R8C/38T-A Group

The basic principle of capacitive touch

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Summary

The Touch panel microcomputer R8C/33T Group contains a hardware peripheral (SCU: sensor control unit) that monitors the “touch” of the human body by measuring the stray capacitance generated between the touch electrode and the human.

In this application note, we introduce the method of detecting touch by various electrostatic capacitance methods and explain details about the method used in the SCU.

Target device

R8C/33T, R8C/3JT, R8C/3NT, R8C/36T-A and R8C/38T-A Group

Contents

1. What is the touch panel?

1.1 Kind of touch panel

We define the touch panel as follows. (The terminology used varies according to the country and the manufacturer.)

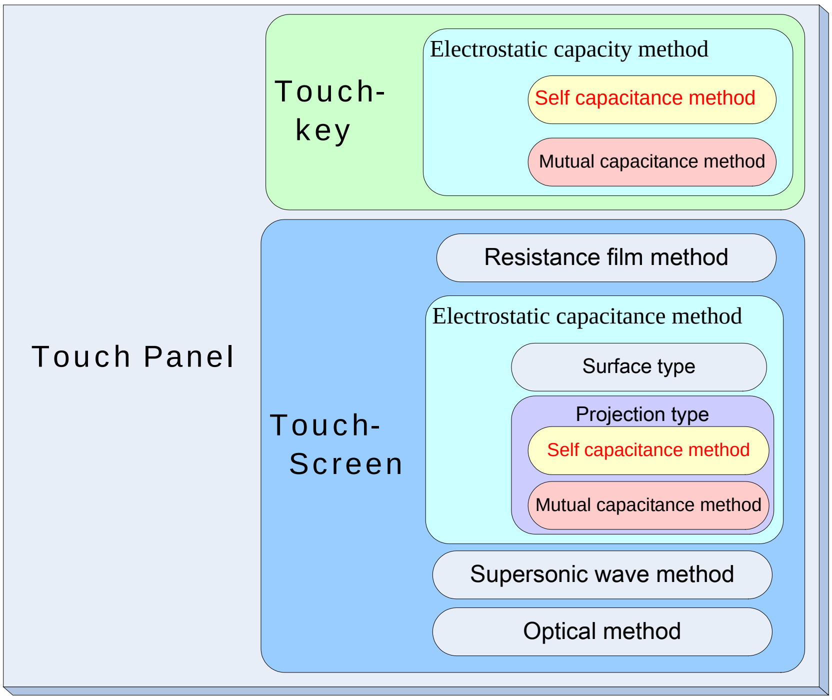


Figure 1-1 Type of touch panel

1.2 Touch key

The electrostatic capacitance method is the general principle used in "Touch" measurements.

The touch electrode is formed with materials such as PCB (printed circuits board), ITO (Indium Tin Oxide) films and electro conductive rubbers. The electric capacitance generated between the touch electrode and the human body is measured and a key ON or OFF judgment is made. As an application example, there are matrix keys, sliders, a wheel, etc. When the detection of movement around the circumference is desired, the wheel is used.

Figure 1-2 and Figure 1-3 show the example of the PCB layouts with touch electrodes.

When a lot of keys are necessary, the matrix configuration is used. The touch key matrix is like the key scanning matrix used with mechanical switches. When detection of movement of the finger that is the top to bottom or right and left is desired, the slider is used, and when the detection of movement around the circumference is desired, the wheel is used.

