

## RX Family

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## QE Touch Module Using Firmware Integration Technology

### Introduction

The QE Touch Module Using Firmware Integration Technology (FIT) is part of the QE for Capacitive Touch tool suite. It provides the capacitive touch API to be used by the main application.

### Target Device

The following is a list of devices that are currently supported by this API:

- RX113 Groups
- RX130 Group
- RX231, RX230 Groups

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

### Related Documents

- Using QE and FIT to Develop Capacitive Touch Applications (R01AN4516EU)
- Firmware Integration Technology User's Manual (R01AN1833EU)
- Board Support Package Firmware Integration Technology Module (R01AN1685EU)
- Adding Firmware Integration Technology Modules to Projects (R01AN1723EU)

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## 1. Overview

The QE Touch FIT module is part of the QE for Capacitive Touch tool suite. Within e2studio, the QE for Capacitive Touch Tool is used to define scan configurations and generate input data and constants used by this module. This module provides the API for the user's application. Transparent to the user, this module relies upon the QE CTSU FIT module for the peripheral driver.

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### 1.1 Features

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Below is a list of the features supported by the QE Touch FIT module.

- All arguments for Open() are generated by the QE for Capacitive Touch tool
- Sensors can be configured for Self or Mutual mode operation
- Buttons, sliders, and wheels are supported
- Scans may begin by a software trigger or an external trigger
- Up to eight scan configurations can be supported in a single application.

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### 1.2 Self Mode

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The driver makes use of the following terminology and definitions when in self-capacitance mode:

#### *Self Mode*

In self-capacitance mode, only one CTSU TS sensor is necessary to functionally operate a touch button/key. A series of these sensors physically aligned can be used to create a **slider**. If the series of sensors are aligned such that they create a circular pattern, this is referred to as a **wheel**.

#### *Scan Order*

In Self mode, the hardware scans the specified number of sensors in ascending order. For example, if sensors 5, 8, 2, 3, and 6 are specified in your application, the hardware will scan them in the order: 2, 3, 5, 6 and 8.

#### *Element*

An element refers to the index of a sensor within the scan order. Using the previous example, sensor number 5 is element 2.

#### *Buffer Contents*

At the lowest level, both the CTSUSC sensor count and CTSURC reference count registers are loaded into the driver buffer for each sensor in the scan configuration. Though the RC is not used, both registers are placed into the buffer for two reasons. 1) Both registers must have their contents read for proper scan operation. 2) This allows for identical processing for both interrupt and DTC operation at a later point. Note, however, that API calls such as R\_TOUCH\_GetData() which access this buffer will load only the sensor values.

#### *Scan Time*

The scanning of sensors occurs in the background by the CTSU peripheral and does not utilize any main processor time. It takes approximately 500us to scan a single sensor. If DTC is not used, an additional 2.2us overhead (system clock 54MHz) is added for the main processor to transfer data to/from registers when each sensor is scanned.

#### *Methods/Scan Configurations*

These terms are used interchangeably. A single method (scan configuration) refers to the set of sensors to be scanned along with what mode they are to be scanned in (Self or Mutual). One to eight methods per application can be defined within the QE for Capacitive Touch tool suite. Typically there is only one method used per application. However, more advanced applications may require different scan configurations to be enabled as different features are enabled within the product, or when a combination of Self and Mutual sensor configurations are present.

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### 1.3 Mutual Mode

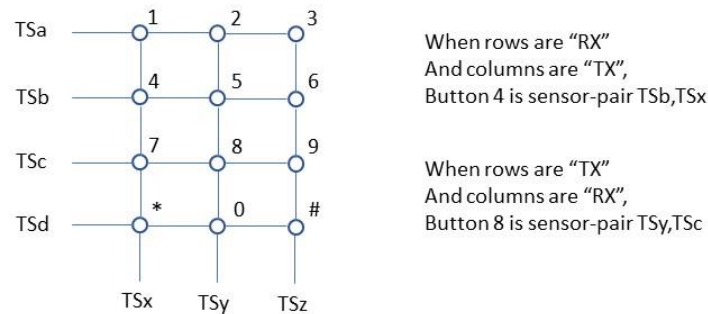
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The driver makes use of the following terminology and definitions when in mutual-capacitance mode:

#### *Mutual Mode*

In mutual-capacitance mode, two CTSU TS sensors are necessary to functionally operate a single touch button/key. This mode is typically used when a matrix/keypad with more than four keys is present. This is because Mutual mode requires fewer sensors to operate than the equivalent in Self mode does.

Consider a standard phone keypad. You can think of it as a matrix of four rows and three columns. One TS sensor is shared for each row, and another sensor is shared for each column. Each button/key is identified by a **sensor-pair**. The RX sensor is always listed first in the pair. (All row or all column sensors are designated as RX, and the others are designated TX. The peripheral scans both the RX and TX sensors in a sensor-pair, subtracts the difference, and the result is used to determine whether a button/key is touched or not.)



As you can see, only seven sensors are necessary to scan 12 buttons. In self mode, 12 sensors are required.

At this time, sliders and wheels are not supported in Mutual mode.

### Scan Order

In Mutual mode, the hardware scans the sensor-pairs in ascending order, with sensors configured as RX being the **primary**, and the sensors configured as TX the **secondary**. For example, if sensors 10, 11, and 3 are specified as RX sensors, and sensors 2, 7, and 4 are specified as TX sensors, the hardware will scan them in the following sensor-pair order:

3,2 - 3,4 - 3,7  
 10,2 - 10,4 - 10,7  
 11,2 - 11,4 - 11,7

### Element

In mutual-capacitance mode, an element refers to the index of a sensor-pair within the scan order. Using the previous example, sensor-pair 10,7 is element 5.

