCTSUFN is completed. Get the judgment result before the next measurement. Please use the API function R_CTSU_AutoJudgeDataGet ().

Select either JMM or VMM as the majority voting method. Below is an example of the ctsu_cfg_t member settings for JMM. For VMM, set “jc” to 0 and “majirimd” to 1.

```
    .tlot = 2,     // Non-touch  judgment continuous count : 3 times
    .thot = 2,     // Touch judgment continuous count : 3 times
    .jc = 1,       // Judgement by two frequency
    .ajmmat = 2,   // Moving average : 2^2times
    .ajbmat = 7,   // Baseline average count : 2^(7+1)times
    .majirimd = 0, // JMM
    .mtucfen = 1,  // Mutual-capacitance
    .ajfen = 1,    // Enable automatic judgement
```

Set “CTSU_CFG_AUTO_JUDGE_ENABLE = 1” to enable the automatic judgement. In this case, set “CTSU_CFG_AUTO_CORRECTION_ENABLE = 1” to enable the automatic CCO correction function as well. For VMM, set “CTSU_CFG_AUTO_MULTI_CLOCK_CORRECTION_ENABLE = 1” to enable the automatic frequency correction function as well.

The following (a) to (e) describe the automatic judgment and its setting. In the case of JMM, (a) ~ (e) settings are set for each multi-clock measurement.

(a) Measurement mode

Select self-capacitance or mutual-capacitance with “mtucfen” of ctsu_auto_button_cfg_t. Set the self-capacitance to 0. Set the mutual capacitance to 1.

(b) Baseline

Set the baseline from the measurement result in the non-touch state. After completing the initial offset adjustment with R_CTSU_OffsetTuning (), the baseline is initially set (set BLINI bit) when

R_CTSU_ScanStart () is called for the first time. After that, when R_CTSU_AutoJudgementDataGet () is called, the baseline initialization is canceled (clear BLINI bit) and the baseline update process is started.

The baseline is updated every set number of measurements to follow changes in the surrounding environment. If “non-touch” state continues for the set number of measurements, the baseline is updated to the average value. When judgement result is “touch”, the number of counts is cleared.

Set the number of measurements (baseline update interval) with “ajbmat” of ctsu_cfg_t. Common to all buttons in the touch interface configuration. Adjusts the ability to follow changes in the surrounding environment.

(c) Touch threshold

Judgment is made using a threshold with an arbitrary offset from the baseline.

The threshold is set by adding hysteresis. Chattering is prevented by giving hysteresis to the transition from “touch” to “non-touch”. Increasing the hysteresis value is more effective in preventing chattering, but be aware that it will be more difficult to transition from “touch” to “non-touch”.

Set the threshold and hysteresis for each button with threshold and hysteresis of ctsu_auto_button_cfg_t. This module calculates the upper threshold and the lower threshold from these and sets them in the CTSUAJTHR register.

Figure 8 shows the self-capacitance judgement. Since the electrode capacitance of the self-capacitance button increases when touched, it is judged “touch” when the upper threshold is exceeded.

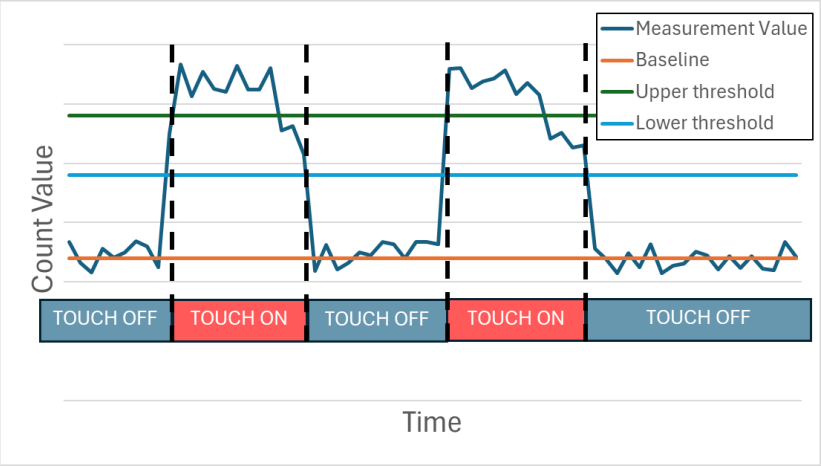

Figure 8 Self-capacitance judgement

Figure 9 shows the mutual-capacitance judgement. Since the mutual capacitance button reduces the capacitance between electrodes when touched, it is judged as "touch" when the lower threshold is exceeded.

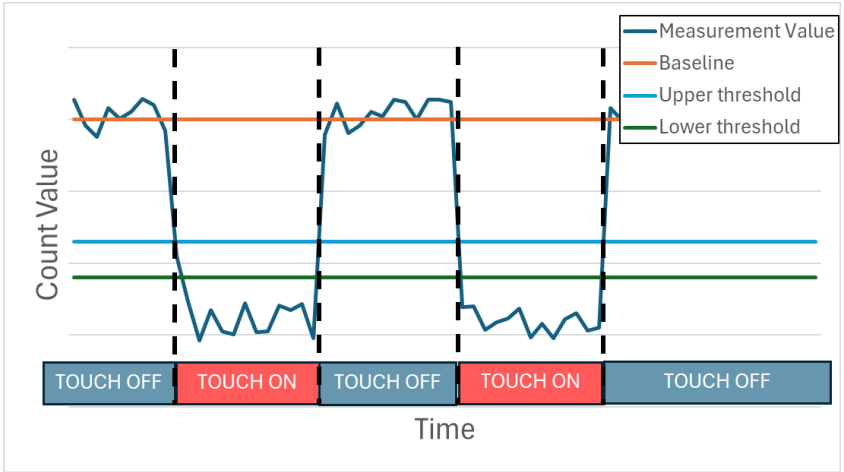

Figure 9 Mutual-capacitance judgement

(d) The number of consecutive “non-touch” and “touch” detections

This is a filter function to judge"touch" or "non-touch" when "touch" or "non-touch" state continues for a certain number of times.

Set the number of times with “tlot” and “thot” of ctsu_cfg_t. Common to all buttons in the touch interface configuration. Increasing the number of consecutive times will be more effective against chattering, but be aware that the reaction speed will decrease.

(e) Moving average

With the automatic judgment function, Set the number of moving averages with “ajmmat” of ctsu_cfg_t. Common to all buttons in the touch interface configuration.

Figure 10 shows the button judgment operation described above.

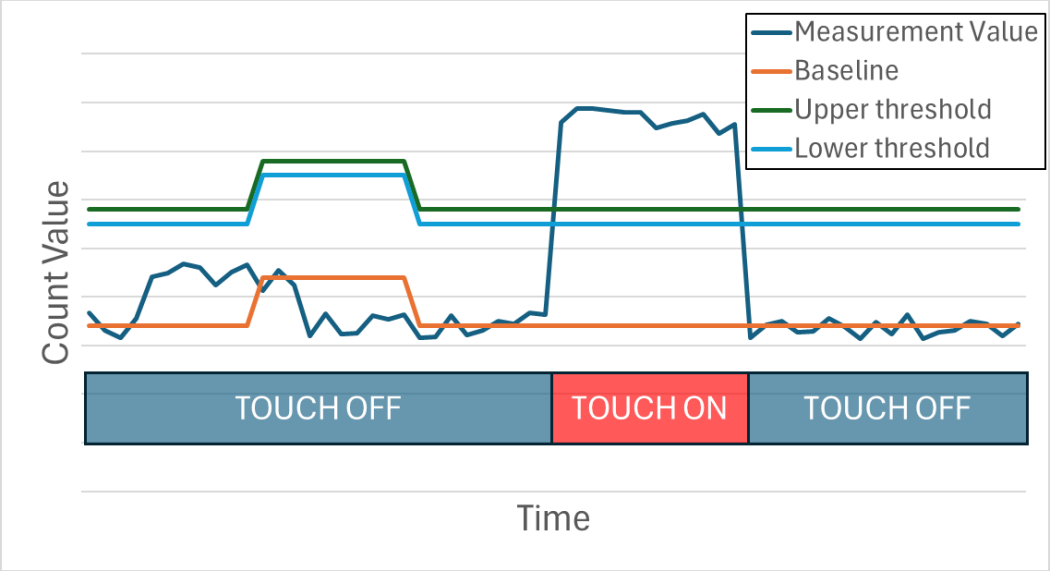

Figure 10 Button judgement

1.2 Measurement Mode

This module supports all three modes offered by the CTSU2L peripheral: self-capacitance, mutual capacitance, and current measurement modes. The temperature correction mode is also offered as a mode for updating the correction coefficient.

1.2.1 Self-capacitance Mode

The self-capacitance mode is used to measure the capacitance of each pin (TS).

The CTSU peripheral measures the pins in ascending order according to the TS numbers, then stores the data. For example, even if you want to use TS5, TS8, TS2, TS3 and TS6 in your application in that order, they will still be measured and stored in the order of TS2, TS3, TS5, TS6, and TS8. Therefore, you will need to reference buffer indexes [2], [4], [0], [1], and [3].

[CTSU1]

In default settings, the measurement period for each TS is wait-time plus approximately 526us.

