RL78 Family

CTSU Module Software Integration System

Introduction

This application note describes the CTSU Module.

Target Device

RL78/G23 Group

When using this application note with an MCU other than that specified here, adjust the contents to meet the specifications of your target MCU and fully evaluate before using the CTSU module.

Related Documents

RL78 Family TOUCH Module (R11AN0485)

Contents

1. Overview

The CTSU module is a CTSU2L driver for the Touch Module. The CTSU module is configured assuming access via the Touch middleware layer, but can also be accessed from the user application.

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 terminals 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 (ELCL).

As the measurement process is carried out by the CTSU2L peripheral, it does not use up main processor processing time.

The CTSU module processes 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 ICO Correction function

The CTSU2L peripheral has a built-in correction circuit to handle the potential microvariations related to the manufacturing process of the sensor ICO MCU.

The module temporarily transitions to the correction process during initialization after power is turned on. In the correction process, the correction circuit is used to generate a correction coefficient (factor) to ensure accurate sensor measurement values.

When temperature correction is enabled, an external resistor connected to a TS terminal 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 ICO.

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 ICO dynamic range.

This module automatically 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.

This function can be turned off in the configuration settings.

Default target value

Mode	Default target value
Self-capacitance	15360 (37.5%)
Self-capacitance using active shield	6144 (15%)
Mutual-capacitance	10240 (20%)

The percentage is for the CCO's input limit. 100% is the measured value 40960.The default target value is based on 256us.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

・CTSU2 (Self-capacitance mode)

Target value	Target value (multi frequency)	CTSUSNUM	Measurement time
7680	15360 (128us + 128us)	0x7	128us
15360	30720 (256us + 256us)	0xF	256us
3840	7680 (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. When setting STCLK to other than 0.5MHz because the CTSU clock is not an integer, follow the hardware manual for the measurement time.

1.1.5 Multi-frequency Measurements

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

With the default settings, the module takes measurements at three different frequencies. After standardizing the results obtained at the three frequencies in accordance with the first frequency reference value, the measured value is determined based on majority in a process referred to as “normalization.”

The user can get the data before the majority decision. The user can also use this data for your own noise filtering. If the processed data is written back to the module buffer, it can be judged by the TOUCH module. See Chapters 3.9 and 3.10 for details.

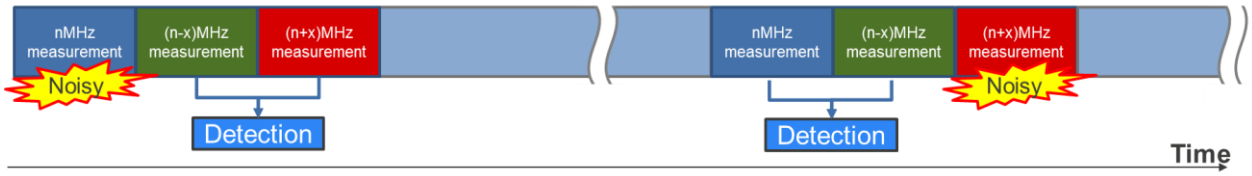

Figure 1 Multi-frequency Measurements

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

Drive frequency is calculated in the following equation:

