R8C/33T group

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Base of electrostatic capacitance method touch key

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 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.)
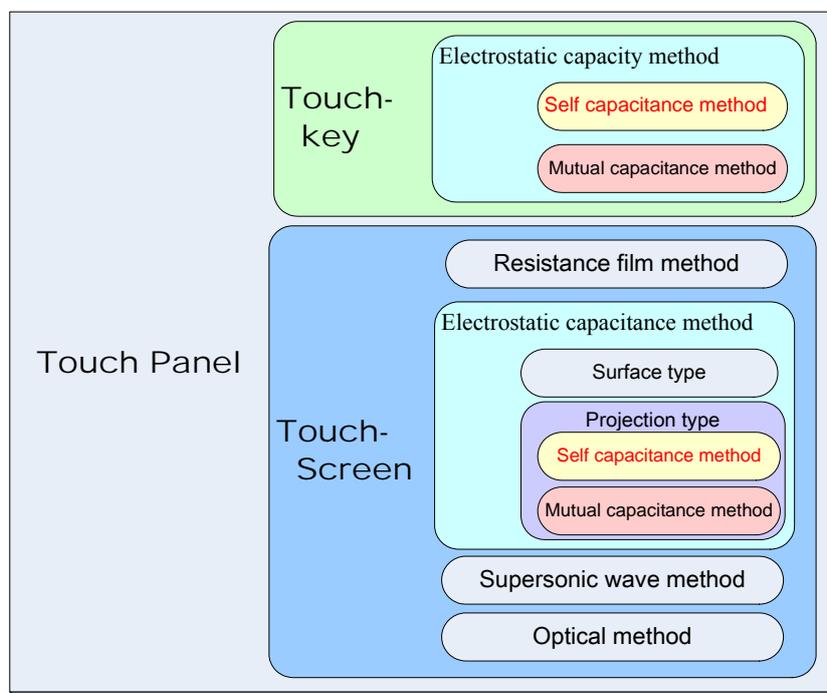

Figure 1-1 Type of touch panel

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 electroconductive rubbers. The electric capacitance generated between the touch electrode and the human body is measured and a key ON or OFF judgement 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.
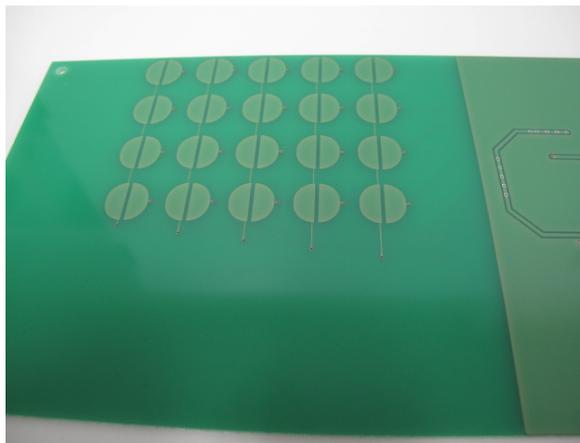
Figure 1-2 and Figure 1-3 show the example of the PCB layouts with touch electrodes.

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.
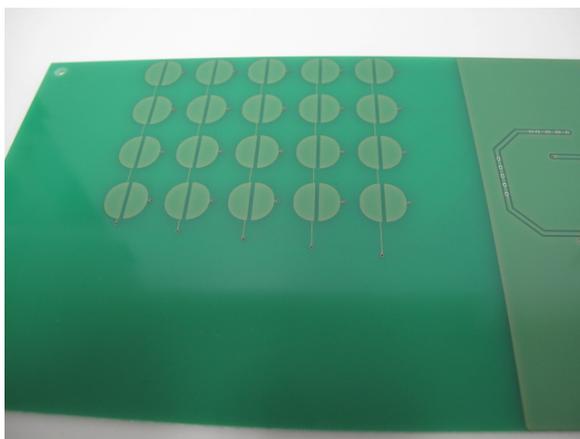

