RX261/RX260 Group

Smart Wakeup Solution

Introduction

This application note explains the software that operates with low power consumption on the RX261 Capacitive Touch Evaluation System.

Target Device

RX261 (R5F52618BGFP)

This software can also be run on the RX260, but please change the project settings, etc. to RX260 and evaluate before use.

Related Document

1. RX261 Group Capacitive Touch Evaluation System User's Manual (R12UZ0150JJ0100)

Contents

1. Outline

This application note describes the automatic judgment function and the multi-electrode connection function of CTSU2SLa in RX261 to provide low-power touch operation.

This software has two modes: "standby mode" and "active mode". In standby mode, touch detection with any button is performed, and then the mode shifts to active mode. When the transition conditions are satisfied, such as non-touch in active mode, the mode shifts to standby mode. This is a system that loops through this behavior.

In this application note, this system is referred to as the "Smart Wakeup Solution."

2. Operation Environment

Table 2.1 shows confirmed operation environment of this software.

Table 2.1 Operation confirmed environment

Item	Contents
Demo board	RX261 capacitive touch evaluation system (RTK0EG0055S01001BJ) • RX261 CPU board (RTK0EG0054C01001BJ) • Application board for capacitive touch evaluation (RTK0EG0019B01002BJ) - Self-Capacitance Buttons / Wheels / Slider Board
MCU	R5F52618BGFP
Operating frequency	24MHz
Operating voltage	5V
Integrated development environment	e^2 Studio 2024-07
C compiler	CC-RX v3.06.00
OCD emulator	E2 emulator Lite
QE for Capacitive Touch	V4.00

3. Software Functions

This software has two modes, "standby mode" and "active mode", and operates by switching modes depending on the transition conditions.

Therefore, we will create two touch interface configurations and perform touch measurement corresponding to the two modes.

Figure 1.1 shows software operation image.

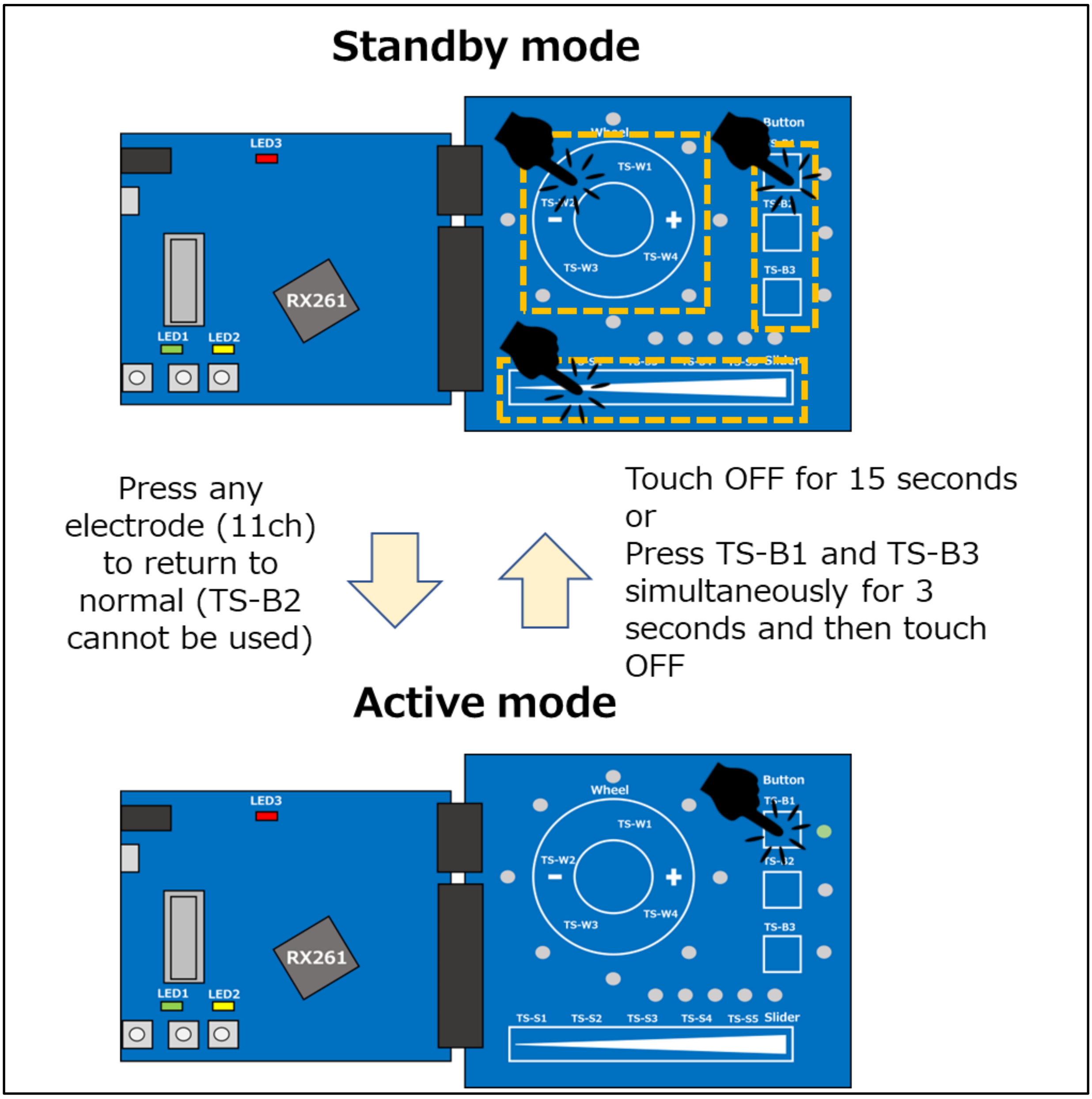


Figure 1.1 Software operation image

This section describes each mode and what happens when switching modes.

3.1 Standby mode

The CPU is set to a low-power mode and touch measurement is performed using the automatic judgment function and the multiple electrode connection function. By using the multiple electrode connection function, 11 channels can be measured at one time to reduce power consumption.

Figure 3.1 shows an image of CPU operating mode and CTSU operating status.

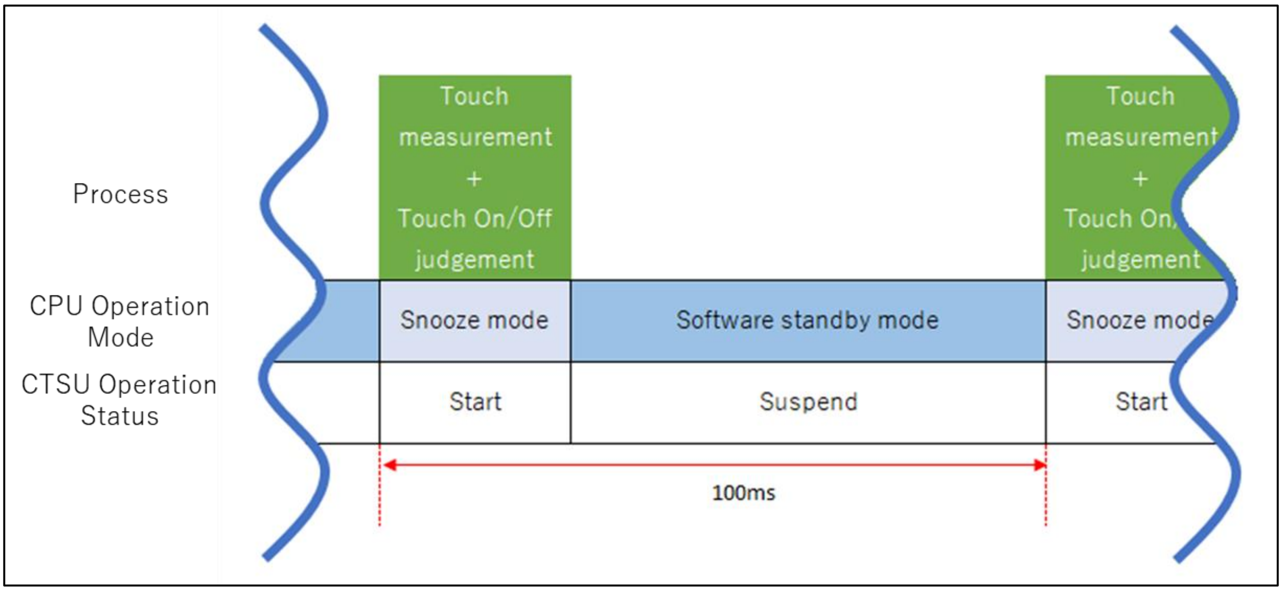


Figure 3.1 Image of CPU operating mode and CTSU operating status

- Set the CTSU measurement start trigger to an external trigger of the LPT's compare match interrupt (event input from ELC) and perform touch measurements at 100msec intervals.
- Use LPC to transition the CPU to software standby mode. CTSU will be suspended.
- External trigger detection puts the CPU into snooze mode.
- CTSU measurement in snooze mode is judged by touch by an automatic judgment function using DTC. If the touch-on decision is not detected, the system transitions to software standby again. When the touch-on judgment is detected, the system transitions from standby mode to active mode.