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

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

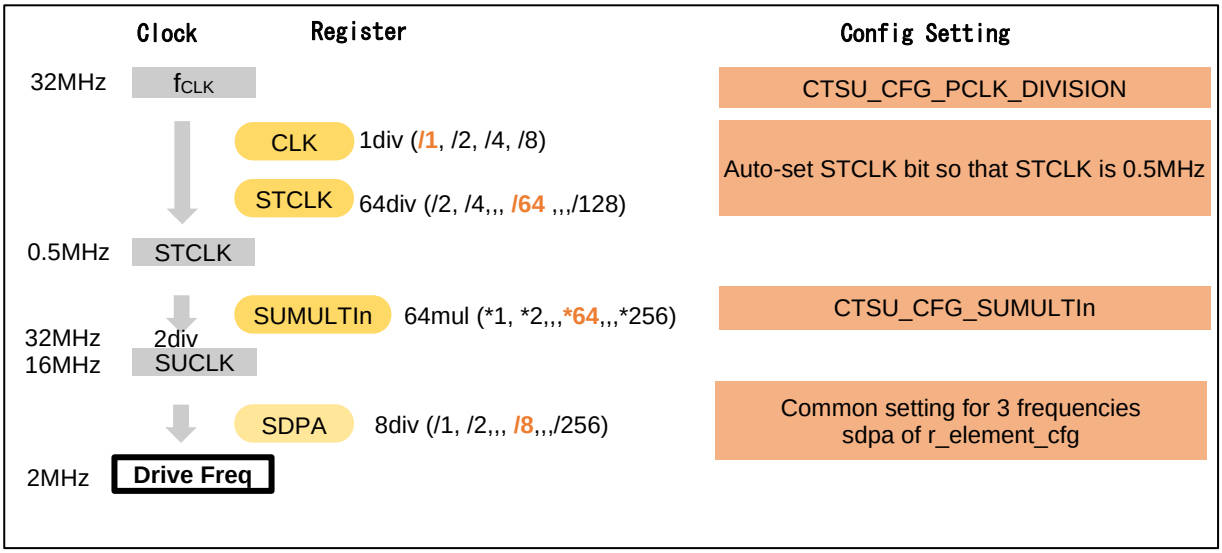

Figure 2 Drive Frequency Settings

1.1.6 Shield Function

The CTSU2L peripheral has a built-in function that outputs a shield signal in phase with the drive pulse from the shield terminal and the non-measurement terminal 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, 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,
```

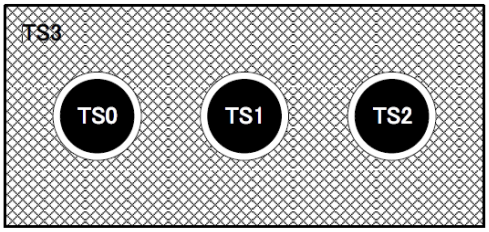

Figure 3 Example of Shield Electrode Structure

1.1.7 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.

1.1.8 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.

1.1.9 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 provides 9 types for CTSU2L.

The diagnosis function is executed by calling the API function. This is executed independently from the other measurements and does not affect them.

To enable the diagnosis function, set CTSU_CFG_DIAG_SUPPORT_ENABLE to 1.

For CTSU2L, use ADC.

1.1.10 Automatic judgment measurement using SMS

This function uses SMS to operate from measurement to touch judgment without CPU operation. Since the CPU operates only in STOP mode and SNOOZE mode, it can measure with low power consumption. Only external trigger setting and DTC setting is supported. Please use 32-bit interval timer with f_{sxp} selected for the external trigger.

For the touch interface for which you want to use this function, please call R_CTSU_SmsSet () and then start measurement with R_CTSU_ScanStart (). It is recommended to execute after the initial offset adjustment is completed.

Every time the CTSU peripheral measures with an external trigger and reads the result, SMS performs the processing equivalent to R_CTSU_DataGet () and the touch judgment processing.

When touch ON is determined, an INTSMSE interrupt is occurred and the same callback function as for normal measurement is called and cancel the SMS measurement setting. At that time the application can get the measurement result by calling R_CTSU_DataGet () as in the normal operation.

When using this function, SMS cannot be used for other processing of the system.

To enable this function, set the measurement setting by external trigger and CTSU_CFG_DTC_SUPPORT_ENABLE to 1 and CTSU_CFG_SMS_SUPPORT_ENABLE to 1. Since DTC repeat transmission is used, the lower 8 bits of the variable specified in the repeat area must be 00H. Therefore, set the address of the RAM area and the address where the lower 8 bits are 00H in CTSU_CFG_SMS_TRANSFER_ADDRESS and CTSU_CFG_SMS_CTSUWR_ADDRESS. Variables placed in CTSU_CFG_SMS_TRANSFER_ADDRESS use 544 bytes. The variable placed in CTSU_CFG_SMS_CTSUWR_ADDRESS uses (4 * number of elements * number of multi-frequency). For example, 36 bytes are used for 3 frequency measurement with 3 self-capacity buttons.

To tuning with the QE for Capacitive Touch, set CTSU_CFG_SMS_TRANSFER_ADDRESS to value other than 0xFEF00 to 0xFC800, and CTSU_CFG_SMS_CTSUWR_ADDRESS to value other than 0xFF200 to 0xFCB00.

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 terminal (TS).

The CTSU2L peripheral measures the terminals 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].

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

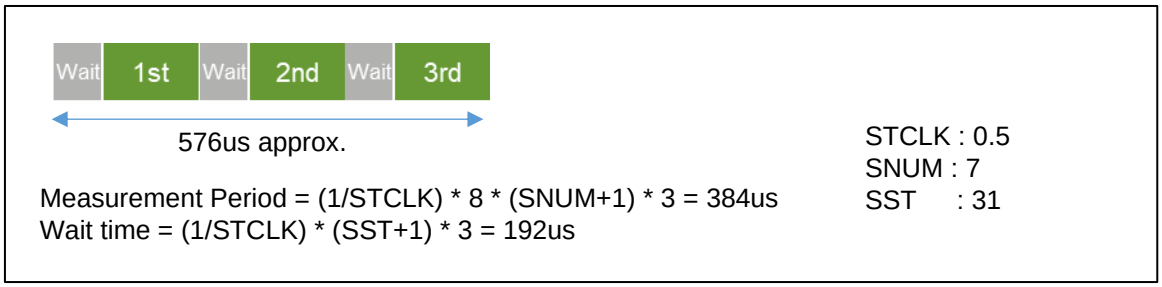

Figure 4 Self-capacitance Measurement Period

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 terminals.

The CTSU2L peripheral measures all specified combinations of Rx and Tx. For example, when Rx is TS1 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. Therefore, the measurement period for one electrode under the default settings is approximately 1152us.

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.

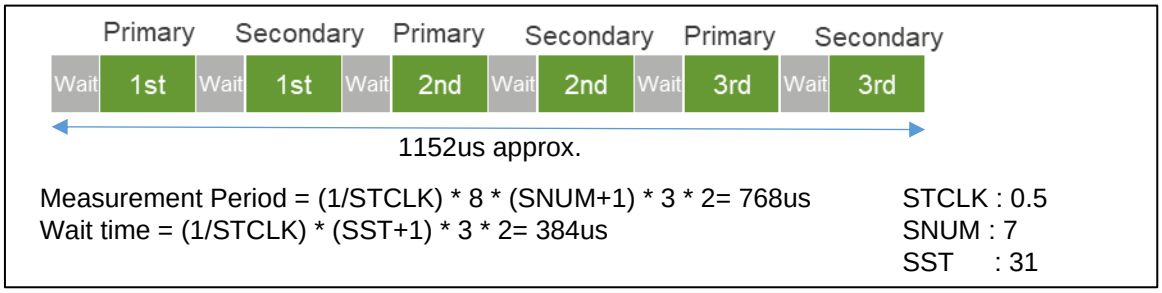

Figure 5 Mutual Capacitance Measurement Period

1.2.3 Current Measurement Mode

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

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.

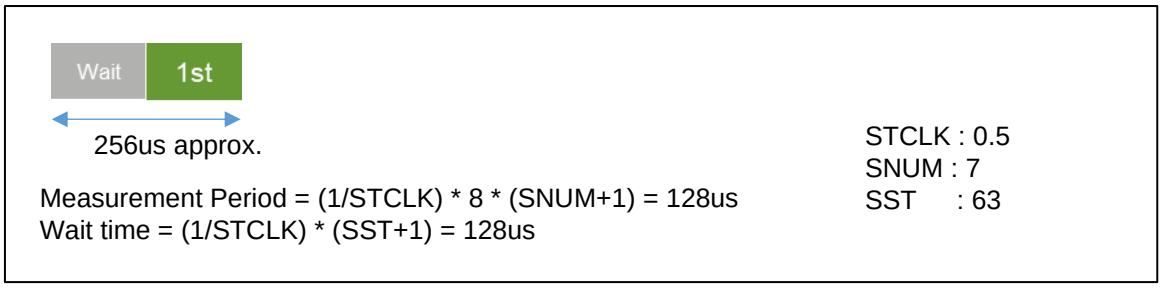

Figure 6 Current Measurement Period

1.2.4 Temperature Correction Mode

The temperature correction mode is used to periodically update the correction coefficient using an external resistor connected to a TS terminal. This involves three processes as described below. Also refer to the timing chart in Figure 7.

1. Measure the correction circuit. One set comprises twelve measurements.

2. Measure the current when TSCAP voltage is applied to the external resistor to create a correction coefficient based on an external resistor that does not depend on temperature. Execute the next measurement after the previous measurement set is completed (as described in step 1).

3. Flow offset current to the external resistor and measure the voltage with the ADC. This will adjust the RTRIM register and handle the temperature drift of the internal reference resistor. In the config settings, set the number of times step 2 should be executed before carrying out this measurement.

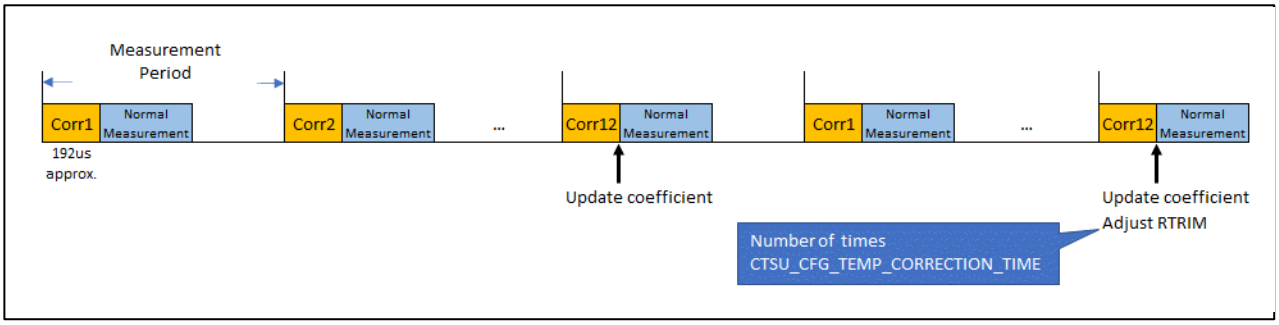

Figure 7 Temperature Correction Measurement Timing Chart

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 1.1.9.

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 (ELCL).

