R8C/33T Group

Reducing the power consumption in stand-by mode

R01AN0345EJ0100
Rev.1.00
May 22. 2013

Summary

Touch panel microcomputer R8C/33T group builds hardware (SCU: sensor control unit) that perceives the contact of the human body by measuring the stray capacity generated between the touch electrode and the human body into.

In this application note, we provide the method how to reduce the power consumption using the intermittent measurement of the touch and the intermittent judgment of the touch key.

Target device

R8C/33T group

Contents

1. Outline

In the product using the machine point of contact switch, the method for the reducing of the power consumption of the microcomputer in the standby mode has been established. However, because the key detection method is different, similar processing cannot be done for the touch key.
In this application note, using the feature of microcomputer R8C/33T with built-in the touch detection circuit, we provide the method of reducing the power consumption by intermittent operating as short as possible at the microcomputer operation time. There are some the methods of microcomputers of the intermittent operation and we illustrate the two methods, one is using the multipurpose timer, other is using the watchdog Timer to realize the lowest power consumption.

2. Reducing the power consumption by the intermittent operation using Timer RB

2.1 Condition of the operation

The condition of operating firmware that provides this application note shows as follows.

- Combining high speed and low speed and on the chip oscillators are used for CPU clock.
- The weight mode and the touch detection process are executed alternately by using timer RB for constant intervals.
  Note; The timer RC interrupt is as a hardware trigger of touch measurement by SCU. However, it is not possible that timer RC interrupt wakes up the measurement by SCU with switching low speed OCO to high speed OCO. In addition regarding the power consumption, the timer RA/RB is lower than the timer RC. So we have used the timer RB for constant intervals.
- The SCU measurement clock and CPU processing clock are 5MHz (1/4 of CPU clock)
- When the touch detection doesn't operate, CPU sets the WAIT mode with the low speed oscillator(125KHz).
- The touch detection interval is 100mSEC.
- 15 touch Channels are active. (22 channels are scanned by SCU and 7ch are set in the state of the measurement prohibition.)
- SCU keeps stopping and all channels are set to ‘output-low’ except the period of touch measurement.

2.2 Result of the current consumption

Table 1 Result of the current consumption

Operational mode	CPU clock	Operation time	Current consumption
Timer B1 interrupt (Set OCO to high-speed and Start SCU)	125KHz	1.5ms	250uA
SCU operation (in WAIT MODE)	5MHz	5ms	450uA
CPU operation (ON/OFF judgment, drift processing, and SCU is stopped)	5MHz	6ms	1.3mA
WAIT MODE (SCU is stopped)	125KHz	87.5ms	Under 20uA *1

*1: Below measurement limit

Average current consumption

124uA （by 15ch）

2.3 Content of processing

2.3.1 Processing flow

Figure 1 shows the processing flow.