Figure 1-2 Touch electrode matrix key formed to PCB

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

1.3   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 1-4 shows example of rhombus shape electrode, Figure 1-5 shows 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.
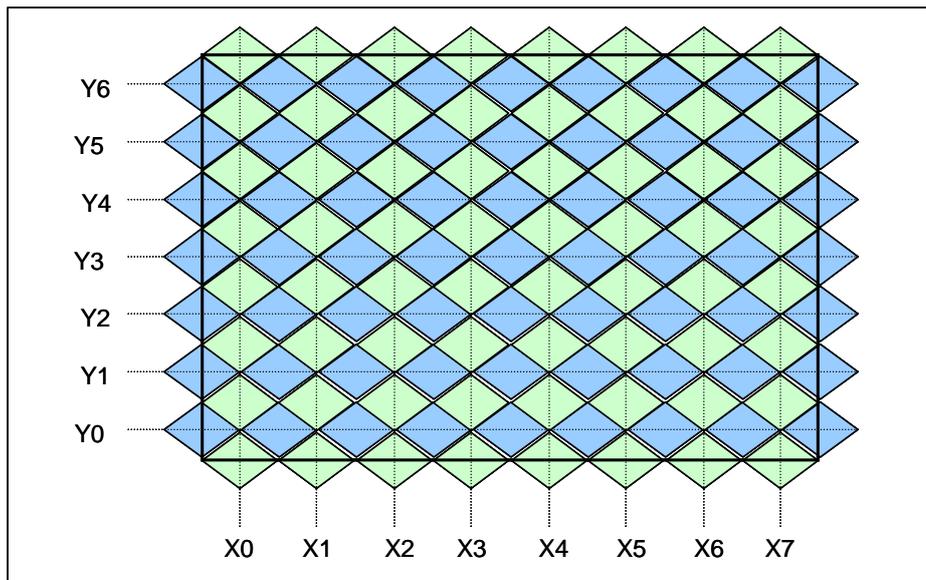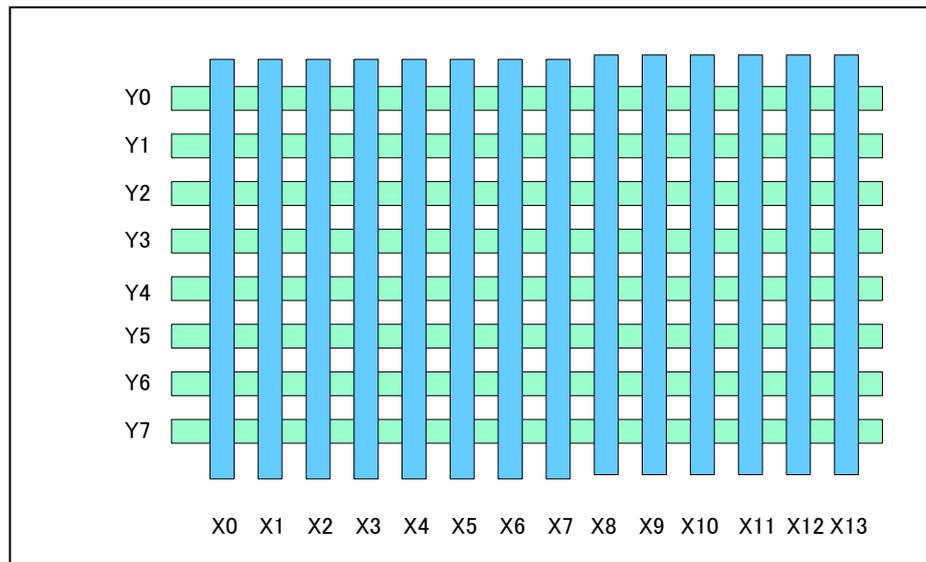
Figure 1-4 Rhombus shape electrode

