Capacitive Sensor MCU

Capacitive Touch Ripple Noise Prevention Guide

Introduction

This application note is a guide for users who use the capacitive touch sensor unit (Capacitive Touch Sensing Unit: hereafter referred to as CTSU) in the self-capacitance method, helping them understand how ripple noise from the power supply or peripheral circuit affects on CTSU measurement values and on touch detection and take noise countermeasures.

Target Device

RX Family and RL78 Family MCUs embedding the CTSU

(CTSU indicates CTSU2, CTSU2L, CTSU2SL, etc.)

Contents

1. Outline

This application note is a guide for system and hardware designers who develop products with capacitive touch sensors.

This application note explains the principles of capacitive touch detection and the ripple noise that affects capacitive touch sensor measurement. Also introduces the configuration, selecting criteria, and circuit layout of the power supply required for ripple noise control.

For detailed information and basic handling of the capacitive touch sensor, refer to the following document.

Capacitive Touch Sensor Microcontroller CTSU Capacitive Touch Introduction Guide (R30AN0424)

The capacitive touch sensors embedded in Renesas MCUs are categorized into three generations according to its functionalities. The first-generation capacitive touch sensor uses a third-party IP (SCU/TSCU) and is used in R8C family (not recommended for new designs). The second-generation is a CTSU that Renesas has uniquely developed, being deployed in the RX family, Renesas Synergy™, and RA family. Today, CTSU2, which is the third-generation with advanced functionalities, is used in MCUs in various families.

In other materials like user's manual, the capacitive sensor of the second generation is written as CTSU/CTSUa/CTSUb, and the third generation is written as CTSU2/CTSU2L/CTSU2La/CTSU2SL, but this application note describes them as CTSU1 and CTSU2 respectively.
For features, types, and differences between CTSU1 and CTSU2, refer to "Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide".

1.1 Measurement Principles of CTSU

Figure 1-1 shows the measurement circuit of CTSU.

CTSU measures the capacitance by outputting a sensor drive pulse from TS terminal and measuring the charge/discharge current. The following equation is established when the electrode-side current is I, sensor drive pulse frequency is F, parasitic capacitance is C_P, capacitance of detection target is C_s, and sensor drive pulse voltage is V.

$$I = F(C_s + C_P)V$$

The current I is the sum of the current I_1 supplied from VDC (Voltage Down Converter) for measurement and the current I_2 supplied from the offset DAC.

For the current I_1 supplied from the measurement VDC, a proportional current I_{OUT} is applied to the current-controlled oscillator (Current Controlled Oscillator: hereinafter CCO) via the current mirror. CCO outputs a pulse-frequency proportional to I_{OUT} to the sensor counter. The sensor counter measures the sensor drive pulse for a fixed period and stores the measurement value of the current I_{OUT} in the sensor counter register.

The amount of current (measured value) differs when only the parasitic capacitance C_p is used and when a C_s is applied due to finger-contact etc. By using this, the change in capacitance is detected from the change in the current measurement value.

The capacitor connected to TSCAP terminal has the role of stabilizing the internal voltage.

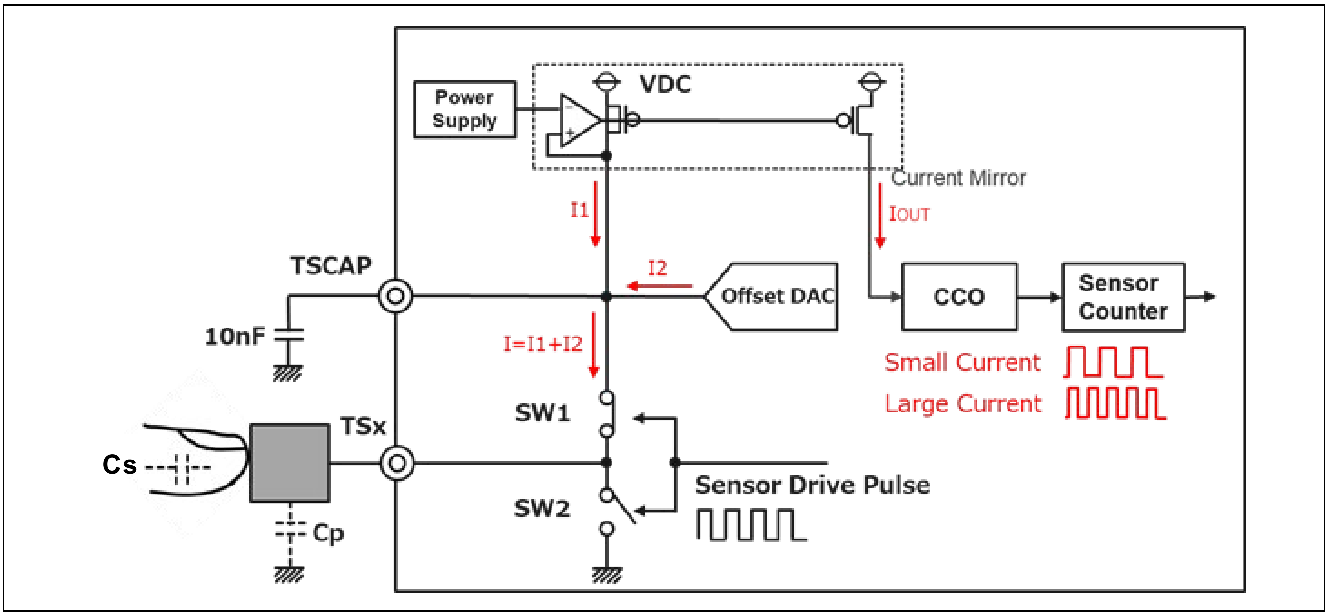

Figure 1-1 Measurement circuit of CTSU

1.2 Effects of Ripple Noise on CTSU Measurement

Figure 1-2 shows a principle diagram of the effect of ripple noise on CTSU measurement. When ripple noise infiltrates the power supply of the MCU, the ripple noise V_n affects the VDC, and the noise currents I_n, I_n' are added to the currents on the CTSU internal circuit I_1, I_{OUT}, then the measurement value of I_{OUT} will be inaccurate. Therefore, if the system requires high accuracy and reliability for touch measurement, it is necessary to design the power supply such that ripple is minimized.

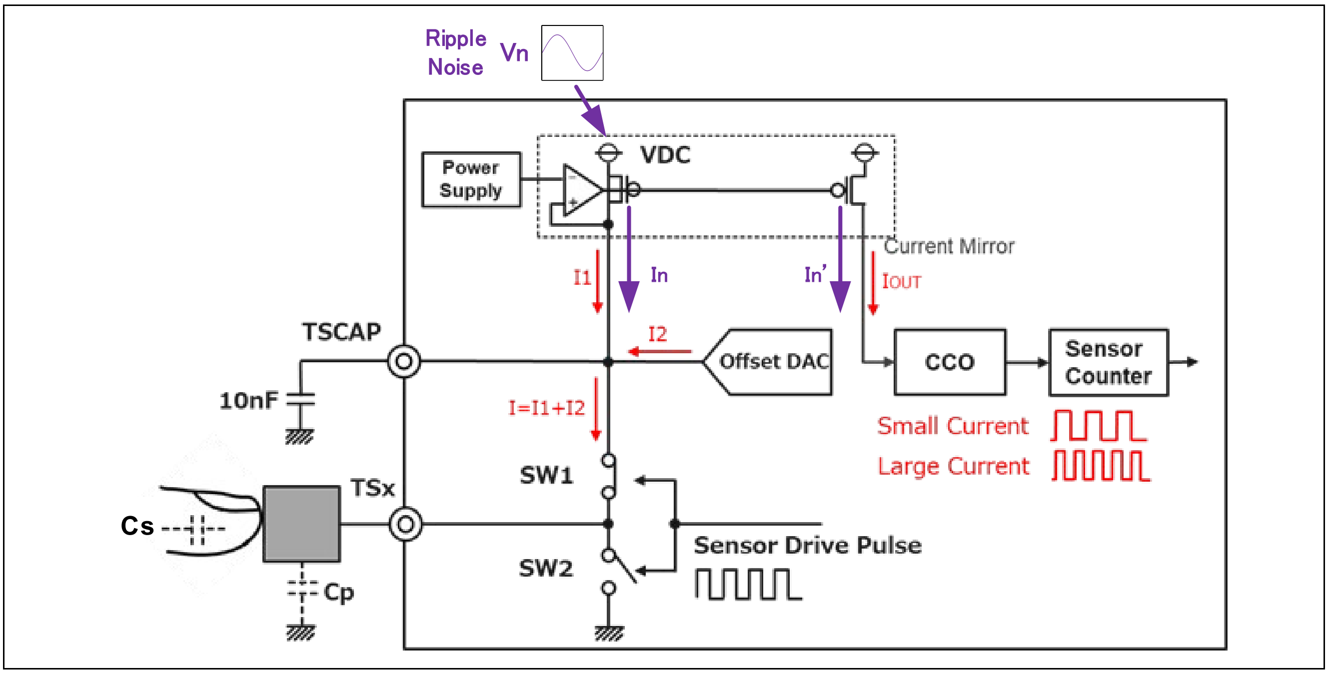

Figure 1-2 Effects of ripple noise on CTSU measurement

2. Ripple Noise

2.1 Definition of Ripple Noise

This application note indicates ripple noise as the following.

