RL78/L23 Group

Low power consumption Smart Wakeup Solution

Introduction

This application note explains the software that touch measurement processing with low power consumption on the RL78/L23 Capacitive Touch Evaluation System.

Target Device

RL78/L23 (R7F100LPL3CFB)

Related Documents

1. RL78/L23 Group Capacitive Touch Evaluation System User's Manual (R12UZ0175)
2. RL78 family CTSU module Software Integration System (R11AN0484)
3. RL78 family TOUCH module Software Integration System (R11AN0485)

Contents

1. Outline

This application note describes the SMS(SNOOZE Mode Sequencer) function and the MEC(Multiple Electrode Connection) function of CTSU2La in RL78/L23 for providing 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 transitions to active mode. When Touch OFF state continues in active mode, the mode transitions to standby. The system 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 the confirmed operation environment of this software.

Table 2.1 Confirmed operation environment

Item	Contents
MCU board (parts common with e2 studio projects)	RL78/L23 capacitive touch evaluation system (RTK0EG0063S01001BJ) • RL78/L23 CPU board (RTK0EG0062C01001BJ) • Application board for capacitive touch evaluation − Self-Capacitance Buttons / Wheel / Slider Board (RTK0EG0019B01002BJ v1.1b)
MCU	R7F100LPL (RL78/L23 MCU Group)
Operating frequency	12MHz
Operating voltage	3.3V
Integrated development environment	e^2 Studio 2025-07
C compiler	Renesas CC-RL V1.15.00
OCD emulator	E2 emulator Lite
QE for Capacitive Touch	V4.2.0

3. Software Functions

The smart wakeup solution is designed to optimize the return from low-power status to active mode. This design uses input to touch sensors as triggers to transition to the active operating status. It minimizes standby power consumption while providing quick response when needed.

Figure 3.1 shows the software operation image.

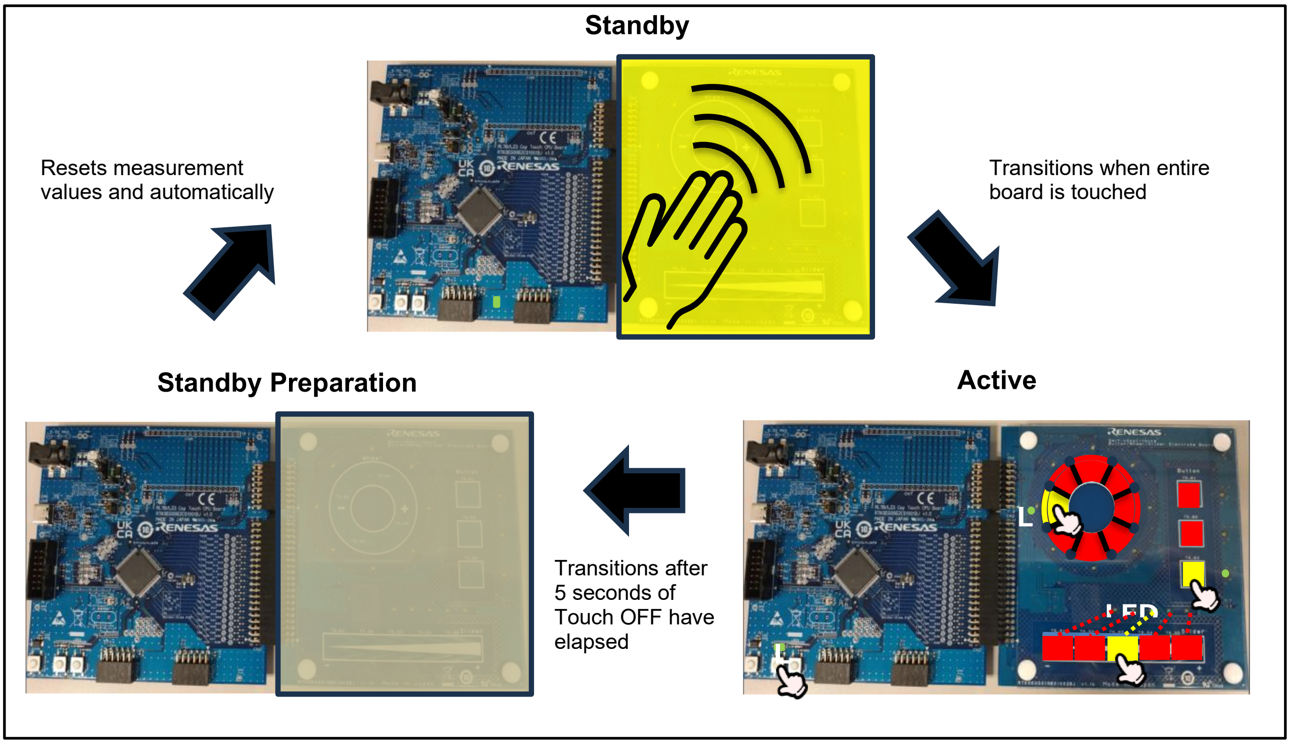

Figure 3.1 Software operation image

Refer to the following sections for details regarding each state:

- 5.7 Standby preparation
- 5.8 Standby
- 5.9 Active

4. Capacitive Touch Settings

The software's touch interface configuration, configuration (method) settings, and tuning results using the QE tuning function are provided in this section.

4.1 Touch Interface Configuration

Figure 4.1 shows the touch interface configuration.

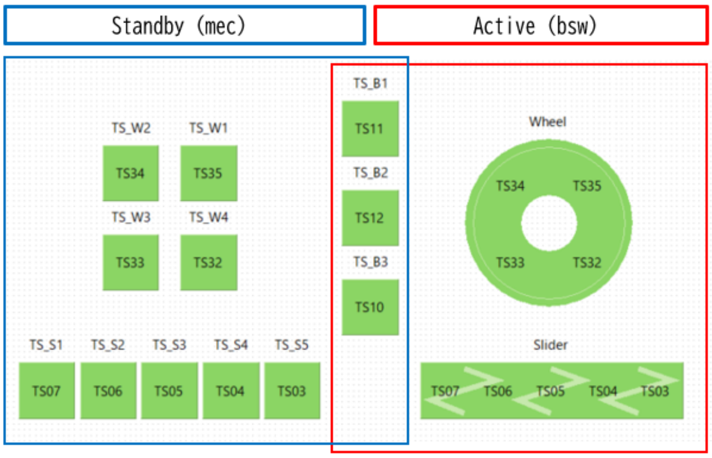

Figure 4.1 Touch interface configuration

4.2 Configuration (method) Settings

Figure 4.2 shows the touch interface settings. Each setting is described in detail below.

mec setting: This sets all buttons and is used during standby mode measurement (see Figure 3.1). This enables the SMS function for measurements in standby mode, and the multi-electrode connection function for measurements in low-power mode.

bsw setting: This sets three buttons, a slider and a wheel, and is used during active mode measurement (see Figure 3.1). After SMS touch judgment, it sets the touch interface configuration assuming use of slider and wheel.

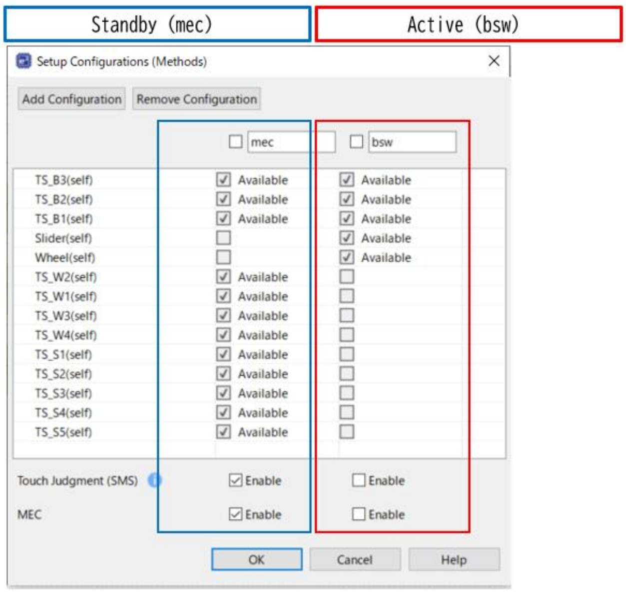

Figure 4.2 Configuration (method) settings

5. Software Specification

5.1 Software Structure

The following modules are added to create an application by using QE for Capacitive Touch and Smart Configurator. The software structure diagram is shown below.