### Buffer Contents

At the lowest level, both the CTSUSC sensor count and CTSURC reference count registers are loaded into the driver buffer for each sensor in a sensor-pair in the scan configuration. Though the RC is not used, both registers are placed into the buffer for two reasons. 1) Both registers must have their contents read for proper scan operation. 2) This allows for identical processing for both interrupt and DTC operation at a later point. Note, however, that API calls such as R\_TOUCH\_GetData() which access this buffer will load only the sensor values.

### Scan Time

The scanning of sensors occurs in the background by the CTSU peripheral and does not utilize any main processor time. It takes approximately 1000us (1ms) to scan a single sensor-pair. If DTC is not used, an additional 4.4us overhead (system clock 54MHz) is added for the main processor to transfer data to/from registers when each sensor-pair is scanned.

### Methods/Configurations

These terms are used interchangeably. A single method (scan configuration) refers to the set of sensors to be scanned along with what mode they are to be scanned in (self or mutual). One to eight methods per application can be defined within the QE for Capacitive Touch Tool. Typically there is only one method used per application. However, more advanced applications may require different scan configurations to be enabled as different features are enabled within the product, or when a combination of Self and Mutual sensor configurations are present.

## 1.4 Trigger Sources

Scanning of sensors may begin by either a software trigger or an external event initiated by the Event Link Controller (ELC). Typically, a software trigger is used.

For software triggers, a periodic timer such as the CMT is configured whose interval is large enough to allow for all sensors to be scanned and data to be updated (see *Scan Time* in sections 1.2 and 1.3). When the timer expires, the following sequence of events occurs:

- A flag is set in the timer interrupt routine
- A slight delay occurs until the main application detects that the flag has been set (red bar in Figure 1).
- Using a Touch Middleware driver, the main application makes an API call to load the scanned data, update internal values (such as moving averages), and issue a software trigger to begin another scan. Using the FIT QE Touch driver, this is done using the API function `R_TOUCH_UpdateDataAndStartScan()`.

### Software Trigger Timing

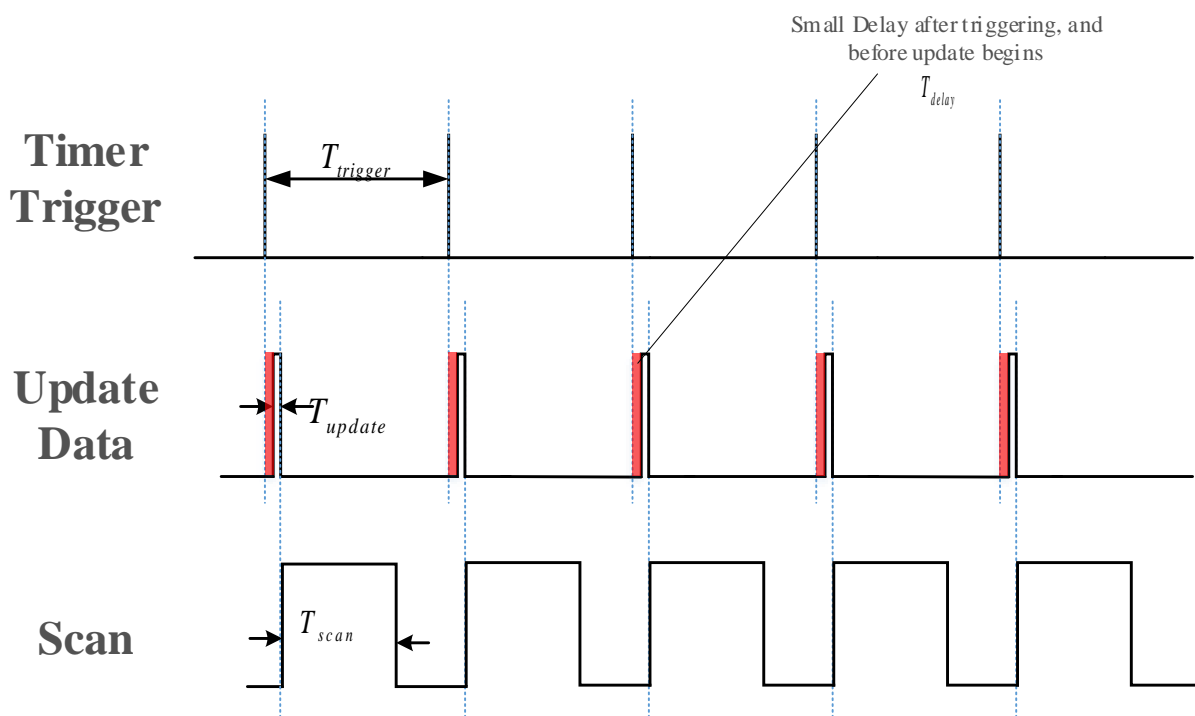


Figure 1: Software Trigger Timing Diagram (timing not to scale)

Using an external trigger is processed almost identically to using software triggers. Typically, a periodic timer such as the MTU is configured whose interval is large enough to allow for all sensors to be scanned and data to be updated (see *Scan Time* in sections 1.2 and 1.3). This timer is then linked to the ELC which in turn is linked to the CTSU. When the timer expires, the following sequence of events occurs:

- The ELC is triggered which triggers the CTSU to start a scan.
- When a scan completes, a flag is set in the CTSU scan-complete interrupt routine
- A slight delay occurs until the main application detects that the flag has been set (red bar in Figure 2.).
- Using a Touch Middleware driver, the main application makes an API call to load the scanned data and update internal values (such as moving averages). Using the FIT QE Touch driver, this is done using the API function `R_TOUCH_UpdateData()`.