(1) AC ripple caused by AC power supplies (mainly 50Hz/60Hz commercial power supply frequency)

(2) Switching noise caused by switching power supplies, switching circuits, etc. (from several tens of kHz to several MHz)

For capacitive touch sensors, it is (2) Switching noise with high frequencies that are the most important to consider. This application note focuses on the switching noise, describing considerations of its effects and precautions on design. Note that the switching power supply in this application note refers to AC/DC converters and DC/DC converters.

2.2 Causes of Ripple Noise

The ripple noise on the switching power supply or switching circuit is generated when the current caused by switching of transistors flows into supply lines. The switching frequencies of general switching power supplies are from tens of kHz to several MHz. The ripple noise due to switching includes the switching frequencies and its harmonics. When selecting a power supply, it is required to consider not only the noise magnitude but also the noise frequencies to estimate the influence of the ripple noise on touch sensing measurement.

Figure 2-1 shows the equivalent circuit of a general bulk converter, which is a type of switching regulators. When switching between SW1 and SW2 for the input voltage V_{IN}, it varies as V_{SW}. By smoothing V_{SW} by a post-filter that consists of L_F and C_F, the output voltage V_{OUT} is obtained. The V_{OUT} has the ripple that has the switching frequency as the fundamental frequency component. The magnitude and the frequency components of the ripple noise depend on the input voltage, duty cycle, switching frequency, and characteristics of the post filter. Since the appropriate parameter setting to minimize the ripple noise differs depending on each power supply, we highly recommend that you confirm design materials by the power supply manufacture and evaluate them sufficiently before using.

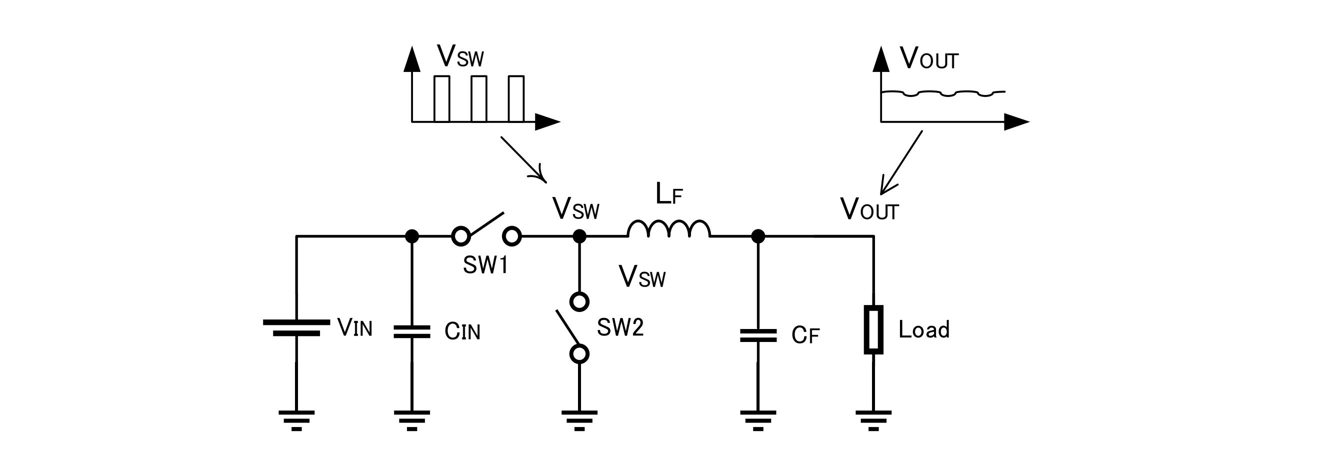

Figure 2-1 Equivalent circuit of bulk converter and ripple noise

2.3 Effects of Ripple Noise on Touch Judgement

2.3.1 Fluctuation of Measurement Value Caused by Ripple Noise

The fluctuation amount of the measurement value due to ripples varies according to the magnitude and frequency of the ripple and the device temperature (Ta). Figure 2-2 shows an example where the touch difference is 1000 without ripple noise and the measurement value is reduced by 4.5% with ripple noise. When there is no ripple noise, the touch difference is 1000, and when there is ripple noise, the touch difference is reduced by 4.5% for both touch on and off states, and the touch difference is reduced from 1000 to 955.

When using CTSU to judge touch ON/OFF on the button, if the touch threshold value for touch ON/OFF judgement has enough margin to produce correct detection results in the presence or absence of supply ripple, the final touch judgement is not affected. In applications that use the CTSU measurement value as it is, such as position sensor, distance sensor, and level sensor, it is particularly required to carefully take countermeasures against ripple noise.

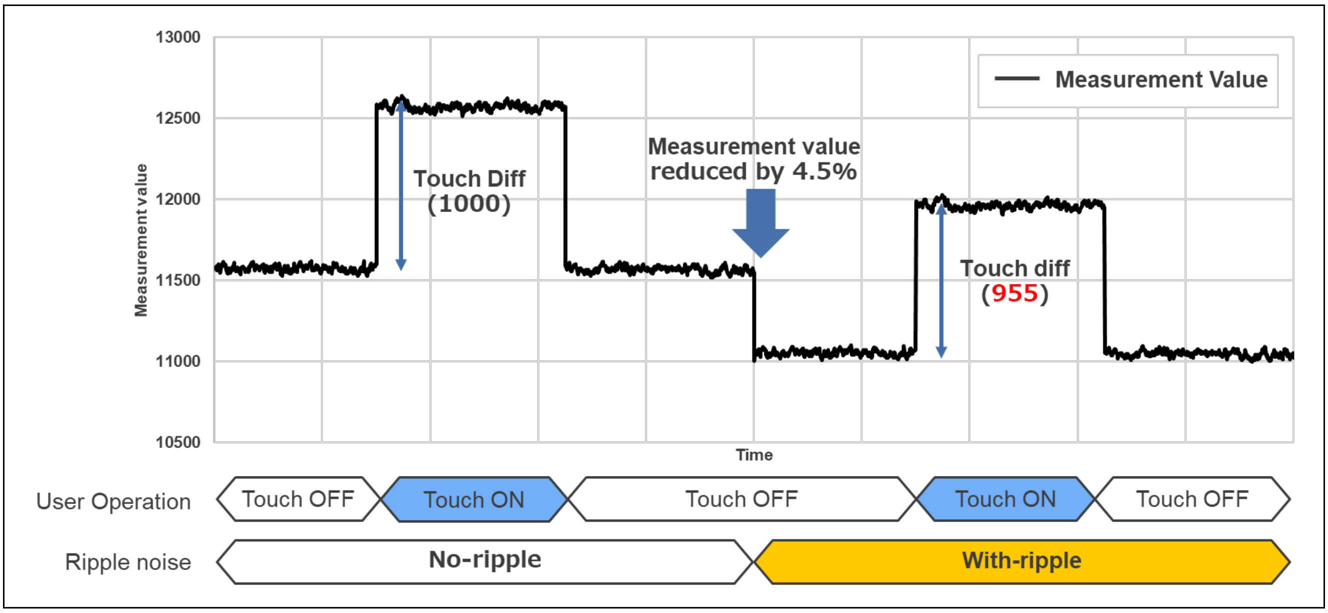

Figure 2-2 Example of measurement value deterioration due to ripples [touch difference=1000, Measurement value reduced by 4.5%]

2.3.2 False Judgement Caused by Ripple

The section 2.3.1 explains fluctuation of the measurement value caused by ripple noise, and this section describes the risk of false judgement caused by ripple noise.
If the presence/absence, frequency, or magnitude level of the ripple fluctuates due to peripherals operation or environmental factors, the CTSU measurement value fluctuates following this fluctuation, and there is a risk of a false judgement.

For example, consider a case of CTSU measurement with self-capacitance method in a system where the frequency or magnitude of the ripple noise fluctuates depending on the operation of peripheral circuits other than the MCU.

When the status changes from no-ripple noise to with-ripple noise as Figure 2-3, the software that processes the CTSU measurement values updates the reference value*Note1 with Drift Correction Processing*Note2 after a fixed period. After the update, if the status changes from with-ripple to no-ripple, the CTSU measurement value that has been decreased by the ripple recovers (increases). If the amount of this increase exceeds the threshold value for touch detection, a false judgement occurs.

