RX140 Group

Touchless Button Demo Solution Sample Software

Introduction

This application note describes touchless button demo solution (RTK0EG0036D01001BJ) Software specification using a sample application of self-capacitance method based on Capacitive Touch Sensing Unit2SL (CTSU2SL), the hardware that detects the contact or approach of human by measuring capacitance generated between touch electrodes and the human body.

Target Device

RX140 Group

Related Documentation

1. RX Family Using QE and FIT to Develop Capacitive Touch Applications (R01AN4516)
2. RX140 Capacitive Touch Evaluation System User's Manual (R12UZ0102)
3. RA2L1 Group Touchless Button Demo Solution (Hardware) (R01AN5812)

Contents

1. Overview

This application note describes sample software running in a touchless button demo solution.

The touchless button reference design uses Renesas's capacitive touch solution to detect human body proximity, such as fingers and hands, without physical contact. The electrode detects the proximity of the finger using the self-capacitance method, and the LED lights and the buzzer sounds.

1.1 Function

Touch detection at a position about 15mm away from the touch surface is possible. The LED of the button detected by touch among nine touchless buttons is lit, and the buzzer sounds. Figure 1-1 shows an operation image diagram.

It is also possible to change the LED toggle lighting operation to LED dimming operation according to the detection distance. It is also possible to change the buzzer sounding from enabled to disabled. See 5.1 Build Options for how to change the settings.

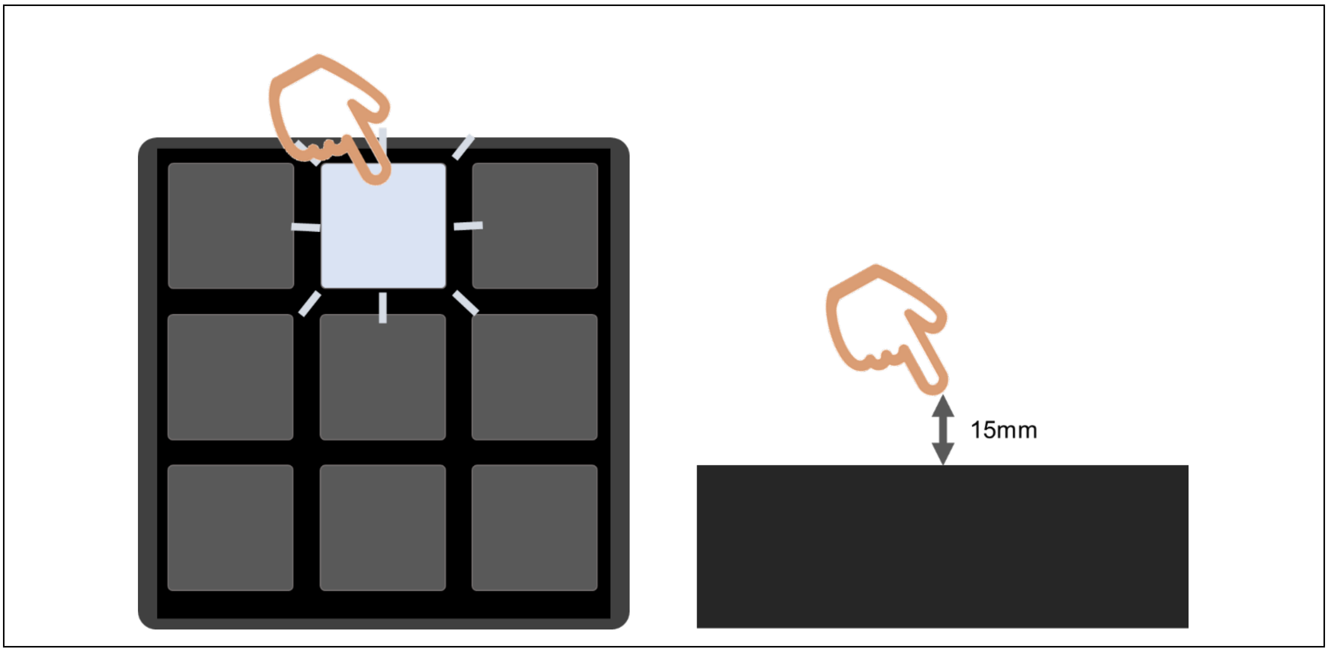

Figure 1-1 Operation Image Diagram

1.2 Touchless implementation method

The thresholds for touch judgment are adjusted based on the tuning results in QE for Capacitive Touch. Refer to "4.4 Sensitivity adjustment method" for details on this adjustment method.

2. Operating Environment

Table 2-1 lists the software operating environments.

Table 2-1 Operating environment

Item	Description
Evaluation board	RTK0EG0038C01001BJ
Microcomputer used	R5FA51406ADFN(Renesas RX140 MCU group)
Operating frequency	32MHz
Working voltage	5.0V
Integrated development environment	e^2 studio 2022-07
C compiler	CC-RX Compiler V3.04.00
Development support tool for capacitive touch sensor	QE for Capacitive Touch V3.1.0
Emulator	E2 emulator Lite

Figure 2-1 shows the device connection diagram.