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

The CTSU module includes the following functions.

Function	Description
R_CTSU_Open()	Initializes the specified touch interface configuration.
R_CTSU_StartScan()	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_SmsSet()	Makes settings for automatic judgment measurement using SMS of the specified touch interface configuration.
R_CTSU_Close()	Closes specified touch interface configuration.
R_CTSU_Diagnosis()	Executes diagnosis.
R_CTSU_StartStop()	Stops measurement of the 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.

2. API Information

Operations of this module has been confirmed under the following conditions.

2.1 Hardware Requirements

The MCU used in the development must support the following function.

- CTSU2L

2.2 Software Requirements

This driver depends on the following module:

- Board support package (r_bsp) v1.13 or newer

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

- Code generator DTC v1.00 or newer

Finally, the driver assumes use of the capacitive touch sensor development support tool:

- QE for Capacitive Touch V2.0.0 or newer, recommended V3.0.2 or newer

2.3 Supported Toolchains

Module operations have been confirmed on the following toolchains

- Renesas CC-RL Toolchain v1.11.00
- IAR Embedded Workbench for Renesas RL78 v4.21.1
- LLVM for RL78 10.0.0.202203

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_api.h”.

Select “r_ctsu_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. "1": Omit parameter check process from code. "2": Include parameter check process in code. "BSP_CFG_PARAM_CHECKING_ENABLE": Selection depends on BSP setting.
CTSU_CFG_USE_DTC *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_DTC_USE_SC *Default value: "0"	When using DTC, select whether to use the DTC settings of Smart Configurator. "0": DTC setting inside the CTSU module is used. "1": DTC setting in Smart Configurator. Please assign CTSUWR to No.22 and CTSURD to No.23, and set normal mode and 16-bit transfer.
CTSU_CFG_SMS_SUPPORT_ENABLE *Default value: "0"	Select whether to enable the automatic judgment measurement function using SMS.
CTSU_CFG_SMS_TRANSFER_ADDRESS *Default value: "0xFF800"	This is the address setting of the repeat area used for DTC repeat transfer. See Section 1.1.10.
CTSU_CFG_SMS_CTSUWR_ADDRESS *Default value: "0xFFB00"	This is the address setting of the repeat area used for DTC repeat transfer. See Section 1.1.10.
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 3 (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 3 (low).
CTSU_CFG_INTCTSUFN_PRIORITY_LEVEL *Default value: 2	Sets the CTSUFN interrupt priority level. The priority level range is from 0 (high) to 3 (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.	
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_LOW_VOLTAGE_MODE	Enables/disables the low voltage mode. This value is set in the CTSUCRAL register's ATUNE0 bit.
CTSU_CFG_PCLK_DIVISION	Sets the PCLK frequency division rate. This value is set in the CTSUCRAL register's CLK bit.
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-frequency measurements.

CTSU_CFG_SUMULTI0	Sets the multiplication factor for the first frequency in a multi-frequency measurement. Recommended: 0x3F
CTSU_CFG_SUMULTI1	Sets the multiplication factor for the second frequency in a multi-frequency measurement. Recommended: 0x36
CTSU_CFG_SUMULTI2	Sets the multiplication factor for the third frequency in a multi-frequency measurement. Recommended: 0x48
CTSU_CFG_TEMP_CORRECTION_SUPPORT	Enables/disables temperature correction.
CTSU_CFG_TEMP_CORRECTION_TS	Sets the temperature correction terminal 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	Enables/disables RTRIM correction for temperature correction. The ADC must be selected to operate with RTRIM correction enabled.
CTSU_CFG_DIAG_SUPPORT_ENABLE	Enables/disables diagnosis function.

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 the CC-RL C compiler listed in “section 2.3 Supported Toolchains”. The code size varies according to the C compile version and compile options.

This is the value when one self-capacity button is set in the default setting of Smart Configurator. It also includes sample applications generated by the TOUCH module and QE for Capacitive Touch.

ROM and RAM Usage the configuration options with Self-capacitance 1element	
CTSU_CFG_PARAM_CHECKING_ENABLE 0	ROM: 5501 bytes
CTSU_CFG_DTC_SUPPORT_ENABLE 0	RAM: 282 bytes

ROM and RAM Usage Size of each mode, amount of increase by adding elements				
Mode and element num	Self-capacitance 1 element	+ 1 element	Mutual capacitance 1 element	+1 element
ROM	4806 bytes	+28 bytes	5183 bytes	+17 bytes
RAM	274 bytes	+34 bytes	290 bytes	+52 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 in r_ctsu_api.h along with the prototype declaration.

The following is the control structure for the touch interface configuration. This does not need to be set in the application. Using QE for Capacitive Touch allows the variables corresponding to the touch interface configuration to be output by qe_touch_config.c. Make sure to set qe_touch_config.c in the module’s first API argument.

