RA Family

Using QE and FSP to Develop Capacitive Touch Applications

Introduction
This document demonstrates the necessary steps for creating an application example that integrates capacitive touch sensing using Renesas RA Microcontrollers.

Target Device
RA family with Capacitive Touch Sensing Unit (CTSU, CTSU2)

Contents
1. Application Example Overview ................................................................. 2
2. Related Documents ................................................................................ 2
3. High Level Integration Steps ................................................................. 2
4. Required Development Tools and Software Components ......................... 2
5. Application Example Overview ................................................................. 3
6. Capacitance Touch Application Development Procedure ......................... 3
  6.1 Project Creation ................................................................................ 3
  6.2 Using RA Configurator to Add Modules .............................................. 6
  6.3 Creating the Capacitive Touch Interface ............................................. 18
  6.4 Modifying Debug Session for Capacitive Touch Tuning ..................... 22
  6.5 Tuning the Capacitive Touch Interface Using QE for Capacitive Touch Plug-in ... 23
  6.6 Adding rm_touch middleware API Calls to Application Example ........... 26
  6.7 Monitoring Touch Performance Using e²studio Expressions Window and QE for Capacitive Touch... 30
  6.8 Monitoring Touch Performance with QE for Capacitive Touch Using Serial Communication .......... 36
7. qe_touch_sample.c Listing After Modifications ..................................... 38
  7.1 When Using a Software Trigger to Start the CTSU Measurement Process ........................................ 38
  7.2 When Using an External Trigger to Start the CTSU Measurement Process ........................................ 40

Website and Support ................................................................................. 42

Revision History ......................................................................................... 43
1. **Application Example Overview**

This document demonstrates how to implement capacitive touch sensing functions using Renesas RA MCUs using the following procedures:

- Create a project using the RA Smart Configurator with the RA6M2 MCU board or RA2L1 MCU board
- Create a capacitive touch interface with QE for Capacitive Touch for tuning and monitoring.

2. **Related Documents**

This application example is intended to give the user a short introduction to creating a working RA capacitive touch sensing project. A thorough review of all the applicable documentation for the e² studio/RA Smart Configurator, Flexible Software Package (FSP) drivers/middleware, and QE for Capacitive Touch plug-in help (contained within the e² studio IDE help index) is strongly suggested to answer any questions or for more details on usage of any of the tools utilized in this application example.

3. **High Level Integration Steps**

The following high-level steps give the reader an overview of how to integrate touch detection into this project. These same steps should apply to any typical user development application.

1. Create a new project with the e² studio project creation wizard.
2. Use the RA Smart Configurator to add the required modules to the created e² studio project.
3. Use the QE for Capacitive Touch e² studio plug-in to create the capacitive touch interface.
4. Use the QE for Capacitive Touch e² studio plug-in to tune the application project.
5. Add the needed FSP module API calls to the user project to enable capacitive touch sensing operations in the application.
6. Monitor the application project using QE for Capacitive Touch e² studio plug-in to demonstrate capacitive touch sensing detection.

4. **Required Development Tools and Software Components**

This project utilizes the following development environment:

<table>
<thead>
<tr>
<th>Development Tool</th>
<th>RA6M2 (CTSU)</th>
<th>RA2L1 (CTSU2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board kit</td>
<td>RA6M2 MCU Group Evaluation Kit (EK-RA6M2)</td>
<td>RA2L1-embedded CapTouch CPU Board (RTK0EG0022S01001BJ)</td>
</tr>
<tr>
<td>Renesas e² studio Integrated Development Environment (IDE)</td>
<td>2023-07 or later</td>
<td></td>
</tr>
<tr>
<td>GCC ARM Embedded Compiler</td>
<td>12.2.1.20230214 or later</td>
<td></td>
</tr>
<tr>
<td>Renesas QE for Capacitive Touch</td>
<td>3.3.0 or later</td>
<td></td>
</tr>
<tr>
<td>Flexible Software Package (FSP)</td>
<td>4.6.0 or later</td>
<td></td>
</tr>
</tbody>
</table>
5. Application Example Overview

In the main loop of the application example, the following processing is performed as shown in Figure 1.

A code listing of the completed application example after modifications is provided in section 7, qe_touch_sample.c Listing After Modifications for review.

![Figure 1. Application Example Overview](image)

6. Capacitance Touch Application Development Procedure

6.1 Project Creation

1. On your PC, start the e² studio IDE using the Windows > Start menu or the icon on your desktop. When the dialog appears, create the Workspace wherever you like.

2. Start a new project by clicking File > New > Renesas C/C++ Project > Renesas RA from the e² studio menu.

3. When the New C/C++ Project dialog box opens, select “Renesas RA CC++ Project”, then click Next.

4. In the Renesas RA C/C++ Project wizard, go to the Project Name and Location page and enter a Project Name (any name can be used).