3.2 Active mode

Operates the 2 buttons, slider, and wheel on the touch board.

- When the touch board is touched, the corresponding LED lights up.
- When the following conditions are satisfied, the system transitions from active mode to standby mode.
  - 15 seconds elapses in the non-touch state
  - 3 seconds elapses with the TS-B1 and TS-B3 touch at the same time on the touch board

3.3 Standby preparation process

When transitioning from active mode to standby mode, standby preparation is performed to prevent false touch detection.

In order to transition to standby mode in a non-touch state, the standby preparation measures the baseline average number of times, and if all are non-touch, it transitions to standby mode.

The following shows the flow from standby preparation to active mode and then to standby mode again.

state	Standby Preparation	Start Standby	Standby	Standby Release	Active	Timer Monitoring	Standby Preparation	Start Standby	Standby	…
config01	Measurement in progress	Baseline average number of measurements completed	Measurement in progress	Touch ON	Measurement stop	Measurement stop	Measurement in progress	Baseline average number of measurements completed	Measurement in progress	…
config02	Measurement stop	Measurement stop	Measurement stop	Measurement stop	Measurement in progress	Touch OFF for 15 seconds or Press TS-B1 and TS-B3 simultaneously for 3 seconds and then touch OFF	Measurement stop	Measurement stop	Measurement stop	…

Figure 3.2 State transition image

This transition can be expressed in measured values as follows.

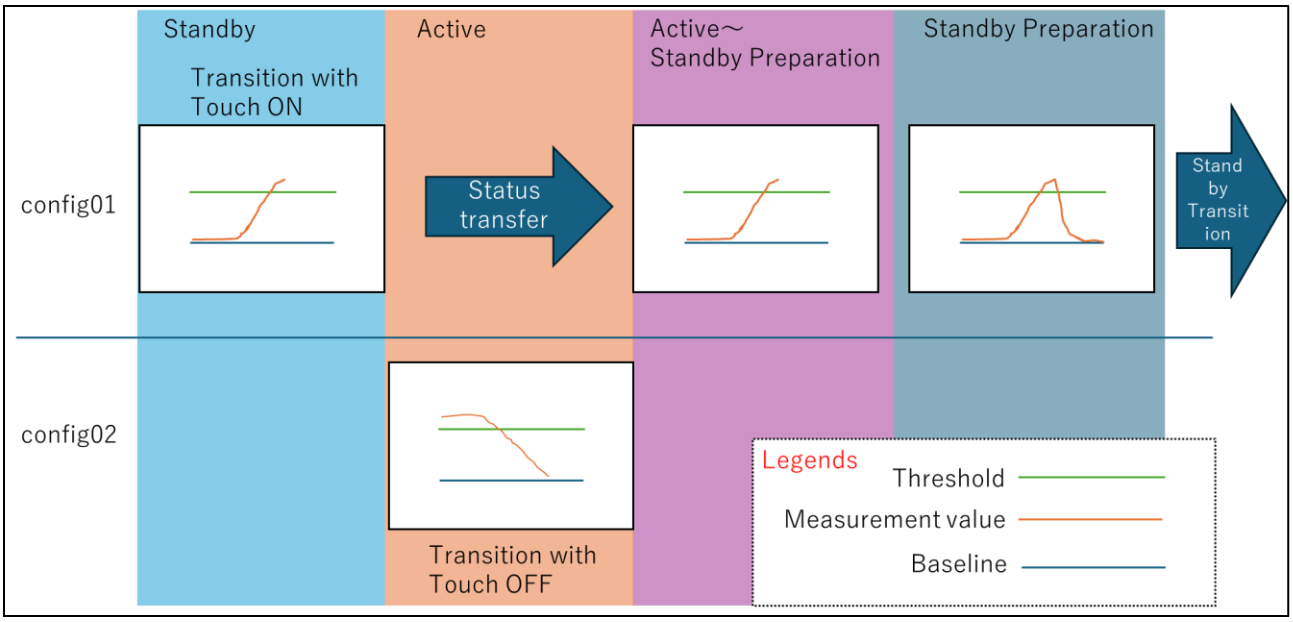


Figure 3.3 Measurement value transition image

The smart wake-up solution loops between standby and active modes. If the parasitic capacitance changes significantly during each mode due to environmental changes, the baseline update process cannot operate in the touch interface configuration that is not in operation, and the threshold value may be exceeded without touch, and touch judgment may not be possible. In that case, a system reset will be required, so be careful when using it in a place where the environment changes significantly.

4. Software Specifications

4.1 Software Structure

Figure 4.1 shows the software structure diagram.

By using QE for Capacitive Touch and RX Smart Configurator, the following modules are added to create an application.