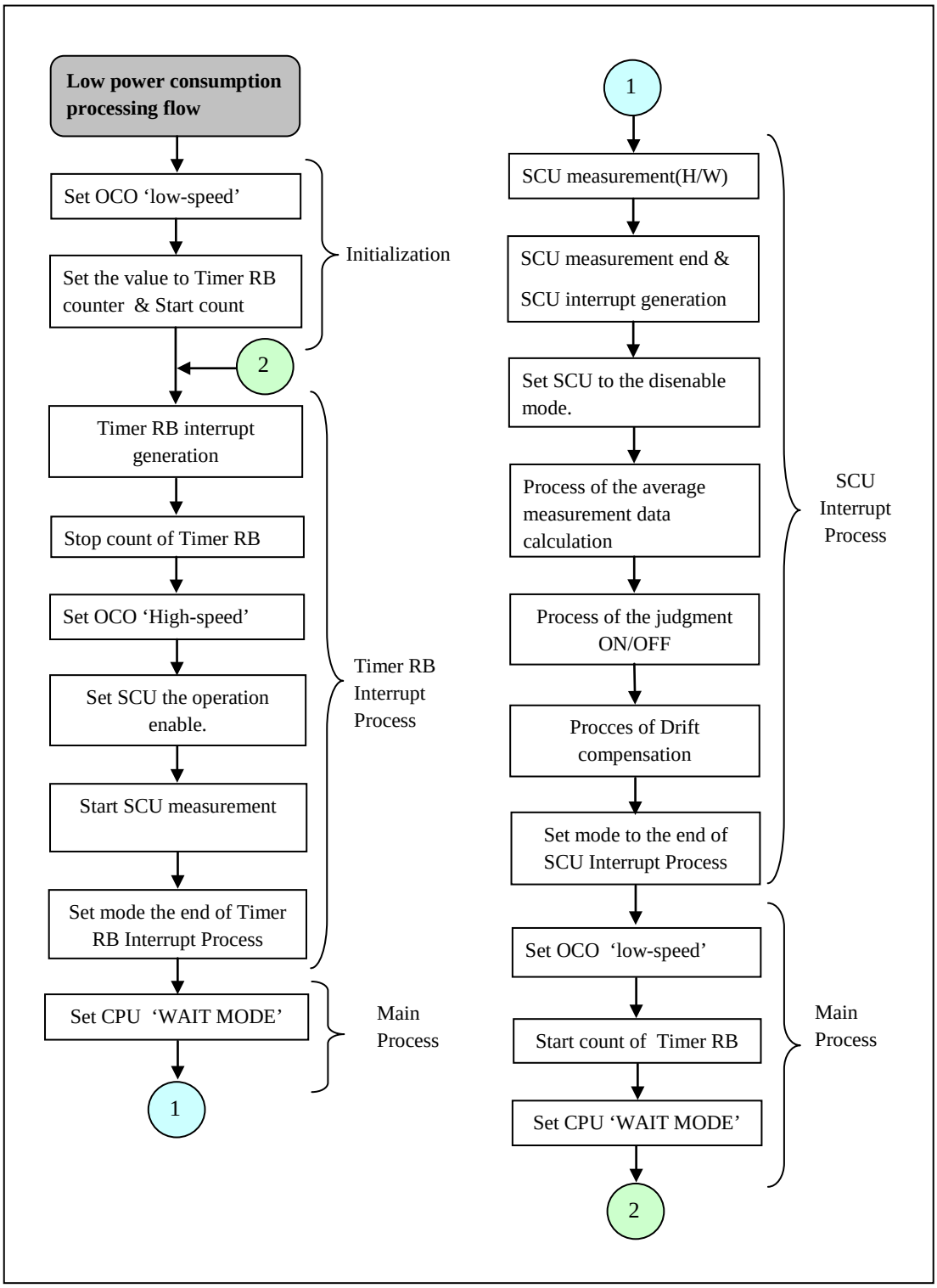

Figure 1 Processing flow for low power consumption

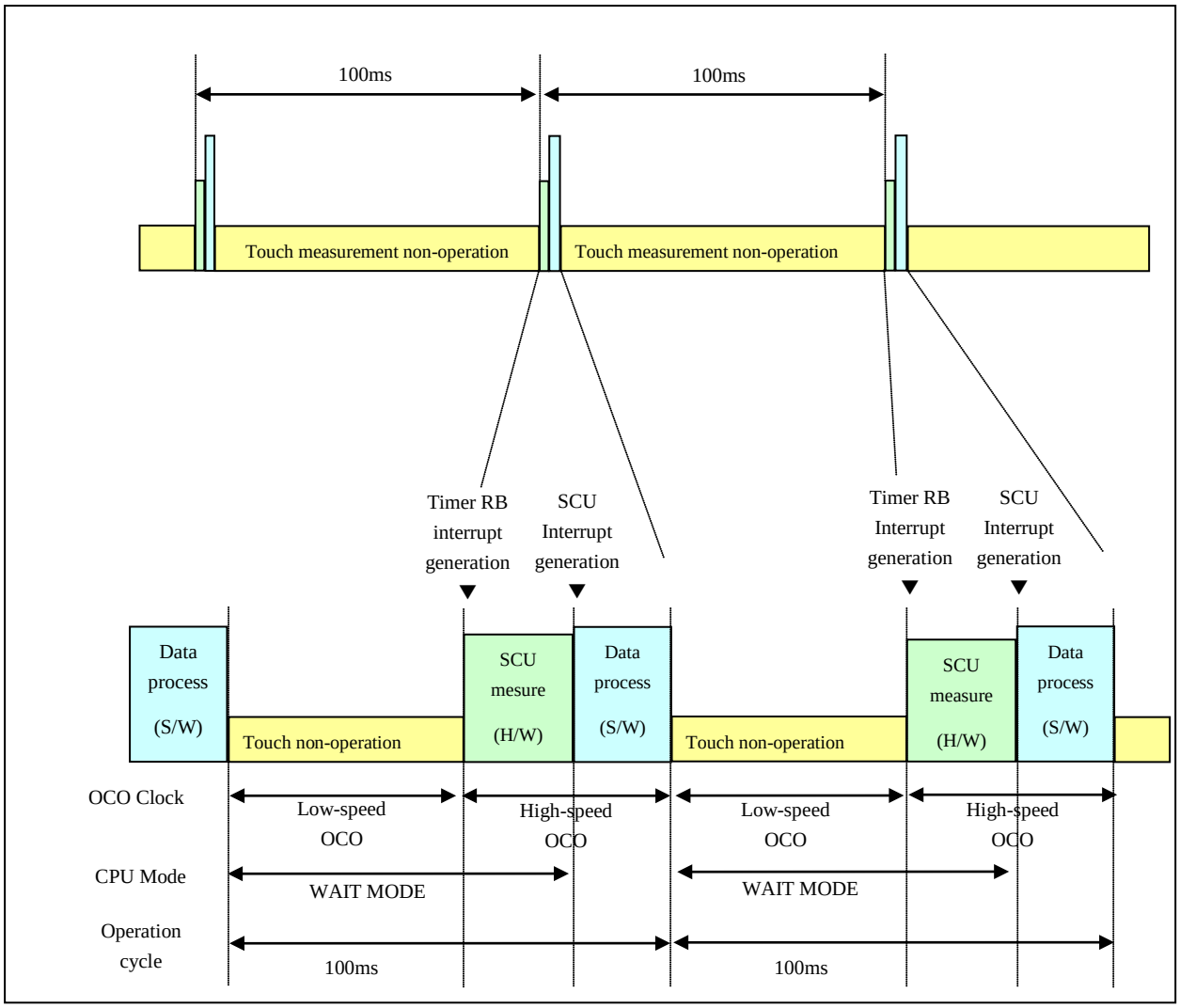

Figure 2 Processing for low power consumption / Timing diagram

Figure 2 shows the timing diagram of processing for low power consumption.

- The generation Timer RB Interrupt makes CPU wake-up from WAIT MODE, so it is necessary to set CPU WAIT MODE again to measure the values by SCU with WAIT MODE.
- SCU Clock should be 4MHz or 5MHz while SCU measurement, so it is necessary to set OCO High-speed from Low-speed at Timer RB interrupt process.
- If the processes of the average measurement data calculation, the drift compensation delete from SCU interrupt process, it is possible further reducing power consumption because CPU working time is shorter than before.

2.3.2 Outline flow chart

（1）The main processing

Figure 3 shows the outline flow of the main process. Please refer to "2.4.1 main process" for details.