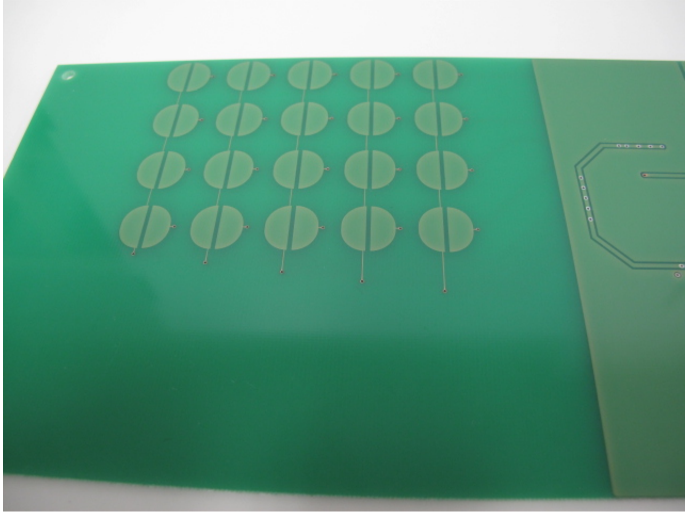


Figure 1-2 Touch electrode matrix key formed to PCB

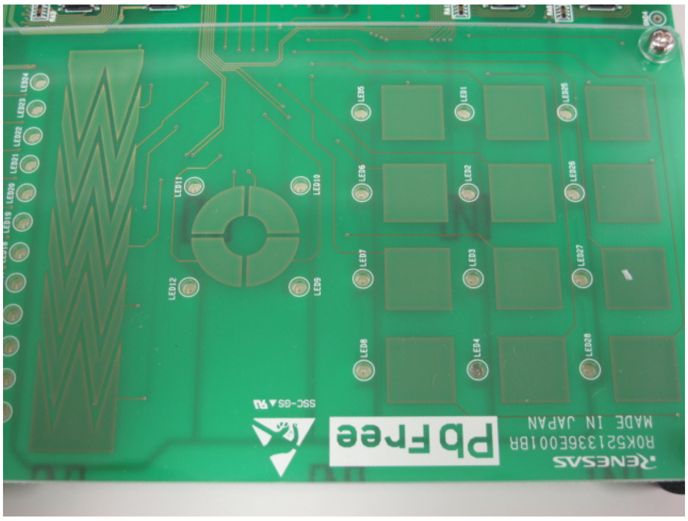


Figure 1-3 Key, wheel, and slider touch electrode formed to PCB

2. Touch screen

The resistance film type, optical type, and the supersonic wave type, etc. are examples of touch screen methods. This chapter explains the projection type of the electrostatic capacitance method. The projection type of the electrostatic capacitance method uses materials such as printed wiring boards and the ITO films and forms the sensing electrodes into an XY matrix. Figure 1-4shows example of rhombus shape electrode, Figure 1-5shows the example lattice shape electrode. A rhombus shape electrode is used the self-capacitance method. A lattice shape electrode is used the mutual capacitance method.

While the touch key detects key ON or OFF based on interaction with only one electrode, the touch screen detects X and Y coordinates position on the screen from information on two or more electrodes.

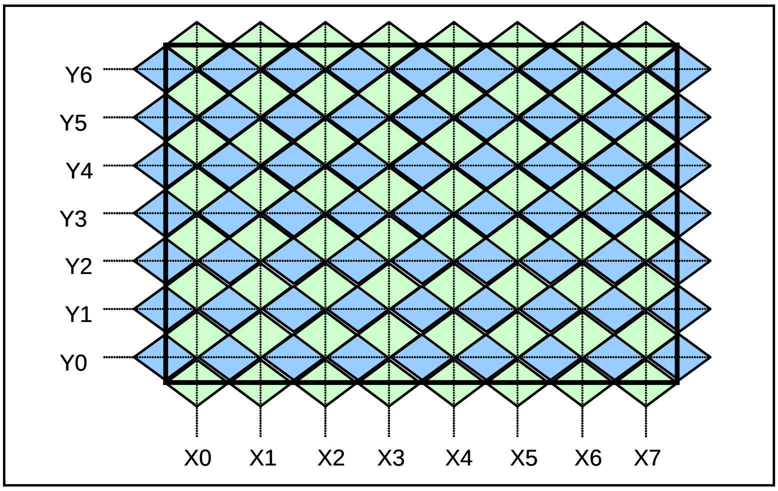


Figure 1-1 Rhombus shape electrode

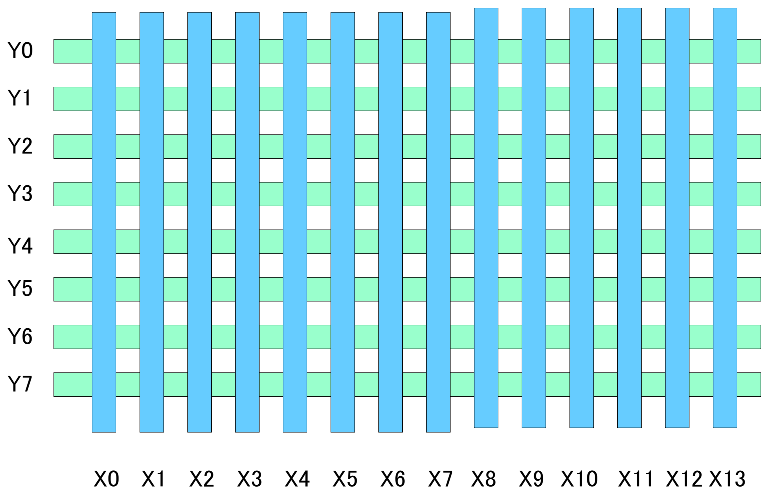


Figure 1-2 Lattice shape electrode

3. Electrostatic capacitance method

3.1 Principle

3.1.1 Self capacitance detection method

Figure 2-1 shows the principle of the self capacitance detection method. When not touched, a parasitic capacitance exists in touch electrode between the GND pattern and metallic frame of the PCB around the electrode. (Left figure) The electric capacitance is generated between the touch electrode and the finger because the human body is a conductor which is grounded to virtual GND so when the finger approaches the capacitance increases. (Right figure) The self-capacitance detection method perceives the approach of the finger by measuring an increase in the electric capacitance between non-touch and touch conditions. The self-capacitance method structure is simple, but because wiring to the electrode and the measurement IC cannot be protected by the GND pattern, the noise tolerance is low.