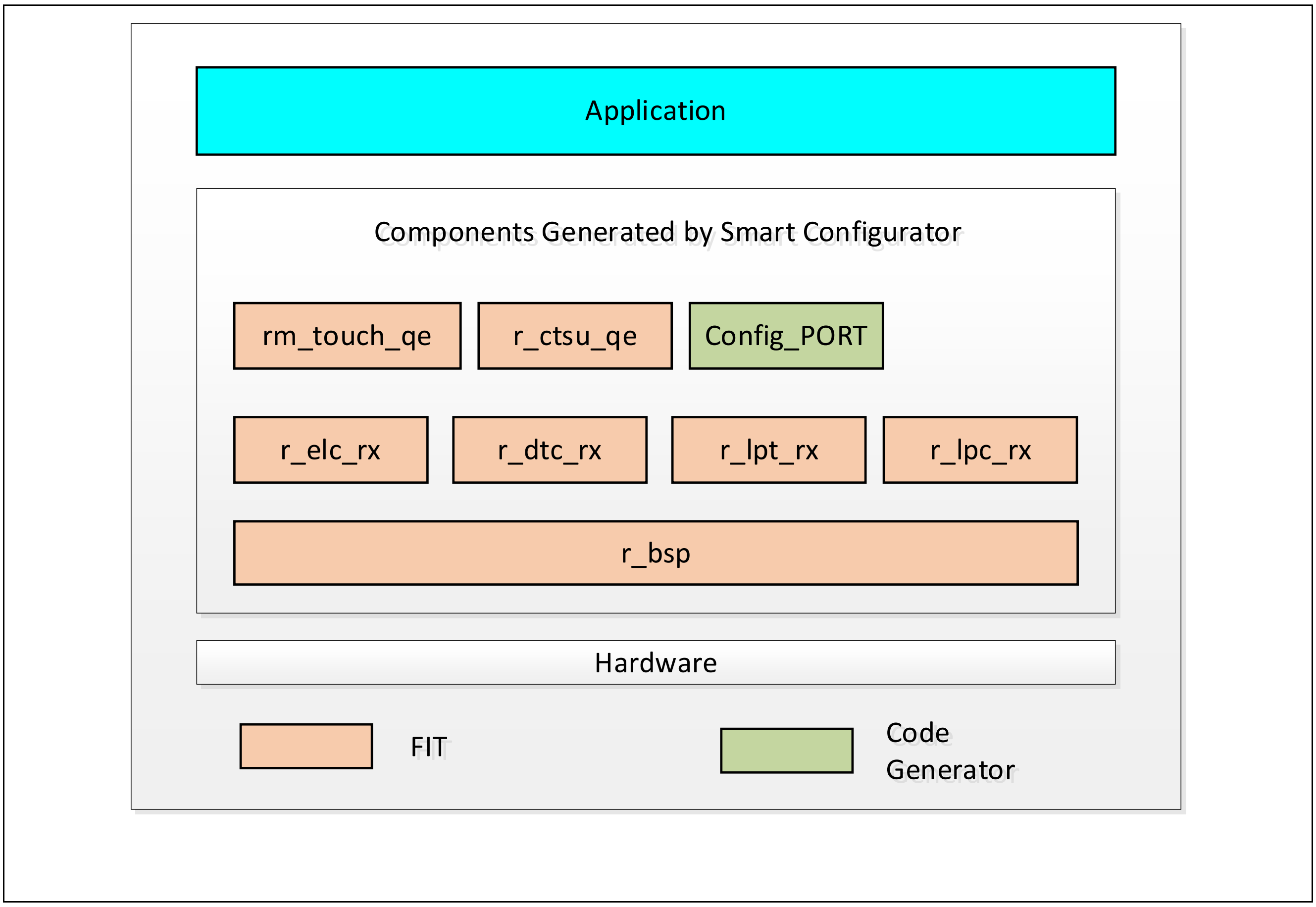


Figure 4.1 Software structure diagram

The component is shown in Table 4.1. See the Smart Configurator for component settings.

Table 4.1 Component

Component	Version
r_bsp	7.51
r_lpc_rx	2.40
r_ctsu_qe	3.00
r_dtc_rx	4.50
r_elc_rx	4.00
r_lpt_rx	5.00
rm_touch_qe	3.00
Config_PORT	2.4.1

4.2 File Structure

Figure 4.2 shows the source file tree. (Omit the smart configurator file.)

```
├── qe_gen
│       qe_touch_config.c ・・・・・・・・・Touch QE Configuration definition source file
│       qe_touch_config.h ・・・・・・・・・Touch QE Configuration definition header file
│       qe_touch_define.h ・・・・・・・・・Touch QE Configuration definition header file
│       qe_touch_sample.c ・・・・・・・・・Touch QE Application file
│       qe_touch_sample.h ・・・・・・・・・Touch QE Application header file
├── src
│       r_board_control.c ・・・・・・・・・Board control source file
│       r_board_control.h ・・・・・・・・・Board control header file
│       smart_wakeup_rx261_rssk.c ・・・・Main source file
│
├── QE-Touch
      smart_wakeup_rx261_rssk.tifcfg・・・Configuration file
```

Figure 4.2 Source file tree

Table 4.2 shows the source files.

Table 4.2 The source files

File name	Contents
smart_wakeup_rx261_rssk.c	Main source file
r_board_control.c	Board control source file
qe_touch_config.c	Touch QE Configuration definition header file
qe_touch_sample.c	Touch QE Application file

Table 4.3 shows the header files.

Table 4.3 The header files

File name	Contents
r_board_control.h	Board control header file
qe_touch_config.h	Touch QE Configuration definition header file
qe_touch_define.h	Touch QE Configuration definition header file
qe_touch_sample.h	Touch QE Application header file

4.3 List of Constants

Table 4.4 shows the list of constants.

Table 4.3 List of Constants

Constant name	Setting value	Description Contents
WAKEUP_LPT_PERIOD	(100000)	LPT cycle (100msec)
WAKEUP_LPT_PERIOD_STANDBY	(100000)	LPT compare match value during standby mode (100msec)
WAKEUP_LPT_PERIOD_NORMAL	(20000)	LPT compare match value during active mode (20msec)
WAKEUP_WAIT_MEASUREEND	((WAKEUP_LPT_PERIOD_NORMAL / 1000) + 5)	Waiting time for measurement completion (25msec)
WAKEUP_TIME_SLEEP	(15000U)	No operation judgment time (15sec)
WAKEUP_TIME_TOUCH	(3000U)	Touch judgment time (3sec)
WAKEUP_TIME_AJBMAT	(32)	Baseline update count
WAKEUP_TIME_BASELINE	(WAKEUP_TIME_AJBMAT * 2)	Baseline update count
WAKEUP_TIME_CYCLE	(26U)	Measurement cycle time
WAKEUP_COUNT_SLEEP	(WAKEUP_TIME_SLEEP / WAKEUP_TIME_CYCLE)	No operation judgment count
WAKEUP_COUNT_TOUCH	(WAKEUP_TIME_TOUCH / WAKEUP_TIME_CYCLE)	Touch judgment count
WAKEUP_STATUS_STANDBY	(WAKEUP_STATUS_BUTTON0 + WAKEUP_STATUS_BUTTON2)	Transition judgment status of standby mode
LED		
LED_IO_LEVEL_LOW	(0)	PORT level Low
LED_IO_LEVEL_HIGH	(1)	PORT level High
LED_ROW0	PORT1.PODR.BIT.B2	PORT1 PODR register Bit2
LED_ROW1	PORT1.PODR.BIT.B3	PORT1 PODR register Bit3
LED_ROW2	PORT5.PODR.BIT.B1	PORT5 PODR register Bit1
LED_ROW3	PORT5.PODR.BIT.B2	PORT5 PODR register Bit2
LED_COL0	PORTE.PODR.BIT.B0	PORTE PODR register Bit0
LED_COL1	PORTE.PODR.BIT.B1	PORTE PODR register Bit1
LED_COL2	PORTA.PODR.BIT.B7	PORTA PODR register Bit7
LED_COL3	PORT5.PODR.BIT.B0	PORT5 PODR register Bit0
CTSU		
WAKEUP_MODE_STANDBY	(1)	Standby mode
WAKEUP_MODE_NORMAL	(0)	Active mode
WAKEUP_STATUS_BUTTON0	(0x0002)	TS-B1 Button status
WAKEUP_STATUS_BUTTON1	(0x0004)	TS-B2 Button status
WAKEUP_STATUS_BUTTON2	(0x0001)	TS-B3 Button status
WAKEUP_STATUS_WHEEL_RESOLUTION	(360 / 8)	Wheel Status resolution
WAKEUP_STATUS_SLIDER_RESOLUTION	(100 / 5)	Slider Status resolution

4.4 List of Global Variable

Table 4.5 shows the list of global variable.

Table 4.4 List of Global variable

Variable name	Attribute	Description
gs_snooze_mode	lpc_snooze_mode_t	Snooze mode setting

4.5 List of Functions

Table 4.6 shows the list of functions.

Table 4.6 List of Function

Function Name	Outline of processing
qe_touch_main	Main function
init_peripheral_function	Initialization of peripheral functions
activate_standby_callback	Callback of before transition to standby mode
snooze_callback	Callback of snooze mode release interrupt
r_control_cpu_board_led	LED control of CPU board
r_control_touch_board_led	LED control of Touch board
r_turn_off_touch_board_led	LED all off of Touch board

4.6 Overall Processing

Figure 4.3 shows overall processing flowchart.

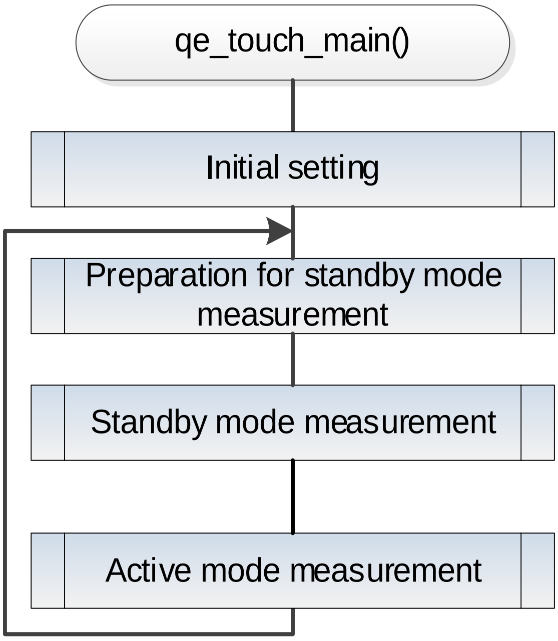


Figure 4.3 Overall processing flowchart

4.7 Initial Setting Processing

Figure 4.4 shows Initial setting processing flowchart.