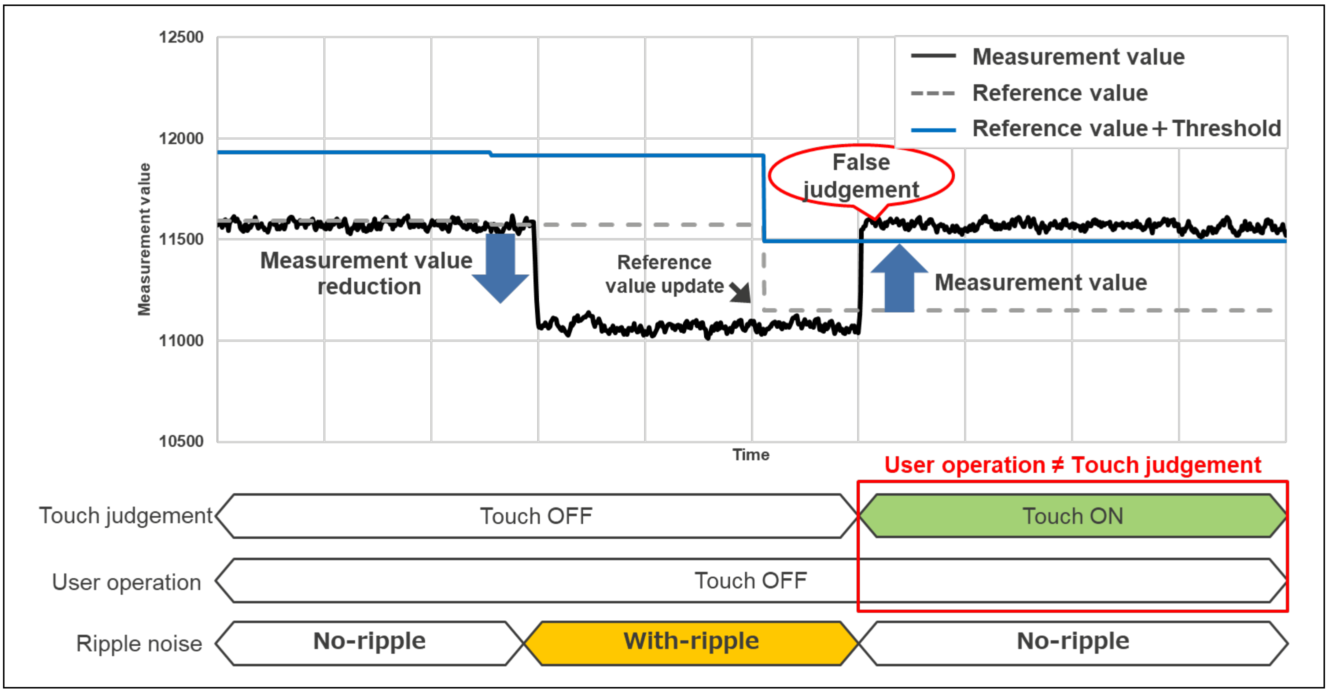

Figure 2-3 Example of false touch judgement due to ripples

*Note1: Reference value

The reference value is set to the measurement value when power is supplied to the MCU and a touch is OFF. The threshold value set by the user is used to judge touch ON/OFF as relative to this reference value. When the drift correction processing is enabled, it is updated in real-time every set number of measurement.

*Note2: Drift Correction Processing

To correctly judge the change in capacitance due to a touch even if the capacitance of the electrode varies due to change of the environment, the reference value*Note1 is updated with the average of values measured during a specified period of time only in touch OFF.

For details, refer to “2.4 Drift Correction Processing and Touch Detection” in Capacitive Sensor Microcontrollers CTSU Capacitive Touch Introduction Guide (R30AN0424).

3. Ripple Noise Countermeasures

As mentioned before, if precise measurement or highly reliable touch sensor functionality is required, countermeasures against ripple noise are very essential. This section describes the design concept of the power supply and board that doesn't cause the ripple noise and precautions.

3.1 Power Supply Circuit

3.1.1 Selection of Power Supply Circuit

It is the most important to select an appropriate power supply circuit to reduce ripple noise. For the system that requires measurement accuracy and reliability, select a power supply with as little ripple as possible. Make sure to carefully confirm the characteristics of the power supply circuit and recommended circuits/components and evaluate them using the actual device before implementing it in products. If selection of peripheral components or design of peripheral circuits and layouts is insufficient, it may make the characteristics of the power supply worse or the operation unstable.

The followings are the categories of general power supplies.

(1) AC/DC converter

・Transformer system

・Switching system

(2) DC/DC converter

・Linear regulator

・Switching regulator

We recommend using a linear regulator for the power supply of touch sensors to keep the effects of noise to a minimum. However, linear regulators have some disadvantages such as lower output voltage than input voltage, large power loss, and high cost. Therefore, a switching regulator is sometimes adopted, not a linear regulator. Particularly when using a switching regulator, it is required to pay attention to ripple noise caused by switching. This section describes the characteristics of each power supply and precautions for use.

(1) AC/DC converter

An AC/DC converter is a circuit that converts AC voltage like commercial power supply to DC voltage and outputs it. AC/DC converters are roughly categorized as transformer system or switching system.

・Transformer system

The AC/DC converter of transformer system is a circuit that steps down AC power supply voltage by a transformer at first, then rectifies it by a diode bridge and so on, finally, outputs DC voltage with ripples removed by smoothing circuit such as a capacitor. In this system, the AC power supply ripple is left in output voltage, and it is affected by the load, so if stable voltage is required, place a switching regulator or linear regulator in the second stage.

In this system, the main noise frequency is the commercial power frequency and its second harmonic frequency (in case of full-wave rectification). As ripple removal is difficult in this circuit, it is common practice to place a linear regulator in the second stage for stabilization.

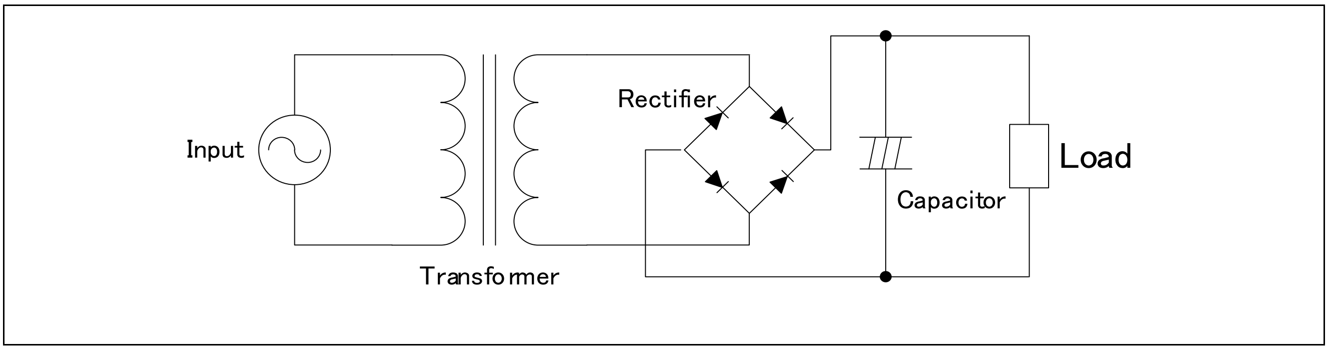

Figure 3-1 Typical configuration of transformer-system AC/DC converter

・Switching system

The AC/DC converter of switching system rectifies AC voltage by a diode bridge, then removes ripples in a smoothing circuit such as capacitor and converts it to DC voltage. After that, switches the DC voltage on and off by a switching element to convert it to high-frequency voltage, and transfers the energy to the secondary side by a transformer. Lastly, rectifies the secondary side voltage by a diode bridge, removes ripples in a smoothing circuit such as capacitor, and outputs DC voltage. This circuit follows the load fluctuation by feedback of the output voltage fluctuation and control of the switching frequency and duty cycle of the switching element.

In this system, ripple noise from 10kHz to several MHz including switching noise and its harmonics is overlapped on the output. When using such a power supply circuit, power supply IC, or power supply module, make sure to confirm the characteristics such as output ripple in datasheets and select appropriate components for a smoothing filter and so on. Even if the load is small or large, improper combination of the load and components may make the operation unstable. Make sure to sufficiently evaluate it with the actual device throughout all of the assumed load conditions.

When the switching frequency is adjustable, confirm “5. Ripple Characteristics” and consider setting it to the one so that the touch sensor is less susceptible.

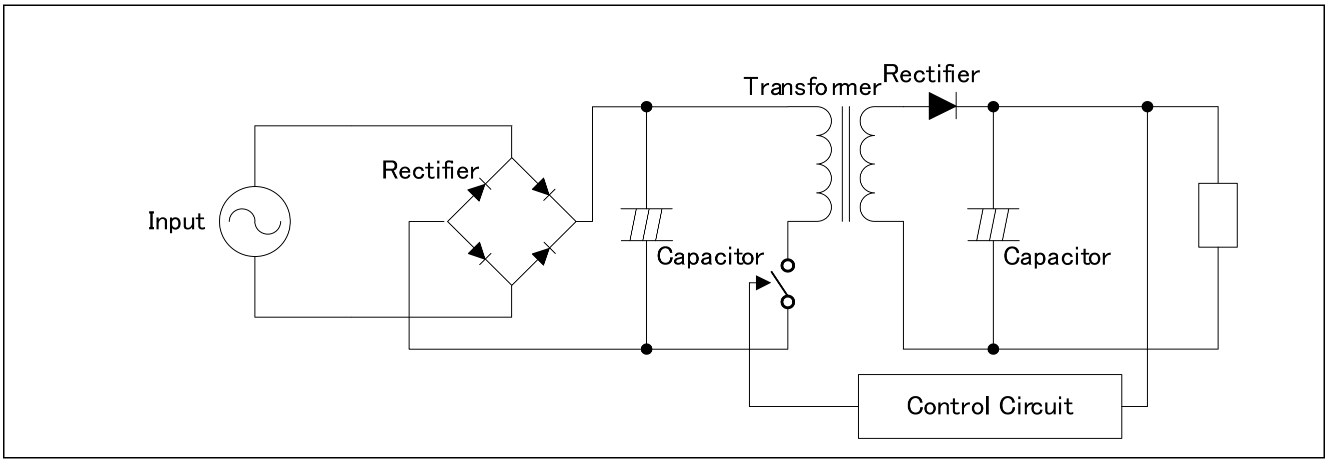

Figure 3-2 Typical configuration of switching-system AC/DC converter

(2) DC/DC converter

A DC/DC converter is a circuit that convers one direct voltage to another direct voltage. DC/DC converters are roughly categorized as linear regulator and switching regulator.

