RX140 Group

Smart Wakeup Solution

Introduction

This application note explains the software for a Smart Wakeup Solution that provides low power standby on the RX140 Capacitive Touch Evaluation System.

Target Device

RX140 (R5F51406ADFN)

Related Document

1. RX140 Group Capacitive Touch Evaluation System User's Manual (r12uz0102ej0100)

Contents

1. Outline

This software performs standby with low power consumption by using the automatic judgment function of CTSU2SL and the multi-electrode connection (All TS Pin Output Control bit: enabled) function installed in RX140. After waking up from the low power consumption standby mode, the LED lights up according to the touch operation. Figure 1.1 shows software operation image.

- Multiple electrode connection function:

  This function can measure as one electrode by connecting multiple self-capacitance electrodes inside the MCU. Since multiple electrodes can be measured at one time, measurement time can be shortened, and power consumption can be reduced. An example of use is a system that waking up from the low power consumption mode by any button, and usability can be improved by changing the conventional system that waking up only with the power button to a system that waking up with multiple buttons.

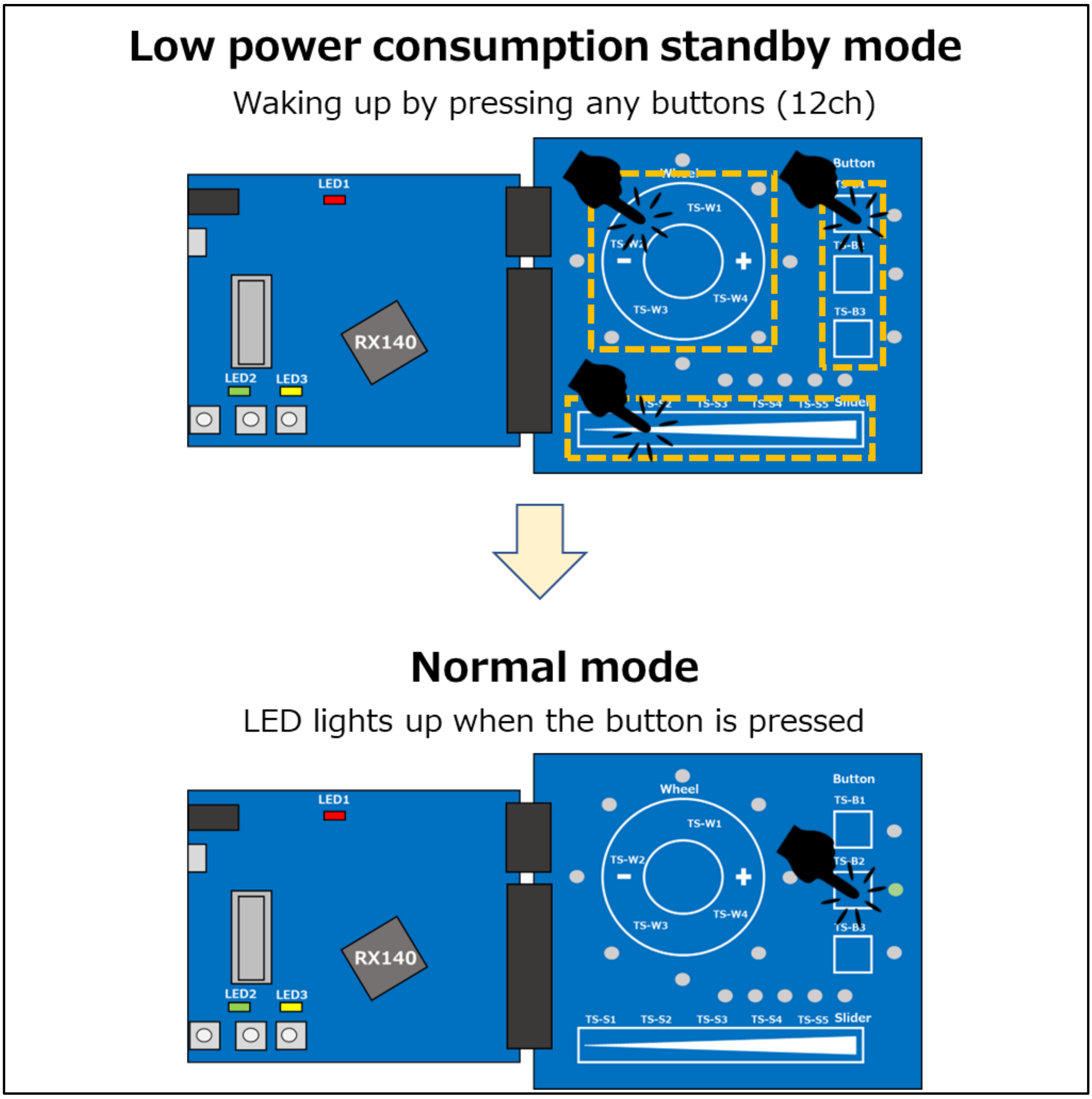

Figure 1.1 Software operation image

2. Operation Environment

Table 2.1 shows confirmed operation environment of this software.

Table 2.1 Operation confirmed environment

Item	Contents
Demo board	RX140 capacitive touch evaluation system (RTK0EG0039S01001BJ) • RX140 CPU board (RTK0EG0038C01001BJ) • Application board for capacitive touch evaluation (RTK0EG0019B01002BJ) - Self-Capacitance Buttons / Wheels / Slider Board
MCU	R5FA51406ADFN
Operating frequency	48MHz
Operating voltage	5V
Integrated development environment	e² Studio 2022-04
C compiler	CC-RX v3.04.00
OCD emulator	E2 emulator Lite
QE for Capacitive Touch	V3.10
CTSU QE API (r_ctsu_qe) [QE CTSU module Firmware Integration Technology]	V2.10
Touch QE API (rm_touch_qe) [QE TOUCH module Firmware Integration Technology]	V2.10

3. Software Functions

The software operates as follows.

1. Low power consumption standby using automatic judgment function and multi-electrode connection function
2. Normal operation after waking up (LED lights up according to the touch operation)

3.1 Low Power Consumption Standby

Use the CTSU2SL module, the DTC module, the LPC module, the LPT module and the ELC module.

- Use the LPC to transition MCU(R5FA51406ADFN) to low power consumption mode.
- Set the measurement start trigger to the external trigger of the LPT compare match interrupt (event input from ELC), and measure CTSU2SL at 100 msec intervals during software standby mode.
- DTC is used for CTSU measurement operation in snooze mode.
- By using the automatic judgment function of CTSU2SL, if the touch ON judgment is not detected as a result of CTSU measurement during snooze mode, the software standby is entered again without starting the CPU.
- By using the multiple electrode connection function of CTSU2SL, 12ch can be measured at once to reduce power consumption.
- By touching any of the 12ch electrodes, the mode transition from the low power consumption standby mode to the normal operation mode.

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

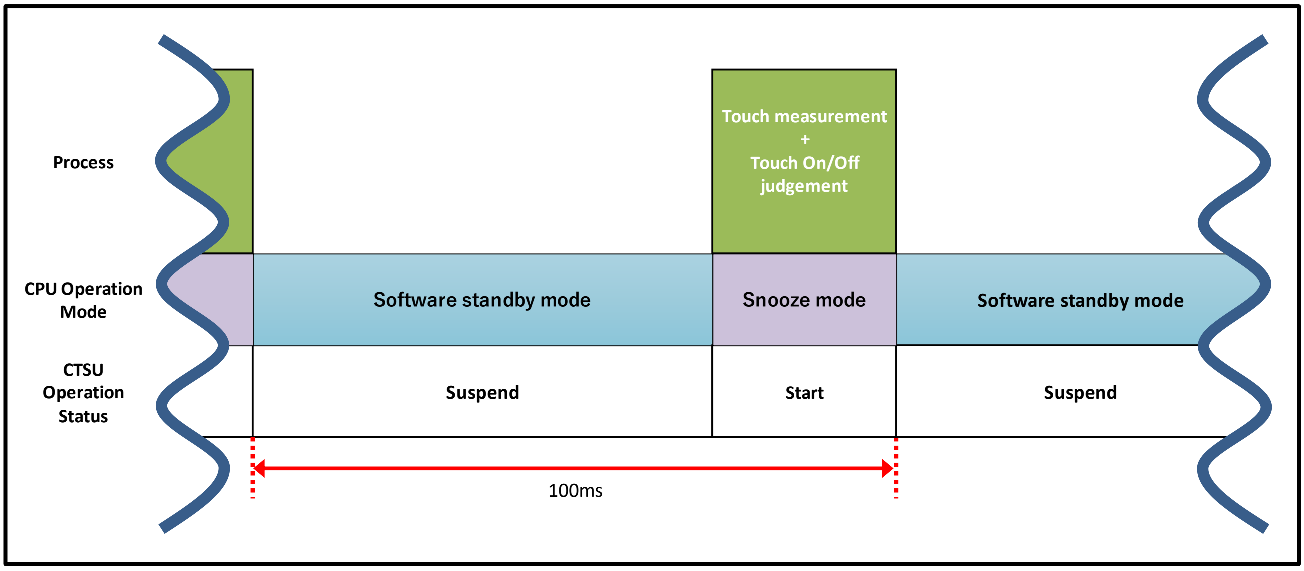

Figure 3.1 Image of CPU operating mode and CTSU operating status

3.2 Normal Operation After Waking up

The software uses the CTSU2SL module.

