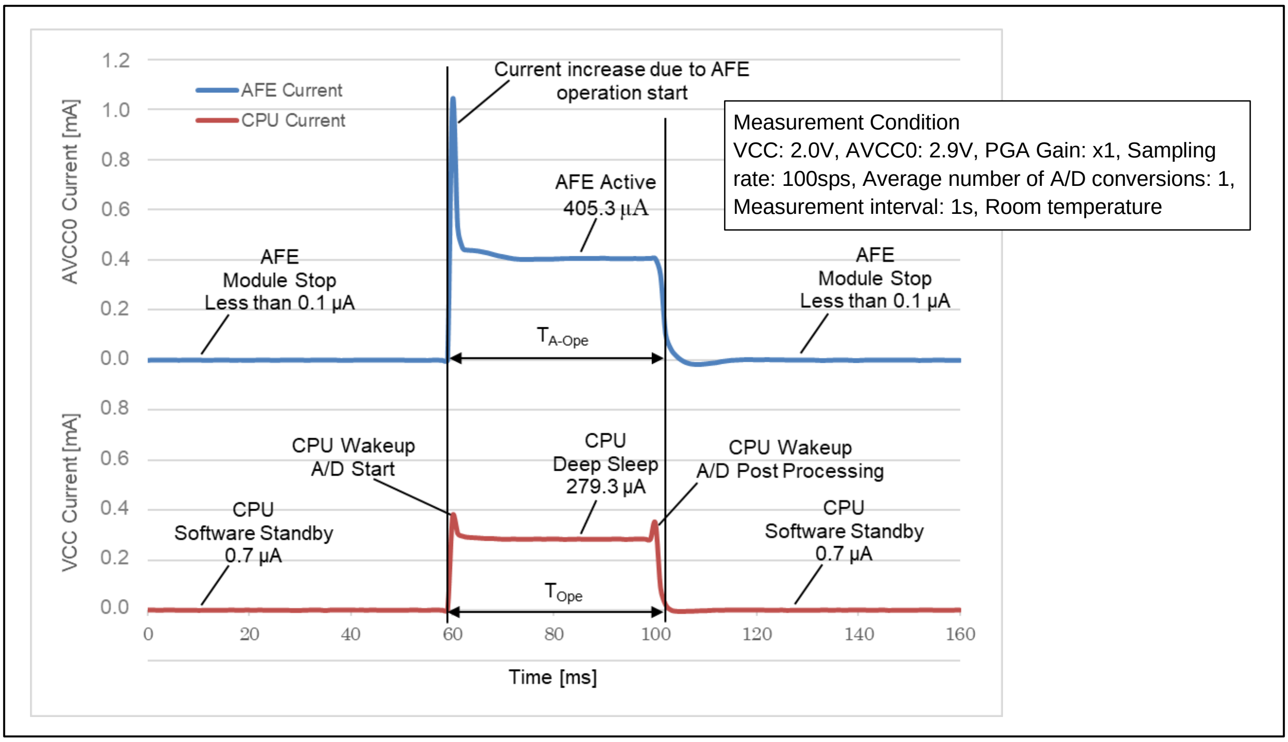
# RX23E-A Group

## Usage of Low Power Function for sensor measurement


### Summary

This document describes a method to reduce power consumption by combining low power consumption functions and intermittent operation. The RX23E-A is an MCU that integrates an analog front end (AFE) and a CPU on a single chip. The 24-bit Δ-Σ A/D converter (DSAD) mounted on the AFE section has a low power mode in addition to a normal mode. The CPU has a deep sleep mode and a software standby mode. Combining these low power consumption functions of the RX23E-A with intermittent operation makes it possible to support low power applications. In this document, we actually measured the current consumption using an RSSK board and a sample program that implements low power consumption functions and intermittent operation.

For the AFE section, current consumption is reduced by stopping the AFE module during standby. For the CPU section, current consumption is reduced by minimizing CPU operation time by switching to software standby mode during standby and deep sleep mode during A/D conversion. Converted into power, this is equivalent to 0.005mW for the AFE section and 0.002mW for the CPU section, for a total of 0.007mW. The RMS noise during measurement was 4.642µVrms (20.04bit), confirming that noise performance was obtained.


**Current consumption measurement example**

Target applications

Battery-powered wireless and portable instruments

— Temperature sensor, Strain gauge, Gas detector, Liquid analyzer

### Target device

RX23E-A (R5F523E6ADFL)

## Contents

# 1. Overview

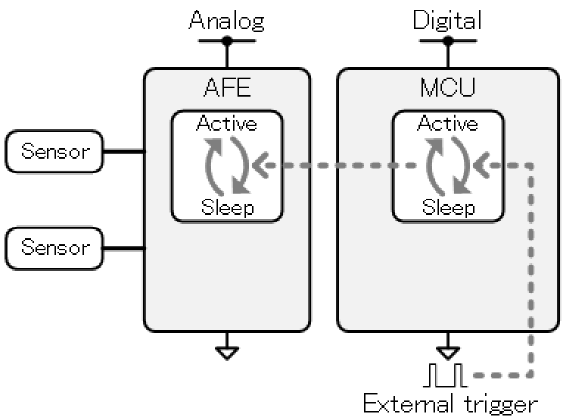
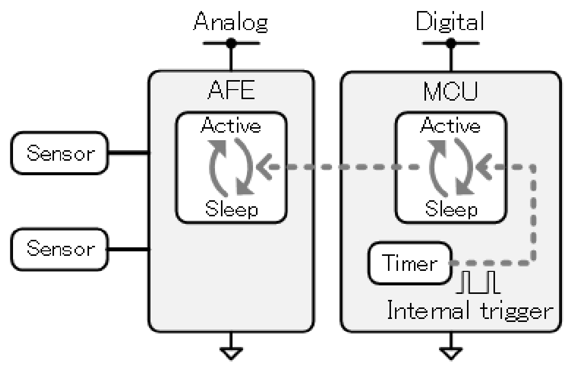
The application assumed to be targeted by this document is a battery-powered wireless portable measuring instrument, which requires both low power consumption performance and measurement accuracy. In such instruments, it is important to keep each power consuming function such as sensors, AFE, and MCU operating at the minimum necessary while keeping the entire system operating efficiently.

One of the methods to reduce power consumption of measuring instruments is intermittent operation. In intermittent operation, the system periodically repeats the operation that stops the MCU and/or AFE, shifts to the low-power consumption state, and resumes only the necessary section to the normal state if necessary. When measuring, the system shifts from the low-power state to the normal state. The state transition is triggered by the interrupt request signal from the on-chip timer or the external input signal. Examples of external input signal sources are host system, RTC, and so on.

Table 1-1 shows an example of a measurement instrument system with intermittent operation. The difference between configuration 1 and 2 is the method to generate the interrupt request signal for intermittent operation, and the others are the same. The system configuration 1 receives the signal from outside of the MCU, and the system configuration 2 uses the MCU on-chip timer.

The method to receive the signal from outside of the MCU (Table 1-1, System configuration 1) requires a host system or RTC outside of the MCU, but it allows flexible operation because it does not use an MCU on-chip timer. On the other hand, the method to use a MCU on-chip timer (Table 1-1, System configuration 2) does not need additional components, but there are some limitations due to the number or performance of the MCU timers.

**Table 1-1 Examples of intermittent operation measurement system**

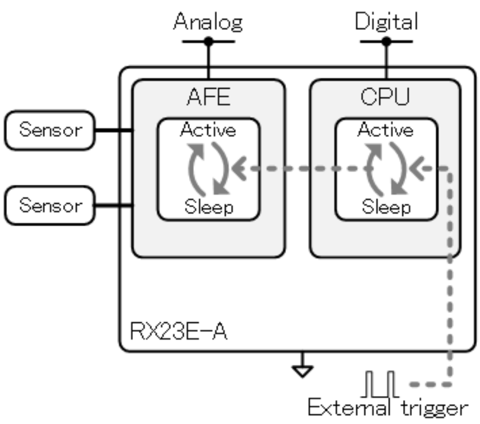
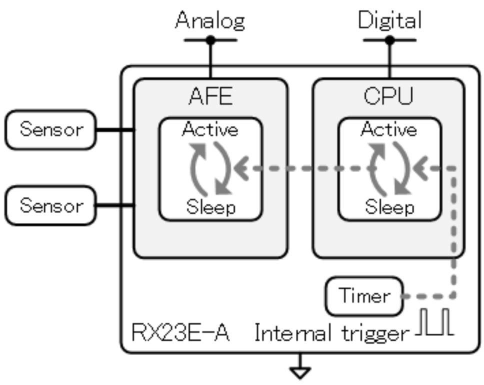
| System configuration1 (External Trigger) | System configuration2 (Internal Trigger) |
|---|---|
| The external trigger switches the operation of the AFE and/or MCU.   | The internal trigger switches the operation of the AFE and/or MCU.   |

RX23E-A is an MCU with various power-saving functions to implement low-power operation.

Table 1-2 shows examples of the portable battery-powered measurement system with intermittent operation by RX23E-A. As shown in Table 1-2, RX23E-A enables the intermittent measurement system shown in Table 1-1. For details on RX23E-A power-saving functions, low-power timer, and DSAD, refer to the related section in RX23E-A Group User's Manual: Hardware.

11. Low Power Consumption
26. Low-Power Timer (LPT)
34. 24-bit Delta-Sigma A/D Converters (DSADA)

**Table 1-2 Examples of intermittent operation measurement system using RX23E-A**

| **Item** | **System configuration1 (External Trigger)** | **System configuration2 (Internal Trigger)** |
|---|---|---|
| System configuration diagram | The external trigger switches the operation of the AFE and/or CPU.<br> | The internal trigger switches the operation of the AFE and/or CPU.<br> |
| System features | As it should receive the measurement timing externally, additional components (MCU, RTC module, etc.) are required. | As no need to receive the trigger signal externally, no need for external device to generate the measurement interval, nor wiring. |
| Measurement trigger generation/ Measurement cycle | Optimal components to input measurement trigger externally can be selected based on the product specification. The measurement interval can be set in a wider range (from several hundreds of msec to several years). | It can be generated by the LPT built in RX23E-A. The measurement cycle can be set within the LPT specification (139 sec Max.). For over 139-sec cycle, use a software counter together. |
| Power consumption | As an external module such as RTC is used, the power consumption is increased by that amount. | To measure at an interval that exceeds the LPT time setting, software counting process is required, and the power consumed by CPU is increased. |

## 1.1 Application to RX23E-A

This document describes an example of using the power-saving functions of RX23E-A and how to perform A/D conversion with intermittent operation. As the RX23E-A power-saving function, the software standby mode and deep sleep mode, module stop function are used. The interrupt request to return from software standby mode to the normal state supports 1. Internal trigger (on-chip timer), and 2. External trigger (external input).

To operate intermittent measurement, the system is in the deep sleep mode during measurement operation, and the system is in the software standby mode when waiting (during low-power operation).

The sample program runs on the RSSK board, and PC tool Program allows users to configure the measurement conditions, perform calibration, and obtain the measurement results. Can store the measurement data up to 4096. Figure 1-1 shows an example of RX23E-A low-power measurement system.

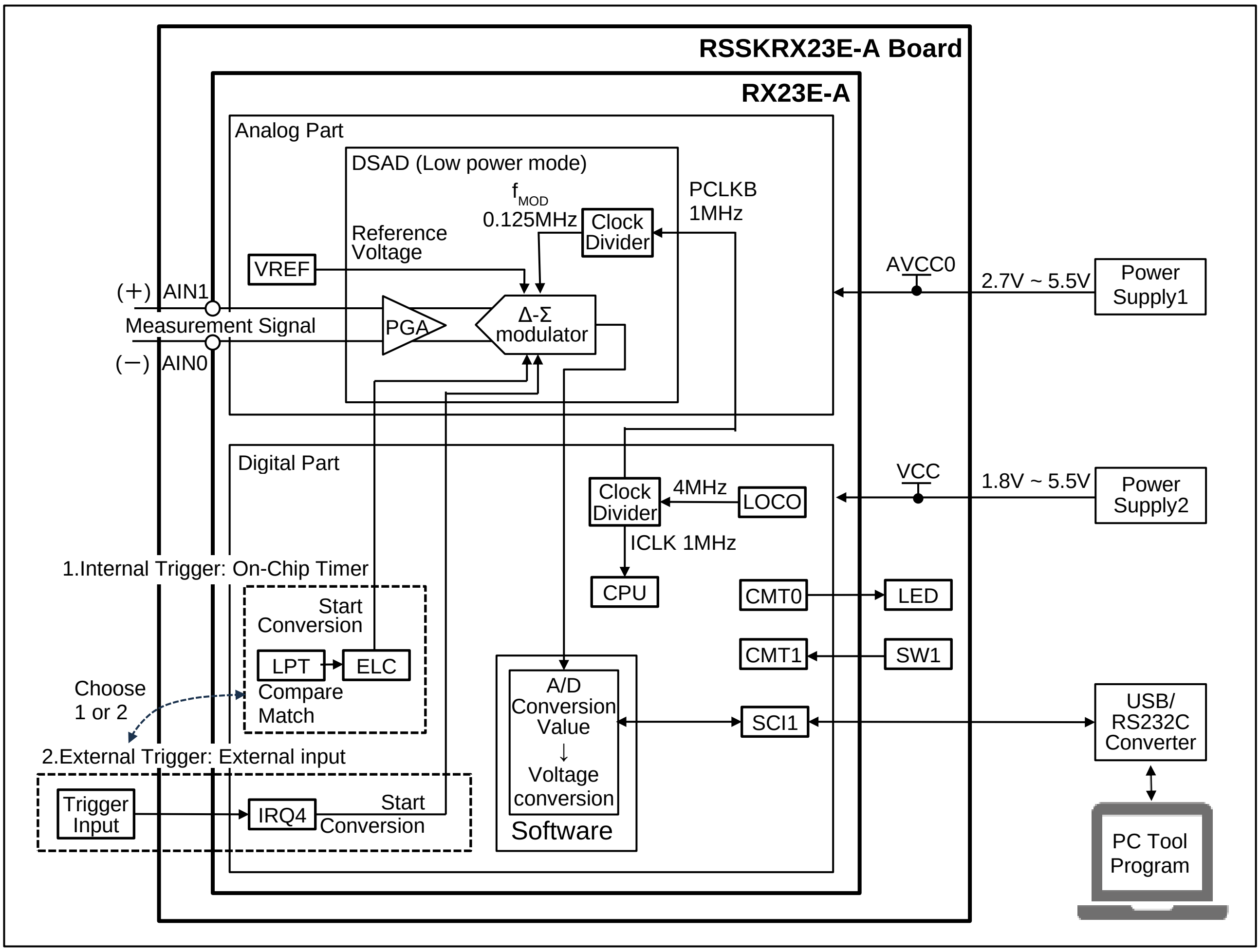



**Figure 1-1 Example of RX23E-A low-power measurement system**

## 1.2 How to Select Measurement Trigger

This sample program supports both internal and external triggers. To switch the measurement trigger, compile it under the condition in Table 1-3. After compiling, write the sample program to RX23E-A. Compiled object programs (*.mot files) for each measurement trigger are also included in the sample program set.