```
typedef struct st_ctsu_instance_ctrl
{
    uint32_t                open;              ///< Whether or not driver is open.
    volatile ctsu_state_t   state;             ///< CTSU run state.
    ctsu_md_t               md;                ///< CTSU Measurement Mode Select(copy from cfg)
    ctsu_tuning_t           tuning;            ///< CTSU Initial offset tuning status.
    uint16_t                num_elements;      ///< Number of elements to scan
    uint16_t                wr_index;          ///< Word index into ctsuwr register array.
    uint16_t                rd_index;          ///< Word index into scan data buffer.
    uint8_t               * p_tuning_count;    ///< Pointer to tuning count of each element. g_ctsu_tuning_count[]
is set by Open API.
    int32_t               * p_tuning_diff;     ///< Pointer to difference from base value of each element.
g_ctsu_tuning_diff[] is set by Open API.
    uint16_t                average;           ///< CTSU Moving average counter.
    uint16_t                num_moving_average; ///< Copy from config by Open API.
    uint8_t                 ctsucr1;           ///< Copy from (atune1 << 3, md << 6) by Open API. CLK, ATUNE0, CSW,
and PON is set by HAL driver.
    ctsu_ctsuwr_t         * p_ctsuwr;          ///< CTSUWR write register value. g_ctsu_ctsuwr[] is set by Open API.
    ctsu_self_buf_t       * p_self_raw;        ///< Pointer to Self raw data. g_ctsu_self_raw[] is set by Open API.
    uint16_t              * p_self_corr;       ///< Pointer to Self correction data. g_ctsu_self_corr[] is set by
Open API.
    uint16_t              * p_self_data;       ///< Pointer to Self moving average data. g_ctsu_self_data[] is set
by Open API.
```