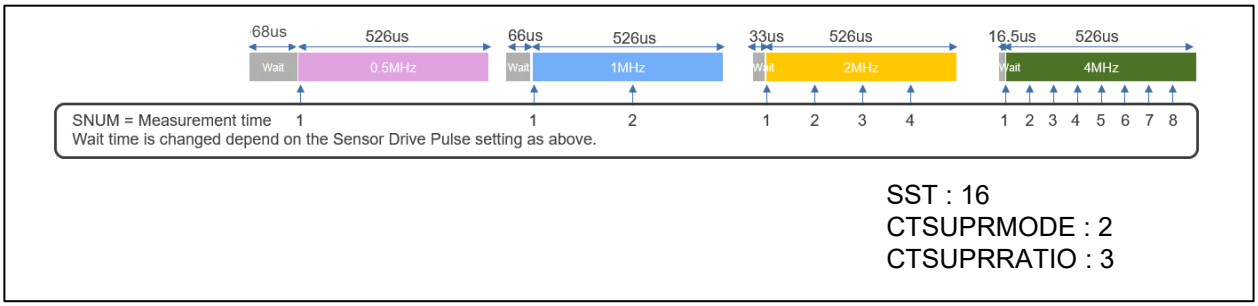

Figure 11 Self-capacitance Measurement Period (CTSU1)

[CTSU2L]

In default settings, the measurement period for each TS is approximately 576us.

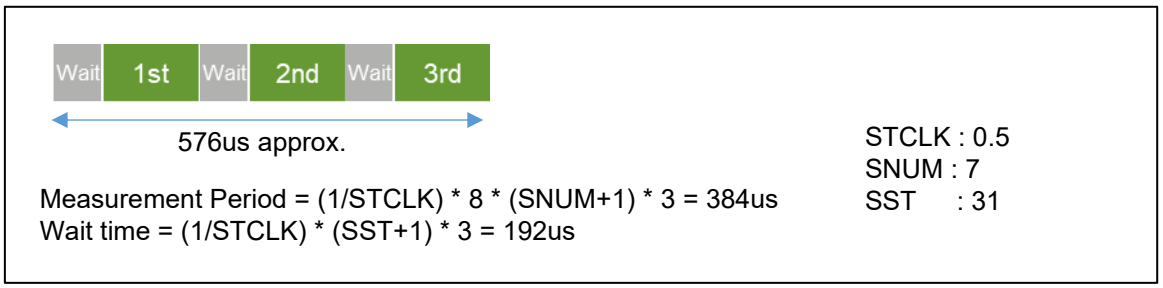

Figure 12 Self-capacitance Measurement Period (CTSU2L)

1.2.2 Mutual Capacitance Mode

The mutual capacitance mode is used to measure the capacitance generated between the receive TS (Rx) and transmit TS (Tx), and therefore requires at least two pins.

The CTSU2L peripheral measures all specified combinations of Rx and Tx. For example, when Rx is TS10 and TS3, and Tx is TS2, TS7 and TS4, the combinations are measured in the following order and the data is stored.

TS3-TS2, TS3-TS4, TS3-TS7, TS10-TS2, TS10-TS4, TS10-TS7

To measure the mutual capacitance generated between electrodes, the CTSU2L peripheral performs the measurement process on the same electrode twice.

The mutual capacitance is obtained by inverting the phase relationship of the pulse output and switched capacitor in the primary and secondary measurements, and calculating the difference between the two measurements. This module does not calculate the difference, but outputs the secondary measured result.

[CTSU1]

In default settings, the measurement period for each TS is twice of wait-time plus approximately 526us.

[CTSU2L]

In default settings, the measurement period for each TS is approximately 1152us.

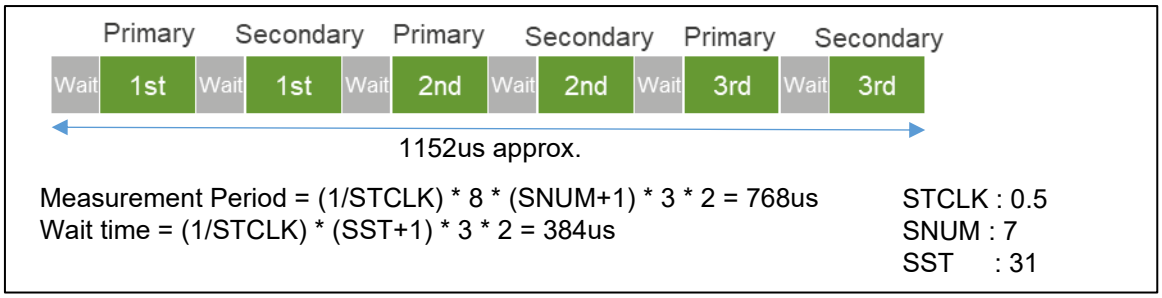

Figure 13 Mutual Capacitance Measurement Period (CTSU2L)

1.2.3 Current Measurement Mode (CTSU2L)

The current measurement mode is used to measure the minute current input to the TS pin.

The order of measurement and data storage is the same as that of the self-capacitance mode.

As this does not involve the switched capacitor operation, the measurement is only performed once. The measurement period for one TS under default settings is approximately 256us. The current measurement mode requires a longer stable wait time than the other modes, so the SST is set to 63.

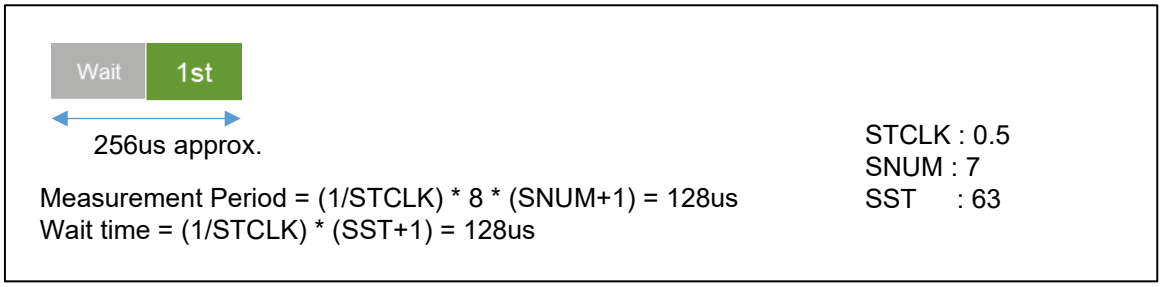

Figure 14 Current Measurement Period

1.2.4 Temperature Correction Mode (CTSU2L)

The temperature correction mode is used to periodically update the correction coefficient using an external resistor connected to a TS pin. This involves three processes as described below. Also refer to the timing chart in Figure 15 Temperature Correction Measurement Timing Chart.

A total of 13 measurements (12 correction measurements from Corr1 to Corr12 and external resistance measurements (ex_R)) are one set of temperature compensation. In order not to interfere with normal measurements, temperature correction is performed separately for each normal measurement.

Set the number of sets in which the sensor CCO correction factor is updated (average number of times) in the macro definition CTSU_CFG_TEMP_CORRECTION_TIME.

At that time, the RTRIM register is also adjusted by passing an offset current through an external resistor and measuring the voltage with the ADC.

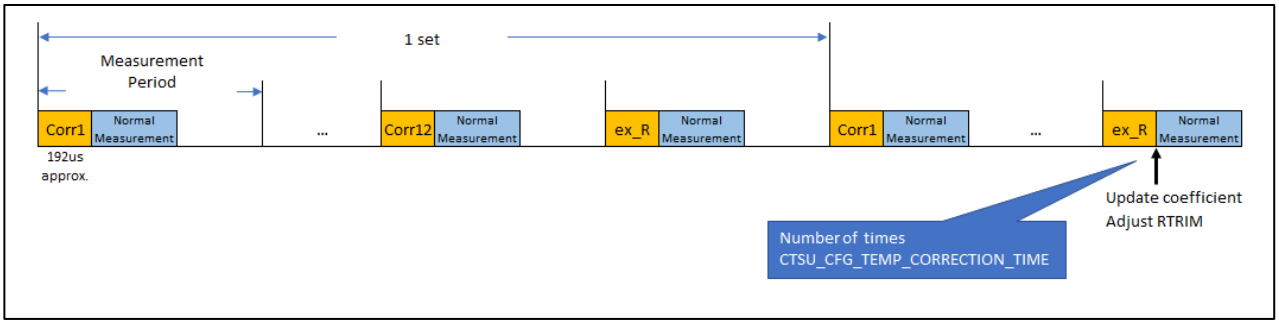

Figure 15 Temperature Correction Measurement Timing Chart

For CTSU2L, use ADC FIT (r_s12ad_rx). If an error occurs in the ADC module used for temperature correction mode, return FSP_ERR_ABORTED as the return value of R_CTSU_DataGet(). For ADC module errors, see ADC FIT (r_s12ad_rx).

Consider the following three points when using the temperature correction function of CTSU2L.

1. When using the CTSU2L temperature correction function, CTSU driver must measure ADC. Therefore, when using ADC FIT on an application, be sure to close ADC FIT before using the temperature correction function.
2. If you did not close the ADC FIT, CTSU driver return value of FSP_ERR_ABORTED. Please refer to the sample below and close the ADC FIT so that the ADC measurement in the CTSU driver can be performed when the next temperature correction function is executed.

```
R_CTSU_ScanStart(g_qe_ctsu_instance_temp_correction.p_ctrl);
while (0 == g_qe_touch_flag) {}
g_qe_touch_flag = 0;

err = R_CTSU_DataGet(g_qe_ctsu_instance_temp_correction.p_ctrl, &dummyD);
if (FSP_SUCCESS == err)
{
    /* TODO: Add your own code here. */
}
else if (FSP_ERR_ABORTED == err)
{
    adc_err = R_ADC_Close(0);
    if (ADC_SUCCESS != adc_err)
    {
        while (true) {}
    }
}
```

3. When creating an RTOS application, consider the scheduling of temperature correction functions tasks for the CTSU module and tasks for the ADC module.

1.2.5 Diagnosis Mode

The diagnosis mode is a mode in which various internal measurement values are scanned by using this diagnosis function. The details are described in 1.1.10.

1.3 Measurement Timing

As explained in section 1.1.2, measurements are initiated by a software trigger or an external event which is triggered by the Event Link Controller (ELC).

The most common method is using a timer to carry out periodic measurements. Make sure to set the timer interval to allow the measurement and internal value update processes to complete before the next measurement period. The measurement period differs according to touch interface configuration and measurement mode. See section 1.2 for details.

