RL78/F25 Group

Low power consumption Smart Wakeup Solution

Introduction

This application note explains the software that processes touch measurements with low power consumption on the RL78/F25 Capacitive Touch Evaluation System.

Target Device

RL78/F25 (R7F125FPL)

Related Documents

1. RL78/F25 Group Capacitive Touch Evaluation System User's Manual (R12UZ0149)
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 automatic judgment function and the multi-electrode connection (MEC) function of CTSU2SLa in RL78/F25 for providing low-power touch operation.

This software has three states: "Standby", “Standby Preparation”, and "Active". In Standby, touch detection with any button is performed, and then the mode transitions to Active. When the non-touch state continues in Active, 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
Board	RL78/F25 capacitive touch evaluation system (RTK7F125FPST0000BJ) • RL78/F25 CPU board (RTK7F125FPCT0000BJ) • Application board for capacitive touch evaluation – Self-Capacitance Buttons / Wheels / Slider Board (RTK0EG0019B01002BJ v1.1b)
MCU	R7F125FPL (RL78/F25 MCU Group)
Operating frequency	16MHz
Operating voltage	3.3V
Integrated development environment	e^2 studio 2025-07
C compiler	Renesas CC-RL V1.15.00
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. 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.

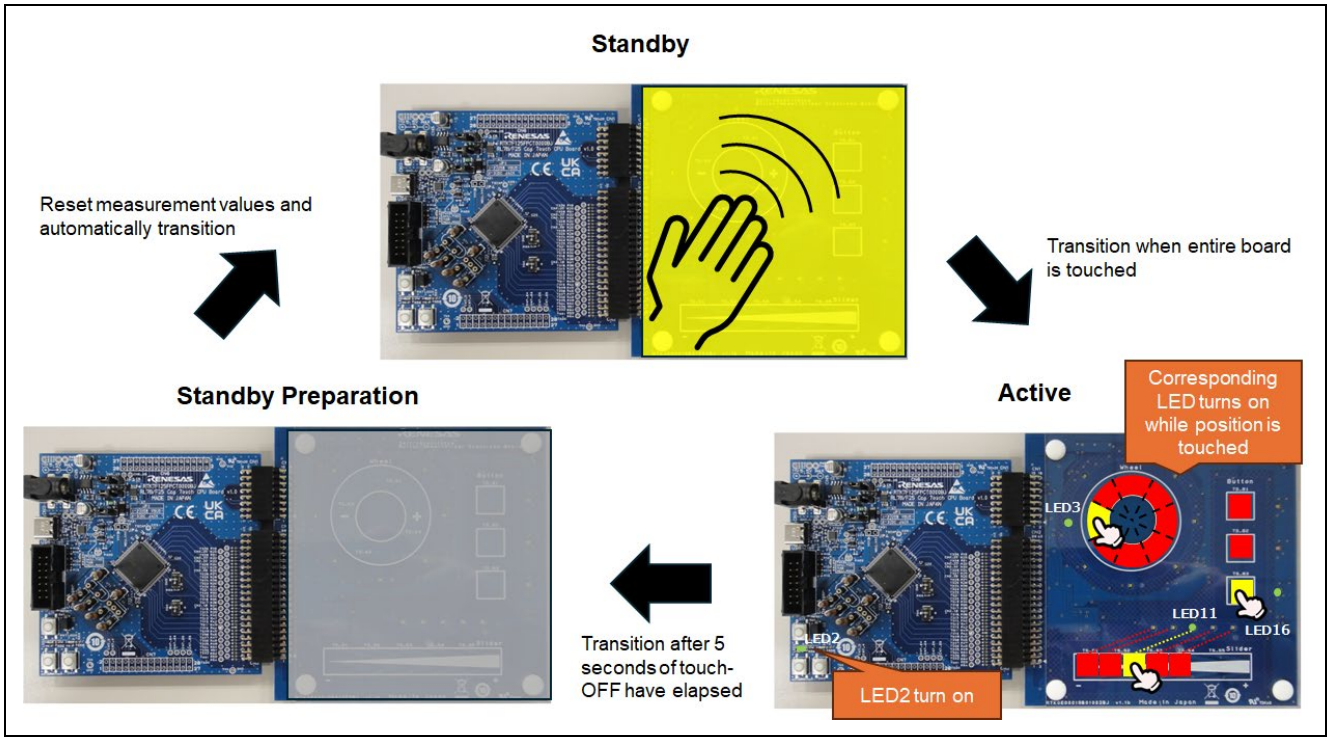

Figure 3.1 Software operation image

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.

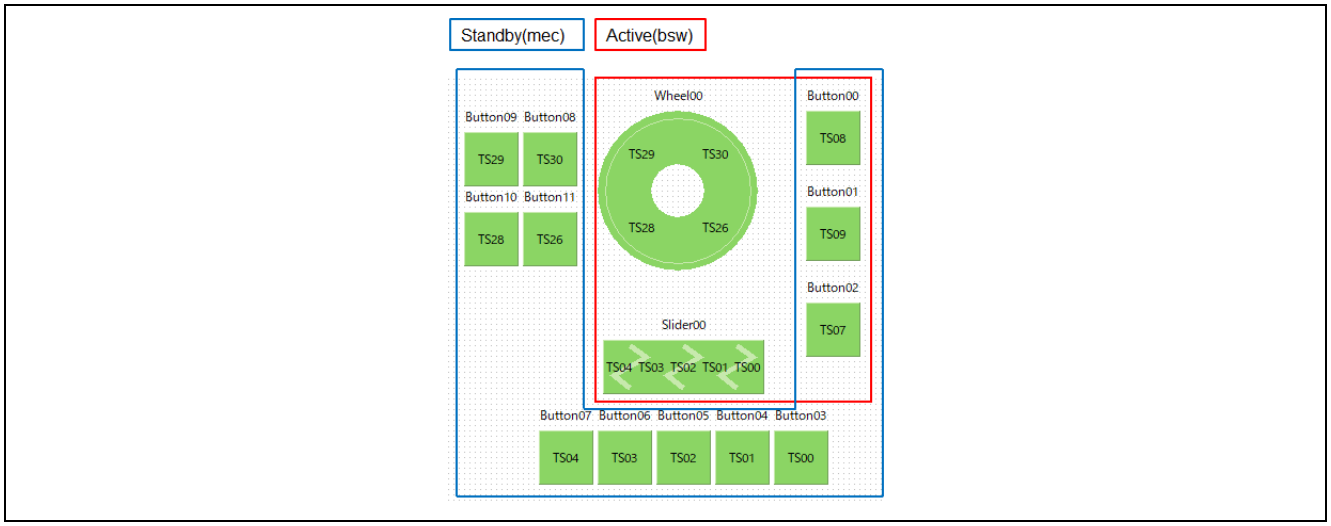

Figure 4.1 Touch interface configuration

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 measurement (see Figure 3.1). This enables the automatic judgment function for measurements in Standby, 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 measurement (see Figure 3.1). After automatic touch judgment, it sets the touch interface configuration assuming use of slider and wheel.

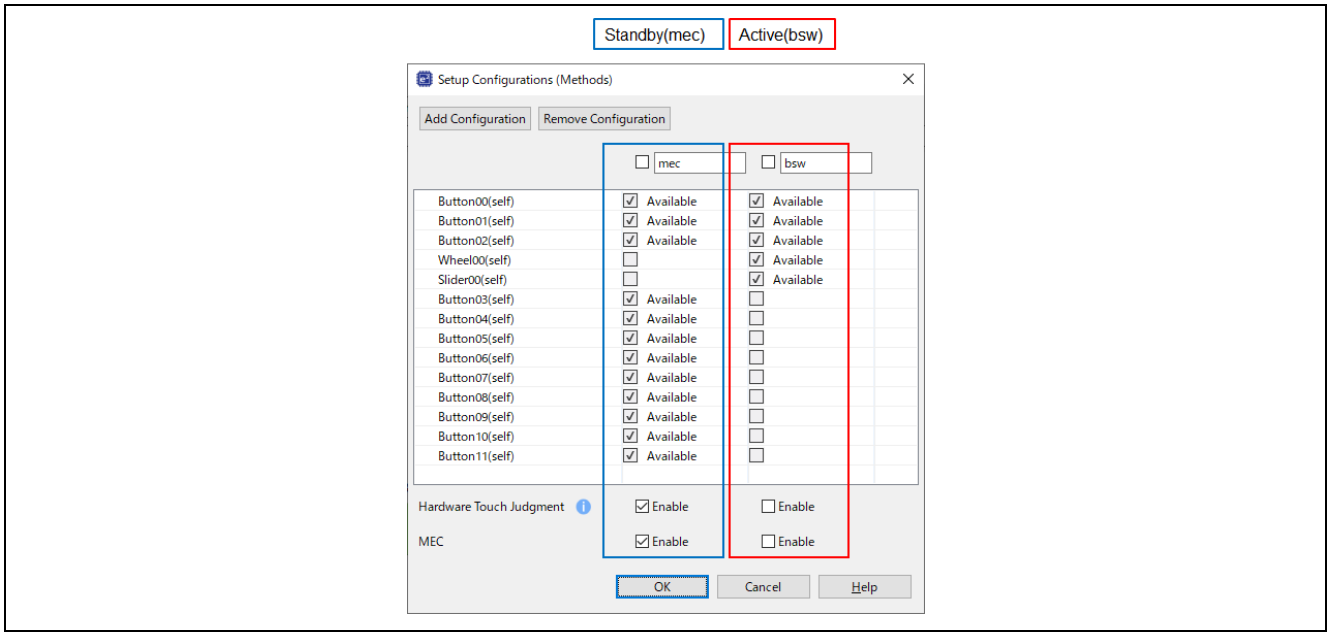

Figure 4.2 Configuration (method) settings

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 Figure 5.1.