- The LED lights up according to the touch operation.
- If 15 seconds have passed in the non-touch state or if touch TS-B1 and TS-B3 on the board for 3 seconds or more at the same time, the normal operation mode will shift to the low power consumption standby mode

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.

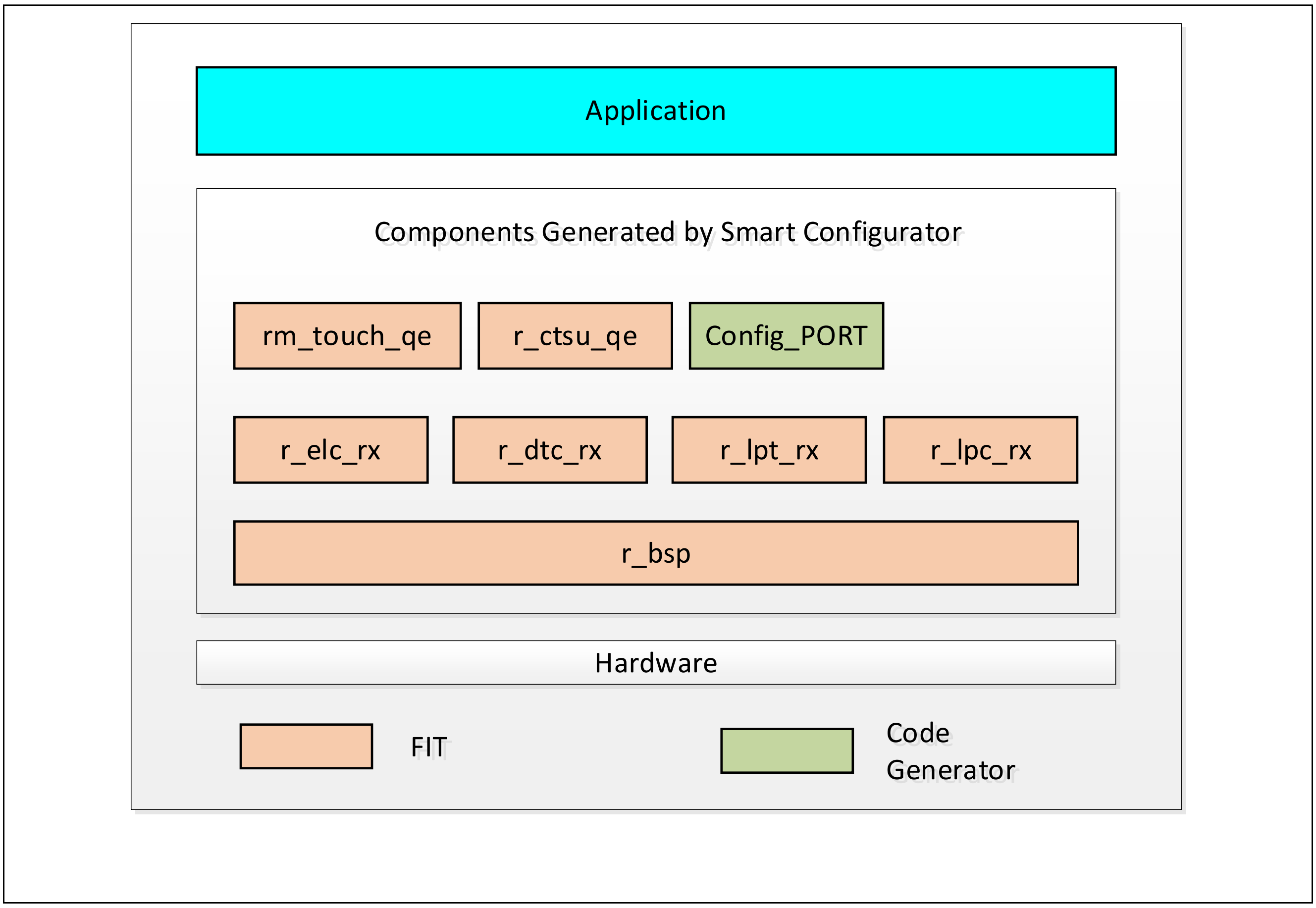

Figure 4.1 Software structure diagram

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

Table 4.1 Component

Component	Version
r_bsp	7.10
r_lpc_rx	2.03
r_ctsu_qe	2.10
r_dtc_rx	3.90
r_elc_rx	2.01
r_lpt_rx	3.01
rm_touch_qe	2.10
Config_PORT	2.3.0

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
├── src
│       r_board_control.c  ・・・・・・・・・Board control source file
│       r_board_control.h  ・・・・・・・・・Board control header file
│       smart_wakeup_rx140_rssk.c  ・・・・Main source file
│
├── QE-Touch
      smart_wakeup_rx140_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_rx140_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

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 low power mode (100msec)
WAKEUP_LPT_PERIOD_NORMAL	(20000)	LPT compare match value during normal operation 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 low power consumption mode
LED		
LED_IO_LEVEL_LOW	(0)	PORT level Low
LED_IO_LEVEL_HIGH	(1)	PORT level High
LED_ROW0	PORTJ.PODR.BIT.B7	PORTJ PODR register Bit7
LED_ROW1	PORTE.PODR.BIT.B5	PORTE PODR register Bit5
LED_ROW2	PORT4.PODR.BIT.B0	PORT4 PODR register Bit0
LED_ROW3	PORTJ.PODR.BIT.B6	PORTJ PODR register Bit6
LED_COL0	PORT4.PODR.BIT.B7	PORT4 PODR register Bit7
LED_COL1	PORT4.PODR.BIT.B6	PORT4 PODR register Bit6
LED_COL2	PORT4.PODR.BIT.B5	PORT4 PODR register Bit5
LED_COL3	PORT4.PODR.BIT.B4	PORT4 PODR register Bit4
CTSU		
WAKEUP_MODE_STANDBY	(1)	Low power consumption mode
WAKEUP_MODE_NORMAL	(0)	Normal operation 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 low power consumption 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.