**Table 1-3 Operable items (macro setting change)**

| Compile condition | | Operation specification |
|---|---|---|
| $e^2$ Studio | Internal Trigger: set on-chip timer<br>[Build configuration] -> [Active] -> [Use LPT], and compile | Measurement cycle<br>1 sec: fix pin PB1 to High<br>5 min: fix pin PB1 to Low |
| | External Trigger: set external input<br>[Build configuration] -> [Active] -> [Use IRQ4], and compile | Measurement cycle<br>Depends on the external trigger. A/D measurement is triggered when detecting the external input rising edge. |

Note: This system performs A/D conversion at 100SPS (=every 10ms). Settling takes about 40ms, so this system does not assume triggers with the interval less than 40ms.

## 1.3 Operating Mode and Setting Values

This system has three operating modes. Table 1-4 shows the functions of each mode. The initial setting is No.1 Data acquisition mode, and the modes can be switched as “No.1→No.2→No.3→No.1…” with SW1 of RSSK. In communication mode, you can change settings and obtain measurement data by connecting to a PC using the Windows GUI program PC Tool Program.

**Table 1-4 Operating mode**

| No. | Name | | LED1 state | Main operation | PC Tool Program operation TAB |
|---|---|---|---|---|---|
| 1 | Communication mode | Data acquisition mode | Blinking at intervals of 0.25sec | Transmission of measured data (voltage value) | Application TAB |
| | | | | Alert threshold setting | Application TAB |
| 2 | | Measurement setting mode | Blinking at intervals of 0.5sec | Register setting | Resisters TAB |
| | | | | Calibration | Resisters TAB |
| 3 | Measurement mode | Measurement mode | OFF | A/D measurement by intermittent operation, voltage conversion | No connection to PC Tool Program |

### 1.3.1 Operable Items in Data Acquisition Mode

Table 1-5 and Figure 1-2 shows the operable items in the data acquisition mode.

**Table 1-5 Operable items of Data acquisition mode**

| Operation target | | Item | Operation |
|---|---|---|---|
| PC Tool Program | Top of the TAB | Connect/Disconnect | Press Connect/Disconnect button. |
| | Application TAB | Setting of alert threshold for measured voltage | Command Value text box [Note], Set button<br>Setting range: 0-10[V] (Initial value:10[V]) |
| | Application TAB | Get measurement data | Press Run button to get measurement voltage data stored in memory. |
| | Application TAB | Measurement data output | Lists measurement data. The range of the list can be selected and copied in CSV format. |

Note: Due to the specifications of PC Tool Program, the setting value cannot be read when connecting to PC, and the initial value of the sample program is set to 10V.

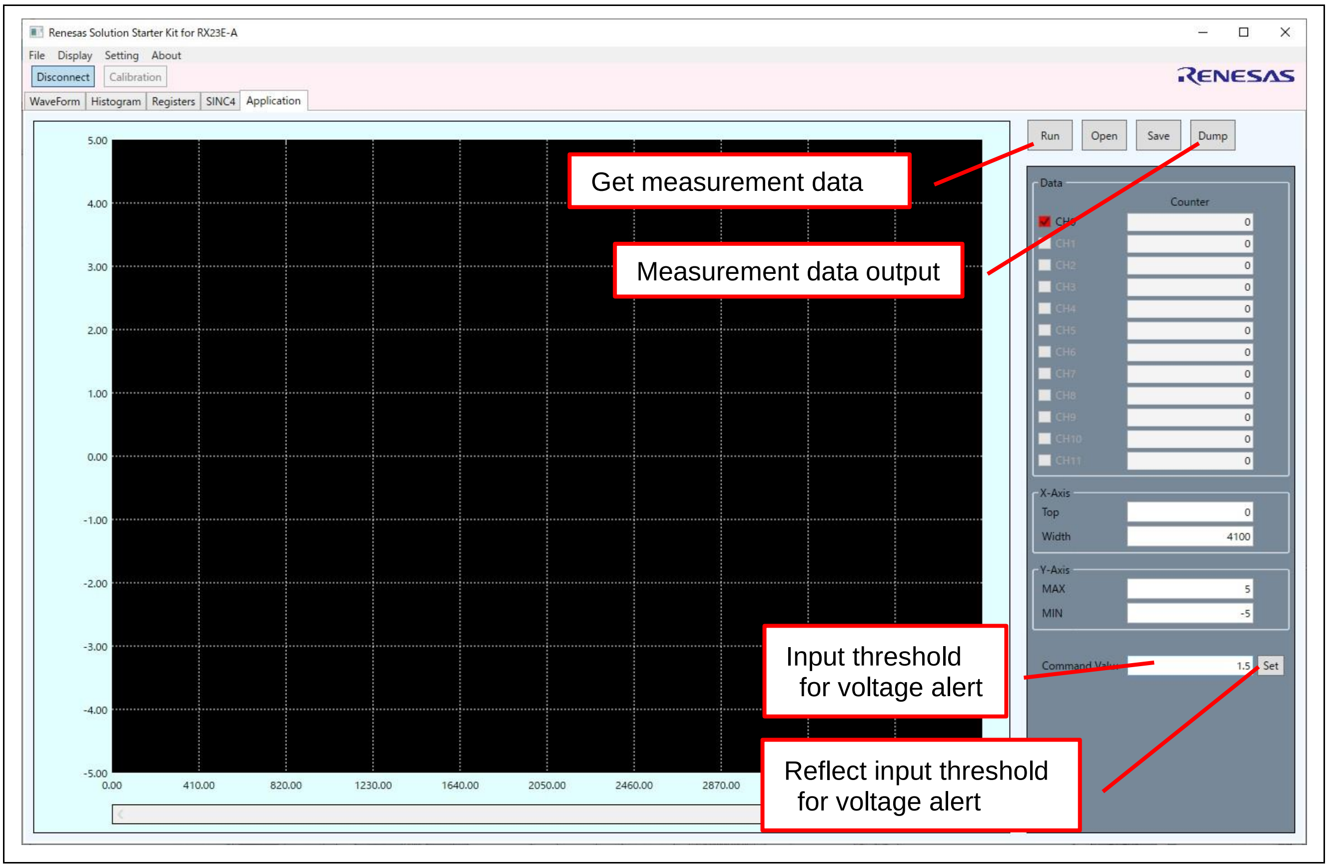



**Figure 1-2 PC Tool Program Application TAB**

### 1.3.2 Operable Items in Measurement Setting Mode

Table 1-6 and Figure 1-3, Figure 1-4 show the operable items in the Measurement Setting mode.

**Table 1-6 Operable items of Measurement setting mode[Note2]**

| Operation target | | Item | Operation |
|---|---|---|---|
| PC Tool Program | Top of the TAB | Connect/Disconnect | Press Connect/Disconnect button |
| | SINC4 TAB, Resisters TAB | DSAD0 averaging count setting | After setting the averaging count on SINC4 TAB, press the Apply button to move to Register TAB, and press the Set button.<br>Initial value: 1 Setting value: 1 or 16 |
| | Resisters TAB | AFE power supply mode setting | Select from the DSADLVM pull down list and press the Set button.<br>Initial setting: 2.7V <= AVCC0<br>Setting: 2.7V <= AVCC0 or 3.6V <= AVCC0 |
| | Resisters TAB | DSAD0 PGA gain setting | Select the setting value and press the Set button.<br>Initial value: 1, Setting value: 1 or 128 |
| | Top of the TAB | Calibration[Note1] | Press the Calibration button. |
| | Resisters TAB | Calibration correction value setting | After calibration, check the checkmarks on GCR0 and OFCR0 in Register TAB and press the Set button. |

Notes: 1. Calibration can be performed when RSSK and the PC are connected AND in Measurement setting mode. For details on calibration, refer to RSSKRX23E-A PC Tool Program Operation Manual. If the power is turned off, the calibration correction value is deleted. When supplying the power again, perform calibration again. When the gain is changed, calibration is required as well. For the calibration condition for this evaluation, refer to 7.2.