The execution timing of software triggers and external triggers differ slightly.

Since a software trigger sets the start flag after setting the touch interface configuration with R_CTSU_ScanStart (), there is a slight delay after the timer event occurrence. However, as the delay is much smaller than the measurement period, a software trigger is recommended for most instances as it is easy to set.

An external trigger is recommended for applications in which this slight delay is not acceptable or that require low-power consumption operations. When using an external trigger with multiple touch interface configurations, use R_CTSU_ScanStart() to set another touch interface configuration after one measurement is completed.

1.4 API Overview

This module has the following API functions.

The first argument of all API functions must be a pointer to a control structure. If you pass pointers for other arguments, make sure that they are not NULL and that you have reserved the required size for each API. However, R_CTSU_CallBackSet() is an exception, so please refer to the detailed description of API functions 3.4.

Function	Description
R_CTSU_Open()	Initializes the specified touch interface configuration.
R_CTSU_ScanStart()	Starts measurement of specified touch interface configuration.
R_CTSU_DataGet()	Gets measured values of specified touch interface configuration.
R_CTSU_CallbackSet()	Set callback function of specified touch interface configuration.
R_CTSU_Close()	Closes specified touch interface configuration.
R_CTSU_Diagnosis()	Executes diagnosis.
R_CTSU_ScanStop()	Stops measurement of specified touch interface configuration.
R_CTSU_SpecificDataGet()	Read the measurements for the specified data type for the specified touch interface.
R_CTSU_DataInsert()	Inserts the specified data in buffer of touch measurement results for the specified touch interface configuration.
R_CTSU_OffsetTuning()	Adjusts the offset register (SO) for the specified touch interface configuration.
R_CTSU_AutoJudgementDataGet()	Use the automatic judgement function to get all the button judgment results of the specified touch interface configuration.

2. API Information

Operations of this FIT module have been confirmed under the following conditions.

2.1 Hardware Requirements

The MCU used in the development must support one of the following functions:

- CTSU
- CTSUa
- CTSU2L
- CTSU2SL
- CTSU2SLa

2.2 Software Requirements

This driver depends on the following FIT modules:

- Board support package module (r_bsp) v7.50 or newer

According to the configuration settings, the driver may also depend on the following modules:

- DTC module r_dtc v4.50 or newer (In case of using DTC transfer)

  When using DTC transfer, set the Heap size of the r_bsp property to 0x1000 or more.

  Heap size of 0x1600 is recommended when using the GCC compiler.
- ADC module r_s12ad_rx_v5.40 or newer (In case of using Temperature correction mode or diagnosis mode)

This driver also assumes the use of following tool:

- Renesas QE for Capacitive Touch V4.2.0 or newer

2.3 Supported Toolchains

This FIT module has been confirmed with the development environment and compiler shown below.

Development environment

- Renesas e^2 studio 2025-07
- IAR Embedded Workbench for Renesas RX 5.10.1

Compiler

- Renesas CC-RX Toolchain v3.07.00
- GCC RX Toolchain v14.2.0.202505
- IAR C/C++ Compiler for Renesas RX version 5.10.1

2.4 Restrictions

The module code is non-reentrant and protects simultaneous calls for multiple function.

2.5 Header File

All interface definitions to be called and used in the API are defined in “r_ctsu_qe_if.h”.

Select “r_ctsu_qe_config.h” as the configuration option in each build.

2.6 Integer Type

This driver uses ANSI C99. The types are defined in stdint.h.

2.7 Compilation Settings

The following table provides the names and setting values for the configuration option settings used the CTSU module.

r_ctsu_config.h Configuration Options	
CTSU_CFG_PARAM_CHECKING_ENABLE *Default value: “BSP_CFG_PARAM_CHECKING_ENABLE”	Selects whether to include the parameter check process in the code. Selecting “0” allows the user to omit the parameter check process from the code to shorten the code size. “0”: Omit parameter check process from code. “1”: Include parameter check process in code. “BSP_CFG_PARAM_CHECKING_ENABLE”: Selection depends on BSP setting.
CTSU_CFG_USE_DTC_SUPPORT_ENABLE *Default value: “0”	Select “1” to use the DTC, rather than the main processor, to run the CTSU2L’s CTSUWR interrupt and CTSURD interrupt processes. Note: If the DTC is used elsewhere in the application, it may compete with the use of this driver.
CTSU_CFG_AUTO_JUDGE_ENABLE *Default value: “0”	Set to “1” to enable the automatic judgment code.
CTSU_CFG_INTCTSUWR_PRIORITY_LEVEL *Default value: “2”	Sets the CTSUWR interrupt priority level (also necessary when using the DTC). The priority level range is from 0 (high) to 15 (low).
CTSU_CFG_INTCTSURD_PRIORITY_LEVEL *Default value: “2”	Sets the CTSURD interrupt priority level (also necessary when using the DTC). The priority level range is from 0 (high) to 15 (low).
CTSU_CFG_INTCTSUFN_PRIORITY_LEVEL *Default value: “2”	Sets the CTSUFN interrupt priority level. The priority level range is from 0 (high) to 15 (low).
The following configurations depend on the touch interface configuration and cannot be set using Smart Configurator. These configurations are set when using QE for Capacitive Touch. In this case, QE_TOUCH_CONFIGURATION is defined in the project. Although r_ctsu_config.h becomes invalid, qe_touch_define.h is defined instead	
QE_TOUCH_VERSION	QE version
CTSU_CFG_NUM_SELF_ELEMENTS	Sets the total number of TS for self-capacitance, current measurement, and temperature correction.
CTSU_CFG_NUM_MUTUAL_ELEMENTS	Sets the total number of matrixes for mutual capacitance.
CTSU_CFG_NUM_AUTOJUDGE_SELF_ELEMENTS	Sets the total number of TS for self-capacitance with automatic judgement.
CTSU_CFG_NUM_AUTOJUDGE_MUTUAL_ELEMENTS	Sets the total number of matrixes for mutual capacitance with automatic judgement.
CTSU_CFG_LOW_VOLTAGE_MODE	Enables/disables the low voltage mode. This value is set in the CTSUCRAL register’s ATUNE0 bit. Note: This software does not support Low Voltage Mode on CTSU1, please set 0 using CTSU1.
CTSU_CFG_PCLK_DIVISION	Sets the PCLK frequency division rate. This value is set in the CTSUCR1 register’s CTSUCLK bit for CTSU1 and CTSURAL register’s CLK bit for CTSU2L.

CTSU_CFG_TSCAP_PORT	Sets the TSCAP port. Example: For P30, set “0x0300”.
CTSU_CFG_VCC_MV	Sets the VCC (voltage). Example: for 5.00V, set “5000”.
CTSU_CFG_NUM_SUMULTI	Sets the number of multi-clock measurements.
CTSU_CFG_SUMULTI0	Sets the multiplication factor for the second frequency in a multi-clock measurement. Recommended for RX260, RX261: 0x2F Other recommended: 0x3F
CTSU_CFG_SUMULTI1	Sets the multiplication factor for the second frequency in a multi-clock measurement. Recommended for RX260, RX261: 0x28 Other recommended: 0x36
CTSU_CFG_SUMULTI2	Sets the multiplication factor for the third frequency in a multi-clock measurement. Recommended for RX260, RX261: 0x36 Other recommended: 0x48
CTSU_CFG_TEMP_CORRECTION_SUPPORT	Enables/disables temperature correction.
CTSU_CFG_TEMP_CORRECTION_TS	Sets the temperature correction pin number
CTSU_CFG_TEMP_CORRECTION_TIME	Sets the update interval for the correction coefficient of the temperature correction. Assuming 13 measurements per set in the temperature correction mode, indicate the number of sets per update.
CTSU_CFG_CALIB_RTRIM_SUPPORT	Select whether RTRIM correction of temperature correction enabled. Setting ADC is necessary to operation with this setting enabled.
CTSU_CFG_DIAG_SUPPORT_ENABLE	Enables/disables diagnosis function.
CTSU_CFG_DIAG_DAC_TS	Sets the number of TS pin to be used for diagnosis in CTSU1.
CTSU_CFG_AUTO_CORRECTION_ENABLE	Select whether to enable or disable the automatic CCO correction process.
CTSU_CFG_AUTO_MULTI_CLOCK_CORRECTION_ENABLE	Select whether to enable or disable the automatic frequency correction process.
CTSU_CFG_MULTIPLE_ELECTRODE_CONNECTION_ENABLE	Select to enable or disable the MEC feature.
CTSU_CFG_MAJORITY_MODE	Bitmap of majority judgement mode processing. The first bit is VMM, and the second bit is JMM. Set according to the touch interface configuration. 1 : VMM 2 : JMM 3 : VMM and JMM

2.8 Code Size

ROM (code and constants) and RAM (global data) size are determined according to the configuration options as described in “section 2.7 Compilation Setting” during a build. The values shown are reference values when the compile option is the default for C compiler listed in “section 2.3 Supported Toolchains”. The default of compile options is as follows: the optimization level is 2, the optimization type is size priority, and the data-endian is a little endian. The code size varies according to the C compiler version or the compile options.

Using Renesas CC-RX Toolchain v3.06.00, the following is the size at compilation settings.
Only settings related to size are shown.

- CTSU_CFG_PARAM_CHECKING_ENABLE 0
- CTSU_CFG_DTC_SUPPORT_ENABLE 0
- CTSU_CFG_AUTO_JUDGE_ENABLE 0
- CTSU_CFG_LOW_VOLTAGE_MODE 0
- CTSU_CFG_TEMP_CORRECTION_SUPPORT 0
- CTSU_CFG_CALIB_RTRIM_SUPPORT 0
- CTSU_CFG_AUTO_CORRECTION_ENABLE 0
- CTSU_CFG_AUTO_MULTI_CLOCK_CORRECTION_ENABLE 0
- CTSU_CFG_MULTIPLE_ELECTRODE_CONNECTION_ENABLE 0

The size of the self-capacitance and the mutual capacitance are shown in one element, and the size is increased by adding one element. It also includes qe_touch_config.c output by QE.

