Introduction

This application note describes how to design electrode patterns for RX Family MCUs embedding the Capacitive Touch Sensing Unit (CTSU).

Target Devices

RX113, RX130, RX230, RX231

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1. **Self-capacitance Method: Electrode Layout Patterns**

1.1 **Outline**

Capacitive touch switch sensitivity and anti-noise performance are both influenced by electrode shape and size, wire routing, patterns surrounding the electrode, overlay panel thickness, inclusion of air gap, internal configuration of product casing, and other factors. All of these factors need to be taken into consideration when designing the electrode as well as the surrounding area. This application note describes how to design electrode pad and wiring as well as related issues and potential problems. It also provides recommended applications.

1.2 **Button Electrode Shape**

Figure 1-1 shows recommended patterns for electrode pads assuming use for finger touch contact in the self-capacitance method.

The recommended ideal dimensions for electrode pads is between 10.0 x 10.0mm and 15.0 x 15.0mm, ensuring that the size is not too big nor too small for the target human interface (example: finger).

Shapes with angles of 90 degrees or less, such as an “E” or a triangle, are not recommended as they tend to perform as an antenna, degrading RF noise immunity.

When planning to embed LEDs or other components in the electrode pad, make sure you make the hole as small as possible to ensure the capacity count change value can be obtained when the pad is touched. Note that any conductive material can be used for the electrode, but keep in mind that carbon and other materials with high surface resistance may reduce the touch sensitivity of the button. In addition, depending on where the finger is placed, materials with high surface resistance are not always consistently sensitive. If using a material with high surface resistance, we recommend using wiring layouts (b) or (c) as shown in Figure 1-2. Layout (b) arranges the wiring as close to the center of the electrode as possible and layout (c) surrounds the electrode with a material of low surface resistance, ensuring the resistance value is constant, regardless of where the finger touches the surface. When using copper or other considerably low surface resistance material, the wiring can also be routed from the button electrode itself.

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**Figure 1-1**  Recommended Electrode Pad Design for Self-capacitance Method
1.3 Button Electrode and Wiring Layout

1.3.1 Outline
The wiring between the button electrode and the MCU terminal must be as short as possible and the distance between wires as long possible. Sufficient distance between button electrodes is also essential. The longer the wiring, the more it is susceptible to RF noise, which can cause an increase of parasitic capacitance. Wires placed too close to each other can also cause an increase in parasitic capacitance. Because non-measurement touch electrodes at ground level, when buttons located close together are touched, crosstalk is generated and it becomes difficult to determine which button was touched.

1.3.2 Recommended Layout and Conditions
Figure 1-3 shows an example of electrode routing for the self-capacitance method. This example assumes that no other pattern routing will be implemented in the electrode area or corresponding wire routing area (the red area in Figure 1-3). Arranging a well-balanced wiring design that avoids excessively long or short wires makes adjustment of touch sensitivity easier. We also suggest increasing the distance between electrodes by making the panel twice as thick (including the air gap) to prevent crosstalk (to be described in detailed later).

When using Workbench6 (integrated touch evaluation tool) to conduct source code auto-generation and auto-sensitivity adjustment, the recommended resistance between the MCU pin and the electrode (including electrode/wiring/damping resistance) is 2KΩ or less. For parasitic capacity, the resistance should be 50pF or less. If these resistance values exceed...
the recommendations, the conditions may be more restrictive due to touch sensitivity adjustments and noise immunity, etc.

![Electrode Wiring Conditions](image)

**Figure 1-4** Electrode Wiring Conditions for Self-capacitance Method

You can confirm the total capacity of each electrode as displayed in the Workbench6 First Step Guide. Figure 1-5 shows the measurement result screen for parasitic capacity displayed in the Workbench6 First Step Guide.

![Parasitic Capacity Measurement](image)

**Figure 1-5** Workbench6 First Step Guide: Parasitic Capacity Measurement Result Screen
1.3.3 Button Electrode Layout Example

Figure 1-6 describes a sample MCU wiring layout for a control panel design in which touch keys A-H are positioned on the board. This figure explains how the sensitivity of each touch key is influenced when the MCU is placed at position 1 or 2.