5. Next, in the Device and Tools Selection dialog box, select the following:

<table>
<thead>
<tr>
<th>Item</th>
<th>RA6M2 (CTSU)</th>
<th>RA2L1 (CTSU2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSP Version</td>
<td>4.6.0</td>
<td></td>
</tr>
<tr>
<td>Board</td>
<td>EK-RA6M2</td>
<td>RSSK-RA2L1</td>
</tr>
<tr>
<td>Device</td>
<td>R7FA6M2AF3CFB</td>
<td>R7FA2L1AB2DFP</td>
</tr>
<tr>
<td>Toolchains</td>
<td>GNU ARM Embedded 12.2.1.20230214</td>
<td></td>
</tr>
<tr>
<td>Debugger</td>
<td>J-Link ARM</td>
<td>J-Link ARM, E2 (ARM) OR E2 Lite (ARM)</td>
</tr>
</tbody>
</table>
6. Once complete, click **Next**.
7. In the **Build Artifact and RTOS Selection** dialog box, select the following:

**Table 3. Build and RTOS Selection**

<table>
<thead>
<tr>
<th>Item</th>
<th>RA6M2 (CTSU)</th>
<th>RA2L1 (CTSU2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build Artifact Selection</td>
<td>Executable</td>
<td>No RTOS</td>
</tr>
<tr>
<td>RTOS Selection</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Once complete, click **Next**.

In the next dialog box, **Project Template Selection**, select “Bare Metal – Minimal”, then click **Finish**.

**Figure 4. Build and RTOS Selection**

**Figure 5. Project Template Selection**

Once complete, the RA Smart Configurator perspective appears in the e² studio default window, ready for project configuration. This completes the new project creation process.

Using RA Configurator to Add Modules
6.2 Using RA Configurator to Add Modules

1. Using the tabs in the lower-middle pane of the e2 studio, select the BSP tab to display the Board Support Package (BSP) configuration.

![Figure 6. BSP Tab](image)

2. To set the power supply, select the following from the lower-left of the e2 studio screen: Properties > Settings > RA Common > MCU Vcc (mV). For this example, the MCU Vcc (mV) is set to 3300 mV.

![Figure 7. Power Supply Voltage Setting](image)

3. Select the Clocks tab to configure the clocks.

![Figure 8. Clocks Tab](image)

4. For this example, the following settings are used.

<table>
<thead>
<tr>
<th>Table 4. Clocks Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock</td>
</tr>
<tr>
<td>PLL Src</td>
</tr>
<tr>
<td>Clock Src</td>
</tr>
<tr>
<td>PCLKB</td>
</tr>
</tbody>
</table>
5. Next, select the **Pins** tab. Assign the pins in order to connect the sensor port of the MCU to the Capacitive Touch Application Board.

**Note:** Depending on the selections made in Device Selection > Board when creating the project, the sensor port may be assigned to the TS pin by default.
6. Under **Pin Selection**, expand **Peripherals**. Open **Input:CTSU** and select **CTSU0**.

![Figure 12: Select Peripherals (CTSU0)](image)

7. In **Pin Configuration**, change the **Operation Mode** from “Disabled” to “Enabled”.

![Figure 13: Operation Mode (CTSU0)](image)

8. Enable the TS pins that you will be using. Since RA2L1 (CTSU2) can control the output of non-measurement pins at once, all TS pins should be enabled. In this application example, the following TS pins are assigned for use in capacitive touch interface, and so forth.

<table>
<thead>
<tr>
<th>Item</th>
<th>TS Pins Used in Application Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>RA6M2 (CTSU)</strong></td>
</tr>
<tr>
<td>TS pins used in the application example</td>
<td>● TSCAP pin</td>
</tr>
<tr>
<td></td>
<td>● TS2 pin</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 14: TS Pin Configurations (RA6M2)](image)
9. For RA6M2 (CTSU), we recommend that the touch sensor pins that are NOT being used by the application be setup so that they are driven to ‘low-level output’ at startup.

To do so, expand the Ports tree node in Pin Selection. Expand the P2 sub-node and select “P206”. Change the Mode setting of the pin configuration from “Disable” to “Output” mode (Initial Low)

Note: Only one port is setup here as a usage example. Set all unused sensor ports in the same manner.

![Pin Configuration Diagram]

**Figure 15. TS Pin Configurations (RA2L1)**

**Figure 16. Low Output Drive Setting**
10. Select **Pin Selection > Peripherals**, then open the **Connectivity:SCI** tree and select “SCI9.”