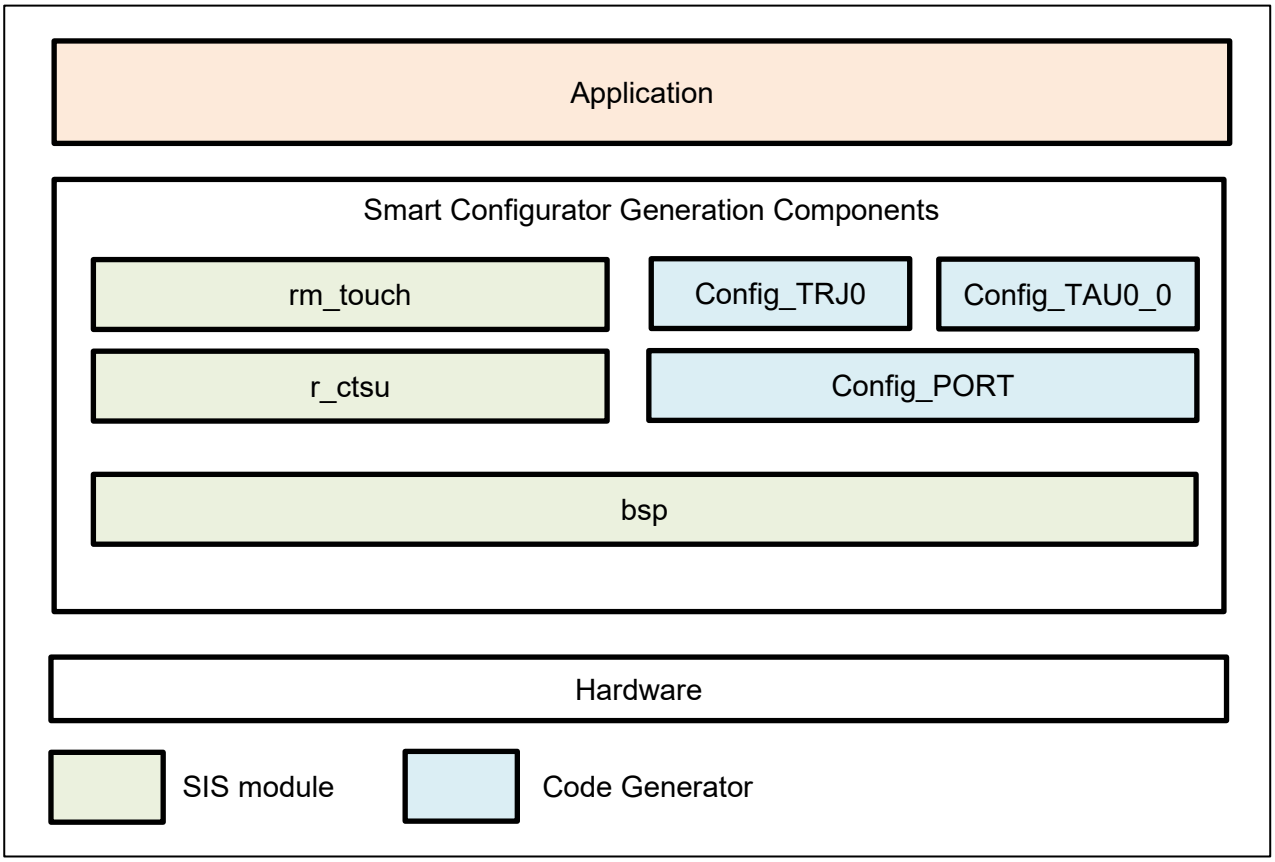

Figure 5.1 Software structure diagram

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

Table 5.1 Component list

Component	Version
Board Support Packages. - v1.91 (r_bsp)	1.91
Capacitive Sensing Unit driver. (r_ctsu)	2.20
Interval Timer	1.8.0
Ports	1.8.0
Touch middleware. (rm_touch)	2.20

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 _rl78f25_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 file
│       r_rssk_touch_led.h・・・・・・・・・Touch electrode LED processing header file
├── QE-Touch
        smart_wakeup_rl78f25_rssk.tifcfg・・・Touch I/F structure file
        smart_wakeup_rl78f25_rssk_log_tuning20250416210442.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_rl78f25_rssk.c	Main source file
r_board_control.c	Board control source file
r_rssk_touch_led.c	Touch electrode LED processing 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
r_board_control.h	Board control header file
r_rssk_touch_led.h	Touch electrode LED processing header
qe_touch_config.h	Touch QE configuration definition header file
qe_touch_define.h	Touch QE configuration definition header file

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		
_000E_TRJ_TRJ0_VALUE	(0x000EU)	Value to set timer (TRJ) to 1 msec
_05DB_TRJ_TRJ0_VALUE	(0x05DBU)	Value to set timer (TRJ) to 100 msec
BASELINE_SET_TIME	(_000E_TRJ_TRJ0_VALUE)	Specifies the baseline setting time (1msec) required for automatic judgment
SOFTWARE_MODE_TIME	(_05DB_TRJ_TRJ0_VALUE)	Specifies the TRJ underflow value (100msec) during Standby
NORMAL_MODE_TIME	(_012B_TRJ_TRJ0_VALUE)	Specifies the TRJ underflow value (20msec) during Active
BUTTON_OFF_STATE	(0x0000)	Value when button is in non-touch state
SLIDER_OFF_STATE	(0xFFFF)	Value when slider is in non-touch state
WHEEL_OFF_STATE	(0xFFFF)	Value when wheel is in non-touch state
TOUCH_OFF_PERIOD	(250U)	Non-touch judgment count (20ms * 250 = 5sec)
WAKEUP_TIME_BASELINE	(32)	Number of measurements for Standby Preparation
File name: r_rssk_touch_led.c		
LED_COL0	(P0_bit.no0)	COL0 control port definition
LED_COL1	(P0_bit.no3)	COL1 control port definition
LED_COL2	(P3_bit.no2)	COL2 control port definition
LED_COL3	(P3_bit.no0)	COL3 control port definition
LED_ROW0	(P0_bit.no1)	ROW0 control port definition
LED_ROW1	(P0_bit.no2)	ROW1 control port definition
LED_ROW2	(P12_bit.no6)	ROW2 control port definition
LED_ROW3	(P12_bit.no7)	ROW3 control port definition
LED_COL_MAX	(4)	Number of COL signals
LED_ROW_MAX	(4)	Number of ROW signals
LED_IO_LEVEL_LOW	(0)	Port LOW output
LED_IO_LEVEL_HIGH	(1)	Port HIGH output
LED_COL_OFF	(BSP_IO_LEVEL_LOW)	COL signal OFF
LED_COL_ON	(BSP_IO_LEVEL_HIGH)	COL signal ON
LED_ROW_OFF	(BSP_IO_LEVEL_HIGH)	ROW signal OFF
LED_ROW_ON	(BSP_IO_LEVEL_LOW)	ROW signal ON
SLIDER_LED_NUM	(5U)	Number of slider LEDs
SLIDER_RESOLUTION	(100)	Slider touch result: maximum value
WHEEL_LED_NUM	(8U)	Number of wheel LEDs
WHEEL_LED_MSB	(1U << (WHEEL_LED_NUM - 1))	Wheel control bit MSB
WHEEL_RESOLUTION_DEGREE	(360)	Wheel touch result: maximum value (in degrees)
WHEEL_POSITION_OFFSET_DEGREE	(112)	Wheel touch position: offset (in degrees)
File name: r_board_control.h		
WAKEUP_MODE_STANDBY	(1)	Standby state
WAKEUP_MODE_NORMAL	(0)	Active State

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
r_rssk_timer_callback	LED control callback function
File name: r_rssk_touch_led.c	
r_rssk_touch_led_control	Touch board LED control processing
create_led_bitstring_button	Touch board button LED control processing
create_led_bitstring_wheel	Touch board wheel LED control processing
create_led_bitstring_slider	Touch board slider LED control processing
r_rssk_touch_led_off	Touch board LED off processing
File name: r_board_control.c	
r_control_cpu_board_led	CPU board LED control processing

5.5 Processing Overview

Figure 5.3 shows the flowchart of this software. The LED control is controlled by the timer interrupt handler. Please refer to the 5.9 Active.