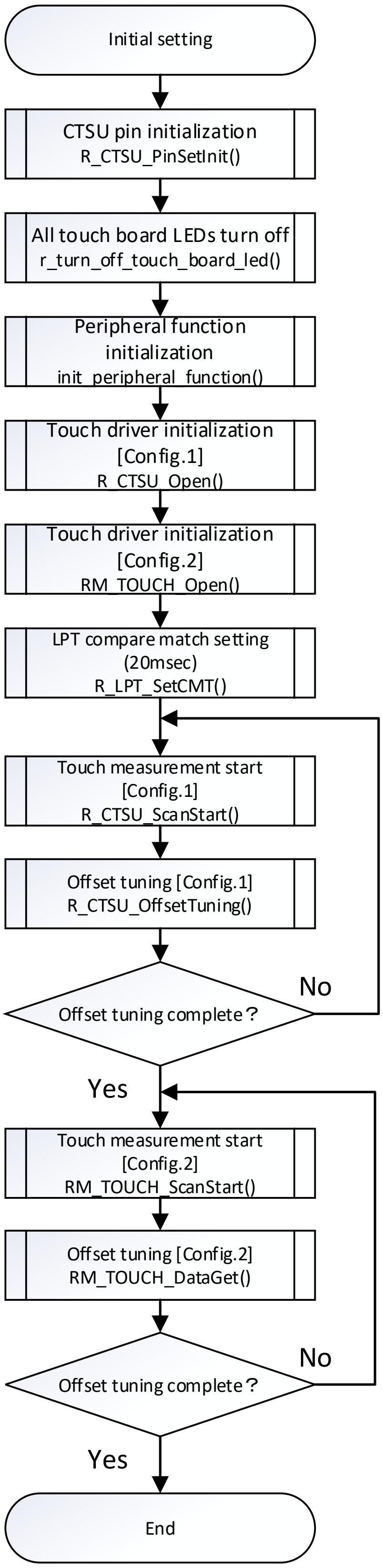


Figure 4.4 Initial setting processing flowchart

4.8 Standby Mode Measurement Preparation Processing

Figure 4.5 shows standby mode measurement preparation processing flowchart.

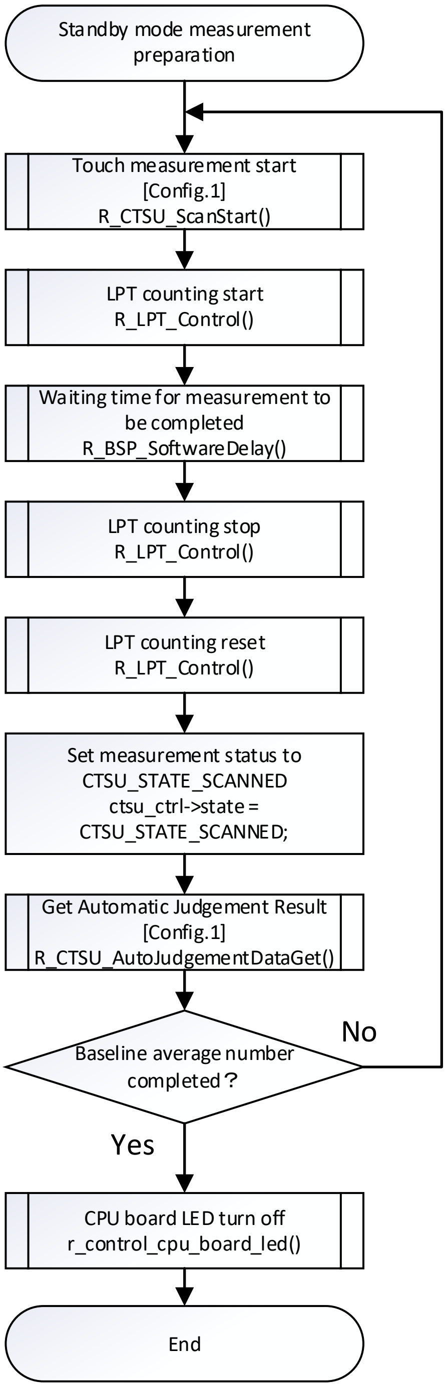


Figure 4.5 Standby mode measurement preparation processing flowchart

4.9 Standby mode Measurement Processing

Figure 4.6 shows standby mode measurement processing flowchart.

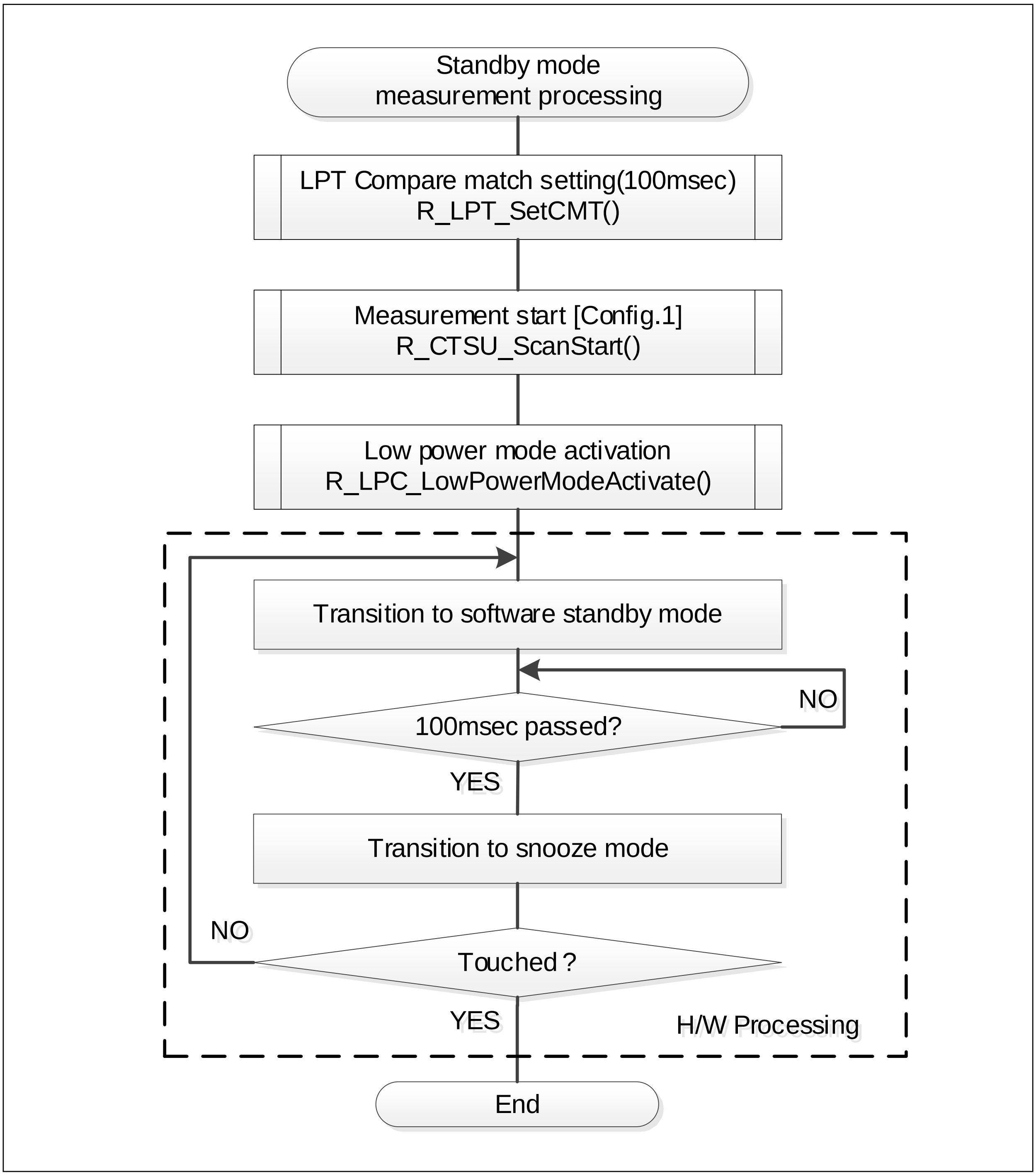


Figure 4.6 Standby mode measurement processing flowchart

4.10 Active mode Measurement Processing

Figure 4.7 shows active mode measurement processing flowchart.