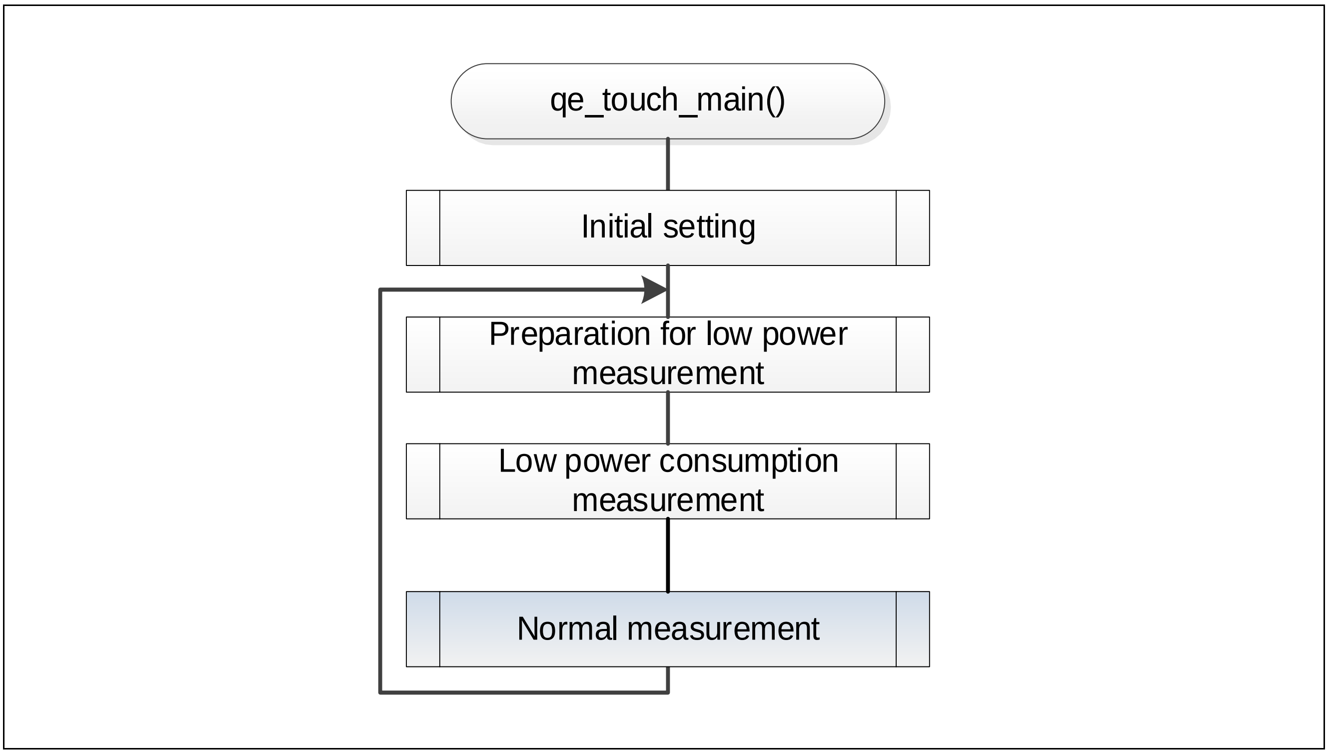

Figure 4.3 Overall processing flowchart

4.7 Initial Setting Processing

Figure 4.4 shows Initial setting processing flowchart.

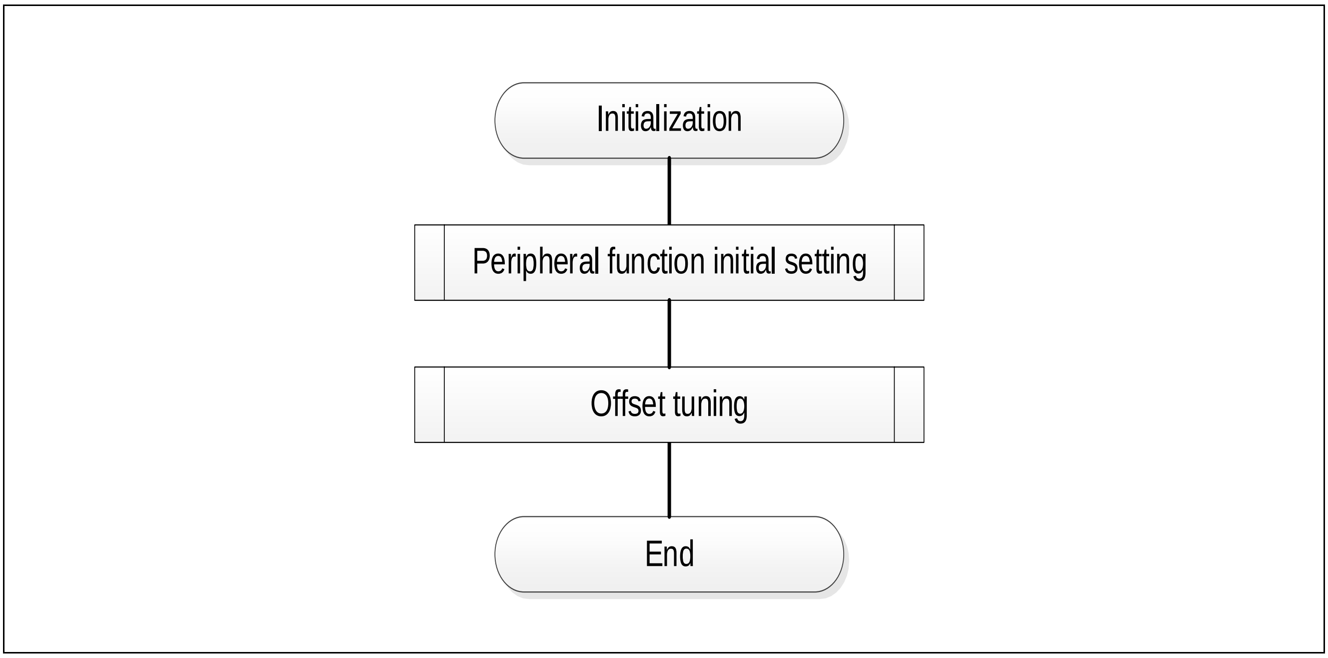

Figure 4.4 Initial setting processing flowchart

4.7.1 Peripheral Function Initial Setting

Figure 4.5 shows peripheral function initial setting flowchart.

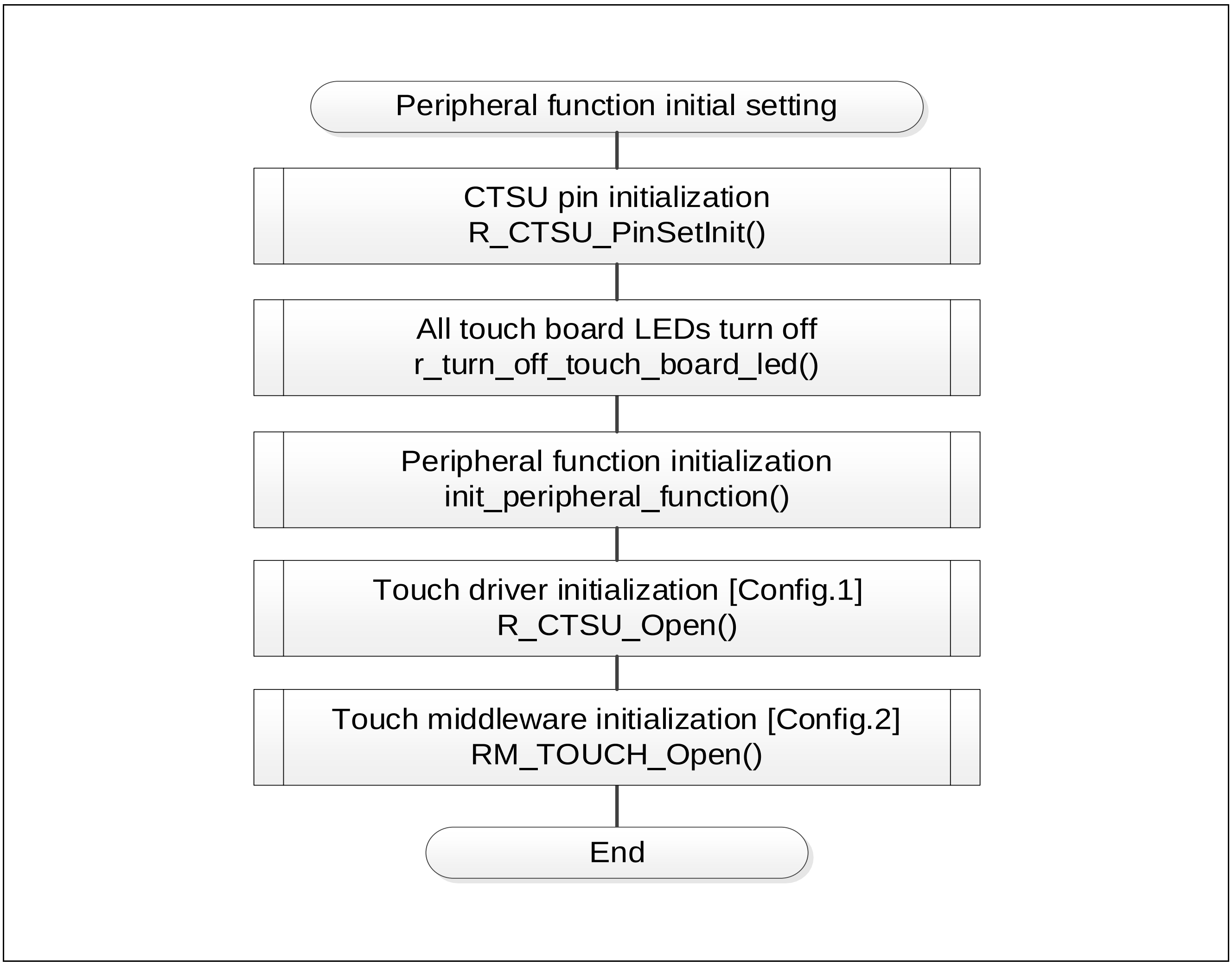

Figure 4.5 Peripheral function initial setting flowchart

4.7.2 Offset Tuning

Figure 4.6 shows offset tuning flowchart.