2. If you configure settings other than those specified, it may not operate correctly.

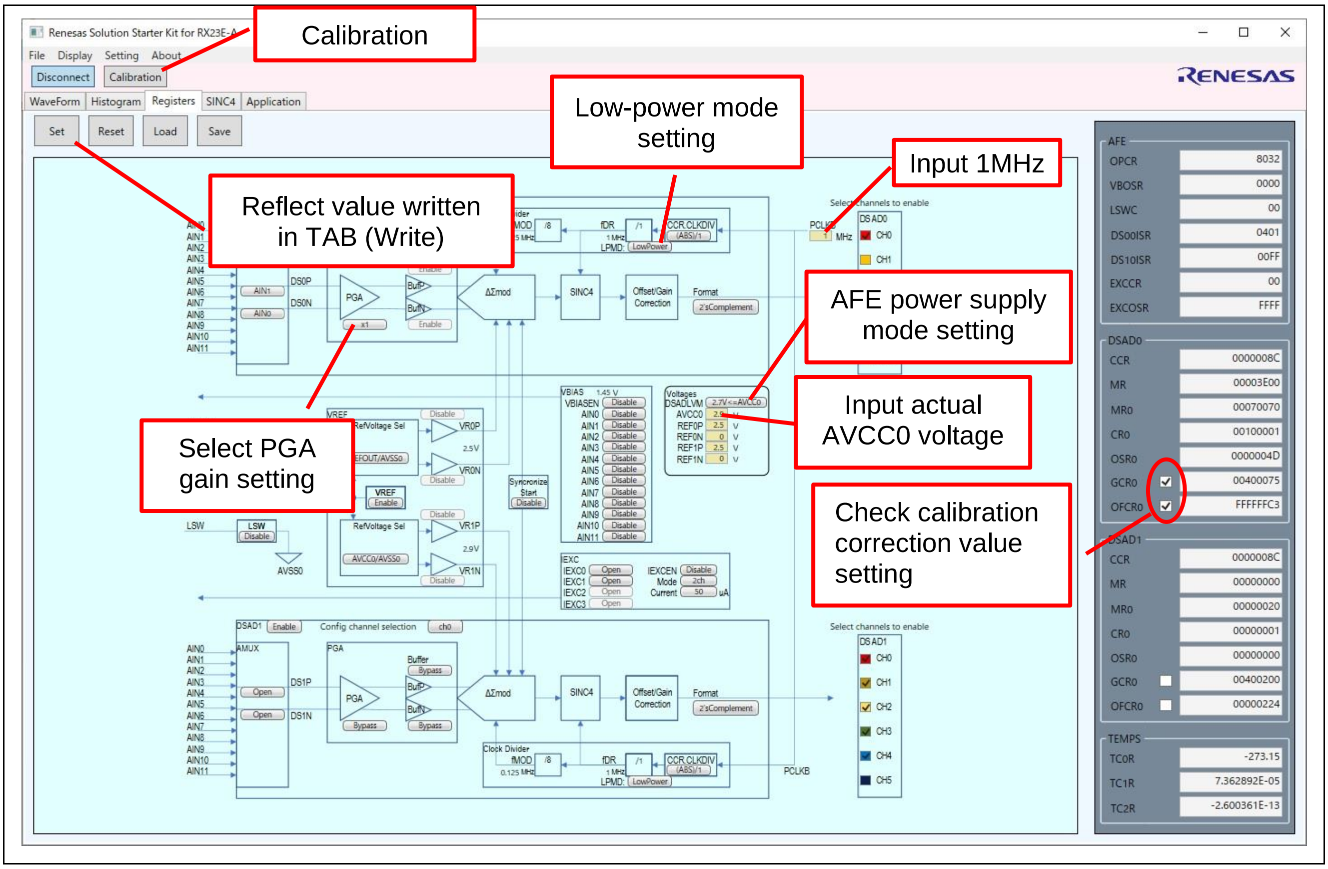



**Figure 1-3 PC Tool Program Resister TAB**

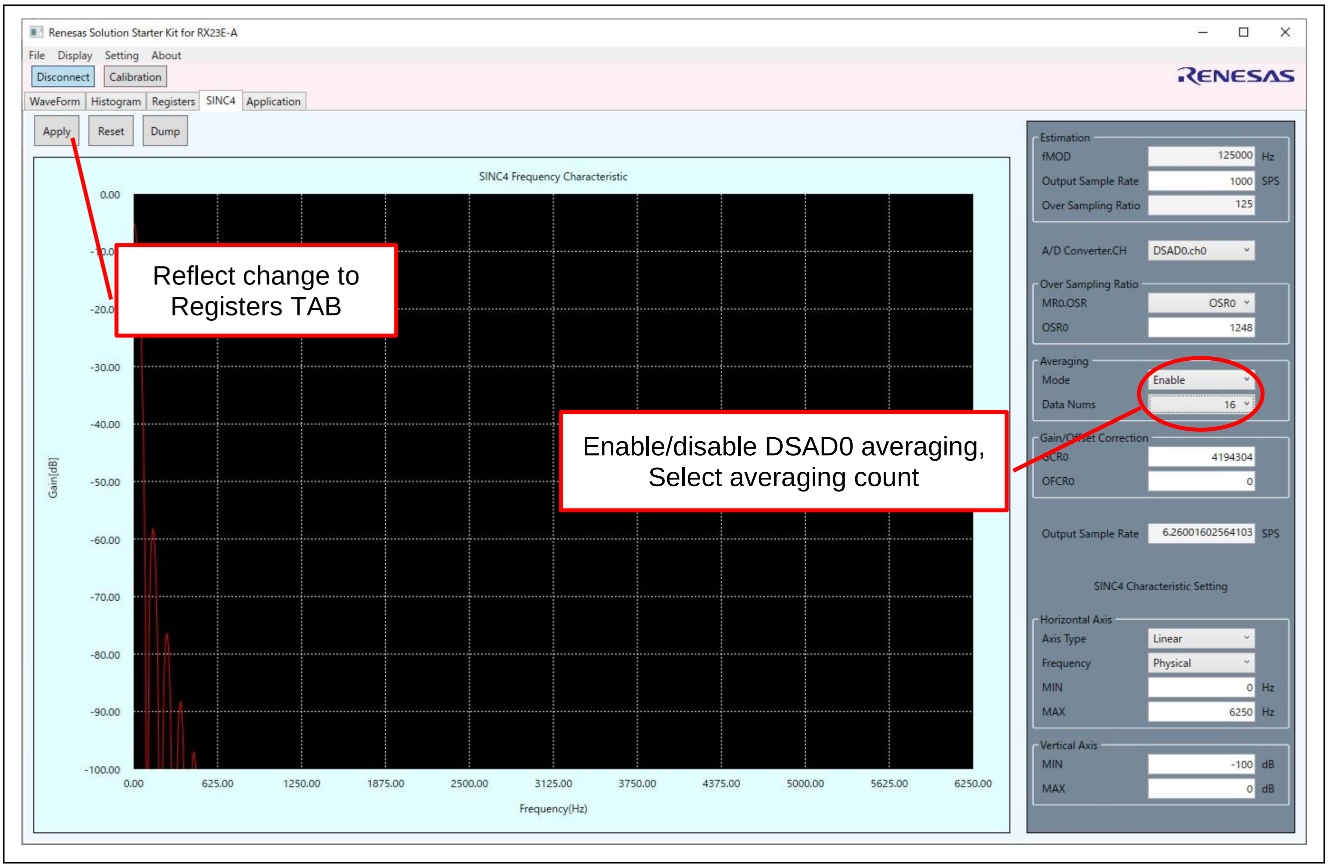



**Figure 1-4 PC Tool Program SINC4 TAB**

## 1.4 Measurement Procedure

Table 1-7 shows the measurement procedure of this system.

**Table 1-7 Low power measurement system Measurement procedure**

| No | Item | Description |
|---|---|---|
| 1 | Evaluation preparation | change the RSSK board by referring to 4.1. |
| 2 | Power on | Apply power to the RSSK board. |
| 3 | Measurement settings | Set AFE and DSAD from PC Tool Program. The configurable values and setting method are described in 1.3.2.Check that the LED is flashing at 1 sec intervals. |
| 4 | Calibration | Perform calibration before measurement. It is necessary to set the low-power offset correction value and gain correction value for the DSAD low-power mode. The calibration conditions for the evaluation results in this APN are listed in Table 7-6. For details, please refer to 1.3.2 and the RSSKRX23E-A PC Tool Program Operation Manual. Make sure that the LED is flashing at 1 sec intervals. |
| 5 | Measurement | Measure under the conditions set in step 4. |
| 6 | Data acquisition | After connecting to the PC Tool Program, you can check the results in the Application tab. For details, see 1.3.1 and the RSSKRX23E-A PC Tool Program Operation Manual. Make sure the LED is flashing at 0.5 sec intervals. |

## 2. Environment for Operation Confirmation

**Table 2-1 Environment for Operation Confirmation**

| Item | | Description |
|---|---|---|
| Board | | RSSKRX23E-A board (RTK0ESXB10C00001BJ) |
| | MCU | RX23E-A (R5F523E6ADFL)<br>Power voltage<br>VCC: 2.0V<br>AVCC0: 2.9V or 5.0V<br>Clock source: LOCO 4MHz<br>Operating frequency (ICLK): 1MHz<br>Peripheral operating frequency (PCLKB): 1MHz<br>DSAD0 modulator clock frequency ($f_{MOD}$): 0.125MHz<br>DSAD0 operating mode: low-power mode |
| RS485-USB I/F | | AE-UM232R (AKIZUKI DENSHI TSUSHO)<br>VCCIO:2.0V |
| IDE | | e2studio 2024-10 (Renesas Electronics)<br>Renesas Smart Configurator V24.10.0 |
| Tool Chain | | Renesas CC-RX V3.06.00 |
| Emulator | | Renesas E2 Emulator Lite (RTE0T0002LKCE00000R) |
| PC Program | | Renesas Solution Starter Kit for RX23E-A Ver2.01 |

Figure 2-1 shows the clock generation circuit of this system. Use LOCO to generate clocks for each operating frequency.

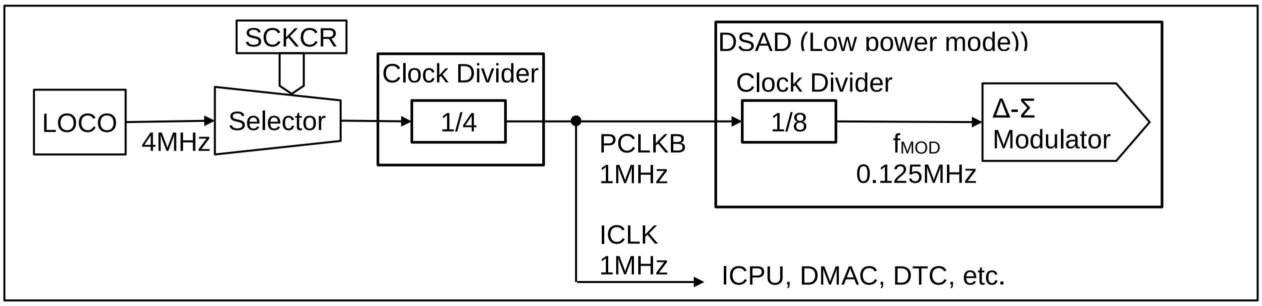



**Figure 2-1 Block diagram of clock generation circuit**

## 3. Related Documents

- R01UH0801 RX23E-A Group User's Manual: Hardware
- R20UT4542 RSSKRX23E-A User's Manual
- R20AN0540 RSSKRX23E-A PC Tool Program Operation Manual

# 4. System Overview

## 4.1 Hardware Configuration

The changes made to the RSSKRX23E-A board are shown in Table 4-1. For details on RSSK, refer to RSSKRX23E-A User's Manual.

**Table 4-1 Changes made to the RSSKRX23E-A board**

| Part reference No. | Before change | After change | Why changed |
|---|---|---|---|
| R52, R58, R59, R66, R70, R89, R90, R98, R99 | 0 | DNF[Note2] | To shut down the unused ICs power supply |
| R64, R65, R94 | 33 | DNF | |
| R95 | 390 | DNF | |
| R56 | 3.9k | DNF | |
| R26[Note1], R69 | 10k | DNF | |
| J2-9, J2-10, J2-11, J2-12, J3-3, J3-4, J3-7, J3-8, J3-9, J3-10, J4-7, J4-9, J5-1, J5-3 | DNF | 10kΩ | To connect pull-up resistors |
| R62, R63 | DNF | 0Ω | J5: for UART pin connection |
| D1, D3 | 40V 2A | DNF | To prevent leakage current of negative direction [Note 3] |

Notes: 1. Remove only when using external input.
2. DNF: Do Not Fit
3. Be careful not to connect the power supply in reverse.

**Table 4-2 Unused pin settings**

| Pin No | Pin name | I/O | Setting |
|---|---|---|---|
| 1 | AIN10 | I | Connect to AVSS0 (Short SO12) |
| 2 | AIN11 | I | Connect to AVSS0 (Short SO13) |
| 6 | P37/XTAL | Hi-Z | Connect to VCC via a resistor (pull up) |
| 8 | P36/EXTAL | Hi-Z | Connect to VCC via a resistor (pull up) |
| 12 | P35/NMI | Hi-Z | Already connected to VCC via a resistor by initial setting |
| 13 | P31/CTS1# | Hi-Z | Already connected to VCC via a resistor by initial setting |
| 17 | P17/SCK1/SDA | Hi-Z | Connect to VCC via a resistor (pull up) |
| 18 | P16/SMOSI1/SCL | Hi-Z | Connect to VCC via a resistor (pull up) |
| 19 | P15/SMISO1/CRXD0 | Hi-Z | Connect to VCC via a resistor (pull up) |
| 20 | P14/SS1#/CTXD0 | Hi-Z | Connect to VCC via a resistor (pull up) |
| 21 | PH3 | Hi-Z | Connect to VCC via a resistor (pull up) |
| 23 | PH1/TXD5 | Hi-Z | Connect to VCC via a resistor (pull up) |
| 24 | PH0/RXD5 | Hi-Z | Connect to VCC via a resistor (pull up) |
| 25 | PC7/MTIOC3A | Hi-Z | Connect to VCC via a resistor (pull up) |
| 26 | PC6/MTIOC3C | Hi-Z | Connect to VCC via a resistor (pull up) |
| 27 | PC5/MTIOC3B | Hi-Z | Connect to VCC via a resistor (pull up) |
| 28 | PC4/MTIOC3D | Hi-Z | Connect to VCC via a resistor (pull up) |
| 36 | LSW | O | Connect to AVSS0 (Short SO1) |
| 41 | AIN2 | I | Connect to AVSS0 (Short SO4) |
| 42 | AIN3 | I | Connect to AVSS0 (Short SO5) |
| 43 | AIN4/REF1N | I | Connect to AVSS0 (Short SO6) |
| 44 | AIN5/REF1P | I | Connect to AVSS0 (Short SO7) |
| 45 | AIN6 | I | Connect to AVSS0 (Short SO8) |
| 46 | AIN7 | I | Connect to AVSS0 (Short SO9) |
| 47 | AIN8/IEXC1 | I | Connect to AVSS0 (Short SO10) |
| 48 | AIN9/IEXC0 | I | Connect to AVSS0 (Short SO11) |

**Table 4-3 RSSKRX23E-A board jumper settings**

| Function | Circuit ref number | Connection | Setting |
|---|---|---|---|
| External reference selection (REF0N) | JP7 | 5-6 | AVSS0 |
| External reference selection (REF0P) | JP8 | 5-6 | AVCC0 |
| VCC selection | JP14 | 1-2 | $V_d$ |
| AVCC0 selection | JP15 | 1-2 | $V_a$ |