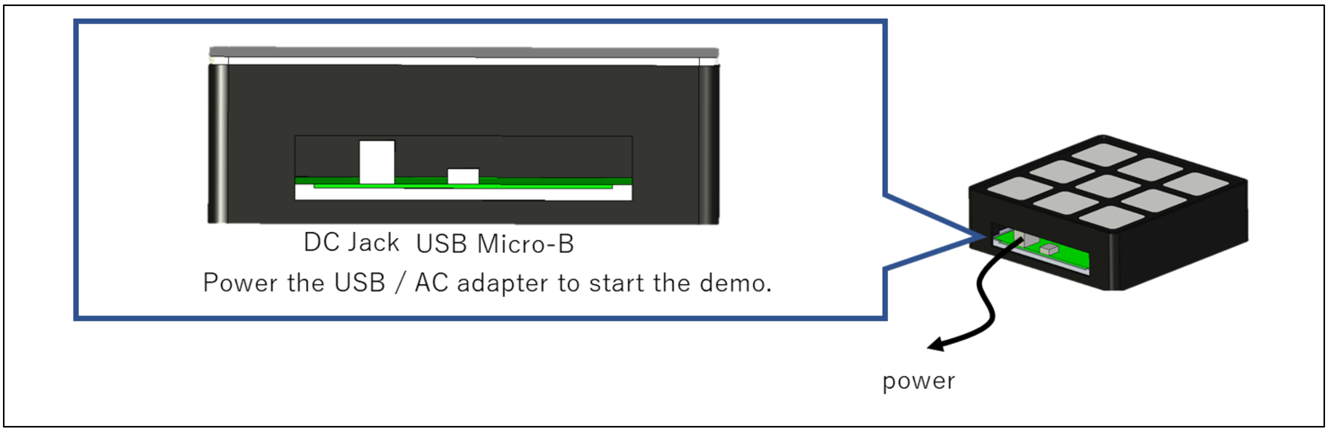

Figure 2-1 Device connection diagram

3. Sample software

This section describes the sample software.

3.1 Outline of Operation

The processing flow of the sample software is shown below.

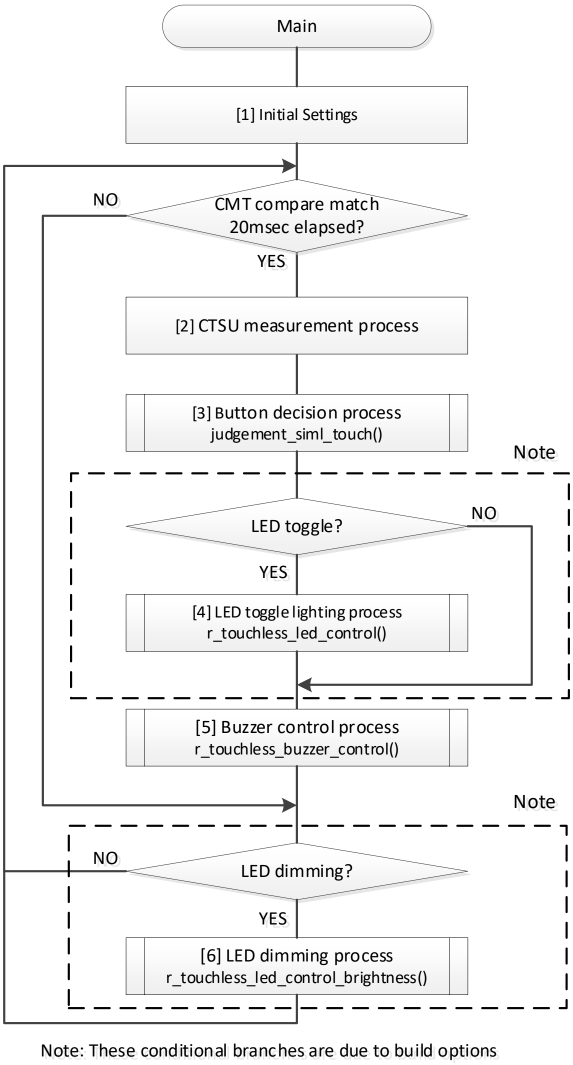

Figure 3-1 Processing flow

1. Initial Settings
   - Initialization of each peripheral function and activation of CMT
   - LED and buzzer control initialization
   - CTSU Offset Tuning

2. CTSU measurement process

   Performs CTSU measurement at the compare match cycle (20msec) of CMT, and acquires the touch judgment result and touch count value.

3. Button decision process

   Determine the button for LED-control from among nine buttons based on the result obtained in CTSU measurement process. Refer to 3.2 Button decision process for details.

4. LED toggle lighting process

   The LED is toggled on from the result of the button decision process. Refer to 3.3.1 LED toggle lighting process for details.

5. Buzzer control process

   The buzzer sounds from the result of the button decision process. Refer to 3.4 Buzzer control processing for details.

6. LED dimming process

   Dimming of the LED is performed from the result of the button decision process. Refer to 3.3.2 LED dimming process for details.