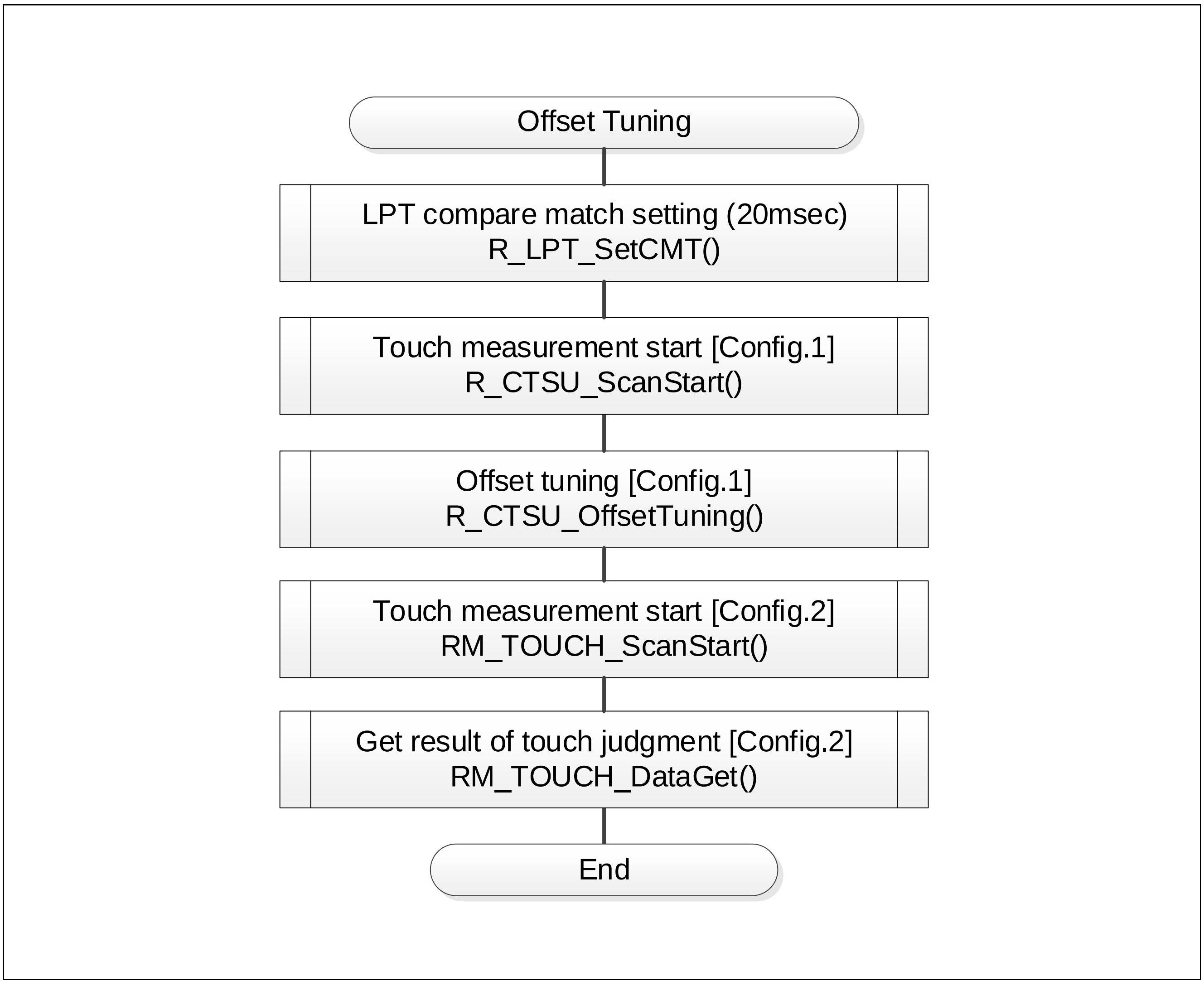

Figure 4.6 Offset tuning flowchart

4.8 Low Power Consumption Measurement Preparation Processing

Figure 4.7 shows low power consumption measurement preparation processing flowchart.

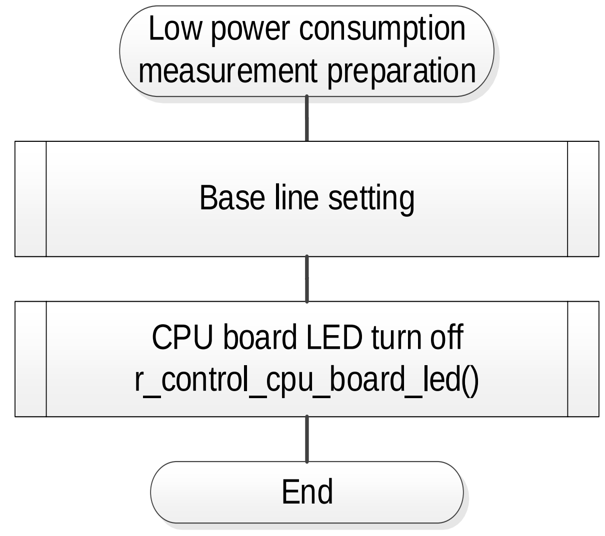

Figure 4.7 Low power consumption measurement preparation processing flowchart

4.8.1 Baseline Setting

Figure 4.8 shows baseline setting flowchart.

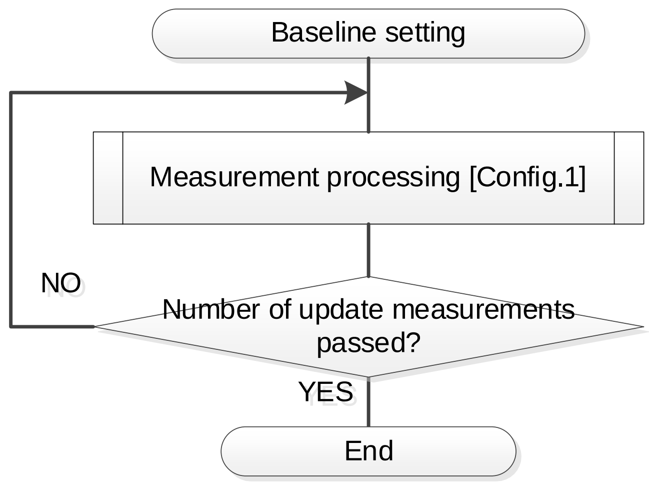

Figure 4.8 Baseline setting flowchart

4.8.1.1 Measurement processing [Config.1]

Figure 4.9 shows measurement processing [Config.1] flowchart.