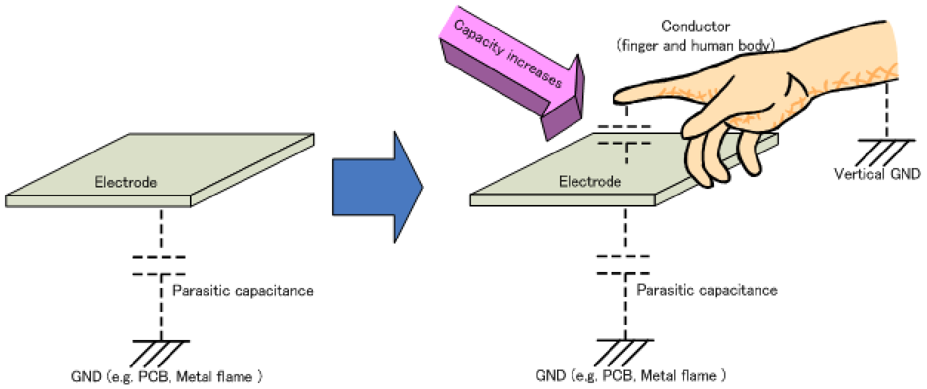


Figure 2-1Self-capacitance method

3.1.2 Mutual capacity detection method

Figure 2-2 shows the principle of mutual capacitance method. The mutual capacitance method is composed of the reception electrode and the transmission electrode. If the receiving side is grounded, and the pulse is input at the transmission side, an electric field (Field coupling) is generated in interelectrode capacitance. (Left figure)

During a touch the electric field of interelectrode decreases because part of the electric field is redirected to the human bodies when the finger approaches. (Right figure) The mutual capacitance method detects the approach of the finger by measuring a decrease in the charge according to a decrease in the electric field of non-touch to touch. The structure becomes complex because it needs the mechanism to generate the pulse which is transmitted for the mutual capacitance method. However, since the transmission electrode and reception electrode can be shielded from outside noise sources, the noise tolerance can better.

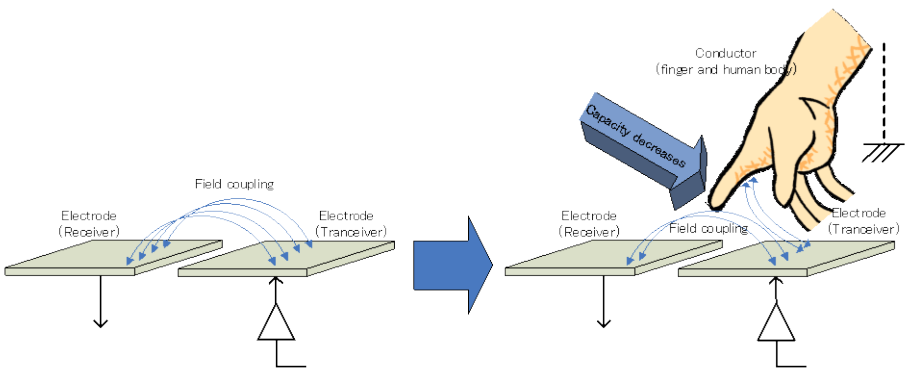


Figure 2-2 Mutual capacitance method

4. Explanation the method of Comparison of voltage division by series capacitance (OMRON method)

4.1 Principle

Figure 3-1 shows the method of Comparison of voltage division by series capacitance (OMRON method).

The Omron method is a self-capacitance method. This method measures the electric capacitance of Cx by the following methods.

(1) Capacitor Cc is charged then is gradually discharged through resistance Rc.

(2) The charge of Cc is moved to the comparison capacitor Cr and the electric capacitance Cx .

(3) The divided voltage of Cr and Cx is measured.

A detailed measuring method is as follows.

(1) SW1 is assumed turning on and Cc is charged. (SW2,SW3 is OFF)
(2) SW1, SW2, and SW3 are turned off. The charge of Cc is maintained.
(3) SW2 and SW3 are turned on for a fixed time.
Cc is partially discharged through resistance Rc while all the charge on Cx and Cr are discharged.
(4) SW1, SW2, and SW3 are turned off.
The charge of Cc moves to Cx and Cr.
(5) The voltage of Cx is compared with Vref with a comparator.

For the process (4)、(5), the equivalent circuit is shown in Figure 3-2. The voltage Cr and Cx must equalize to the voltage on Cc. The charge of Cc distributes to Cx and Cr. The relationship of voltages Vr, Vc, Vx and capacitance, Cc, Cr, and Cx are as follows.

$$Vc = Vr + Vx \qquad (a)$$

$$Vr:Vx = 1/Cr:1/Cx \qquad (b)$$

$$Vx = Cr/(Cr+Cx) \times Vc \qquad (c)$$

Process (3), (4), (5) are executed until Vx < Vref. As shown in equation (c),number of discharge cycles to reach the condition Vx < Vref will decrease when the capacitance of Cx is large.

This number of discharge cycles is used as a judgment of touch or non-touch.