・Linear regulator

Also referred to as a series regulator, the linear regulator controls output voltage as desired by feedback of the output voltage signals to a transistor placed between input and output in series. Though a linear regulator causes power loss, the characteristic output typically has low noise and no switching noise, because it has no switching circuit. Though the output noise of linear regulators is small in general, the operation may be unstable depending on the constant of the output filter or load conditions. Make sure to sufficiently evaluate it with the actual device.

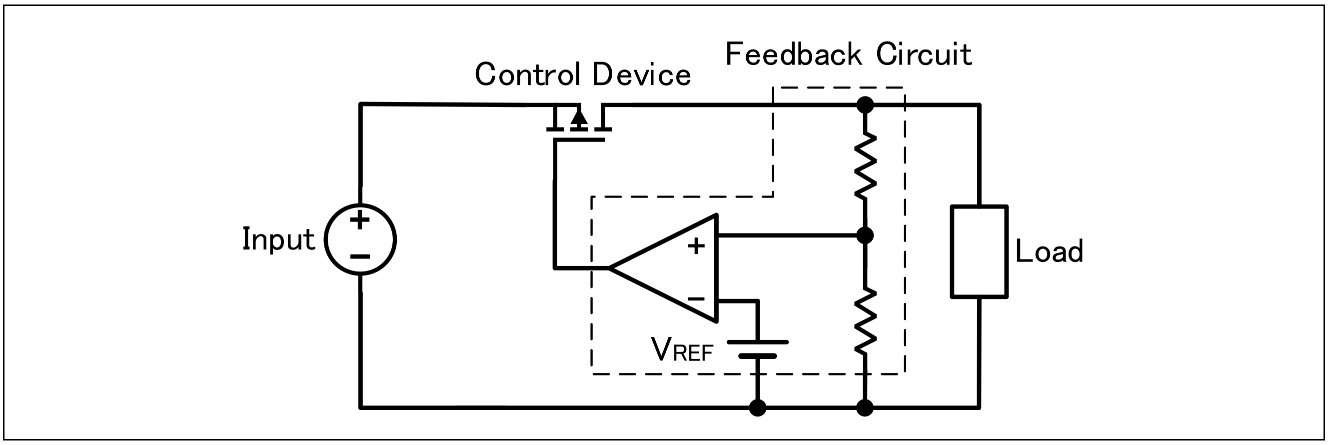

Figure 3-3 Linear regulator basic configuration

・Switching regulator

It is a circuit that has switches between input and output and controls the output voltage by regulating the periods of switch ON and OFF. By switching ON and OFF at high-speed and smoothing the output voltage via a LC filter, it outputs stable voltage. As no current flows to the output side while the switch is OFF, the power loss is small, but there is noise caused by switching.

In this system, ripple noise from 10kHz to several MHz including switching noise and its harmonics is overlapped on the output. When using such a power supply circuit, power supply IC, or power supply module, make sure to confirm the characteristics such as the output ripple in datasheets and select appropriate components for a smoothing filter and so on. Even if the load is small or large, improper combination of the load and components may make the operation unstable. Make sure to sufficiently evaluate it with the actual device throughout all the assumed load conditions.

When the switching frequency is adjustable, confirm “5. Ripple Characteristics” and consider setting it to the one so that the touch sensor is less susceptible.

Figure 3-4 shows a buck converter configuration. There are other converters that can support a wide range of input/output voltage such as boost converters and buck-boost converters, and isolated converters with transformers.

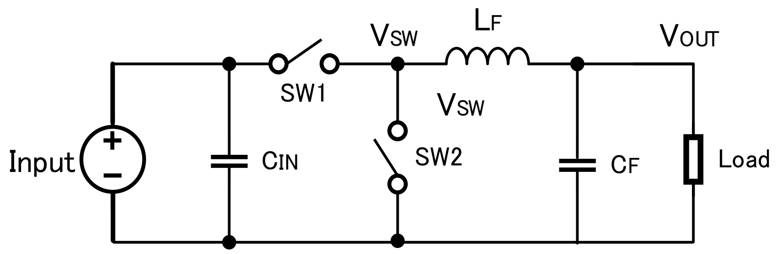

Figure 3-4 Switching regulator basic configuration (buck converter)

3.1.2 Characteristics of Power Supply

The followings are the characteristics which you should particularly pay attention to when selecting power supply for the system including a touch sensor.

・Input/Output ripple voltage

In a switching regulator, there are the ripples on both input side and output side.

The input ripple is caused as a switching circuit intermittently draws transient current due to switching. If the parasitic inductance on the input part is large, a large voltage spike may be created according to the current variation, and it is required to take countermeasures such as connecting an input capacitor to the place where the inductance is low for the input pin.

The output ripple varies depending on the power supply or the switching frequency. Though use of an output filter can reduce the ripple, it is required to consider the effects of the parasitic components (ESR, ESL, etc.) of the capacitor used as output filter sufficiently. When using a laminated ceramic capacitor as an output capacitor, note that the effective capacity is reduced due to the DC bias characteristic when applying high voltage. Reduction of the effective capacity may increase the ripple voltage, deteriorate the transient response characteristics, or make operation unstable.

・Line regulation

It is a characteristic showing the output voltage fluctuation for the input voltage fluctuation. It is the characteristic for continuous fluctuation of voltage, not for transient fluctuation. Though many recent line regulator ICs are excellent in the regulation characteristic, it is required to design a filter circuit and the wiring so that the whole system relies not only on the performance of the switching regulator IC, and that the input voltage is stable itself.

・PSRR (Power Supply Rejection Ratio)

It is a characteristic showing the fluctuation ratio of the output voltage for the input power supply, expressed as a frequency characteristic. The higher PSRR means larger removal of noise infiltrating the input power supply and less susceptible to the output. The line regulation is a characteristic for DC, and PSRR is expressed as an AC characteristic. When confirming the characteristic of the noise reduction ratio for high frequency input noise, see the PSSR, not the line regulation. Particularly when placing a linear regulator on the second stage of a switching regulator, it is crucial to select a linear regulator with the PSRR characteristic that can remove the ripple noise generated by the switching regulator. To make a switching regulator fully bring out its PSRR characteristic, it is required to select a low-ESR capacitor as a peripheral component and design the wiring to keep the resistance of the feedback loop of the power supply and the parasitic inductance to a minimum. To make a switching regulator fully bring out its PSRR characteristic, it is required to select a low-ESR capacitor as a peripheral component and design the wiring to keep the resistance of the feedback loop of the power supply and the parasitic inductance to a minimum.

・Load regulation

This is a characteristic that shows the output voltage fluctuation for the load current fluctuation. As well as the line regulation, it is not the characteristic for transient response. In the actual circuit, there are not only the load regulation of the power supply IC in use, but also the output voltage fluctuation caused by voltage drop due to the wiring resistance in the current path to the load. Therefore, if there is a circuit with large fluctuation of the load, some considerations are required such as dividing the wiring path for the power supply IC that needs accuracy.

・Load transient response

The load transient response refers to a characteristic showing the response speed for the output voltage to return to the set voltage when the output voltage rapidly fluctuates. It is determined depending on the ESR characteristic of the output capacitor and the response characteristic of the power supply circuit. If there is a circuit with transient load fluctuation, it is required to consider this characteristic.

3.2 Switching Circuit

As well as switching regulators, a circuit like motor driver or inverter can create ripple noise due to high-speed switching required by those circuits. The noise generated from these circuits can infiltrate a power supply, GND, touch sensor electrode, or touch sensor MCU via various paths and may lower the measurement accuracy.

The noises are categorized by the noise infiltration path.

(1) Radiated noise

This noise is radiated to the air, being picked up via a noise source itself or cables as an antenna. It can be reduced by covering the noise source with a shield case or pattern, or attaching a noise filter to the cable. It is also effective to keep the noise source apart from the circuit that is susceptible to noise.

(2) Induced noise

The noise that is transmitted by static induction or electromagnetic induction. The noise transmitted by static induction can be reduced by using shield lines and grounding them at one point. The influence of the noise transmitted by electromagnetic induction can be reduced by using twisted-pair cables as signal lines to reduce electromagnetic of two signal lines, combining shields, and keeping away from other circuits.

(3) Conducted noise

It is high-frequency noise conducted via power supply lines or earth wires. Some countermeasures are effective, such as placing a noise filter in the power supply and removing the grounding on the circuit side that is more susceptible.