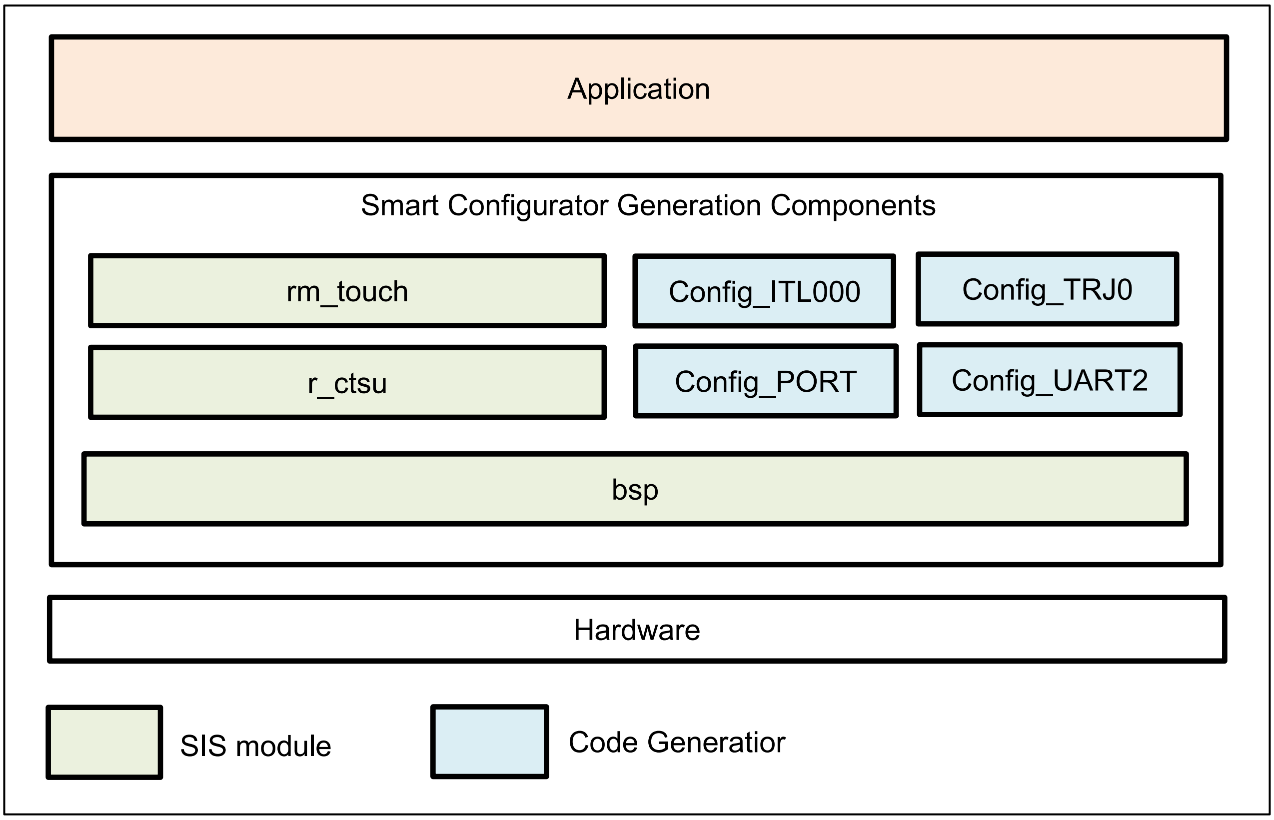

Figure 5.1 Software structure diagram

Table 5.1 shows the list of components. Refer to the Smart Configurator for component settings.

Table 5.1 Component list

Component	Version	Configuration
bsp	1.91	r_bsp
r_ctsu	2.20	r_ctsu
rm_touch	2.20	rm_touch
UART	1.10.0	Config_UART2
Interval Timer	1.8.0	Config_TRJ0, Config_ITL000
PORT	1.8.0	Config_PORT

5.2 File Structure

Figure 5.2 shows the source file tree. Note that Smart Configurator files have been omitted for brevity.

```
├── 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
│     smart_wakeup_rl78l23_rssk.c ・main file
│     r_board_control.c  ・・・・・・Board control source file
│     r_board_control.h  ・・・・・・Board control header file
│     r_rssk_touch_led.c・・・・・・Touch electrode LED processing source
│     r_rssk_touch_led.h・・・・・・Touch electrode LED processing header
├── QE-Touch
      smart_wakeup_rl78l23_rssk.tifcfg・・・Touch I/F structure file
      smart_wakeup_ rl78l23_rssk_log_tuning 20250821144515.log・・・QE tuning log
```

Figure 5.2 Source file tree

Table 5.2 shows the list of source files.

Table 5.2 Source files

File name	Contents
smart_wakeup_rl78l23_rssk.c	Main source file
r_board_control.c	Board control source file
qe_touch_config.c	Touch QE configuration definition source file
qe_touch_sample.c	Touch QE application file

Table 5.3 shows the list of header files.

Table 5.3 Header files

File name	Contents
qe_touch_config.h	Touch QE configuration definition header file
qe_touch_define.h	Touch QE configuration definition header file
r_board_control.h	Board control header file
r_rssk_touch_led.h	Touch electrode LED processing header

5.3 List of Constants

Table 5.4 shows the list of constants.

Table 5.4 List of constants

Constant name	Setting value	Description
File name: qe_touch_sample.c		
ITL_COUNT_20MS	(0x28)	Active Interval Timer Count (20msec)
ITL_COUNT_100MS	(0xCC)	Standby Interval Timer Count (100msec)
IDLE_TIME_CNT	(100)	Touch OFF detection count (30ms * 100 = 3sec)
File name: r_rssk_touch_led.c		
LED_COL_MAX	(4)	Number of COL signals
LED_ROW_MAX	(4)	Number of ROW signals
LED_COL0	(P14_bit.no0)	COL0 control port definition
LED_COL1	(P8_bit.no4)	COL1 control port definition
LED_COL2	(P8_bit.no3)	COL2 control port definition
LED_COL3	(P8_bit.no2)	COL3 control port definition
LED_ROW0	(P2_bit.no1)	ROW0 control port definition
LED_ROW1	(P2_bit.no0)	ROW1 control port definition
LED_ROW2	(P8_bit.no1)	ROW2 control port definition
LED_ROW3	(P8_bit.no0)	ROW3 control port definition
LED_COL_OFF	(0U)	COL signal OFF
LED_COL_ON	(1U)	COL signal ON
LED_ROW_OFF	(1U)	ROW signal OFF
LED_ROW_ON	(0U)	ROW signal ON
BUTTON_LED_B3	(0x04)	Button 3 Control
BUTTON_LED_B2	(0x02)	Button 2 Control
BUTTON_LED_B1	(0x01)	Button 1 Control
SLIDER_LED_NUM	(5U)	Number of slider LEDs
SLIDER_RESOLUTION	(100)	Slider touch result: maximum value
SLIDER_LED_RESOLUTION	(SLIDER_RESOLUTION / SLIDER_LED_NUM)	Slider Control
WHEEL_LED_NUM	(8U)	Number of wheel LEDs
WHEEL_LED_MSB	(1U << (WHEEL_LED_NUM - 1))	Wheel control bit MSB
WHEEL_RESOLUTION_DEGR EE	(360)	Wheel touch result: maximum value (in degrees)
WHEEL_POSITION_DEGREE	(112)	Wheel touch position: offset (in degrees)
WHEEL_LED_RESOLUTION	(WHEEL_RESOLUTION_DEGREE / WHEEL_LED_NUM)	Wheel Control
File name: r_board_control.c		
RSSK_LED1_PORT	(P6_bit.no4)	CPU LED2 control port definition
RSSK_LED2_PORT	(P6_bit.no5)	CPU LED2 control port definition
RSSK_LED_ON	(0U)	LED signal ON
RSSK_LED_OFF	(1U)	LED signal OFF

5.4 List of Functions

Table 5.5 shows the list of functions.

Table 5.5 List of functions

Function name	Processing outline
File name: qe_touch_sample.c	
qe_touch_main	Main function
touch_initial_offset_tuning	Offset tuning
touch_prepare_standby_mode	Standby prepare mode
touch_standby_mode	Standby mode
touch_active_mode	Active mode
qe_sms_init	SMS initialize
qe_sms_trigger_start	SMS timer start
qe_sms_trigger_stop	SMS timer stop
r_rssk_initialize	Peripheral functions initialize
led_timer_callback	LED control Callback
set_timer_count	Interval timer set
File name: r_rssk_touch_led.c	
r_rssk_touch_led_control	Touch board LED control
create_led_bit_button	Button data create
create_led_bit_wheel	Wheel data create
create_led_bit_slider	Slider data create
r_rssk_touch_led_off	LED OFF
File name: r_board_control.c	
r_control_cpu_board_led	Touch board LED control processing

5.5 Overall Processing

Figure 5.3 provides the overall processing flowchart.

