RX Family

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CTSU Noise immunity improving with Dual frequencies noise canceling process

Introduction

This document describes how to implement data correction with double sampling gained by switching between two types of sensor drive pulse frequencies using the Capacitive Touch Sensing Unit (CTSU).

Target Device

RX113, RX130, RX230, RX231

Contents

1. Outline

The CTSU is equipped with a noise balancing function which works to minimize noise based on spectrum diffusion and 180° clock phase shift. However, this function is not always enough to handle external noise levels and the measurement results may be inaccurate.

This application note explains the data correction method and software specifications that enable the user to minimize this phenomenon using double sampling from two of sensor drive pulse frequencies.

2. Mechanism of Noise Influence

Figure 2.1 shows a schematic diagram of the quantification of the capacitance charge/discharge current measured by the CTSU. The CTSU drives the Switched Capacitor Filter (SCF) with a drive pulse to charge and discharge the electrostatic capacitance generated by the electrodes. This charge/discharge current is converted to DC current by the power supply circuit and the smoothing circuit. This value is converted by the current oscillator into a frequency proportional to the current, which is then converted to a digital value by the frequency counter. For details concerning the conversion principle, please refer to the following application note: CTSU Basis of Cap Touch Detection (Document No. R30AN0218EJ0100).

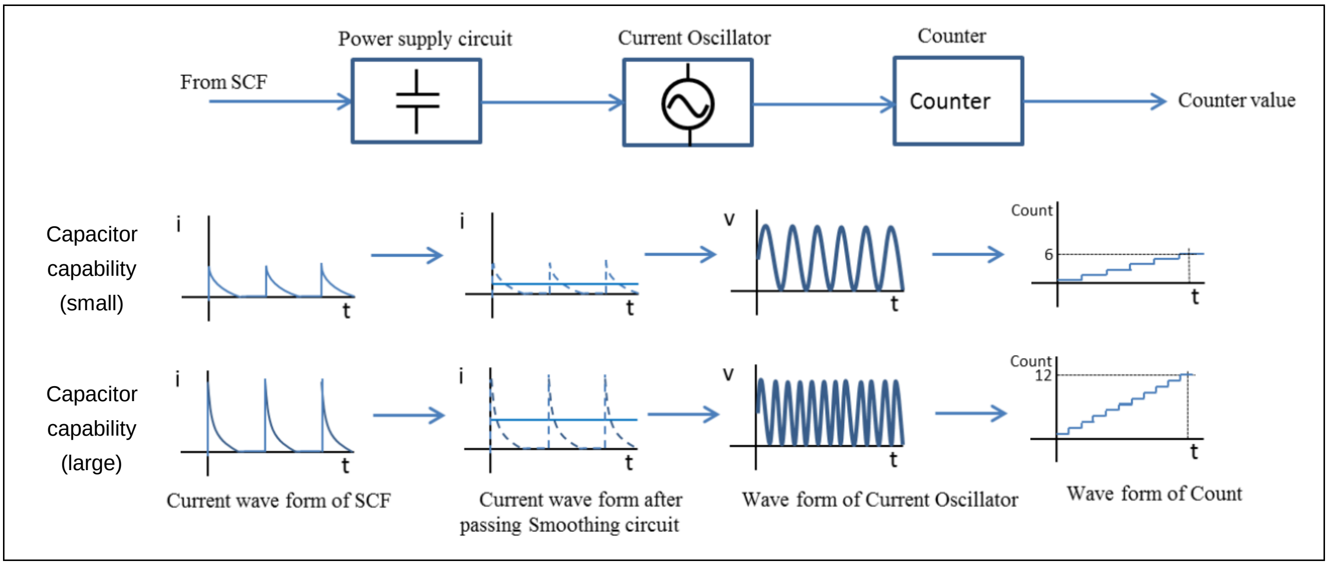

Figure 2.1 CTSU Quantification of Electrostatic Charge/Discharge

Figure 2.2 shows an image of the noise overlap on the sensor. The charge/discharge waveform synchronous with the drive pulse edge can be obtained when measuring the electrostatic capacitance. At this time, noise applied to the sensor will cause the charge/discharge current to increase or decrease, which will affect the conversion results. If noise is applied in the same cycle as the drive pulse, the perceived charge/discharge current will increase, as will the count value. To avoid miscalculations, the device should not be used in an environment that is susceptible to sudden synchronous noise.