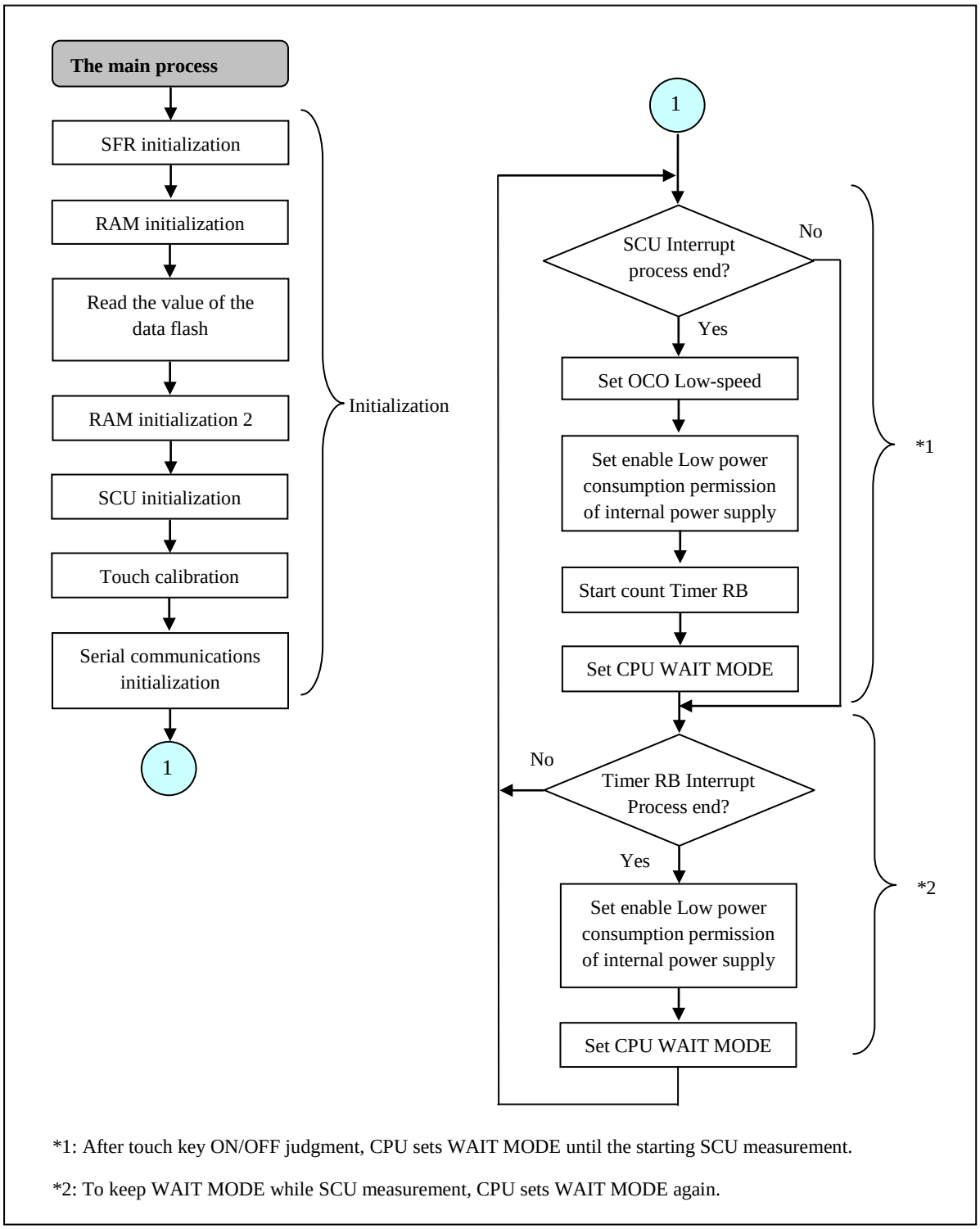

Figure 3 Outline flow of the main processing

（2） SCU Interrupt Process

Figure 4 shows the outline flow of SCU interrupt. Refer to "2.4.2 SCU interrupt" for details.

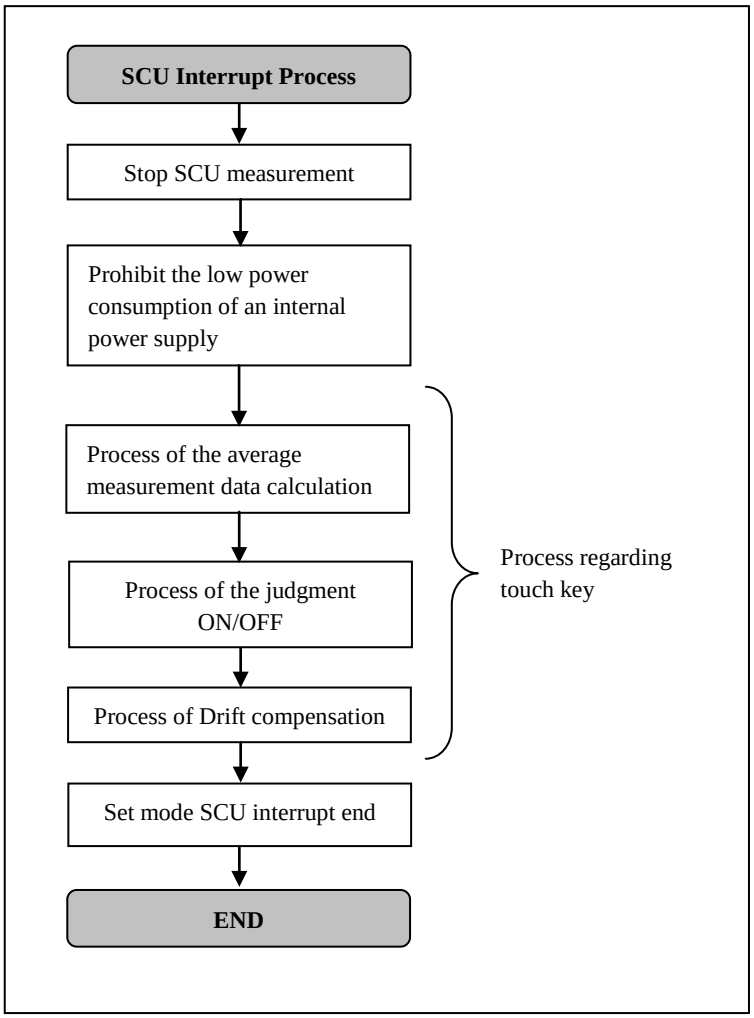

Figure 4 Outline flow of SCU interrupt

（3） Timer RB Interrupt Process

Figure 5 shows Timer RB interrupt outline flow. Please refer to "2.4.3 Timer RB interrupt" for details.