## External Trigger Timing

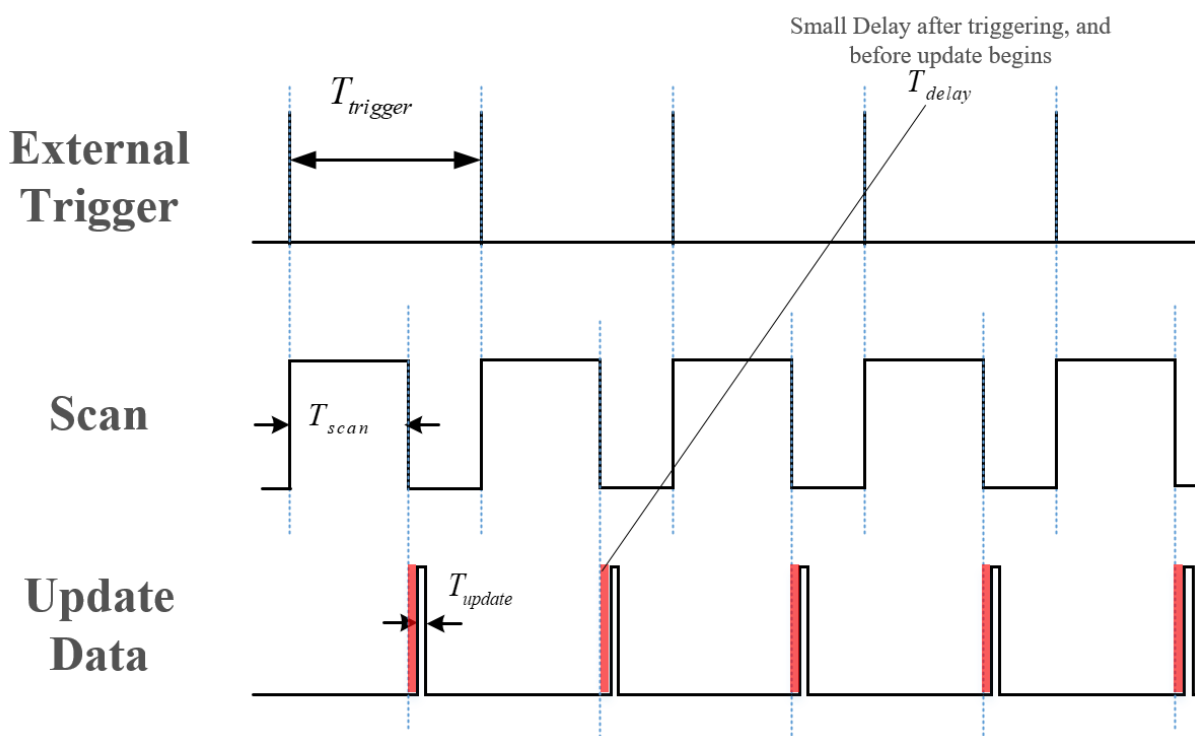


Figure 2: External Trigger Timing Diagram (timing not to scale)

With either trigger mechanism, the time it takes for the main application to detect a flag set in an interrupt routine can vary by a several microseconds with each scan depending upon the user's polling algorithm. Also, the time it takes to update the scanned data can vary by several microseconds depending upon such things as whether a sensor is touched or not (different paths through an else-if statement). In general, these subtle differences are minimal with each scan, and are extremely small compared to overall time spent performing a scan. For these reasons, the majority of users prefer the software triggering mechanism because of its simpler setup. But for those rare cases where a slight variation in scan interval is not acceptable, the external trigger mechanism can be used. **NOTE: DTC cannot be used when external triggers are used.**

## 2. API Information

This Driver API follows the Renesas API naming standards.

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### 2.1 Hardware Requirements

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This driver requires that your MCU supports the following peripheral(s):

- CTSU

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### 2.2 Software Requirements

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This driver is dependent upon the following FIT packages:

- Renesas Board Support Package (r\_bsp) v3.71.
- QE CTSU FIT module (r\_ctsu\_qe) v1.00.

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### 2.3 Limitations

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- This code is not re-entrant and protects against multiple concurrent function calls.

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### 2.4 Supported Toolchains

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This driver is tested and working with the following toolchains:

- Renesas RX Toolchain v2.08.00

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### 2.5 Header Files

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All API calls and their supporting interface definitions are located in “r\_touch\_qe\_if.h”. This file should be included by the user’s application.

Build-time configuration options are selected or defined in the file “r\_touch\_qe\_config.h”.

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### 2.6 Integer Types

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This project uses ANSI C99 “Exact width integer types” in order to make the code clearer and more portable. These types are defined in stdint.h.

## 2.7 Configuration Overview

Configuring this module is done through the supplied `r_touch_qe_config.h` header file. Each configuration item is represented by a macro definition in this file. Each configurable item is detailed in the table below.

<i>Configuration options in <code>r_flash_rx_config.h</code></i>		
Equate	Default Value	Description
<b>TOUCH_CFG_PARAM_CHECKING_ENABLE</b>	1	Setting to 0 omits parameter checking. Setting to 1 includes parameter checking.
<b>TOUCH_CFG_UPDATE_MONITOR</b>	1	Setting to 1 provides data for the monitoring tool to display data. Setting to 0 excludes the code needed for the monitoring tool to display data.

**Table 1: QE Touch general configuration settings**



## 2.8 Code Size

The code size is based on optimization level 2 and optimization type for size for the RXC toolchain in Section 2.4. The ROM (code and constants) and RAM (global data) sizes are determined by the build-time configuration options set in the module configuration header file. Note: The “+” in the table denotes QE generated file usage in addition to driver. RAM usage which varies with number of sensors and how they are configured.