3.3 Power Supply Configuration and Board Layout

3.3.1 Power Supply Configuration

For a circuit susceptible to noise like a touch sensor, it is also effective to insert a separate power supply, other than a power supply with large noise or a circuit of noise source. If there is a device or circuit with high current loads or large load fluctuation on the board, we recommend separating the power supply, for the touch sensor and for other circuits as shown in Figure 3-5. If such a configuration is difficult, select a switching regulator for shared power supply that has low noise and high immunity to wide load fluctuation. Since operation of the switching regulator varies according to the load current, the ripple noise may be increased in some cases depending on the load current. Make sure to evaluate it sufficiently with the actual device before implementation to products. To prevent the influence of voltage dropping due to the load current fluctuation, arrange the wiring by separating the power supply lines for the circuit with large load fluctuation and for the touch sensor. For the detailed layout of power supply and GND, refer to "3.3.2 Power Supply / GND Layout Design"

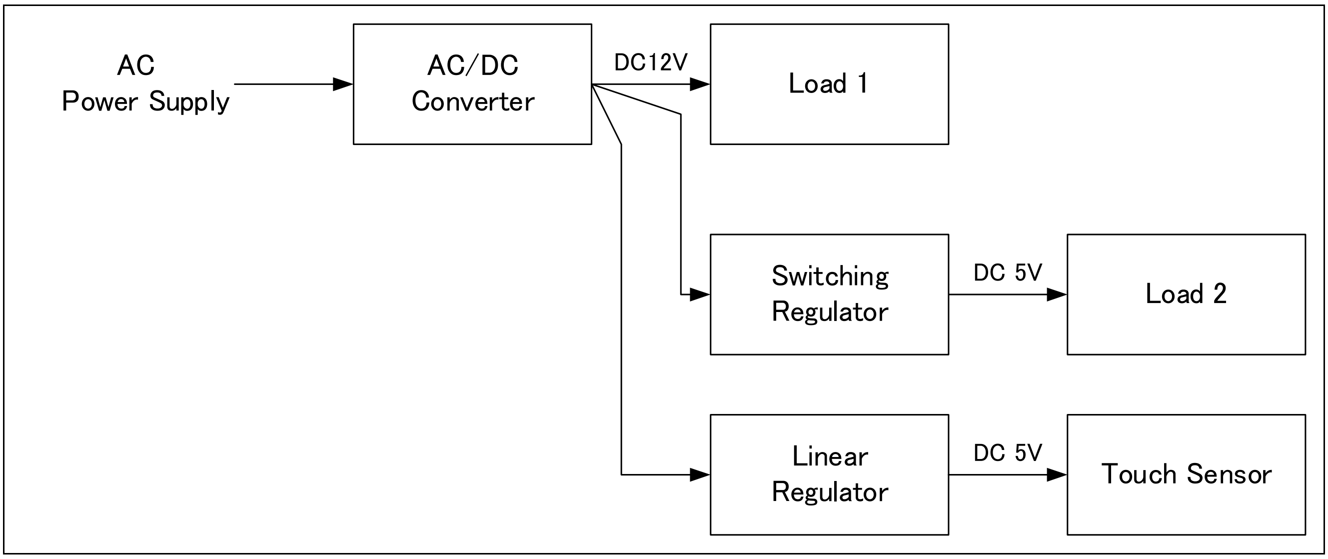

Figure 3-5 Example of Power Supply Configuration

3.3.2 Power Supply / GND Layout Design

(1) Power Supply Layout

If there is a devices or circuit with high current loads or large load fluctuation, and if it is impossible to insert a separate power supply for each, arrange the wiring as shown in Figure 3-6 (b) or (C), so that the power supply line is not shared. In addition, to prevent noise infiltration into the touch sensor from the noise source, it is also effective to separate power supply patterns and weaken the electrical coupling between each power supply line by placing a shield around the power supply pattern.

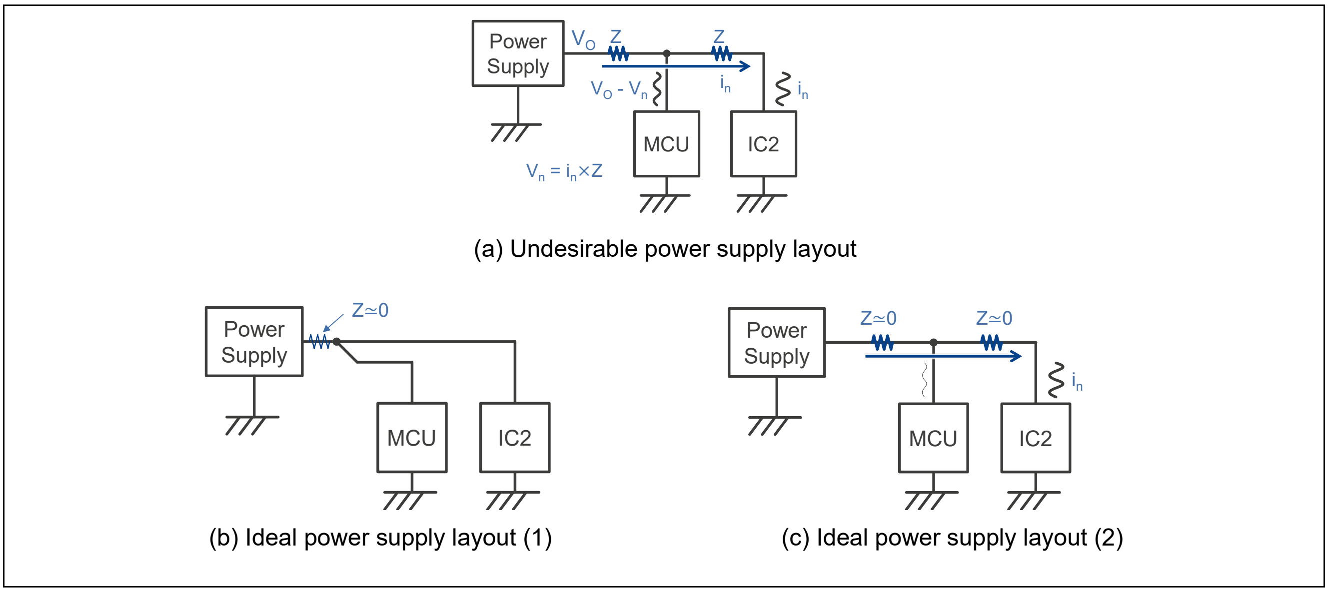

Figure 3-6 Power Supply Layout

(2) GND Layout

If there is a device or circuit with high current loads or large load fluctuation, and if it is impossible to insert a separate power supply for each, arrange the wiring as shown in Figure 3-7 (b) or (C) so that the GND line is not shared by each device or circuit. In addition, to prevent noise infiltration into the touch sensor from the noise source, it is also effective to separate the GND pattern.

Cover empty spaces on the board with a solid GND pattern as much as possible following the precautions mentioned above. If multiple layers like double-sided boards and multiple-layer boards share the GND, keep the impedance between solid patterns small by stitching GND vias properly and design the board so that there is no open stub pattern.

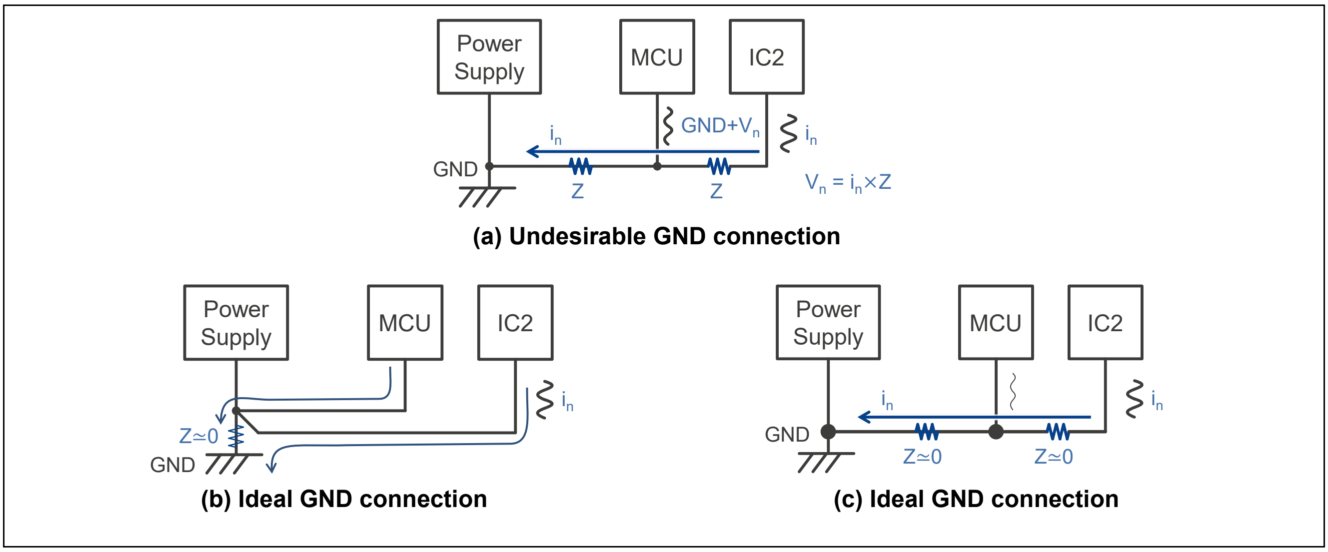

Figure 3-7 GND Layout

3.4 Touch Parameter Tuning

3.4.1 Threshold Value and Hysteresis Tuning

The threshold value and the hysteresis are touch parameters that are effective as countermeasures against false judgement due to ripple noise. The relation between touch ON/OFF judgement and each value is shown in Figure 3-8, where C_{sdef} is the default value of touch difference, α is the threshold value, and β is the hysteresis.

(a) Threshold value

The threshold value is a parameter that is related to detection of touch ON/OFF from the measurement value. In the self-capacitance method, touch ON is detected when the following formula is established. The same unit is used for each value in the formula: capacitance or measurement value.

$$\text{Touch difference } C_s > \text{Threshold value } \alpha$$

After auto-tuning of QE for Capacitive Touch, the threshold α is set to 60% of the touch ON/OFF difference. For example, when the touch ON/OFF difference default value C_{sdef} is 1000 on auto-tuning, the threshold value α is set to 600, and when the touch difference C_s.exceeds 600, touch ON is detected. If users set the threshold value α to other values, set it in “CapTouch Parameter List” of QE for Capacitive Touch.