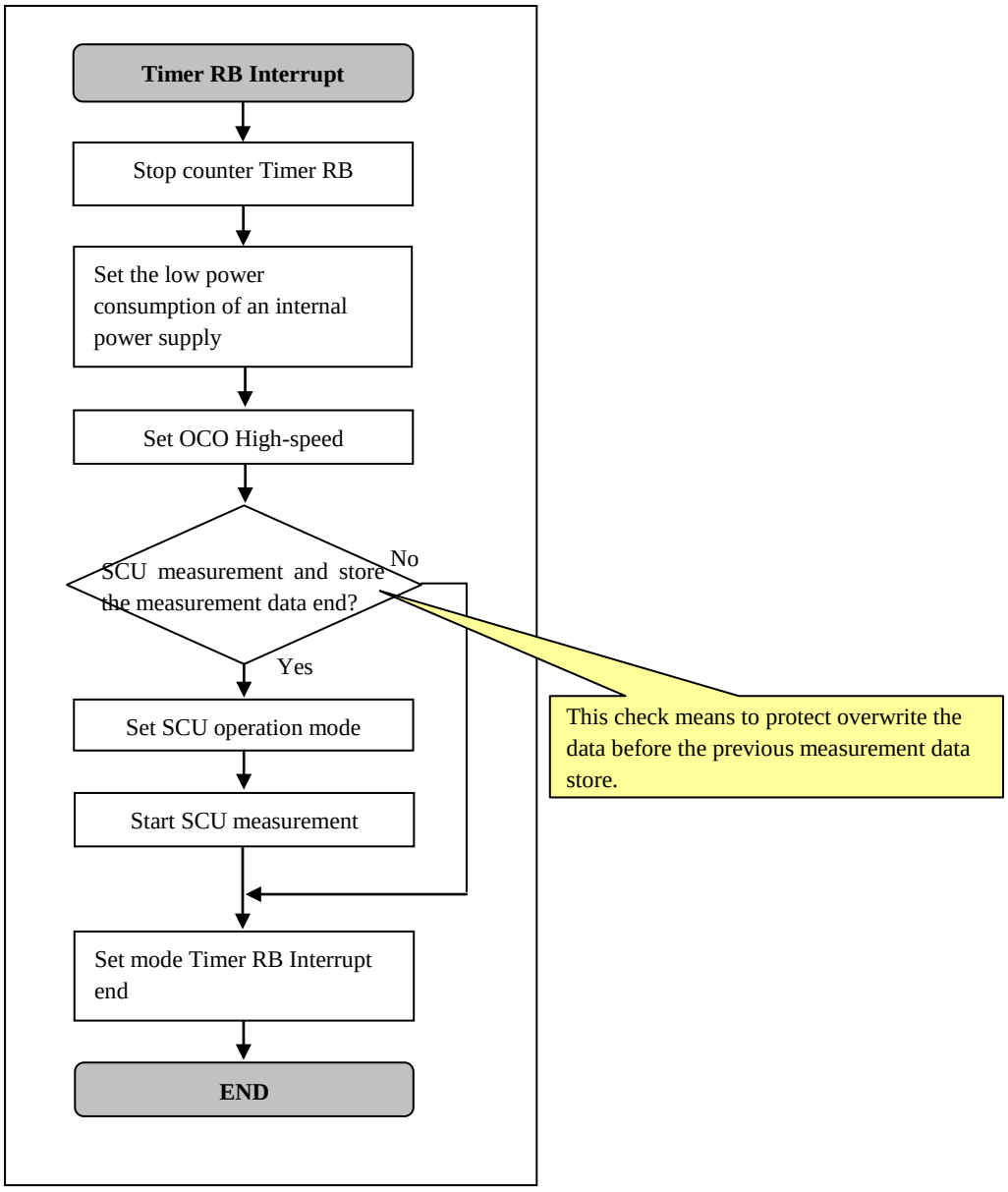

Figure 5 Outline flow of Timer RB interrupt

2.4 Source code (excerpt)

We explain the part of the main process, SCU process and timer RB process regarding the low power consumption as follows.

2.4.1 The main process

The source code regarding the low power consumption is shown in Figure 6.

< Content of process >

- It is process that switches CPU to WAIT MODE , and also switches CPU to WAIT MODE during "SCU measurement period" and "Idling period" because Timer RB interrupt makes CPU wake-up.
- SCU clock should be 4MHz or 5MHz when it is measuring the data, so OCO should set High-speed from Low-speed when SCU will start measurement.

```
if( scu_int_end == on ){                    // check SCU int end
      scu_int_end = off;                    // mode clear
      prcr = 0x09;                          // CM0、CM1、OCD、FRA0、FRA1、FRA2、
                                            //  VCA2、VW0C、VW1C、VW2C write enable
      fra01 = 0;                            // Low-speed oco select
      fra00 = 0;                            // High-speed oco disenable
      vca20 = 1;                            // Internal power supply low power consumption
                                            //  enable bit
      prcr = 0;                     // CM0、CM1、OCD、FRA0、FRA1、FRA2、VCA2、
                                            //  VW0C、VW1C、VW2C write desable
      tstart_trbcr = 1;             // Timer RB count start
      fmr01 = 0;                            // CPU rewriting mode is invalidity
      asm( "FSET I" );              // Interrupt enable
      asm( "WAIT" );                        // wait mode
      asm( "nop" );                         // 1 cycle wait
      asm( "nop" );                         // 1 cycle wait
      asm( "nop" );                         // 1 cycle wait
      asm( "nop" );                         // 1 cycle wait
 }
 if( trb_int_end == on ){                   // check timer RB int end
      trb_int_end = off;            // mode clear
      prcr = 0x09;                          // CM0、CM1、OCD、FRA0、FRA1、FRA2、
                                            //  VCA2、VW0C、VW1C、VW2C write enable
      vca20 = 1;                            // Internal power supply low power consumption
                                            //  enable bit
      prcr = 0;                     // CM0、CM1、OCD、FRA0、FRA1、FRA2、
                                            //  VCA2、VW0C、VW1C、VW2C write desable
      fmr01 = 0;                            // CPU rewriting mode is invalidity
      asm( "FSET I" );              // Interrupt enable
      asm( "WAIT" );                        // wait mode
      asm( "nop" );                         // 1 cycle wait
      asm( "nop" );                         // 1 cycle wait
      asm( "nop" );                         // 1 cycle wait
      asm( "nop" );                         // 1 cycle wait
}
```

Figure 6 Source code of the main processing (excerpt)

2.4.2 SCU Interrupt Process

The source code of SCU Interrupt Process regarding the low power consumption is shown in Figure 7.