Note: Steps 10 and 11 should only be set when using serial communication for monitoring. Otherwise, skip to Step 12.

![Select Peripherals (SCI9)](image17)

11. Select **Pin Configuration > Operation Mode**, then change “Disabled” to “Asynchronous UART”. Also make sure **TXD** is set to “P203” and **RXD** is set to “P202”.

![Operation Mode (SCI9)](image18)

12. Next, select the **Stacks** tab.

![Stacks Tab](image19)

13. Select **New Stack > CapTouch > Touch (rm_touch)** to add the CTSU driver and middleware.

![Add CTSU Driver and Middleware](image20)
14. **HAL/Common Stacks** appear as shown in the following figure.

![HAL/Common Stacks](image1)

**Figure 21. HAL/Common Stacks (after CTSU is added)**

15. Next, click the **CTSU Driver on r_ctsu** module to display **Properties**.

   **Note:** Steps 15 to 18 should only be set when using the Data Transfer Controller (DTC). Use the DTC to transfer data between memory and registers without going through the CPU. When not using the DTC, skip to Step 19.

![CTSU Driver on r_ctsu Module](image2)

**Figure 22. CTSU Driver on r_ctsu Module**

16. Set the DTC from **Properties** at the bottom-left of the screen. Select **Settings > Common > Support for using DTC** and change the setting from “Disabled” to “Enabled”.

![Support for Using DTC](image3)

**Figure 23. Support for Using DTC**
17. Click the **Add DTC Driver for Transmission** module and select the **New > Transfer (r_dtc)** to add the DTC driver for transmission.

![Figure 24. Add DTC Driver for Transmission](image)

18. In the same manner, click the **Add DTC Driver for Reception** module and select the **New > Transfer (r_dtc)** to add the DTC driver for reception.

![Figure 25. Add DTC Driver for Reception](image)

19. Click the **TOUCH (rm_touch)** module to display **Properties**.

   **Note:** Steps 19 to 26 should only be set when using serial communication for monitoring. Otherwise, skip to Step 27.

![Figure 26. TOUCH Driver on rm_touch Module](image)
20. At the bottom left of the screen, select **Properties > Settings > Common > Support for QE monitoring using UART** and change “Disabled” to “Enabled”.

![Figure 27. Support for QE Monitoring using UART](image1)

21. Click the **Add SCI UART Driver** module and select **New > UART (r_sci_uart)** to add the UART driver.

![Figure 28. Add UART Driver](image2)

22. Click the **g_uart_qe UART Driver on r_sci_uart** module to display **Properties**.

![Figure 29. g_uart_qe UART Driver on r_sci_uart Module](image3)
23. Set the SCI channel. At the bottom-left of the screen, select **Properties > Settings > Module g_uart_qe UART Driver on r_sci_uart** > **General > Channel** and change the channel setting from “0” to “9”.

![Figure 30. Channel](image)

24. From **Properties** set the DTC as well. Select **Common > DTC Support** and change “Disable” to “Enable”.

**Note:** Steps 24 to 26 should only be set when using the Data Transfer Controller (DTC). Use the DTC to transfer data between memory and registers without going through the CPU. When not using the DTC, skip to Step 27.

![Figure 31. DTC Support](image)

25. Click the **Add DTC Driver for Transmission** module and select **New > Transfer (r_dtc)** to add the DTC driver for transmission.

![Figure 32. Add DTC Driver for Transmission (SC19)](image)
26. In the same manner, click the **Add DTC Driver for Reception** module and select **New > Transfer (r_dtc)** to add the DTC driver for reception.

![Add DTC Driver for Reception (SC19)](image)

**Figure 33. Add DTC Driver for Reception (SC19)**

27. Select **New Stack > Timers > Timer, Low-Power (r_agt)** to add the AGT driver.

   **Note:** Steps 27 to 33 should only be set when using an external trigger as the CTSU measurement start trigger. Otherwise (for example, when using a software trigger), skip to Step 34.

![Add AGT Driver](image)

**Figure 34. Add AGT Driver**

28. Click the **g_timer0 Timer, Low-Power (r_agt)** module to display **Properties**.

![g_timer0 Timer Driver on r_agt Module](image)

**Figure 35. g_timer0 Timer Driver on r_agt Module**
29. Set the AGT. At the bottom left of the screen, select **Properties > Settings > Module g_timer0 Timer Driver on r_agt > General > Period**. Enter “100” as the **Period** setting and select milliseconds as the unit.

![Figure 36. Period / Period Unit](image)

30. Now set the AGT interrupts by selecting **Module g_timer0 Timer Driver on r_agt > Interrupts > Underflow Interrupt Priority** and setting the priority to anything other than “Disabled”. In the example, Priority 2 is selected, which generates an AGT0 interrupt every 100 ms.