```
      ctsu_mutual_buf_t      * p_mutual_raw;       ///< Pointer to Mutual raw data. g_ctsu_mutual_raw[] is set by Open
API.
      uint16_t               * p_mutual_pri_corr;  ///< Pointer to Mutual primary correction data.
g_ctsu_mutual_pri_corr[] is set by Open API.
      uint16_t               * p_mutual_snd_corr;  ///< Pointer to Mutual secondary correction data.
g_ctsu_mutual_snd_corr[] is set by Open API.
      uint16_t               * p_mutual_pri_data;  ///< Pointer to Mutual primary moving average data.
g_ctsu_mutual_pri_data[] is set by Open API.
      uint16_t               * p_mutual_snd_data;  ///< Pointer to Mutual secondary moving average data.
g_ctsu_mutual_snd_data[] is set by Open API.
      ctsu_correction_info_t * p_correction_info;  ///< Pointer to correction info
      ctsu_txvsel_t            txvsel;             ///< CTSU Transmission Power Supply Select
      ctsu_txvsel2_t           txvsel2;            ///< CTSU Transmission Power Supply Select 2 (CTSU2 Only)
      uint8_t                  ctsuchac0;          ///< TS00-TS07 enable mask
      uint8_t                  ctsuchac1;          ///< TS08-TS15 enable mask
      uint8_t                  ctsuchac2;          ///< TS16-TS23 enable mask
      uint8_t                  ctsuchac3;          ///< TS24-TS31 enable mask
      uint8_t                  ctsuchac4;          ///< TS32-TS39 enable mask
      uint8_t                  ctsuchtrc0;         ///< TS00-TS07 mutual-tx mask
      uint8_t                  ctsuchtrc1;         ///< TS08-TS15 mutual-tx mask
      uint8_t                  ctsuchtrc2;         ///< TS16-TS23 mutual-tx mask
      uint8_t                  ctsuchtrc3;         ///< TS24-TS31 mutual-tx mask
      uint8_t                  ctsuchtrc4;         ///< TS32-TS39 mutual-tx mask
      uint16_t                 self_elem_index;    ///< Self element index
      uint16_t                 mutual_elem_index;  ///< Mutual element index
      uint16_t                 ctsu_elem_index;    ///< CTSU element index
      ctsu_range_t             range;              ///< According to atune12. (20uA : 0, 40uA : 1, 80uA : 2, 160uA : 3)
      uint8_t                  ctsucr2;            ///< Copy from (posel, atune1, md) by Open API. FCMODE and SDPSEL and
LOAD is set by HAL driver.
      uint8_t                  sms;                ///< Whether or not SMS use.
  #if (CTSU_CFG_DIAG_SUPPORT_ENABLE == 1)
      ctsu_diag_info_t       * p_diag_info;        ///< pointer to diagnosis info
  #endif
      ctsu_cfg_t const       * p_ctsu_cfg;         ///< Pointer to initial configurations.
      void (* p_callback)(ctsu_callback_args_t *); ///< Callback provided when a CTSUFN occurs.
      ctsu_event_t             error_status;       ///< Error status variable.
      void const             * p_context;          ///< Placeholder for user data.
      bool     serial_tuning_enable;                ///< Flag of serial tuning status.
      uint16_t serial_tuning_mutual_cnt;            ///< Word index into ctsuwr register array.
      uint16_t tuning_self_target_value;            ///< Target self value for initial offset tuning
      uint16_t tuning_mutual_target_value;          ///< Target mutual value for initial offset tuning
  } ctsu_instance_ctrl_t;
```

The following is the configuration setting structure for the touch interface configuration.

Using QE for Capacitive Touch allows the variables and initialization values corresponding to the touch interface configuration to be output by qe_touch_config.c. Make sure to set qe_touch_config.c in the second argument of R_CTSU_Open().