(b) Hysteresis

The hysteresis is a parameter that is related to detection of touch OFF from the measurement value. In the self-capacitance method, touch OFF is detected when the following formula is established. The same unit is used for each value in the formula: capacitance or measurement value.

$$\text{Touch difference } C_s > \text{Touch difference default } C_{sdef} - (\text{Threshold value } \alpha - \text{Hysteresis } \beta)$$

After auto-tuning of QE for Capacitive Touch, the hysteresis β is set to 5% of the threshold value. For example, when the touch ON/OFF difference default value C_{sdef} is 1000, and the threshold value α is 600, the hysteresis β is set to 30, and the measurement value for touch OFF detection is set to 570 by subtracting 30 of the hysteresis β from 600 of the threshold value α. Touch OFF is detected when the touch difference C_s is significantly reduced under 430. If users set the hysteresis β to other values, set it in “CapTouch Parameter List” of QE for Capacitive Touch.

For more information on how to tune the threshold value and hysteresis, refer to “1.2 Manual tuning with CapTouch parameters in Capacitive Touch Sensor MCU QE for Capacitive Touch Advanced Mode Parameter Guide”

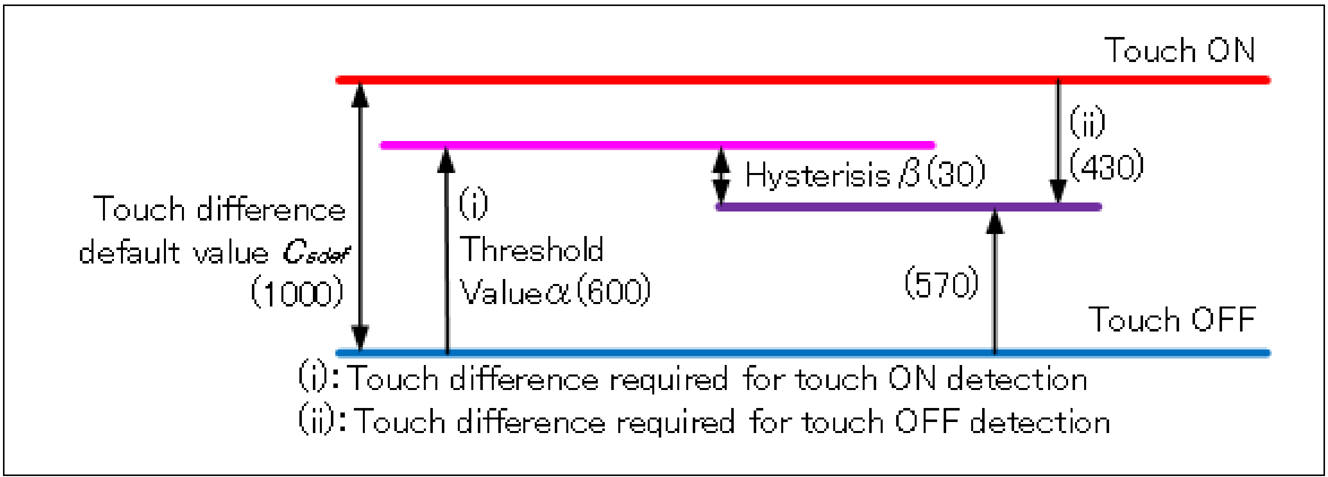

Figure 3-8 Relation between touch ON/OFF detection, threshold value, and hysteresis

To prevent false touch detection, it is crucial to keep the ripple noise infiltrating to the MCU to a minimum at first. If there is a large fluctuation in the measured value due to ripple noise, adjusting the threshold or hysteresis may not prevent false detection. If it is impossible to prevent false detection even after taking measures against ripple noise, consider the following countermeasures.

・Make the touch ON/OFF difference bigger by electrode design

・Make the threshold bigger to tighten the touch ON detection condition

・Make the threshold smaller and hysteresis bigger to tighten the touch OFF detection condition

For information on electrode design, refer to Capacitive Sensor MCU Capacitive Touch Electrode Design Guide (R30AN0389).

Table 3-1 shows the relation between threshold value α, hysteresis β, and touch ON/OFF margins C_{nm_on}, and C_{nm_off}, when the touch ON/OFF difference default value at touch parameter tuning C_{sdef} is 1pF, the change in capacitance by ripple noise C_n is 0.2pF. The touch ON/OFF margins C_{nm_on}, and C_{nm_off} are obtained by the following formulas.

$$C_{nm\_on} = (\text{i}) - C_n$$

$$C_{nm\_off} = (\text{ii}) - C_n$$

To show the principle of CTSU, Table 3-1 is represented using capacitance values, not measurement values. Each value in Table 3-1 corresponds to Figure 3-8. Table 3-1 indicates that the touch ON margin is improved by increasing the threshold value, and that the touch OFF margin is improved by decreasing the threshold value and increasing the hysteresis.

When changing parameters for the threshold value and hysteresis in the "CapTouch Parameter List" of QE for Capacitive Touch, set them using the touch sensor measurement value, not the capacitance value. Though tuning the threshold value and hysteresis is effective as a ripple noise countermeasure, touch ON/OFF may not be detected if the touch ON/OFF difference is small. Make sure to use the actual device and confirm the touch ON/OFF difference, fluctuation of the measurement value with and without noise, and the variation before tuning the threshold value and hysteresis.

Table 3-1 Relation between threshold value/hysteresis settings,

touch ON/OFF judgements, and margins.

Touch ON/OFF difference default C_{sdef} [pF]	Change in capacitance caused by ripple noise C_n [pF]	Threshold value α		Hysteresis β		ON detection (i) [pF]	OFF detection (ii) [pF]	ON margin C_{nm_on} [pF]	OFF margin C_{nm_off} [pF]
		[pF]	[%]	[pF]	[%]				
1.0	0.2	0.6	60	0.03	5%	0.6	0.43	0.40	0.23
1.0	0.2	0.6	60	0.2	33%	0.6	0.60	0.40	0.40
1.0	0.2	0.7	70	0.2	29%	0.7	0.50	0.50	0.30
1.0	0.2	0.8	80	0.6	75%	0.8	0.80	0.60	0.60

(1) RX130 Capacitance / Measurement Value Conversion Formula

In the self-capacitance method of RX130, where the measurement time setting is 526μs, the reduction amount of the measurement value $Count$ when ripple noise infiltrates the MCU power supply is calculated by using the capacitance reduction amount C_s [pF] described in "5.1 Ripple Characteristics (RX130)" and the capacitance and measurement value conversion formula as below.

In this formula, K_δ[-] is the modulation coefficient, f_d [MHz] is the drive pulse frequency, V_{VDC} [V] is VDC power supply voltage, I_{FS} [μA] is the measurement max current, and $Count_{FS}$ [LSB] is the full scale of the measurement value. V_{VDC} and $Count_{FS}$ are fixed values. K_δ, f_d, and I_{FS} depend on the user settings.

$$Count\ [\mathrm{LSB}] = \left(\frac{K_\delta \cdot f_d \cdot C_s \cdot V_{VDC}}{I_{FS}}\right) \cdot Count_{FS}$$

K_δ is calculated by the following formula.

$$K_\delta = \frac{\text{Number of measurement pulses}}{\text{Measurement time}}$$

For detailed information on K_δ, refer to "CTSU Synchronous Noise Reduction Setting Register" in RX130 User's Manual Hardware.

Table 3-2 shows default values of the coefficients for the capacitance and measurement value conversion formula for RX130.

Table 3-2 Default Variables for RX130 capacitance/measurement value conversion formula

Self-capacitance method, Measurement time setting 526μs
CTSU Power Supply Operating Mode Setting : Normal operating mode (CTSUCR1.CTSUATUNE0 = 0)
CTSU Power Supply Capacity Adjustment : Normal output (CTSUCR1.CTSUATUNE1＝0)

V_{VDC} (typ.) [V]	f_d [MHz]	K_δ [-]	I_{FS} [μA]	$Count_{FS}$ [LSB]
1.6	2	$\frac{248}{263}$	38.4	40960

(2) RL78/G22 Capacitance / Measurement Value Conversion Formula

In the self-capacitance method of RL78/G22, where the measurement time setting is 256μs, the reduction amount of the measurement value $Count$ when ripple noise infiltrates the MCU power supply is calculated by using the capacitance reduction amount C_s [pF] described in “5.2 Ripple Characteristics (RL78/G22)” and the capacitance and measurement value conversion formula as below.

In this formula, f_d [MHz] is the drive pulse frequency, V_{VDC} [V] is VDC power supply voltage, I_{FS} [μA] is the measurement max current, and $Count_{FS}$ [LSB] is the full scale of the measurement value. V_{VDC} and $Count_{FS}$ are fixed values. f_d, and I_{FS} depend on the user settings.

$$Count\ [\mathrm{LSB}] = \left(\frac{f_d \cdot C_s \cdot V_{VDC}}{I_{FS}}\right) \cdot Count_{FS}$$

Table 3-3 shows default values of the coefficients for the capacitance and measurement value conversion formula for RL78/G22

Table 3-3 Default Variables for RL78/G22 capacitance/measurement value conversion formula

Self-capacitance method, Measurement time setting 256μs
Measurement power-supply voltage = 1.5V (CTSUCRAL.ATUNE0 = 0)
Measurement power-supply current = 20μA (CTSUCRAL.ATUNE1＝0, CTSUCRAH.ATUNE2＝1)

V_{VDC} (typ.) [V]	f_d[MHz]	I_{FS} [μA]	$Count_{FS}$ [LSB]
1.5	2	20	30720

3.4.2 Example of Countermeasure against False Touch Judgement

Figure 3-9 shows an example of false touch OFF judgement. While the end user is keeping touch ON operation, if the status changes from no-ripple noise to with-ripple noise, the measurement value is decreased. If this decrease amount is lower than [the reference value + threshold value – hysteresis], it is judged as touch OFF, and the user operation doesn't match the touch judgement. In such a case, it is possible to prevent false touch judgement by making the hysteresis bigger as Figure 3-10.