< Content of processing >

- When SCU measurement of the H/W control ends, this interrupt generates.
- When SCU non-operates, all touch CH (ports) set output Low for low power consumption.
  It means SCU sets prohibition. (Output Low has been set in initial process.)
- The multiple interrupt is permitted in this source code.
- The internal power supply low power consumption mode prohibit because OCO should set High-speed in this process.
- Setting CPU WAIT MODE in the main process, SCU interrupt end sets ON after all processes are over.

```
#pragma INTERRUPT      Int_Measure
void Int_Measure( void )
{
        scue = 0;                       // SCU enable bit -> disenable
        prcr = 0x09;                    // CM0、CM1、OCD、FRA0、FRA1、FRA2、VCA2、
                                        //  VW0C、VW1C、VW2C write enable
        vca20 = 0;                      // Internal power supply low power consumption
                                        //  enable bit
        prcr = 0;               // CM0、CM1、OCD、FRA0、FRA1、FRA2、VCA2、
                                        //  VW0C、VW1C、VW2C write disenable
        asm( "FSET I" );        // interrupt enable
        FT_Add_M_Ave();                 // Make Ncount-value
        Make_Cthr();                    // Make ON/OFFdecision-value
        on_off_judgement();             // ON/OFFjudgement
        correct_sub( cCh,sDci); // Drift correction
        if (sif == ON) {
                sif = OFF;              // SCU interrupt factor clear
        }
        scu_int_end = on;       // set SCU int end mode
}
```

Figure 7 Source code of SCU interrupt processing (excerpt)

2.4.3 Timer RB Interrupt

Figure 8 shows the content of Timer RB Interrupt process.

< Content of processing >

- OCO sets High-speed for SCU measurement with 5MHz (Or, 4MHz),.
- CPU clock can select 20MHz or 5MHz (switchable).
- When the condition of "SCU measurement end" and "S/W processing end" becomes complete, SCU measurement permit and restart.
- Setting CPU WAIT MODE in the main process, Timer RB Interrupt end sets ON after all processes are over.

```
#pragma   INTERRUPT      Int_Trb
  void    Int_Trb(void){

          tstart_trbcr = 0;          // Timer RB count stop
          prcr = 0x09;                        // CM0、CM1、OCD、FRA0、FRA1、FRA2、
                                              //  VCA2、VW0C、VW1C、VW2C write enable
          vca20 = 0;                          // Internal power supply low power consumption
                                              //  enable bit
          fra00 = 1;                          // High-speed oco enable
          for(wait=0; wait<0x02; wait++) //500us// Waitting for stable of oscillation
          {
                  _asm("nop");
          }
          fra01 = 1;                          // High-speed oco select
  #if USE_CPU_20MHz == 1
          fra2 = 0x00;                        // Divide-by-2 mode (20MHz)
  #else
          fra2 = 0x06;                        // Divide-by-8 mode (5MHz)
  #endif
          prcr = 0;                  // CM0、CM1、OCD、FRA0、FRA1、FRA2、VCA2、
                                              //  VW0C、VW1C、VW2C write desable
          if( scstrt == OFF
          && sif == OFF
          ){
                  scue = 1;                   // SCU enable bit -> enable
                  scstrt = ON;                // SCU Measurement starting
          }
          trb_int_end = on;          // set timer RB int end mode
  }
```

Figure 8 Source code of Timer RB interrupt processing

3. Reducing the power consumption by the intermittent operation using Watchdog timer

The watch dog timer is built into this microcomputer, and it works regardless of state (stop/wait) of CPU when the operation at the underflow is assumed to be "Reset". Because Watch dog timer count source is special Low-speed OCO, the power consumption is less than using OCO for CPU. Using Watch dog timer makes even lower power consumption.
We explain the example of operating the touch detection by intermittent operation using the Watchdog timer as follows.

3.1 Operation condition

The operation conditions of the firmware using the Watchdog timer are as follows.

- The touch detection and the ON/OFF judgment are executed by using the Watchdog timer at constant intervals.
- The operation conditions of the Watchdog timer are as follows.
  ① Count Source Protection Mode is enable. It means count source is Low-speed OCO(125KHz) for the Watchdog timer.
  ② Operations at underflow is "Watchdog timer reset".
  ③ 【3FFFh】 setting of underflow cycle of Watchdog timer.
- It is necessary to initialize the register because Watchdog makes CPU reset. Even reset, the data of RAM holds before reset to pass the process of RAM clear.
  (We have to consider that whether RAM data keeps before reset because some other factor may reset the CPU.)
- CPU clock is 5MHz of High-speed OCO.
- When the SCU does not work and CPU does not have any processes, CPU sets STOP MODE and waits for reset by the Watchdog timer. The Watchdog timer down counts Low-speed OCO (125KHz).
- The touch detection cycle is 147ms.
- The touch detection CH are 15. (22ch scan mode and 7ch prohibit.)
- When SCU non-operates, all touch CH (ports) set output Low for low power consumption.