Figure 1-5 Lattice shape electrode

2. Electrostatic capacitance method

2.1 Principle

2.1.1 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
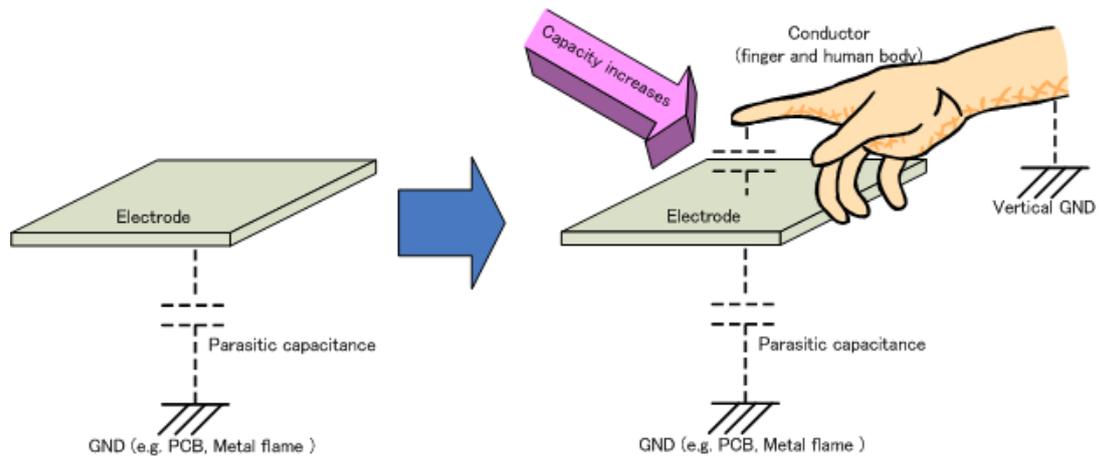
electrode and the measurement IC cannot be protected by the GND pattern, the noise tolerance is low.

Figure 2-1Self-capacitance method

2.1.2　　Mutual capacity detection method

since the transmission electrode and reception electrode can be shielded from outside noise sources, the noise tolerance can better.

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.
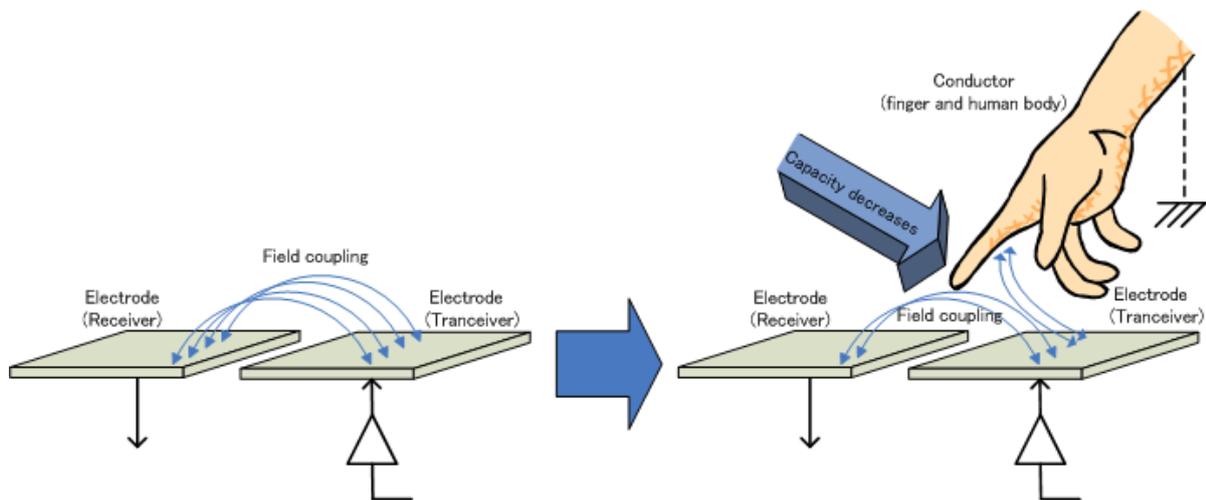

Figure 2-2 Mutual capacitance method

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

3.1 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 capitances, Cc, Cr, and Cx are as follows.

$$Vc = Vr + Vx \qquad \text{(a)}$$

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

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

 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.