![Figure 1-6 Example of Electrode Routing based on MCU Position (1)](image)

Figure 1-7 shows a wiring example for MCU position “1.” MCU position 1 presents two positive conditions for Electrode A (electrode pad is large and electrode wiring is short), and two negative conditions for Electrode D (electrode pad size is small and wiring is long). In this case, Sensitivity of Electrode A tends to be high and Electrode D low.

Long wiring presents the following 3 risks:

- Long electrode wiring tends to make the wire act as an antenna, which makes it easier for RF noise to mix in with the frequencies and, thus, increase risk of malfunction.
- Long electrode wiring generates more parasitic capacitance between the patterns surrounding the electrode and the conductor, reducing the measurement value.
- Long wiring used with carbon or other materials with high surface resistance increases the resistance value, which reduces the measurement value.
Figure 1-7  Example of Electrode Routing based on MCU Position (2)

Figure 1-8 shows a wiring example for MCU position 2, which has two opposing conditions for both electrodes to offset sensitivity. Electrode A’s merit is its large electrode pad and its demerit is its lengthy electrode wiring. Electrode D’s merit is its lengthy electrode wiring and its demerit is its small electrode pad. In a comparison with the electrodes of MCU position 1, Electrode A provides less sensitivity and, conversely, Electrode D is able to suppress sensitivity deterioration.

It is essential to take various factors into consideration when designing the electrode patterns to create a balanced layout that prevents electrode sensitivity deterioration.

Figure 1-8  Example of Electrode Routing based on MCU Position (3)
1.3.4 Wiring Layout Example Based on PCB Configuration

Figure 1-9 shows a single-layer board layout for the self-capacitance method. When using a single-layer board, the layouts for electrode pads and wiring are all on the same layer.

Figure 1-9 Example of Single-layer Board Layout for Self-capacitance Method

Figure 1-10 shows a multi-layer board layout for the self-capacitance method. When using a multi-layer board, the risk of erroneously detecting a finger touch on the wiring area can be minimized by positioning only the electrodes on the top layer and wiring on the bottom layer.

Figure 1-10 Example of Multi-Layer Board Layout for Self-capacitance Method
1.4 Button Electrode Application Examples

1.4.1 Water-resistant electrode layout pattern designs

The self-capacitive touch button is not as water-resistant as is the mutual-capacitive version, which will be described in a comparison later in the document. And although water-related malfunctions cannot be completely avoided, there are a few steps that can be taken to improve water resistance, as described here.

Figure 1-11 shows a self-capacitance method water-resistance layout pattern example. In the example using dummy electrodes (figure on left), the button electrode is surrounded by dummy electrodes. When both dummy and button electrodes are ON, the sensor detects malfunction due to water and ignores the button ON state. As the figure suggests, malfunction due to water can be managed per group by creating button groups and surrounding each group with dummy electrodes.

When two button electrodes are too close, water droplets or water film can cause false touch detection of neighboring channels. We strongly suggest designing a layout pattern with ample distance between electrodes. Small droplets in the vicinity of button electrodes that are placed too close can cause several electrodes to bridge, leading to false touch detection. Separating electrode buttons with ample space makes it harder for them to bridge, thus reducing the risk of false detection.

1.4.2 When panel and button electrodes are separated

Figure 1-12 shows an example configuration with space between the panel and button electrodes. Although the configuration depends on the size of the button electrode, parasitic capacitance and other factors, if all conditions are favorable, touch can be detected even with a 2mm air gap between the panel and electrodes. However, when dealing with strict noise immunity requirements, if the air gap is larger than 2mm and touch detection is difficult due to other conditions, you may need to extend the button electrodes to the panel, as shown on the right of Figure 1-12.
1.5 Effect of Panel Thickness

The self-capacitance method detects the capacitance generated when there is contact between the human body and a button electrode. Accordingly, in this kind of touch detection, the larger the touch surface of the button electrode and the longer the distance between the finger, for example, and the electrode, the higher the sensitivity. As the maximum touch surface size of the button electrode is limited (10mm to 15mm), the distance, or panel thickness, is the key factor in adjusting sensitivity.