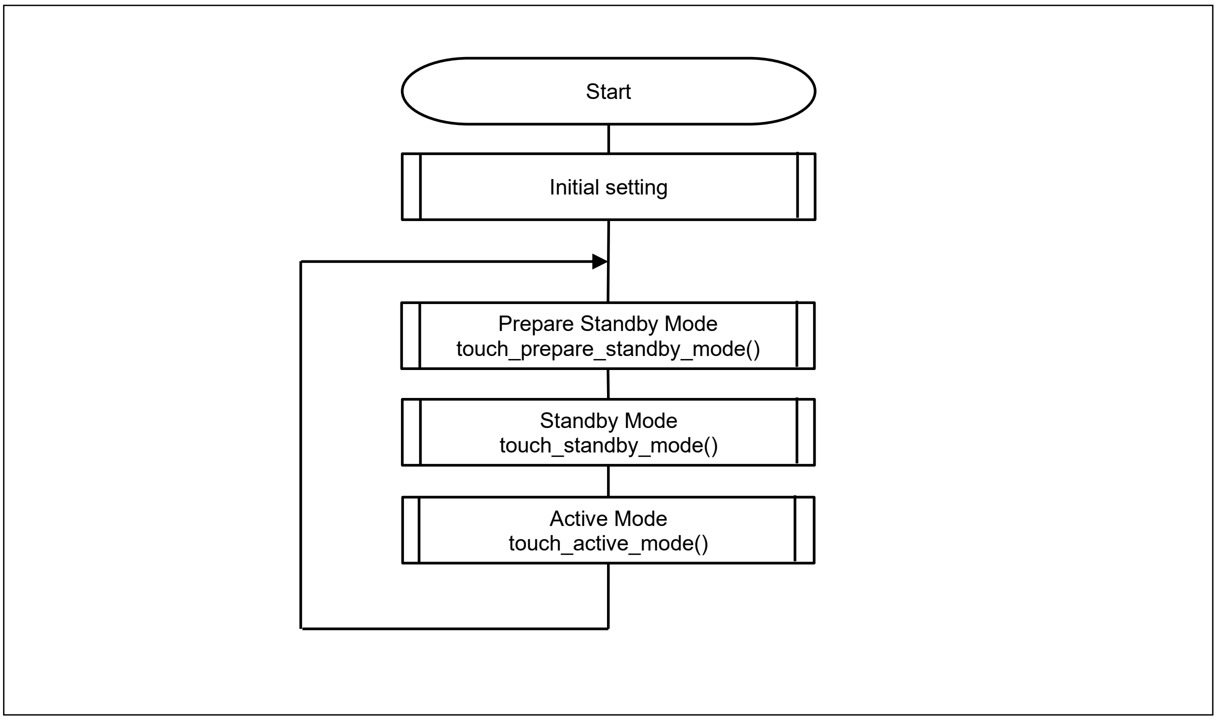

Figure 5.3 Overall processing flowchart

LEDs are controlled with interrupt functions. For details, see 5.9 Active.

The following shows the transitioning flow from standby mode to active mode, and then back to standby mode. This flow is explained based on the operation explanation in Figure 3.1, focusing on the states of the two configurations (mec and bsw).

State	Prepare Standby Mode	Standby Mode	Touch board	Active Mode	Touch OFF Timeout	Prepare Standby Mode	Standby Mode
mec	Measurement baseline	Measurement Wait Touch	Measurement Touch ON	STOP	STOP	Measurement Baseline	Measurement Wait Touch
bsw	STOP	STOP	STOP	Mesurement	Measurement timeout (5 seconds)	STOP	STOP

Figure 5.4 State transition image

Refer to the following sections for details regarding each state:

・5.7 Standby preparation
・5.8 Standby
・5.9 Active

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 function properly in a touch interface configuration that is not in operation. As a result, the touch threshold may be exceeded without touch, leading to incorrect or failed touch judgment. In such cases, a system reset will be required, so caution should be taken when using the device in environments that experience significant changes.

5.6 Initial Setting Processing

Figure 5.5 shows the initial setting processing flowchart.

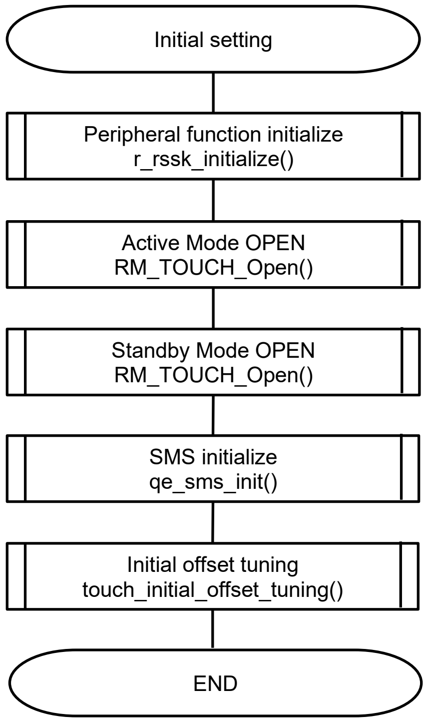

Figure 5.5 Initial setting processing flowchart

5.7 Standby preparation

This state prevents false touch judgment when transitioning from active mode to standby mode.

If all measurements are Touch OFF, the system transitions to standby mode. For details regarding standby mode, refer to section 5.8.

The following chart shows the standby preparation process flow.

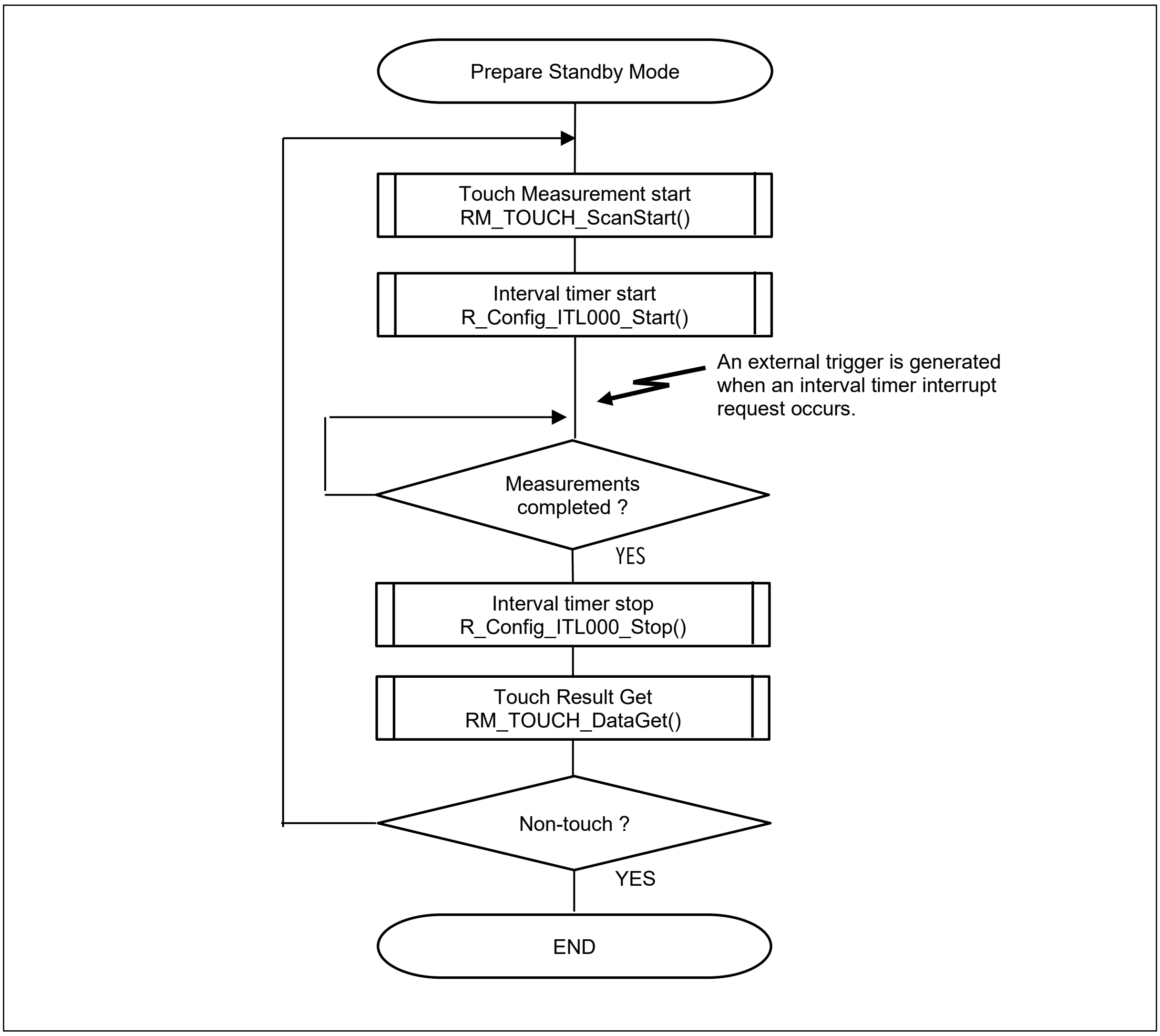

Figure 5.6 Standby preparation flowchart

5.7.1 Role of baseline setting

In this application, the baseline is set in the standby preparation processing is performed.