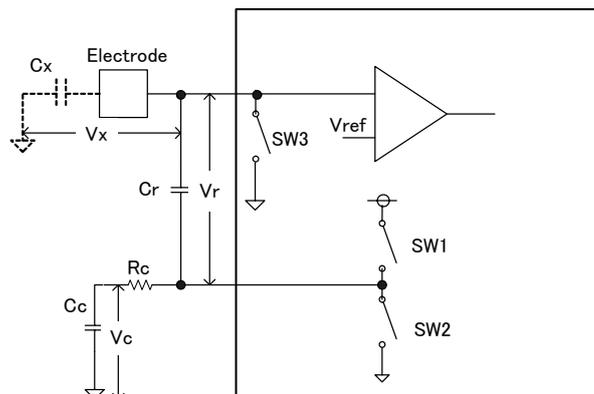This number of discharge cycles is used as a judgment of touch or non-touch.

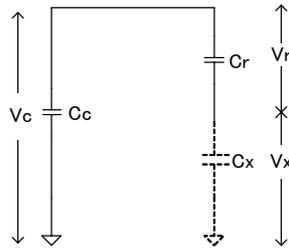**Figure 3-1 the method of Comparison of voltage division by series capacitance**

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.
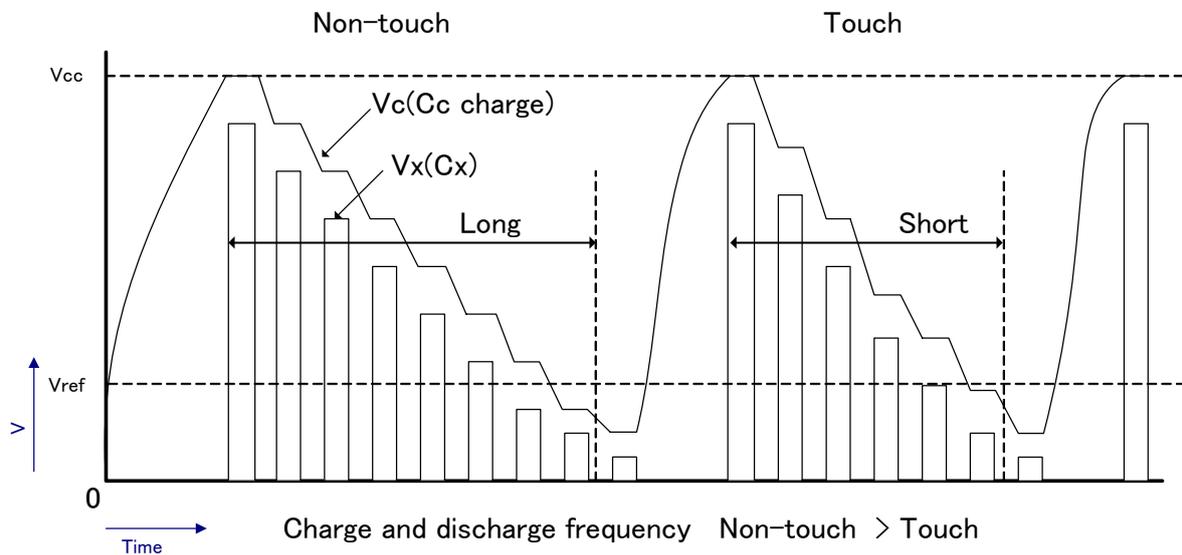
Figure 3-3 Wave outline of touch detection operation

3.2   Idea of touch circuit

3.2.1   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.