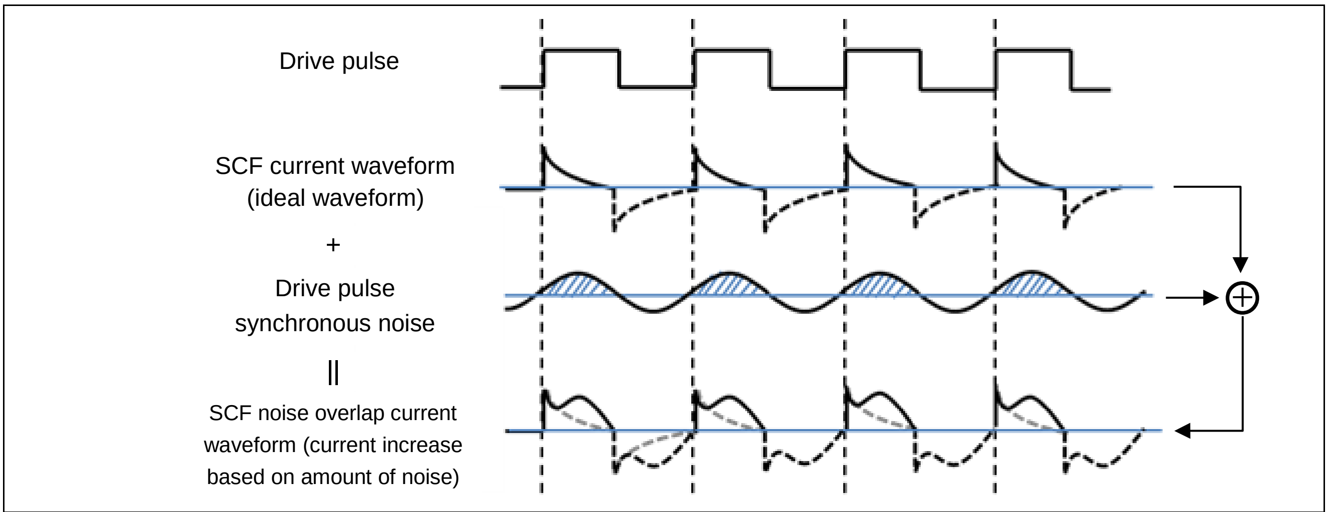

Figure 2.2 Noise Overlap on Sensor

Noise influence on measurements tends to increase the charge/discharge current when the frequency is an odd multiple or an odd inverse multiple of the drive pulse frequency. On the other hand, when the noise frequency is an even multiple or even inverse multiple of the drive frequency, the increase/decrease of the current value is much smoother and noise influence is cancelled.

Figure 2.3 shows an image of noise overlap during frequency switch measurement. In the 1st measurement (No. 1), the frequency switch value is measured with drive pulse f1. In the 2nd measurement (No. 2), the value is measured with drive pulse f2, which is 1/2 f1. When external noise occurs in the same cycle as f1, the current appearing in the 1st measurement increases, and the measured value is increased accordingly. In the 2nd measurement, the SCF current waveform is influenced by noise but because the current integral value around the pulse is equivalent to the ideal waveform, the measured valued is determined to be the same as the value measured before the noise occurred. Data can be corrected with methods such as using a comparison of the results from the two differing types of pulses. When the difference compared to the previous value is minimal, the measurement results are considered valid.