1.5.1 Relationship of panel thickness and touch sensitivity

Figure 1-13 shows the relationship of the amount of capacitance change and sensitivity distance in the self-capacitance method. In this method, the capacitance increases or decreases depending on the distance between the finger and the electrode, allowing touch detection over a broad range. However, this also means that if the threshold has a large margin in comparison to the capacitance, touch detection may occur before the finger actually has contact with the panel.

![Diagram showing relationship between capacitance, threshold, and distance](image-url)

Figure 1-13  Relationship of Capacitance Change and Sensitivity Distance in Self-capacitance Method
1.5.2 Relationship of panel thickness and crosstalk

Figure 1-14 shows the relationship of the inter-electrode distance and panel thickness in the self-capacitance method. If the button electrodes are placed too close together, they may cause neighboring button electrodes to turn ON erroneously (left side of figure). To prevent crosstalk, or false detection, among neighboring button electrodes, the recommended distance between button electrodes is 1 to 2 times thicker than the panel (including air gap).

![Diagram of inter-electrode distance and panel thickness relationship](image)

**Actual example**

**Figure 1-14  Relationship of Inter-electrode Proximity and Overlay Thickness for Self-capacitance Method**

1.6 LED Wiring Layout

1.6.1 Direct lighting example

Figure 1-15 shows the electrode pad and LED wiring for the self-capacitance method. We recommend routing the LED around the outer edge of the electrode pad, as shown to the right of the figure.

Routing the LED wiring in the electrode pad requires a hole to be made in the electrode, reducing the touch-sensitive surface area and bringing the LED wiring in close proximity to the electrode. This increases the risk of weaker sensitivity due to an increased parasitic capacitance.

![Diagram of LED wiring example](image)

**Figure 1-15  Electrode Pad and LED Routing Example for Self-capacitance Method**
1.6.2 Indirect Lighting (using light guide plate)

Figure 1-16 shows an example of LED routing using an electrode pad and a light guide plate for the self-capacitance method. The LED (the light source) must be a set distance from light-emitting surface to ensure even lighting. Placing multiple LEDs (light sources) in opposing positions helps to eliminate uneven lighting.

![Figure 1-16 Example of LED Routing using Electrode Pad Light Guide Plate for Self-capacitance Method](image)

1.7 Anti-noise Layout Pattern Designs

The button electrode configuration enables it to act as an antenna (MCU pin is open only for coupling capacitance) and makes it vulnerable to electromagnetic field noise. Renesas Touch MCUs employ several anti-noise countermeasures to ensure high noise immunity. However, an MCU alone cannot prevent influence from all noise. Hardware countermeasures are indispensable when using the MCU in a severe noise environment. The following are a few examples.

In general, the longer the wiring, the more chances for noise to synchronize and mix with the many noise frequencies. Make sure the wiring between button electrodes and the MCU is kept as short as possible.

1.7.1 Anti-noise measure using ground pattern

A ground pattern can be placed around the button electrodes as a noise guard, preventing malfunctions due to electromagnetic field noise. Please note that ground patterns can generate parasitic capacitance that may lower touch sensitivity. Parasitic capacity can be minimized by using a mesh configuration as the ground pattern.

Figure 1-17 shows an anti-noise layout pattern example of a single-layer board for the self-capacitance method. We recommend using a mesh ground pattern to cover the area around the electrode wiring. Make sure the distance between the electrode wiring and the mesh ground is 5mm or more.
Figure 1-17  Example of Single-layer Anti-noise Layout Pattern for Self-capacitance Method

Figure 1-18 shows an anti-noise layout pattern example of a multi-layer board for the self-capacitance method. In this case, a mesh ground pattern can be positioned on both the upper and lower layers. Make sure to connect the two layers of ground pattern in multiple places with through holes to prevent generating a potential difference.
Figure 1-18  Example of Multi-layer Anti-noise Layout Pattern for Self-capacitance Method
1.7.2 Anti-noise measure using MCU power supply circuit

The influence of noise is not always due to factors related to the button electrode or wiring. Noise inserted from the power supply line is also a major cause of malfunctions. Make sure you design a stable power supply for the touch MCU. The following described a few examples of power supply-related anti-noise measures.