$$C = \kappa \, \varepsilon_0 A/d$$

C: Capacitance
A: Electrode area
d: Interelectrode distance
ε_0: Electric constant
κ: Relative permittivity
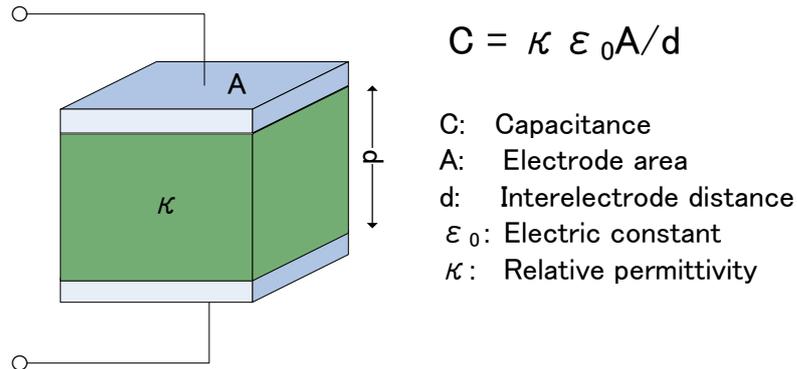
Figure 3-4 Electrostatic capacitance model

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 3-1shows 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

3.2.2   Parasitic capacitance

When GND pattern, wiring, and a metallic frame exist around the electrode, parasitic capacitance is generated. It is necessary to exclude it as much as possible since the parasitic capacitance may obstruct the measurement of the electric capacitance generated between person's fingers.   Other important consideration are:

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

3.2.3   Noise

Because the touch electrode cannot be guarded from noise by the GND pattern as mentioned above, other noise counter-measures are necessary. The noise countermeasures are implemented 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 are used at the noise source
- The signal wiring and touch wiring are not run parallel to each other.

4. 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.

4.1   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 data sheet for actual details since a simplified description is provided in this document. Figure 4-1 shows 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.
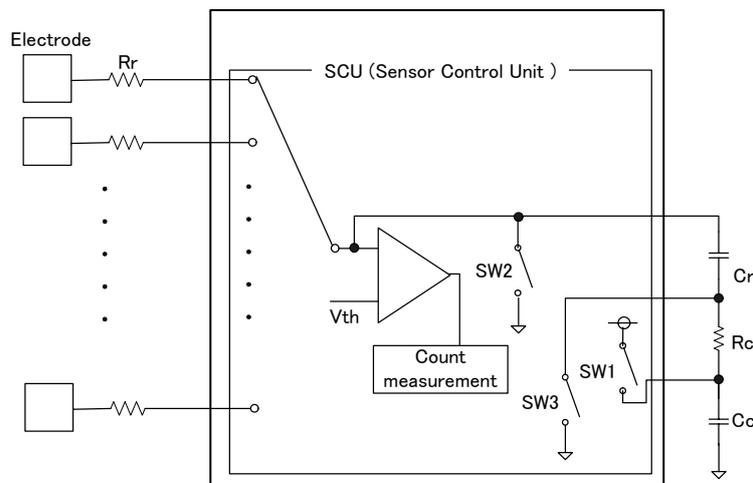
Figure 4-1 R8C/33T touch detection circuit imitative chart

4.2   Wiring pattern

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

4.2.1   Width of electrode wiring

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

4.2.2   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.

4.2.3   Electrode wiring length

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

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

4.2.5   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.

Distance between electrode and wring 2mm～

electrode

Distance between electrode 5mm～

Width of electrode wiring   0.2～0.3mm

Distance between electrode wiring 2mm～
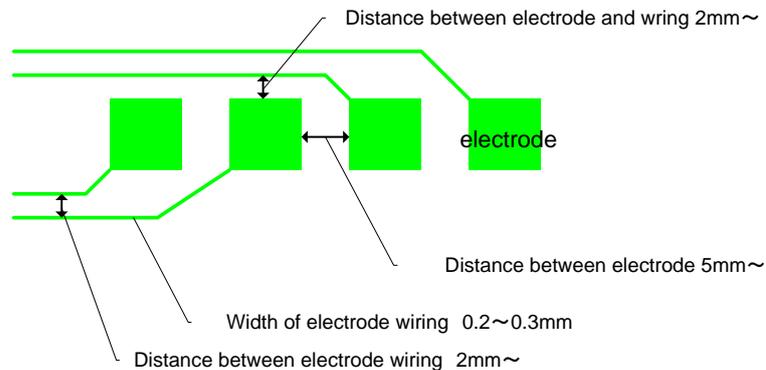
Figure 4-2Wiring pattern

4.3   Size of electrode

The recommendation of the size of the electrode is an area of about 10×10-15×15mm. Shape of electrode is free, but the part that comes in contact with the finger and its circumference become effective as a capacitor. So a size up to twice the area that comes in contact with the finger becomes a standard.