3.2 Result of a measurement of current consumption

Table 2 Result of a measurement of current consumption

Operational mode	MCU clock	Operation time	Current consumption
Reset & initialization	125KHz	9.0ms	220uA
SCU measurement (WAIT MODE)	5MHz	4.1ms	450uA
CPU operation (Only the ON/OFF judgment)	5MHz	1.0ms	1.3mA
Touch measurement non-operation (STOP MODE)	125KHz	132.9ms	4uA *1

*1: The value described in the hardware manual.

Average current consumption

38.5uA （15ch）

3.3 Processing flow

3.3.1 Flow of processing

The processing flow for low power consumption is shown in Figure 9 (Using Watchdog timer).

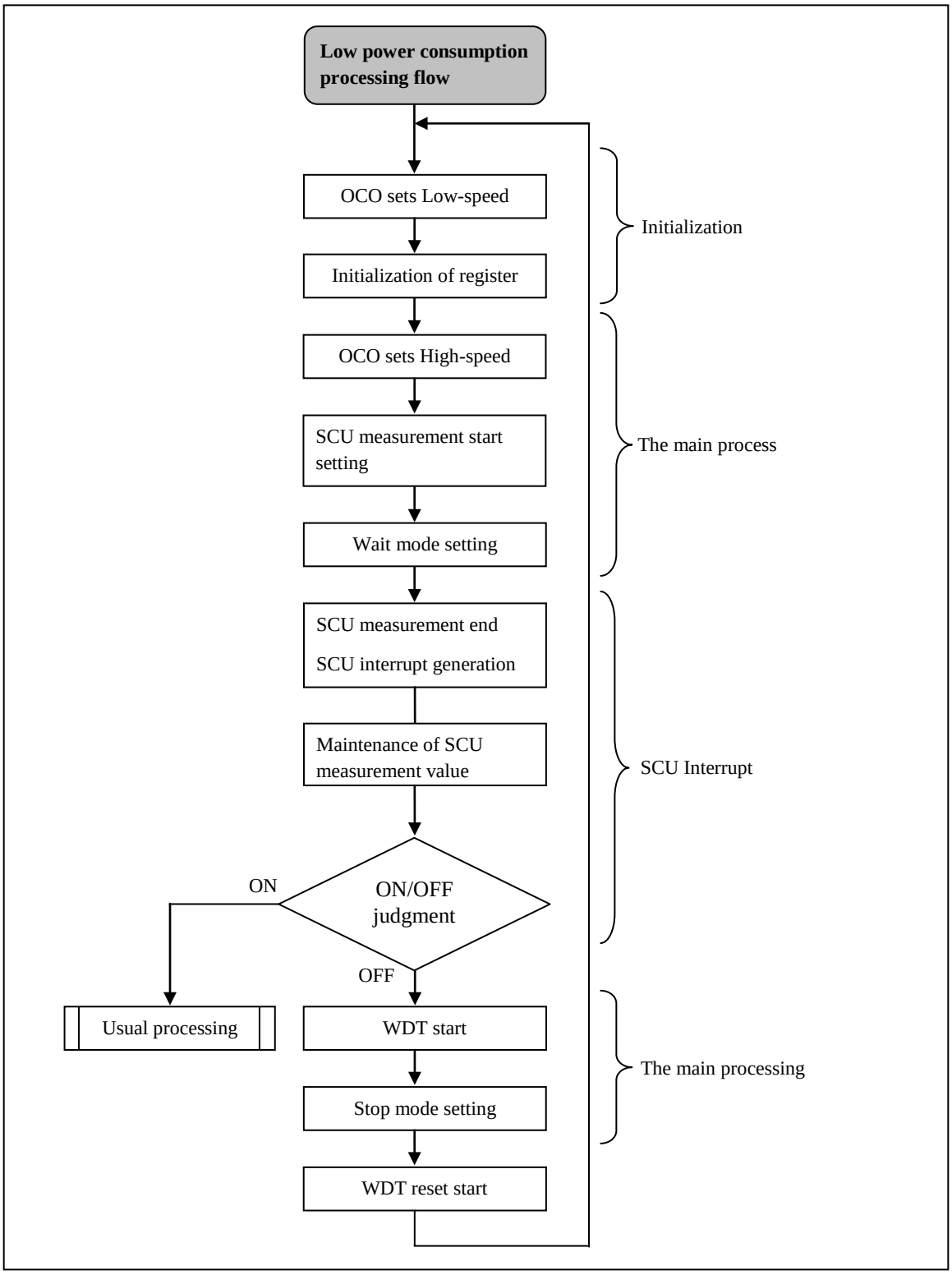

Figure 9 Processing flow for low power consumption (Watchdog timer use)