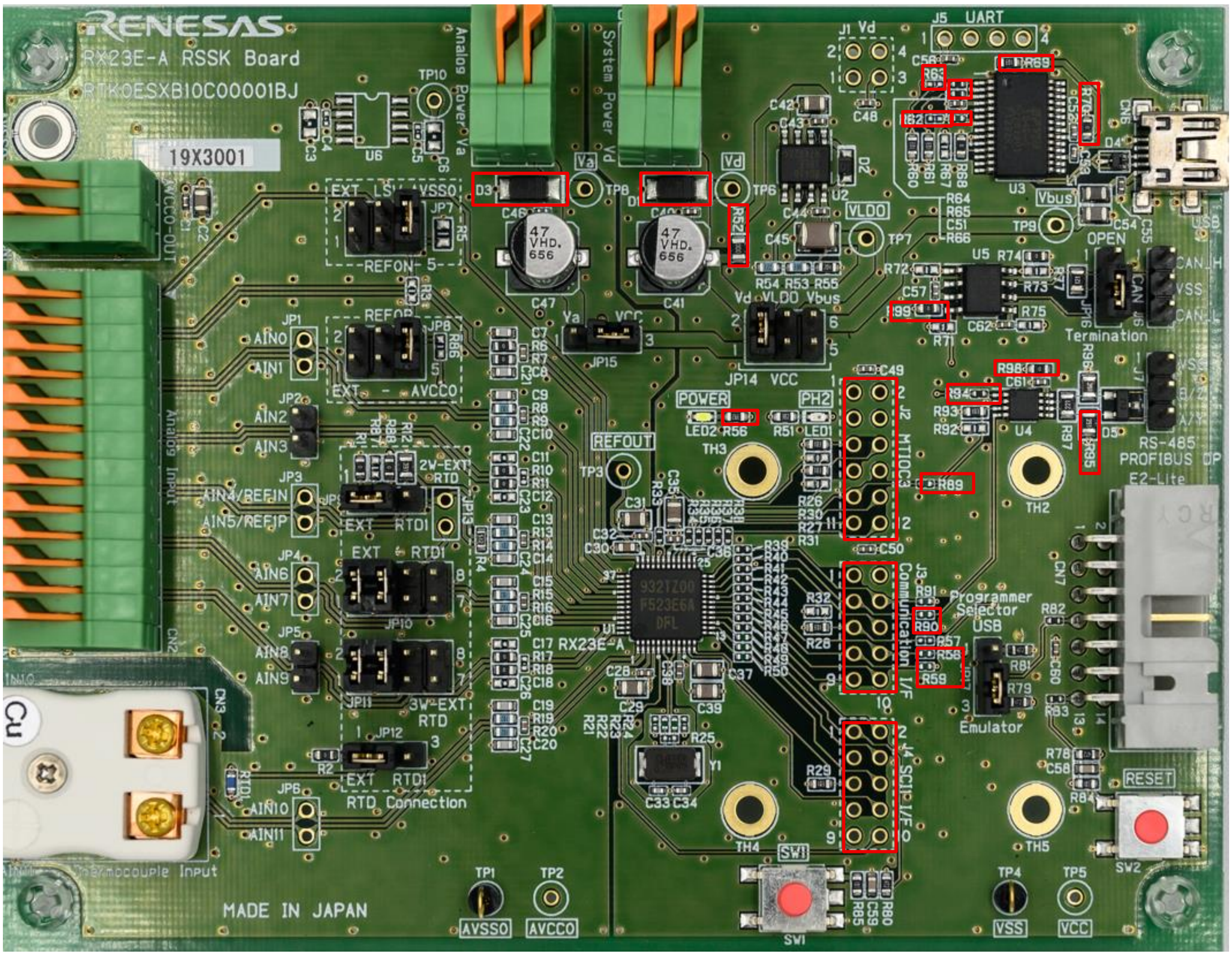



**Figure 4-1 RSSK RX23E-A board changed part (front side)**

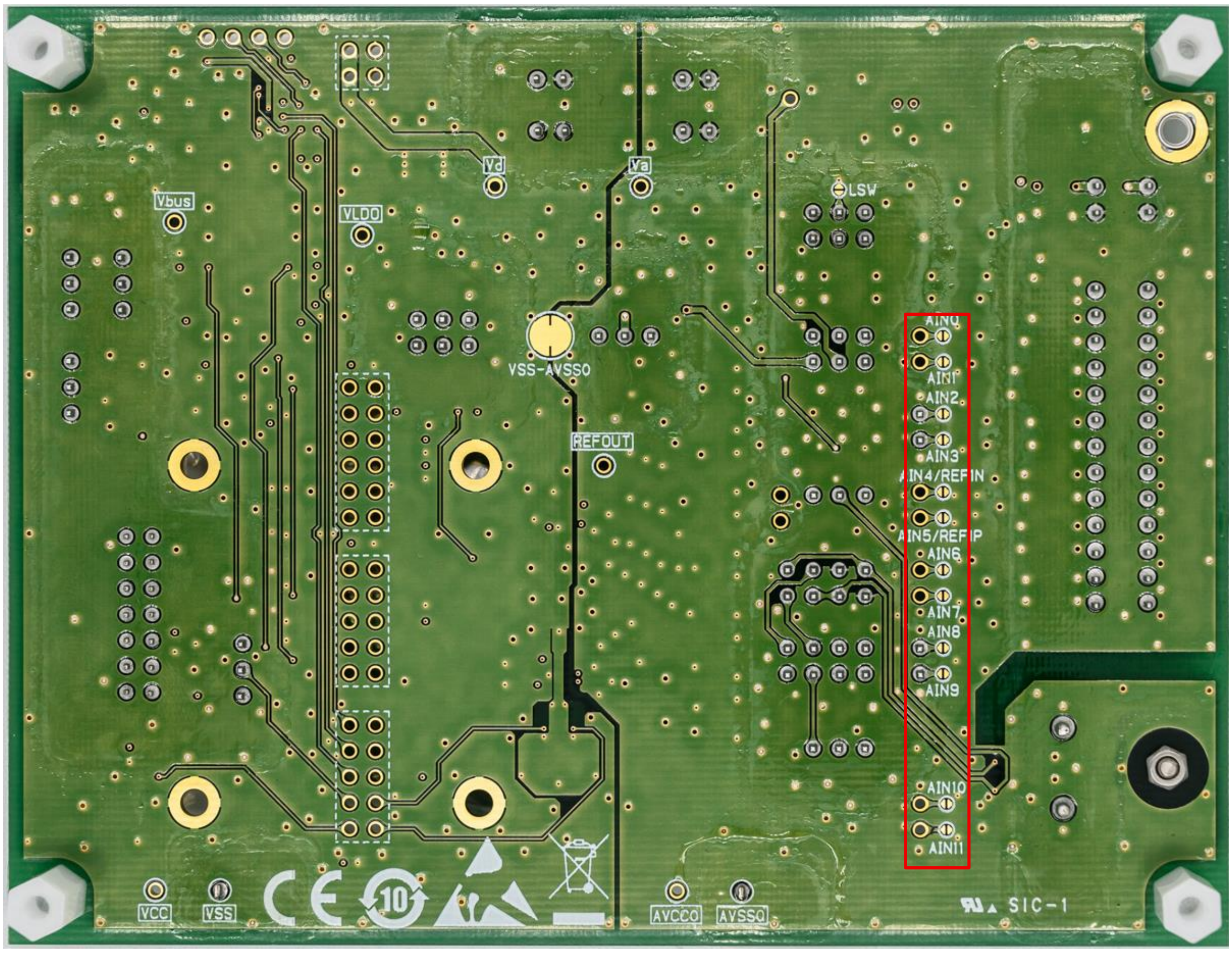


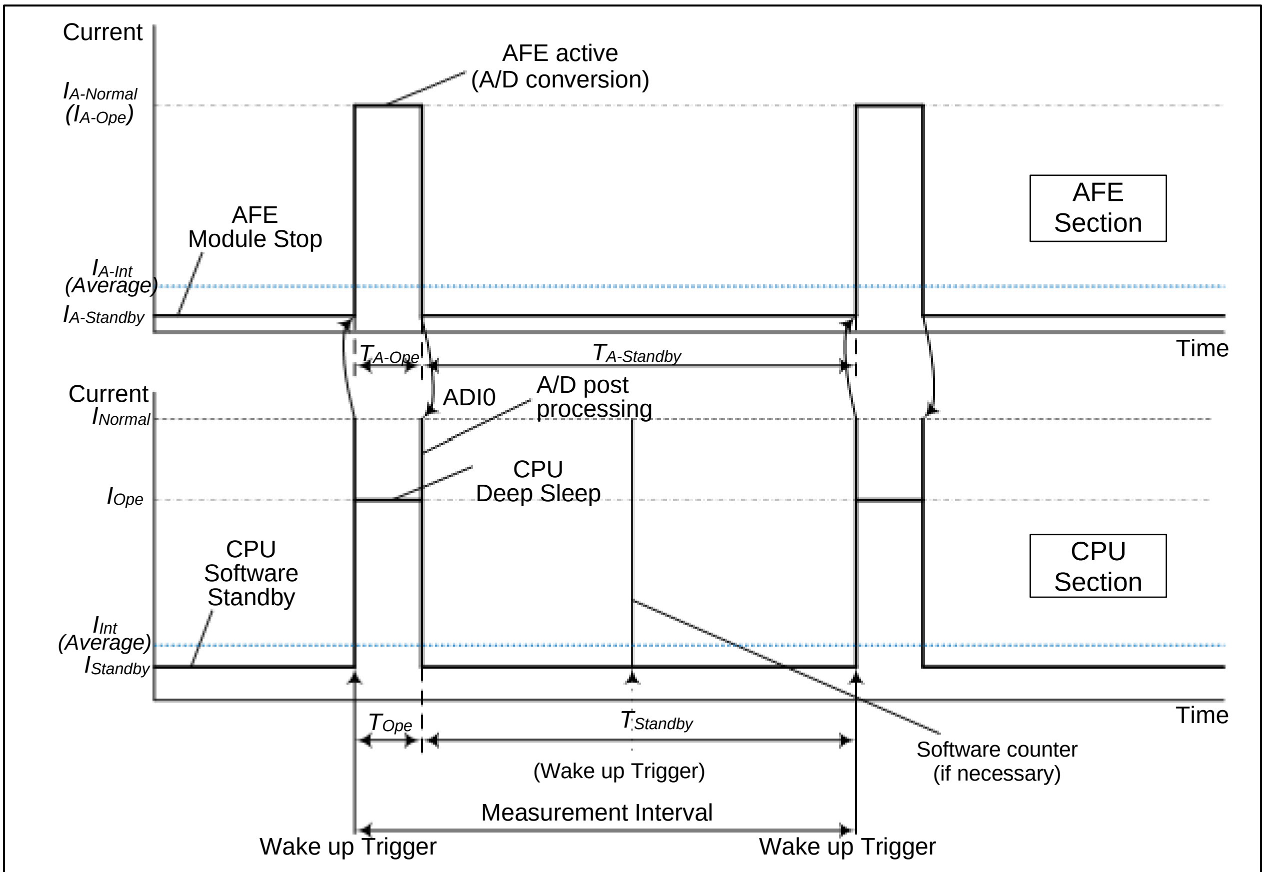

Figure 4-2 RSSK RX23E-A board changed part (back side)

## 4.2 Explanation of Operation

### 4.2.1 Intermittent Operation

As shown in Table 1-4, this system allows three operating settings. Figure 4-3 shows an image of intermittent operation. The system performs the following three operations periodically for intermittent operation.

1. After the RX23E-A enters the measurement mode, the CPU enters software standby mode.
2. By the interrupt request signal, the CPU returns from the software standby mode to the normal state, starts A/D conversion, and after that, shifts to the deep-sleep mode. While the CPU shifts to deep-sleep mode, the DSAD performs A/D conversion.
3. After completion of A/D conversion, the CPU returns from the deep-sleep mode to the normal state by DSAD conversion completion interrupt (ADI0), obtains the A/D conversion result, and processes the postprocessing. After that, the state goes back to 1.
   The interrupt request signal to return from software standby supports 1. On-chip timer and 2. External input.
   1. On-chip timer uses the LPT, generating the interrupt request signal by generating ELC interrupt from LPT compare match event. The LPT built in RX23E-A can generate the cycle up to around 139 seconds. If you want to generate for a longer period than LTP can, it is possible by using a CPU software counter together.
   2. External input uses the signal applied to PB0 (IRQ4) as the interrupt request signal. RX23E-A keeps waiting in the software standby mode until the interrupt request signal is applied.




AFE Section: $I_{A\text{-}Normal}$ = $I_{A\text{-}Ope}$ = Normal operating current, $I_{A\text{-}Standby}$ = Module stop current

$I_{A\text{-}Int}$ = Average current during intermittent operation, $T_{A\text{-}Ope}$ = Operating time

$T_{A\text{-}Standby}$ = Module stop time

CPU Section: $I_{Normal}$ =Normal operating current, $I_{Ope}$ = Deep Sleep mode Current,

$I_{Standby}$ = Software standby mode current, $I_{Int}$ = Average current during intermittent operation

**Figure 4-3 Image of intermittent operation**

The following describes the operation of the CPU during intermittent operation.

Under the normal operation, the average power consumption $W_d$ is calculated by the following equation, where the operating voltage in the CPU section is $V_d$ and the average current consumption is $I_{Normal}$.

$$W_d = V_d \cdot I_{Normal}$$

Under the intermittent operation, the average power consumption $W_d$ is calculated by the following equations, where the operating voltage is $V_d$, and the average current consumption is $I_{Int}$.

$$I_{Int} = \frac{I_{Ope} \cdot T_{Ope} + I_{Standby} \cdot T_{Standby}}{T_{Ope} + T_{Standby}}$$

$$W_d = V_d \cdot I_{Int}$$

Under the same intermittent operation, the average power consumption is $W_a$ calculated by the following equation, where the operating voltage in the AFE section is $V_a$ , the average current consumption is $I_{A-int}$ .

$$I_{A-Int} = \frac{I_{A-Ope} \cdot T_{A-Ope} + I_{A-Standby} \cdot T_{A-Standby}}{T_{A-Ope} + T_{A-Standby}}$$

$$W_a = V_a \cdot I_{A-Int}$$

The total of average power consumption $W_{Intermittent}$ is as follows:

$$W_{Intermittent} = W_d + W_a$$

Since intermittent operation can reduce the average current consumption (blue line) than normal operation, the power consumption is smaller when operating with the same voltage.

### 4.2.2 Voltage Measurement

The pin input voltage is calculated from the A/D conversion result. Assuming the PGA setting gain $G_{PGA}$, the full-scale of A/D conversion $2^{24}$ , and the DSAD reference voltage $V_{REF}$ , the relation of the input pin voltage $V$ for the A/D conversion result DATA is expressed by the following formula.

$$V = \frac{2 \cdot V_{REF}}{2^{24} \cdot G_{PGA}} \cdot DATA$$

# 5. Sample Program

## 5.1 Overview of Operation

Figure 5-1 shows the process flow of this sample program.

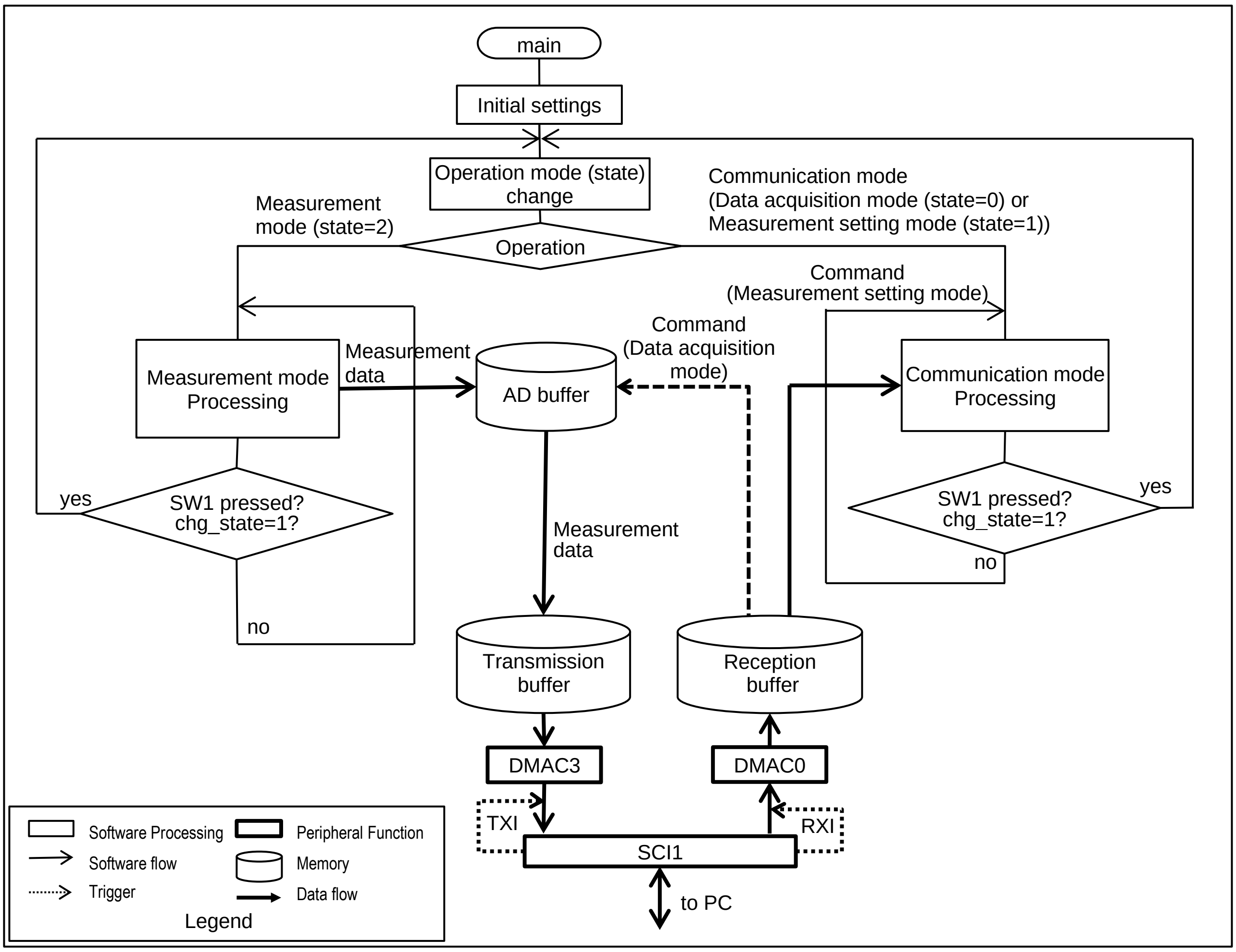



**Figure 5-1 General Flow**

This system has three operating modes: one measurement mode and two communication modes (data acquisition mode and measurement setting mode). You can change the operation mode by pressing SW1 of RSSK. In the data acquisition mode and measurement setting mode, you can use the PC Tool Program to acquire data or change measurement condition settings.