![Figure 37. Underflow Interrupt Priority](image)
31. Select **New Stack > System > Event Link Controller (r_elc)** to add the ELC Driver.

![Figure 38. Add ELC Driver](image)

32. Click the **CTSU Driver on r_ctsu module** to display **Properties**.

![Figure 39. CTSU Driver on r_ctsu Module](image)

33. Set the CTSU measurement start trigger. At the bottom-left of the screen, select **Properties > Settings > Module CTSU Driver on r_ctsu > Scan Start Trigger** and change the trigger from “Software” to “AGT0 INT (AGT interrupt)”. This setting makes the CTSU start the measurement with an AGT0 interrupt.

![Figure 40. Scan Start Trigger](image)
34. At this point, all application modules necessary for capacitive touch operations have been added. The final step is to generate the application code modules necessary for the project by clicking **Generate Project Content** icon at the upper-right of the screen.

![Generate Project Content](image)

**Figure 41. Generate Project Content**

### 6.3 Creating the Capacitive Touch Interface

1. From the e2 studio IDE, use Renesas Views > Renesas QE > CapTouch Workflow (QE) to open the main perspective for configuring capacitive touch to the project.

![CapTouch Workflow (QE) Menu](image)

**Figure 42. CapTouch Workflow (QE) Menu**

2. In the **CapTouch Workflow (QE)** pane, select the project you want to configure for touch interface by using the pull-down tab and selecting “Capacitive_Touch_Project_Example” as shown below.

![Select a Project](image)

**Figure 43. Select a Project**
3. Next, select **Prepare a Configuration** in the menu on the left-hand side of "CapTouch Workflow (QE)" to display the items for setting. Select **Create a new configuration** from the pull-down menu to generate a new configuration for a touch interface.

![Select a Configuration](image1)

**Figure 44. Select a Configuration**

4. The **Create Configuration of Touch Interfaces** dialog box opens, showing the area for positioning the touch interface (default blank canvas).

![Create Configuration of Touch Interfaces Dialog Box](image2)

**Figure 45. Create Configuration of Touch Interfaces Dialog Box**
5. Add a button to the touch interface area by selecting **Button** on the right side of the **Create Configuration of Touch Interfaces** dialog box, and then clicking on the blank canvas. Press the ESC key on your keyboard or select **Button** again to complete the step. The added button remains red, as shown in the figure below, indicating that it has not been assigned a touch sensor yet.

![Figure 46. Add a Button](image)

6. Double click **Button00** in the touch interface canvas to display the **Setup Touch Interface** dialog box. From the pull-down menu, select the MCU sensor port you want to assign to this button. When a sensor port that has been enabled by the RA Smart Configurator is correctly assigned to the button, the setting error disappears and the button turns green, indicating that it has been set.

<table>
<thead>
<tr>
<th>Item</th>
<th>RA6M2 (CTSU)</th>
<th>RA2L1 (CTSU2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch sensor to be selected</td>
<td>TS02</td>
<td>TS11</td>
</tr>
</tbody>
</table>

![Figure 47. Setup Touch Interface (set button)](image)
7. Next, on the right side of the **Create Configuration of Touch Interfaces** dialog box, select **Shield Pin** and then click on the canvas to add a shield pin. Press the ESC key on your keyboard or select **Shield Pin** again to complete the step. The added shield pin remains red, as shown in the figure below, indicating it has not been assigned a touch sensor yet.

   **Note:** When creating a project, if “EK-RA6M2” (RA6M2 MC Group Evaluation Kit) is selected in Device Selection > Board, the Shield Pin is disabled and cannot be selected.

   ![Figure 48. Add Shield Pin](image)

8. Double click “Shield00” in the touch interface canvas to open the Setup Touch Interface dialog box. From the pull-down menu, select the MCU sensor port to assign to this shield pin. When a sensor port that has been enabled by the RA Smart Configurator is correctly assign to the pin, the setting error disappears and the button turns green, indicating that it has been set.

<table>
<thead>
<tr>
<th>Item</th>
<th>RA6M2 (CTSU)</th>
<th>RA2L1 (CTSU2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch sensor to be selected</td>
<td>-</td>
<td>TS00</td>
</tr>
<tr>
<td>(Cannot be set for EK-RA6M2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   ![Figure 49. Setup Touch Sensor (Shield Pin)](image)
9. Click **Create** in the **Create Configuration of Touch Interfaces** dialog box to complete the touch interface settings.

![Create Button](figure49.png)

**Figure 49. Create Button**

10. Select **Renesas Views > Renesas QE > CapTouch Tuning Result (QE)** from the menu of the e² studio and open the **CapTouch Tuning Result (QE)** view to display the configuration of the touch interface in the **Tuning** panel.