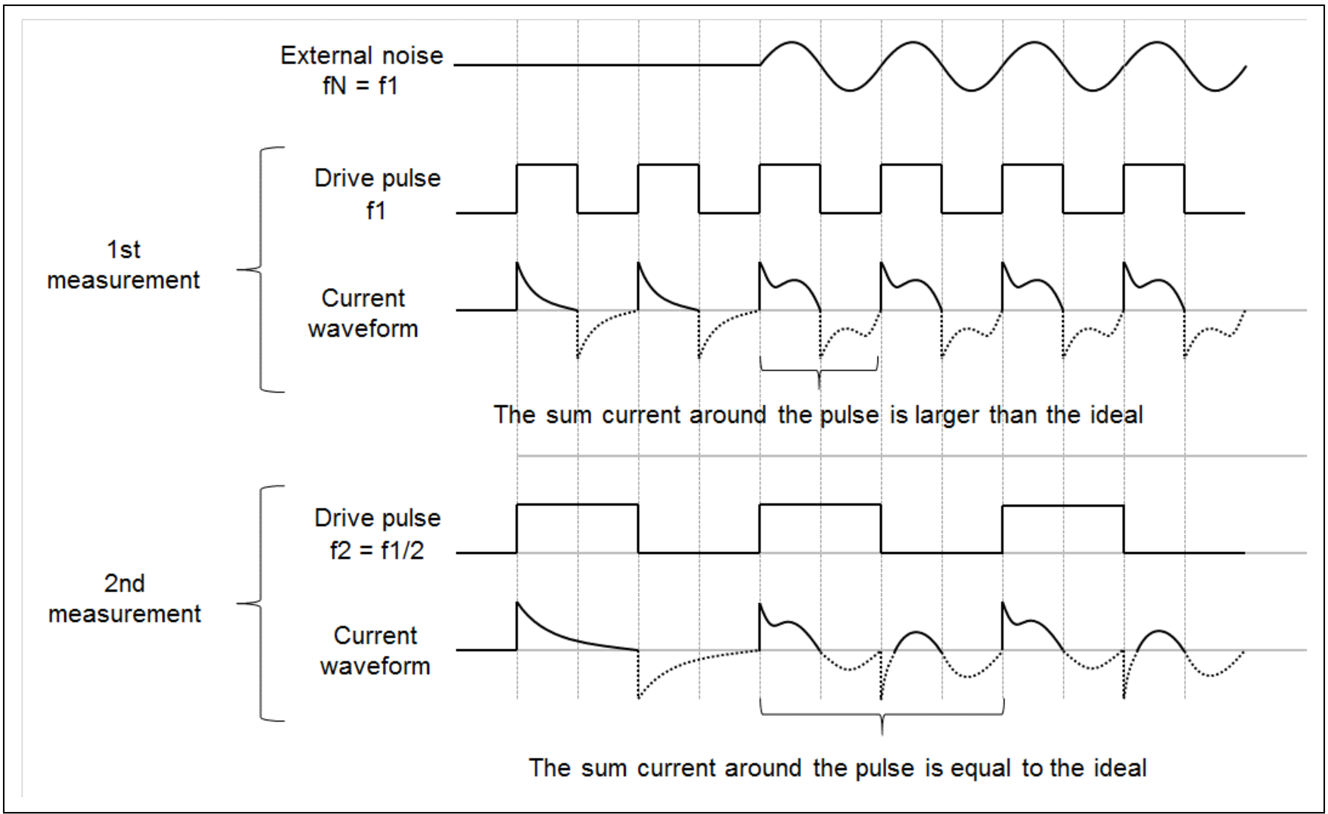

Figure 2.3 Image of Noise Overlap During Frequency Switch Measurement

3. Example of Actual Frequency Switch Measurement

Figure 3.1 shows an example of the noise frequency count value measurement for 4MHz and 2MHz drive pulse frequencies.

In the ideal, noise-free environment, a fixed value represents the measurement result of only CTSU potential noise amplitude. In this example, an abnormal measurement occurs between each drive pulse frequency and its odd multiple frequency. However, a comparison of the two results shows that one measurement has been affected by noise and one is a normal measurement result. Both results can be used together to correct the data.

The noise influence occurring in the peripheral range surrounding the drive pulse frequency is created by the CTSU spectrum diffusion function. The range of overlap of frequency spectrum can be minimized by setting the maximum frequency allowed for f1 and f2 in your system.