```
typedef struct st_ctsu_cfg
{
    ctsu_cap_t               cap;                ///< CTSU Scan Start Trigger Select
    ctsu_txvsel_t            txvsel;             ///< CTSU Transmission Power Supply Select
    ctsu_txvsel2_t           txvsel2;            ///< CTSU Transmission Power Supply Select 2
    ctsu_atune12_t           atune12;            ///< CTSU Power Supply Capacity Adjustment
    ctsu_md_t                md;                 ///< CTSU Measurement Mode Select
    ctsu_posel_t             posel;              ///< CTSU Non-Measured Channel Output Select
    uint8_t                  ctsuchac0;          ///< TS00-TS07 enable mask
    uint8_t                  ctsuchac1;          ///< TS08-TS15 enable mask
    uint8_t                  ctsuchac2;          ///< TS16-TS23 enable mask
    uint8_t                  ctsuchac3;          ///< TS24-TS31 enable mask
    uint8_t                  ctsuchac4;          ///< TS32-TS39 enable mask
    uint8_t                  ctsuchtrc0;         ///< TS00-TS07 mutual-tx mask
    uint8_t                  ctsuchtrc1;         ///< TS08-TS15 mutual-tx mask
    uint8_t                  ctsuchtrc2;         ///< TS16-TS23 mutual-tx mask
    uint8_t                  ctsuchtrc3;         ///< TS24-TS31 mutual-tx mask
    uint8_t                  ctsuchtrc4;         ///< TS32-TS39 mutual-tx mask
```