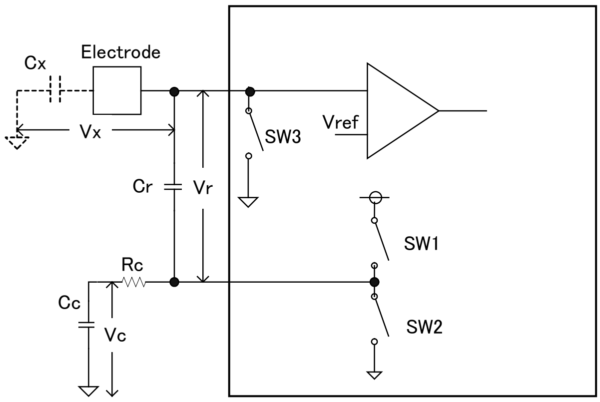


Figure 3-1 The method of Comparison of voltage division by series capacitance

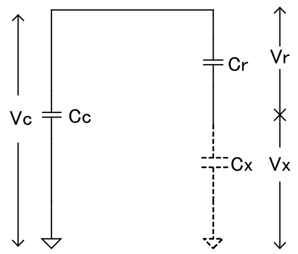


Figure 3-2 Process(4)、(5) equivalent circuit

Figure 3-3 shows a typical wave outline when touch detection operates. The rectangular shape waves shows changing voltage of Cx, and a mountain shape of waves is changing voltage of Cc. Voltage Vc decreases gradually as above-mentioned steps (3), (4), and (5) are repeated. Voltage Vx is the voltage shown by equation (c) in step (4), and 0V in step (3) since switch SW3 is closed. The number of cycles to reach Vx <Vref decreases when the capacitance of Cx increases by touch. The number of cycles is used to judge non-touch or touch.

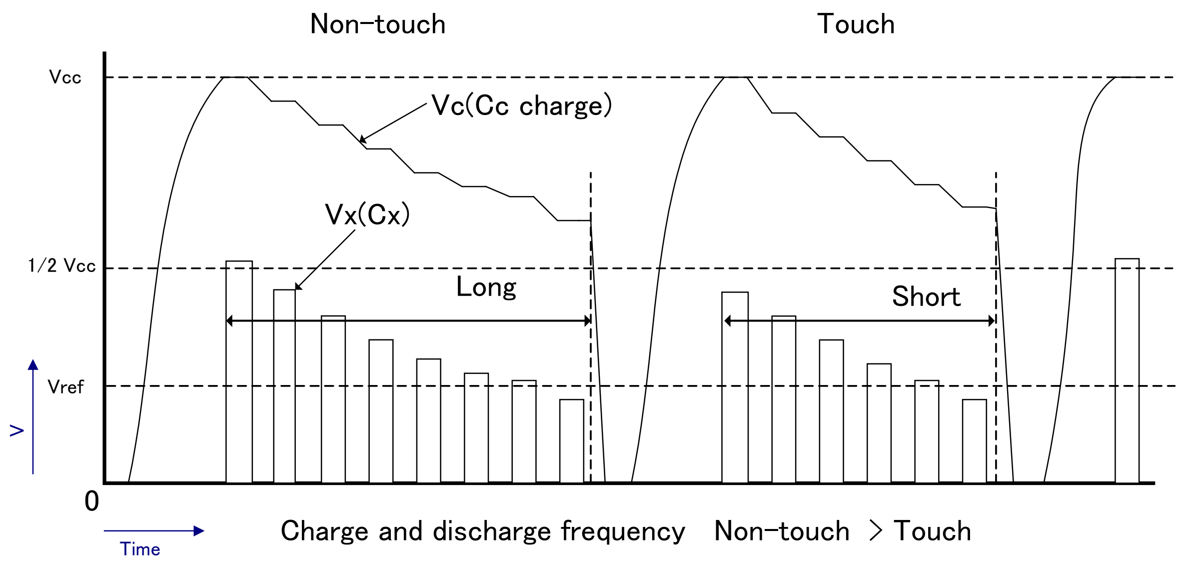


Figure 3-3 Wave outline of touch detection operation

4.2 Idea of touch circuit

4.2.1 Basis of electric capacitance

Figure 3-4 shows the model of electrostatic capacitance.

Electric capacitance C is as follows:.

- It is proportional to electrode surface area A.
- It is proportional to the relative permittivity κ of the interelectrode material.
- It is in inverse proportion to the distance of interelectrode.

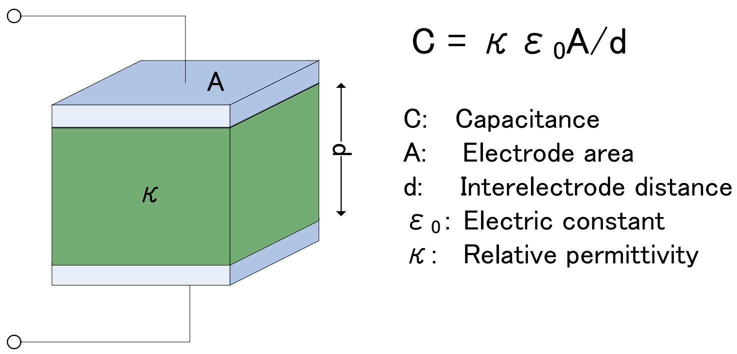


Figure 3-4 Electrostatic capacitance model

The electric capacitance generated in man's finger and electrode is a few pF. A large value will provide an accuracy improvement of the touch detection if it is possible to improve it. However, the electrode surface area is related to the touch area of the finger and it is not effective to increase the area past some value. The interelectrode distance depends on thickness of the material with which the surface of the touch key is covered. Table 3-1 shows the relative permittivity of some common materials. It is different according to each material. The glass has the best relative permittivity excluding water. Acrylic and plastic are also often used.