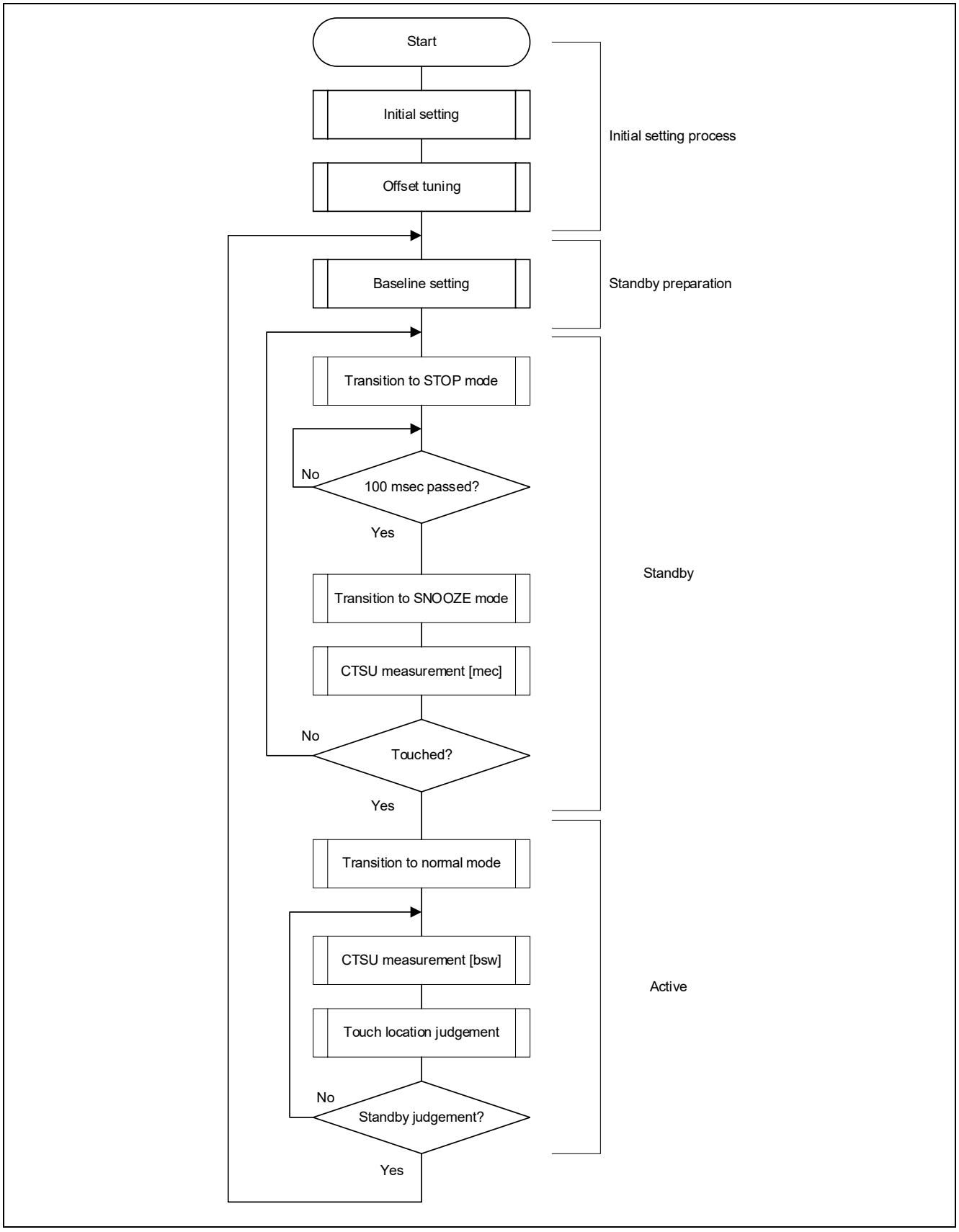

Figure 5.3 Overall processing flowchart

5.5.1 State Transition

Figure 5.4 shows the state transitions from standby, Standby Preparation, active, and back to standby again. This explains the operation of Figure 3.1, and explains the processing of two touch interface configurations (mec, bsw). Refer to the following sections for details regarding each state.

- 5.7 Standby Preparation
- 5.8 Standby
- 5.9 Active

State	Standby Preparation	Reset the measurement value and transition automatically	Standby	Transition when entire board is touched	Active	Transitions after 5 seconds of touch-off have elapsed	Standby Preparation	Start Standby	Standby	...
mec	Measurement in progress	Number of baseline average measurements completed	Measurement in progress	Touch ON	Measurement stop	Measurement stop	Measurement in progress	Number of baseline average measurements completed	Measurement in progress	...
bsw	Measurement stop	Measurement stop	Measurement stop	Measurement stop	Measurement in progress	Touch OFF for 5 seconds	Measurement stop	Measurement stop	Measurement stop	...

Figure 5.4 State transition image

The smart wake-up solution loops between standby and Actives. 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.

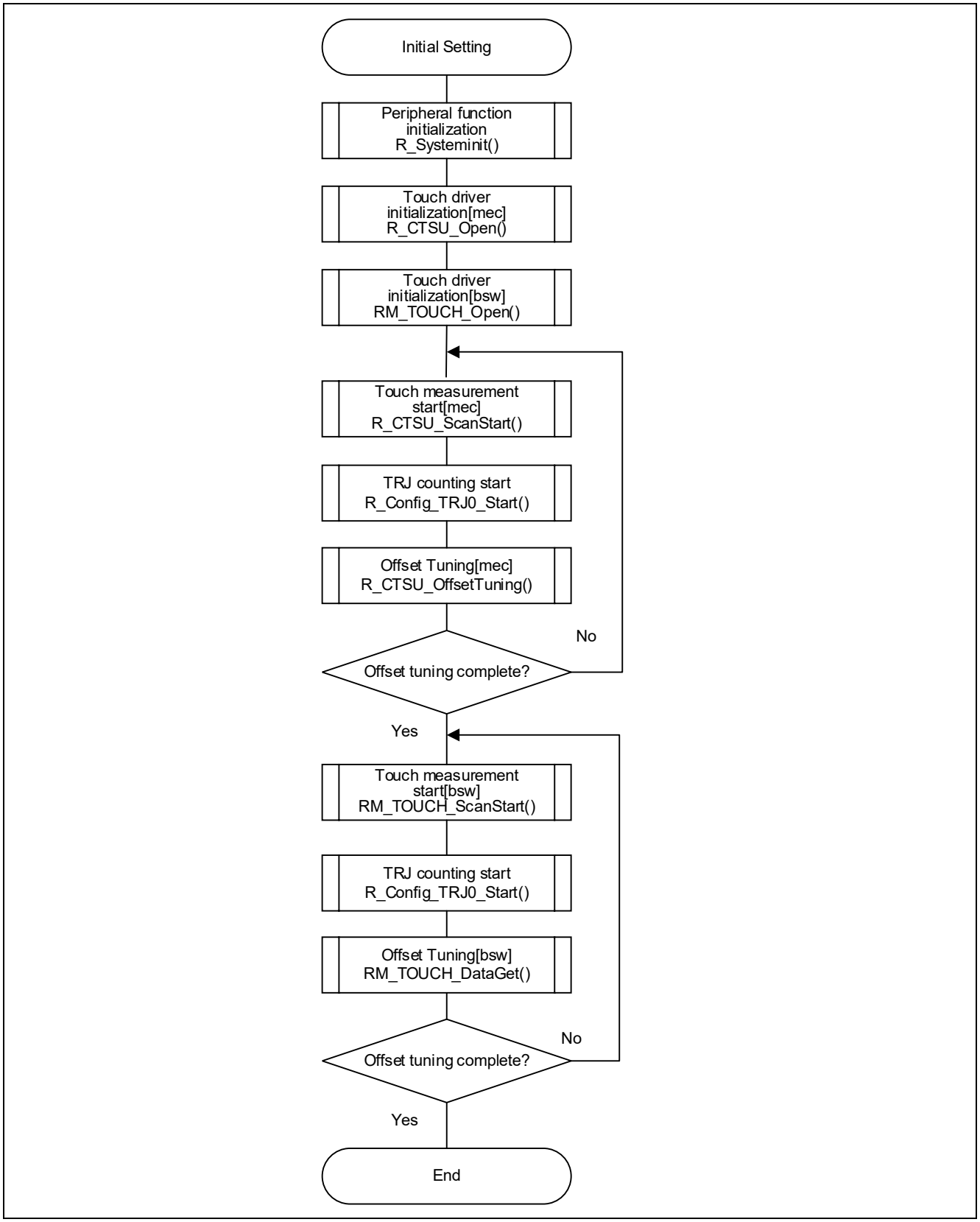

Figure 5.5 Initial setting processing flowchart

5.7 Standby Preparation

Standby Preparation prevents false touch judgment when transitioning from Active to Standby.