When using PC Tool Program, it should be connected to RSSKRX23E-A beforehand. For details about how to use PC Tool Program, refer to the Application Note"RSSKRX23E-A PC Tool Program Operation Manual".

DSAD0 and LPT settings in measurement operation are configured with Smart Configurator (SC) and executed at initialization of the program execution (before shifting to the measurement mode).

The following provides an overview of each of the processes.

- Initial setting
- Performs the following initial settings.
  — Operation mode initialization (Default setting: Data acquisition mode)
  — LED1 initial setting
  — SW1 chattering prevention setting (CMT1 setting)

- Measurement mode
  — Measurement mode initial setting
  — A/D Conversion

- Communication mode
  — Communication mode initial setting
  — Received packet processing
  — Packet transmission processing
  — Data packet creation
  — Measurement condition settings (set with PC Tool Program)
  — Measurement data transmission
  — Calibration implementation

## 5.2 Functions and Settings of MCU Used

Table 5-1 lists the peripheral functions used in this example, and Table 5-2 lists the pins used. Table 5-3 lists the clock settings.

The settings for peripheral functions are generated by using the code generation function of Smart Configurator.

**Table 5-1 Peripheral functions used**

| Peripheral functions | Use |
|---|---|
| AFE, DSAD0 | Input signal A/D conversion |
| CMT0 | Generates LED blinking interval |
| CMT1 | SW1 Chattering suppression |
| DMAC0 | Packet reception from PC Tool Program |
| DMAC3 | Packet transmission to PC Tool Program |
| ELC | Generates A/D conversion start trigger in combination with LPT |
| ICU | Interrupt control when switch is pressed (IRQ3)<br>External trigger input to start A/D conversion (IRQ4) |
| LPT | Generates measurement interval for intermittent operation |
| PB1 | Measurement interval selection (H: 1sec, L: 5min) |
| PH0 | Clears the measurement result buffer (AD buffer)<br>H: Normal, L: Clear |
| PH2 | LED control |
| SCI1 | Communication with PC Tool Program |

**Table 5-2 Pins used**

| Pin No. | Pin name | I/O | Use | |
|---|---|---|---|---|
| | | | Measurement mode | Communication mode |
| 14 | RXD1/P30 | I | Hi-Z[Note] | Reception data input pin |
| 15 | IRQ3/P27 | I | SW1 input pin | |
| 16 | TXD1/P26 | O | Hi-Z | Transmission data output pin |
| 22 | PH2 | O | LED1 output pin | |
| 24 | PH0 | I | Hi-Z | Data acquisition mode:<br>Delete the number of measurement data |
| 29 | PB1 | I | LPT cycle selection, Hi-Z after selection | Hi-Z |
| 31 | IRQ4/PB0 | I | IRQ4 input pin | Hi-Z |
| 39 | AIN0 | I | DSAD0 analog input pin (-) | |
| 40 | AIN1 | I | DSAD0 analog input pin (+) | |

Note: Hi-Z : high impedance

**Table 5-3 Clock settings**

| Item | Setting |
|---|---|
| Clock used | LOCO clock (4MHz) |
| | IWDT-dedicated low-speed clock (15kHz) |
| SCKCR (ICLK) | x1/4 (1MHz) |
| SCKCR (PCLKB) | x1/4 (1MHz) |
| Low power timer clock (LPTCLK) | 15 (kHz) |
| DSAD0 modulator clock frequency ($f_{MOD}$) | x1/8 (0.125MHz) |

### 5.2.1 Voltage Measurement

DSAD0 is used to measure voltage. When the measurement trigger is the on-chip timer, LPT and ELC are used to return CPU from software standby. The peripheral function settings are shown below.

**Table 5-4 DSAD0 settings**

<table>
<tr><th colspan="3">Item</th><th>Setting</th></tr>
<tr><td colspan="3">Analog input channel setting</td><td>Channel 0</td></tr>
<tr><td colspan="3">Δ-Σ A/D Convertor operation voltage setting</td><td>2.7V～5.5V</td></tr>
<tr><td colspan="3">Δ-Σ A/D Convertor operation mode setting</td><td>Low-power mode</td></tr>
<tr><td colspan="3">Operation clock setting</td><td>PCLKB(1MHz)</td></tr>
<tr><td colspan="2">Conversion start trigger setting</td><td>Start trigger source</td><td>Software trigger</td></tr>
<tr><td colspan="2" rowspan="2">Interrupt setting</td><td>Enable Δ-Σ A/D conversion completion interrupt (ADI0)</td><td>Enabled<br>Priority Level15 (highest)</td></tr>
<tr><td>Enable Δ-Σ A/D conversion scan completion interrupt (SCANENDI0)</td><td>Disabled</td></tr>
<tr><td colspan="2">Inter-unit synchronized start setting</td><td>Enable synchronized start</td><td>Not set</td></tr>
<tr><td colspan="2" rowspan="3">Voltage fault and disconnection detection setting</td><td>Enable reference voltage fault detection</td><td>Not set</td></tr>
<tr><td>Enable positive input signal voltage fault detection</td><td>Not set</td></tr>
<tr><td>Enable negative input signal voltage fault detection</td><td>Not set</td></tr>
<tr><td colspan="4">Channel 0 Tab</td></tr>
<tr><td rowspan="17"></td><td rowspan="3">Analog input setting</td><td>Positive input signal</td><td>AIN1</td></tr>
<tr><td>Negative input signal</td><td>AIN0</td></tr>
<tr><td>Reference input</td><td>REFOUT/AVSS0</td></tr>
<tr><td rowspan="2">Amplifier setting</td><td>Amplifier selection</td><td>PGA</td></tr>
<tr><td>PGA gain setting</td><td>x1</td></tr>
<tr><td rowspan="9">Δ-Σ A/D conversion setting</td><td>A/D conversion mode</td><td>Normal operation</td></tr>
<tr><td>Data format</td><td>Two's complement</td></tr>
<tr><td>A/D conversion number</td><td>1<br>Exponential operation mode (the number of A/D conversion is from 1 to 8032)</td></tr>
<tr><td>Oversampling ratio</td><td>Other ratio</td></tr>
<tr><td>OSRm register value</td><td>77 1248 (100SPS)</td></tr>
<tr><td>Set offset calibration value</td><td>Not set</td></tr>
<tr><td>Set gain calibration value</td><td>Not set</td></tr>
<tr><td>Enable averaging data</td><td>Not set</td></tr>
<tr><td colspan="2">Disconnect detection assist setting</td><td>Not set</td></tr>
</table>

**Table 5-5 LPT settings**

| Item | | Setting |
|---|---|---|
| Low-power timer operation setting | Clock source | IWDT-dedicated on-chip oscillator |
| | Frequency | 1/16, 0.938 (kHz) |
| Compare match setting | Timer cycle value | 60000ms |
| | Register (LPTPRD) | 56249 |
| | Compare value 0 | 56248 |

**Table 5-6 ELC settings**

| **Item** | | **Setting** |
|---|---|---|
| Source | Configuration | Config_LPT |
| | Resource | LPT |
| | Event | LPT compare match |
| Destination | Configuration | Config_ELC |
| | Resource | LPT dedicated interrupt |
| | Operation | Issue LPT compare match interrupt request |
| | Priority | Level 15 (highest) |
| Port group and single-port setting | Setting | Not set |

### 5.2.2 Communication

SCI1, DMAC, and ICU are used for communication with PC Tool Program. The settings for each peripheral function are shown below.

**Table 5-7 SCI1 settings**

<table>
<tr><th colspan="2">Item</th><th>Setting</th></tr>
<tr><td colspan="2">Start bit edge detection setting</td><td>Low level on RXD1 pin</td></tr>
<tr><td colspan="2">Data length setting</td><td>8 bits</td></tr>
<tr><td colspan="2">Parity setting</td><td>None</td></tr>
<tr><td colspan="2">Stop bit length setting</td><td>1 bit</td></tr>
<tr><td colspan="2">Transfer direction setting</td><td>LSB-first</td></tr>
<tr><td>Instant transmission setting</td><td>Enable instant transmission</td><td>Unchecked</td></tr>
<tr><td rowspan="4">Transfer rate setting</td><td>Transfer clock</td><td>Internal clock</td></tr>
<tr><td>Bit rate</td><td>31250 (bps)</td></tr>
<tr><td>Enables bit rate modulation function</td><td>Checked</td></tr>
<tr><td>SCK1 pin function</td><td>SCK1 is not used.</td></tr>
<tr><td colspan="2">Noise filter setting</td><td>Not used</td></tr>
<tr><td colspan="2">Hardware flow control setting</td><td>None</td></tr>
<tr><td rowspan="2">Data handling setting</td><td>Transmit data handling</td><td>Data handled by DMAC</td></tr>
<tr><td>Receive data handling</td><td>Data handled by DMAC</td></tr>
<tr><td rowspan="2">Interrupt setting</td><td>Enables reception error interrupt</td><td>Not used</td></tr>
<tr><td>TXI1,RXI1,TEI1,ERI1 priority</td><td>Level 15 (highest)</td></tr>
<tr><td colspan="2">Multiple interrupts setting</td><td>Not used</td></tr>
<tr><td colspan="2">Callback function setting</td><td>Not used</td></tr>
</table>

**Table 5-8 DMAC settings**

| **Item** | | **Setting** | |
|---|---|---|---|
| | | **DMAC0** | **DMAC3** |
| Transfer setting | Activation source | SCI1(TXI1) | SCI1(TXI1) |
| | Activation source flag control | Clear interrupt flag of the activation source | |
| | Transfer mode | Free running mode | Normal mode |
| | Transfer data size | 8 bits | |
| | Transfer count / Repeat size / Block size | - | 1 |
| | Total transfer size | | 1 byte |
| Source address setting | Source address | 0x0008A025<br>Fixed | 0x00000000<br>Incremented<br>(Set at runtime by software) |
| | Specify the transfer source as extended repeat area | - | Enabled |
| | Extended repeat area | | Lower 12 bits of the address (4K bytes) |
| | Start address of expanded repeat area | | 0x00000000<br>(Set at runtime by software) |
| | End address of expanded repeat area | | 0x00000000<br>(Set at runtime by software) |
| Destination address setting | Destination address | 0x00000000<br>Incremented<br>(Set at runtime by software) | 0x0008A023<br>Fixed |
| | Specify the transfer destination as extended repeat area | Enabled | - |
| | Extended repeat area | Lower 9 bits of the address (512 bytes) | |
| | Start address of expanded repeat area | 0x00000000<br>(Set at runtime by software) | |
| | End address of expanded repeat area | 0x00000000<br>(Set at runtime by software) | |
| Interrupt setting | | Not used | |

### 5.2.3 I/O Ports and Interrupt Controller Settings

**Table 5-9 I/O Ports settings**

| Item | Setting | | |
|---|---|---|---|
| Port selection | PORT1 | PORT2 | PORT3 |
| Used port | Apply to all | Apply to all | Apply to all |
| Setting | Unused GPIO<br>Pull-up: Unchecked<br>CMOS output<br>High-drive output: Unchecked | Unused GPIO<br>Pull-up: Unchecked<br>CMOS output<br>High-drive output: Unchecked | Unused GPIO<br>Pull-up: Unchecked<br>CMOS output<br>High-drive output: Unchecked |

| Item | Setting | | |
|---|---|---|---|
| Port selection | PORTB | | PORTC |
| Used port | PB0 | PB1 | Apply to all |
| Setting | Unused GPIO<br>Pull-up: Unchecked<br>CMOS output<br>High-drive output: Unchecked | In<br>Pull-up: Unchecked<br>High-drive output: Unchecked | Unused GPIO<br>Pull-up: Unchecked<br>CMOS output<br>High-drive output: Unchecked |

| Item | Setting | |
|---|---|---|
| Port selection | PORTH | |
| Used port | PH0, PH1, PH3 | PH2 |
| Setting | Unused GPIO<br>Pull-up: Unchecked<br>CMOS output<br>High-drive output: Unchecked | Out<br>CMOS output<br>Output 1: Checked<br>High-drive output: Unchecked |

**Table 5-10 ICU settings**

| Item | | Setting |
|---|---|---|
| Software interrupt setting | Software interrupt | Unchecked |
| NMI pin interrupt setting | NMI pin interrupt | Unchecked |
| IRQ0 setting | IRQ0 | Unchecked |
| IRQ1 setting | IRQ1 | Unchecked |
| IRQ2 setting | IRQ2 | Unchecked |
| IRQ3 setting | IRQ3 | Checked |
| | Detection type | Low level |
| | Digital filter | PCLK/64 |
| | Priority | Level 15 (highest) |
| IRQ4 setting | IRQ4 | Checked |
| | Detection type | Rising edge |
| | Digital filter | No filter |
| | Priority | Level 15 (highest) |
| IRQ5 setting | IRQ5 | Unchecked |
| IRQ6 setting | IRQ6 | Unchecked |
| IRQ7 setting | IRQ7 | Unchecked |

### 5.2.4 LED and Switch

Use CMT to prevent SW1 chattering and control LED ON/OFF. The following shows the settings for each peripheral function.