Table 3-1 Relative permittivity of each material

Dielectric Material	*k*
Acrylic	2.4-4.5
Glass	4.5-7.5
Nylon Plastic	3.0-5.0
Flexible Vinyl Film	3.2
Air	1.0
Water	80

4.2.2 Parasitic capacitance

When GND pattern, wiring, and a metallic frame exist near the electrode, parasitic capacitance is generated. It is necessary to eliminate the parasitic capacitance as much as possible since it may obstruct the measurement of the electric capacitance generated between the electrode and a finger.

However, depends on the noise environment, stable touch detection is enabled by protecting around the electrode with GND pattern. In this case, it is necessary to avoid creating parasitic capacitance with mesh GND pattern.

Other important considerations are:

- The GND pattern is not arranged around the electrode. (Some noise environments require GND pattern.)
- Maximum practical distance of other electrodes and wirings is maintained.
- The non-dielectric panel material is selected.

4.2.3 Noise

The electrode of parasitic capacitance can be easily affected by the external noises because it, as an antenna, may convey the noise in some forms. (The noise countermeasures in circuit configuration should be implemented along with in the detector circuit and the firmware.

- Noise interception of power supply circuit. A power supply with a regulator is preferable in the touch detection circuit.
- GND patterns to protect from the noise source
- The signal wiring and touch wiring shouldn't be paralleled.
- If needed, protect the electrode and its wiring with GND patterns.

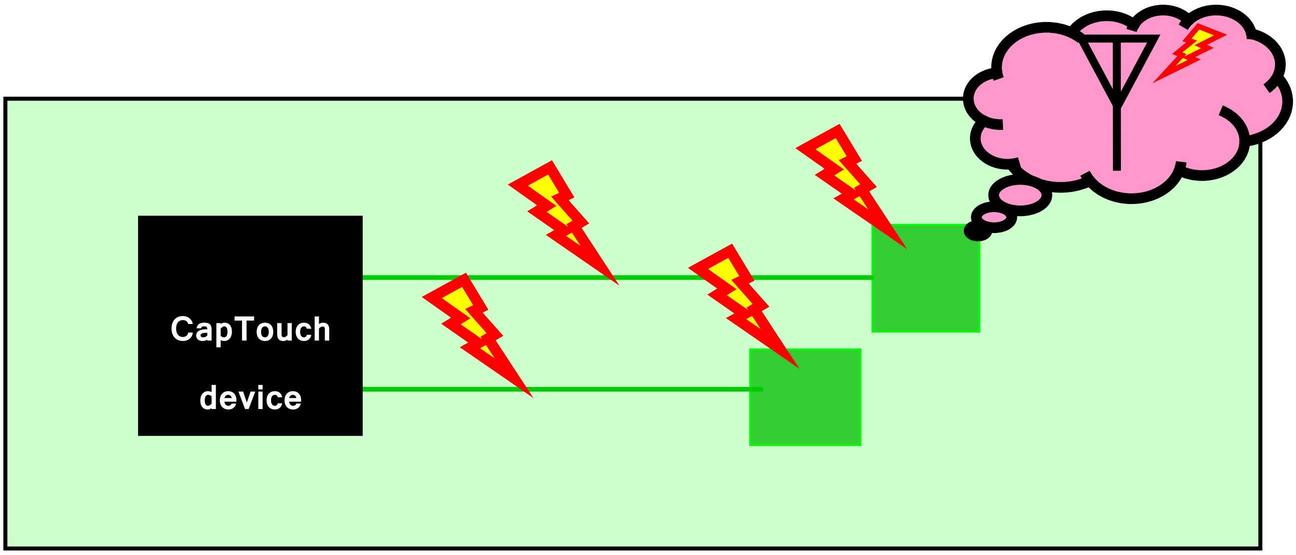


Figure 3-5 Touch electrode model

5. Recommended touch circuit

The electrode pattern, resistance, and the capacitor, etc. recommended when the touch circuit is designed with R8C/33T are described as follows.

5.1 Application of Omron method to R8C/33T

Before the explanation of recommended touch circuit, we will explain the Omron method used in touch panel microcomputer R8C/33T. Refer to the R8C/33T datasheet for actual details since a simplified description is provided in this document. Figure 4-1shows Pattern diagrams of R8C/33T touch detection circuit. The difference with the Omron method is as follows.

- The CR circuit is used with two or more electrodes. The CR circuit is connected to the different electrodes via the selector.
- To charge Cc at a high speed without resistance, there is the terminal just to charge capacitor Cc.
- The SCU (Sensor Control Unit) controls the selector, the switch for the electrical charge and discharge, the electrical charge and discharge time, and the measurement of the electrical charge and discharge cycles. Therefore the capacitance measurement of two or more electrodes is automated.
- Resistor Rr is added for port protection in a real circuit.