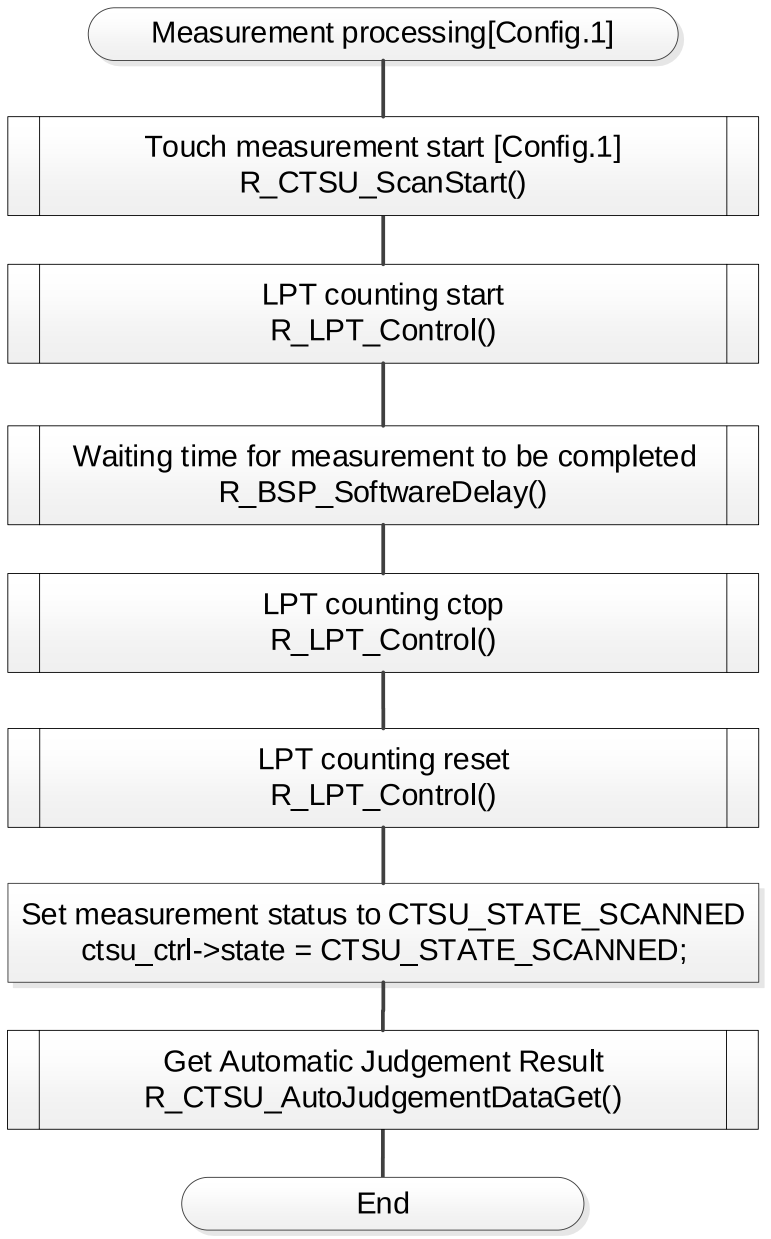

Figure 4.9 Measurement processing [Config. 1] flowchart

4.9 Low Power Consumption Measurement Processing

Figure 4.10 shows low power consumption measurement processing flowchart.

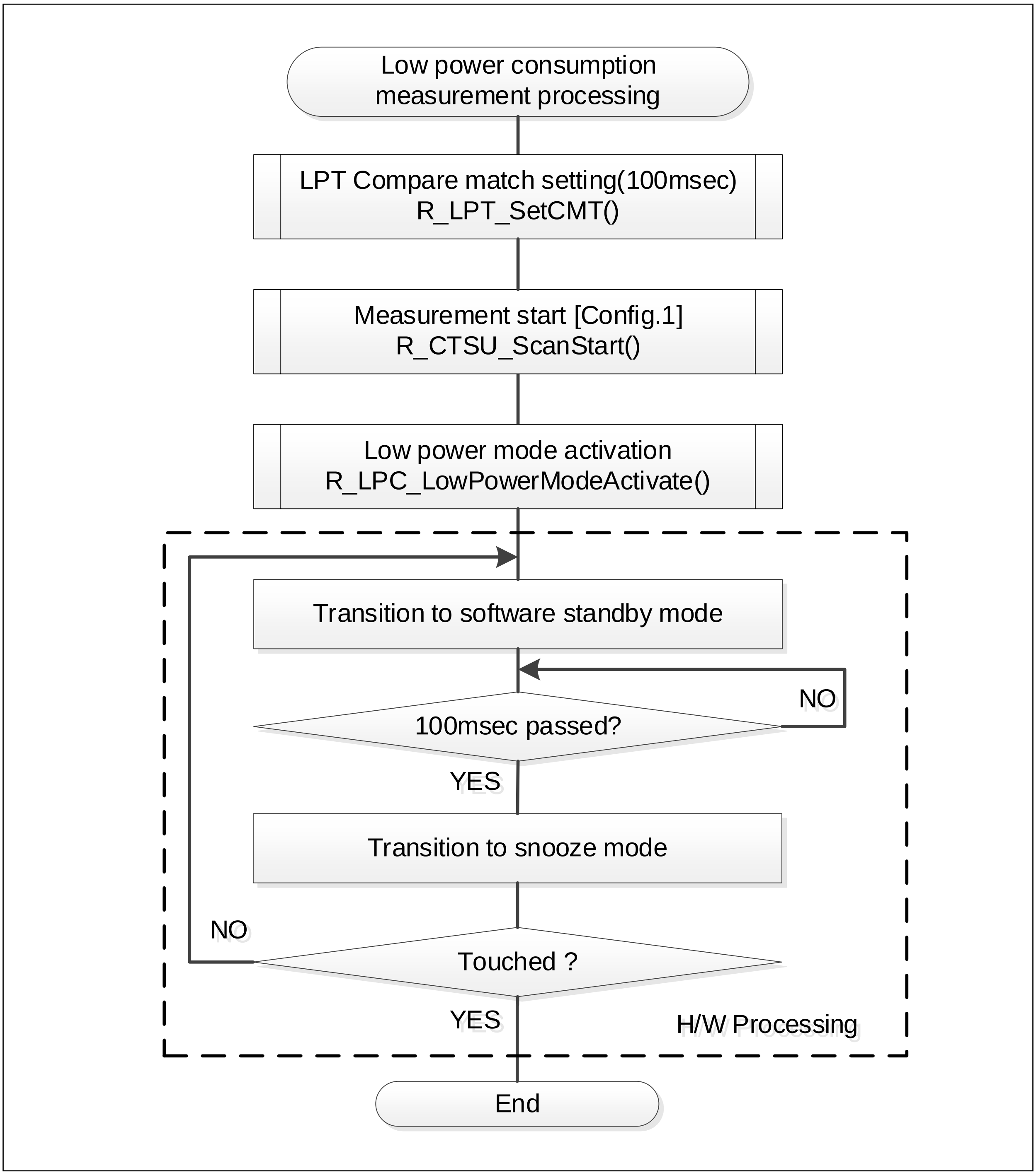

Figure 4.10 Low power consumption measurement processing flowchart

4.10 Normal Measurement Processing

Figure 4.11 shows normal measurement processing flowchart.