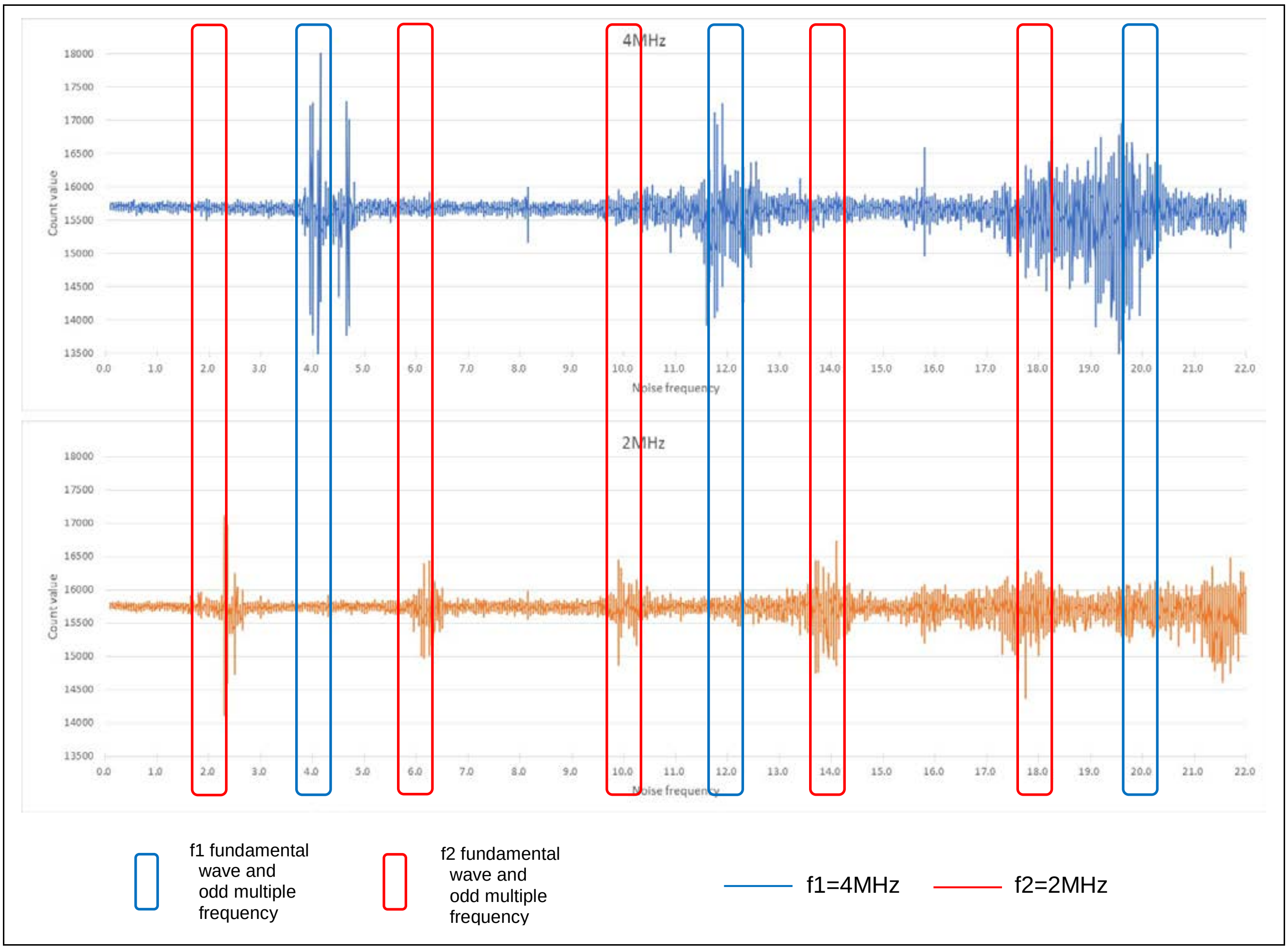

Figure 3.1 Example of Noise Frequency vs.Count Value : 4MHz and 2MHz Drive Frequencies

4. Software Specification

4.1 Operation Specification

This function described in the document is only supported when the self-capacitance method button is enabled.