3.2 Button decision process

This process is used to control only one button when a simultaneous touch judgment occurs. Figure 3-2 shows the flow of the button decision process.

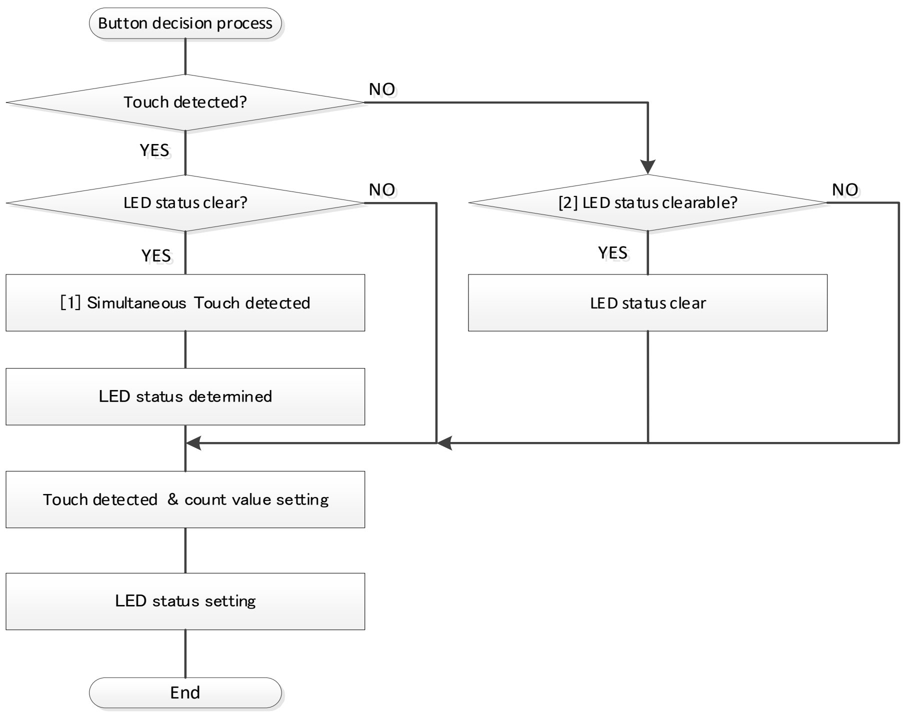

Figure 3-2 Button decision processing flow

1. The simultaneous touch judgment is judged by the following rules.

- Only the location where the first touch judgment was made is enabled.
- If multiple values are detected at the same time, the maximum range of touch count value change is enabled.
- When the same touch count value changes, the area with the smaller TS number (elem_index) takes precedence.

2. The LED state controls which button is lit. To prevent chattering of the touch judgment, the LED status is cleared when a non-touch judgment occurs five times consecutively.

3.3 LED lighting process

There are two types of lighting patterns: Toggle Lighting and Light Lighting.

3.3.1 LED toggle lighting process

Toggles the LED on/off corresponding to the touched button. After the first touch judgment, the LED will not be controlled until a non-touch judgment occurs. Figure 3-3 shows the flow of LED toggle lighting processing.

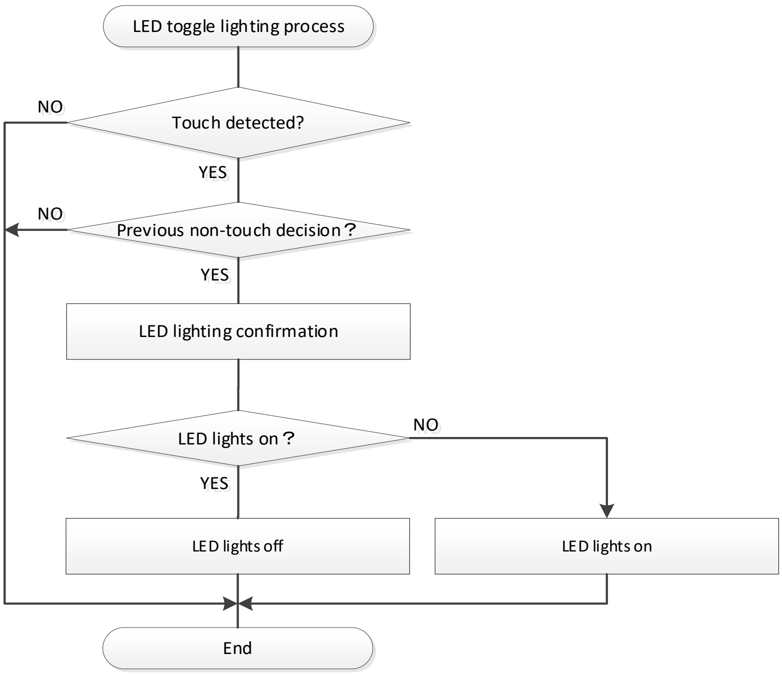

Figure 3-3 Flowchart of LED Toggle Lighting Process

3.3.2 LED dimming process

Adjusts the amount of light on the LED according to the distance between the button and finger.