[CTSU1]

- CTSU_CFG_NUM_SUMULTI 1

Mode and element num	Self-capacitance 1 element	+ 1 element	Mutual capacitance 1 element	+1 element
ROM	3315 bytes	+8 bytes	3606 bytes	+8 bytes
RAM	223 bytes	+23 bytes	241 bytes	+35 bytes

[CTSU2L] VMM

- CTSU_CFG_NUM_SUMULTI 3
- CTSU_CFG_MAJORITY_MODE 1

Mode and element num	Self-capacitance 1 element	+ 1 element	Mutual capacitance 1 element	+1 element
ROM	4701 bytes	+8 bytes	5026 bytes	+8 bytes
RAM	457 bytes	+41 bytes	491 bytes	+63 bytes

[CTSU2L] JMM

- CTSU_CFG_NUM_SUMULTI 3
- CTSU_CFG_MAJORITY_MODE 2

Mode and element num	Self-capacitance 1 element	+ 1 element	Mutual capacitance 1 element	+1 element
ROM	4827 bytes	+8 bytes	5142 bytes	+8 bytes
RAM	465 bytes	+49 bytes	507 bytes	+79 bytes

2.9 Arguments

The following are the structures and enums used as arguments of the API functions. Many of the parameters used in the API functions are defined by the enums, which provides a way to check types and reduce errors.

These structures and enums are defined inr_ctsu_qe.h, r_ctsu_qe_api.h.

Table 1 shows the ctsu_ctrl_t structures (control structures). For information about the data types used in this structure r_ctsu_qe see .h. Manage the measurement settings and measurement results for each touch interface configuration. By using QE for Capacitive Touch, the variables of the control structure according to the touch interface configuration are output to qe_touch_config.c, so set them as the first argument of the API of this module.

Table 1 ctsu_ctrl_t Structure

Data Type	Member	Description
uint32_t	open	Open flag
volatile ctsu_state_t	state	Measurement state
ctsu_cap_t	cap	Measurement trigger
ctsu_md_t	md	Measurement mode
ctsu_tuning_t	tuning	Initial offset tuning flag
uint16_t	num_elements	Number of elements
uint16_t	wr_index	Index of the CTSUWR interrupt
uint16_t	rd_index	Index of the CTSURD interrupt
uint8_t *	p_element_complete_flag	Pointer to the flag indicating the completion of offset tuning for the element
int32_t *	p_tuning_diff	Pointer to the difference from the target value
uint16_t	average	Number of moving average operations
uint16_t	num_moving_average	Number of samples used for moving average operation
uint8_t	ctsucr1	CTSUCR1 setting
ctsu_ctsuwr_t *	p_ctsuwr	CTSUWR setting
ctsu_self_buf_t *	p_self_raw	Pointer to the self-capacitance raw value buffer
uint16_t *	p_self_corr	Pointer to the self-capacitance corrected value buffer
uint16_t *	p_self_mfc	Pointer to the self-capacitance multi-clock corrected value buffer
ctsu_data_t *	p_self_data	Pointer to the self-capacitance measurement value buffer
ctsu_mutual_buf_t *	p_mutual_raw	Pointer to the mutual-capacitance raw value buffer
uint16_t *	p_mutual_pri_corr	Pointer to the mutual-capacitance primary corrected value buffer
uint16_t *	p_mutual_snd_corr	Pointer to the mutual-capacitance secondary corrected value buffer
uint16_t *	p_mutual_pri_mfc	Pointer to the mutual-capacitance primary multi-clock corrected value buffer
uint16_t *	p_mutual_snd_mfc	Pointer to the mutual-capacitance secondary multi-clock corrected value buffer
ctsu_data_t *	p_mutual_pri_data	Pointer to the mutual-capacitance primary measurement value buffer
ctsu_data_t *	p_mutual_snd_data	Pointer to the mutual-capacitance secondary measurement value buffer
ctsu_correction_info_t *	p_correction_info	Pointer to the correction information
ctsu_txvsel_t	txvsel	TXVSEL setting
ctsu_txvsel2_t	txvsel2	TXVSEL2 setting
uint8_t	ctsuchac0	CHAC0 setting
uint8_t	ctsuchac1	CHAC1 setting
uint8_t	ctsuchac2	CHAC2 setting
uint8_t	ctsuchac3	CHAC3 setting

Data Type	Member	Description
uint8_t	ctsuchac4	CHAC4 setting
uint8_t	ctsuchtrc0	CHTRC0 setting
uint8_t	ctsuchtrc1	CHTRC1 setting
uint8_t	ctsuchtrc2	CHTRC2 setting
uint8_t	ctsuchtrc3	CHTRC3 setting
uint8_t	ctsuchtrc4	CHTRC4 setting
uint16_t	self_elem_index	Index of the self-capacitance element
uint16_t	mutual_elem_index	Index of the mutual-capacitance element
uint16_t	ctsu_elem_index	Element index
ctsu_cfg_t const *	p_ctsu_cfg	Pointer to the configuration structure
void	(* p_callback) (ctsu_callback_args_t *)	Pointer to the callback function
uint8_t	interrupt_reverse_flag	Flag for indicating reversal of the order of interrupts
ctsu_event_t	error_status	Error state
ctsu_callback_args_t *	p_callback_memory	Callback function stored (for TrustZone)
void const *	p_context	Context pointer
bool	serial_tuning_enable	Flag for enabling serial tuning
uint16_t	serial_tuning_mutual_cnt	Serial tuning
uint16_t	tuning_self_target_value	Target value for self-capacitance offset tuning
uint16_t	tuning_mutual_target_value	Target value for mutual-capacitance offset tuning
uint8_t	tsod	TSOD setting
uint8_t	mec_ts	TS pin number to be used for MEC
uint8_t	mec_shield_ts	TS pin number to be used for MEC shield
CTSU_CFG_DIAG_SUPPORT_ENABLE == 1		
ctsu_diag_info_t *	p_diag_info	Pointer to the diagnostic information
BSP_FEATURE_CTSU_VERSION == 2		
uint8_t *	p_frequency_complete_flag	Pointer to the flag for indicating the completion of offset tuning for a multi-clock scan
uint8_t *	p_selected_freq_self	Pointer to the selected frequency number (self-capacitance)
uint8_t *	p_selected_freq_mutual	Pointer to the selected frequency number (mutual-capacitance)
ctsu_range_t	range	Current range
uint8_t	ctsucr2	CTSUCR2 setting
(BSP_FEATURE_CTSU_VERSION == 2 && CTSU_CFG_AUTO_JUDGE_ENABLE == 1)		
ctsu_auto_judge_t *	p_auto_judge	Pointer to the auto judgement information
uint32_t	adress_auto_judge	Address of p_auto_judge
uint32_t	adress_ctsuwr	Address of p_ctsuwr
uint32_t	adress_self_raw	Address of p_self_raw
uint32_t	adress_mutual_raw	Address of p_mutual_raw
uint32_t	count_auto_judge	Number of DTC transfers in auto judgement
uint32_t	count_ctsuwr_self_mutual	Number of CTSUWR interrupts in auto judgement
uint8_t	blini_flag	BLINI setting flag
uint8_t	ajmmat	AJMMAT setting
uint8_t	ajbmat	AJBMAT setting
(BSP_FEATURE_CTSU_VERSION == 2 && CTSU_CFG_AUTO_MULTI_CLOCK_CORRECTION_ENABLE == 1)		
uint32_t	p_mcact1	Pointer to MCACT1 settings
uint32_t	p_mcact2	Pointer to MCACT2 settings
uint8_t	mcact_flag	Automatic Frequency Correction Setting Flag

Table 2 shows the ctsu_cfg_t structure (config structure).

By using QE for Capacitive Touch, variables according to the touch interface configuration are output to "qe_touch_config.c", so set it as the second argument of "R_CTSU_Open()". The configuration value is assumed to be set by "Smart Configurator" or "QE for Capacitive Touch", and this software does not check for errors to improve processing efficiency. Be careful if you want to modify the configs manually.

Table 2 ctsu_cfg_t Structure

Data Type	Member Name	Description	Range of the Value
ctsu_cap_t	cap	Selects the CTSU scan start trigger.	CTSU_CAP_SOFTWARE: software trigger. CTSU_CAP_EXTERNAL: external trigger.
ctsu_txvsel_t	txvsel	Selects the transmission power.	CTSU_TXVSEL_VCC: VCC is selected. CTSU_TXVSEL_INTERNAL_POWER: VDD is selected.
ctsu_txvsel2_t	txvsel2	Selects the transmission power 2. (only for CTSU2)	CTSU_TXVSEL_MODE: Power is selected by the TXVSEL setting. CTSU_TXVSEL_VCC_PRIVATE: Dedicated VCC is selected.
ctsu_atune1_t	atune1	Adjusts the power capability. (only for CTSU)	CTSU_ATUNE1_NORMAL: Normal output CTSU_ATUNE1_HIGH: Large-current output
ctsu_atune12_t	atune12	Adjusts the power capability. (only for CTSU2)	CTSU_ATUNE12_80UA：80uA mode CTSU_ATUNE12_40UA：40uA mode CTSU_ATUNE12_20UA：20uA mode CTSU_ATUNE12_160UA：160uA mode
ctsu_md_t	md	Selects the CTSU measurement mode.	CTSU_MODE_SELF_MULTI_SCAN: Self multi-scan mode CTSU_MODE_MUTUAL_FULL_SCAN: Mutual full-scan mode CTSU_MODE_MUTUAL_CFC_SCAN: Mutual simultaneous scan mode (only for CTSU2) CTSU_MODE_CURRENT_SCAN: Current-scan mode (only for CTSU2) CTSU_MODE_CORRECTION_SCAN: Correction scan mode (only for CTSU2) CTSU_MODE_DIAGNOSIS_SCAN: Diagnosis scan mode
ctsu_posel_t	posel	Selects the output from non-measurement pins.	CTSU_POSEL_LOW_GPIO: Low level is output (GPIO). CTSU_POSEL_HI_Z: Hi-Z state CTSU_POSEL_LOW: Low level is output (TXVSEL or TXVSEL2 setting) CTSU_POSEL_SAME_PULSE: In-phase (transmission) pulses are output (TXVSEL or TXVSEL2 setting)
uint8_t	tsod	Selects measurement or fixed output from the TS pins.	0: Electrostatic capacitance measurement mode 1: A fixed level (high or low) is output from the TS pins.
uint8_t	mec_ts	TS pin number to be used for the MEC function	0 to 35
uint8_t	mec_shield_ts	TS pin number of the active shield to be used for the MEC function	0 to 35
uint8_t	tlot	Number of consecutive judgements of a value exceeding the low threshold in auto judgement	0 to 255
uint8_t	thot	Number of consecutive judgements of a value exceeding the high threshold in auto judgement	0 to 255