This transition can be expressed in measured values as follows.

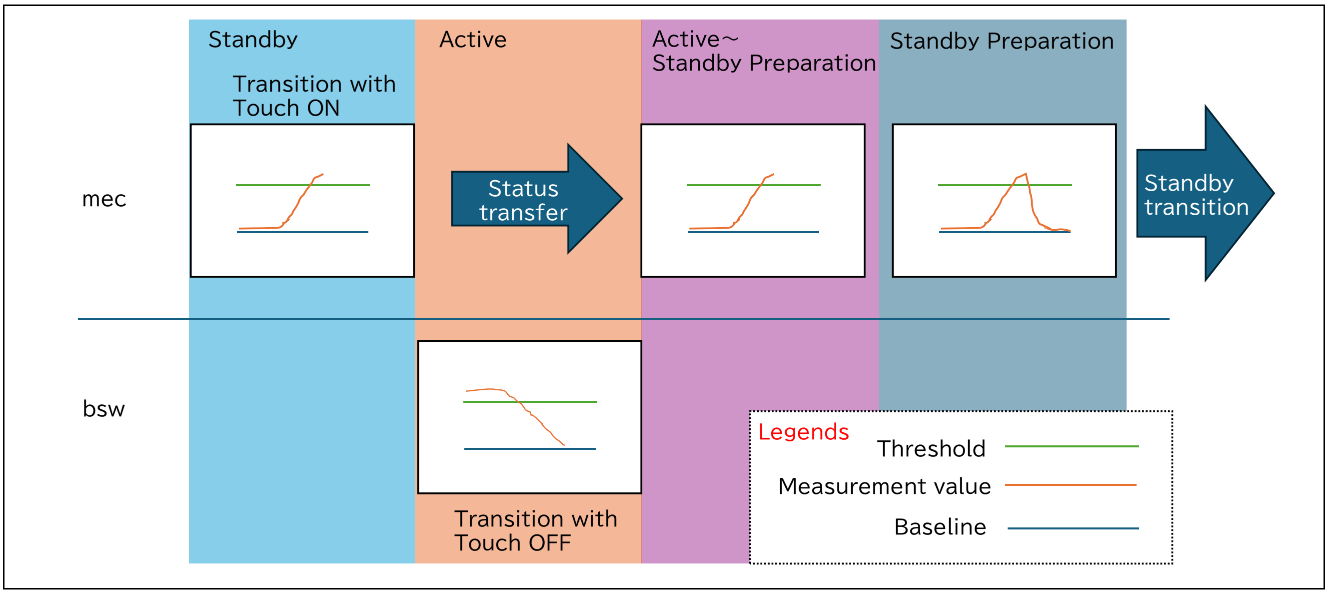

Figure 5.7 Measurement value transition image

This setting has the following role:

・Idle running process to prevent touch judgment malfunction

In this process, the measurement is repeated until the touch judgment of the MEC is turned off.

Based on the driver specifications, baseline updates must be performed in the active state before transitioning to the first standby. This process also serves as a baseline update.

5.8 Standby

The CPU is set to a low-power mode and touch measurement is performed using the SMS function and the MEC function. By using the MEC function, 12 channels can be measured at one time to reduce power consumption.

The following shows an image of CPU operating mode and CTSU operating status

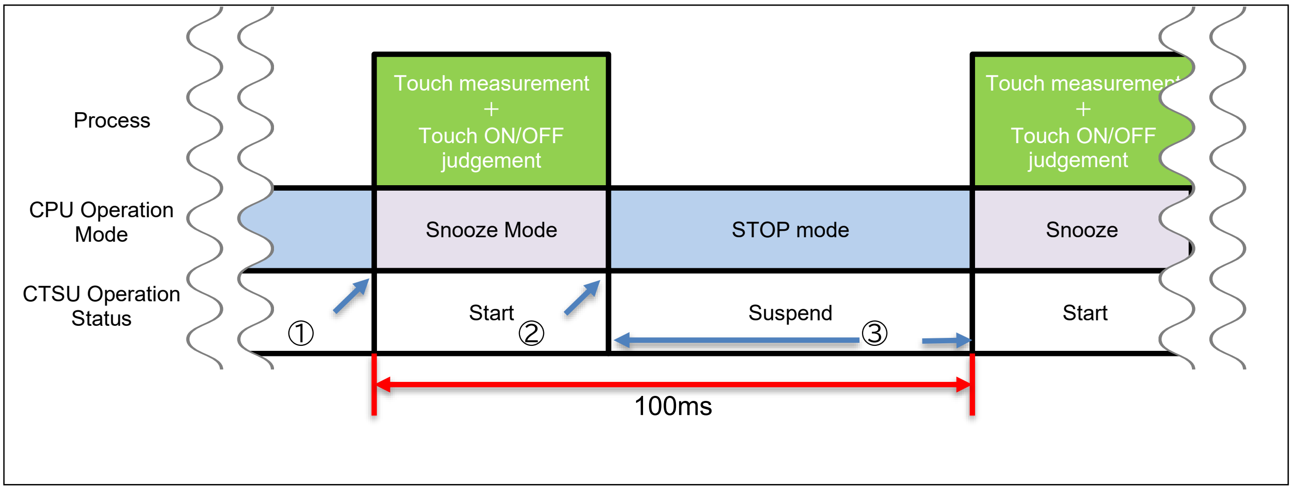

Figure 5.8 Image of CPU operating mode and CTSU operating status

The above figure shows the flow in which the interval timer interrupt is set as an snooze request, and the CTSU starts the measurement after receiving the snooze entry. The numbers indicated within the figure are described below.

① CPU transitions to snooze mode upon detecting an external trigger.

② CTSU measurement in snooze mode is judged based on touch detected using DTC. If the touch-on decision is not detected, the system transitions to STOP mode again. When the touch-on judgment is detected, the system transitions from STOP mode to active mode.

③ CPU transitions to STOP mode. CTSU will be suspended.

The following figure shows the standby flowchart.