The function measures each channel of the CTSU measurement pin, measuring at two different drive pulse frequencies. In other words, two measurement results are obtained from 1 channel.

The two drive pulse frequencies are 4MHz and 2MHz. (However, When RX230/RX231 are run at 54MHz, please replace 4MHz with 3.375MHz and 2MHz with 1.6875MHz.)

Only one drive pulse frequency can be measured per touch measurement cycle. The 1st touch measurement cycle measures at 4MHz and the 2nd measurement cycle measures at 2MHz. Please refer to the timing charge below for details.

4.2 Timing Chart

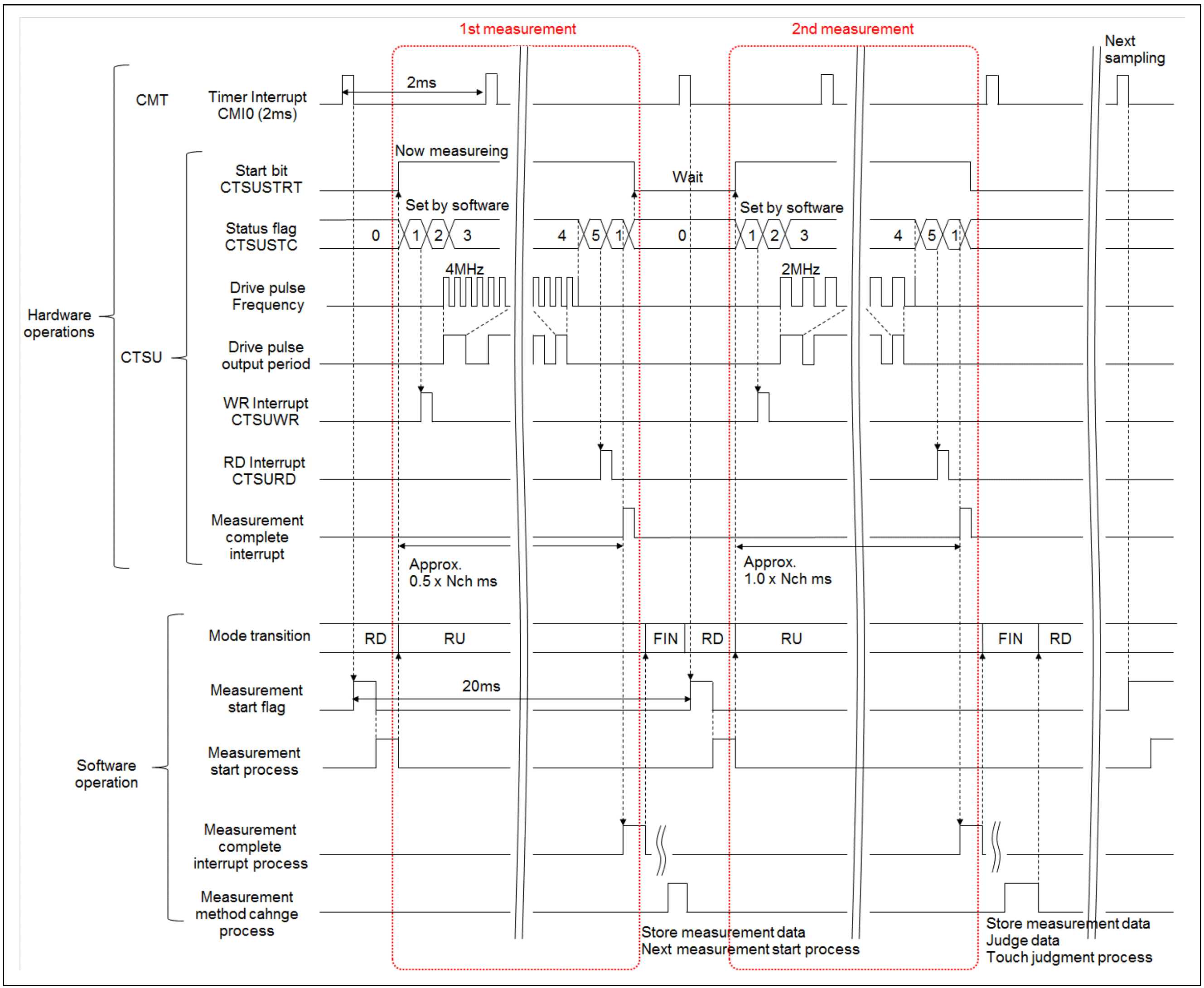

Figure 4.1 Timing chart

4.3 How to Determine Measurement Results

Measurement results are retrieved with R_Get_Cap_Touch_Result() in the same manner as in the normal self-capacitance method.

For more details concerning R_Get_Cap_Touch_Result(), please refer to application note “CTSU API reference guide” (Document No. R30AN0215EJ0103).

The following is used to determine the measurement results; main() is located in r_main.c.

```
void main(void)
{
    uint16_t   button[2];

    while (1U)
    {
        if (_1_TIMING == g_touch_system.flag.timing)
        {
            g_touch_system.flag.timing = 0;
            R_Set_Cap_Touch_Measurement_Start( method );

            if (_00_GET_OK == R_Get_Cap_Touch_Data_Check( method ))
            {
                if (_1_FINISH == R_Get_Cap_Touch_Initial_Status())
                {
                    if (_0_SUCCESS == R_Set_Cap_Touch_Result_Create( method ))
                    {
                        g_ts_result = R_Get_Cap_Touch_Result( method );
                        button[method] = g_ts_result.button[0];
                        if (1 == method )
                        {