Data Type	Member Name	Description	Range of the Value
uint8_t	jc	Criteria for auto judgement	0: Touch-ON is detected when the result of judgement is that the high threshold has been exceeded once. 1: Touch-ON is detected when the result of judgement is that the high threshold has been exceeded twice. 2: Touch-ON is detected when the result of judgement is that the high threshold has been exceeded three times. 3: Touch-ON is detected when the result of judgement is that the high threshold has been exceeded four times.
uint8_t	ajmmat	Number of moving average operations for the measurement values in auto judgement	0 to 11 (2^ set value)
uint8_t	ajbmat	Number of average calculations for the baseline values in auto judgement	0 to 15 (2^ (set value + 1). 0 indicates that updating of the baseline value is stopped.)
uint8_t	mtucfen	Calculation of mutual capacitance in auto judgement	0: No subtraction 1: The first measurement value is subtracted from the second measurement value.
uint8_t	ajfen	Enables or disables auto judgement.	0: Auto judgement is disabled. 1: Auto judgement is enabled.
uint8_t	autojudge_monitor_num	QE monitoring configuration number for auto judgement	0 to 7
uint8_t	ctsuchac0	Mask for enabling TS00 to TS07	0x00 to 0xFF
uint8_t	ctsuchac1	Mask for enabling TS08 to TS15	0x00 to 0xFF
uint8_t	ctsuchac2	Mask for enabling TS16 to TS23	0x00 to 0xFF
uint8_t	ctsuchac3	Mask for enabling TS24 to TS31	0x00 to 0xFF
uint8_t	ctsuchac4	Mask for enabling TS32 to TS39	0x00 to 0xFF
uint8_t	ctsuchtrc0	Mask for mutual-capacitance transmission TS00 to TS07	0x00 to 0xFF
uint8_t	ctsuchtrc1	Mask for mutual-capacitance transmission TS08 to TS15	0x00 to 0xFF
uint8_t	ctsuchtrc2	Mask for mutual-capacitance transmission TS16 to TS23	0x00 to 0xFF
uint8_t	ctsuchtrc3	Mask for mutual-capacitance transmission TS24 to TS31	0x00 to 0xFF
uint8_t	ctsuchtrc4	Mask for mutual-capacitance transmission TS32 to TS39	0x00 to 0xFF
ctsu_element_cfg_t *	p_elements	Element configuration pointer	—
uint8_t	num_rx	Number of receiving pins	0 to 36
uint8_t	num_tx	Number of transmitting pins	0 to 36
uint16_t	num_moving_average	Number of moving average operations for measured data	0 to 65535
bool	tunning_enable	Initial offset tuning flag	true: Enable false: Disable
void *	p_callback	CTSUFN interrupt callback	—
void *	p_context	Context pointer	—

Data Type	Member Name	Description	Range of the Value
void *	p_extend	Extended configuration pointer	—
uint16_t	tuning_self_target_value	Target value of self-capacitance initial offset	0 to 65535
uint16_t	tuning_mutual_target_value	Target value of mutual-capacitance initial offset	0 to 65535
ctsu_auto_button_cfg_t *	p_ctsu_auto_buttons	Pointer to the array of button settings for use in auto judgement	—

The followings are the enums used for the above listed structures.

```
/** CTSU Events for callback function */
typedef enum e_ctsu_event
{
    CTSU_EVENT_SCAN_COMPLETE = 0x00,   ///< Normal end
    CTSU_EVENT_OVERFLOW      = 0x01,   ///< Sensor counter overflow (CTSUST.CTSUSOVF set)
    CTSU_EVENT_ICOMP         = 0x02,   ///< Abnormal TSCAP voltage (CTSUERRS.CTSUICOMP set)
    CTSU_EVENT_ICOMP1        = 0x04    ///< Abnormal sensor current (CTSUSR.ICOMP1 set)
} ctsu_event_t;

/** CTSU Scan Start Trigger Select */
typedef enum e_ctsu_cap
{
    CTSU_CAP_SOFTWARE,               ///< Scan start by software trigger
    CTSU_CAP_EXTERNAL                ///< Scan start by external trigger
} ctsu_cap_t;

/** CTSU Transmission Power Supply Select */
typedef enum e_ctsu_txvsel
{
    CTSU_TXVSEL_VCC,                 ///< VCC selected
    CTSU_TXVSEL_INTERNAL_POWER        ///< Internal logic power supply selected
} ctsu_txvsel_t;

/** CTSU Transmission Power Supply Select 2 (CTSU2 Only) */
typedef enum e_ctsu_txvsel2
{
    CTSU_TXVSEL_MODE,                ///< Follow TXVSEL setting
    CTSU_TXVSEL_VCC_PRIVATE,          ///< VCC private selected
} ctsu_txvsel2_t;

/** CTSU Power Supply Capacity Adjustment (CTSU Only) */
typedef enum e_ctsu_atune1
{
    CTSU_ATUNE1_NORMAL,              ///< Normal output (40uA)
    CTSU_ATUNE1_HIGH                ///< High-current output (80uA)
} ctsu_atune1_t;

/** CTSU Power Supply Capacity Adjustment (CTSU2 Only) */
typedef enum e_ctsu_atune12
{
    CTSU_ATUNE12_80UA,               ///< High-current output (80uA)
    CTSU_ATUNE12_40UA,               ///< Normal output (40uA)
    CTSU_ATUNE12_20UA,               ///< Low-current output (20uA)
    CTSU_ATUNE12_160UA               ///< Very high-current output (160uA)
} ctsu_atune12_t;

/** CTSU Measurement Mode Select */
typedef enum e_ctsu_mode
{
    CTSU_MODE_SELF_MULTI_SCAN  = 1,    ///< Self-capacitance multi scan mode
    CTSU_MODE_MUTUAL_FULL_SCAN = 3,    ///< Mutual capacitance full scan mode
    CTSU_MODE_MUTUAL_CFC_SCAN  = 7,    ///< Mutual capacitance cfc scan mode (CTSU2 Only)
    CTSU_MODE_CURRENT_SCAN     = 9,    ///< Current scan mode (CTSU2 Only)
    CTSU_MODE_CORRECTION_SCAN  = 17,   ///< Correction scan mode (CTSU2 Only)
    CTSU_MODE_DIAGNOSIS_SCAN   = 33    ///< Diagnosis scan mode
} ctsu_md_t;

/** CTSU Non-Measured Channel Output Select (CTSU2 Only) */
typedef enum e_ctsu_posel
{
```

```
    CTSU_POSEL_LOW_GPIO,             ///< Output low through GPIO
    CTSU_POSEL_HI_Z,                ///< Hi-Z
    CTSU_POSEL_LOW,                 ///< Output low through the power setting by the TXVSEL[1:0] bits
    CTSU_POSEL_SAME_PULSE            ///< Same phase pulse output as transmission channel through the
power setting by the TXVSEL[1:0] bits
} ctsu_posel_t;

/** CTSU Spectrum Diffusion Frequency Division Setting (CTSU Only) */
typedef enum e_ctsu_ssdiv
{
    CTSU_SSDIV_4000,                ///< 4.00 <= Base clock frequency (MHz)
    CTSU_SSDIV_2000,                ///< 2.00 <= Base clock frequency (MHz) < 4.00
    CTSU_SSDIV_1330,                ///< 1.33 <= Base clock frequency (MHz) < 2.00
    CTSU_SSDIV_1000,                ///< 1.00 <= Base clock frequency (MHz) < 1.33
    CTSU_SSDIV_0800,                ///< 0.80 <= Base clock frequency (MHz) < 1.00
    CTSU_SSDIV_0670,                ///< 0.67 <= Base clock frequency (MHz) < 0.80
    CTSU_SSDIV_0570,                ///< 0.57 <= Base clock frequency (MHz) < 0.67
    CTSU_SSDIV_0500,                ///< 0.50 <= Base clock frequency (MHz) < 0.57
    CTSU_SSDIV_0440,                ///< 0.44 <= Base clock frequency (MHz) < 0.50
    CTSU_SSDIV_0400,                ///< 0.40 <= Base clock frequency (MHz) < 0.44
    CTSU_SSDIV_0360,                ///< 0.36 <= Base clock frequency (MHz) < 0.40
    CTSU_SSDIV_0330,                ///< 0.33 <= Base clock frequency (MHz) < 0.36
    CTSU_SSDIV_0310,                ///< 0.31 <= Base clock frequency (MHz) < 0.33
    CTSU_SSDIV_0290,                ///< 0.29 <= Base clock frequency (MHz) < 0.31
    CTSU_SSDIV_0270,                ///< 0.27 <= Base clock frequency (MHz) < 0.29
    CTSU_SSDIV_0000                 ///< 0.00 <= Base clock frequency (MHz) < 0.27
} ctsu_ssdiv_t;

/** CTSU select data type for slect data get */
typedef enum e_ctsu_specific_data_type
{
    CTSU_SPECIFIC_RAW_DATA,
    CTSU_SPECIFIC_CORRECTION_DATA,
    CTSU_SPECIFIC_SELECTED_FREQ,
} ctsu_specific_data_type_t;

/** Callback function parameter data */
typedef struct st_ctsu_callback_args
{
    ctsu_event_t event;              ///< The event can be used to identify what caused the callback.
    void const * p_context;          ///< Placeholder for user data. Set in ctsu_api_t::open function
in ::ctsu_cfg_t.
} ctsu_callback_args_t;

/** CTSU Control block. Allocate an instance specific control block to pass into the API calls.
 * @par Implemented as
 * - ctsu_instance_ctrl_t
 */
typedef void ctsu_ctrl_t;

/** CTSU Configuration parameters. */
/** Element Configuration */
typedef struct st_ctsu_element
{
    ctsu_ssdiv_t ssdiv;              ///< CTSU Spectrum Diffusion Frequency Division Setting (CTSU
Only)
    uint16_t    so;                 ///< CTSU Sensor Offset Adjustment
    uint8_t     snum;               ///< CTSU Measurement Count Setting
    uint8_t     sdpa;               ///< CTSU Base Clock Setting
} ctsu_element_cfg_t;

/** Configration of each automatic judgement button */
typedef struct st_ctsu_auto_button_cfg
{
    uint8_t  elem_index;             ///< Element number used by this button fo automatic judgement.
    uint16_t threshold;              ///< Touch/non-touch judgement threshold for automatic
judgement.
    uint16_t hysteresis;             ///< Threshold hysteresis for chattering prevention for
automatic judgement.
} ctsu_auto_button_cfg_t;
```