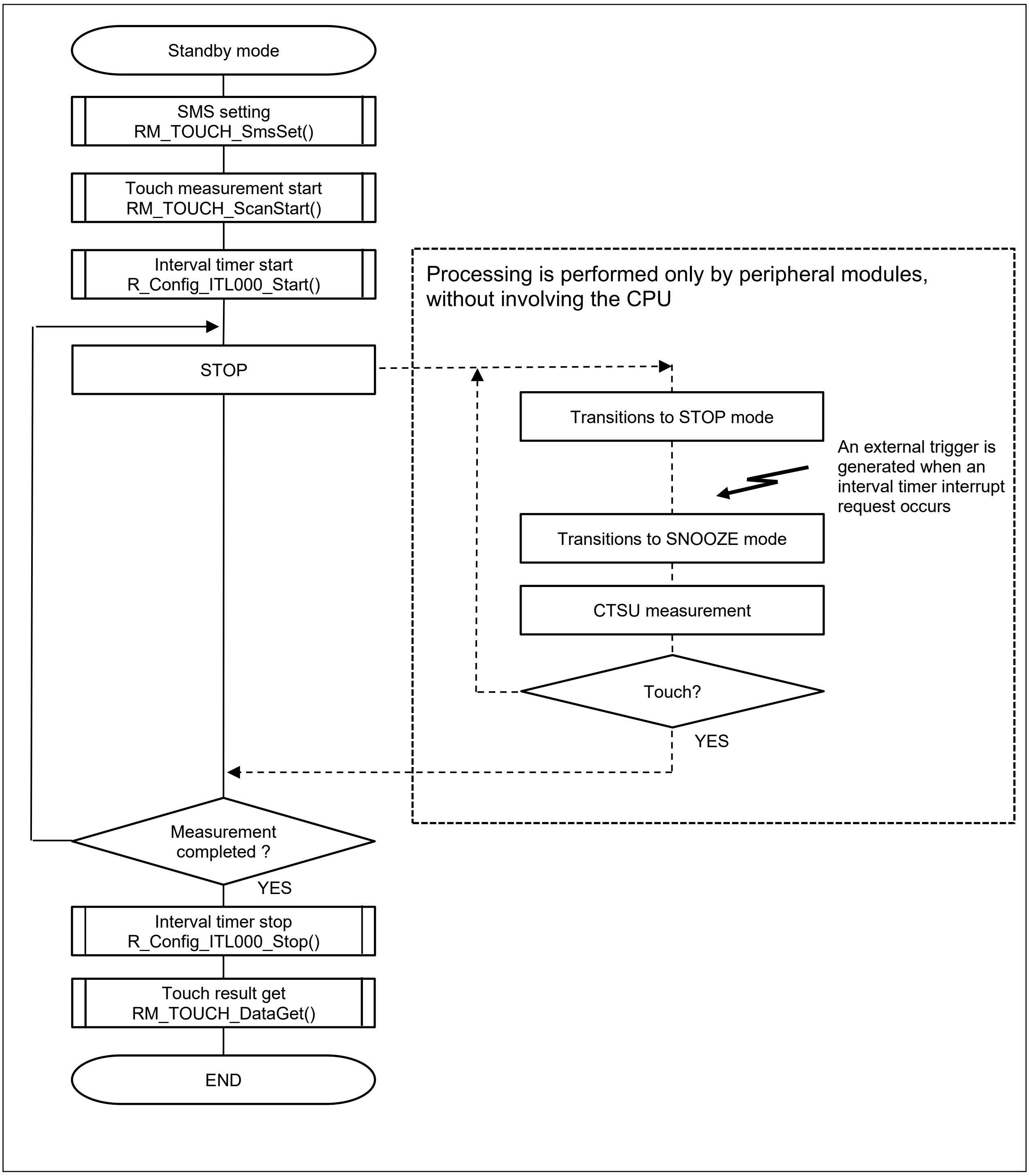

Figure 5.9 Standby flowchart

5.8.1 Transition to STOP mode

STOP is executed to transition to STOP mode.

5.8.2 Transition to snooze mode

An external trigger (interval timer interrupt) is used to transition from STOP mode to snooze mode.

5.8.3 Branch out from snooze mode

CTSU measurement in snooze mode uses the SMS function and MEC function.

Touch OFF judgment : system transitions to STOP mode

Touch judgment : system transitions to active mode

5.9 Active

This mode operates the three buttons, slider, and wheel on the touch board.

- When the touch board is touched, the corresponding LEDs lights up. When no touch is detected, the LEDs remain off. See Figure 3.1 for details on which LEDs respond to touch.
- When 3 seconds elapse in Touch OFF state, the system transitions from active mode to standby mode.

The following is the flowchart for the active mode measurements.

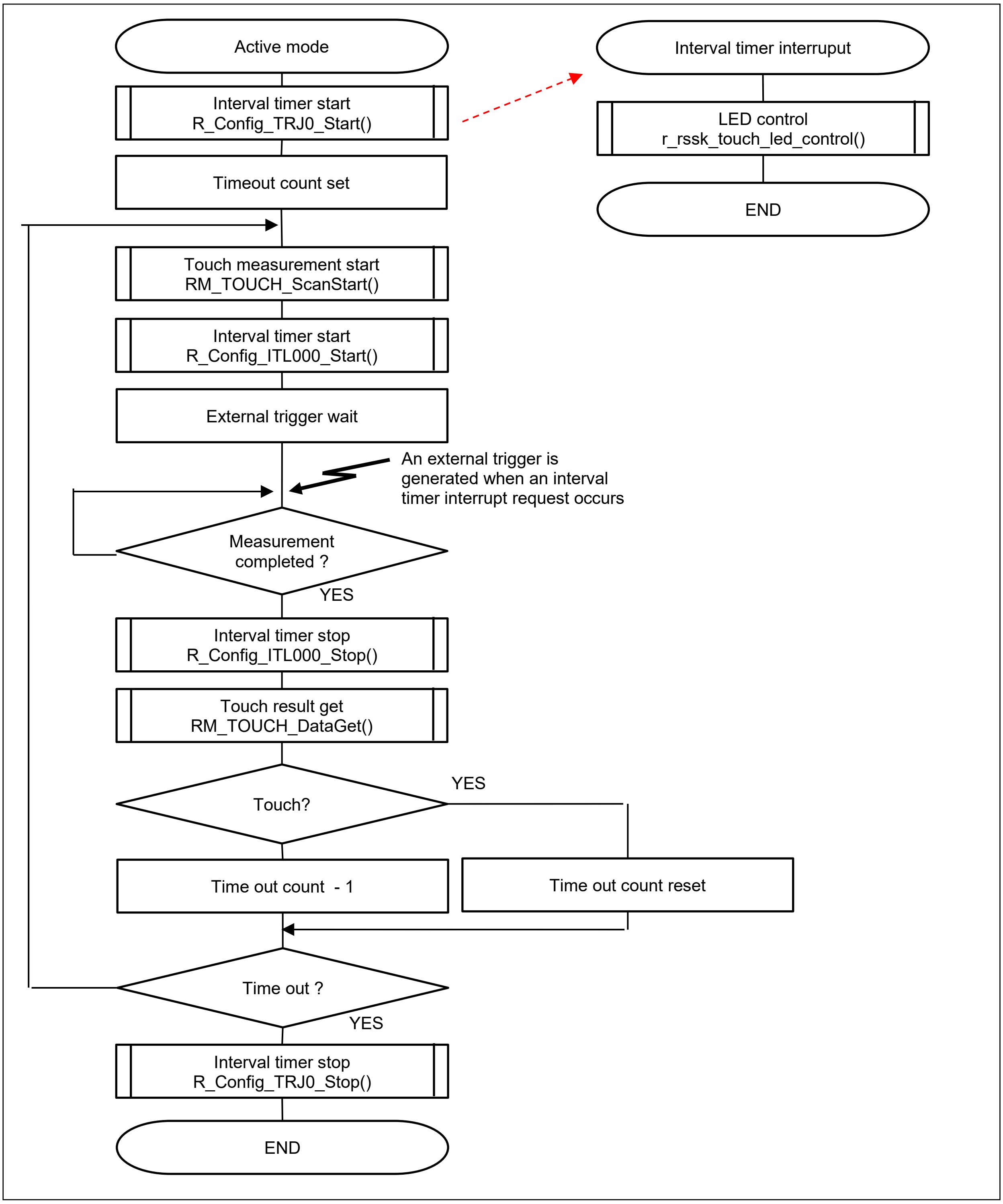

Figure 5.10 Active mode measurement processing flowchart

5.9.1 Active to standby preparation

CTSU measurement is performed in active, and if there is standby judgment, the system transitions to standby mode.

・The CTSU measurement uses an interval timer cycle of 20msec and bsw for the pin configuration

・When Touch OFF state continues for 5 seconds, standby judgment.

5.9.2 Active operations

Active mode performs the following operations.

1. Perform CTSU measurement with bsw to measure buttons/slider/wheel touch.
2. Corresponding LED turns on while position is touched (button/slider/wheel).
3. LED1 of the CPU turns on.

Note: For details on which LED corresponds to each electrode, see Figure 5.11.

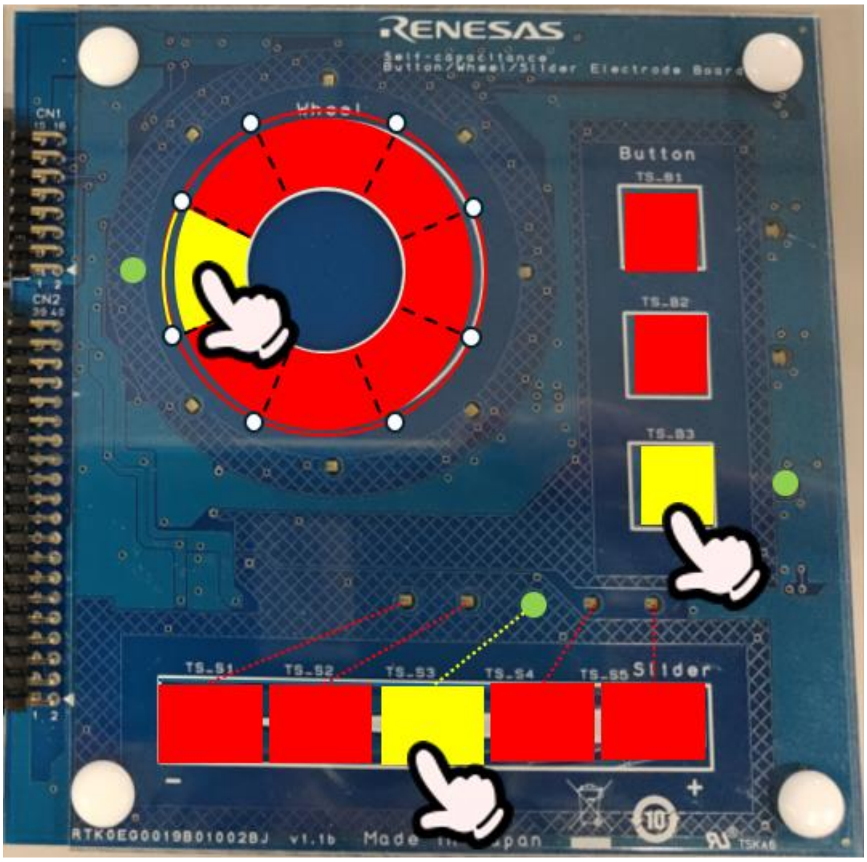

Figure 5.11 Example operating range of touch button electrode

6. Tuning Results

The following table lists the QE tuning results, with the software operating under the settings shown in the list.