```
      ctsu_element_cfg_t const * p_elements;             ///< Pointer to elements configuration array
      uint8_t                    num_rx;                 ///< Number of receive terminals
      uint8_t                    num_tx;                 ///< Number of transmit terminals
      uint16_t                   num_moving_average;     ///< Number of moving average for measurement data
      uint8_t                    tunning_enable;         ///< Initial offset tuning flag
      uint8_t                    judge_multifreq_disable; ///< Disable to judge multi frequency
      void (* p_callback)(ctsu_callback_args_t * p_args); ///< Callback provided when CTSUFN ISR occurs.
      void const * p_context;                            ///< User defined context passed into callback function.
      void const * p_extend;                             ///< Pointer to extended configuration by instance of
interface.
      uint16_t     tuning_self_target_value;             ///< Target self value for initial offset tuning
      uint16_t     tuning_mutual_target_value;           ///< Target mutual value for initial offset tuning
  } ctsu_cfg_t;
```

The following 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 (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_CURRENT_SCAN     = 9,    ///< Current scan mode
      CTSU_MODE_CORRECTION_SCAN  = 17    ///< Correction 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;

  /** 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;

  /** Element Configuration */
  typedef struct st_ctsu_element
  {
      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;
```

2.10 Return Values

The following provides return values for the API functions. The enum is defined in fsp_common_api.h, along with the API function prototype declaration.

```
 /* Return error codes */
 typedef enum e_fsp_err
 {
    FSP_SUCCESS,
    FSP_ERR_ASSERTION,          ///< A critical assertion has failed
     FSP_ERR_INVALID_POINTER,   ///< Pointer points to invalid memory location
    FSP_ERR_INVALID_ARGUMENT,  ///< Invalid input parameter
    FSP_ERR_NOT_OPEN,           ///< Requested channel is not configured or API not open
    FSP_ERR_ALREADY_OPEN,      ///< Requested channel is already open in a different configuration
    FSP_ERR_NOT_ENABLED,       ///< Requested operation is not enabled
    FSP_ERR_INVALID_STATE,     ///< API or command not valid in the current state
    FSP_ERR_CTSU_SCANNING,         ///< Scanning.
    FSP_ERR_CTSU_NOT_GET_DATA,     ///< Not processed previous scan data.
    FSP_ERR_CTSU_INCOMPLETE_TUNING, ///< Incomplete initial offset tuning.
    FSP_ERR_CTSU_DIAG_NOT_YET,         ///< Diagnosis of data collected no yet.
    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 LDO internal resistance 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.
 } fsp_err_t;
```

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.

Format

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

Parameters

p_ctrl	Pointer to the control structure (normally generated by QE for Capacitive Touch)
p_cfg	Pointer to the config structure (normally generated by QE for Capacitive Touch)

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_USE_DTC 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

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	Pointer to the control structure (normally generated by QE for Capacitive Touch)

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_USE_DTC is enabled, the function also sets the DTC.

The resulting value is notified in the callback generated from the INTCTSUFN interrupt handler.

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	Pointer to the control structure (normally generated by QE for Capacitive Touch)
p_data	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 */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

This function reads all previously measured values into the specified buffer. The required buffer size varies depending on the measurement mode. Prepare twice the number of TS for the self-capacitance and current measurement modes, and twice the number of matrixes for the mutual-capacitance mode. If normalization (majority frequency) is turned off, prepare multiple CTSU_CFG_NUM_SUMULTI terminals for each mode. 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_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 1.1.5. The measured value is the value resulting from the sensor ICO correction, normalization (when on), and moving average processes executed in this function.

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 Pointer to the control structure (normally generated by QE for Capacitive Touch)

p_callback Pointer to callback function

p_context Pointer to send to callback function

p_callback_memory 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_SmsSet

This function makes settings for automatic judgment measurement using SMS of the specified touch interface configuration.

Format

```
fsp_err_t R_CTSU_SmsSet (ctsu_ctrl_t * const p_ctrl,
                         uint16_t * p_threshold,
                         uint16_t * p_hysteresis,
                         uint16_t count_filter)
```

Parameters

p_ctrl	Pointer to the control structure (normally generated by QE for Capacitive Touch)
p_threshold	Pointer to the touch judgement threshold
p_context	Pointer to the touch judgement hysteresis
count_filter	Touch count match filter value (upper 8 bits are for OFF, lower 8 bits are for ON)

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 following: Use the argument setting for touch judgment processing.