2.10 Return Values

The following provides return values for the API functions. The enum is defined in fsp_common_api.h.

```
/** Common error codes */
typedef enum e_fsp_err
{
   FSP_SUCCESS = 0,

   FSP_ERR_ASSERTION           = 1,       ///< A critical assertion has failed
   FSP_ERR_INVALID_POINTER      = 2,      ///< Pointer points to invalid memory location
   FSP_ERR_INVALID_ARGUMENT     = 3       ///< Invalid input parameter
   FSP_ERR_INVALID_CHANNEL      = 4,      ///< Selected channel does not exist
   FSP_ERR_INVALID_MODE         = 5,      ///< Unsupported or incorrect mode
   FSP_ERR_UNSUPPORTED          = 6,      ///< Selected mode not supported by this API
   FSP_ERR_NOT_OPEN            = 7,       ///< Requested channel is not configured or API not open
   FSP_ERR_ABORTED             = 18,      ///< An operation was aborted

   /* Start of CTSU Driver specific */
   FSP_ERR_CTSU_SCANNING            = 6000,      ///< Scanning.
   FSP_ERR_CTSU_NOT_GET_DATA         = 6001,     ///< Not processed previous scan data.
   FSP_ERR_CTSU_INCOMPLETE_TUNING    = 6002,     ///< Incomplete initial offset tuning.
   FSP_ERR_CTSU_DIAG_NOT_YET         = 6003,     ///< Diagnosis of data collected no yet.
   FSP_ERR_CTSU_DIAG_LDO_OVER_VOLTAGE = 6004,    ///< Diagnosis of LDO over voltage failed.
   FSP_ERR_CTSU_DIAG_CCO_HIGH        = 6005,     ///< Diagnosis of CCO into 19.2uA failed.
   FSP_ERR_CTSU_DIAG_CCO_LOW         = 6006,     ///< Diagnosis of CCO into 2.4uA failed.
   FSP_ERR_CTSU_DIAG_SSCG           = 6007,      ///< Diagnosis of SSCG frequency failed.
   FSP_ERR_CTSU_DIAG_DAC            = 6008,      ///< Diagnosis of non-touch count value failed.
   FSP_ERR_CTSU_DIAG_OUTPUT_VOLTAGE   = 6009,    ///< Diagnosis of LDO output voltage failed.
   FSP_ERR_CTSU_DIAG_OVER_VOLTAGE     = 6010,    ///< Diagnosis of over voltage detection circuit failed.
   FSP_ERR_CTSU_DIAG_OVER_CURRENT     = 6011,     ///< Diagnosis of over current detection circuit failed.
   FSP_ERR_CTSU_DIAG_LOAD_RESISTANCE  = 6012,     ///< Diagnosis of LDO internal resistance value failed.
   FSP_ERR_CTSU_DIAG_CURRENT_SOURCE   = 6013,     ///< Diagnosis of Current source value failed.
   FSP_ERR_CTSU_DIAG_SENSCLK_GAIN     = 6014,     ///< Diagnosis of SENSCLK frequency gain failed.
   FSP_ERR_CTSU_DIAG_SUCLK_GAIN      = 6015,      ///< Diagnosis of SUCLK frequency gain failed.
   FSP_ERR_CTSU_DIAG_CLOCK_RECOVERY   = 6016,     ///< Diagnosis of SUCLK clock recovery function failed.
   FSP_ERR_CTSU_DIAG_CFC_GAIN        = 6017,      ///< Diagnosis of CFC oscillator gain failed.
} fsp_err_t;
```

2.11 Callback function

This FIT module calls the registered callback function when the processing of the measurement completion interrupt is completed. Set it to the member p_callback of the config structure. It has already been set in the output code of QE. It can also be set with R_CTSU_CallbackSet (). Please refer to 3.4.

The callback function should be provided by the application. When the tuning result is output using QE, the sample code of the callback function below is also output. The output function changes depending on the software judgment and the automatic judgment. If both configurations are present, both are output.

Software Judgement

```
void qe_touch_callback(touch_callback_args_t * p_args)
{
    g_qe_touch_flag = 1;
    g_qe_ctsu_event = p_args -> event;
}
```

Automatic Judgement

```
void qe_ctsu_auto_callback(ctsu_callback_args_t * p_args)
{
    g_qe_touch_flag = 1;
    g_qe_ctsu_event = p_args -> event;
}
```

As shown below, it is assumed that g_qe_touch_flag is polled between R_CTSU_ScanStart() and R_CTSU_DataGet().

```
R_CTSU_ScanStart(g_qe_ctsu_instance.p_ctrl);

while (0 == g_qe_touch_flag) {}
g_qe_touch_flag = 0;

R_CTSU_DataGet(g_qe_ctsu_instance.p_ctrl, &data);
```

For information about the arguments of the callback function, see the ctsu_callback_arg_t in Chapter 2.9. touch_call_back_arg_t is a typedef of ctsu_callback_arg_t in the Touch module. As explained in Chapter 1.1.8, you can check whether there is an error in the measurement by using the structure member event.

2.12 Adding the FIT Module to Your Project

2.12.1 Adding source tree and project include paths

This module must be added to each project in which it is used. Renesas recommends using “Smart Configurator” described in (1) or (3). However, “Smart Configurator” only supports some RX devices. Please use the methods of (2) or (4) for unsupported RX devices.

(1) Adding the FIT module to your project using “Smart Configurator” in e2 studio
By using the “Smart Configurator” in e2 studio, the FIT module is automatically added to your project. Refer to “Renesas e2 studio Smart Configurator User Guide (R20AN0451)” for details.

(2) Adding the FIT module to your project using “FIT Configurator” in e2 studio
By using the “FIT Configurator” in e2 studio, the FIT module is automatically added to your project. Refer to “Adding Firmware Integration Technology Modules to Projects (R01AN1723)” for details.

(3) Adding the FIT module to your project using “Smart Configurator” on CS+
By using the “Smart Configurator Standalone version” in CS+, the FIT module is automatically added to your project. Refer to “Renesas e2 studio Smart Configurator User Guide (R20AN0451)” for details.

(4) Adding the FIT module to your project in CS+
In CS+, please manually add the FIT module to your project. Refer to “Adding Firmware Integration Technology Modules to CS+ Projects (R01AN1826)” for details.

2.12.2 Setting driver options when not using Smart Configurator

The Touch-specific options are found and edited in r_config¥r_touch_qe_config.h.

2.13 IEC 60730 Compliance

This module complies with both R.1 (IEC 60335-1) and software class B (IEC 60730-1). For the latest information on the support status, refer to the web page Functional Safety Solutions for Home Appliances (IEC/UL 60730).

3. API Functions

3.1 R_CTSU_Open

This function initializes the module and must be executed before using any of the other API functions. Please execute this function for each touch interface configuration.

Format

```
fsp_err_t R_CTSU_Open (ctsu_ctrl_t * const p_ctrl,
                       ctsu_cfg_t const * const p_cfg)
```

Parameters

p_ctrl	[in] Pointer to the control structure
p_cfg	[in] Pointer to the config structure

Return Values

FSP_SUCCESS	*/* Successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_ALREADY_OPEN	*/* Open() is called without calling Close() */*
FSP_ERR_INVALID_ARGUMENT	*/* Configuration parameters are invalid */*

Properties

Prototype is declared in r_ctsu_api.h

Description

This function enables control structure initialization, register initialization, and interrupt setting according to the argument p_cfg.
Also, the correction coefficient generation process is executed while processing the first touch interface structure. The process takes approximately 120ms.
The DTC is initialized if CTSU_CFG_DTC_SUPPORT_ENABLE is enabled when the first touch interface configuration is processed.

Example

```
fsp_err_t err;

/* Initialize pins (function created by Smart Configurator) */
R_CTSU_PinSetInit();

/* Initialize the API. */
err = R_CTSU_Open(&g_ctsu_ctrl, &g_ctsu_cfg);

/* Check for errors. */
if (err != FSP_SUCCESS)
{
    . . .
}
```

Special Notes:

The port must be initialized before calling this function. We recommend using the R_CTSU_PinSetInit() function generated by SmartConfigurator as the port initialization function.
When the touch interface configuration is in diagnosis mode, execute the R_CTSU_Open () of the other touch interface configuration first.