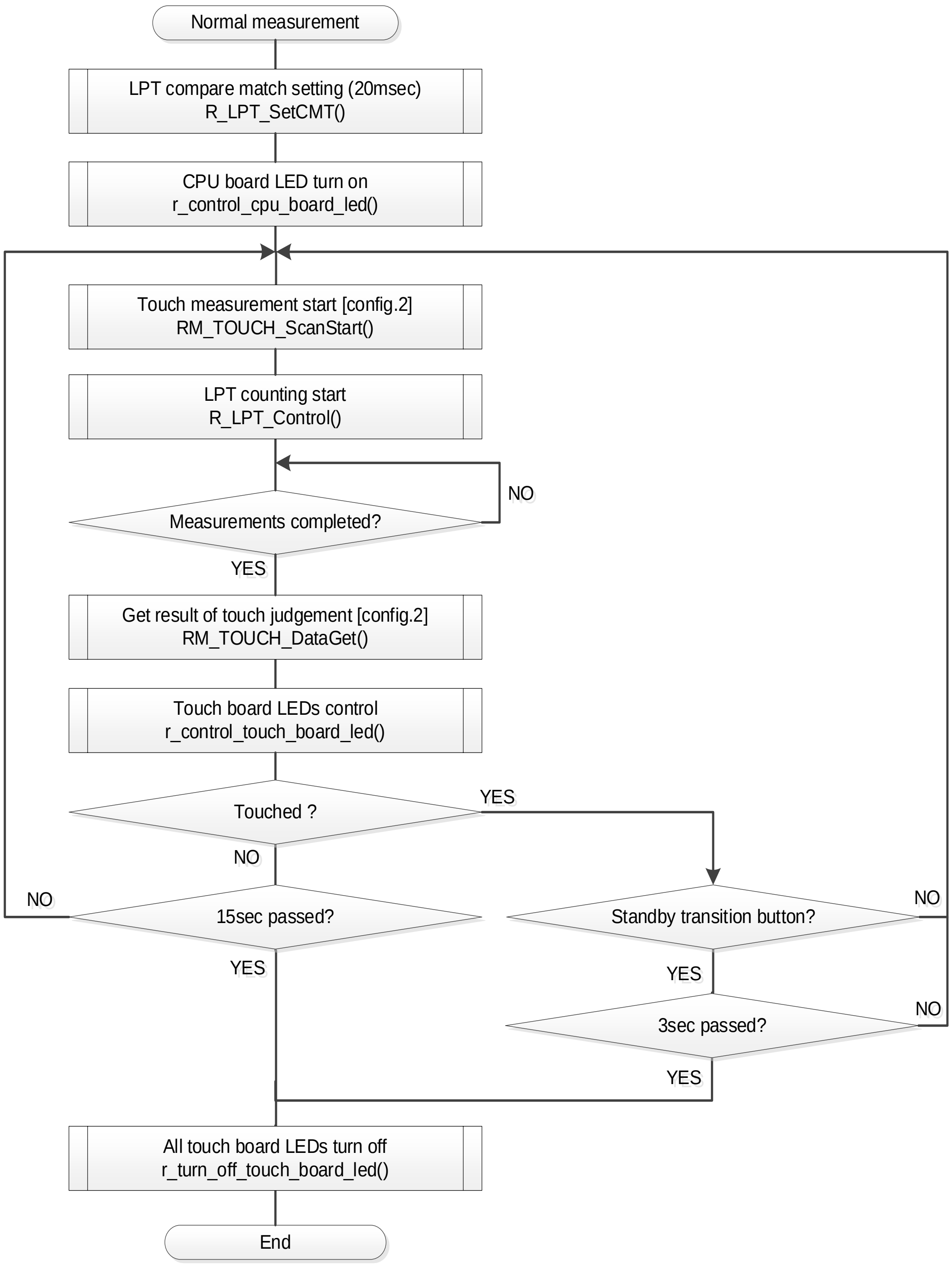

Figure 4.11 Normal measurement processing flowchart

5. Capacitive Touch Setting

The Capacitive touch setting of this software is shown.

5.1 Touch Interface Configuration

Figure 5.1 shows the touch interface configuration.

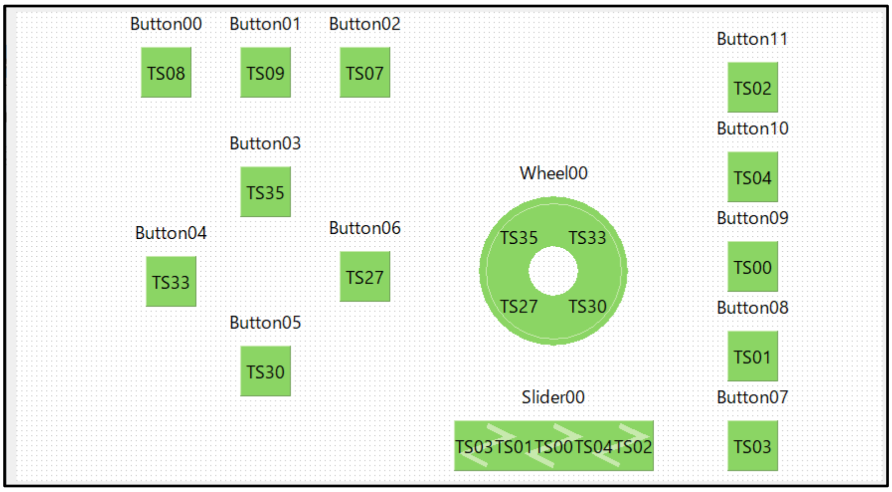

Figure 5.1 Touch interface configuration

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 three buttons, a slider, and a wheel.

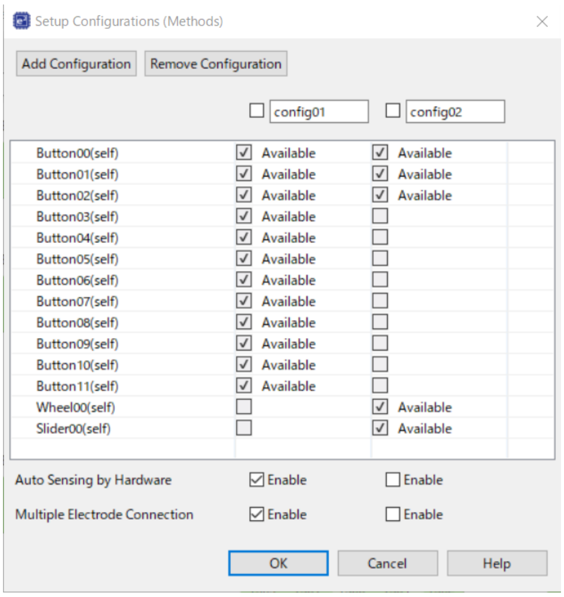

Figure 5.2 Touch interface settings

5.3 Tuning Result

Tabel 5.1 shows the tuning result of QE. This software operates with the settings shown in Table 5.1.

Table 5.2 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	169.444	0.5	252	0.128	0x2AA	0x03	0x1F
config02	Button00	TS08	18.181	2	1000	0.128	0x0F6	0x07	0x07
config02	Button01	TS09	16.763	2	1000	0.128	0x0D8	0x07	0x07
config02	Button02	TS07	16.576	2	1000	0.128	0x0D7	0x07	0x07
config02	Wheel00	TS33	23.063	1	689	0.128	0x06B	0x07	0x0F
config02	Wheel00	TS35	24.556	1	689	0.128	0x079	0x07	0x0F
config02	Wheel00	TS27	21.333	1	689	0.128	0x059	0x07	0x0F
config02	Wheel00	TS30	20.125	1	689	0.128	0x04D	0x07	0x0F
config02	Slider00	TS03	15.152	2	879	0.128	0x0B8	0x07	0x0F
config02	Slider00	TS01	16.125	2	879	0.128	0x0CC	0x07	0x0F
config02	Slider00	TS00	17.778	2	879	0.128	0x0E4	0x07	0x0F
config02	Slider00	TS04	18.056	2	879	0.128	0x0F6	0x07	0x0F
config02	Slider00	TS02	19.333	2	879	0.128	0x10C	0x07	0x0F

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: The value of the yellow marker part was changed manually.

*3: Manually changed a part of the setting of "g_qe_ctsu_cfg_config01" in "qe_touch_config.c".

tlot = 2 → 1 / thot = 2 → 1 / ajbmat = 7 → 4

6. Power Consumption Measurement

6.1 Operating Conditions of Low Power Consumption Standby

Table 6.1 shows the operation condition of low power consumption standby.

Table 66.1 Operating conditions of low power consumption standby

Item	Description
Operating frequency	24MHz High-speed on-chip oscillator（HOCO） 32KHz Low-speed on-chip oscillator（LOCO）
System clock (ICLK)	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 = 0)
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 RX140 CPU board
Software	KEITHLEY/KickStart Software	Get result of current consumption measurement from Keithley DM7510 and output the result to log-file.

6.3 RX140 CPU Board

Figure 66.1 the front side of RX140 CPU board.

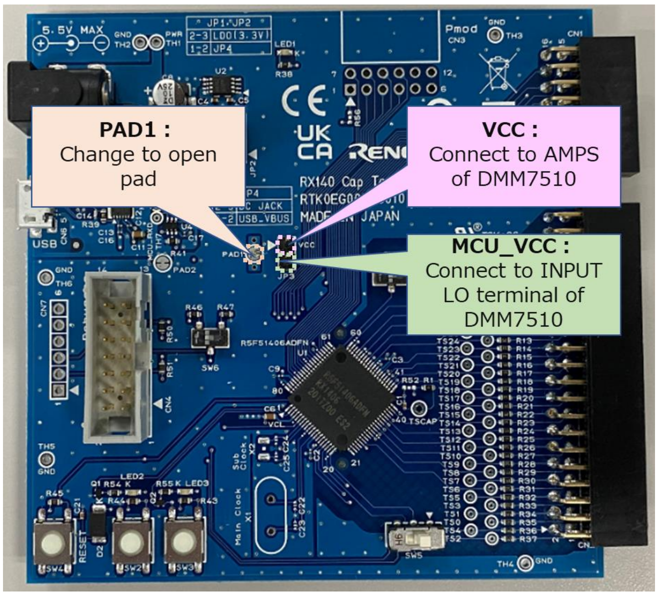

Figure 66.1 RX140 CPU board (front side)

Cut the bridge pattern between the pads for the default short PAD1. Figure 6.2 shows the shape of the jumper pad.