**Table 5-11 CMT Settings**

| **Item** | | **Setting** | |
|---|---|---|---|
| | | **CMT0** | **CMT1** |
| Use | | Generates LED1 blinking interval | Prevents SW1 chattering |
| Count clock setting | | PCLK/8 | |
| Compare match setting | Interval value | 250ms | 100ms |
| | Compare match interrupt (CMI0, CMI1) | Checked | |
| | Enables multiple interrupt (CMI0, CMT1) | Unchecked | |
| | Priority | Level 15 (highest) | Level 0 (disabled) |

## 5.3 Measurement Mode

Figure 5-2 shows the processing steps of the measurement mode.

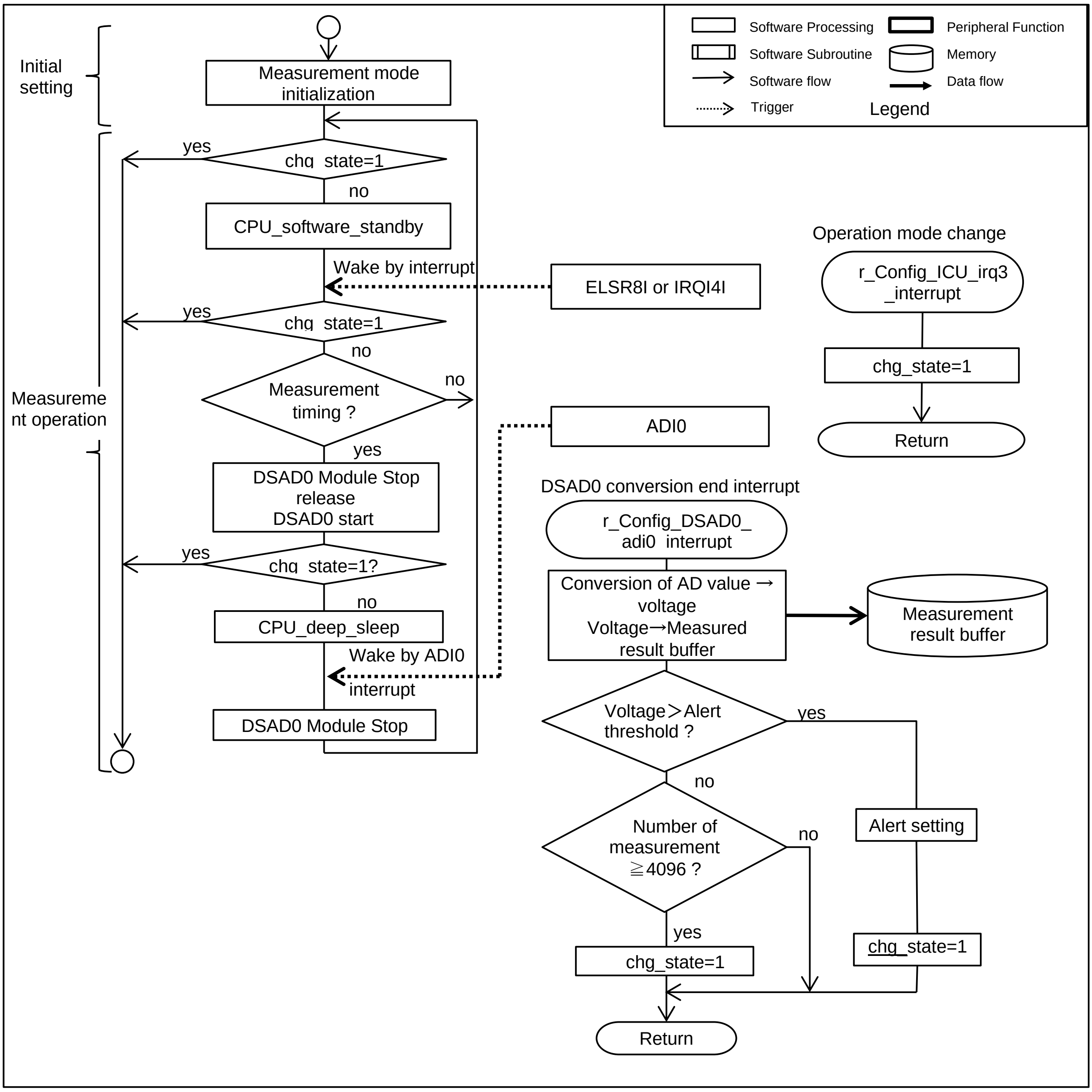



**Figure 5-2 Processing steps in measurement mode**

The overview of the measurement mode is as follows.

Measurement mode initial setting

— Perform initial settings shown in Table 5-12.

**Table 5-12 Measurement mode initial settings**

| Item | Value | Description |
|---|---|---|
| I/O port setting | – | P27(IRQ3) and PB0(IRQ4)[Note] : interrupt input<br>All of other I/O ports: input (Hi-Z) |
| DSAD operation setting | False | Disables DSAD0 and DSAD1 (module stop state) |
| DMAC0, DMAC3 setting | False | Disables DMAC0 and DMAC3 (module stop state) |
| SCI1 setting | False | Disables SCI1 (module stop state) |
| CMT0 setting | False | Disables CMT0 (module stop state) |

Note: In case of using external input as a measurement trigger. If using the on-chip timer, this is an input (Hi-Z).

Measurement operation

— After performing the initial setting in the transition to the measurement mode, the CPU keeps software standby until A/D conversion is triggered by the external interrupt (IRQ4I) or the RX23E-A built-in timer LPT interrupt (ELSR8I). When using the LPT, since the LPT cannot generate interrupt directly, use ELSR8I interrupt that is generated by ELC on the LPT compare match event.

— The A/D conversion value is stored in the memory after voltage conversion. If the converted voltage exceeds the threshold voltage set by the user, an alert is displayed (LED is turned on), the system stops measuring and automatically shifts to the Data acquisition mode. In the same way, if the number of measurement data exceeds 4096, the system stops measuring and automatically shifts to the Data acquisition mode. Otherwise, the measurement continues until SW1 is pressed.

## 5.4 Communication Mode

Figure 5-3 shows the processing steps of the communication mode.

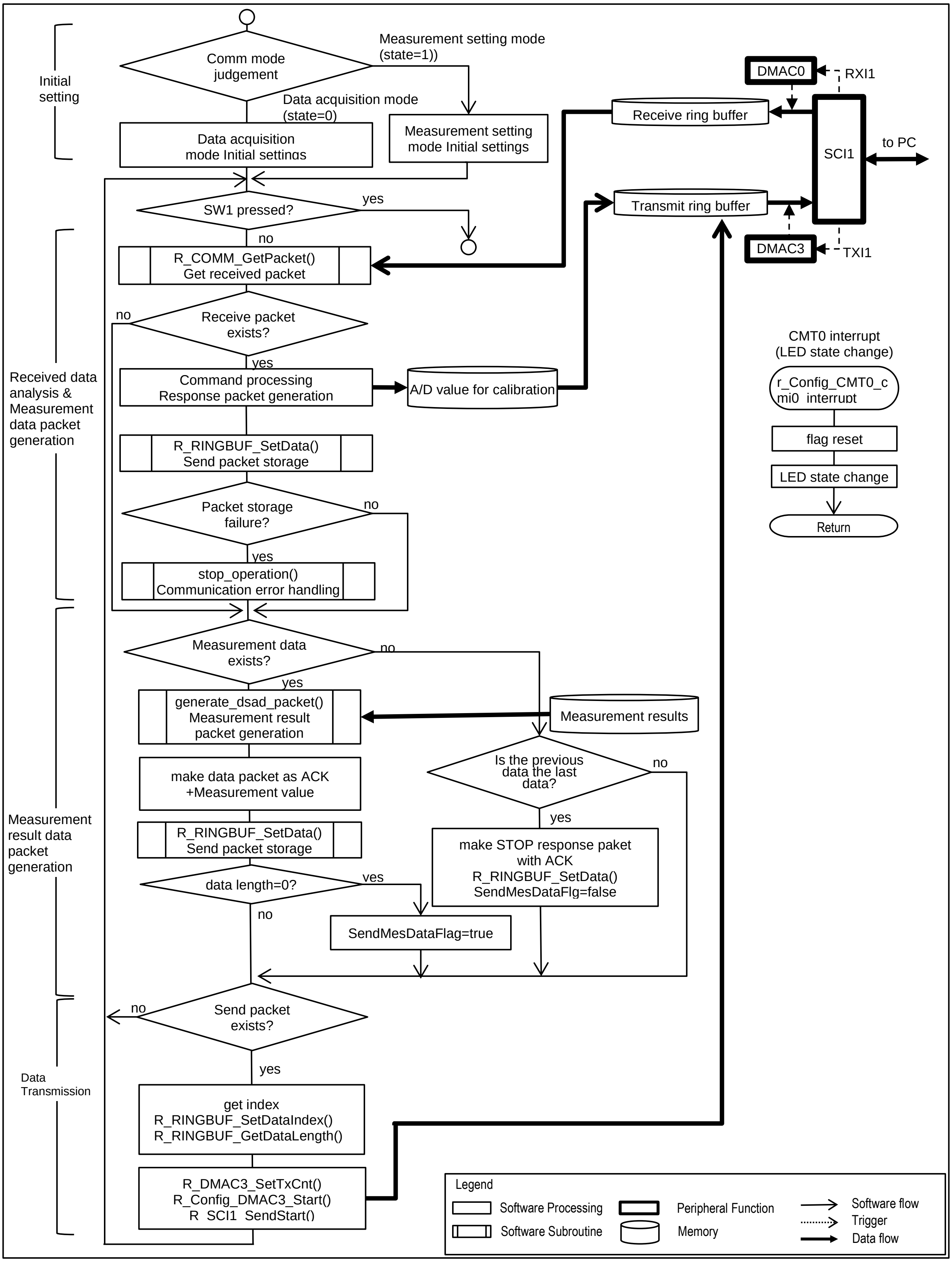



**Figure 5-3 Communication mode processing steps**

The overview of each process is as follows.

Communication mode initial setting

— Table 5-13 lists the initial setting items in the communication mode.

**Table 5-13 Communication mode initial settings**

| Item | Value | Description |
|---|---|---|
| I/O port setting | − | Sets I/O ports for the communication mode<br>P26(TXD1), P30(RXD1), P27(IRQ3), PB0(High impedance), PH2(LED1) |
| DSAD0 operation setting | True | Enables DSAD0 setting |
| DSAD0 operation mode and ADI0 setting | False | DSAD0 operation mode: low-power mode<br>Disables ADI0 |
| DMAC0,DMAC3 | True | Enables DMAC0 and DMAC3 |
| SCI1 setting | True | Enables SCI1 |
| CMT0 setting | True | Enables CMT0 |
| LED operation setting | State | Used in the communication mode<br>State = 0 or 1<br>0: Blinking at 250ms interval<br>1: Blinking at 500ms interval |

Receive packet processing

— Obtains a reception packet from the receive ring buffer, analyzes the command, processes accordingly, and stores a response packet in the transmit ring buffer. Table 5-14 lists the commands supported by this program and the processes corresponding to the command. Returns a NAKC for a command that is not supported. If a response packet cannot be stored in the transmit ring buffer, processes a communication error.

**Table 5-14 Response packet handled and processed**

| Command | Operating mode | |
|---|---|---|
| | Data acquisition mode (state=0) | Measurement setting mode (state=1) |
| Negotiation | Measurement value | DSAD value (ch0 only) |
| Read | AFE, DSAD register values | |
| Write | - | Sets AFE, DSAD register values |
| Run | All measured data | Starts DSAD0, A/D value,...A/D value |
| Stop | Stops sending measurement data | Stops DSAD |
| Version | Version character string | |
| User value | Sets an alert threshold value (ALM_THRESH) | - |

Measured data packet generation

— If the measured result transmission enabled flag is set AND if there is an update of measured value, creates a transmission packet of measured value and stores it in the transmit ring buffer.

If a response packet cannot be stored in the transmit ring buffer, processes a communication error.

Packet transmission process

— When data is not under transmission and if there is an un-transmitted data in the transmit ring buffer, starts transmission with DMAC3.

Executing calibration

— Executes calibration. Please refer to the RSSKRX23E-A PC Tool Program Operation Manual (R20AN0540EJ0201) for details.