3.2 R_CTSU_ScanStart

This function starts measurement of the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_ScanStart (ctsu_ctrl_t * const p_ctrl)
```

Parameters

p_ctrl [in] Pointer to the control structure

Return Values

FSP_SUCCESS	*/* Successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_SCANNING	*/* Now scanning */*
FSP_ERR_CTSU_NOT_GET_DATA	*/* Did not obtain previous results */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

When a software trigger occurs, this function sets and starts the measurement based on the touch interface configuration. With an external trigger, the function sets the measurement and goes to the trigger wait state.
If CTSU_CFG_DTC_SUPPORT_ENABLE is enabled, the function also sets the DTC.
The resulting value is notified in the callback generated from the INTCTSUFN interrupt handler.
When using the automatic judgement function, the measurement settings are initialized when this function is called for the first time after offset tuning is completed.

Example

```
fsp_err_t err;

/* Initiate a sensor scan by software trigger */
err = R_CTSU_ScanStart(&g_ctsu_ctrl);

/* Check for errors. */
if (err != FSP_SUCCESS)
{
    . . .
}
```

Special Notes:

None

3.3 R_CTSU_DataGet

This function reads all the values previously measured in the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_DataGet (ctsu_ctrl_t * const p_ctrl, uint16_t * p_data)
```

Parameters

p_ctrl	[in] Pointer to the control structure
p_data	[out] Pointer to the buffer that stores the measured value.

Return Values

FSP_SUCCESS	*/* CTSU initialization successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_SCANNING	*/* Scanning */*
FSP_ERR_CTSU_INCOMPLETE_TUNING	*/* Tuning initial offset */*
FSP_ERR_ABORTED	*/* Operate error of ADC data collection */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function reads all previously measured values into the specified buffer(p_data).
CTSU1: The value passed through sensor CCO correction and moving average.
CTSU2L JMM: The value passed through sensor CCO correction and moving average.
CTSU2L VMM: Sensor passed through sensor CCO correction, frequency correction and moving average.
The required buffer size varies depending on the measurement mode. Prepare the number of TS for the self-capacitance and current measurement modes, and twice the number of matrixes for the mutual-capacitance mode. In the case of CTSU2 JMM, data of 3 frequencies is stored, so prepare 3 times more.
The value measured in the temperature correction mode is not stored. When RTRIM adjustment is performed, the RTRIM value is stored. At this time, the ADC settings have been changed in this function, so perform the process to return to the ADC settings you are using. Otherwise, store 0xFFFF.
When initial offset adjustment is on, FSP_ERR_CTSU_INCOMPLETE_TUNING is returned several times until the adjustment is complete. Measured values are not stored in the buffer at this time. For more details on initial offset adjustment, refer to section 1.1.6.

Example:

```
fsp_err_t err;
uint16_t buf[CTSU_CFG_NUM_SELF_ELEMENTS];

/* Get all sensor values */
err = R_CTSU_DataGet(&g_ctsu_ctrl, buf);
```

Special Notes:

None

3.4 R_CTSU_CallbackSet

This function sets the function specified for the measurement completion callback function.

Format

```
fsp_err_t R_CTSU_CallbackSet (ctsu_ctrl_t * const p_api_ctrl,
                              void (* p_callback)(ctsu_callback_args_t *),
                              void const * const p_context,
                              ctsu_callback_args_t * const p_callback_memory)
```

Parameters

p_api_ctrl [in] Pointer to the control structure

p_callback [in] Pointer to callback function

p_context [in] Pointer to send to callback function

p_callback_memory [in] Set to NULL

Return Values

FSP_SUCCESS	*/* Successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function sets the function specified for the measurement completion callback function. By default, the callback function is set to the function of member p_callback of ctsu_cfg_t, so use it when you want to change to another function during operation.

You can also set the context pointer. If not used, set p_context to NULL. Set p_callback_memory to NULL.

Example:

```
fsp_err_t err;

/* Set callback function */
err = R_CTSU_CallbackSet(&g_ctsu_ctrl, ctsu_callback, NULL, NULL);
```

Special Notes:

None

3.5 R_CTSU_Close

This function closes the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_Close (ctsu_ctrl_t * const p_ctrl)
```

Parameters

p_ctrl [in] Pointer to the control structure

Return Values

FSP_SUCCESS */* Successfully completed */*

FSP_ERR_ASSERTION */* Argument pointer not specified */*

FSP_ERR_NOT_OPEN */* Called without calling Open() */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function closes the specified touch interface configuration.

Example:

```
fsp_err_t err;

/* Shut down peripheral and close driver */
err = R_CTSU_Close(&g_ctsu_ctrl);
```

Special Notes:

None

3.6 R_CTSU_Diagnosis

This is the API function providing the function for diagnosis of the CTSU inner circuit.

Format

```
fsp_err_t R_CTSU_Diagnosis (ctsu_ctrl_t * const p_ctrl)
```

Parameters

p_ctrl [in] Pointer to the control structure

Return Values

FSP_SUCCESS	*/* All diagnoses are success */*
FSP_ERR_ASSERTION	*/* Missing argument pointer */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_NOT_GET_DATA	*/* Not processed previous scan data */*
FSP_ERR_CTSU_DIAG_LDO_OVER_VOLTAGE	*/* Diagnosis of LDO over voltage failed */*
FSP_ERR_CTSU_DIAG_CCO_HIGH	*/* Diagnosis of CCO into 19.2uA failed */*
FSP_ERR_CTSU_DIAG_CCO_LOW	*/* Diagnosis of CCO into 2.4uA failed */*
FSP_ERR_CTSU_DIAG_SSCG	*/* Diagnosis of SSCG frequency failed. */*
FSP_ERR_CTSU_DIAG_DAC	*/* Diagnosis of non-touch count value failed */*
FSP_ERR_CTSU_DIAG_OUTPUT_VOLTAGE	*/* Diagnosis of LDO output voltage failed */*
FSP_ERR_CTSU_DIAG_OVER_VOLTAGE	*/* Diagnosis of over voltage detection circuit failed */*
FSP_ERR_CTSU_DIAG_OVER_CURRENT	*/* Diagnosis of over current detection circuit failed */*
FSP_ERR_CTSU_DIAG_LOAD_RESISTANCE	*/* Diagnosis of LDO internal resistance value failed */*
FSP_ERR_CTSU_DIAG_CURRENT_SOURCE	*/* Diagnosis of Current source value failed */*
FSP_ERR_CTSU_DIAG_SENSCLK_GAIN	*/* Diagnosis of SENSCLK frequency gain failed */*
FSP_ERR_CTSU_DIAG_SUCLK_GAIN	*/* Diagnosis of SUCLK frequency gain failed */*
FSP_ERR_CTSU_DIAG_CLOCK_RECOVERY	*/* Diagnosis of SUCLK clock recovery function failed */*

Properties

Prototyped in file r_ctsu_api.h

Description

This is the API function providing the function for diagnosis of the CTSU inner circuit
Call when the return value of the function R_CTSU_DataGet is FSP_SUCCESS.

Example:

```
fsp_err_t err;
uint16_t  dummy;

/* Open Diagnosis function */
R_CTSU_Open(g_qe_ctsu_instance_diagnosis.p_ctrl, g_qe_ctsu_instance_diagnosis.p_cfg);

/* Scan Diagnosis function */
R_CTSU_ScanStart(g_qe_ctsu_instance_diagnosis.p_ctrl);
while (0 == g_qe_touch_flag) {}
g_qe_touch_flag = 0;

err = R_CTSU_DataGet(g_qe_ctsu_instance_diagnosis.p_ctrl,&dummy);
if (FSP_SUCCESS == err)
{
   err = R_CTSU_Diagnosis(g_qe_ctsu_instance_diagnosis.p_ctrl);
   if ( FSP_SUCCESS  == err )
   {
       /* Diagnosis was succssed. */
   }
}
```

Special Notes:

None.

3.7 R_CTSU_ScanStop

This function stops measuring the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_ScanStop (ctsu_ctrl_t * const p_ctrl)
```

Parameters

p_ctrl [in] Pointer to the control structure

Return Values

FSP_SUCCESS	*/* Successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function stops measuring the specified touch interface configuration.

Example:

```
fsp_err_t err;

/* Stop CTSU module */
err = R_CTSU_ScanStop(&g_ctsu_ctrl);
```

Special Notes:

None

3.8 R_CTSU_SpecificDataGet

This function reads the measurements for the specified data type for the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_SpecificDataGet (ctsu_ctrl_t * const      p_ctrl,
                                  uint16_t               * p_specific_data,
                                  ctsu_specific_data_type_t specific_data_type)
```

Parameters

p_ctrl	[in] Pointer to the control structure
p_specific_data	[out] Pointer to specific data array.
specific_data_type	[in] Specific data type to get

Return Values

FSP_SUCCESS	*/* CTSU initialization successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_SCANNING	*/* Scanning */*
FSP_ERR_CTSU_INCOMPLETE_TUNING	*/* Tuning initial offset */*
FSP_ERR_NOT_ENABLED	*/* Specify unsupported types */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

When CTSU_SPECIFIC_RAW_DATA is set to specific_data_type, the RAW data is stored in p_specific_data. Prepare a buffer that is the number of elements multiplied by the number of elements in CTSU1 and the number of elements multiplied by the number of frequencies in CTSU2.
When CTSU_SPECIFIC_CCO_CORRECTION_DATA is set to specific_data_type, the sensor CCO correction data is stored in p_specific_data. Prepare a buffer that is the number of elements multiplied by the number of elements in CTSU1 and the number of elements multiplied by the number of fequencies in CTSU2.
When CTSU_SPECIFIC_CORRECTION_DATA is set to specific_data_type, the p_specific_data stores multi-clock correction data. Only the VMM of CTSU2 is valid. Prepare a buffer for the elements.
When CTSU_SPECIFIC_SELECTED _DATA is set specific_data_type, p_specific_data contains a bitmap of the frequencies used in the majority vote. The first frequency corresponds to bit 0, the second frequency corresponds to bit 1, and the third frequency corresponds to bit 2. For example, if the first and third frequencies were used, store the 0x05. Only the VMM of CTSU2 is valid.

Example:

```
fsp_err_t err;
uint16_t specific_data[CTSU_CFG_NUM_SELF_ELEMENTS * CTSU_CFG_NUM_SUMULTI]

/* Get Specific Data */
err = R_CTSU_SpecificDataGet(&g_ctsu_ctrl, &specific_data[0],
CTSU_SPECIFIC_RAW_DATA );
```

Special Notes:

When the specific_data_type is set to something other than CTSU_SPECIFIC_RAW_DATA, execute this API after calling R_CTSU_DataGet().

3.9 R_CTSU_DataInsert

This function inserts the specified data in buffer of touch measurement results for the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_DataInsert (ctsu_ctrl_t * const p_ctrl,
                             uint16_t * p_insert_data)
```

Parameters

p_ctrl	[in] Pointer to the control structure
p_insert_data	[in] Pointer to insert data array.