Table 6.1 Tuning results

Configuration	Name	Touch sensor	Parasitic capacitance [pF]	Sensor drive pulse frequency [MHz]	Touch threshold	Time [ms]	so	snum	sdpa
MEC	mec00	TS03	218.41	0.231	605;516;693	0.576	0x149	0x07	0x3B
BSW	TS_B3	TS10	21.542	2.176	1085	0.576	0x10F	0x07	0x06
BSW	TS_B2	TS12	21.486	2.181	1132	0.576	0x0ED	0x07	0x06
BSW	TS_B1	TS11	23.132	2.038	1132	0.576	0x0E7	0x07	0x06
BSW	Slider	TS07	18.278	2.074	715	0.576	0x0D9	0x07	0x06
BSW	Slider	TS06	19.424	2.074	-	0.576	0x0C7	0x07	0x06
BSW	Slider	TS05	20.188	2.074	-	0.576	0x0FC	0x07	0x06
BSW	Slider	TS04	20.583	2.074	-	0.576	0x117	0x07	0x06
BSW	Slider	TS03	22.694	2.074	-	0.576	0x0FC	0x07	0x06
BSW	Wheel	TS34	25.896	1.757	945	0.576	0x123	0x07	0x06
BSW	Wheel	TS35	27.132	1.757	-	0.576	0x105	0x07	0x06
BSW	Wheel	TS32	27.076	1.757	-	0.576	0x112	0x07	0x06
BSW	Wheel	TS33	25.083	1.757	-	0.576	0x124	0x07	0x06

Note: 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.

7. Power Consumption Measurement

7.1 Standby Mode Operating Conditions

Table 7.1 shows the operating conditions for standby mode.

Table 7.1 Standby mode operating conditions

Item	Description
VDD	3.3V
High-speed on-chip oscillator	12MHz
Middle-speed on-chip oscillator	-
X1 oscillator	-
Low-speed on-chip oscillator	32.768kHz
XT1 oscillator	-
fIHP（High-Speed On-Chip Oscillator Peripheral Clock Frequency）	24MHz
fHOCO (High-Speed On-Chip Oscillator Clock Frequency)	12MHz
Timer Clock	1.2MHz
fMAIN (Main System Clock Frequency)	12MHz
fCLK (CPU / Peripheral Hardware Clock Frequency)	1.2MHz
fIMP (Middle-Speed On-Chip Oscillator Peripheral Clock Frequency)	-
fMXP (High-Speed Peripheral Clock Frequency)	-
fIL (Low-Speed On-Chip Oscillator Clock Frequency)	32.768kHz
fSXP/fSUBR (Low-Speed Peripheral Clock Frequency / Subsystem Clock R Frequency)	32.768kHz
fSXR (Subsystem Clock XR Frequency)	-

7.2 Current Measuring Equipment and Software

Table 7.2 shows the measuring equipment and software used in current consumption measurement.

Table 7.2 Current measuring equipment and software

Type	Name	Use
Digital multi meter	KEITHLEY/DMM7510	Measure current consumption
Software	KEITHLEY/KickStart Software (V 1.9.8.21)	Get result of current consumption measurement from Keithley DMM7510 and output the result to log-file.

7.3 CPU Board

The following figure shows the front of the CPU board.

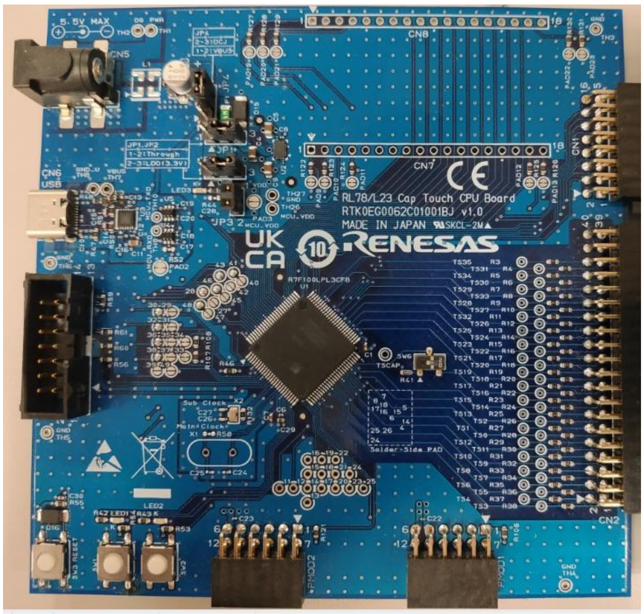

Figure 7.1 RL78/L23 CPU board (front side)

Cut the bridge pattern between the pads for the default short PAD3. The following figure shows the shape of the jumper pad.

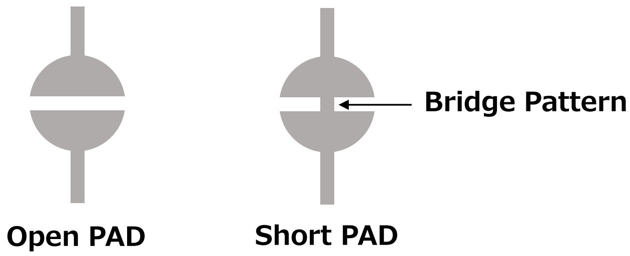

Figure 7.2 Jumper pad shape

7.4 CPU Board Jumper Settings

Table 7.3 shows the jumper settings of the CPU board for measuring current consumption.

Table 7.3 Jumper settings

Position	Jumper setting	Use
JP1	2-3 pins closed	3.3V use LDO
JP2	2-3 pins closed	3.3V use LDO
JP3	OPEN	Measure current consumption
JP4	1-2 pins closed	Power supply from CN6 USB

Other jumper settings and switch settings are factory-default.

7.5 Current Consumption Measurement Environment

The following figure shows the environment necessary for measuring current consumption.

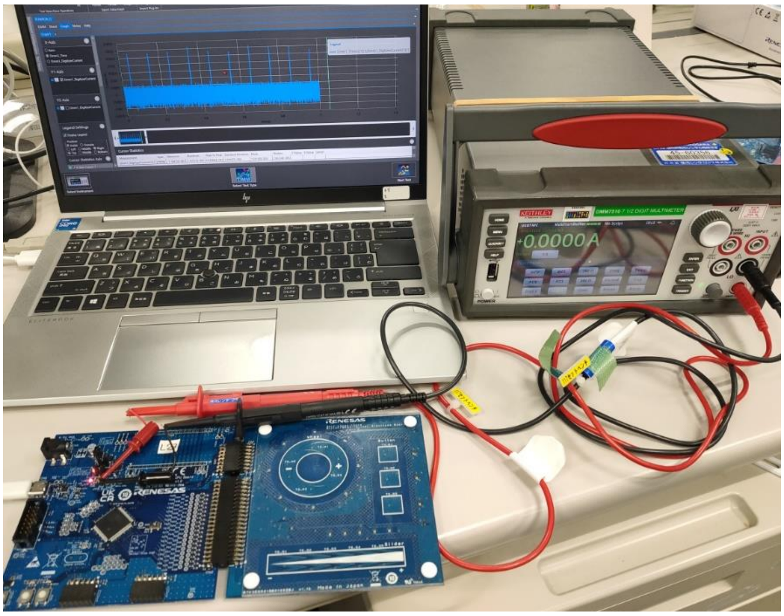

Figure 7.3 Current Consumption Measurement Environment

7.6 Current Consumption Measurement Settings

The following figure shows the Keithley KickStart settings for measuring current consumption.