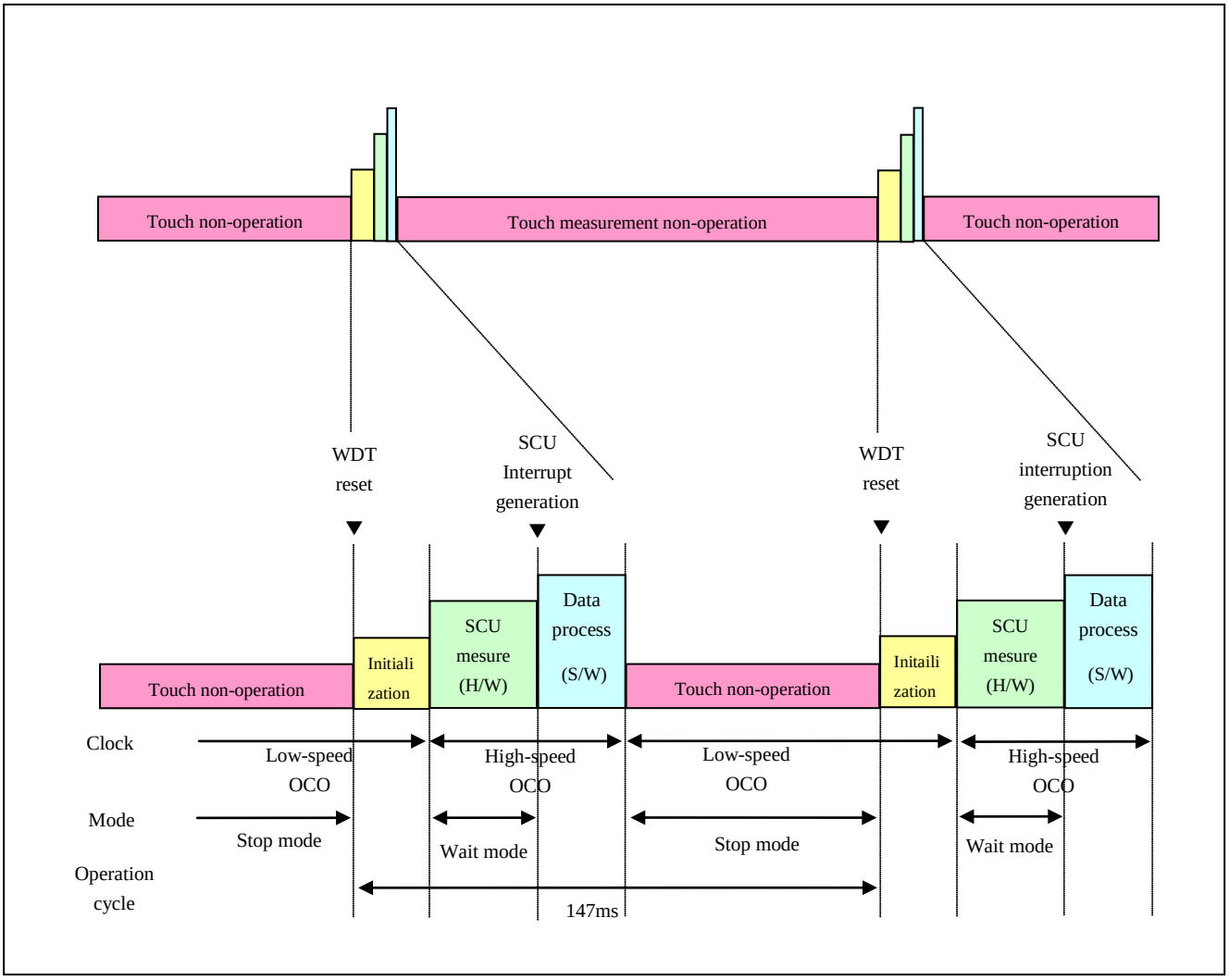

Figure 10 Processing and timing diagram for low power consumption

Figure 10 shows the process timing diagram for low power consumption.

- Initialization is 9ms necessity because it contains "Reset stability waiting of the microcomputer", "S/W start-up", "Initialization of the register", and "Stability waiting of high speed and on the chip oscillator".
- SCU measurement and touch ON/OFF judgment are processed with High-speed OCO.
- It counts down with low-speed OCO of the watch dog timer when the touch detection non-operates though it is stop mode.

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	May 22. 2013	—	Numbering change (Contents is as same as R01AN0345EJ0100)

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   Handle unused pins in accord 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
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4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.
5. Differences between Products
   Before changing from one product to another, i.e. to one with a different type number, confirm that the change will not lead to problems.
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