(a) 3-pin regulator

Fluctuations in power supply to the touch MCU can affect the touch measurement. To avoid this, use a 3-pin regulator or similar part to ensure stable power supply. Note that a voltage drop or ripple may occur, depending on the power supply load of the DC-DC converter.

(b) Floating

For hot chassis products using AC power, the power should be floated to the touch MCU from the AC source. When either the power supply or ground are connected to AC, voltage noise of 1/2 the AC may be inserted in the button electrode upon human contact, causing a malfunction.

(c) Noise filter

If noise from the power supply circuit is anticipated, insert a noise filter or ferrite core just before the touch MCU power supply. Use an LC noise filter for normal mode noise and a ferrite core for common mode.

(d) Power supply separation

Separate the power supply source for devices with large current consumption and the touch MCU power supply. Also note that directly driving a device with large current consumption, such as an LED, using a general-purpose port on the touch MCU can cause an internal voltage drop and unstable touch measurement.
2. Mutual Capacitance Method: Electrode Layout Patterns

2.1 Outline

The mutual-capacitance method boasts button electrodes with superior water-resistance, support based on using matrix structure, and many other functions not available with self-capacitance. However, mutual-capacitance requires complicated button electrode configurations and wire routing, making sensitivity adjustment difficult. The merits and demerits of each method must be taken into account when designing layout patterns. Furthermore, unlike the self-capacitance method, sensitivity is lost when panel thickness falls below a specified level. The designer must carefully consider the button electrode configuration when determining panel thickness.

2.2 Button Electrode Layout Pattern Designs

Mutual-capacitance method button electrodes are configured as receiver electrode (Rx) and transmitter electrode (Tx). Touch measurement measures the electromagnetic field (coupling capacitance) between Tx and Rx and captures the phenomenon of the capacitive coupling decreasing as a fingertip (i.e. human body) in close proximity attracts part of the electromagnetic field. Therefore, the layout pattern must be designed to (1) maximize the capacitance coupling between Rx and Tx, and (2) make the rate of capacitance coupling reduction as large as possible when a finger is in proximity.

Figure 2-1 shows the recommended electrode pad pattern for the mutual-capacitance method. The receiver electrode, which is more susceptible to noise, is protected by encompassing the sides of Rx with the sides of Tx. This configuration increases the distance between Tx and Rx opposing sides (called “facing distance” herein) as well as the surface area that comes in contact with the finger. The recommended distance between Tx and Rx is approximately 0.6 times the panel thickness (including the air gap).
2-shaped electrode (Panel thickness 2.0mm or less)  

2-shaped electrode (Panel thickness 4.0mm or less)  

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Figure 2-1 Mutual Capacitance Method: Electrode Pad Recommended Patterns  

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Figure 2-2 shows an image of the electrode pad’s Tx/Rx coupling capacitance electromagnetic field and panel thickness for the mutual-capacitance method. A greater Tx/Rx facing distance is required when using a thick overlay panel. However, as most products limit the electrode pad size, it is often difficult to extend the distance. In Figure 2-1, Type 2 Electrode (panel thickness = 2.0mm or less) is a pattern designed assuming an overlay panel thickness of 2mm or less, while the figure to the right shows the same pattern assuming an overlay panel thickness of 4mm. The pad size is increased from 10.0 x 10.0mm to 17.2mm x 17.2mm. This may be too big for some applications. In this case you may need to use a reduced Tx/Rx facing distance, like that of Type C Electrode. Take note that, compared to Type 2 electrode, the shorter Tx/Rx distance of Type C Electrode means the measured value may also be smaller.
Figure 2-2  Electrode Pad Tx/Rx Electromagnetic Field and Panel Thickness Image for Mutual-capacitance Method

Figure 2-3 shows a coupling capacitance image based on electrode pad Tx/Rx parallel run distance and Tx/Rx facing distance in the mutual-capacitance method. The longer the parallel run distance of transmitter electrode Tx and receiver electrode Rx, the larger the Tx/Rx coupling capacitance, which results in greater change in the measured value when a touch is detected. When electrode pads are the same size, the longer the Tx/Rx parallel run distance, the more complicated the layout. In addition, a longer Tx/Rx facing distance supports thicker overlay panels and air gaps, but creates a denser electromagnetic field, leading to lower sensor counts.