While 1msec is lit repeatedly, the LED dimming process adjusts the lighting duration to express the dimming. Therefore, the process is constantly performed in the main loop. Figure 3-4 shows the timing of the flash control process.

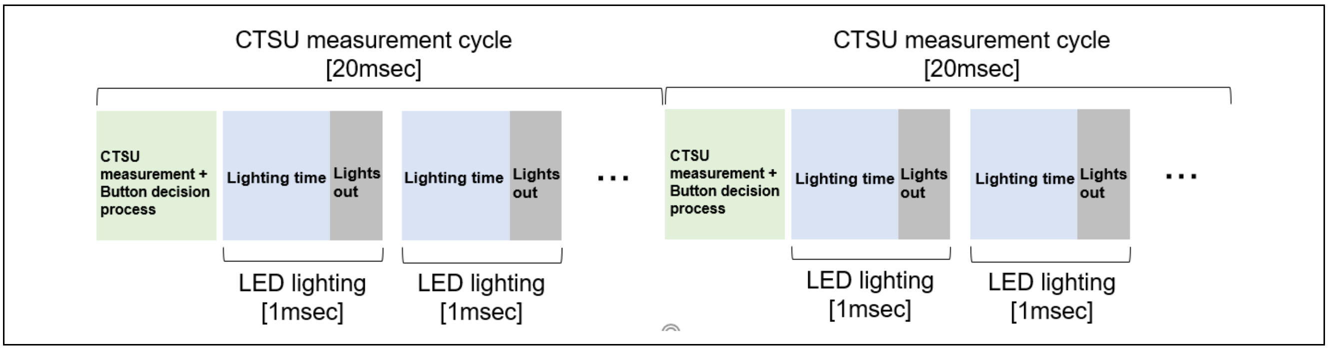

Figure 3-4 Flash control processing timing

Use the touch count value of CTSU measurement result to measure the distance.

Use the following formula to determine the lighting time.

*Lighting time = ((Touch count value-LED lighting threshold value) * LED dimming period)/LED count value change width) * 10 [usec]*

LED lighting threshold: Count reference value + touch threshold value
LED dimming cycle : Lighting cycle [= 1msec]/Min. lighting time [=10usec]
LED count value change width: change width of touch count value until max. lighting time [= 1msec]

3.4 Buzzer control process

Use MTU4's PWM-pulse outputting to make the buzzer sound. Figure 3-5 shows the flow of buzzer control processing.

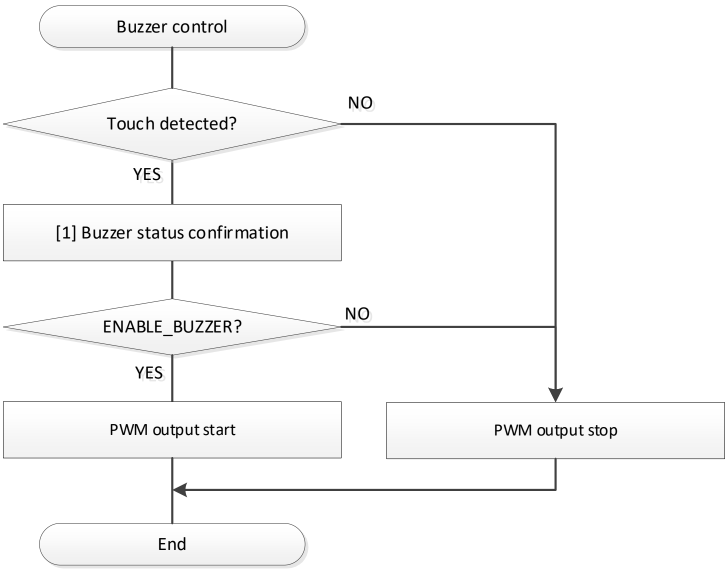

Figure 3-5 Flowchart of buzzer control processing

1. Controls the sounding status of the buzzer. Figure 3-6 shows the state transition diagram of the buzzer state.

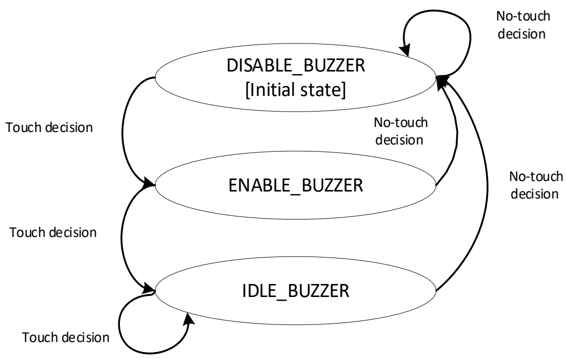

Figure 3-6 Buzzer state transition diagram

3.5 Software configuration

Figure 3-7 shows the software configuration diagram.

Capacitance measurement in CTSU2SL uses the Capacitive Touch Sensor-compatible Development Support Tool QE for Capacitive Touch and software generated by the Smart Configurator (QE Touch Module, QE CTSU Module).

The application notifies the user of the touch detection result by LED display or buzzer.