## 5.5 Program Configuration

### 5.5.1 File Configuration

**Table 5-15 File configuration (1/2)**

| Item | Description |
|---|---|
| src | |
| ├smc_gen | Smart Configurator generation |
| │ ├Config_CMT0 | |
| │ │ ├Config_CMT0.c | |
| │ │ ├Config_CMT0.h | |
| │ │ └Config_CMT0_user.c | |
| │ ├Config_CMT1 | |
| │ │ ├Config_CMT1.c | |
| │ │ ├Config_CMT1.h | |
| │ │ └Config_CMT1_user.c | |
| │ ├Config_DMAC0 | |
| │ │ ├Config_DMAC0.c | |
| │ │ ├Config_DMAC0.h | |
| │ │ └Config_DMAC0_user.c | |
| │ ├Config_DMAC3 | |
| │ │ ├Config_DMAC3.c | |
| │ │ ├Config_DMAC3.h | |
| │ │ └Config_DMAC3_user.c | |
| │ ├Config_DSAD0 | |
| │ │ ├Config_DSAD0.c | |
| │ │ ├Config_DSAD0.h | |
| │ │ └Config_DSAD03_user.c | |
| │ ├Config_ELC | |
| │ │ ├Config_ELC.c | |
| │ │ ├Config_ELC.h | |
| │ │ └Config_ELC_user.c | |
| │ ├Config_ICU | |
| │ │ ├Config_ICU.c | |
| │ │ ├Config_ICU.h | |
| │ │ └Config_ICU_user.c | |
| │ ├Config_LPT | |
| │ │ ├Config_LPT.c | |
| │ │ ├Config_LPT.h | |
| │ │ └Config_LPT_user.c | |
| │ ├Config_PORT | |
| │ │ ├Config_PORT.c | |
| │ │ ├Config_PORT.h | |
| │ │ └Config_PORT_user.c | |

**Table 5-16 File configuration (2/2)**

| Item | Description |
|---|---|
| src | |
| │ ├Config_SCI1 | Smart Configurator generation |
| │ │ ├Config_SCI1.c | |
| │ │ ├Config_SCI1.h | |
| │ │ └Config_SCI1_user.c | |
| │ ├general | |
| │ ├r_bsp | |
| │ ├r_config | |
| │ └r_pincfg | |
| ├r_main.c | Main processing |
| ├r_communication_control_api.c | Communication control program |
| ├r_communication_control_api.h | Communication control API definition |
| ├r_ring_buffer_control_api.c | Ring buffer control program |
| ├r_ring_buffer_control_api.h | Ring buffer control API definition |
| └r_userdata.h | User definition |
| HardwareDebug-IRQ4—<br>rx23ea_lowpower_fw_for_rssk.mot | Compiled object file<br>(Measurement trigger: external input) |
| HardwareDebug-LPT—<br>rx23ea_lowpower_fw_for_rssk.mot | Compiled object file<br>(Measurement trigger: on-chip timer) |

### 5.5.2 Macro Definitions

**Table 5-17 main.c setting list**

| Definition name | Value | Description |
|---|---|---|
| D_CMD_THRSH_MIN | 0.0F | Voltage alert threshold value (lower limit) |
| D_CMD_THRSH_MAX | 10.0F | Voltage alert threshold value (upper limit) |
| D_INITIAL_VOLTAGE_ERR_THRESHOLD | 10.0F | Voltage alert initial value |
| D_DSAD_2VREF | 5.0F | DSAD0 full-scale voltage (=Vref x 2) |
| D_DSAD_FULL_ADVAL | 16777216.0F | DSAD0 full AD value (= 2^24) |
| D_LONG_INT_CNT | 5 | Minutes count number for long interval |
| IRQ4EN | - | When defined (default setting), trigger source is LPT.<br>When not defined, trigger source is IRQ4.<br>For how to change, refer to Table 1-3. |

**Table 5-18 r_userdata.h setting list**

| Definition name | Value | Description |
|---|---|---|
| D_MAX_DATA_CNT | 4096 | Largest number of stored measurement result |

**Table 5-19 Config_CMT0.h setting list**

| Definition name | Value | Description |
|---|---|---|
| _F423_CMT0_CMCOR_VALUE | 0xF423U | LED blinking interval: 500ms |
| _7A11_CMT0_CMCOR_VALUE | 0x7A11 | LED blinking interval: 250ms |

**Table 5-20 Config_LPT.c and Config_LPT.h setting list**

| Definition name | Value | Description |
|---|---|---|
| _0752_LPT_LPTPRD_VALUE | 0x0752 | 1-sec cycle measurement |
| _0751_LPT_LPCMR0_VALUE | 0x0751 | Compare match timer for 1-sec cycle measurement |
| _DBB9_LPT_LPTPRD_VALUE | 0xDBB9 | 5-min cycle measurement |
| _DBB8_LPT_LPCMR0_VALUE | 0xDBB8 | Compare match timer for 5-min cycle measurement |

### 5.5.3 Structures and Unions

**Table 5-21 r_userdata.h: enumerated type list**

| | | |
|---|---|---|
| **Enum name** | e_state_t | |
| **Description** | Mode status management | |
| **Member** | Name | Description |
| | E_GETTING_DATA | Data acquisition mode, 0 |
| | E_SET_REGISTERS | Measurement setting mode, 1 |
| | E_MEASUREMENT | Measurement mode, 2 |
| | E_MODE | Limiter |

**Table 5-22 r_userdata.h: structures list**

| | | | |
|---|---|---|---|
| **Structure Type name** | st_params_t | | |
| **Description** | Parameter information | | |
| **Member** | Type | Name | Description |
| | e_state_t | state | Operating mode state variables |
| | uint8_t | chg_state | Status change flag |
| | uint8_t | lpt_5min | LPT timer use setting flag<br>0: 1-second measurement,<br>1: 5-minutes measurement |
| | uint32_t | lp_cntr | Software counter for 5-minutes measurement |
| | bool | dsad_average | Average number of A/D conversions |
| | float | v_conversion_coef | A/D value voltage conversion formula |
| | float | alm_thresh | Voltage alarm threshold level setting |
| | bool | alm_err | Alarm occurrence flag<br>True: Alarm occurred<br>False: No abnormality |
| | bool | send_mes_data_flag | Measurement data transmission flag<br>True: Send data<br>False: Do not send data |
| **Structure Type name** | st_mesdata_t | | |
| **Description** | Measurement data information | | |
| **Member** | Type | Member | Type |
| | int32_t | d_number | Measurement data index |
| | int32_t | sd_index | Send data index |
| | float | data | Measurement data |

### 5.5.4 Functions

**Table 5-23 main.c function**

| **Function name** | main | | | |
|---|---|---|---|---|
| **Description** | Main function | | | |
| **Argument** | I/O | Type | Name | Description |
| | — | void | - | - |
| **Return value** | O | void | - | |

| **Function name** | analysis_packet | | | |
|---|---|---|---|---|
| **Description** | Processes command and creates response packet | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | uint8_t | rcv_pkt[] | Reception packet (receive command) |
| | O | uint8_t | send_pkt[] | Transmission packet (response packet) |
| | O | bool | *p_flag | true=DSAD is running, false=DSAD is stopped |
| **Return value** | - | static size_t | Number of characters stored in send_pkt | |

| **Function name** | generate_dsad_packet | | | |
|---|---|---|---|---|
| **Description** | Generates DSAD data packet | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | uint8_t | unit | DSAD unit number selection: 0 or 1 |
| | O | uint8_t | send_pkt[] | Generated DSAD data packet |
| | O | uint32_t | data | A/D conversion result |
| **Return value** | - | static size_t | Number of characters stored in send_pkt | |

| **Function name** | generate_measurement_packet | | | |
|---|---|---|---|---|
| **Description** | Generates voltage measured value data packet | | | |
| **Argument** | I/O | Type | Name | Description |
| | O | unit8_t | send_pkt[] | Generated measurement data packet |
| | I | float | data | Measurement value |
| **Return value** | - | static void | Number of characters stored in send_pkt | |

| **Function name** | stop_operation | | | |
|---|---|---|---|---|
| **Description** | Stops transmission at transmission error and initializes buffer | | | |
| **Argument** | I/O | Type | Name | Description |
| | O | st_ring_buf_t | *ary | Pointer to transmission buffer to be set to DMAC3 |
| **Return value** | - | static void | - | |

| **Function name** | cpu_software_standby | | | |
|---|---|---|---|---|
| **Description** | Shifts CPT into software standby mode | | | |
| **Argument** | I/O | Type | Name | Description |
| | - | void | - | |
| **Return value** | - | void | - | |

| Function name | cpu_deep_sleep | | | |
|---|---|---|---|---|
| Description | Shifts CPT into Deep sleep mode | | | |
| Argument | I/O | Type | Name | Description |
| | - | void | - | |
| Return value | - | void | - | |

**Table 5-24 r_communication_control_api.c function**

| Function name | R_COMM_GetPacket | | | |
|---|---|---|---|---|
| Description | Gets character string of specified length from ring buffer | | | |
| Argument | I/O | Type | Name | Description |
| | I | st_ring_buf_t | *r_buf | Pointer to receive ring buffer |
| | O | uint8_t | r_packet[] | Reception packet |
| Return value | - | size_t | Number of characters got | |

| Function name | R_RINGBUF_GetData | | | |
|---|---|---|---|---|
| Description | Sets character string of specified length to ring buffer | | | |
| Argument | I/O | Type | Name | Description |
| | O | float | *data | Pointer to voltage measurement value |
| | I | st_mesdata_t | *st_mdata | Pointer to measurement value structure |
| Return value | - | bool | true=data exists, false=data not exists | |

**Table 5-25 r_ring_buffer_control_api.c function**

| Function name | R_RINGBUF_GetData | | | |
|---|---|---|---|---|
| Description | Gets character string of specified length from ring buffer | | | |
| Argument | I/O | Type | Name | Description |
| | I | st_ring_buf_t | *ary | Pointer to ring buffer |
| | O | uint8_t | data[] | Character strings got |
| | I | size_t | len | Number of characters to be got |
| | I | bool | index_update | Enables/disables update the position to get character string (true=enabled) |
| Return value | - | size_t | Number of characters got | |

| Function name | R_RINGBUF_SetData | | | |
|---|---|---|---|---|
| Description | Sets character string of specified length to ring buffer | | | |
| Argument | I/O | Type | Name | Description |
| | O | st_ring_buf_t | *ary | Pointer to ring buffer |
| | I | uint8_t | data[] | Character string to be set |
| | I | size_t | len | Number of characters to be set |
| Return value | - | size_t | Number of characters set | |

| Function name | R_RINGBUF_GetDataLength | | | |
|---|---|---|---|---|
| Description | Gets number of characters stores in ring buffer | | | |
| Argument | I/O | Type | Name | Description |
| | I | st_ring_buf_t | *ary | Pointer to ring buffer |
| Return value | - | size_t | Number of characters stored | |

| Function name | R_RINGBUF_SetDataIndex | | | |
|---|---|---|---|---|
| Description | Updates ring buffer index | | | |
| Argument | I/O | Type | Name | Description |
| | I | st_ring_buf_t | *ary | Pointer to ring buffer |
| | I | uint32_t | value | Index value to be set |
| | I | uint8_t | select | Setting target: 0=Read index, 1=Write index |
| Return value | - | uint32_t | Set value | |

| Function name | R_RINGBUF_InitRcvBuffer | | | |
|---|---|---|---|---|
| Description | Initializes transmission/reception ring buffer | | | |
| Argument | I/O | Type | Name | Description |
| | I | st_ring_buf_t | *in_ary | Pointer to receive ring buffer |
| Return value | - | void | - | |

**Table 5-26 Config_DMAC0.c function**

| Function name | R_DMAC0_SetDestAddr | | | |
|---|---|---|---|---|
| Description | Sets transfer destination address to DMAC0 | | | |
| Argument | I/O | Type | Name | Description |
| | I | void | *p_addr | Destination address |
| Return value | I | void | - | |

**Table 5-27 Config_DMAC3.c function**

| Function name | R_DMAC3_SetSrcAddr | | | |
|---|---|---|---|---|
| Description | Sets transfer source address to DMAC3 | | | |
| Argument | I/O | Type | Name | Description |
| | I | void | *p_addr | Source address |
| Return value | - | void | - | |

| Function name | R_DMAC3_SetTxCnt | | | |
|---|---|---|---|---|
| Description | Sets number of transmission characters to DMAC3 | | | |
| Argument | I/O | Type | Name | Description |
| | I | uint32_t | cnt | Number of characters to be transferred |
| Return value | - | void | - | |

| Function name | R_DMAC_Activate | | | |
|---|---|---|---|---|
| Description | Enables/disables (module stop) DMAC0 and DMAC3 | | | |
| Argument | I/O | Type | Name | Description |
| | I | bool | flag | True=enabled, false=disabled (module stop) |
| Return value | - | void | - | |

**Table 5-28 Config_DSAD0.c function**

| **Function name** | R_DSAD0_Start_NoIEN | | | |
|---|---|---|---|---|
| **Description** | Starts DSAD0 operation | | | |
| **Argument** | I/O | Type | Name | Description |
| | - | void | - | - |
| **Return value** | - | void | - | |

| **Function name** | R_DSAD0_GetData | | | |
|---|---|---|---|---|
| **Description** | Returns DSAD0 A/D conversion result | | | |
| **Argument** | I/O | Type | Name | Description |
| | O | uint32_t | *data | Pointer to A/D conversion result |
| **Return value** | - | bool | true=Got A/D conversion result, false=Cannot get. | |

| **Function name** | R_DSAD0_LP_Configure | | | |
|---|---|---|---|---|
| **Description** | DSAD0 operating mode and ADI0 enable/disable setting | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | bool | flag | true=low power, false=communication mode |
| **Return value** | - | void | - | |

**Table 5-29 Config_DSAD0_user.c function**

| **Fanction name** | R_Config_DSAD0_Create_UserInit | | | |
|---|---|---|---|---|
| **Description** | Initializes the gain correction register and offset correction register (GCR0, OFCR0) of DSAD0<br>Releases the DSAD1 module stop and initializes the CCR. | | | |
| **Argument** | I/O | Type | Name | Description |
| | - | void | - | - |
| **Return value** | - | void | - | |

| **Function name** | R_DSAD_Activate | | | |
|---|---|---|---|---|
| **Description** | Enables/disables (module stop) DSAD0 and DSAD1 | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | bool | act_flag0 | true=DSAD0 enabled, false=disabled (module stop) |
| **Return value** | I | bool | act_flag1 | true=DSAD1 enabled, false=disabled (module stop) |
| **Return value** | - | void | - | |

| **Function name** | r_Config_DSAD0_adi0_interrupt | | | |
|---|---|---|---|---|
| **Description** | Converts DSAD0 A/D conversion result at measurement mode into voltage and stores it in memory (g_mdata) | | | |
| **Argument** | I/O | Type | Name | Description |
| | - | void | - | - |
| **Return value** | - | void | - | |