                            if ((0 != ((button[0] & button[1]) & 0x0001))
                            {
                                /* Button ON */
                            }
                            else if ((0 == ((button[0] | button[1]) & 0x0001))
                            {
                                /* Button OFF */
                            }
                            else
                            {
                                /* Hold the value */
                            }
                        }
                    }
                }
                else
                {
                    R_Set_Cap_Touch_Initial_Tuning( method );
                }
            }
            method = R_Set_Cap_Touch_Next_Method_Change( method );
        }
    }
```

The 4MHz measurement result can be obtained in method 0; and the 2MHz measurement result in method 1.

This sample program judges the button results after the 2MHz measurement is complete.

The button is determined to be ON or OFF based on the measurement results of both methods.

Sample button judgements are as shown in the following table.

Table 4.1 Sample Button Judgements

method = 0 (4MHz)	method = 1 (2MHz)	Judgement	Notes
OFF	OFF	OFF	
OFF	ON	Save judged value	Judged as applied noise
ON	OFF	Save judged value	Judged as applied noise
ON	ON	ON	

4.4 Constants

Table 4.2 lists the constants used for 4MHz and 2MHz measurements.

Table 4.2 Constants Used for 4MHz/2MHz Measurements (r_ctsu.h)

r_ctsu.h		
Constant Name	Setting Value	Description
SELF_METHOD_NUM	0,1,2	Self-capacitance measurement method number

Table 4.3 to Table 4.4 list constants used for 4MHz measurements.

Table 4.3 Constants Used for 4MHz Measurements (r_ctsu.h)