![Tuning Pane](figure50.png)

**Figure 50. Tuning Pane**

11. Build the project using the hammer icon in the upper left-hand side of the e² studio screen. The project should build without any errors or warnings.

![Build Button](figure51.png)

**Figure 51. Build Button**

### 6.4 Modifying Debug Session for Capacitive Touch Tuning

1. The debug configuration needs to be modified slightly so that a special tuning kernel can be downloaded into the MCU RAM after the debug session starts. Enter the Debug Configuration by clicking the drop-down list button of the bug icon from the e² Studio Tools button.

![Debug Configuration Editing Button](figure52.png)

**Figure 52. Debug Configuration Editing Button**

2. Select the **Startup** tab.

![Startup Tab](figure53.png)

**Figure 53 Startup Tab**
3. Ensure the two check boxes **Set breakpoint at:** and **Resume** are checked and appear as follows in the Runtime Options. You may need to scroll down in the dialog box to see these check boxes.

![Runtime Option](image)

Figure 54. Runtime Option

4. Click **Apply** to use these modified settings. This completes the project configuration and debug setup for tuning.

6.5 Tuning the Capacitive Touch Interface Using QE for Capacitive Touch Plug-in

1. Make sure that the emulator is connected correctly to the board and PC.

2. Select **Start Tuning (Emulator)** in the menu on the left-hand side of “CapTouch Workflow (QE)” to open the settings of “Tuning Touch Sensors”. Click on **Start Tuning** to start automatic tuning.

![Start Tuning](image)

Figure 55. Start Tuning

3. At the start of the first debug session, e² studio may display a message regarding a switch to the Debug perspective. Click the **Remember my decision** check box and **YES** to continue the Debug session and the QE for Capacitive Touch automatic tuning.

![Confirm Perspective Switch](image)

Figure 56. Confirm Perspective Setting
4. QE for Capacitive Touch automatic tuning now begins. Please carefully read the **Automatic Tuning Processing** dialog windows as they guide you through the tuning process. An example screen is shown below. Typically, no interaction is required during the initial tuning process steps.

![Automatic Tuning Processing Dialog (now preparing)](image)

**Figure 57.** Automatic Tuning Processing Dialog (now preparing)

5. After several automated steps, a dialog box with information similar to what is shown below appears. This is the touch sensitivity measurement step of the tuning process. As the first interactive step of the tuning process, press “Button00” (sensor) using normal touch pressure as indicated in the dialog box (RA6M2: TS02, RA2L1: TS11-CFC). When pressing the sensor, the bar graph increases to the right and the touch counts increase numerically. While continuing to apply pressure to the sensor, press any key on the PC keyboard to accept the measurement.

![Automatic Tuning Processing Dialog (now measuring)](image)

**Figure 58.** Automatic Tuning Processing Dialog (now measuring)

6. Once sensitivity measurement for the button is complete, a dialog like the following appears allowing threshold confirmation. This is the detection threshold that is used by the middleware to determine if a touch event has occurred.

![Automatic Tuning Processing](image)

**Figure 59** Automatic Tuning Processing (tuning complete)
7. Click the **Continue the Tuning Process** button in the dialog box shown. This exits the tuning process and disconnects from the Debug session on the target board. This should return you to the default **Cap Touch Workflow (QE)** screen in the e² studio IDE.

![Continue the Tuning Process Button](image)

**Figure 60. Continue the Tuning Process Button**

8. The only remaining step is the output of the tuned parameter files. Select **Output Parameter Files** from the menu on the left-hand side of "CapTouch Workflow (QE)", and click on **Output Parameter Files**.

   Note: Carry out this step if you are **NOT** using an external trigger (that is, when you are using a software trigger) to start the CTSU measurement.

![Output Parameter Files](image)

**Figure 61. Output Parameter Files**

9. When using an external trigger to start the CTSU measurement, Check the **Use an external trigger** box and click on **Output Parameter Files**.

   Note: Carry out this step if you are using an external trigger to start the CTSU measurement process.

![Parameter File Output Settings](image)

**Figure 62. Parameter File Output Settings**
10. In the Project Explorer window, confirm that `qe_touch_config.c`, `qe_touch_config.h` and `qe_touch_define.h` files have been added. These contain the tuning information necessary for enabling touch detection with drivers.

![Parameter Files](image)

**Figure 63. Parameter Files**

11. Build the project using the hammer icon in the upper left-hand side of the e² studio IDE. Confirm that the build results shown in the Console window do not show any errors.