In order to transition to Standby in a non-touch state, measurements are conducted for the number of baseline averages in Standby. If all measurements are non-touch, the system transitions to Standby. For details regarding Standby, refer to section 5.8.

Figure 5.6 shows the Standby Preparation process flow.

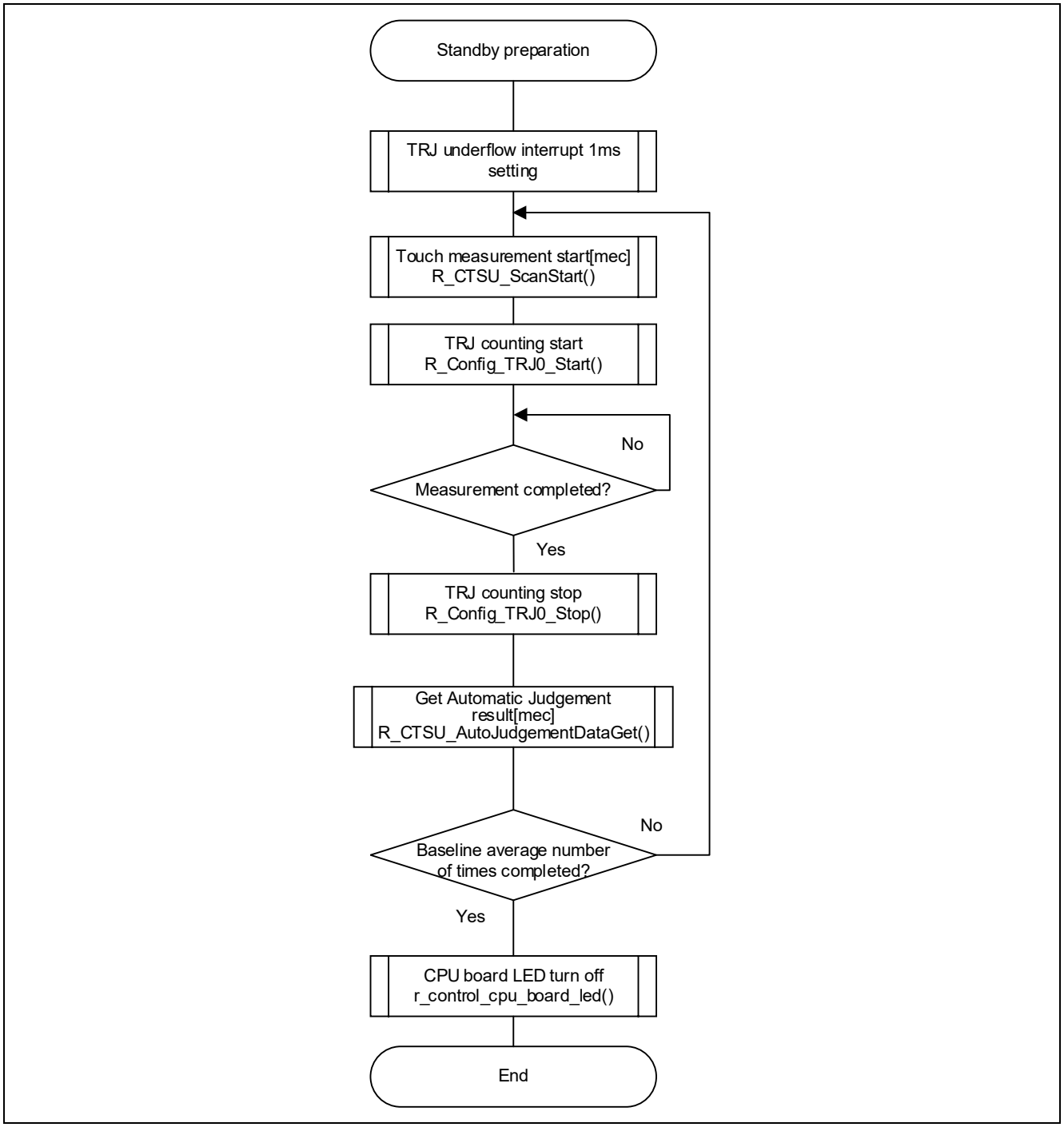

Figure 5.6 Standby Preparation flowchart

5.7.1 Number of baseline averages

The baseline average number is calculated using the following formula.

Number of baseline averages = $2^{(ajbmat+1)}$

In this application, the setting value for ajbmat is 4, so the number of baseline averages is 32.

5.7.2 Role of baseline setting

In this application, before measuring in Standby, 32 measurements are taken in preparation for Standby to reset the baseline.

The reason for this process is to start measurement in Standby with the MEC's touch detection turned off.

Figure 5.7 shows the measurement values in each state.

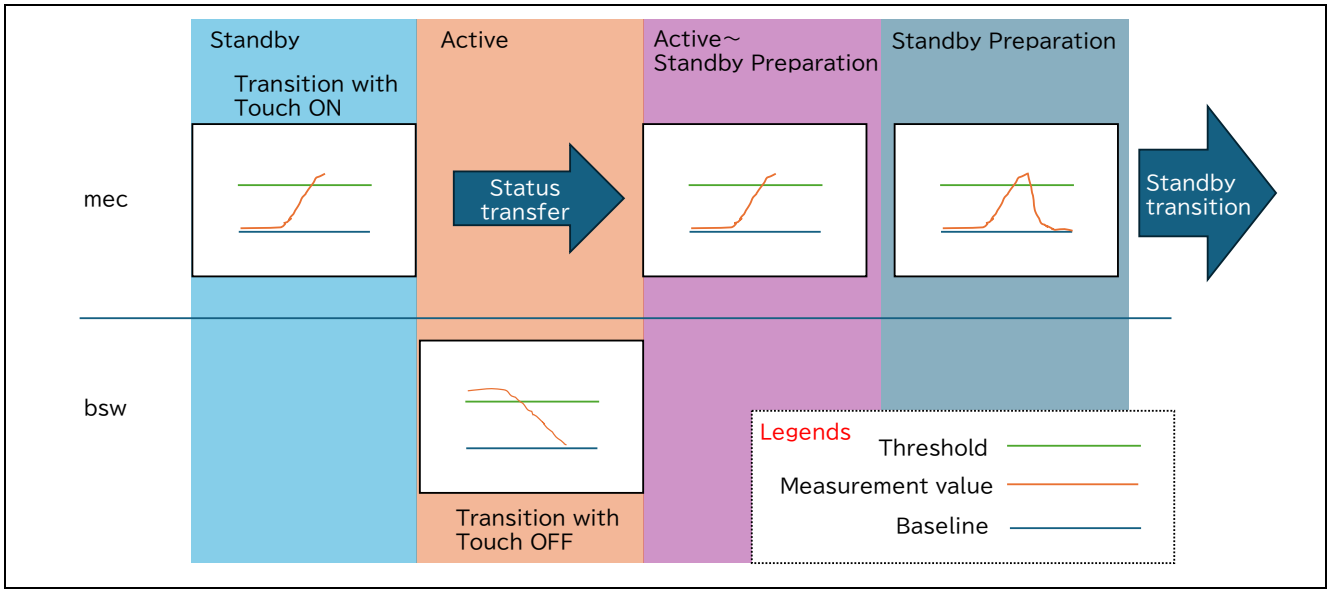

Figure 5.7 Measurement value transition image

5.8 Standby

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 (MEC) function, 12 channels can be measured at one time to reduce power consumption.