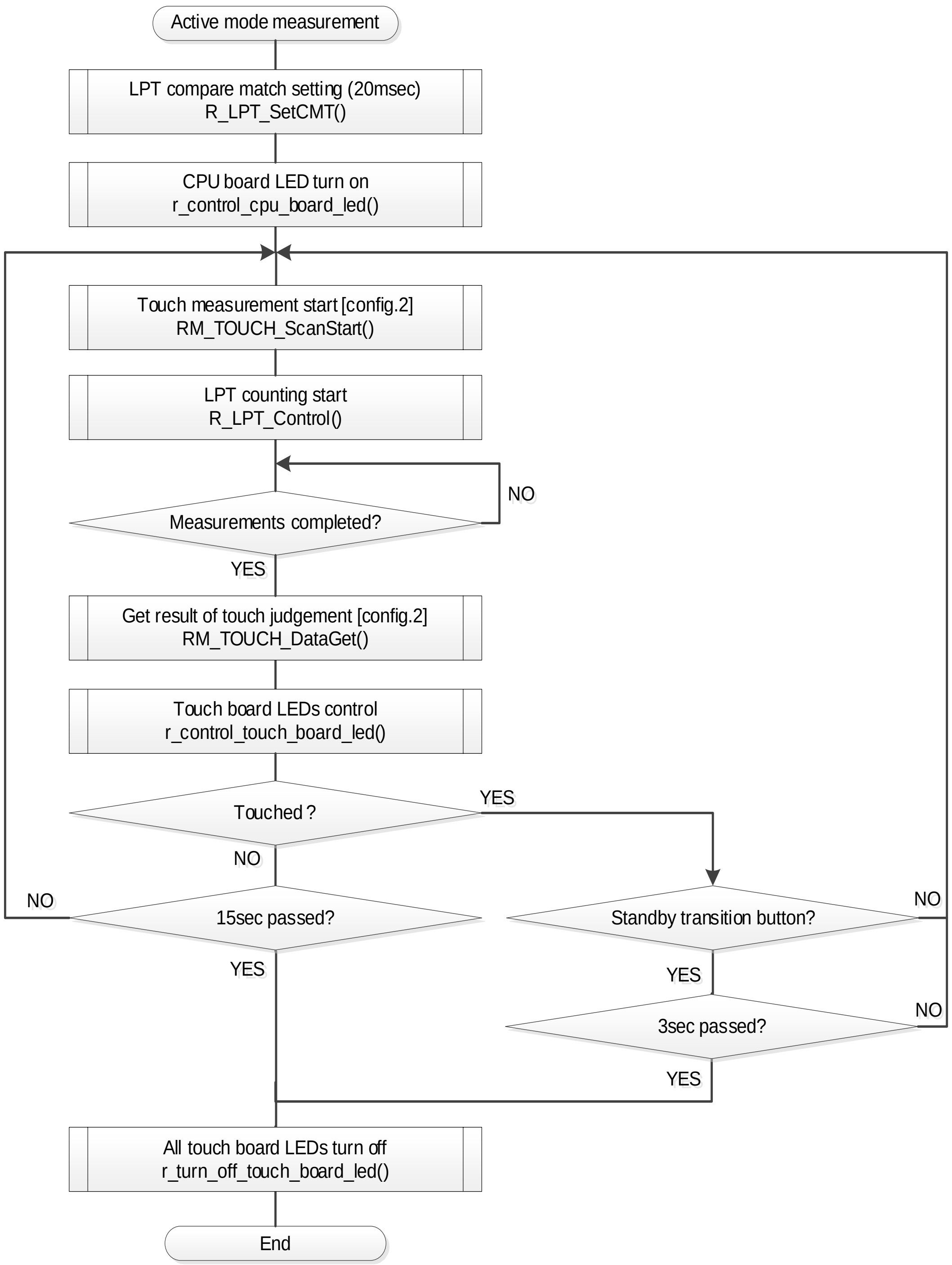


Figure 4.7 Active mode measurement processing flowchart

5. Capacitive Touch Setting

The touch interface configuration of this software, the configuration (method) settings, and the tuning results using the QE tuning function are shown.

5.1 Touch Interface Configuration

Figure 5.1 shows the touch interface configuration.

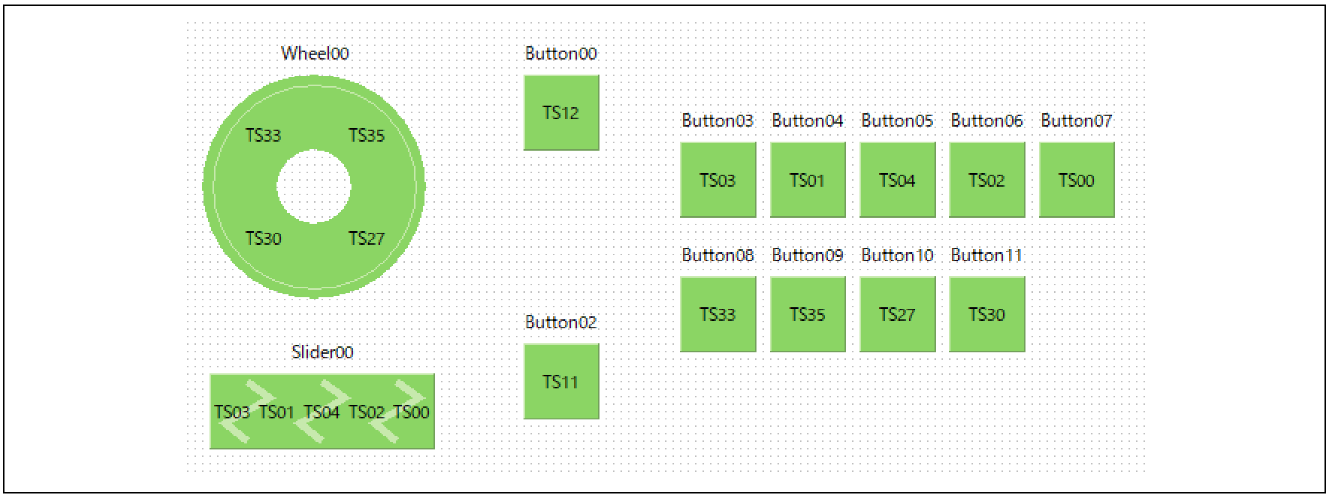


Figure 5.1 Touch interface configuration

5.2 Configuration (method) Setting

Figure 5.2 shows the touch interface settings. “config01” is all buttons, and the automatic judgment function and multiple electrode connection are enabled. “config02” sets two buttons, a slider, and a wheel.