   Note: A build error is generated if monitoring via serial communication is enabled in Flexible Software Package (FSP) V3.0.0. See [https://github.com/renesas/fsp/issues/78](https://github.com/renesas/fsp/issues/78) for more details.

### 6.6 Adding rm_touch middleware API Calls to Application Example

1. To implement a program (code) to scan the states of the touch sensors, select Implement Program in the menu on the left-hand side of "CapTouch Workflow (QE)" and then click on Show Sample.

![Show Sample Code](image)

**Figure 64. Show Sample Code**
2. The **Show Sample Code** window opens and shows the sample code in text. Click the **Output to a File** button to output the sample code. Finally, click **OK** to close the window.

![Show Sample Code Window](image)

**Figure 65.** Show Sample Code Window

3. You can confirm that the new `qe_touch_sample.c` file has been created in **Project Explorer**.

![Project Explorer](image)

**Figure 66.** `qe_touch_sample.c`
4. In **Project Explorer**, select **ra_gen** and double click on main.c to open the file. Make sure **hal_entry** is selected in the main() function and right-click on **Open Declaration**. This opens the hal_entry() function declaration.

**Figure 67. Open Declaration (hal_entry function)**

5. In the **hal_entry()** function, add the code to call the **qe_touch_main()** function and the prototype declaration as shown in the image below.

**Figure 68. Function Call (qe_touch_main function)**
6. In the `hal_entry()` function, select the `qe_touch_main()` function, then click on Open Declaration to open the `qe_touch_main()` declaration.
   
   Note: Carry out Steps 6 and 7 only if you are using an external trigger to start the CTSU measurement process. If you are NOT using an external trigger (that is, when you are using a software trigger), skip to Step 8.

   ![Figure 69. Open Declaration (qe_touch_main function)](image)

7. When using an external trigger to start the CTSU measurement process, enable the code after commenting out the API that controls the AGT driver of the `qe_touch_main()`.

   ![Figure 70. Code Modifications](image)

8. This completes all the necessary code modifications required for this application example. Build the code to confirm that there are no errors or warnings.
6.7 Monitoring Touch Performance Using e²studio Expressions Window and QE for Capacitive Touch

1. Start a Debug session by clicking the Bug icon in the upper left-hand corner of e² studio.
2. The debugger stops at the hal_entry() function call. This is the first code point in the main() function.
3. Open the declaration of hal_entry() function.

4. Open the declaration of the qe_touch_main() function.

5. Scroll down in the qe_touch_main.c file to the RM_TOUCH_DataGet() function in the while (true) loop. With the argument “button_status” selected, right click and select Add Watch Expression... This opens the Add Watch Expression dialog box, where you can add the variable “button_status” to the expressions window.
6. Right click in the **Expressions** window to select **Enable Real-time Refresh** and enable real-time refresh in the added variable.

![Enable Real-time Refresh Menu](image1)

6.6. **Figure 74.** Enable Real-time Refresh Menu

7. Click the **Resume** (green arrow) button, located near the middle of the e2 studio tool bar, to continue code execution.

8. Press the sensor on the board (RA6M2: TS02, RA2L1: TS11-CFC) which was configured as “Button00” in section 6.3, **Creating Capacitive Touch Interface**. When pressed, the “button_status” value in the Expressions window becomes ‘1’, confirming the touch with a binary indication.

![Touch Status Confirmation in Expressions Window](image2)

6.8. **Figure 75.** Touch Status Confirmation in Expressions Window

9. Select **Start Monitoring (Emulator)** in the menu on the left-hand side of “CapTouch Workflow (QE)”. Click on **Show Views** to start **CapTouch Board Monitor (QE)**.

![Start Monitoring](image3)

6.9. **Figure 76.** Start Monitoring
10. The **CapTouch Board Monitor** pane should appear as shown in the image below.

![Figure 77. CapTouch Board Monitor Window (RA6M2)](image)

11. Click the **Enable Monitoring** button. The dialog text changes from “Monitoring: Disabled” to “Monitoring: Enabled.”

![Figure 78. CapTouch Board Monitor Window (RA2L1)](image)

![Figure 79. Enable Monitoring Function](image)
12. Touch “Button00” (RA6M2: TS02, RA2L1: TS11-CFC) on the Capacitive Touch Application board. The CapTouch Board Monitor shows a touch with a finger image on the button like the following image.

![CapTouch Board Monitor](image)

**Figure 80. Touch Status Confirmation in CapTouch Board Monitor Window**

13. To see a graphical representation of the ‘touch counts’ from the board, use the CapTouch Status Chart.

![CapTouch Status Chart](image)

**Figure 81. CapTouch Status Chart Window**

14. Using the Touch I/F pull-down menu, select “Button00 @ config01”.

![Select Touch I/F](image)

**Figure 82. Select Touch I/F**
15. The graph begins to display running values. Touch “Button00” (RA6M2: TS02, RA2L1: TS11-CFC) on the board to view the touch counts shown as a step change on the running graph. The green line is the touch threshold, which the rm_touch middleware uses to determine whether a button is actuated/touched. The red blocks at the bottom of the graph are a visual indication to the user that the touch counts have exceeded the threshold and a touch is detected.