ROM and RAM usage example: 2 button sensors and 4 slider sensors	
<b>ROM usage:</b> <b>TOUCH_PARAM_CHECKING_ENABLE 1 &gt; TOUCH_PARAM_CHECKING_ENABLE 0</b> <b>TOUCH_CFG_UPDATE_MONITOR 1 &gt; TOUCH_CFG_UPDATE_MONITOR 0</b>	
<b>Minimum Size</b>	ROM: 6979 + 447 = 7426 bytes
	RAM: 244 + 433 = 677 bytes
<b>Maximum Size</b>	ROM: 7862 + 447 = 8309 bytes
	RAM: 356 + 433 = 789 bytes

## 2.9 API Data Types

The API data structures are located in the file “r\_typedefs\_qe.h” and discussed in Section 3.

## 2.10 Return Values

This shows the different values API functions can return. This return type is defined in “r\_typedefs\_qe.h”.

```

/* Return error codes */
typedef enum e_qe_err
{
    QE_SUCCESS = 0,
    QE_ERR_NULL_PTR,                // missing argument
    QE_ERR_INVALID_ARG,
    QE_ERR_BUSY,
    QE_ERR_ALREADY_OPEN,
    QE_ERR_CHAN_NOT_FOUND,
    QE_ERR_TUNING_IN_PROGRESS,
    QE_ERR_TRIGGER_TYPE,           // function not available for trigger type
} qe_err_t;

```

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## 2.11 Adding the QE Touch FIT Module to Your Project

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For detailed explanation of how to add a FIT Module to your project, see document R01AN1723EU “Adding FIT Modules to Projects”.

### 2.11.1 Adding source tree and project include paths

In general, a FIT Module may be added in 3 ways:

1. Using an e2studio FIT tool, such as File>New>Renesas FIT Module (prior to v5.3.0), Renesas Views->e2 solutions toolkit->FIT Configurator (v5.3.0 or later), or projects created using the Smart Configurator (v5.3.0 or later). This adds the module and project include paths.
2. Using e2studio File>Import>General>Archive File from the project context menu.
3. Unzipping the .zip file into the project directory directly from Windows.

When using methods 2 or 3, the include paths must be manually added to the project. This is done in e2studio from the project context menu by selecting Properties>C/C++ Build>Settings and selecting Compiler>Source in the ToolSettings tab. The green “+” sign in the box to the right is used to pop a dialog box to add the include paths. In that box, click on the Workspace button and select the directories needed from the project tree structure displayed. The directories needed for this module are:

- \${workspace\_loc}/\${ProjName}/r\_touch\_qe
- \${workspace\_loc}/\${ProjName}/r\_touch\_qe/src
- \${workspace\_loc}/\${ProjName}/r\_config

### 2.11.2 Setting driver options when not using Smart Configurator

The TOUCH-specific options are found and edited in \r\_config\r\_touch\_qe\_config.h.

A reference copy (not for editing) containing the default values for this file is stored in \r\_touch\_qe\ref\r\_touch\_qe\_config\_reference.h.

## 3. API Functions

### 3.1 Summary

The following functions are included in this design:

Function	Description
<b>R_TOUCH_Open()</b>	Initializes the Touch and CTSU layer modules.
<b>R_TOUCH_UpdateDataAndStartScan()</b>	Updates buffers with CTSU data from the scan that just completed and then starts another scan.
<b>R_TOUCH_UpdateData()</b>	Updates buffers with CTSU data from the scan that just completed.
<b>R_TOUCH_Control()</b>	Performs special operations defined by the command passed to it.
<b>R_TOUCH_GetRawData()</b>	Gets the sensor values as scanned by the CTSU (no correction applied)
<b>R_TOUCH_GetData()</b>	Gets the sensor values as scanned by the CTSU after correction is applied.
<b>R_TOUCH_GetAllBtnStates()</b>	This function loads a variable indicating which sensors are pressed.
<b>R_TOUCH_GetSliderPosition()</b>	This function returns the current location of where the slider is being touched (0-100).
<b>R_TOUCH_GetWheelPosition()</b>	This function returns the current location of where the wheel is being touched (1-360).
<b>R_TOUCH_Close()</b>	Shuts down the Touch and CTSU layer modules.
<b>R_CTSU_GetVersion()</b>	Returns software version of driver.

## 3.2 R\_TOUCH\_Open

This function initializes the Touch layer and opens the CTSU.

### Format

```
qe_err_t R_TOUCH_Open(ctsu_cfg_t    *p_ctsu_cfgs[],
                      touch_cfg_tg  *p_touch_cfgs[],
                      uint8_t       num_methods,
                      qe_trig_t     trigger);
```

### Parameters

*p\_ctsu\_cfgs*

Pointer to array of scan configurations for the CTSU driver (gp\_ctsu\_cfgs[ ] generated by the QE for Capacitive Touch tool)

*p\_touch\_cfgs*

Pointer to array of scan configurations for the TOUCH driver (gp\_touch\_cfgs[ ] generated by the QE for Capacitive Touch tool)

*num\_methods*

Number of scan configurations in array (QE\_NUM\_METHODS generated by the QE for Capacitive Touch tool)

*trigger*

Scan trigger source (QE\_TRIG\_SOFTWARE or QE\_TRIG\_EXTERNAL)

### Return Values

*QE\_SUCCESS:* TOUCH API initialized successfully.

*QE\_ERR\_ALREADY\_OPEN:* CTSU is already open.

*QE\_ERR\_NULL\_PTR:* Missing argument pointer.

*QE\_ERR\_INVALID\_ARG:* "num\_methods" or "trigger" is invalid. Note: Configuration array contents are not inspected (generated by tool).

*QE\_ERR\_BUSY:* Cannot run because another CTSU operation is in progress. Likely called Open() before Close() completed.