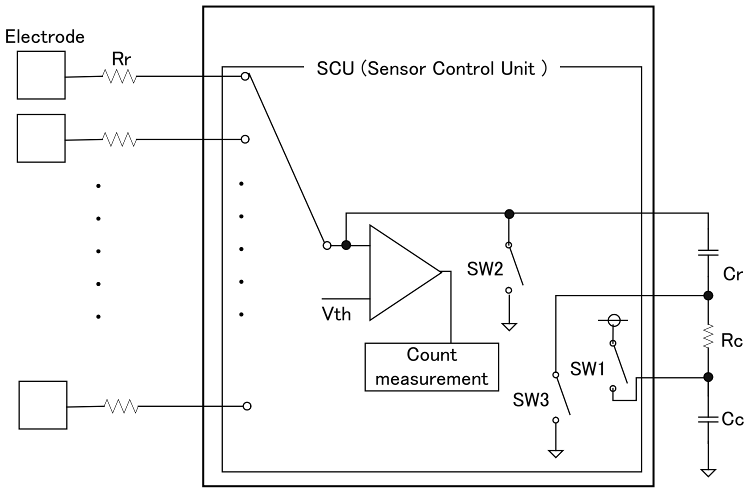


Figure 4-1 R8C/33T touch detection circuit imitative chart

5.2 Wiring pattern

Figure 4-2 shows recommendation wiring pattern. Details are as follows.

5.2.1 Width of electrode wiring

The width of the electrode pattern recommends the width of 0.2-0.3mm.

5.2.2 Each electrode wiring interval

Electrode traces are separated by two mm or more as much as possible when running side by side. Moreover, the distance that the traces run side by side is as short as possible.

5.2.3 Electrode wiring length

The electrode wiring length(between the electrode and the microcomputer) recommended is 180mm or less.

5.2.4 Interelectrode distance

5mm or more is the recommended interval of the adjoined electrode.

5.2.5 Wiring for external C and R

The wiring between external C, R, the microcomputer, and GND recommends the connection by the beeline. Moreover, it is recommended that the back be assumed to be GND pattern for two-layer PCB.

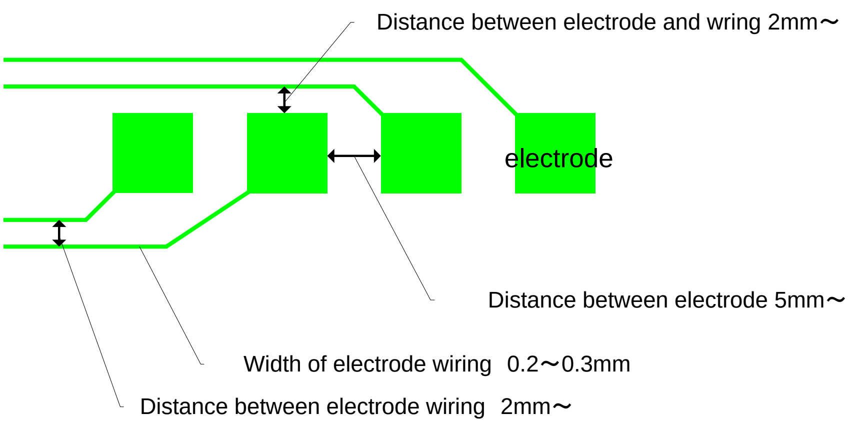


Figure 4-2 Wiring pattern

5.3 Size and form of electrode

The recommended size of the electrode is in forms of ● or ■ with an space of 10×10 to 15×15(in millimeter). In a form of ▲ or E-shape is not recommended since the electrode in those forms work as antenna, and can be easily affected by noises. Lighting with LED lights from the back of the electrode is also effective when its form is in a donut-shape or mesh configuration. However, in those forms, the sensitivity of the electrode can be weakened due to decreased area or noise can be created by the PWM control of LED. The preferable area of the electrode is as the same size of area as or as twice the size of area as the point of finger contact. Because the point and surrounding areas of the finger contact are effective as a capacitor, the bigger size of the electrode than the size stated above can become a parasitic capacitance that may lower the sensitivity.