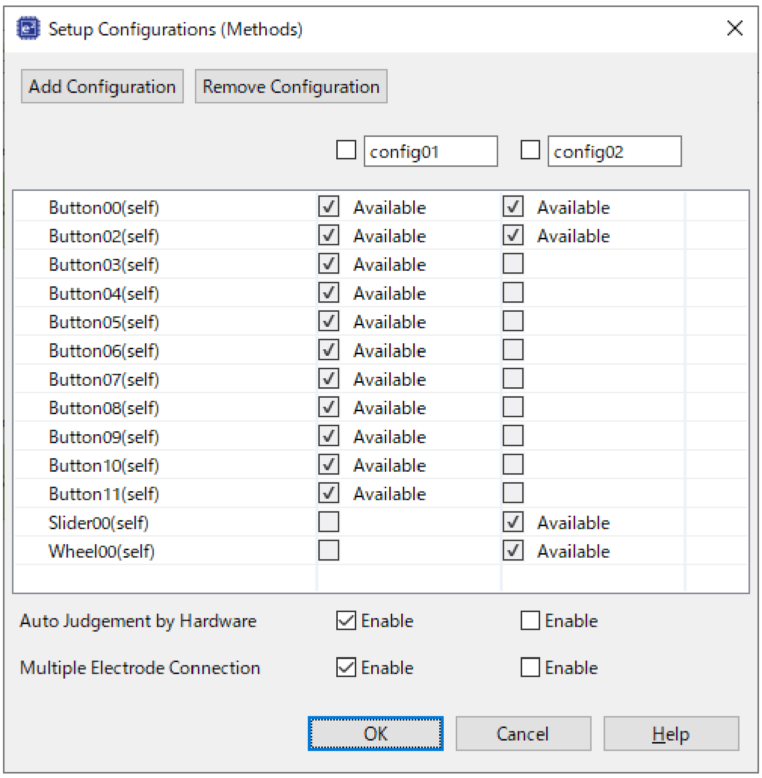


Figure 5.2 Configuration (method) settings

5.3 Tuning Result

Shows the tuning results in QE tuning. This software is operating with the settings shown in the result list.

This software changes the “snum” of config01 (mec00) to 0x03 in the advanced settings during QE tuning.

Table 5.1 Tuning result

Configuration	Name	Touch Sensor	Parasitic capacitance [pF]	Sensor drive pulse frequency [MHz]	Touch Threshold	Measurement time [ms]	so	snum	sdpa
config01	mec00	TS00	163.743	0.5	62;53;71	0.064	0x2CE	0x03	0x17
config02	Button00	TS12	20.632	2	1017	0.128	0x11A	0x07	0x05
config02	Button02	TS11	19.09	2	1116	0.128	0x0F9	0x07	0x05
config02	Slider00	TS03	18.09	2	798	0.128	0x0E9	0x07	0x05
config02	Slider00	TS01	19.174	2	798	0.128	0x0FC	0x07	0x05
config02	Slider00	TS04	21.757	2	798	0.128	0x12B	0x07	0x05
config02	Slider00	TS02	21.0	2	798	0.128	0x11E	0x07	0x05
config02	Slider00	TS00	21.951	2	798	0.128	0x12D	0x07	0x05
config02	Wheel00	TS33	29.938	1	574	0.128	0x0B5	0x07	0x0B
config02	Wheel00	TS35	28.917	1	574	0.128	0x0AC	0x07	0x0B
config02	Wheel00	TS27	24.146	1	574	0.128	0x080	0x07	0x0B
config02	Wheel00	TS30	22.889	1	574	0.128	0x074	0x07	0x0B

so : Variables for sensor offset settings
snum : Variables for setting the measurement period
sdpa : Clock division setting variable

*1: The values in the result list depend on the operating environment at the time of QE tuning, so these values may change when QE tuning is performed again.

*2: To reduce power consumption,manually changed a part of the setting of "g_qe_ctsu_cfg_config01" in "qe_touch_config.c".

tlot(Non-touch criteria) = 2 → 1

thot(Touch Criteria) = 2 → 1

ajbmat(Baseline average number of times) = 7 → 4

6. Power Consumption Measurement

6.1 Operating Conditions of Standby Mode

Table 6.1 shows the operation condition of standby mode.

Table 6.1 Operating conditions of standby mode

Item	Description
Operating frequency	24MHz High-speed on-chip oscillator（HOCO） 15KHz IWDT dedicated on-chip oscillator
FlashIF clock	6MHz
System clock (ICLK)	6MHz
Peripheral module clock A（PCLKA）	6MHz
Peripheral module clock B（PCLKB）	6MHz
Peripheral module clock D（PCLKD）	6MHz
Capacitive Touch measurement cycle	100ms
Sensor drive pulse frequency	0.5MHz
CTSU Measurement Mode	Self-capacitance method (MD1 = 1)
CTSU Scan Mode	Multi-scan mode (MD0 = 1)
CTSU Measurement Operation Start Trigger Select	External trigger (CAP = 1)
CTSU Wait State Power-Saving Enable	Enable power-saving function during wait state (SNZ = 1)
CTSU Power Supply Operating Mode	Normal voltage operating mode (ATUNE0 = 0)
CTSU Current Range Adjustment	40µA (ATUNE1 = 1, ATUNE2 = 0)
CTSU Non-measurement Channel Output Select (POSEL)	GPIO LOW Output (POSEL = 0)
CTSU Sensor Drive Pulse Select (SDPSEL)	High resolution pulse mode (SDPSEL =1)
CTSU Sensor Stabilization Wait Time Setting (SST)	64µs (Recommended value) (SST = 0x1F)
CTSU Multi-Clock	3 frequencies (MCA0, MCA1, MCA2: Available)
CTSU Measurement Count	64µs (SNUM= 3)

6.2 Current Measuring Equipment and Software

Table 6.2 shows measuring equipment and software used in current consumption measurement.

Table 6.2 Current measuring equipment and Software

Type	Name	Use
Digital multi meter	KEITHLEY/DMM7510	Measure current consumption
Power supply	KENWOOD/PA18-1.2A	Supply power to RX261 CPU board
Software	KEITHLEY/KickStart Software	Get result of current consumption measurement from Keithley DM7510 and output the result to log-file.

6.3 RX261 CPU Board

The front of the RX261 CPU board is shown below.

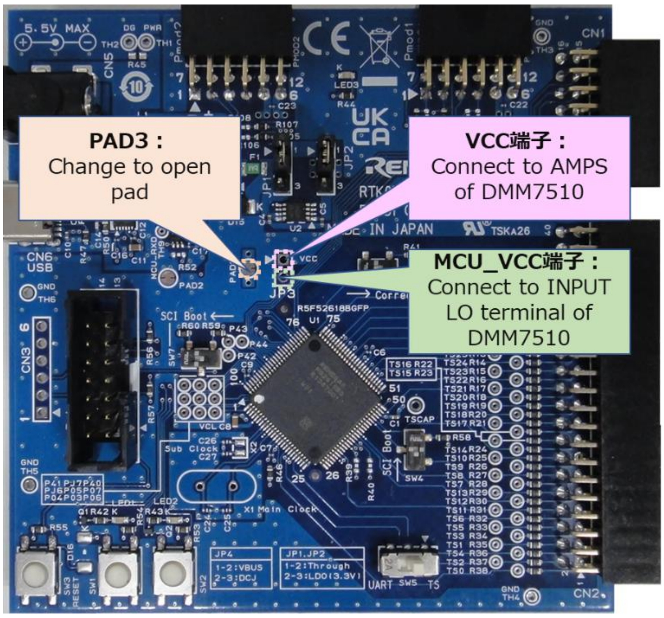


Figure 6.1 RX261 CPU board (front side)

Cut the bridge pattern between the pads for the default short PAD3. Figure 6.2 shows the shape of the jumper pad.

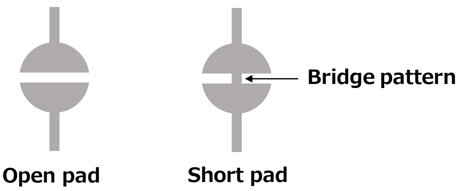


Figure 6.2 Jumper pad shape

6.4 RX261 CPU Board Jumper Setting

Table 6.3 shows the jumper settings of RX261 CPU board to measure current consumption.

Table 6.3 Jumper settings

Position	Jumper setting	Use
JP3	Open	Measure current consumption
JP4	Close 2-3 pin	Power supply from DC jack

Other jumper settings and switch settings are factory-default.