Figure 2-3  Coupling Capacitance Image Based on Electrode Pad Tx/Rx Parallel Run Distance and Racing Distance for Mutual-capacitance Method

2.3  Air Gap

Figure 2-4 shows the electrode Tx/Rx coupling capacitance electromagnetic field and air gap (incl. panel thickness) for the mutual-capacitance method. In this method, when the layout design includes an air gap between the electrode and overlay panel, the Tx/Rx facing distance must be as long as possible, in the same manner as when using a thick panel. The facing distance between the transmitter electrode Tx and receiver electrode Rx depends on the panel thickness. The recommended Tx/Rx facing distance is approx. 0.6 times the panel and air gap thickness.
2.4 Distance from Touch Surface to Electrode

Figure 2-5 shows the relationship between the amount of capacitance change and the sensitive electrode. In the mutual-capacitance method, no matter how close or far apart the finger (human body) and electrodes are, the decrease in Tx/Rx coupling capacitance will be reduced, so panel thickness and air gap thickness are factors to keep in mind at the design stage. As mentioned earlier, the ideal optimal panel thickness, including the air gap, is 1.7 times the distance between the Tx/Rx electrodes.
Figure 2-6 shows the relationship between inter-electrode distance and panel thickness in the mutual capacitance method. As in the self-capacitance method, to avoid false detections (crosstalk) between neighboring electrodes, the recommended inter-electrode distance is 2 times or more the panel thickness (including the air gap).

\[
\text{Inter-electrode distance} \geq (\text{Panel thickness (} + \text{ Air gap)}) \times 2^\sim
\]

![Diagram showing inter-electrode distance and panel thickness](image)

Figure 2-6  Relationship of Inter-electrode Proximity and Overlay Thickness in Mutual-capacitance Method

2.5 Electrode Routing Design

Figure 2-7 shows an electrode routing example for the mutual capacitance method. Tx and Rx electrode wiring must be routed with ample distance near button electrodes and other areas where finger touch is anticipated. This clearance distance will reduce the risk of false detection due to a non-accurate touch, which may occur when a non-electrode pad area is touched. It is important to separate the Tx and Rx electrode wiring so that an unintentional touch does not occur across both traces at the same time. Similarly, if the touch measurement terminals (TS) set to Rx and Tx are adjacent, coupling capacitance may occur between the two terminals, reducing the relative rate of decreasing capacity, thus causing a decrease in sensitivity. To prevent capacitive crosstalk, group the Rx and Tx lines separately and keep them as far away as possible.

![Diagram showing electrode routing example](image)

Figure 2-7  Example of Electrode Routing for Mutual-capacitance Method
In the mutual-capacitance method, set the total capacitance per electrode to 20pF or less, and the total resistance (including the protective resistance value) to 2kΩ or less.

Figure 2-8 shows the electrode wiring limitations for the mutual-capacitance method. The total capacitance for each electrode can be confirmed in the First Step Guide for Workbench 6.

Tx and Rx electrode wiring should not be routed in parallel in short range within the wiring area, they must be kept as far apart as possible. If the wiring must cross due to board constraints, do so at a 90° angle as far from the electrode as possible, and then separate the wiring immediately.

Figure 2-8  Electrode Wiring Restrictions for Mutual-capacitance Method

2.6 Button Electrode Application Examples

2.6.1 Water-resistant electrode layout pattern design

Figure 2-9 depicts cautions regarding water-resistant electrode layout patterns for the mutual capacitance method. If the device is used under flowing water and a water film forms on the electrode surface, when the fingertip touches the water film, the effect is almost as if all electrodes under the water film are touched. This state greatly increases the risk of false detection (crosstalk) between adjacent electrodes in inverse proportion to the resistance value of the flowing water. Using sensing devices in the ocean or in other water containing electrolytes deteriorates the operating conditions for electrostatic touch. The resistance value of the water film is reduced due to an increasingly thicker water film and a high dielectric constant of the water, which is increased even further by the electrolytes.