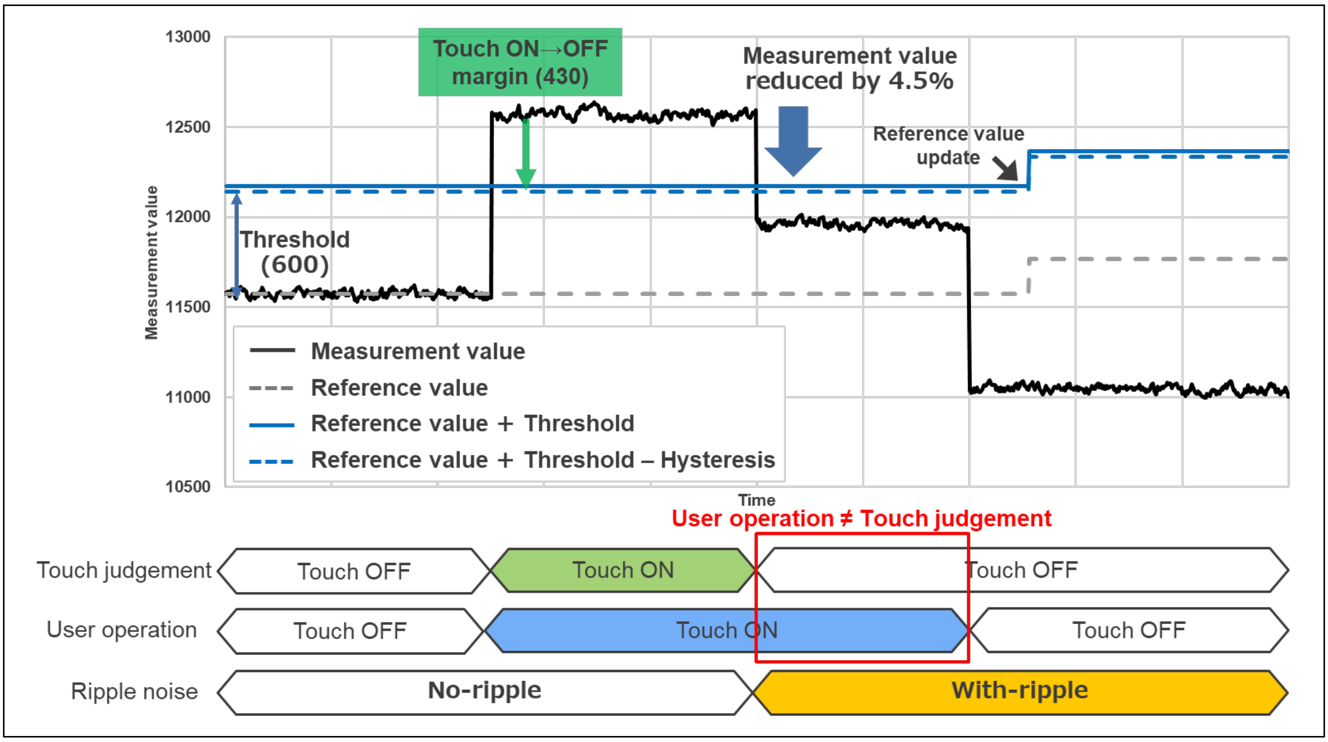

Figure 3-9 Example of false touch off judgement

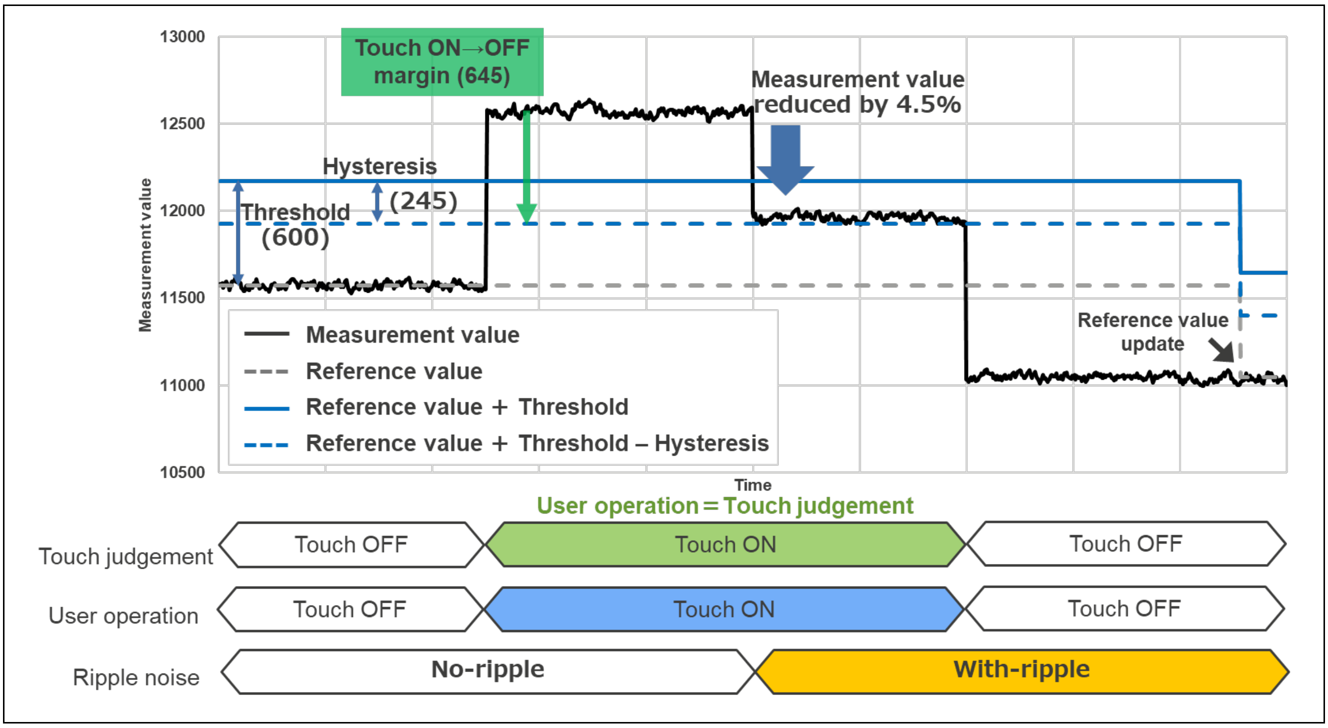

Figure 3-10 Example of improvement of false touch OFF judgement

4. EMC Countermeasures

EMC countermeasures against fluctuation of the power supply and measurement results are crucial as well. For the details of EMC countermeasures, refer to the following document.

Capacitive Sensor MCU Capacitive Touch Noise Immunity Guide (R30AN0426).

5. Ripple Characteristics

5.1 Ripple Characteristics (RX130)

Figure 5-1 shows the characteristic of deterioration of RX130 CTSU1 measured capacitance value when ripple noise is applied to power supply voltage VCC of the MCU. In Figure 5-1, the measurement result is taken under the conditions described in “Conditions”, and the worst values under each condition are plotted on the graph.