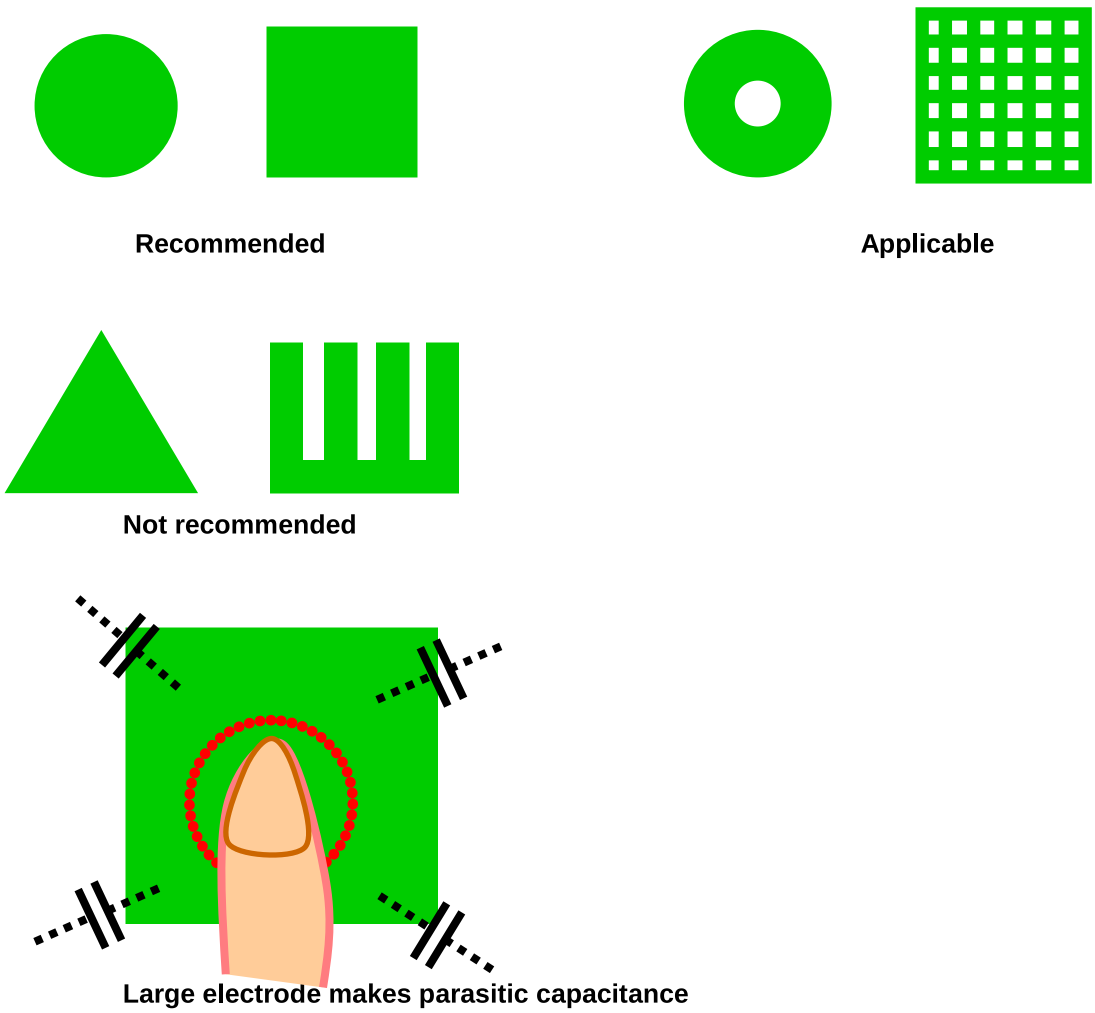
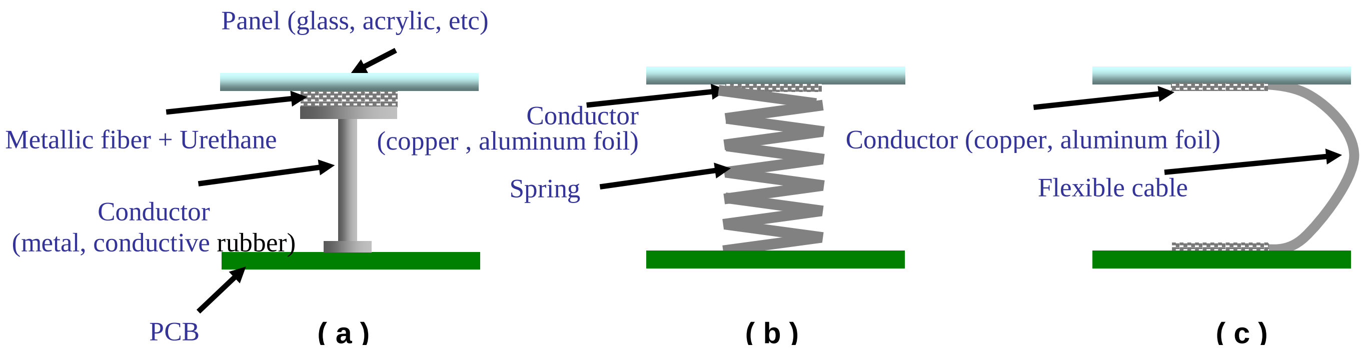


Figure 4-3 Form of touch electrode

The best arrangement of the electrode and the microcomputer is to connect with as short a wiring as possible on the same board. When those two can't be mounted on the same board due to the form of the panel, the alternative arrangement as shown in Figure 4-4 is applicable. In this case, the wiring shorter than 180mm is recommended.



(a) Install a metallic pole on the board. Attach the urethane piece covered with metallic fibers on the top of the pole. The urethane piece and its sickness play a role of clearance for the panel and the PCB.

(b) Install a spring on the board. Place a conductor on the back of the panel. The spring will make the conductor adhere firmly to the panel. The spring and its contraction play a role of clearance for the panel and the PCB.

(c) Install a brake cable with its end as an electrode to be adhered to the panel. The brake cable and its length play a role of clearance of the panel and the PCB.

Figure 4-4 How to connect when board and electrode are widely separated

5.4 Electrode material

Any conductor can be used as a material of the electrode: copper foil, carbon, electric conductive rubber. However, the material with large resistance (e.g. ITO film) may slow down a rise of the measurement waveform, which may affect the touch sensitivity.

5.5 Select a panel

As stated in chapter 3.2.1 *Basis of electric capacitance* the thickness of the panel that covers the electrode affects the parasitic capacitance. Recommended thickness of the panel varies depends on a material.