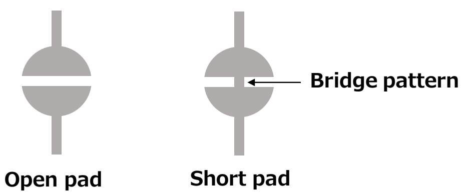

Figure 6.2 Jumper pad shape

6.4 RX140 CPU Board Jumper Setting

Table 6.3 shows the jumper settings of RX140 CPU board to measure current consumption.

Table 6.3 Jumper settings of RX140 Cap Touch CPU board to measure current consumption

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

6.5 Environment to Measure Current Consumption

Figure 6.3 shows environment to measure current consumption.

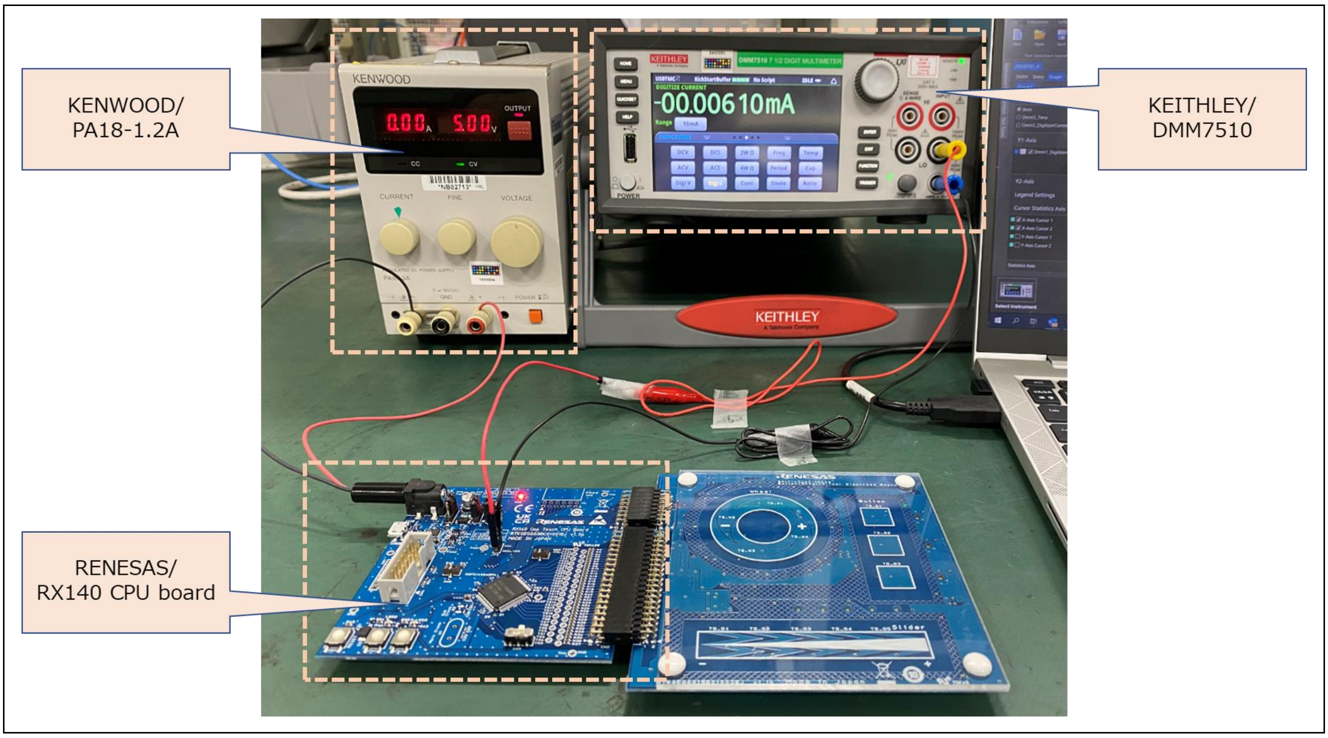

Figure 6.3 Environment to measure current consumption

6.6 Setting to Measure Current Consumption

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

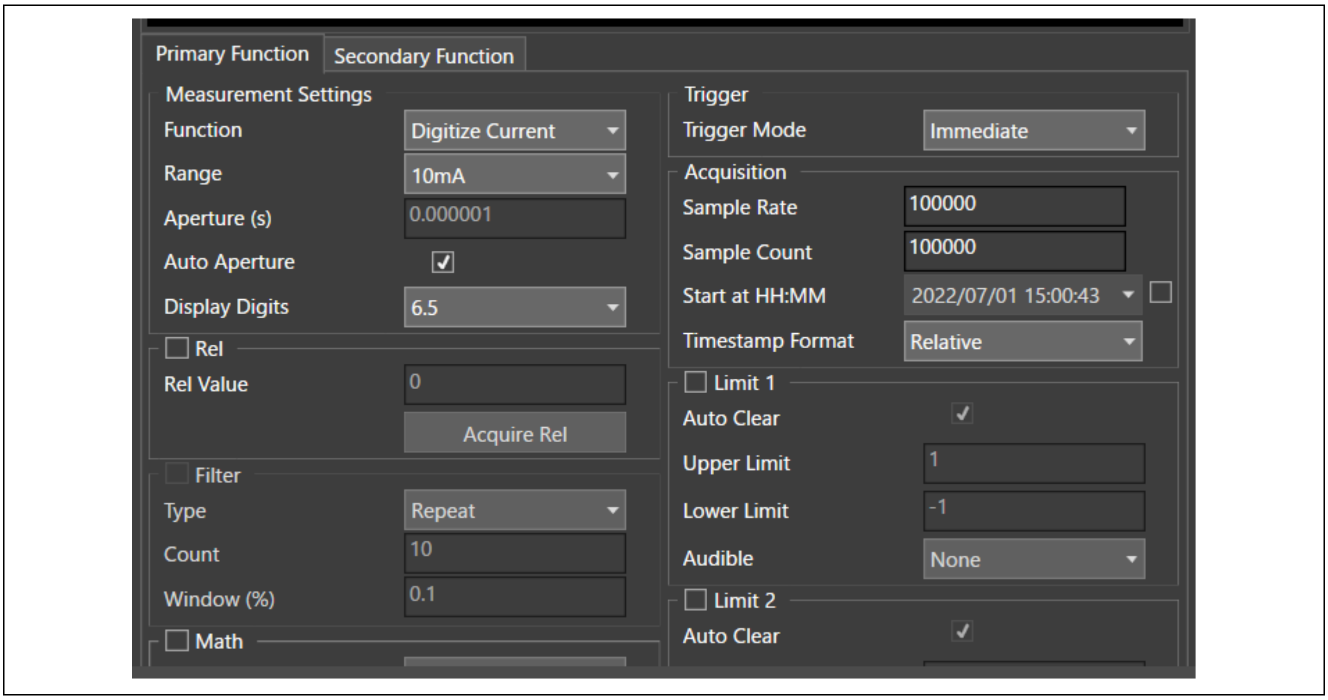

Figure 6.4 Settings of Keithley KickStart to measure current consumption

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).