6.5 Environment to Measure Current Consumption

Figure 6.3 shows environment to measure current consumption.

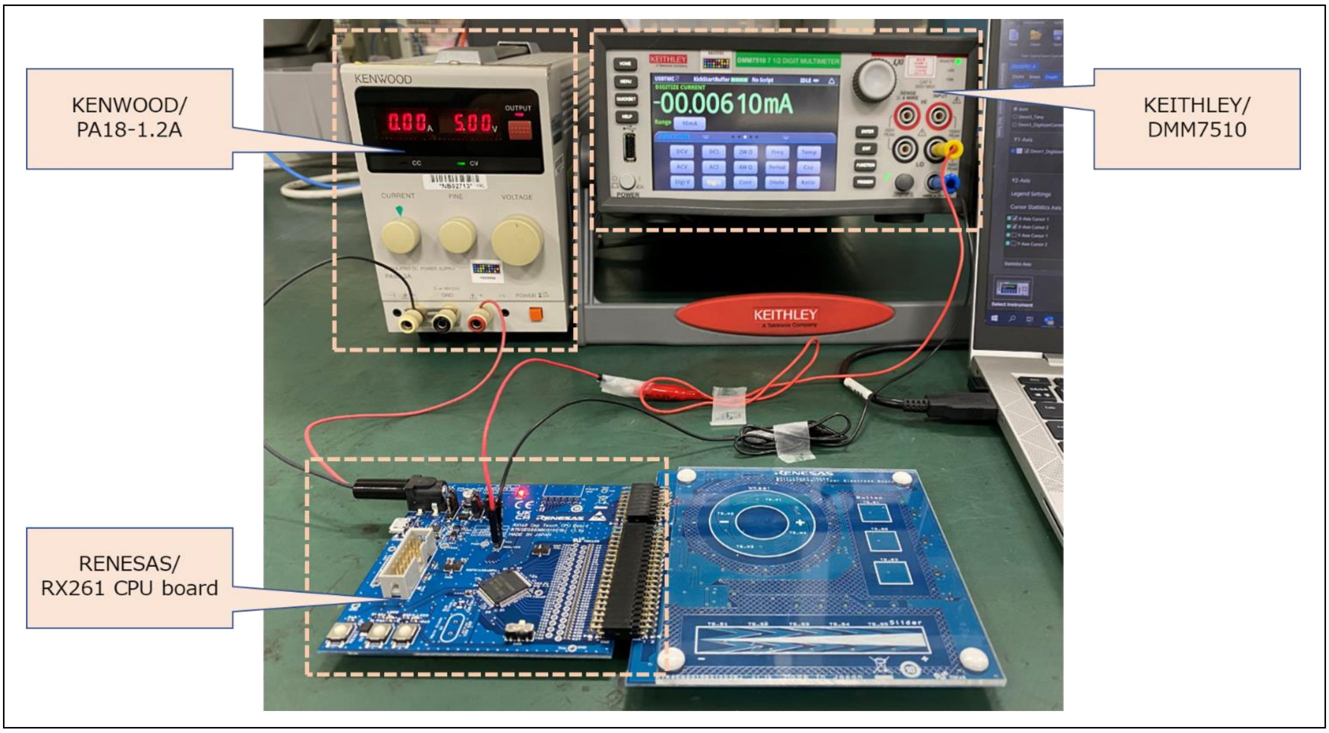


Figure 6.3 Environment to measure current consumption

6.6 Setting to Measure Current Consumption

Figure 6.4 shows settings of Keithley KickStart to measure current consumption.

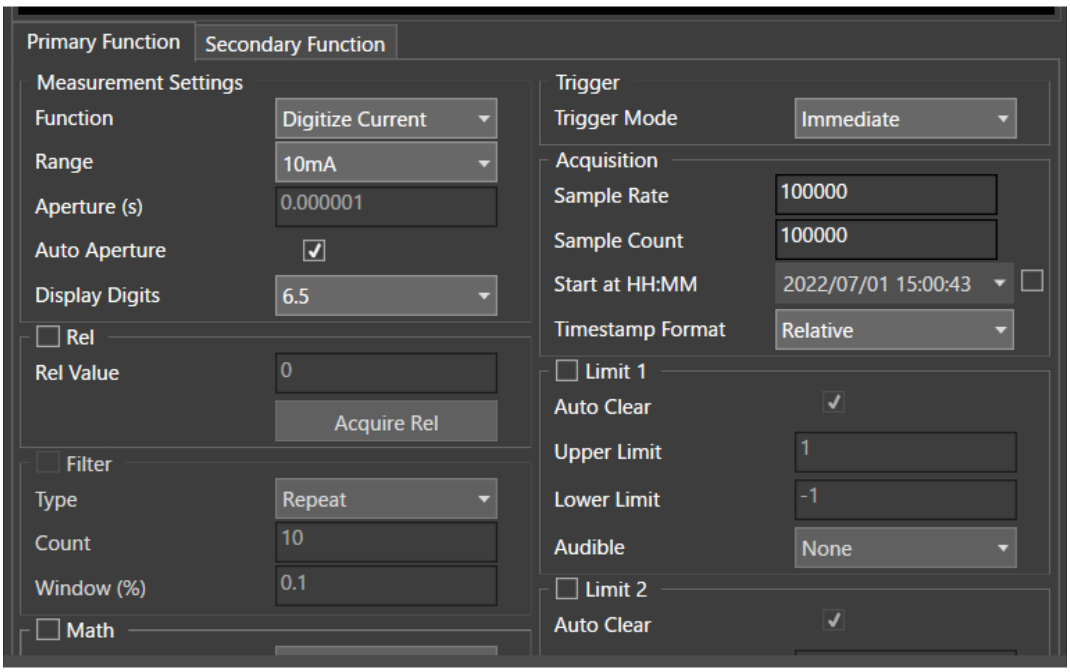


Figure 6.4 Settings of Keithley KickStart to measure current consumption

6.7 Current Consumption Measurement Results

Figures 6.5 and 6.6 show the current consumption waveforms of the operation when the CPU operation mode transitions to the software standby mode and snooze mode (Touch measurement processing, touch on / off judgment processing).