Products that require water resistance must be designed with wide spaces between electrode pads as a countermeasure against false detections between adjacent electrodes.

Figure 2-9  Cautions for Water-resistant Electrode Layout Pattern in Mutual-capacitance Method
Figure 2-10 shows the recommended water-resistant electrode layout for the mutual-capacitance method. Considering that water flows from top to bottom, the best water-resistant layout would be to position all electrodes in a single horizontal line.

Since the Tx wiring, which is not used by the electrode during measurement, outputs low, all Tx can be grouped into one line for water-resistant designs. This will enable the L level output by non-active Tx wiring to bridge with other electrodes via the water film, preventing false detections.

- Figure 2-11 shows the relationship between the electrode proximity and the electrode pad width for the mutual capacitance method. To prevent false detection between adjacent electrodes (crosstalk), the recommended inter-electrode distance is more than 1 to 2 times of pad width.

### Inter-electrode distance ≥ Electrode pad width*1~2

**Actual example**

- Figure 2-12 shows the electrode pad and LED wiring for the mutual-capacitance method. The ideal routing is to position the LED around the outer edge of the electrode pad, as shown to the right of the figure. In the mutual-capacitance method, the Tx/Rx facing area can be increased to improve detection sensitivity. However, this creates

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**2.7 LED Wiring Layout**

**2.7.1 Direct lighting example**

-...

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difficulty in positioning the LED wiring going into the electrode pad at the Tx and Rx electrodes. The Tx/Rx parallel runs are short and may cause sensitivity deterioration for electrode pads of the same size.

2.7.2 Indirect lighting example

Figure 2-13 shows an LED routing example using an electrode pad and a light guide plate for the mutual-capacitance method. The LED (the light source) must be a set distance from light-emitting surface to ensure even lighting. Placing multiple LEDs (light sources) in opposing positions helps to eliminate uneven lighting.

2.8 Anti-noise Layout Pattern Designs

The button electrode configuration makes it act as an antenna (MCU pin is open only for coupling capacitance) and makes it vulnerable to electromagnetic field noise. Renesas Touch MCUs employ several anti-noise countermeasures to ensure high noise immunity. However, an MCU alone cannot prevent influence from all noise. Hardware countermeasures are indispensable when using the MCU in a severe noise environment. The following are a few examples.

In general, the longer the wiring, the more chances for noise to synchronize and mix with the many noise frequencies. Make sure the wiring between button electrodes and the MCU is kept as short as possible.
2.8.1 Anti-noise measure using ground pattern

Figure 2-14 shows an anti-noise layout pattern example for the mutual capacitance method. We recommend using a mesh ground pattern to cover the area around the electrode wiring.

If space restrictions prevent the covering of all wiring, place the mesh GND around the outside, prioritizing the Rx electrode wiring.

Make sure the distance between the electrode wiring and the mesh ground is 5mm or more.

---

**Figure 2-14** Anti-noise Layout Pattern Example for Mutual-capacitance Method:
3. Electrode Application Examples (slider, wheel, proximity sensor)

3.1 Example of Slider Electrode Layout Pattern Design

Figure 3-1 shows the recommended pattern for a slider electrode in the self-capacitance method. This pattern is designed for finger touch and ensures that 3 electrodes respond when the slider is touched anywhere other than the two ends.

To change the size of the slider, adjustments must be made by adding or removing electrodes rather than expanding or shrinking the pattern.

![Figure 3-1 Recommended Pattern for Slider Electrode in Self-capacitance Method](image)

3.2 Example of Wheel Layout Pattern Design

Figure 3-2 shows the recommended wheel electrode pattern for the self-capacitance method. This pattern is designed for finger touch and ensures that 3 electrodes respond no matter where the wheel is touched.

To change the size of the wheel, adjustments must be made by adding or removing electrodes rather than expanding or shrinking the pattern.