r_ctsu.h		
Constant Name	Setting Value	Description
SELF_CTSUATUNE0	0,1	Self-capacitance: power supply operation mode (_0_CTSUATUNE0_NORMAL, _1_CTSUATUNE0_LOW)
SELF_CTSUATUNE1	0,1	Self-capacitance: power capability (_0_CTSUATUNE1_NORMAL, _1_CTSUATUNE1_HIGH)
SELF_CTSUPRRATIO	3	_0011_CTSUPRRATIO_RECOMMEND
SELF_CTSUPRMODE	2 (Rec. value)	Self-capacitance: CTSU basic cycle, measurement pulse adjustment value (_10_CTSUPRMODE_62_PULSES)
SELF_CTSUSOFF	0,1	Self-capacitance: high frequency noise reduction function (_0_CTSUSOFF_ON, _1_CTSUSOFF_OFF)
SELF_ENABLE_TSxx *1	0,1	Self-capacitance: measurement target flag (0: not measurement target, 1: measurement target)
CTSUCHACi_SELF_ENABLE_TS *6	0x0001-0xFFFF	Self-capacitance: CTSUCHACi register setting value
SELF_ENABLE_NUM	1-36	Self-capacitance: number of measurement target touch sensors
CTSUSSDIV_TSxx *1	0000b-1111b	Self-capacitance: CTSU spectrum diffusion frequency division setting
CTSUSSC_TSxx *1	-	Self-capacitance: CTSUSSC register setting value
CTSUSO_TSxx *1	0x000-0x3FF	Self-capacitance: CTSU sensor offset adjustment value
CTSUSNUM_TSxx *1	0x00-0x3F	Self-capacitance: CTSU measurement number setting value
CTSUSO0_TSxx *1	-	Self-capacitance: CTSUSO0 register setting value
CTSURICOA_TS	0x00-0xFF	Self-capacitance: CTSU reference ICO current adjustment value
CTSUSDPA_TSxx *1	0x00-0x1F	Self-capacitance: CTSU base clock setting value
CTSUICOG_TSxx *1	0-3	Self-capacitance: CTSUICO gain adjustment value
CTSUSO1_TSxx *1	-	Self-capacitance: CTSUSO1 register setting value
SELF_WR_SIZE	3*SELF_ENABLE_NUM	Self-capacitance: Write data size
SELF_RD_SIZE	SELF_ENABLE_NUM	Self-capacitance: Read data size

*1 xx…00－35
*6 i…0－4

Table 4.4 Constants Used for 4MHz Measurements (r_touch.h)

r_touch.h		
Constant Name	Setting Value	Description
SELF_KEY_USE_xx *1	0,1	Self-capacitance key function flag 0: enabled, 1: disabled
SELF_KEY_USE_GROUPn *5	0-3	Self-capacitance key function flag group
SELF_KEY_NUM	0-36	Self-capacitance key function enabled number
SELF_TSxx_THR *1	0-65535	Self-capacitance touch/non-touch judgement threshold value
SELF_TSxx_HYS *1	0-65535	Self-capacitance hysteresis value
SELF_TOUCH_ON	0-65535	Self-capacitance continuous touch judgement value
SELF_TOUCH_OFF	0-65535	Self-capacitance continuous non-touch judgement value
SELF_MSA	0-65535	Self-capacitance continuous touch cancel value
SELF_DRIFT_ENABLE	0,1	Enable self-capacitance drift correction
SELF_DRIFT_FREQUENCY	0-65535	Disable self-capacitance drift correction

*1 xx…00－35
*5 n…0－3

Table 4.5 through Table 4.6 lists the constants used for 2MHz measurements.

Table 4.5 Constants Used for 2MHz Measurements (r_ctsu.h)