Figure 5.8 shows an image of CPU operating mode and CTSU operating status

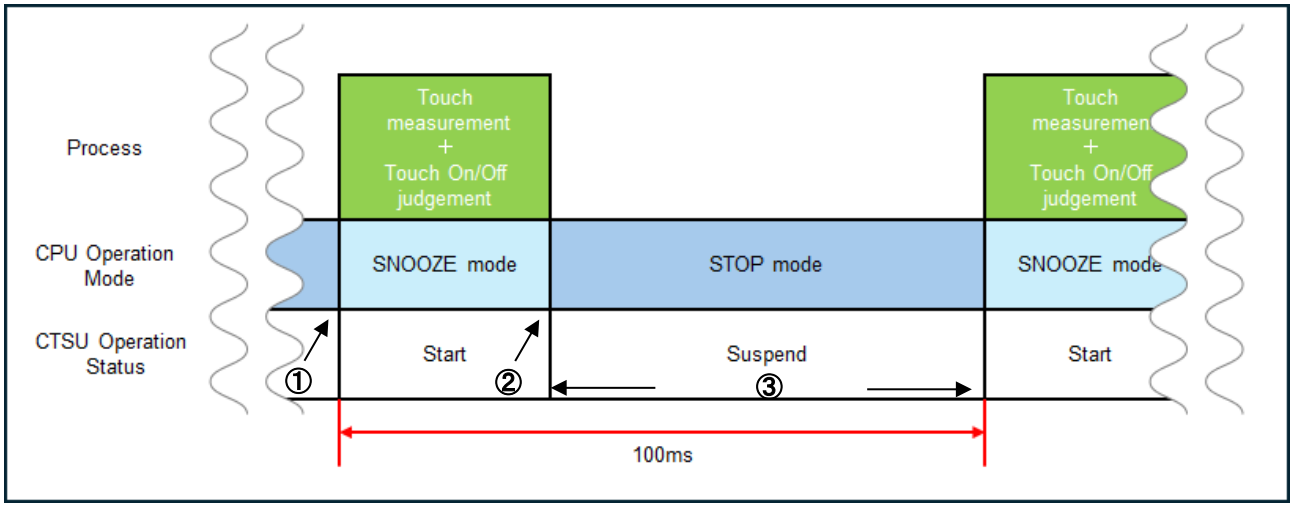

Figure 5.8 Image of CPU operating mode and CTSU operating status

The above figure shows the flow of how the CTSU receives the TRJ underflow interrupt signal as a SNOOZE request and starts measurement. The numbers indicated within the figure are described below.

① CPU transitions to SNOOZE mode upon detecting an trigger.

② CTSU measurement in SNOOZE mode is judged based on touch detected an automatic judgment function 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 Standby to Active.

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

Figure 5.9 shows the standby flowchart.

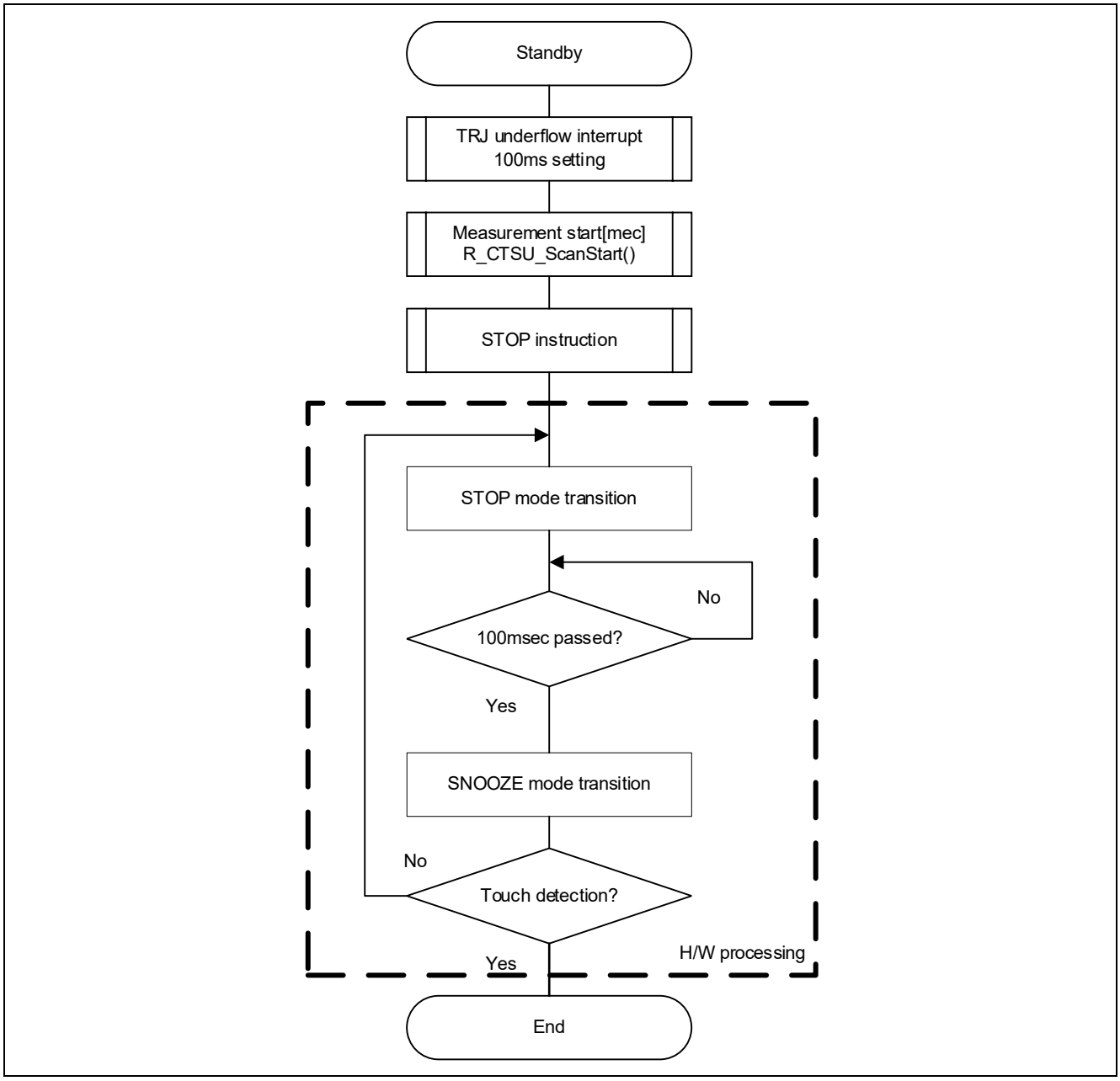

Figure 5.9 Standby flowchart

5.8.1 Transition to STOP mode

Execute the STOP instruction and transition to STOP mode.

5.8.2 Transition to SNOOZE mode

An TRJ underflow interrupt signal 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 automatic judgment function and MEC.

Non-touch judgment: system transitions to STOP mode

Touch judgment: system transitions to Active

5.9 Active

Active operates the 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 5 seconds elapse in the non-touch state, the system transitions from Active to Standby.

Figure 5.10 for the active measurements.