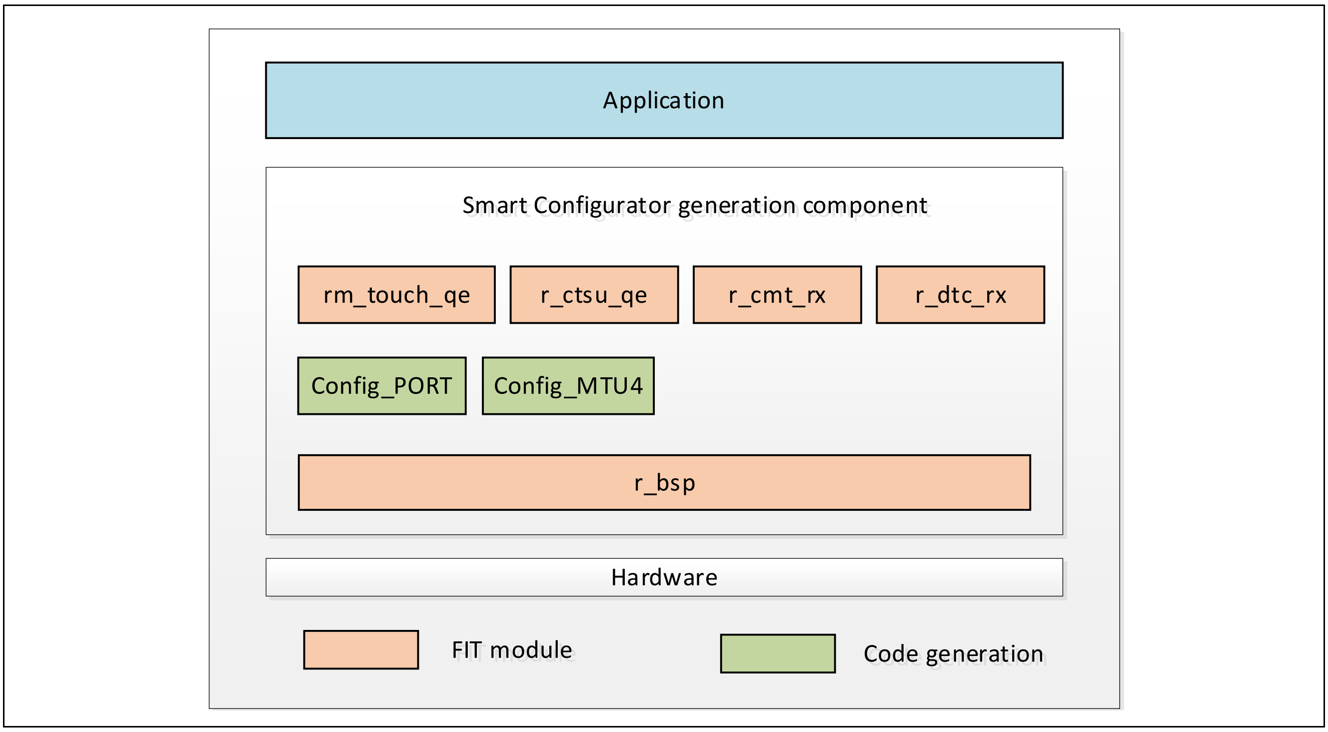

Figure 3-7 Software configuration diagram

3.6 File Configuration

Table 3-1 shows the file configuration. Source/header files generated by the Smart Configurator, such as QE Touch modules, are omitted.

Table 3-1 File configuration

Folder/file name	Overview
touchless_sample_project_rx140	Project folder
.cproject	C project file
.project	Project file
touchless_sample_project_rx140 HardwareDebug.launch	Debug configuration file
touchless_sample_project_rx140.scfg	Smart Configurator configuration file
qe_gen	QE setting file storage folder
qe_touch_config.c	QE Touch configuration definition source file
qe_touch_config.h	QE Touch configuration-definition header file
qe_touch_define.h	QE Touch configuration-definition header file
qe_touch_sample.c	Application file
src	Source file storage folder
r_bord_control.c	Touchless Button Demo Solution LED, Buzzer control source file
r_bord_control.h	Touchless Button Demo Solution LED, Buzzer control header file
touchless_sample_project_rx140.c	Touchless Button Demo Solution Main Source file
QE-Touch	QE for Capacitive Touch generation folders
touchless_sample_project_rx140.tifcfg	Touch I/F configuration file

3.7 List of constants

Table 3-2 lists the constants.