### Properties

Prototyped in file "r\_touch\_qe\_if.h"

### Description

This function initializes the QE TOUCH FIT module which makes calls to the lower level CTSU FIT module. This includes register initialization, enabling interrupts, and initializing the DTC if configured for operation in "r\_touch\_qe\_config.h".

This function also runs an initial correction algorithm that is used for optimizing the QE Capacitive Touch tuning parameters. This is performed to account for small board-to-board variations as well as any minor environmental or physical differences in the Capacitive Touch application system.

Note that this function must be called before any other Touch API function.

### Reentrant

No.

### Example: Software Triggering

```
void main(void)
{
    qe_err_t    err;
    bool        success;
    uint32_t    cmt_ch;
```

```

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

/* Open Touch driver (opens CTSU driver as well) */
err = R_TOUCH_Open(gp_ctsu_cfgs, gp_touch_cfgs,
                  QE_NUM_METHODS, QE_TRIG_SOFTWARE);
if (err != QE_SUCCESS)
{
    while(1) ;
}

/* Setup scan timer for 20ms (50Hz) */
success = R_CMT_CreatePeriodic(50, qetouch_timer_callback, &cmt_ch);
if (success == false)
{
    while(1) ;
}

/* Main loop */
while(1)
{
    if (g_qetouch_timer_flg == true)
    {
        g_qetouch_timer_flg = false;
        R_TOUCH_UpdateDataAndStartScan();

        /* process data here */
    }
}
}

```

### Example: External Triggering

```

void main(void)
{
    qe_err_t    err;
    elc_err_t   elc_err;
    elc_event_signal_t  ev_signal;
    elc_link_module_t  ev_module;

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

    /* Open Touch driver (opens CTSU driver as well) */
    err = R_TOUCH_Open(gp_ctsu_cfgs, gp_touch_cfgs,
                    QE_NUM_METHODS, QE_TRIG_EXTERNAL);
    if (err != QE_SUCCESS)
    {
        while(1) ;
    }

    /* Setup ELC for MTU timer to trigger CTSU */
    elc_err = R_ELC_Open();
}

```

```

if (elc_err != ELC_SUCCESS)
{
    while(1) ;
}

/* WARNING! Cannot use DTC when using external trigger! */
ev_signal.event_signal = ELC_MTU2_CMP2A;
ev_module.link_module = ELC_CTSU;
elc_err = R_ELC_Set(&ev_signal, &ev_module);
if (elc_err != ELC_SUCCESS)
{
    while(1) ;
}

elc_err = R_ELC_Control(ELC_CMD_START, FIT_NO_PTR);
if (elc_err != ELC_SUCCESS)
{
    while(1) ;
}

/* Setup MTU timer for 20ms (50Hz) */
mtu_timer_chnl_settings_t my_timer_cfg;
mtu_err_t result;

my_timer_cfg.clock_src.source          = MTU_CLK_SRC_INTERNAL;
my_timer_cfg.clock_src.clock_edge      = MTU_CLK_RISING_EDGE;
my_timer_cfg.clear_src                 = MTU_CLR_TIMER_A;
my_timer_cfg.timer_a.actions.do_action =
    (mtu_actions_t)(MTU_ACTION_INTERRUPT | MTU_ACTION_REPEAT);
my_timer_cfg.timer_a.actions.do_action = MTU_ACTION_REPEAT;
my_timer_cfg.timer_a.actions.output    = MTU_PIN_NO_OUTPUT;
my_timer_cfg.timer_a.freq               = 50; // 50 Hz.
my_timer_cfg.timer_b.actions.do_action = MTU_ACTION_NONE;
my_timer_cfg.timer_c.actions.do_action = MTU_ACTION_NONE;
my_timer_cfg.timer_d.actions.do_action = MTU_ACTION_NONE;

result = R_MTU_Timer_Open(MTU_CHANNEL_2, &my_timer_cfg, FIT_NO_FUNC);
result |= R_MTU_Control(MTU_CHANNEL_2, MTU_CMD_START, FIT_NO_PTR);
if (result != MTU_SUCCESS)
{
    while(1) ;
}

/* Main loop */
while(1)
{
    if (g_getouch_timer_flg == true)
    {
        g_getouch_timer_flg = false;
        err = R_TOUCH_UpdateData();

        /* process data here */
    }
}
}

```

**Special Notes:**

Pins must be initialized prior to calling this function.

### 3.3 R\_TOUCH\_UpdateDataAndStartScan

This function is used to process data from the previous scan and start another scan by software trigger.

#### Format

```
qe_err_t R_TOUCH_UpdateDataAndStartScan(void);
```

#### Parameters

None

#### Return Values

*QE\_SUCCESS:* Data from previous scan updated and scan started successfully.

*QE\_ERR\_TRIGGER\_TYPE:* Function called when using external triggers.

*QE\_ERR\_BUSY:* Cannot run because another CTSU operation is in progress. Most likely previous scan still running (lengthen timer interval)

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

This function is used when software triggering is specified at Open(). It should be called each time a periodic timer expires (see Section 3.2 Software Triggering example). The first several calls are used to establish a baseline for the sensors. Once that is complete, normal processing of data occurs. Similarly, when a different method is run, its first several calls to this function are used to establish a baseline for its sensors as well.

After processing CTSU scan data, another scan is initiated. If more than one method/scan configuration is present, the next method is automatically scanned. If a TOUCH\_CMD\_SET\_METHOD Control() command was issued, that method continues to be scanned until another Control() command is issued to change it.

This function must be called prior to calling any “R\_TOUCH\_Get” function to get recent data.

#### Reentrant

No.