![Figure 3-2 Recommended Wheel Electrode Pattern for Self-capacitance Method](image)
3.3 Example of Proximity Sensor Electrode Layout Pattern Design

3.3.1 Proximity sensor electrode layout pattern design example

Figure 3-3 shows a proximity sensor sensitivity range image for the self-capacitance method. The maximum sensitivity for detecting a palm with a 100 x 100mm proximity sensor electrode is 300mm. (Based on Renesas Electronics in-house evaluation under ideal conditions with no conductors in the environment; not the guaranteed value).

In an actual product, the sensitivity distance of the electrode may be shortened due to the influence of the internal structure of the casing, etc.

![Proximity Sensor Sensitivity Range Image](image)

Figure 3-3 Proximity Sensor Sensitivity Range Image for Self-capacitance Method

3.3.2 Limitations related to proximity sensor electrode sensitivity distance

Figure 3-4 shows the relationship of the proximity sensor parasitic capacitance and sensitivity distance for the self-capacitance method. The proximity sensor sensitivity distance is affected by the parasitic capacitance added to the opposing side of the sensor electrode’s detection surface.

When the added parasitic capacitance in the opposite direction of the sensor electrode is large, the proximity sensitivity distance becomes shorter.

![Relationship of Proximity Sensor Parasitic Capacitance and Sensitivity Distance](image)

Figure 3-4 Relationship of Proximity Sensor Parasitic Capacitance and Sensitivity Distance for Self-capacitance Method
3.3.3 Usage notes for proximity sensor electrode placement in products

Parasitic capacitance is added when there is a conductor near the opposite side of the proximity sensor electrode in the produce casing or surrounding environment.

The parasitic capacitance added to the electrode varies depending on the size and potential of the area of the target conductor opposing the electrode, the distance to the electrode, and the relative permittivity of the substance in the space between the electrode and the conductor. The electrode positioning should be examined fully in view of these factors.

The proximity sensor electrode is larger than the key electrode, and thus easily influenced by the surrounding environment. Sufficient evaluation is necessary to prevent false detection due to dynamic ambient environment changes, signal line low output, or product installation location.

Figure 3-5 Image of Sensitivity Distance Degradation Due to Added Parasitic Capacitance of Proximity Sensor Electrode Back Surface
4. Appendix

4.1 Button Electrode Electrostatic Capacity Simulation

There are electrostatic capacity differential reference values and sensor counter differential reference values of the electrodes which are introduced in this application note. The electrostatic capacity differential reference values are simulation values and sensor counter differential reference values are forecast values. They may not be same as actual values.

4.1.1 Self-capacitance method button electrode

Simulation condition
- Panel material, Thickness, Relative permittivity: PVC, 5mm, 2.7
- Electrode material, Thickness: Copper, 0.035mm
- Pseudo finger material, Size: Copper, 10mm diameter cylinder * Height 50mm, connected to GND.
- Setting condition: There is 1600 * 800mm metal plate (iron) 100mm below electrode.

Measurement count value condition
- API Firmware generated by Workbench6 Ver1.06. CTSU Base clock is 4MHz
- Defined sensor counter 400 for 0.1pF unit.

(1) Square

<table>
<thead>
<tr>
<th>Electrode size (mm)</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Capacitance between Touch on / off (pF)</td>
<td>0.52</td>
<td>0.57</td>
<td>0.63</td>
<td>0.68</td>
<td>0.73</td>
<td>0.78</td>
</tr>
<tr>
<td>Differential sensor counts between Touch on / off</td>
<td>2080</td>
<td>2280</td>
<td>2520</td>
<td>2720</td>
<td>2920</td>
<td>3120</td>
</tr>
</tbody>
</table>
(2) Circle

<table>
<thead>
<tr>
<th>Electrode size (mm)</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Capacitance between Touch on / off (pF)</td>
<td>0.44</td>
<td>0.50</td>
<td>0.54</td>
<td>0.59</td>
<td>0.64</td>
<td>0.71</td>
</tr>
<tr>
<td>Differential sensor counts between Touch on / off</td>
<td>1760</td>
<td>2000</td>
<td>2160</td>
<td>2360</td>
<td>2560</td>
<td>2840</td>
</tr>
</tbody>
</table>