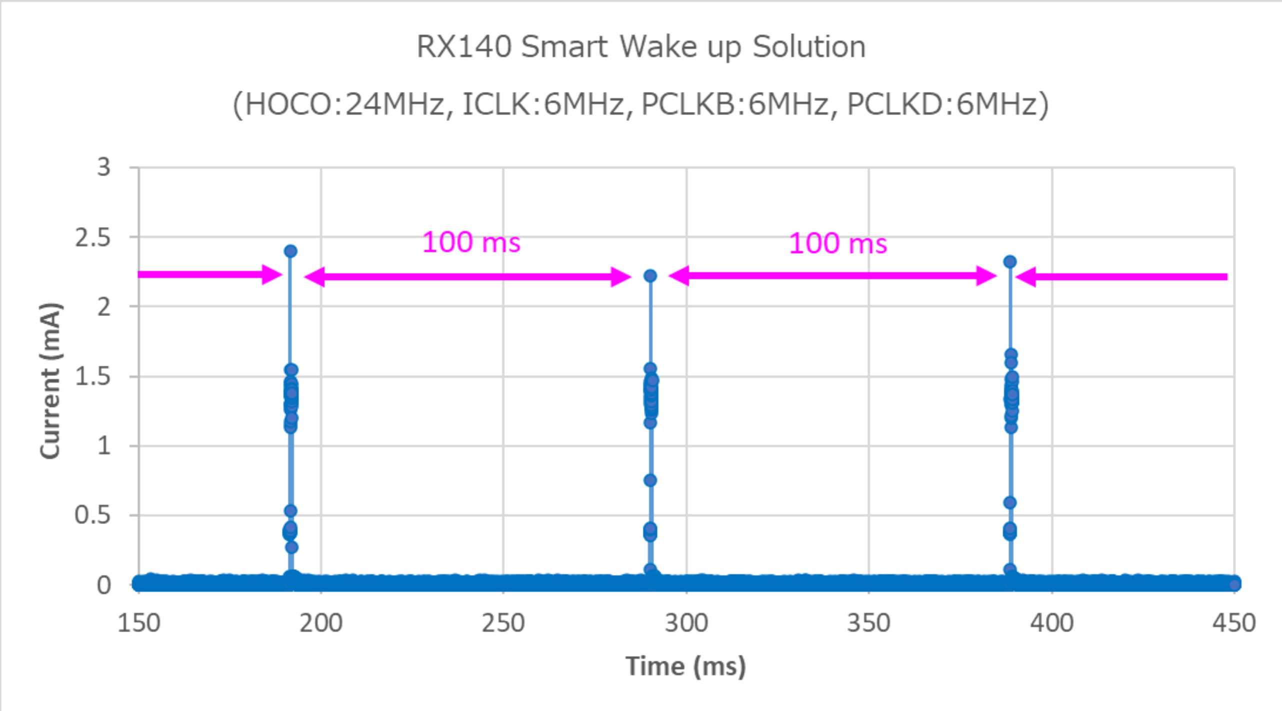

Figure 6.5 Current consumption waveform during low power consumption standby (1/2)

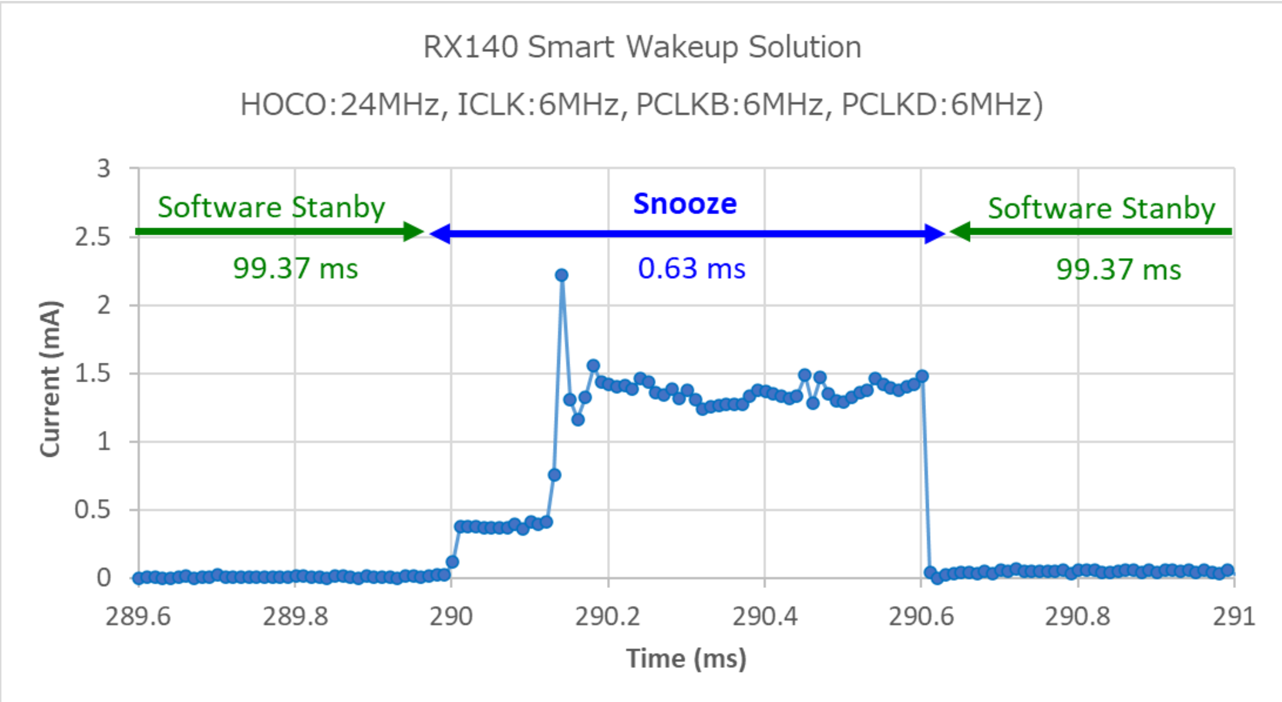

Figure 6.6 Current consumption waveform during low power consumption standby (2/2)

6.8 Current Consumption Calculation Results

Figure 6.7 shows the average current of 100ms cycle in low power consumption standby.

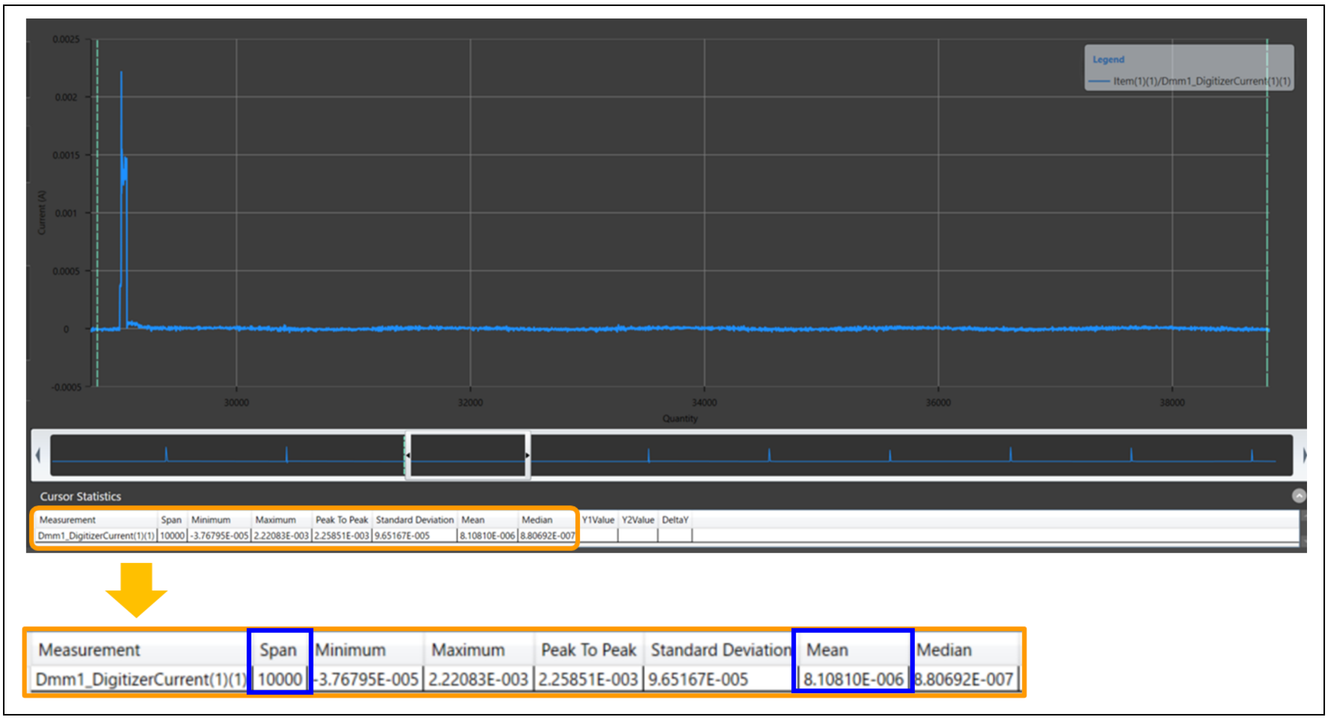

Figure 6.7 Average current of 100ms cycle in low power consumption standby

Current consumption (touch measurement cycle of 100ms) = **8.10810 μA**

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jul.29.22	-	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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