![Figure 83. Confirm Touch Status in CapTouch Status Chart Window](image)

Note: Steps 16 to 19 must be set when displaying and measuring standard deviation.

16. Next, measure the standard deviation. Click on [Start Data Collection] displays the [Data Collection Settings] dialog box. Select the number of data to be collected from the pull-down menu in this dialog box. Select [Non Touch + Touch] for [Data collection target] and click on [Start Data Collection].

![Figure 84. Start Data Collection Button (touch-off state)](image)
17. When the green bar reaches the right edge, collection of the touch-off data is completed and a dialog box is displayed. Click on [OK] to close the dialog box.

![Stop Data Collection Button (touch-off state)](image)

**Figure 85. Stop Data Collection Button (touch-off state)**

18. After that, touch the electrodes to collect touch-on data. Click on [Start Data Collection] while touching the electrodes. Continue to touch the electrodes until the data collection is complete.

![Start Data Collection Button (touch-on state)](image)

**Figure 86. Start Data Collection Button (touch-on state)**
19. When the green bar reaches the right edge to indicate the completion of data collection, the [Standard Deviation Measurement Result] dialog box appears. This dialog box shows the standard deviations of noise and the SNRs.

![Figure 87. Displaying the Measured Results](image)

6.8 Monitoring Touch Performance with QE for Capacitive Touch Using Serial Communication

1. When monitoring is in operation, click the **Enable Monitoring** button. The dialog text changes from “Monitoring: Enabled” to “Monitoring: Disabled”.

![Figure 88. Disable Monitoring Function](image)

2. To finish the debug session, click the **Stop** icon at the top-right of the e2 studio window.

3. Disconnect the emulator from the PC and target board. Confirm that the USB cable is correctly connected to the target board and PC.

   Note: Although operations can be carried out with the emulator connected, the emulator is removed in this step to confirm successful monitoring without the emulator.

4. Reset the board by pressing the **RESET** switch.
5. Open the **CapTouch Workflow** pane and make sure the following folder/file are selected:

- **To Select a Project**: “Capacitive_Touch_Project_Example”
- **To Prepare a Configuration**: “Capacitive_Touch_Project_Example.tifcfg”.

![Select Project / Configuration](image)

6. Then select [Start Monitoring (Serial)] in the menu on the left-hand side of “CapTouch Workflow (QE)”. Select [Connect] to enable the serial communication monitoring function.

![Connect Button](image)

7. “Connected to COMn” should appear at the bottom of Console window. Confirm the message to make sure the connection is successful.

   **Note**: The COM port number for connection varies depending on the PC environment.

![Console Window Output](image)

8. The rest of the process is the same as Step 9 on in Section 6.7 Monitoring Touch Performance Using e²studio Expressions Window and QE for Capacitive Touch.
7. **qe_touch_sample.c Listing After Modifications**

7.1 **When Using a Software Trigger to Start the CTSU Measurement Process**

```c
/* **********************************************************
 * FILE : qe_sample_main.c
 * DATE : 2020-09-10
 * DESCRIPTION : Main Program
 * *
 * NOTE:THIS IS A TYPICAL EXAMPLE.
 * **********************************************************/
#include "qe_touch_config.h"
#define TOUCH_SCAN_INTERVAL_EXAMPLE (20)    /* milliseconds */

void qe_touch_sample_main(void);

void qe_touch_sample_main(void)
{
    fsp_err_t err;

    /* Open Touch middleware */
    err = RM_TOUCH_Open(g_qe_touch_instance_config01.p_ctrl,
                        g_qe_touch_instance_config01.p_cfg);
    if (FSP_SUCCESS != err)
    {
        while (true) {} } } ```

```c
#include "qe_touch_config.h"
define TOUCH_SCAN_INTERVAL_EXAMPLE (20)    /* milliseconds */

void qe_touch_sample_main(void);

void qe_touch_sample_main(void)
{
    fsp_err_t err;

    /* Open Touch middleware */
    err = RM_TOUCH_Open(g_qe_touch_instance_config01.p_ctrl,
                        g_qe_touch_instance_config01.p_cfg);
    if (FSP_SUCCESS != err)
    {
        while (true) {} } } ```
/* Main loop */
while (true) {