(3) Donut

<table>
<thead>
<tr>
<th>Electrode size (mm)</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Capacitance between Touch on / off (pF)</td>
<td>0.44</td>
<td>0.50</td>
<td>0.54</td>
<td>0.59</td>
<td>0.64</td>
<td>0.70</td>
</tr>
<tr>
<td>Differential sensor counts between Touch on / off</td>
<td>1760</td>
<td>2000</td>
<td>2160</td>
<td>2360</td>
<td>2560</td>
<td>2800</td>
</tr>
</tbody>
</table>
4.1.2 Mutual-capacitance method button electrode

Simulation condition
- Panel material, Thickness, Relative permittivity: PVC, 5mm, 2.7
- Electrode material, Thickness: Copper, 0.035mm
- Pseudo finger material, Size: Copper, 10mm diameter cylinder * Height 50mm, connected to GND.
- Setting condition: There is 1600 * 800mm metal plate (iron) 100mm below electrode.

Measurement count value condition
- API Firmware generated by Workbench6 Ver1.06. CTSU Base clock is 4MHz
- Defined sensor counter 400 for 0.1pF unit.

(1) Square 10*10mm Tx-Rx facing distance 1.2mm

- Panel thickness 2.0mm, Air gap 0mm

<table>
<thead>
<tr>
<th>Tx-Rx Coupling capacity (pF)</th>
<th>Decreasing Capacitance when Touch on (pF)</th>
<th>Rate of change when Touch on (%)</th>
<th>Decreasing sensor count value when Touch on (pF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.09</td>
<td>0.23</td>
<td>21</td>
<td>920</td>
</tr>
</tbody>
</table>

(2) Square 17*17mm Tx-Rx facing distance 2.4mm

- Panel thickness 2.0mm

<table>
<thead>
<tr>
<th>Air gap height between panel and electrode (mm)</th>
<th>0.0</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx-Rx Coupling capacity (pF)</td>
<td>1.44</td>
<td>1.16</td>
</tr>
<tr>
<td>Decreasing Capacitance when Touch on (pF)</td>
<td>0.27</td>
<td>0.19</td>
</tr>
<tr>
<td>Rate of change when Touch on (%)</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Decreasing sensor count value when Touch on (pF)</td>
<td>1080</td>
<td>760</td>
</tr>
</tbody>
</table>

(3) Square 11.6*11.6mm Tx-Rx facing distance 2.4mm

- Panel thickness 2.0mm

<table>
<thead>
<tr>
<th>Air gap height between panel and electrode (mm)</th>
<th>0.0</th>
<th>0.05</th>
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</thead>
<tbody>
<tr>
<td>Tx-Rx Coupling capacity (pF)</td>
<td>0.59</td>
<td>0.56</td>
</tr>
<tr>
<td>Decreasing Capacitance when Touch on (pF)</td>
<td>0.20</td>
<td>0.18</td>
</tr>
<tr>
<td>Rate of change when Touch on (%)</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>Decreasing sensor count value when Touch on (pF)</td>
<td>800</td>
<td>720</td>
</tr>
</tbody>
</table>
(4) Square 10.0*10.0mm Tx-Rx facing distance 1.2mm

- Panel thickness 2.0mm, Air gap 0mm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx-Rx Coupling capacity (pF)</td>
<td>0.83</td>
</tr>
<tr>
<td>Decreasing Capacitance when Touch on (pF)</td>
<td>0.21</td>
</tr>
<tr>
<td>Rate of change when Touch on (%)</td>
<td>25</td>
</tr>
<tr>
<td>Decreasing sensor count value when Touch on (pF)</td>
<td>840</td>
</tr>
</tbody>
</table>
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Inquiries
   http://www.renesas.com/contact/

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<th>Date</th>
<th>Page</th>
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<th>Summary</th>
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<td>1.00</td>
<td>13 October 2017</td>
<td>32</td>
<td></td>
<td>Rev.1.00</td>
</tr>
</tbody>
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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. 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.

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   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 Microprocessing unit or Microcontroller unit products 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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