#### Example

```
qe_err_t err;

/* Process data from previous scan and initiate another by software trigger */
err = R_TOUCH_UpdateDataAndStartScan();
if (err != QE_SUCCESS)
{
    . . .
}
```

#### Special Notes:

None.



### 3.4 R\_TOUCH\_UpdateData

This function is used to process data from the previous scan.

#### Format

```
qe_err_t R_TOUCH_UpdateData(void);
```

#### Parameters

None.

#### Return Values

<i>QE_SUCCESS:</i>	<i>Data from previous scan is updated.</i>
<i>QE_ERR_TRIGGER_TYPE:</i>	<i>Function called when using software triggers.</i>
<i>QE_ERR_BUSY:</i>	<i>Cannot run because another CTSU operation is in progress. Most likely previous scan still running (lengthen timer interval)</i>

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

This function is used when external triggering is specified at Open(). It should be called each time a scan completes (see Section 3.2 External Triggering example). The first several calls are used to establish a baseline for the sensors. Once that is complete, normal processing of data occurs. Similarly, when a different method is run, its first several calls to this function are used to establish a baseline for its sensors as well.

After processing CTSU scan data, if more than one method/scan configuration is present, the next method is automatically set to be scanned. If a TOUCH\_CMD\_SET\_METHOD Control() command was issued, that method continues to be scanned until another Control() command is issued to change it.

This function must be called prior to calling any “R\_TOUCH\_Get” function to get recent data.

#### Reentrant

No.

#### Example

```
qe_err_t err;

/* Process data from previous scan */
err = R_TOUCH_UpdateData();
if (err != QE_SUCCESS)
{
    . . .
}
```

#### Special Notes:

None.

### 3.5 R\_TOUCH\_Control

This function is used to perform special operations pertaining to the control of the TOUCH driver.

#### Format

```
qe_err_t R_TOUCH_Control(touch_cmd_t cmd, void *p_arg);
```

#### Parameters

*cmd*

Command to perform.

*p\_arg*

Pointer to command-specific argument.

#### Return Values

*QE\_SUCCESS:* Command completed successfully

*QE\_ERR\_INVALID\_ARG:* Command-specific argument is invalid

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

This function is used to perform special operations with the Touch driver. The “cmd” commands are as follows:

**TOUCH\_CMD\_SET\_METHOD.** Used to stop cycling through methods if was previously cycling, and sets the current method to be the only method used for scanning going forward. Equates are defined in “qe\_common.h” and have the form QE\_METHOD\_XXX. The argument “p\_arg” is a uint8\_t pointer to a variable containing the method number to scan.

**TOUCH\_CMD\_CYCLE\_ALL\_METHODS.** Starts cycling through all methods present beginning with the method after the current one. The argument “p\_arg” is unused.

**TOUCH\_CMD\_CYCLE\_METHOD\_LIST.** Starts cycling through specified list of methods only. The argument “p\_arg” points to a structure of type touch\_mlist\_t.

```
typedef struct
{
    uint8_t    num_methods;           // number of methods to scan
    uint8_t    methods[QE_MAX_METHODS]; // methods in scan order
    uint8_t    cur_index;             // (unused by application)
} touch_mlist_t;
```

#### Reentrant

No.

#### Example: TOUCH\_CMD\_SET\_METHOD

```
qe_err_t err;
uint8_t method
uint64_t btn_states1, btn_states2;

. . .

method = QE_METHOD_CONFIG02;
R_TOUCH_Control(TOUCH_CMD_SET_METHOD, &method);

/* Main loop */
while(1)
{
    if (g_getouch_timer_flg == true)
    {
```

```

g_getouch_timer_flg = false;
R_TOUCH_UpdateDataAndStartScan();

/* if currently running method 1 */
if (method == QE_METHOD_CONFIG01)
{
    /* if the ON button is touched, go to method 2 */
    R_TOUCH_GetAllBtnStates(QE_METHOD_CONFIG01, &btn_states1);
    if ((btn_states1 & CONFIG01_MASK_ON) != 0)
    {
        method = QE_METHOD_CONFIG02;
        R_TOUCH_Control(TOUCH_CMD_SET_METHOD, &method);
    }
}

/* else if currently running method 2 */
else if (method == QE_METHOD_CONFIG02)
{
    /* if the OFF button is touched, go to method 1 */
    R_TOUCH_GetAllBtnStates(QE_METHOD_CONFIG02, &btn_states2);
    if ((btn_states2 & CONFIG02_MASK_OFF) != 0)
    {
        method = QE_METHOD_CONFIG01;
        R_TOUCH_Control(TOUCH_CMD_SET_METHOD, &method);
    }
}
}
}

```

**Example: TOUCH\_CMD\_CYCLE\_ALL\_METHODS**

```

/* Resume cycling through all methods present */
R_TOUCH_Control(TOUCH_CMD_CYCLE_ALL_METHODS, NULL);

```

**Example: TOUCH\_CMD\_CYCLE\_METHOD\_LIST**

```

qe_err_t      err;
touch_mlist_t list;

/* Modify to only scan self method "CTRL_BTNS" and mutual method "keypad"
list.num_methods = 2;
list.methods[0] = QE_METHOD_CTRL_BTNS;
list.methods[1] = QE_METHOD_KEYPAD;
err = R_TOUCH_Control(TOUCH_CMD_CYCLE_METHOD_LIST, &list);

```

**Special Notes:**

None.

### 3.6 R\_TOUCH\_GetRawData

This function gets the sensor values as scanned by the CTSU without correction applied.

#### Format

```
qe_err_t R_TOUCH_GetRawData(uint8_t method,
                             uint16_t *p_buf,
                             uint8_t *p_cnt);
```

#### Parameters

*method*

Method from which to get data from.