Return Values

FSP_SUCCESS	*/* CTSU initialization successfully completed */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_SCANNING	*/* scanning */*
FSP_ERR_CTSU_INCOMPLETE_TUNING	*/*Tuning initial offset */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function is supposed to process the data acquired by R_CTSU_SpecificDataGet () in the user application, such as noise suppression, and store the data in this function. Set the start address of the data array to be stored in p_insert_data. The data is stored in the measurement buffer. (p_ctrl->p_self_data for self-capacitance mode, p_ctrl->p_mutual_pri_data and p_crtl->p_mutual_snd_data for mutual-capacitance)

Example:

```
fsp_err_t err;
uint16_t specific_data[CTSU_CFG_NUM_SELF_ELEMENTS * CTSU_CFG_NUM_SUMULTI]

/* Get Specific Data */
err = R_CTSU_DataGet(&g_ctsu_ctrl, &specific_data[0],
CTSU_SPECIFIC_CORRECTION_DATA);

/* Noise filter process */

/* Insert data */
err = R_CTSU_DataInsert(&g_ctsu_ctrl, &specific_data[0]);
```

Special Notes:

None

3.10 R_CTSU_OffsetTuning

This function adjusts the offset register (SO) for the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_OffsetTuning (ctsu_ctrl_t * const p_ctrl);
```

Parameters

p_ctrl [in] Pointer to the control structure

Return Values

FSP_SUCCESS	*/* CTSU successfully configured */*
FSP_ERR_ASSERTION	*/* Argument pointer not specified */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_SCANNING	*/* Scanning */*
FSP_ERR_CTSU_INCOMPLETE_TUNING	*/* Initial offset tuning in progress */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function adjusts the offset using all the previously measured values. Call this function after the measurement is complete. Execute this function once, it returns FSP_ERR_CTSU_INCOMPLETE_TUNING until the offset adjustment is completed. Return FSP_SUCCESS when the offset adjustment is complete. Repeat the measurement and this function call until the offset adjustment is completed. See Chapter 1.1.4 for offset adjustment.

If automatic judgement is enabled, set the baseline initialization bit flag after offset adjustment is complete.

Example:

```
fsp_err_t err;
err = R_CTSU_ScanStart (g_qe_ctsu_instance_config01.p_ctrl);
while (0 == g_qe_touch_flag) {}
g_qe_touch_flag = 0;
err = R_CTSU_OffsetTuning (g_qe_ctsu_instance_config01.p_ctrl);
```

Special Notes:

None

3.11 R_CTSU_AutoJudgementDataGet

This function gets the result of the automatic judgement button for the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_AutoJudgementDataGet (ctsu_ctrl_t * const p_ctrl,
                                       uint64_t * p_button_status)
```

Parameters

p_ctrl	[in] Pointer to the control structure
p_button_status	[out] Pointer to a buffer that stores the button status

Return Values

FSP_SUCCESS	*/* CTSU successfully configured */*
FSP_ERR_ASSERTION	*/* Null pointer passed as a parameter */*
FSP_ERR_NOT_OPEN	*/* Called without calling Open() */*
FSP_ERR_CTSU_SCANNING	*/* Scanning this instance */*
FSP_ERR_INVALID_MODE	*/* The mode of automatic judgement off is invalid */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function gets the result of the automatic judgement button. Call this function after the measurement is completed. The result is a 64-bit bitmap, stored in the order of TS numbers for the specified touch interface configuration.

When this function is called for the first time after offset tuning is completed, it is set to start the baseline mean calculation.

Example:

```
fsp_err_t err;
uint64_t button_status;

/* Open CTSU Driver  */
err = R_CTSU_Open (&g_ctsu_ctrl, &g_ctsu_cfg);

/* Initial Offset Tuning */
while (true)
{
   err = R_CTSU_ScanStart (&g_ctsu_ctrl);
   while (0 == g_qe_touch_flag) {}
   g_qe_touch_flag = 0;

   err = R_CTSU_OffsetTuning (&g_ctsu_ctrl);
}

/* Main loop */
while (true)
{
   /* for [CONFIG01] configuration */
   err = R_CTSU_ScanStart (&g_ctsu_ctrl);
   while (0 == g_qe_touch_flag) {}
   g_qe_touch_flag = 0;

   /* Get all sensor values */
   err = R_CTSU_AutoJudgementDataGet(&g_ctsu_ctrl, &button_status);
}
```

Special Notes:

This function is only supported by CTSU2SL.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Oct.04.18	—	First edition issued
1.10	Jul.09.19	1 3-5 9,12 21-22 8, 10-14 1,14	Added RX23W support. Added definitions for “correction” and “offset tuning”. Updated API return values. Added CTSU_CMD_GET_METHOD_MODE and CTSU_CMD_GET_SCAN_INFO Control() commands. Added #pragma section macros and configuration option to driver for Safety Module support (includes GCC/IAR support). Added IEC 60730 Compliance section.
1.11	Jan.09.20	4,5 26,27 — —	Added definition for “baseline” (Touch layer). Added CTSU_CMD_SNOOZE_ENABLE and CTSU_CMD_SNOOZE_DISABLE Control() commands. Fixed bug where a custom callback function was called twice after a scan completes. Fixed compile error for RX231 when PLL had multiplier of 13.5.
2.00	Jul.30.21	-	Full-fledged revision
2.01	Dec.17.21	4	Added description to 1.1.4 Initial offset adjustment
		5	Added description to 1.1.6 multi-measurement frequency (CTSU2L)
		6	Added description to 1.1.7 shield function (CTSU2L)
		9	Added description to 1.2.4 temperature compensation mode (CTSU2L)
		10	Added API to 1.4 API overview
		14	Fixed 2.8 Code size
		15~18	Update to 2.9 Arguments
		28	Added description to 3.6 R_CTSU_Diagnosis
		31~32	Create a new 3.8 R_CTSU_SpecificDataGet
		33	Create a new 3.9 R_CTSU_DataInset
2.10	Apr.20.22	3	Add content to the overview
		7	Added 1.1.11 MEC function (CTSU2SL)
		7	Added 1.1.12 Automatic judgment function (CTSU2SL)
		7,8,9	Added 1.1.13 Automatic function (CTSU2SL)
		16	Added contents to 2.7 Compile settings
		19,20	Added content to 2.9 Argument
		37	Added 3.10 R_CTSU_OffsetTuning
		38	Added 3.11R_CTSU_AutoJudgmentDataGet
2.20	Dec.28.22	3	Update 1 Overview
		7	Added to 1.1.10 Diagnosis Function
		12	Replaced figure at 1.2.1 Self-capacitance Mode
		14	Added to 1.2.4 Temperature Compensation Mode (CTSU2L)
		16	Updated 2.2 Software Requirements
		16	Updated 2.3 Supported Toolchains
		19	Updated 2.8 Code Size
		24	Updated 2.9 Arguments
		29	Updated 2.10 Return Value
3.00	Oct.15.24	1	Added RX260/RX261 support.
		3	Updated 1 Overview. Added CTSU2SLa
		4	Updated 1.1.4 Default target value (CTSU2L)
		5~7	Added 1.1.6 Majority Judgement Mode(JMM/VMM)

			Updated Figure 4
		10	Added 1.1.13 Automatic Frequency Correction (CTSU2SLa)
		17	Updated 2.1 Hardware Requirements
		17	Updated 2.2 Software Requirements
		17	Updated 2.3 Supported Toolchains
		18	Updated 2.7 Compilation Settings
		20	Updated 2.8 Code Size
		21	Updated 2.9 Arguments
		32	Updated 3.3 R_CTSU_DataGet
		37	Updated 3.8 R_CTSU_SpecificDataGet
3.10	Feb.19.25	5	Updated 1.1.5 Random Pulse Frequency Measurement (CTSU1)
		10	Updated 1.1.14 Automatic Judgement (CTSU2SL)
		17	Updated 2.2 Software Requirements
		17	Updated 2.3 Supported Toolchains
		18	Updated 2.7 Compilation Settings
		20	Updated 2.8 Code Size
		21	Updated 2.9 Arguments
3.11	Mar.21.25	-	Updated with changes to disclaimer comment in code file. No changes to the content of this APN.
3.20	Jul.31.25	16	Added Description to 1.4 API Overview
		17	Updated 2.2 Software Requirements
		17	Updated 2.3 Supported Toolchains
		20	Updated 2.8 Code Size
		28	Added 2.11 Callback function
		30 - 40	Added input and output information to API function arguments.

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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