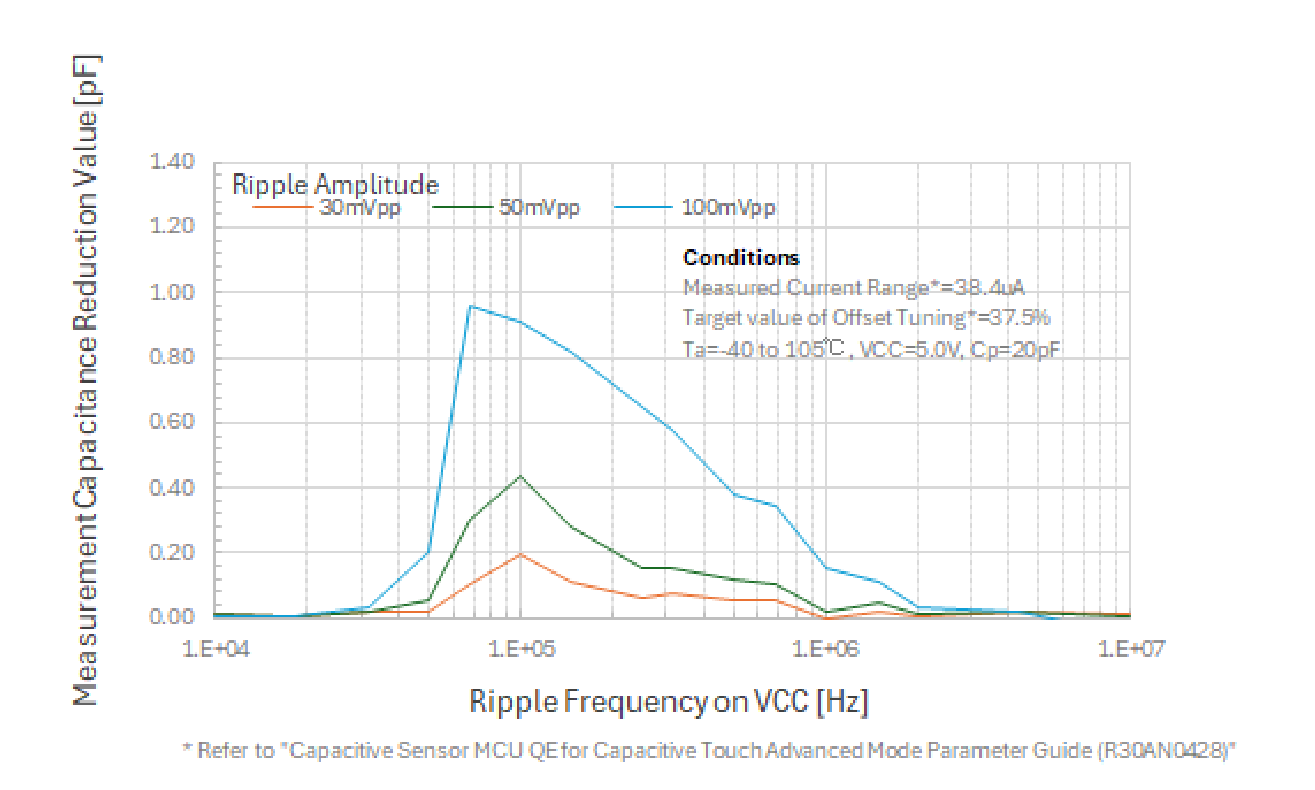

Figure 5-1 Ripple characteristic of RX130 CTSU1 (Measured Current Range = 38.4uA)

5.2 Ripple Characteristics (RL78/G22)

Figure 5-2 and Figure 5-3 show the characteristic of deterioration of RL78/G22 CTSU2 measured capacitance value when ripple noise is applied to power supply voltage VDD of the MCU. In Figure 5-2 and Figure 5-3 the measurement result is taken under the conditions described in "**Conditions**", and the worst values under each condition are plotted on the graph.

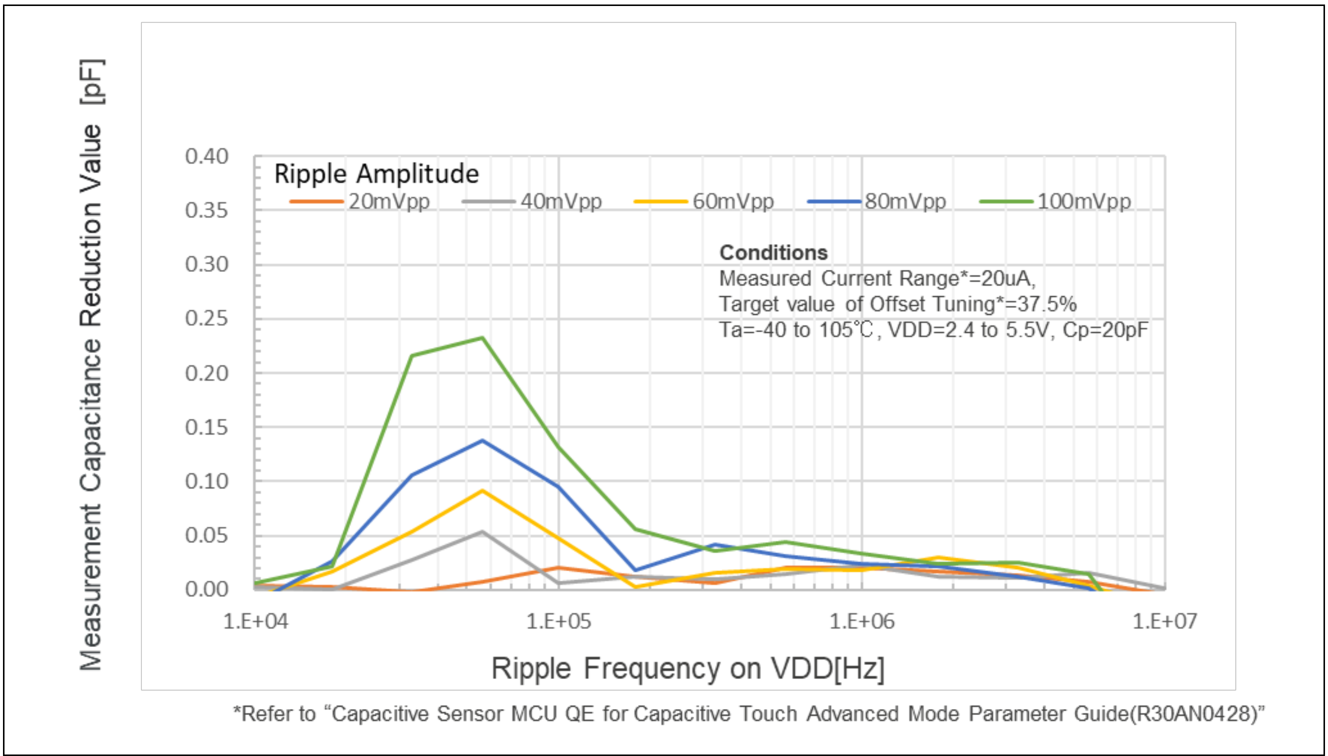

Figure 5-2 Ripple characteristic of RL78/G22 CTSU2 (Measured Current Range = 20uA)

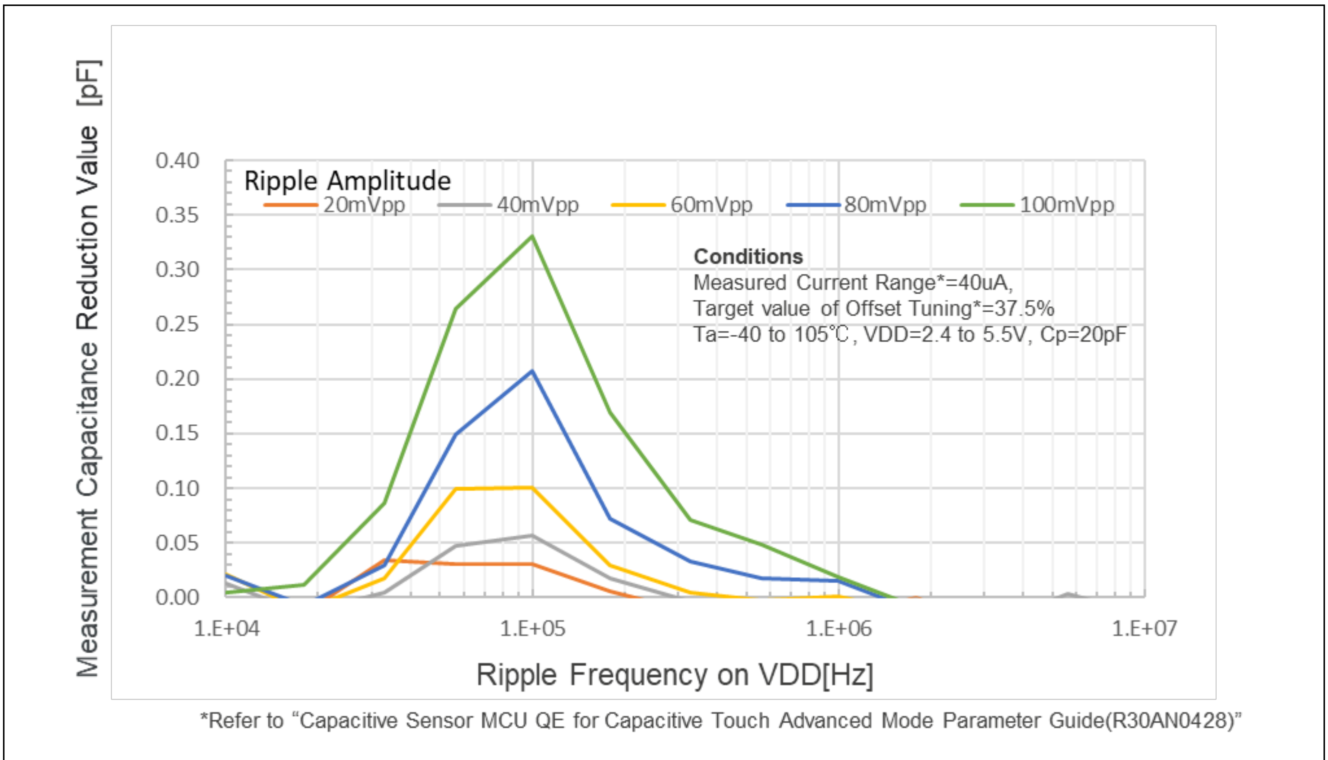

Figure 5-3 Ripple characteristic of RL78/G22 CTSU2 (Measured Current Range = 40uA)

6. Other

6.1 Term

Term	Description
CCO	CCO (Current Control oscillator) refers to the current-controlled oscillator used by the capacitive touch sensor. Some application notes are referred to as ICO.
ICO	Same as CCO.
TSCAP	This capacitor is used to stabilize the internal-voltage of CTSU.
VDC	VDC (Voltage Down Converter) is the power supply for the capacitance sensor built in CTSU.

6.2 Technical inquiries

Contact to Technical Support or search for a KnowledgeBase common question (FAQ) or community forum.

https://www.renesas.com/us/en/contact-us

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jul.12.24	-	First edition, issued

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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