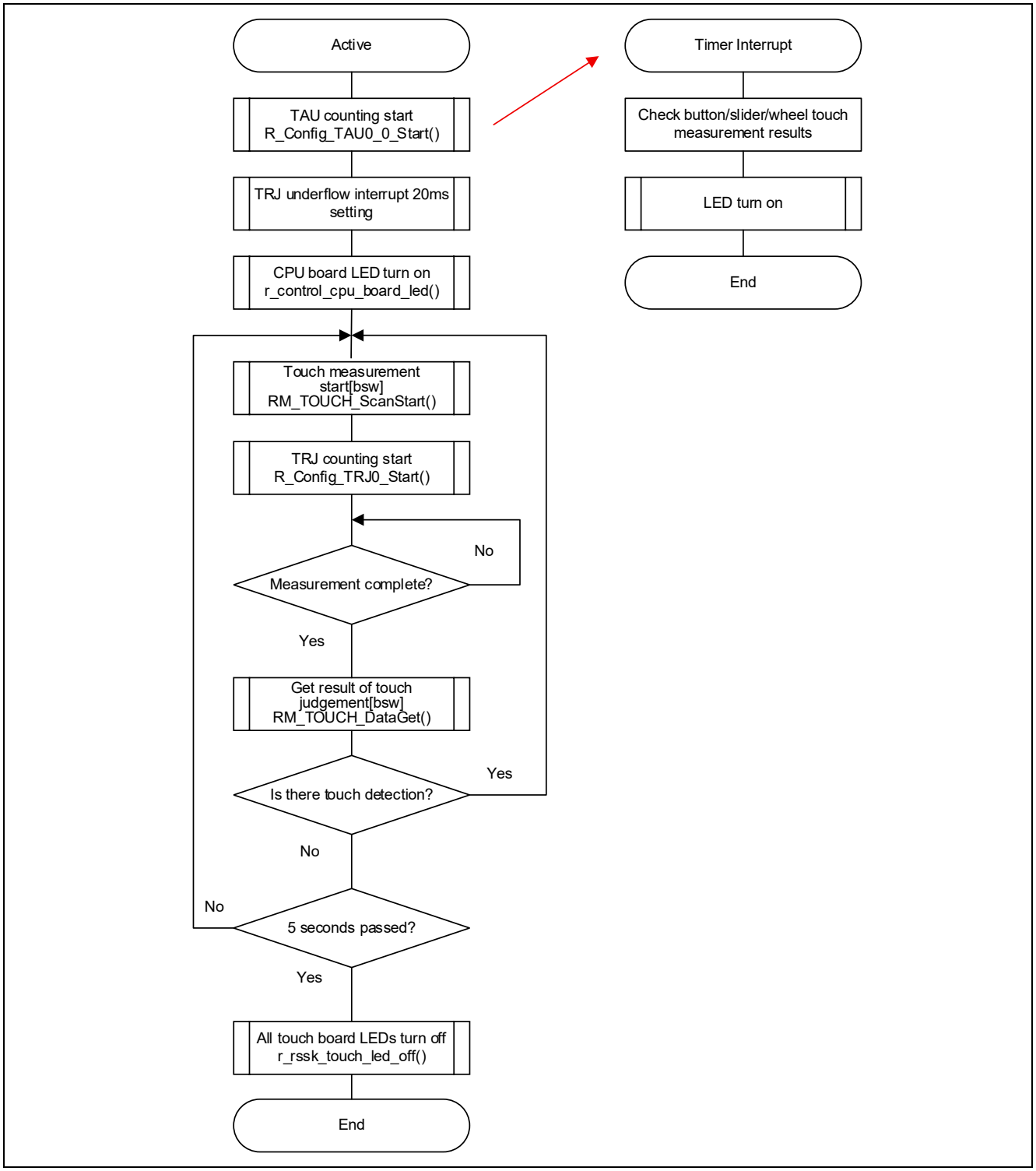

Figure 5.10 Active measurement processing flowchart

5.9.1 Active to Standby preparation

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

- The CTSU measurement uses an TRJ timer cycle of 20msec and bsw for the pin configuration.
- If no touch is performed for 5 seconds, the device will be judged as in Standby.

5.9.2 Active operations

Active 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).
   *For details on which LED corresponds to each electrode, see Figure 5.11.
3. LED2 of the CPU turns on.

Figure 5.11 Operating of touch electrode and LED

6. Tuning Results

Table 6.1 lists the QE tuning results.

Table 6.1 Tuning results

Configuration	Name	Touch sensor	Parasitic capacitance [pF]	Sensor drive pulse frequency [MHz]	Touch threshold	Measurement time [ms]	so	snum	sdpa
mec	mec00	TS00	176.792	0.250	114;97;130	0.128	0x14A	0x07	0x3F
bsw	Button00	TS08	24.542	1.600	991	0.128	0xF5	0x07	0x09
bsw	Button01	TS09	22.083	1.778	1077	0.128	0xF2	0x07	0x08
bsw	Button02	TS07	22.09	1.778	1095	0.128	0xF2	0x07	0x08
bsw	Slider00	TS04	20.604	1.455	664	0.128	0xA2	0x07	0x0A
bsw	Slider00	TS03	20.618	1.455	664	0.128	0xA3	0x07	0x0A
bsw	Slider00	TS02	22.514	1.455	664	0.128	0xBC	0x07	0x0A
bsw	Slider00	TS01	22.257	1.455	664	0.128	0xBA	0x07	0x0A
bsw	Slider00	TS00	26.569	1.455	664	0.128	0xDE	0x07	0x0A
bsw	Wheel00	TS29	25.736	1.455	840	0.128	0xE7	0x07	0x0A
bsw	Wheel00	TS30	27.396	1.455	840	0.128	0xFE	0x07	0x0A
bsw	Wheel00	TS26	27.174	1.455	840	0.128	0xFC	0x07	0x0A
bsw	Wheel00	TS28	26.569	1.455	840	0.128	0xF2	0x07	0x0A

so : Variables for sensor offset setting
snum : Variables for measurement period setting
sdpa : Variables for clock frequency setting

Note 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.

Note 2: To reduce power consumption, a part of the " g_qe_ctsu_cfg_mec " setting in "qe_touch_config.c" was changed manually, as follows.

tlot (Non-touch criteria) = 2 → 1

thot (Touch criteria) = 2 → 1

ajbmat (Number of baseline averages) = 7 → 4

Note 3: The tuning results shown in Table 6.1 are based on using Advanced Mode in QE V4.2.0.
When automatic tuning is performed in QE V4.2.0, the sensor drive pulse frequency displayed in the CapTouch Board Monitor (QE) view reflects the maximum sensor drive pulse frequency, which may differ from the actual sensor drive pulse frequency.
For more details, refer to Section 3.1.4, Item 7 of the QE for Capacitive Touch V4.2.0 Release Notes.

7. Power Consumption Measurement

7.1 Standby Operating Conditions

Table 7.1 shows the operating conditions for Standby.

Table 7.1 Standby operating conditions

Item	Description
CPU operating frequency	16 MHz High-speed on-chip oscillator (HOCO) 15 kHz Low-speed on-chip oscillator (LOCO)
High-speed on-chip oscillator clock frequency (f_{IH})	16 MHz
Main system clock frequency (f_{MAIN})	16 MHz
CPU/peripheral hardware clock frequency (f_{CLK})	16 MHz
Main/PLL selected clock frequency (f_{MP})	16 MHz
Timer RD clock	16 MHz
Timer RJ count clock (f_{IL})	15 kHz
Low-speed on-chip oscillator clock frequency (f_{IL})	15 kHz
Sub/low-speed on-chip oscillator selection clock frequency (f_{SL})	15 kHz
Watchdog timer dedicated low-speed on-chip oscillator clock (f_{WDT})	15 kHz
Touch measurement cycle	100ms
Sensor drive pulse frequency	0.285MHz
CTSU Measurement Mode	Self-capacitance method (MD1 = 0)
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 (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 Control	3 frequencies (MCA0, MCA1, MCA2: available)
CTSU Measurement Count	128μs (SNUM= 7)

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
Power supply	KENWOOD/PA18-1.2A	Supply power to RL78/F25 CPU board
Software	KEITHLEY/KickStart Software	Get result of current consumption measurement from Keithley DM7510 and output the result to log-file.

7.3 RL78/F25 CPU Board

Figure 7.1 shows the front of the RL78/F25 CPU board.

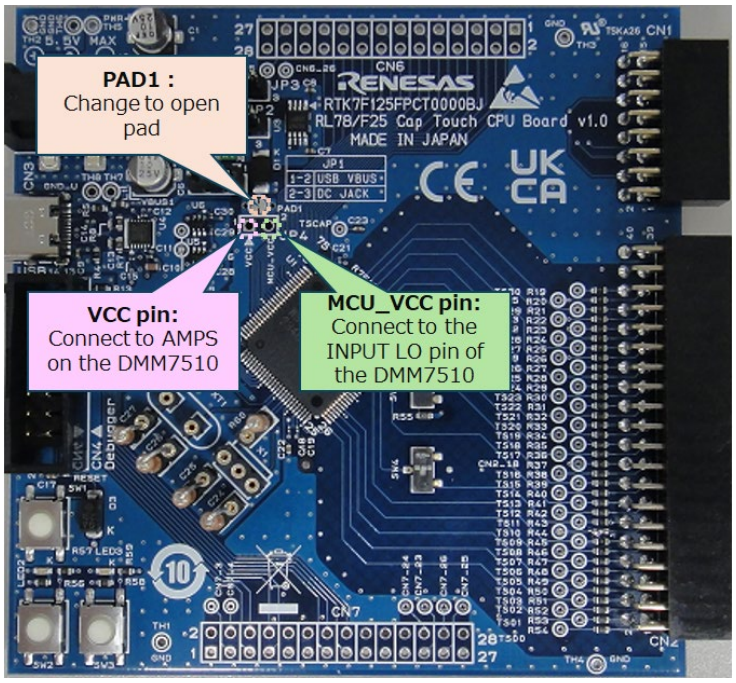

Figure 7.1 RL78/F25 CPU board (front side)

Cut the bridge pattern between the pads for the default short PAD1. Figure 7.2 shows the shape of the jumper pad.

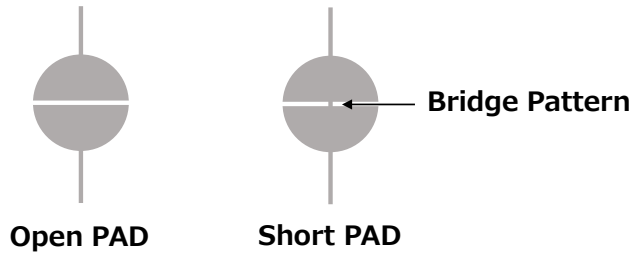

Figure 7.2 Jumper pad shape

7.4 RL78/F25 CPU Board Jumper Settings

Table 7.3 shows the jumper settings of the RL78/F25 CPU board for measuring current consumption.

Table 7.3 Jumper settings

Position	Jumper setting	Use
JP1	2-3 pins closed	Power supply from DC jack
JP4	Open	Measure current consumption

Other jumper settings and switch settings are factory-default.

7.5 Current Consumption Measurement Environment

Figure 7.3 shows the environment necessary for measuring current consumption.