- Disable CTSUFN interrupts
- Enable SMS module
- SMS settings
- ELCL setting
- Start SMS

To start automatic judgment measurement, call R_CTSU_ScanStart () for the same touch interface after calling this function. When touch ON is determined, INTSMSE occurs, and the following settings are made in the interrupt handler of the CTSU module.

- Set the measurement status as an argument of the callback function
- Set the measured value as a variable
- Callback function call
- Allow CTSUFN interrupts
- Disable SMS module

Example:

```
fsp_err_t err;
uint16_t threshold[3] = {1000, 1500, 2000};
uint16_t hysteresis[3] = {50, 75, 100};
uint16_t buf[3];

    /* Start SMS measurement */
    err = R_CTSU_SmsSet(&g_ctsu_ctrl, threshold, hysteresis[3], 0x0303);
    err = R_CTSU_ScanStart(&g_ctsu_ctrl);

     __stop();


    err = R_CTSU_DataGet(&g_ctsu_ctrl, buf);
```

Special Notes:

None

3.6 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 Pointer to the control structure (normally generated by QE for Capacitive Touch)

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

3.7 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 Pointer to the control structure (normally, generated by QE for Capacitive Touch)

Return Values

FSP_SUCCESS */* All diagnoses are normal */*

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_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_qe.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

3.8 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 Pointer to the control structure (normally, generated by QE for Capacitive Touch)

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

3.9 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	Pointer to the control structure (normally generated by QE for Capacitive Touch)
p_specific_data	Pointer to specific data array.
specific_data_type	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	*/* CTSU_SPECIFIC_SELECTED_FREQ for CTSU1 */*

Properties

Prototype is declared in r_ctsu_api.h.

Description

When CTSU_SPECIFIC_RAW_DATA is set for specific_data_type, RAW data will be stored in p_specific_data. These are the data before the calculation of the sensor ICO correction in 1.1.3.

When CTSU_SPECIFIC_CORRECTION_DATA is set for specific_data_type, the corrected data is stored in p_specific_data. These are the data after the calculation of the sensor ICO correction in 1.1.3.

In CTSU2, these store the number of data obtained by multiplying the number of channels by the number of multi-frequency.

When CTSU_SPECIFIC_SELECTED_DATA is set for specific_data_type, p_specific_data stores the bitmap of the frequency used by the majority vote. Only valid for CTSU2. For example, store 0x05 if the 1st and 3rd frequencies were used.

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_CORRECTION_DATA);
```

Special Notes:

None

3.10 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	Pointer to the control structure (normally generated by QE for Capacitive Touch)
p_insert_data	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. For self-capacity mode, store in p_ctrl-> p_self_data. For mutual capacity, store in p_ctrl-> p_mutual_pri_data and p_crtl-> p_mutual_snd_data.

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

3.11 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

Pointer to the control structure (normally generated by QE for Capacitive Touch)

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	*/*Tuning initial offset */*

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

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Apr.13.21	-	First edition issued
1.10	Aug.31.21	5	Added 1.1.9 Diagnosis Function
		5	Added 1.1.10 Automatic judgment measurement using SMS
		8	Added 1.2.5 Diagnosis Mode
		9	Updated 1.4 API overview
		11	Updated 2.7 Compilation settings
		13	Updated 2.8 Code size
		13	Updated 2.9 Arguments
		16	Updated 2.10 Return Values
		-	Deleted R_CTSU_VersionGet
		24	Added 3.5 R_CTSU_SmsSet
		27	Added 3.7 R_CTSU_Diagnosis
		29	Added 3.8 R_CTSU_ScanStop
1.11	Jan.18.22	3,4 5 9 10 13 13-14 30-31 31-32	Added 1.1.4 Initial offset adjustment Added 1.1.6 multi-measurement frequency (CTSU2L) Updated 1.4 API overview Updated 2.2 Software Requirements Updated 2.3 Supported Toolchains Updated 2.8 Code size Updated 2.9 Arguments Added 3.8 R_CTSU_SpecificDataGet Added 3.9 R_CTSU_DataInsert
1.20	Apr.20.22	6 4,5 9 33 24	Added 1.1.10 Automatic judgment measurement using SMS Fixed PCLKB to f_{CLK} Updated 1.4 API overview Added 3.11 R_CTSU_OffsetTuning Fixed Example: in 3.5 R_CTSU_SmsSet

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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