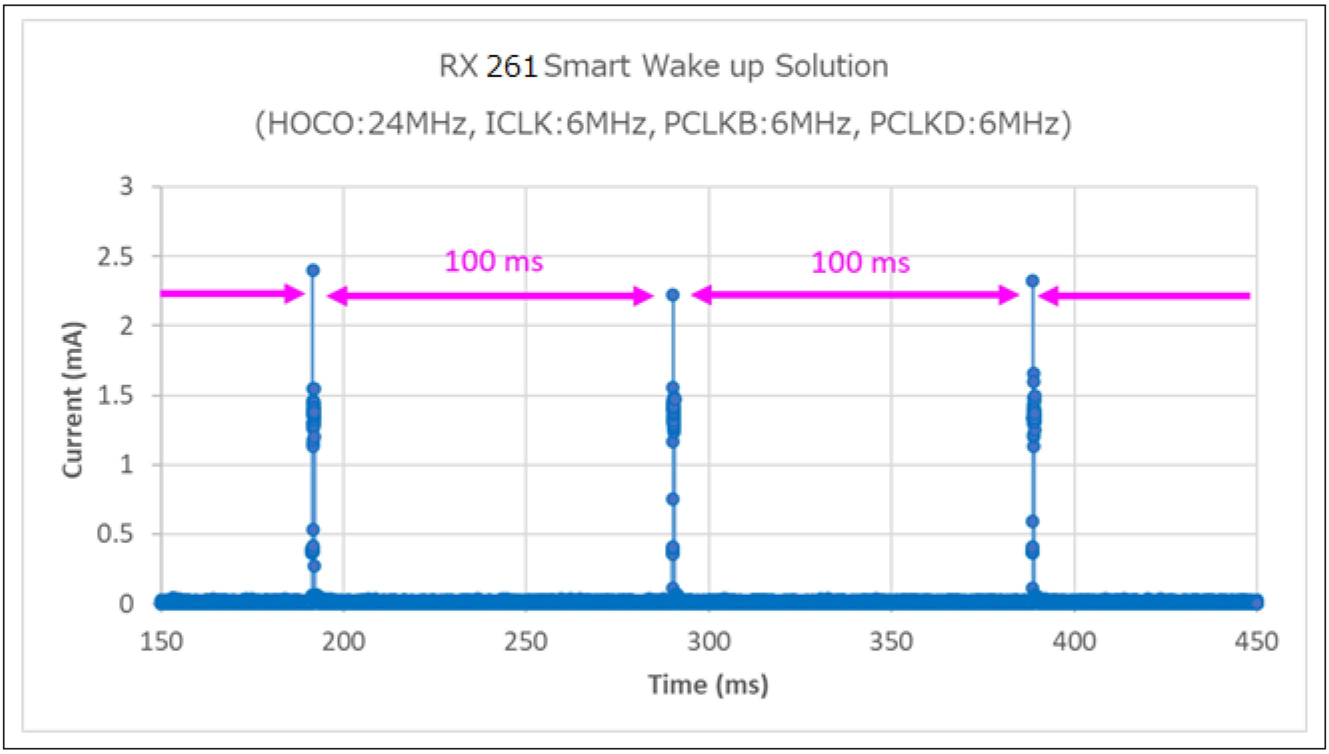


Figure 6.5 Current consumption waveform during standby mode (1/2)

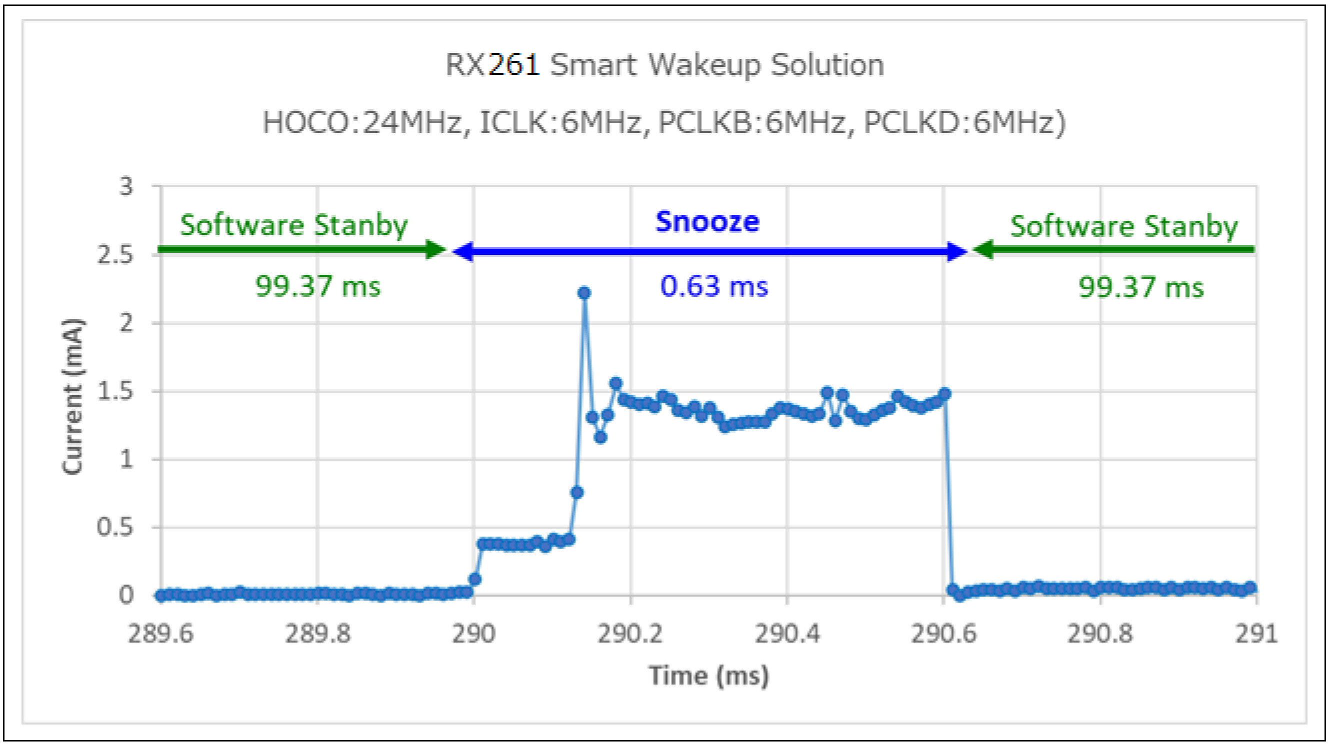
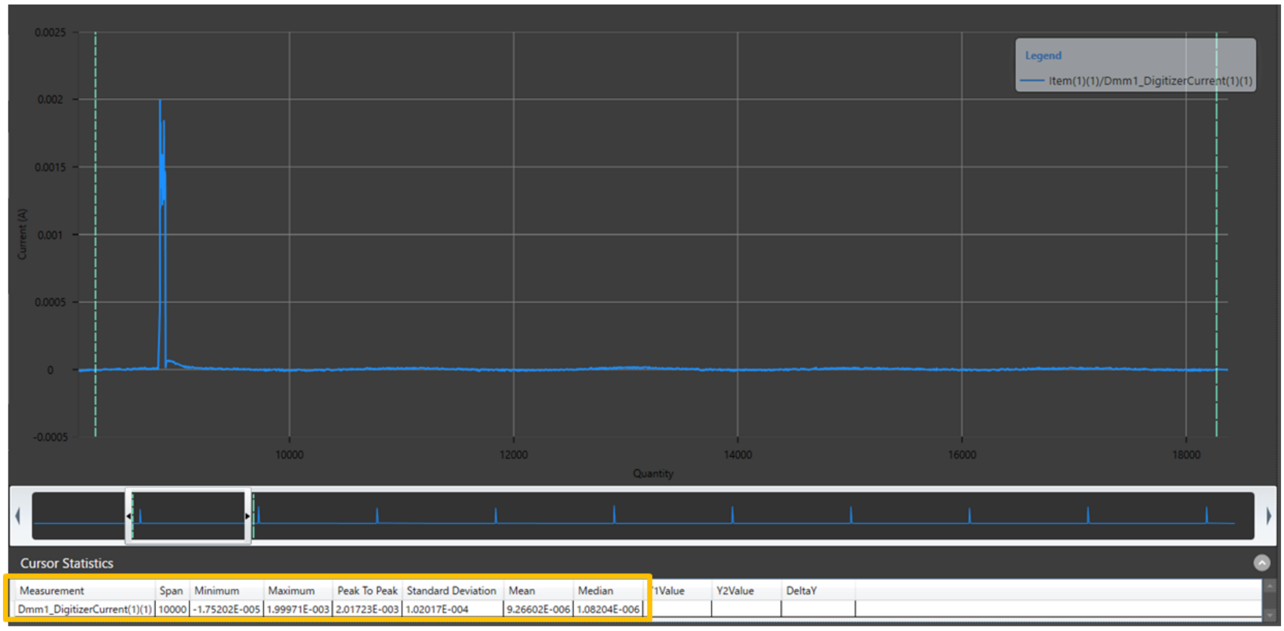


Figure 6.6 Current consumption waveform during standby mode (2/2)

6.8 Current Consumption Calculation Results

Figure 6.7 shows the average current of 100ms cycle in standby mode with automatic judgment function and multiple electrode connection function.



Measurement	Span	Minimum	Maximum	Peak To Peak	Standard Deviation	Mean	Median
Dmm1_DigitizerCurrent(1)(1)	10000	-1.75202E-005	1.99971E-003	2.01723E-003	1.02017E-004	9.26602E-006	1.08204E-006

Figure 6.7 Average current of 100ms cycle in standby mode

Current consumption (touch measurement cycle of 100ms) = **9.26602 μA**

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Nov.7.24	-	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.

Notice

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