Table 3-2 Constants

Constant name	Set value	Description
qe_touch_sample.c		
CMT_FRQ	(50)	CMT period (50Hz = 20msec)
LED_IDLE_STATE	(0U)	LED status initial value
r_bord_control.c		
LED0	(PORT4.PODR.BIT.B3)	LED0 control register pointers
LED1	(PORT4.PODR.BIT.B0)	LED1 control register pointers
LED2	(PORT4.PODR.BIT.B5)	LED2 control register pointers
LED3	(PORT4.PODR.BIT.B6)	LED3 control register pointers
LED4	(PORT4.PODR.BIT.B4)	LED4 control register pointers
LED5	(PORT4.PODR.BIT.B1)	LED5 control register pointers
LED6	(PORT4.PODR.BIT.B7)	LED6 control register pointers
LED7	(PORT4.PODR.BIT.B2)	LED7 control register pointers
LED8	(PORTD.PODR.BIT.B2)	LED8 control register pointers
LED_ON	(1)	LED ON
LED_OFF	(0)	LED off
DISABLE_BUZZER	(0U)	Buzzer disabled state
ENABLE_BUZZER	(1U)	Buzzer enable status
IDLE_BUZZER	(2U)	Buzzer standby status
BRIGHTNESS_TIME	(100)	LED dimming period
BRIGHTNESS_MAX_DELTA	(300)	LED count value change width
r_bord_control.h		
ENABLE_LED_TOGGLE_LIGHT	-	Defined: LED lighting enabled (default) No definition: LED dimming enabled
ENABLE_RING_BUZZER	-	Defined: Buzzer sounding enabled (default) No definition: Buzzer sounding disabled

3.8 Structures and Unions List

Table 3-3 lists the structures and unions.

Table 3-3 Structures and Unions

r_bord_control.c		
Structure type name	st_touchless_led_parameter	
Member variable name	Type	Description
threshold[]	uint16_t	uint16_t type count threshold storage array
delta	uint16_t	uint16_t type count width

3.9 List of Global Variables

Table 3-4 lists the global variables.

Table 3-4 Global variables

Variable Name	Type	Description
qe_touch_sample.c		
gs_timer_flg	bool	CMT Compare Match Notification Flag
gs_led_state	uint64_t	LED lighting condition
r_bord_control.c		
g_led_previous_status[]	uint8_t	LED toggle ON status storage array
g_led_parameter	touchless_led_parameter	LED dimming information storage structure
g_enable_buzzer	uint8_t	Buzzer Status Flag

3.10 List of Functions

Table 3-5 lists the functions.

Table 3-5 List of functions

Function Name	Processing overview
qe_touch_sample.c	
qe_touch_main	Main function
judgement_siml_touch	Touch judgment processing
timer_callback	CMT Compare Match Interrupt Callback
r_bord_control.c	
r_touchless_led_initialize	LED initialization process
r_touchless_led_control	LED toggle lighting process
r_touchless_led_control_brightness	LED dimming process
r_touchless_pin_write	Write LED register value
r_touchless_pin_read	LED register value reading
r_touchless_buzzer_initialize	Buzzer initialization process
r_touchless_buzzer_control	Buzzer processing

3.11 List of Peripheral Functions and Pins Used

Table 3-6 lists the peripheral functions used by this sample software, Table 3-7 lists the pins used, and Table 3-8 lists the unused pins and remedies.

Table 3-6 List of peripheral functions to be used

Peripheral functions	Use
CTSU、DTC	CTSU measurement
PORT	Controlling LEDs
MTU	Buzzer control
CMT	CTSU measurement period

Table 3-7 List of Pins Used

Pin number	Terminal name	I/O	Use
16	TS00	I	CTSU measurement
17	TS01	I	
18	TS02	I	
19	TS03	I	
20	TS04	I	
25	TS05	I	
26	TS06	I	
29	TS07	I	
30	TS08	I	
38	TSCAP	I	
62	MTIOC4C	O	Pulse output for buzzer sounding
64	PD2	O	Output for LED lighting
67	P47	O	
68	P46	O	
69	P45	O	
70	P44	O	
71	P43	O	
72	P42	O	
73	P41	O	
74	PJ7	O	
75	P40	O	

Table 3-8 List of unused pins and remedies

Pin number	Terminal name	I/O	Unused measures
3	P04	O	Open, Low power
80	P05	O	Open, Low power
78	P07	O	Open, Low power
28	P12	O	Open, Low power
27	P13	O	Open, Low power
24	P16	O	Open, Low power
23	P17	O	Open, Low power
22	P20	O	Open, Low power
21	P21	O	Open, Low power
5	PJ1	O	Open, Low power

The peripheral function settings using the smart configurator are shown below.

- CTSU, DTCs, CMTs (CTSU measurement)

Use CTSU to perform touch measurement. DTCs are used to set the registers of CTSU and to acquire the measurement results. In addition, CMT is used for the period of touch measurement.

Table 3-9, Table 3-10, and Table 3-11 show the settings of the peripheral functions.

Table 3-9 CTSU setting

Item	Settings
Data transfer by interrupt	DTC
Automatic judgment function	Disabled

Table 3-10 DTC settings

Item	Setting
DTCER control	All DTCER registers are cleared by the open-function.
Address mode	Full address mode
DTC transfer read skip	Enabled
Sequence transfer	Not used

Table 3-11 CMT settings

Item	Settings
Compare value setting	50[Hz] (=20msec)
Callback function setting	timer_callback()

- PORT (LEDs lit)

Use PORT to light the LEDs. Table 3-12 shows PORT settings.