4.4   Electrode material

There is no restriction in the material of the electrode, if the material is a conductor (e.g. Copper foil, Carbon, Electric conductive rubber).   However, when the material with large resistance (e.g. ITO film) is used, the value of the resistance for the terminal protection requires adjustment.

4.5   Ground pattern

A ground pattern is not arranged near the electrode and the electrode wiring. It is recommended to separate by at least 2 mm or more. It is recommended for PCB with more than two layers PCB that high-speed signal wiring, the R8C33T and the other devices use a GND shield as a noise countermeasures. Moreover, it is recommended that the back of the PCB from Cr, Cc, and Rc also shields GND. Figure 4-3 shows GND shield example.
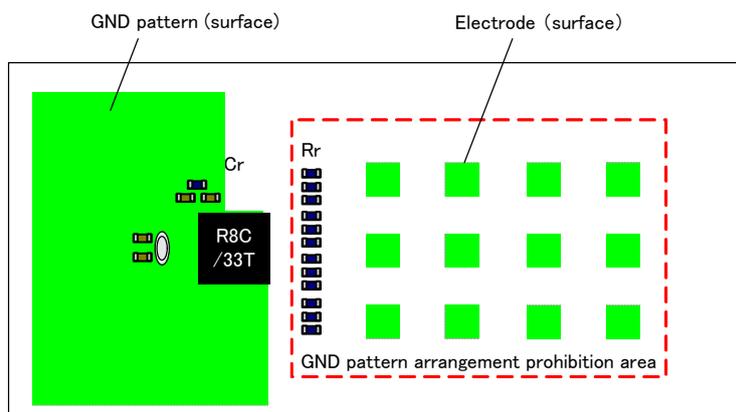
Figure 4-3 GND shield example

4.6　　**Selection of resistance and capacitor**

4.6.1　　**Range of constant**

The recommended C and R values are as follows. A method for adjusting these values is shown in another application note.

- Cc 0.1μF
- Cr 1～50 pF
- Rc 10KΩ or less
- Rr 0～10KΩ

4.6.2　　**Size, temperature characteristic, and error margin**

The chip resistor and the chip capacitor mounting are recommended. The characteristic is as follows.

- Resistance
  Size:　1.6×0.8mm or 1.0×0.5mm
  Accuracy of 1% or better
- Capacitor
  Size:　1.6×0.8mm or 1.0×0.5mm
  Temperature characteristic: 0±60ppm/℃ (-180pF) ±10%(220pF-)
  Accuracy :± 5%(11-220pF) ±0.5pF(6-10pF) ±0.25pF(-5pF) ± 10%(220pF-)

4.7　　**Panel selection**

The material and the thickness of the panel with which the electrode is covered influences the electric capacitance.

Thickness of glass and the acrylic sheet listed as examples though it depends on the material used.

- The glass 4mm or less
- Acrylic 2mm or less

Note the following point.

- Materials which include the conductive material cannot be used.
  (e.g.: The mirror glass and the mirror acrylic sheet have the possibility that might be metalliferous)

- The panel and the electrode should be adhesively bonded.
  The permittivity of air is low. (See Table 3-1)
  If air mixes between the panel and the electrode, the electric capacitance decreases.

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Revision Record

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1.00	Nov. 11, 2009	—	First edition issued
1.01	May 17, 2010	—	Format change

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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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SALES OFFICES

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Renesas Electronics America Inc.
2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited
1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

Renesas Electronics Hong Kong Limited
Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2886-9318, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.
7F, No. 363 Fu Shing North Road Taipei, Taiwan, R.O.C.
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
1 harbourFront Avenue, #06-10, keppel Bay Tower, Singapore 098632
Tel: +65-6213-0200, Fax: +65-6278-8001

Renesas Electronics Malaysia Sdn.Bhd.
Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.
11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141