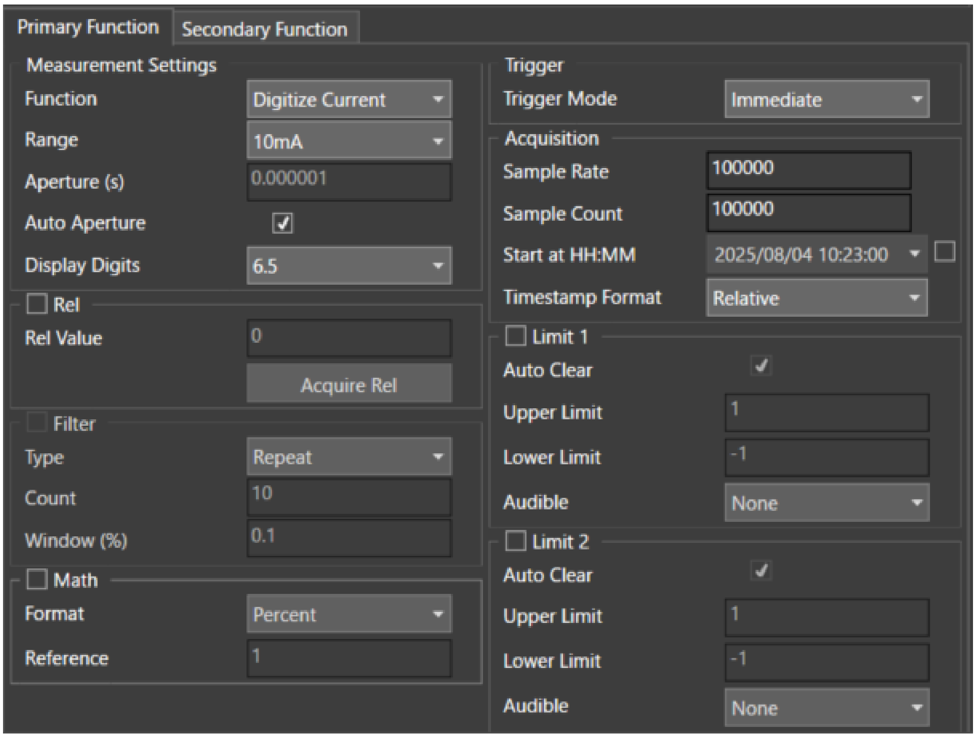

Figure 7.4 Keithley KickStart settings for current consumption measurement

7.7 Current Consumption Measurement Results

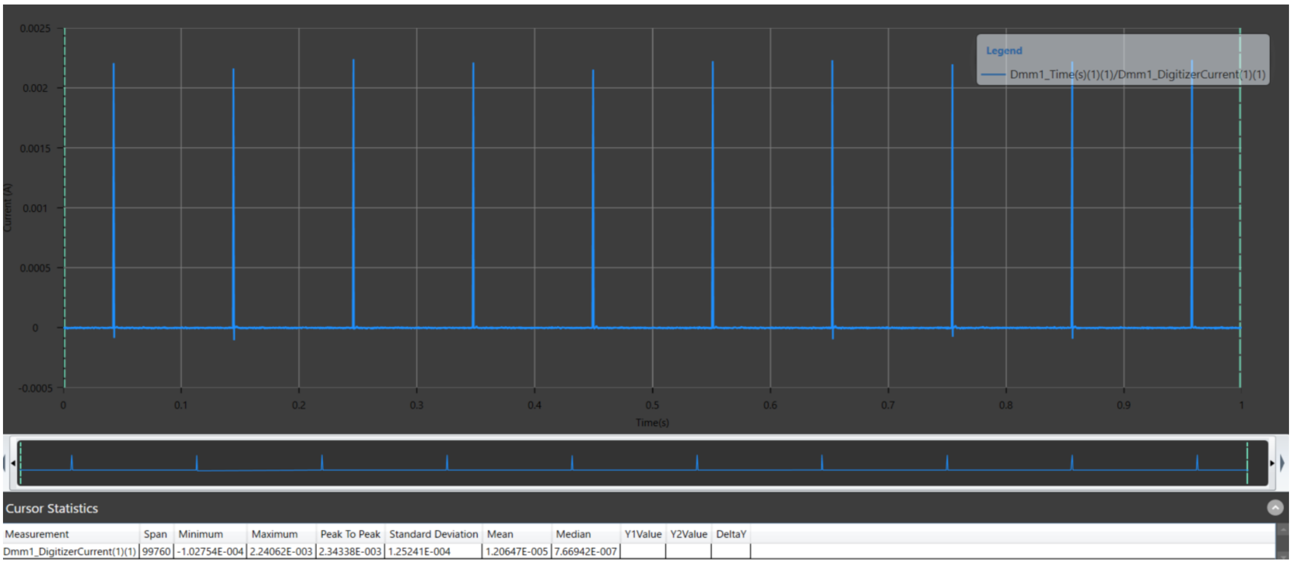

Figure 7.5 and

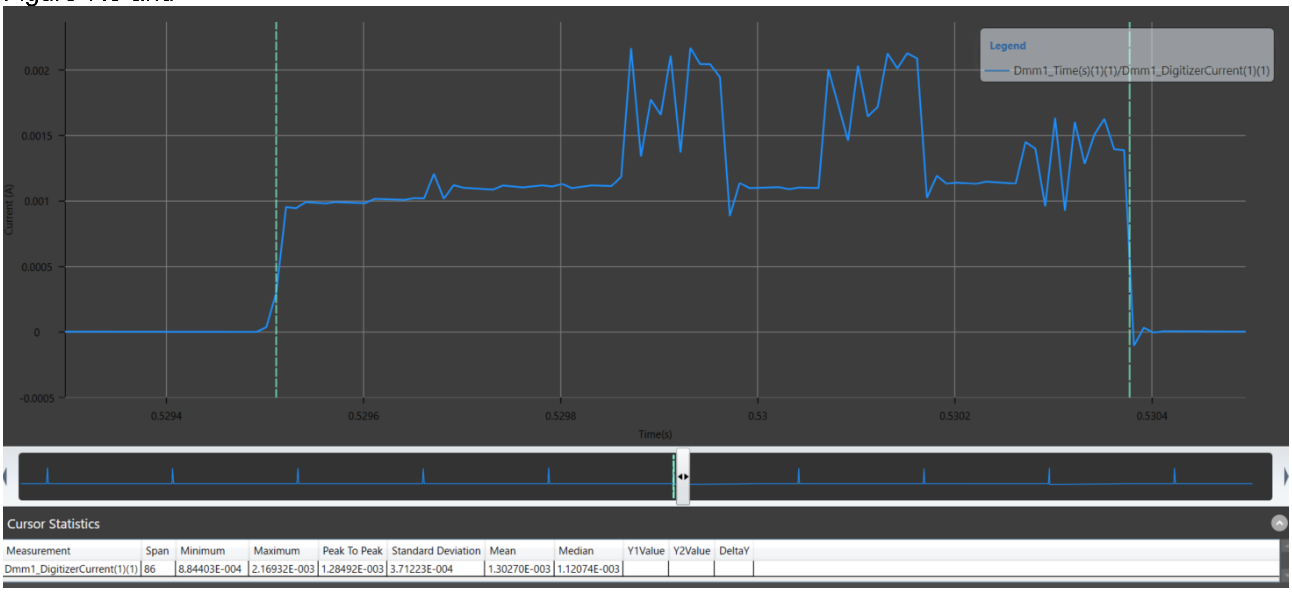

Figure 7.6 show the current consumption waveforms of the operation when the CPU operation mode transitions to the STOP mode and snooze mode (touch measurement processing, touch on / off judgment processing).