*p\_buf*

Pointer to buffer to load data into.

*p\_cnt*

Pointer to variable to load number of words loaded into buffer.

#### Return Values

*QE\_SUCCESS:* Sensors values read successfully

*QE\_ERR\_NULL\_PTR:* Missing argument pointer

*QE\_ERR\_INVALID\_ARG:* Method is invalid

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

**WARNING! This function is for advanced users only.**

This function gets data from the most recently successfully completed scan by the CTSU, without correction applied.

#### Reentrant

No.

#### Example: Self Mode

```
qe_err_t err;
uint16_t sensor_buf[PANEL1_NUM_ELEMENTS];
uint8_t cnt;

err = R_TOUCH_GetRawData(QE_METHOD_PANEL1, sensor_buf, &cnt);
```

#### Example: Mutual Mode

```
qe_err_t err;
uint16_t sensor_buf[PANEL1_NUM_ELEMENTS*2];
uint8_t cnt;

err = R_TOUCH_GetRawData(QE_METHOD_PANEL1, sensor_buf, &cnt);
```

#### Special Notes:

None.

### 3.7 R\_TOUCH\_GetData

This function gets the sensor values as scanned by the CTSU with correction applied.

#### Format

```
qe_err_t R_TOUCH_GetData(uint8_t method,
                          uint16_t *p_buf,
                          uint8_t *p_cnt);
```

#### Parameters

*method*

Method from which to get data from.

*p\_buf*

Pointer to buffer to load data into.

*p\_cnt*

Pointer to variable to load number of words loaded into buffer.

#### Return Values

<i>QE_SUCCESS:</i>	<i>Sensors values read successfully</i>
<i>QE_ERR_NULL_PTR:</i>	<i>Missing argument pointer</i>
<i>QE_ERR_INVALID_ARG:</i>	<i>Method is invalid</i>

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

**WARNING! This function is for advanced users only.**

This function gets data from the most recently successfully completed scan by the CTSU, with correction applied.

#### Reentrant

No.

#### Example: Self Mode

```
qe_err_t err;
uint16_t sensor_buf[PANEL1_NUM_ELEMENTS];
uint8_t cnt;

err = R_TOUCH_GetData(QE_METHOD_PANEL1, sensor_buf, &cnt);
```

#### Example: Mutual Mode

```
qe_err_t err;
uint16_t sensor_buf[PANEL1_NUM_ELEMENTS*2];
uint8_t cnt;

err = R_TOUCH_GetData(QE_METHOD_PANEL1, sensor_buf, &cnt);
```

#### Special Notes:

None.

---

### 3.8 R\_TOUCH\_GetAllBtnStates

---

This function is used to get a mask of all buttons touched.

#### Format

```
qe_err_t R_TOUCH_GetAllBtnStates(uint8_t method, uint64_t *p_mask);
```

#### Parameters

*method*

Method from which to get data from.

*p\_mask*

Pointer to variable to load button-touched mask into. Button masks are defined in qe\_<method>.h.

#### Return Values

*QE\_SUCCESS:* Touched button mask loaded successfully

*QE\_ERR\_NULL\_PTR:* Missing argument pointer

*QE\_ERR\_INVALID\_ARG:* Invalid method

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

This function loads the variable pointed to by “p\_mask” with a bitmask of all the buttons touched. Button masks are defined in the QE generated method .h file.

#### Reentrant

No.

#### Example: Method is PANEL2

```
qe_err_t err;  
uint64_t btn_touched_mask;  
  
err = R_TOUCH_GetAllBtnStates(QE_METHOD_PANEL2, &btn_touched_mask);
```

#### Special Notes:

None.

---

### 3.9 R\_TOUCH\_GetSliderPosition

---

This function gets the current location of where a slider is being touched (if at all).

#### Format

```
qe_err_t R_TOUCH_GetSliderPosition(uint16_t slider_id, uint16_t *p_position)
```

#### Parameters

*slider\_id*

ID of slider to inspect. Slider IDs are defined qe\_<method>.h.

*p\_position*

Pointer to variable to load the slider position into. The position ranges from 0-100, low to high. A value of 65535 indicates the slider is not touched.

#### Return Values

<i>QE_SUCCESS:</i>	<i>Slider position read successfully</i>
<i>QE_ERR_NULL_PTR:</i>	<i>Missing argument pointer</i>
<i>QE_ERR_INVALID_ARG:</i>	<i>Slider ID is invalid</i>

#### Properties

Prototyped in file “r\_touch\_qe\_if.h”

#### Description

This function returns the current location of where the slider is being touched.

#### Reentrant

No.

#### Example: Method is PANEL1. Slider is DIMMER.

```
qe_err_t err;  
uint16_t slider_position;  
  
err = R_TOUCH_GetSliderPosition(PANEL1_ID_DIMMER, &slider_position);
```

#### Special Notes:

None.

### 3.10 R\_TOUCH\_GetWheelPosition

This function gets the current location of where a wheel is being touched (if at all).

#### Format

```
qe_err_t R_TOUCH_GetWheelPosition(uint16_t wheel_id, uint16_t *p_position);
```

#### Parameters

*wheel\_id*

ID of wheel to inspect. Wheel IDs are defined qe\_<method>.h.

*p\_position*

Pointer to variable to load the wheel position into. Position ranges from 1 to 360 degrees. 65535 implies wheel is not being touched.

#### Return Values

*QE\_SUCCESS:* Wheel position read successfully

*QE\_ERR\_NULL\_PTR:* Missing argument pointer

*QE\_ERR\_INVALID\_ARG:* Wheel ID is invalid

#### Properties

Prototyped in file "r\_touch\_qe\_if.h"

#### Description

This function returns the current location of where the wheel is being touched.