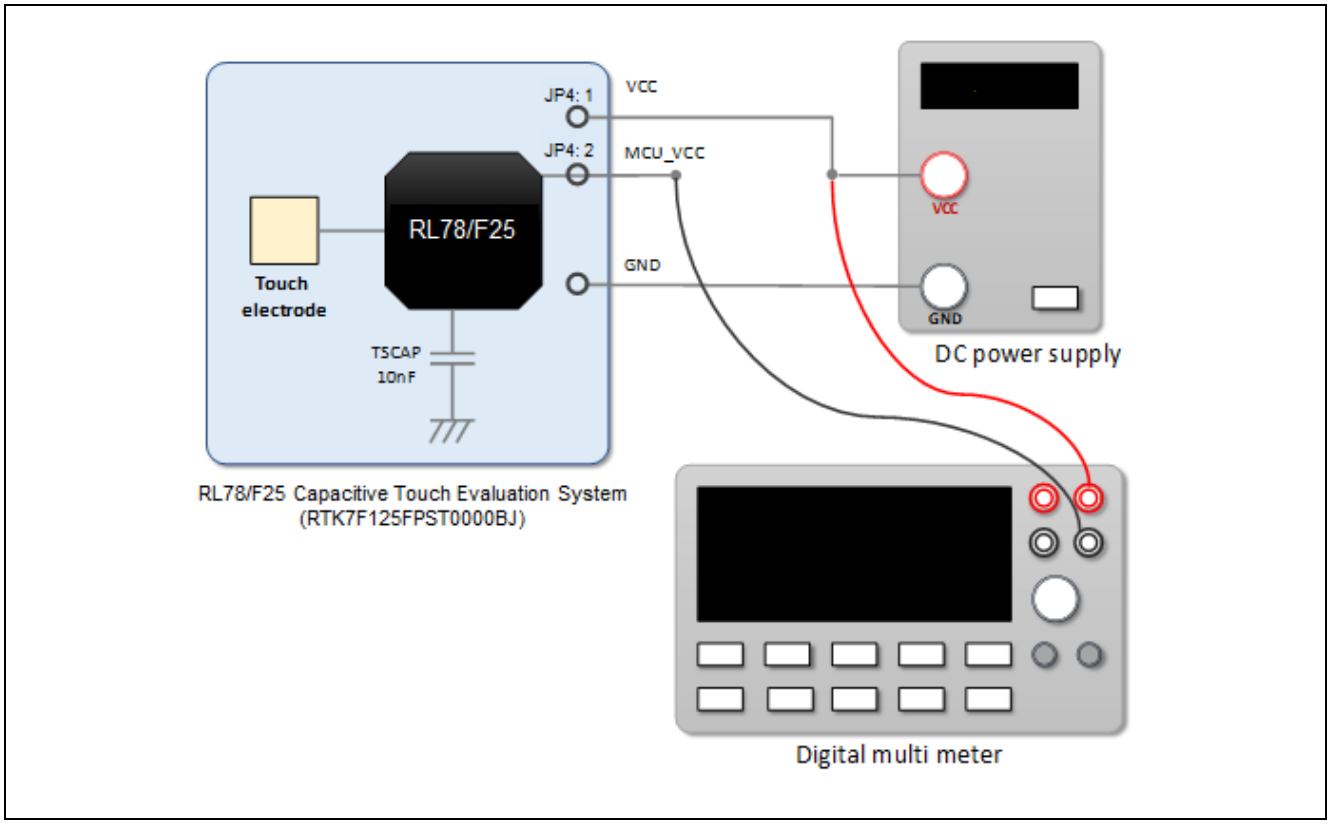

Figure 7.3 Current Consumption Measurement Environment

7.6 Current Consumption Measurement Settings

Figure 7.4 shows the Keithley KickStart settings for measuring current consumption.

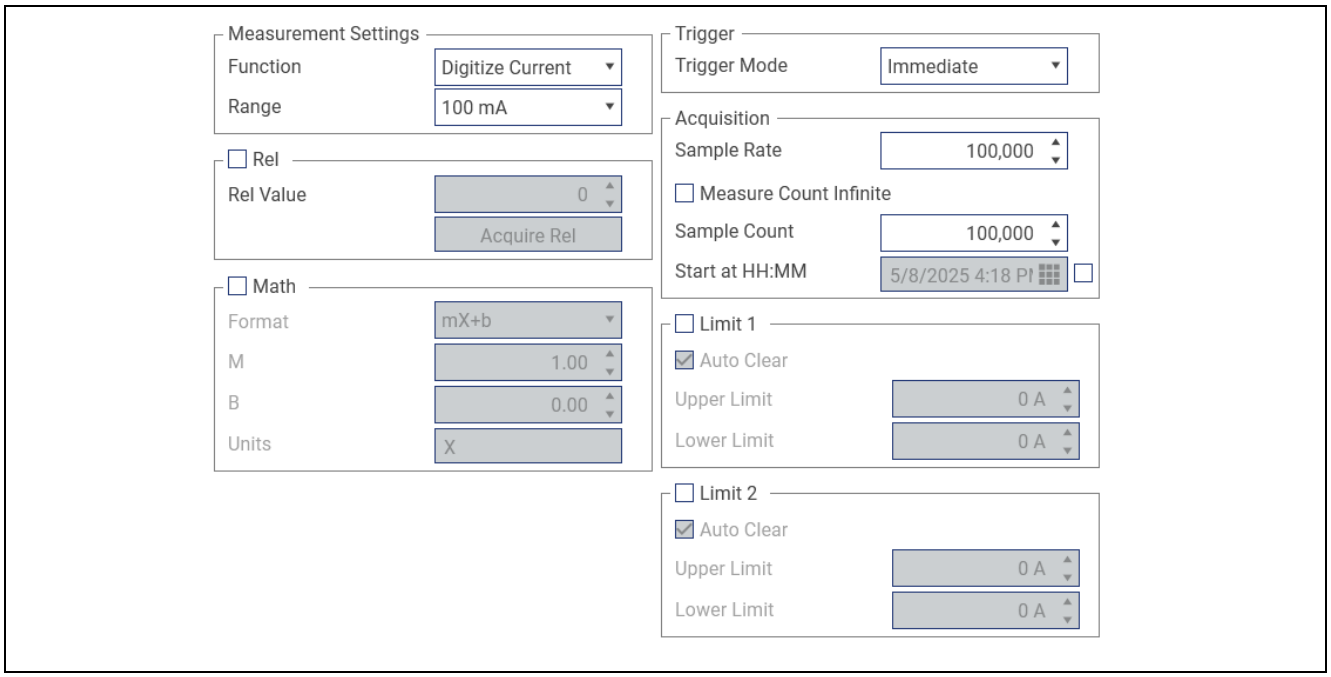

Figure 7.4 Keithley KickStart settings for current consumption measurement

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 software Standby and snooze mode (touch measurement processing, touch on / off judgment processing).

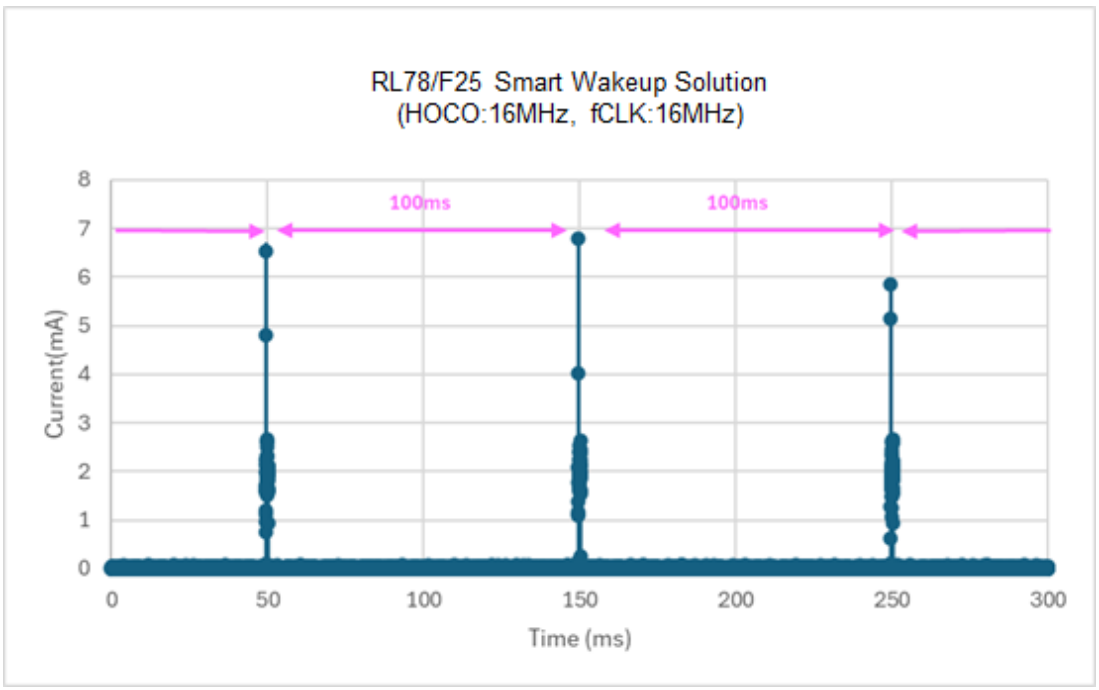

Figure 7.5 Current consumption waveform during Standby (1/2)