    /* for [CONFIG01] configuration */
    err = RM_TOUCH_ScanStart(g_qe_touch_instance_config01.p_ctrl);
    if (FSP_SUCCESS != err)
    {
        while (true) {}
    }
    while (0 == g_qe_touch_flag) {}
    g_qe_touch_flag = 0;

    err = RM_TOUCH_DataGet(g_qe_touch_instance_config01.p_ctrl,
        &button_status, NULL, NULL);
    if (FSP_SUCCESS == err)
    {
        /* TODO: Add your own code here. */
    }

    /* FIXME: Since this is a temporary process, so re-create a waiting
     * process yourself. */
    R_BSP_SoftwareDelay(TOUCH_SCAN_INTERVAL_EXAMPLE,
        BSP_DELAY_UNITS_MILLISECONDS);
}
### 7.2 When Using an External Trigger to Start the CTSU Measurement Process

```c
/* ***************************************************************
 * FILE : qe_sample_main.c
 * DATE : 2020-09-10
 * DESCRIPTION : Main Program
 * NOTE : THIS IS A TYPICAL EXAMPLE.
 * ***************************************************************

#include "qe_touch_config.h"
define TOUCH_SCAN_INTERVAL_EXAMPLE (20) /* milliseconds */

void qe_touch_main(void);
uint64_t button_status;
#if (TOUCH_CFG_NUM_SLIDERS != 0)
uint16_t slider_position[TOUCH_CFG_NUM_SLIDERS];
#endif
#if (TOUCH_CFG_NUM_WHEELS != 0)
uint16_t wheel_position[TOUCH_CFG_NUM_WHEELS];
#endif

void qe_touch_main(void)
{
    fsp_err_t err;
    /* Initializes the software and sets the links defined in the control
       structure. */
    R_ELC_Open(g_elc.p_ctrl, g_elc.p_cfg);
    /* Globally enable event linking in the ELC. */
    R_ELC_Enable(g_elc.p_ctrl);
    /* Open Touch middleware */
    err = RM_TOUCH_Open(g_qe_touch_instance_config01.p_ctrl,
                        g_qe_touch_instance_config01.p_cfg);
    if (FSP_SUCCESS != err)
    {
        while (true) {} // infinite loop due to error
    }
    /* Open AGT driver */
    R_AGT_Open(g_timer0.p_ctrl, g_timer0.p_cfg);
    /* Start AGT. */
    R_AGT_Start(g_timer0.p_ctrl);
}
```
/* Main loop */
while (true)
{

    /* for [CONFIG01] configuration */
    err = RM_TOUCH_ScanStart(g_qe_touch_instance_config01.p_ctrl);
    if (FSP_SUCCESS != err)
    {
        while (true) {}
    }
while (0 == g_qe_touch_flag) {}
    g_qe_touch_flag = 0;

    err = RM_TOUCH_DataGet(g_qe_touch_instance_config01.p_ctrl,  
        &button_status, NULL, NULL);
    if (FSP_SUCCESS == err)
    {
        /* TODO: Add your own code here. */
    }

    /* FIXME: Since this is a temporary process, so re-create a waiting  
    process yourself. */
    R_BSP_SoftwareDelay(TOUCH_SCAN_INTERVAL_EXAMPLE,  
        BSP_DELAY_UNITS_MILLISECONDS);
}
## Website and Support

<table>
<thead>
<tr>
<th>RA Family</th>
<th>Using QE and FSP to Develop Capacitive Touch Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA Product Information</td>
<td><a href="renesas.com/ra">renesas.com/ra</a></td>
</tr>
<tr>
<td>RA Product Support Forum</td>
<td><a href="renesas.com/ra/forum">renesas.com/ra/forum</a></td>
</tr>
<tr>
<td>RA Flexible Software Package</td>
<td><a href="renesas.com/FSP">renesas.com/FSP</a></td>
</tr>
<tr>
<td>Renesas Support</td>
<td><a href="renesas.com/support">renesas.com/support</a></td>
</tr>
<tr>
<td>Capacitive Touch Sensing Unit</td>
<td><a href="renesas.com/solutions/touch-key">renesas.com/solutions/touch-key</a></td>
</tr>
<tr>
<td></td>
<td><a href="renesas.com/qe-capacitive-touch">renesas.com/qe-capacitive-touch</a></td>
</tr>
</tbody>
</table>
Revision History

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<th>Date</th>
<th>Description</th>
<th>Page</th>
<th>Summary</th>
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<td></td>
<td>Section 7.1: Updated source Code</td>
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<tr>
<td>54, 55</td>
<td></td>
<td>Added Section 7.2 When Using an External Trigger to Start the CTSU Measurement Process</td>
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<td></td>
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<tr>
<td>34~36,</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>42, 50</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>


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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