#### Reentrant

No.

#### Example: Method is PANEL2. Wheel is SERVO.

```
qe_err_t err;  
uint16_t wheel_position;  
  
err = R_TOUCH_GetWheelPosition(PANEL2_ID_SERVO, &wheel_position);
```

#### Special Notes:

None.



---

### 3.11 R\_TOUCH\_Close

---

This function closes the Capacitive Touch drivers at both the Touch and CTSU levels.

**Format**

```
qe_err_t R_CTSU_Close(void);
```

**Parameters**

None.

**Return Values**

*QE\_SUCCESS: The CTSU peripheral is successfully closed.*

*QE\_ERR\_BUSY: Cannot run because another CTSU operation is in progress.*

**Properties**

Prototyped in file “r\_touch\_qe\_if.h”

**Description**

This function closes the Touch driver as well as the CTSU driver and the peripheral. It disables interrupts associated with the CTSU and disables the clock to the peripheral.

**Reentrant**

No.

**Example:**

```
qe_err_t err;  
  
err = R_TOUCH_Close();
```

**Special Notes:**

None.

---

### 3.12 R\_TOUCH\_GetVersion

---

Returns the current version of the QE TOUCH FIT module.

**Format**

```
uint32_t R_TOUCH_GetVersion(void);
```

**Parameters**

None.

**Return Values**

Version of the CTSU FIT module.

**Properties**

Prototyped in file “r\_touch\_qe\_if.h”

**Description**

This function will return the version of the currently installed QE TOUCH module. The version number is encoded where the top 2 bytes are the major version number and the bottom 2 bytes are the minor version number. For example, Version 4.25 would be returned as 0x00040019.

**Reentrant**

Yes.

**Example**

```
uint32_t cur_version;

/* Get version of installed TOUCH API. */
cur_version = R_TOUCH_GetVersion();

/* Check to make sure version is new enough for this application's use. */
if (MIN_VERSION > cur_version)
{
    /* This QE TOUCH API version is not new enough and does not have XXX feature
       that is needed by this application. Alert user. */
    ...
}
```

**Special Notes:**

This function is specified to be an inline function.

## 4. Demo Projects

Demo projects are complete stand-alone programs. They include function `main()` that utilizes the module and its dependent modules (e.g. `r_bsp`). The standard naming convention for the demo project is `<module>_demo_<board>` where `<module>` is the peripheral acronym (e.g. `s12ad`, `cmt`, `sci`) and the `<board>` is the standard RSK (e.g. `rskrx113`). For example, `s12ad` FIT module demo project for `RSKRX113` will be named as `s12ad_demo_rskrx113`. Similarly the exported .zip file will be `<module>_demo_<board>.zip`. For the same example, the zipped export/import file will be named as `s12ad_demo_rskrx113.zip`

---

### 4.1 touch\_demo\_rskrx231

---

This is a simple e2studio v7.1 (or later) demo for the `RSKRX231` starter kit using software triggers. Button and slider responses may not be accurate due to differences from original tuning environment and usage (e.g. expectation of how hard or how long a button is pressed when tuned; environmental factors, especially proximity to grounded surfaces).

#### Setup and Execution

1. Import, compile, and download project.
2. Add “`btn_states`” and “`sldr_pos`” to the Expressions window and set for Real-time Refresh.
3. Click 'Reset Go' to start the software. If the program stops at `main()`, press F8 to resume.
4. Observe changes in “`btn_states`” and “`sldr_pos`” as slider and buttons are touched.

#### Boards Supported

`RSKRX231`

---

### 4.2 touch\_demo\_rskrx231\_ext\_trig

---

This is a simple e2studio v7.1 (or later) demo for the `RSKRX231` starter kit using external triggers. Button and slider responses may not be accurate due to differences from original tuning environment and usage (e.g. expectation of how hard or how long a button is pressed when tuned; environmental factors, especially proximity to grounded surfaces).

#### Setup and Execution

1. Import, compile, and download project.
2. Add “`btn_states`” and “`sldr_pos`” to the Expressions window and set for Real-time Refresh.
3. Click 'Reset Go' to start the software. If the program stops at `main()`, press F8 to resume.
4. Observe changes in “`btn_states`” and “`sldr_pos`” as slider and buttons are touched.

#### Boards Supported

`RSKRX231`

---

### 4.3 touch\_demo\_rskrx130

---

This is a simple e2studio v7.1 (or later) demo for the `RSKRX130` starter kit using software triggers. Button and slider responses may not be accurate due to differences from original tuning environment and usage (e.g. expectation of how hard or how long a button is pressed when tuned; environmental factors, especially proximity to grounded surfaces).

#### Setup and Execution

1. Import, compile, and download project.
2. Add “`btn_states`” and “`sldr_pos`” to the Expressions window and set for Real-time Refresh.
3. Click 'Reset Go' to start the software. If the program stops at `main()`, press F8 to resume.
4. Observe changes in “`btn_states`” and “`sldr_pos`” as slider and buttons are touched.

**Boards Supported**

RSKRX130

---

**4.4 Adding a Demo to a Workspace**

---

Demo projects are found in the FITDemos subdirectory of the distribution file for this application note. To add a demo project to a workspace, select File>Import>General>Existing Projects into Workspace, then click “Next”. From the Import Projects dialog, choose the “Select archive file” radio button. “Browse” to the FITDemos subdirectory, select the desired demo zip file, then click “Finish”.

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# Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Oct.04.18	—	First edition issued

# General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU 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. 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

## 2. Processing at Power-on

The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

## 3. Prohibition of Access to Reserved Addresses

Access to reserved addresses is prohibited.

- The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

## 4. Clock Signals

After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

## 5. Differences between Products

Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

- The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the 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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