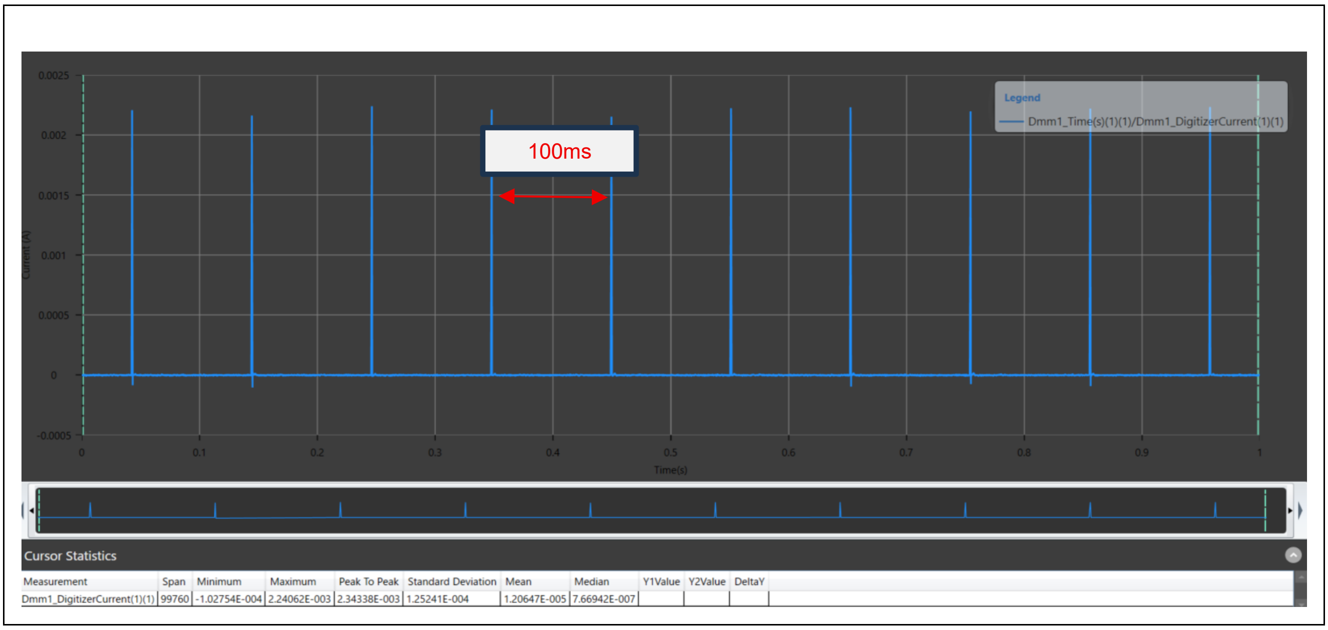

Figure 7.5 Current consumption waveform during standby mode (1/2)

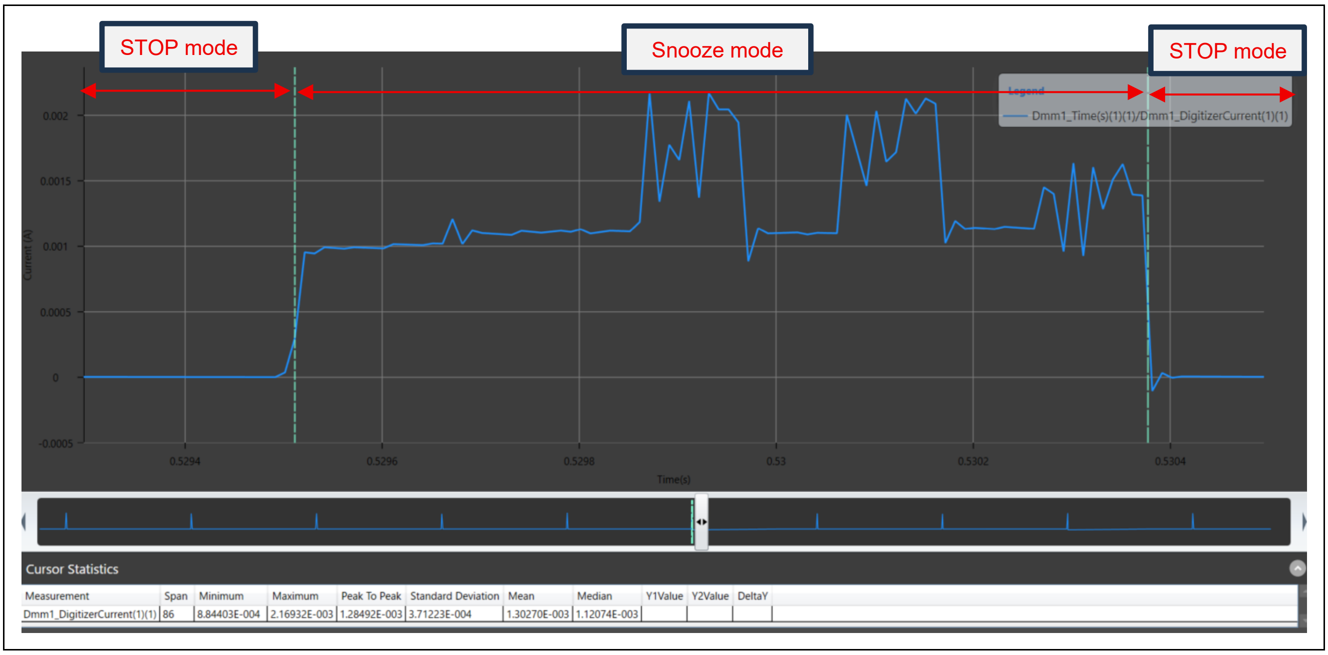

Figure 7.6 Current consumption waveform during standby mode (2/2)

7.8 Average Current Consumption Calculation Results

The following figure shows the average current measured in a touch measurement cycle of 100ms in standby mode with the SMS function and MEC function.

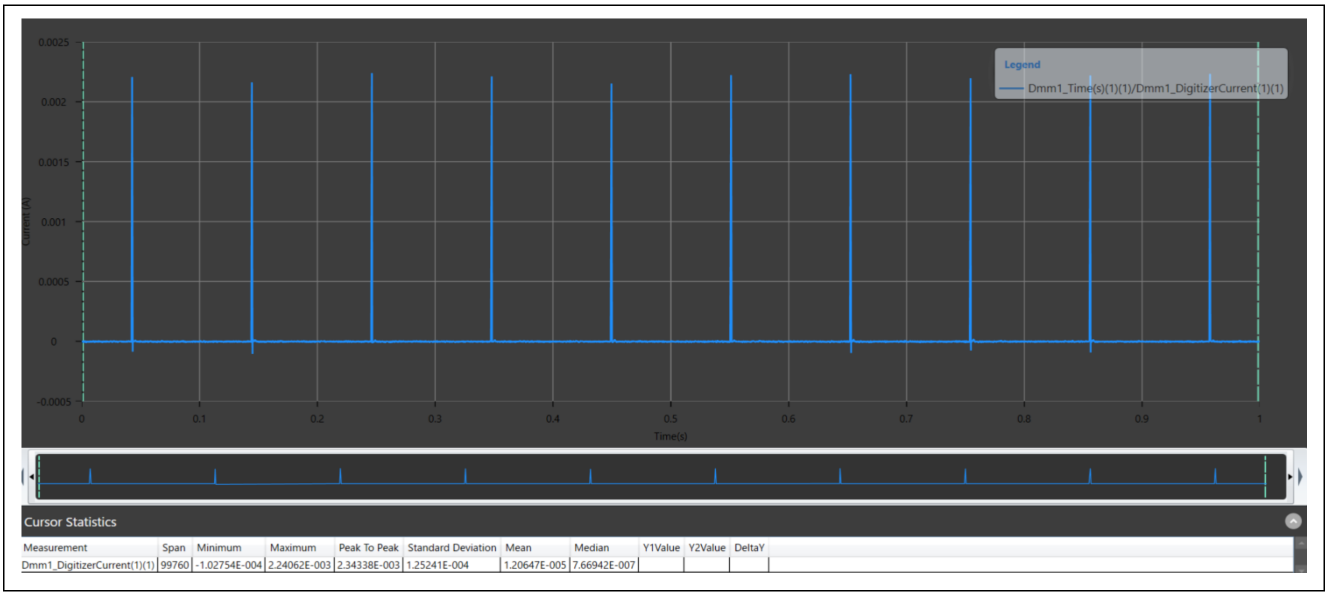

Figure 7.7 Average current of 100ms cycle in standby mode

Average current consumption (touch measurement cycle of 100ms) **= 12.06 μA**

Current consumption varies depending on clock settings etc.

For reference, the average current consumption with the settings shown in Table 7.4 is **16.95 μA**.

Table 7.4 Operating conditions (Clock setting change)

Item	Description
VDD	3.3V
High-speed on-chip oscillator	64MHz
Middle-speed on-chip oscillator	-
X1 oscillator	-
Low-speed on-chip oscillator	32.768kHz
XT1 oscillator	-
fIHP (High-Speed On-Chip Oscillator Peripheral Clock Frequency)	64MHz
fHOCO (High-Speed On-Chip Oscillator Clock Frequency)	64MHz
Timer Clock	3.2MHz
fMAIN (Main System Clock Frequency)	32MHz
fCLK (CPU / Peripheral Hardware Clock Frequency)	3.2MHz
fIMP (Middle-Speed On-Chip Oscillator Peripheral Clock Frequency)	-
fMXP (High-Speed Peripheral Clock Frequency)	-
fIL (Low-Speed On-Chip Oscillator Clock Frequency)	32.768kHz
fSXP/fSUBR (Low-Speed Peripheral Clock Frequency / Subsystem Clock R Frequency)	32.768kHz
fSXR (Subsystem Clock XR Frequency)	-

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Aug.27.25	-	Initial version

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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