Table 3-12 PORT settings

Item	Setting
P40	Set to L output
P41	Set to L output
P42	Set to L output
P43	Set to L output
P44	Set to L output
P45	Set to L output
P46	Set to L output
P47	Set to L output
PD2	Set to L output

- MTU4 (Buzzer)

MTU4 is used in PWM-pulse outputting (2048Hz) for buzzer sounding. Table 3-13 shows MTU4 settings.

Table 3-13 MTU4 settings

Item		Setting
TCNT4 Counters Setting	Counter clear factor	TGRA4 compare match (TGRA4 is used as a cycle register)
	For the counter clock Select	PCLK
General Register Settings	TGRC4	Output compare register
	TGRD4	Output compare register
Output Pin Settings	MTIOC 4 A terminal	Pin output disabled
	TGRB compare Operation at match	-
	MTIOC4C terminal	Initial output of pins is 0, toggled at compare match
	TGRD compare Operation at match	1 output from MTIOC4C terminal
PWM output setting	PWM period	500[us]
	TGRA defaults	15999
	Default TGRB	3903
	Default TGRC	7807
	TGRD defaults	3903
A/D conversion start trigger setting		Not used
Interrupt Settings		Not used

4. Capacitance Touch Settings

The following shows the touch interface configuration, configuration (method) settings, and tuning results of this sample code. The tuning function of QE for Capacitive Touch is being used.

4.1 Touch Interface Configuration

Figure 4-1 shows the touch interface configuration.

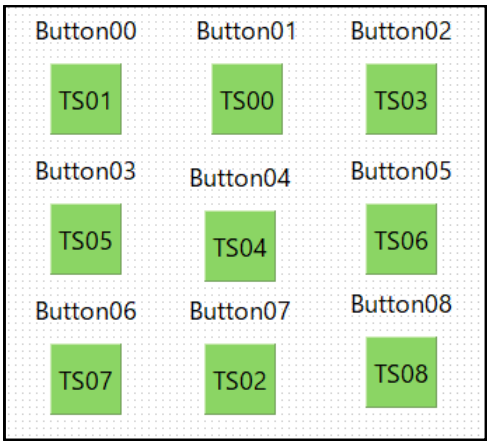

Figure 4-1 Touch Interface Configuration

4.2 Configuration (method) settings

All config01 are set to Auto Judgment and Multi-Electrode Connection disabled.

Figure 4-2 shows the configuration (method) setting screen.

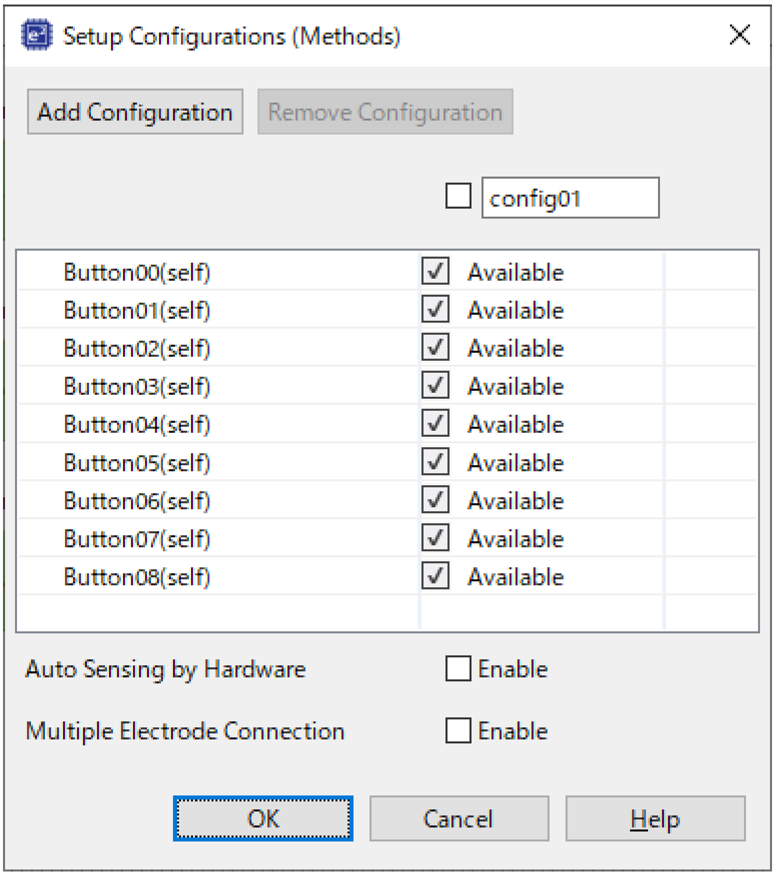

Figure 4-2 Configuration (method) setting screen

4.3 Tuning result

Indicates the tuning result in QE tuning. This program operates with the setting values shown in the results list.

Since the values in the result list depend on the operating environment during QE tuning, these values may change when QE tuning is performed again.