- Glass: 4 millimeters or less
- Acrylic: 2 millimeters or less

Note:

1. Do not use the conducting material such as mirror glasses and acrylic board. (Some acrylic boards contain irons.)

2. Set the panel and the electrode to be adhesively attached. Because the electric permittivity of air is low, the layer of air between the electrode and the panel can cause the decrease of the parasitic capacitance. (See Table 3-1 *Relative permittivity of each material*)

5.6 Ground pattern

It is recommended to arrange a ground pattern at least two millimeter away from the electrode and the electrode wiring. It is recommended for PCB with more than two layers to arrange a GND shield on a high-speed signal wiring, the R8C33T and the back of other devices as a noise countermeasures. As further noise protection, arranging a GND shield on the back side of the PCB including Cr, Cc, and Rc is effective.

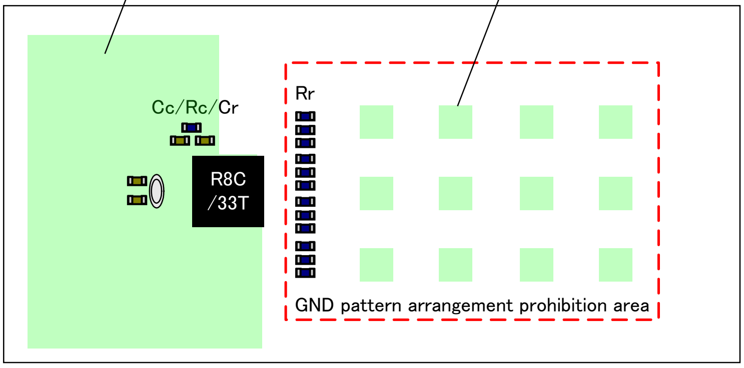


Figure 4-5 GND shield example

The measure against noise with GND patterns set surrounding the electrode is effective when the electromagnetic shield is required in severe noise environment. However, the sensitivity may be lowered due to the parasitic capacitance. In such cases, as shown in Figure 4-6, applying a mesh GND pattern is effective to decrease the parasitic capacitance.

<u>MCU embedded surface</u>

<u>Electrode surface</u>

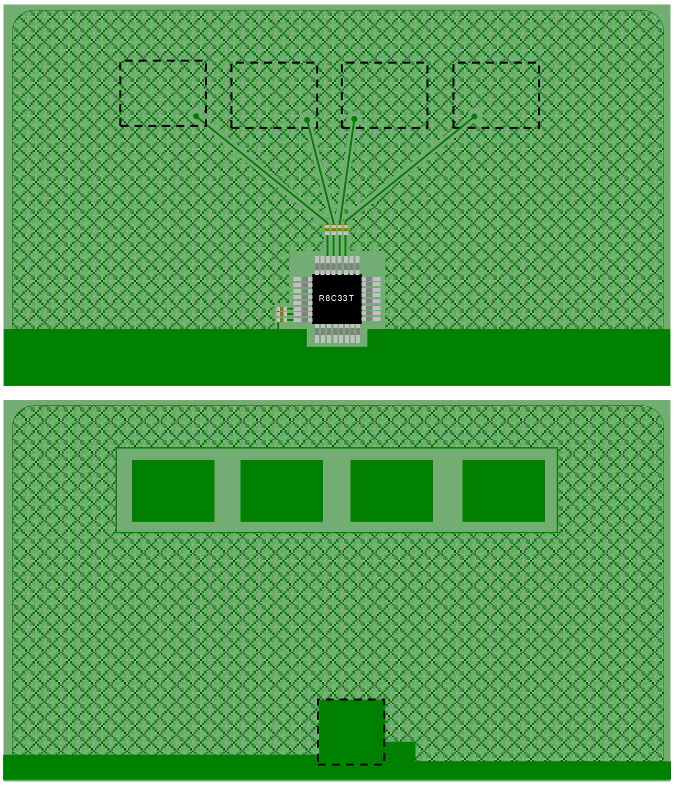


Figure 4-6 Electromagnetic shield GND pattern samples

5.7 Selection of resistance and capacitor

5.7.1 Range of constant

The recommended values of C and R values are as follows. The adjusting methods are stated in another application note.

- Cc: around 0.068 to 0.1μF
- Cr: 1 to 50pF
- Rc: 10KΩ or less
- Rr: 0 to 10KΩ

5.7.2 Size, temperature characteristic, and errors

The recommended specifications of chip resistors and the chip capacitors in mounting are as follows.

- **Resistance**
  Size: 1.6×0.8mm or 1.0×0.5mm
  Allowable error range: ±1% or less
- **Capacitor**
  Size: 1.6×0.8mm or 1.0×0.5mm
  Temperature characteristic: 0±60ppm/℃ (180pF or less) ±10%(220pF or up)
  Allowable error range: ±0.25pF (5pF or less), ±0.5pF (6 to 10pF),
  ±5% (11 to 220pF), ±10%(220pF or more)

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Revision Record <revision history,rh>

Rev.	Date	Description	
		Page	Summary
1.00	May. 21, 2013	—	Numbering change (Contents are as same as REJ05B1347-102)

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 manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins
   Handle unused pins in accord 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 one with a different type number, confirm that the change will not lead to problems.
   — The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type numbers, implement a system-evaluation test for each of the products.

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