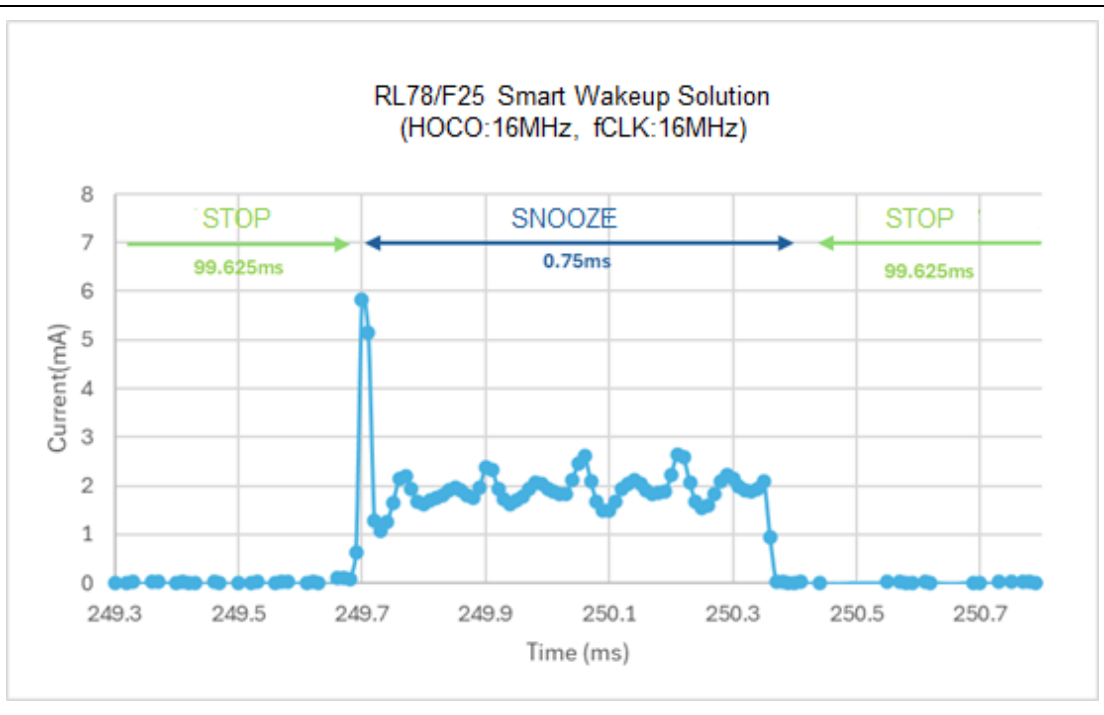

Figure 7.6 Current consumption waveform during Standby (2/2)

7.8 Average Current Consumption Calculation Results

Figure 7.7 shows the average current measured in a touch measurement cycle of 100ms in Standby with the automatic judgment function and multiple electrode connection function.

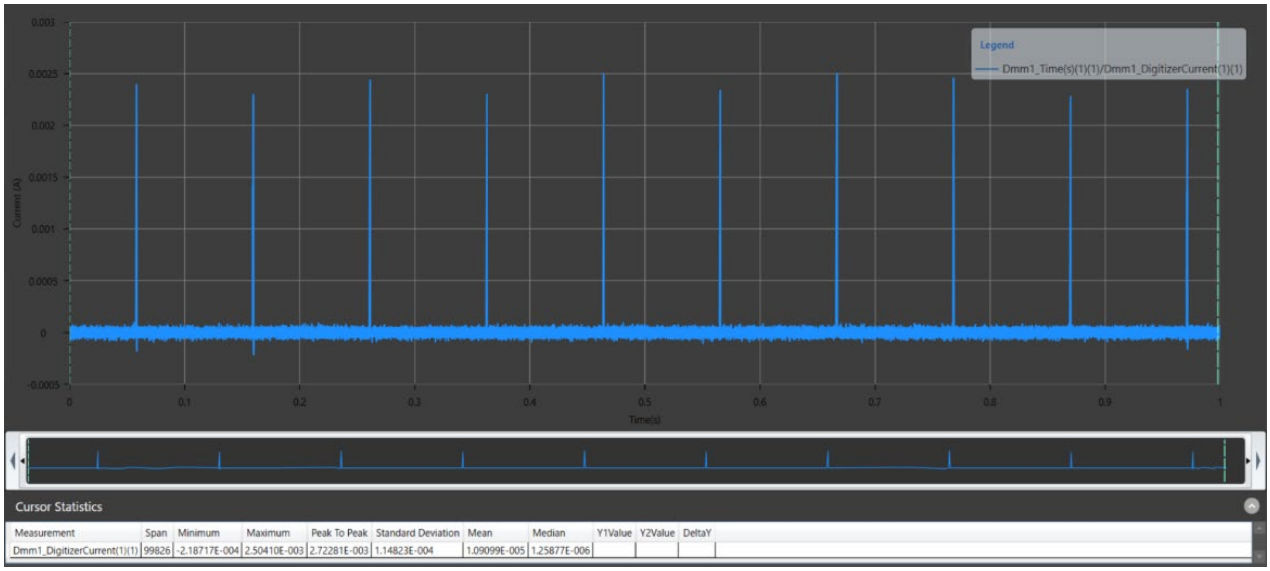

Figure 7.7 Average current of 100ms cycle in Standby

Average current consumption (touch measurement cycle of 100ms) **= 10.91 µA**

The current consumption varies depending on the clock setting, etc. For reference, the average current consumption when changing the clock setting is shown in Table 7.4, Table 7.5, and Table 7.6.

Table 7.4 Change conditions for clock settings 1

Item	Description
CPU operating frequency	40 MHz High-speed on-chip oscillator (HOCO) 15 kHz Low-speed on-chip oscillator (LOCO)
High-speed on-chip oscillator clock frequency (f_{IH})	40 MHz
Main system clock frequency (f_{MAIN})	40 MHz
CPU/peripheral hardware clock frequency (f_{CLK})	40 MHz
Main/PLL selected clock frequency (f_{MP})	40 MHz
Timer RD clock	40 MHz
Timer RJ count clock (f_{IL})	15 kHz
Low-speed on-chip oscillator clock frequency (f_{IL})	15 kHz
Sub/low-speed on-chip oscillator selection clock frequency (f_{SL})	15 kHz
Watchdog timer dedicated low-speed on-chip oscillator clock (f_{WDT})	15 kHz

Average current consumption (touch measurement cycle of 100ms) **= 15.23 µA**

Table 7.5 Change conditions for clock settings 2

Item	Description
CPU operating frequency	32 MHz High-speed on-chip oscillator (HOCO) 15 kHz Low-speed on-chip oscillator (LOCO)
High-speed on-chip oscillator clock frequency (f_{IH})	32 MHz
Main system clock frequency (f_{MAIN})	32 MHz
CPU/peripheral hardware clock frequency (f_{CLK})	32 MHz
Main/PLL selected clock frequency (f_{MP})	32 MHz
Timer RD clock	32 MHz
Timer RJ count clock (f_{IL})	15 kHz
Low-speed on-chip oscillator clock frequency (f_{IL})	15 kHz
Sub/low-speed on-chip oscillator selection clock frequency (f_{SL})	15 kHz
Watchdog timer dedicated low-speed on-chip oscillator clock (f_{WDT})	15 kHz

Average current consumption (touch measurement cycle of 100ms) **= 13.60 µA**

Table 7.6 Change conditions for clock settings 3

Item	Description
CPU operating frequency	2 MHz High-speed on-chip oscillator (HOCO) 15 kHz Low-speed on-chip oscillator (LOCO)
High-speed on-chip oscillator clock frequency (f_{IH})	2 MHz
Main system clock frequency (f_{MAIN})	2 MHz
CPU/peripheral hardware clock frequency (f_{CLK})	2 MHz
Main/PLL selected clock frequency (f_{MP})	2 MHz
Timer RD clock	2 MHz
Timer RJ count clock (f_{IL})	15 kHz
Low-speed on-chip oscillator clock frequency (f_{IL})	15 kHz
Sub/low-speed on-chip oscillator selection clock frequency (f_{SL})	15 kHz
Watchdog timer dedicated low-speed on-chip oscillator clock (f_{WDT})	15 kHz

Average current consumption (touch measurement cycle of 100ms) **= 9.96 µA**

In this case, if the timer of the external trigger at the time of baseline setting is 1ms, the trigger to start the measurement will be turned on again before the callback of the measurement starts and ends the measurement, causing problems with operation, so this timer must be changed to 2ms.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Sep.24.25	-	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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