Table 4-1 QE tuning results

Method	Name	Touch sensor	Parasitic capacitance [pF]	Drive pulse frequency [MHz]	Threshold [Note]	Measuring time [ms]	so	snum	sdpa
Config01	Button00	TS01	31.09	1	120	0.576	0x0B7	0x07	0x0F
Config01	Button01	TS00	32.875	1	120	0.576	0x0C2	0x07	0x0F
Config01	Button02	TS03	32.618	1	120	0.576	0x0C7	0x07	0x0F
Config01	Button03	TS05	29.451	1	120	0.576	0x0A7	0x07	0x0F
Config01	Button04	TS04	29.826	1	120	0.576	0x0AC	0x07	0x0F
Config01	Button05	TS06	30.806	1	120	0.576	0x0B6	0x07	0x0F
Config01	Button06	TS07	27.854	1	120	0.576	0x09A	0x07	0x0F
Config01	Button07	TS02	28.625	1	120	0.576	0x09F	0x07	0x0F
Config01	Button08	TS08	29.833	1	120	0.576	0x0AB	0x07	0x0F

so : Sensor Offset Setting Variables
snum : Variables for the measurement period setting
sdpa : Clock division setting variable

Note: Thresholds have been changed in the qe_touch_config.c

4.4 Sensitivity adjustment method

Use QE for Capacitive Touch to adjust the sensitivity. There are the following methods for adjusting the sensitivity.

- How to use the tune function of QE for Capacitive Touch

  Follow the tutorial from the main window (Cap Touch main) of QE for Capacitive Touch.

- How to change in real time using QE for Capacitive Touch's monitoring function

  Displays Cap Touch parameter list of QE for Capacitive Touch and adjusts it by the following steps.

1. Select the touch I/F corresponding to the button you want to adjust.
2. Click [Enable Monitoring] to start monitoring.
3. When the item is displayed, change the value of [Touch Threshold].
4. Click [Write to target board in real time] and change the touch threshold.
5. Repeat steps 3 to 4 to adjust the sensitivity.

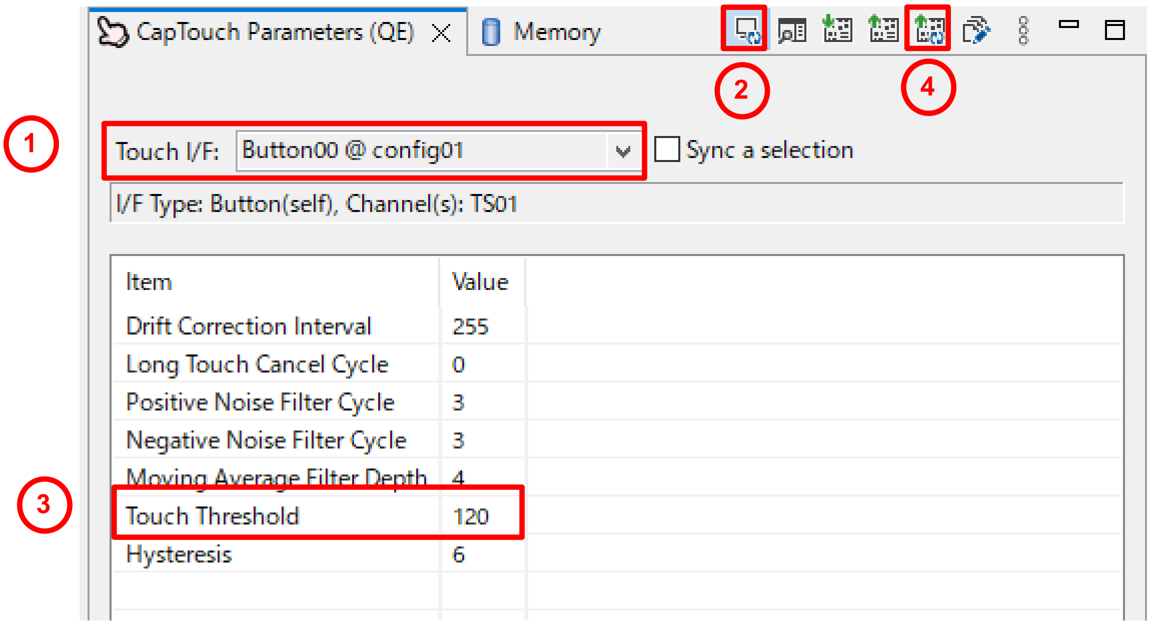

Figure 4-3 Cap Touch Parameters (QE) window

- How to Change Code Manually

  It can be adjusted by changing the member variable of the structure variable g_qe_touch_button_cfg_config01 in the qe_touch_config.c.

  The variable to be changed is as follows.

  ・ threshold : Threshold for touch-based judgment

5. Precautions for use

This section describes precautions for using sample software.

5.1 Build Options

You can switch functions by changing the build options and rebuilding them.

The LED display function can be switched.

Table 5-1 Build options (r_touchless_led.h)

Definition name	Description
ENABLE_LED_TOGGLE_LIGHT	Defined: LED lighting enabled (default) No definition: LED dimming enabled

The buzzer sounding can be enabled or disabled.

Table 5-2 Build options (r_touchless_buzzer.h)

Definition name	Description
ENABLE_RING_BUZZER	Defined: Buzzer sounding enabled (default) No definition: Buzzer sounding disabled

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jul.29.22	-	First edition release

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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