r_ctsu.h		
Constant Name	Setting Value	Description
SELF_DFNC_CTSUATUNE0	0,1	Self-capacitance: power supply operation mode (_0_CTSUATUNE0_NORMAL, _1_CTSUATUNE0_LOW)
SELF_DFNC_CTSUATUNE1	0,1	Self-capacitance: power capability (_0_CTSUATUNE1_NORMAL, _1_CTSUATUNE1_HIGH)
SELF_DFNC_CTSUPRRATIO	3	_0011_CTSUPRRATIO_RECOMMEND
SELF_DFNC_CTSUPRMODE	2 (Rec. value)	Self-capacitance: CTSU basic cycle, measurement pulse adjustment value (_10_CTSUPRMODE_62_PULSES)
SELF_DFNC_CTSUSOFF	0,1	Self-capacitance: high frequency noise reduction function (_0_CTSUSOFF_ON, _1_CTSUSOFF_OFF)
SELF_DFNC_ENABLE_TSxx *1	0,1	Self-capacitance: measurement target flag (0: not measurement target, 1: measurement target)
CTSUCHACi_SELF_DFNC_ENABLE_TS *6	0x0001-0xFFFF	Self-capacitance: CTSUCHACi register setting value
SELF_DFNC_ENABLE_NUM	1-36	Self-capacitance: number of measurement target touch sensors
SELF_DFNC_CTSUSSDIV_TSxx *1	0000b-1111b	Self-capacitance: CTSU spectrum diffusion frequency division setting
SELF_DFNC_CTSUSSC_TSxx *1	-	Self-capacitance: CTSUSSC register setting value
SELF_DFNC_CTSUSO_TSxx *1	0x000-0x3FF	Self-capacitance: CTSU sensor offset adjustment value
SELF_DFNC_CTSUSNUM_TSxx *1	0x00-0x3F	Self-capacitance: CTSU measurement number setting value
SELF_DFNC_CTSUSO0_TSxx *1	-	Self-capacitance: CTSUSO0 register setting value
SELF_DFNC_CTSURICOA_TS	0x00-0xFF	Self-capacitance: CTSU reference ICO current adjustment value
SELF_DFNC_CTSUSDPA_TSxx :1	0x00-0x1F	Self-capacitance: CTSU base clock setting value
SELF_DFNC_CTSUICOG_TSxx *1	0-3	Self-capacitance: CTSUICO gain adjustment value
SELF_DFNC_CTSUSO1_TSxx *1	-	Self-capacitance: CTSUSO1 register setting value
SELF_DFNC_WR_SIZE	3*SELF_DFNC_ENABLE_NUM	Self-capacitance: Write data size
SELF_DFNC_RD_SIZE	SELF_DFNC_ENABLE_NUM	Self-capacitance: Read data size

*1 xx…00－35

*6 i…0－4

Table 4.6 Constants Used for 2MHz Measurements (r_touch.h)

r_touch.h		
Constant Name	Setting Value	Description
SELF_DFNC_KEY_USE_xx *1	0,1	Self-capacitance key function flag 0: enabled, 1: disable
SELF_DFNC_KEY_USE_GROUPn *5	0-3	Self-capacitance key function flag group
SELF_DFNC_KEY_NUM	0-36	Self-capacitance key function enabled number
SELF_DFNC_TSxx_THR *1	0-65535	Self-capacitance touch/non-touch judgement threshold value
SELF_DFNC_TSxx_HYS *1	0-65535	Self-capacitance hysteresis value
SELF_DFNC_TOUCH_ON	0-65535	Self-capacitance continuous touch judgement value
SELF_DFNC_TOUCH_OFF	0-65535	Self-capacitance continuous non-touch judgement value
SELF_DFNC_MSA	0-65535	Self-capacitance continuous touch cancel value
SELF_DFNC_DRIFT_ENABLE	0,1	Enable self-capacitance drift correction
SELF_DFNC_DRIFT_FREQUENCY	0-65535	Disable self-capacitance drift correction

*1 xx…00－35
*5 n…0－3

5. Precautions for Data Correction Function

Please be aware of the following cautions when enabling the data correction function using CTSU frequency switch measurements.

・Button judgement will take longer than normal as two measurements will be taken by switching between two measurement frequencies.

・The touch API's ROM/RAM capacity has been increased to accommodate the double measurements.

・Readjustments cannot be made in the First Step Guide of Workbench6.

・Parameters such as the threshold and hysteresis values have not been adjusted. Please make the necessary adjustments manually based on your own development environment.

・For projects with advanced settings enabled, please be aware that the sensor drive pulse frequency may be fixed to a level higher than the recommended value.

Confirm the recommended frequency in the offset tuning results screen where the First Step Guide advanced settings.

For projects with advanced setting enabled, make sure you use a value below the recommended frequency.

Please make sure you understand the precautions explained here and fully evaluate the user environment before using the function described in this document.

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Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jan 09, 2018	-	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. 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.

5. Differences between Products

   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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