**Table 5-30 Config_ICU_user.c function**

| **Function name** | R_Config_ICU_irq3_interrupt | | | |
|---|---|---|---|---|
| Description | Changes RSSK operating state | | | |
| Argument | I/O | Type | Name | Description |
| | - | void | - | - |
| Return value | - | void | - | |

**Table 5-31 Config_PORT.c function**

| **Function name** | R_PORT_LP_Configure | | | |
|---|---|---|---|---|
| Description | Sets I/O port for low-power operation or communication | | | |
| Argument | I/O | Type | Name | Description |
| | I | bool | lp_flag | true=low power, false=communication mode |
| Return value | - | void | - | |

**Table 5-32 Config_CMT0_user.c function**

| **Function name** | r_Config_CMT0_cmi0_interrupt | | | |
|---|---|---|---|---|
| Description | Blinks LED1 | | | |
| Argument | I/O | Type | Name | Description |
| | I | Void | - | - |
| Return value | - | static void | - | |

**Table 5-33 Config_CMT0.c function**

| **Function name** | R_Config_CMT0_SetLEDInterval | | | |
|---|---|---|---|---|
| **Description** | Set LED1 blinking interval | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | uint32_t | state | 0=com mode2, 1=com mode1 |
| **Return value** | - | void | - | |

| **Function name** | R_CMT0_Activate | | | |
|---|---|---|---|---|
| **Description** | Enables/disables (module stop) CMT0 | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | bool | flag | True=enabled, false=disabled (module stop) |
| **Return value** | - | void | - | |

**Table 5-34 Config_CMT1.c function**

| **Function name** | R_CMT1_Activate | | | |
|---|---|---|---|---|
| **Description** | Enables/disables (module stop) CMT1 | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | bool | flag | True=CMT1 is active, false=module stop |
| **Return value** | - | void | - | |

**Table 5-35 Config_SCI1.c function**

| | | | | |
|---|---|---|---|---|
| **Function name** | R_SCI1_IsTransferEnd | | | |
| **Description** | Returns transmission completion state of SCI1 | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | void | - | − |
| **Return value** | - | bool | true=transmission is completed, false=transmission is not completed | |

| | | | | |
|---|---|---|---|---|
| **Function name** | R_SCI1_SendStart | | | |
| **Description** | Starts SCI1 transmission | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | void | - | - |
| **Return value** | - | MD_STATUS | Returns MD_OK(0x00) | |

| | | | | |
|---|---|---|---|---|
| **Function name** | R_SCI1_SendStop | | | |
| **Description** | Stops SCI1 transmission | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | void | - | - |
| **Return value** | - | MD_STATUS | Returns MD_OK(0x00) | |

| | | | | |
|---|---|---|---|---|
| **Function name** | R_SCI1_ReceiveStart | | | |
| **Description** | Starts SCI1 reception | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | Void | - | - |
| **Return value** | - | MD_STATUS | Returns MD_OK(0x00) | |

| | | | | |
|---|---|---|---|---|
| **Function name** | R_Config_SCI1_Activate | | | |
| **Description** | Enables or disables (module stop) SCI1 | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | bool | flag | true=enabled, false=disabled (module stop) |
| **Return value** | - | void | - | |

**Table 5-36 Config_LPT.c function**

| | | | | |
|---|---|---|---|---|
| **Function name** | R_LPT_SetInterval | | | |
| **Description** | Sets LPT cycle to 1 sec or 5 minutes | | | |
| **Argument** | I/O | Type | Name | Description |
| | I | uint8_t | sec_flag | 1: 1sec, 0: 5minutes |
| | I/O | st_params_t | *params | Pointer to params structure |
| **Return value** | - | void | - | |

# 6. Import a Project

After importing the sample project, make sure to confirm build and debugger setting. This chapter shows how to import projects into e² studio and CS+. After the import is completed, check your build and debug settings.

## 6.1 Importing a Project into e² studio

Follow the steps below to import your project into e² studio. Pictures may be different depending on the version of e² studio to be used)

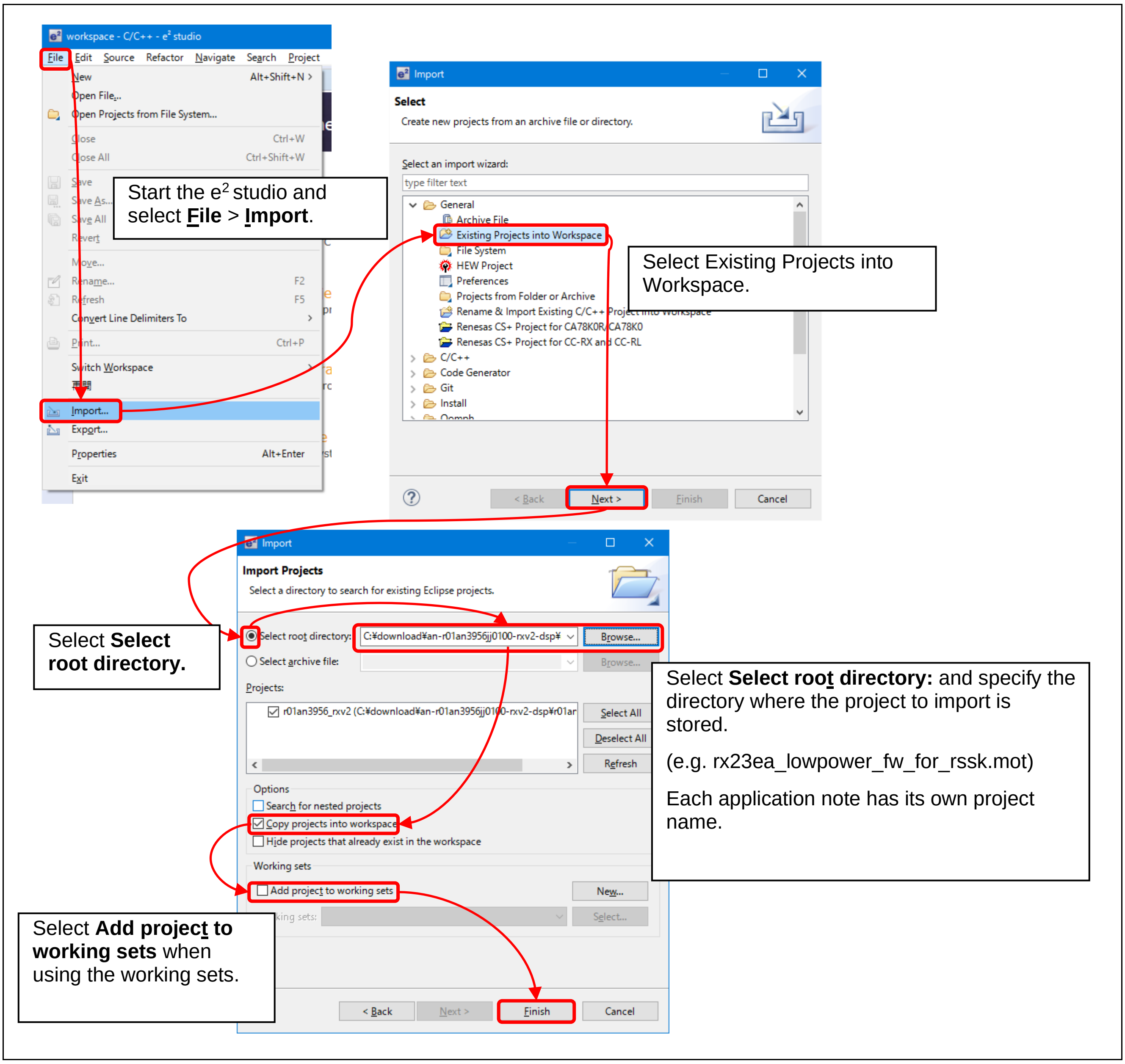



**Figure 6-1 Importing a project into e2 studio**

## 6.2 Importing a Project into CS+

Follow the steps below to import your project into CS+. Pictures may be different depending on the version of CS+ to be used.

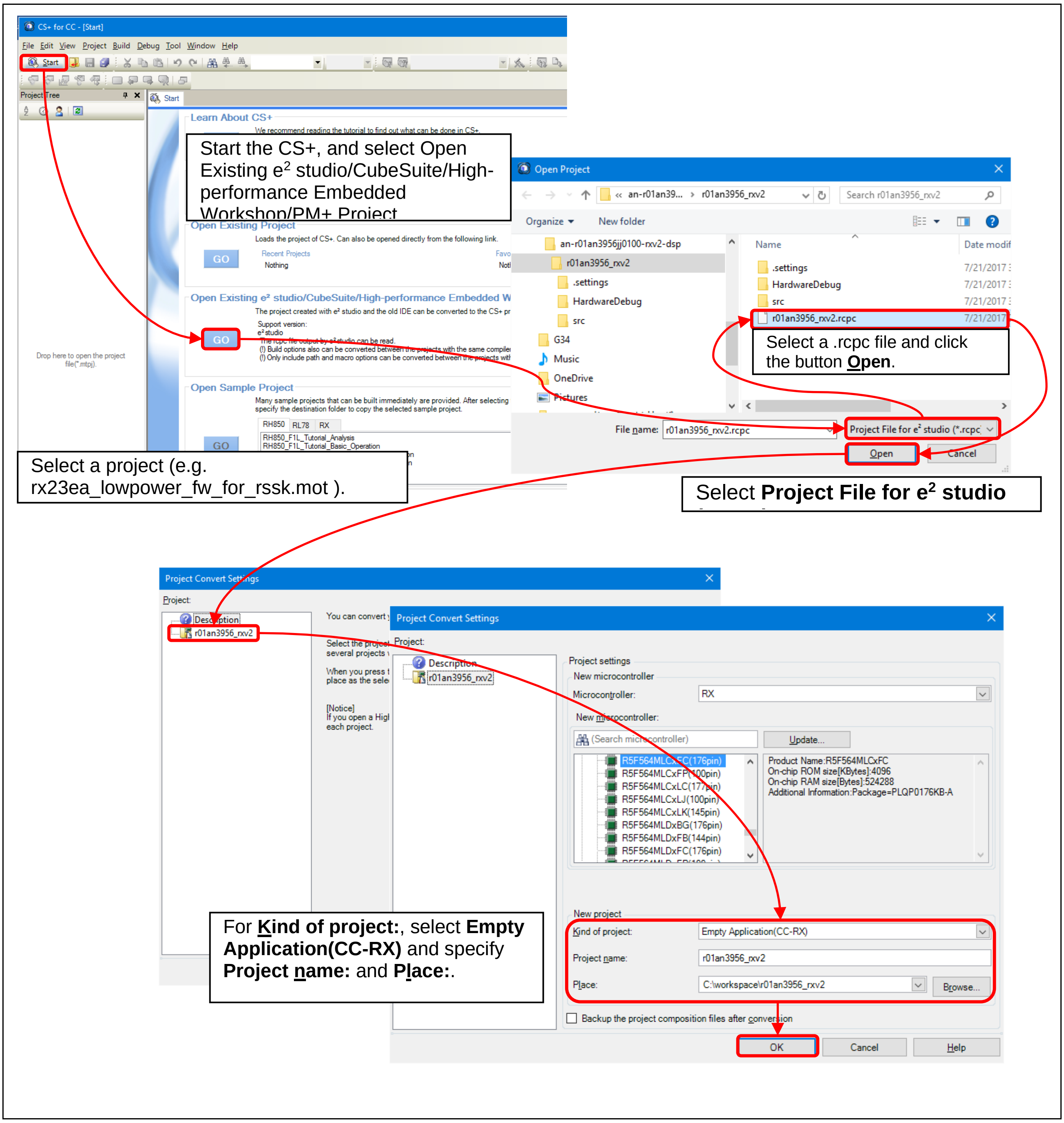



**Figure 6-2 Importing a project into CS+**

# 7. Measurement Result Using Sample Program

## 7.1 Memory Usage

### 7.1.1 Build Conditions

Table 7-1 shows the build conditions for the sample program.

**Table 7-1 Build Conditions**

| Item | Setting |
|---|---|
| **Compiler** | '-isa=rxv2 -include=(include path) -utf8 -nomessage -output=obj -obj_path=${workspace_loc:/${ProjName}/${ConfigName}} -outcode=utf8 -nologo |
| **Linker** | -noprelink -output="rx23ea_lowpower_fw_for_rssk.abs" -form=absolute -nomessage -vect=_undefined_interrupt_source_isr -list -nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -cpu=RAM=00000000-00007fff,FIX=00080000-00083fff,FIX=00086000-00087fff,FIX=00088000-0008dfff,FIX=00090000-0009ffff,FIX=000a0000-000bffff,FIX=000c0000-000fffff,ROM=00100000-00101fff,FIX=007fc000-007fc4ff,FIX=007ffc00-007fffff,ROM=fffc0000-ffffffff -stack -nologo |

### 7.1.2 Memory Usage

The amount of memory usage of sample program is shown in Table 7-2.

**Table 7-2 Amount of Memory Usage**

| Item | | Usage amount [Byte] |
|---|---|---|
| ROM | | 32871 |
| | Code | 14630 |
| | Data | 18241 |
| RAM | | 28590 (23626) |
| | Data | 23470 |
| | Stack | 5120 (156) |

Note: RAM usage shown in "()" is calculated from stack usage.

### 7.1.3 Execution Cycle and Processing Time in Measurement Mode

Table 7-3 shows the numbers of CPU execution cycles and each processing time in the measurement mode of the sample program.

**Table 7-3 Number of execution cycles and processing time**

ICLK=1MHz

| Item | Maximum number of execution cycles (execution time) |
|---|---|
| Interrupt processing | 8 cycles (8µs) |
| A/D value acquisition processing | 10 cycles (10µs) |
| A/D voltage conversion and result storage processing | 12 cycles (12µs) |
| Buffer overflow and alert judgement processing | 22 cycles (22µs) |
| total | 52 cycles (52µs) |

## 7.2 Evaluation Condition

Using the sample program, we evaluated the power consumption and resolution. The configuration of low-power consumption evaluation is shown in Figure 7-1, the equipment used for measurement is shown in Table 7-4, the measurement conditions are shown in Table 7-5 and the calibration conditions are shown in Table 7-6.

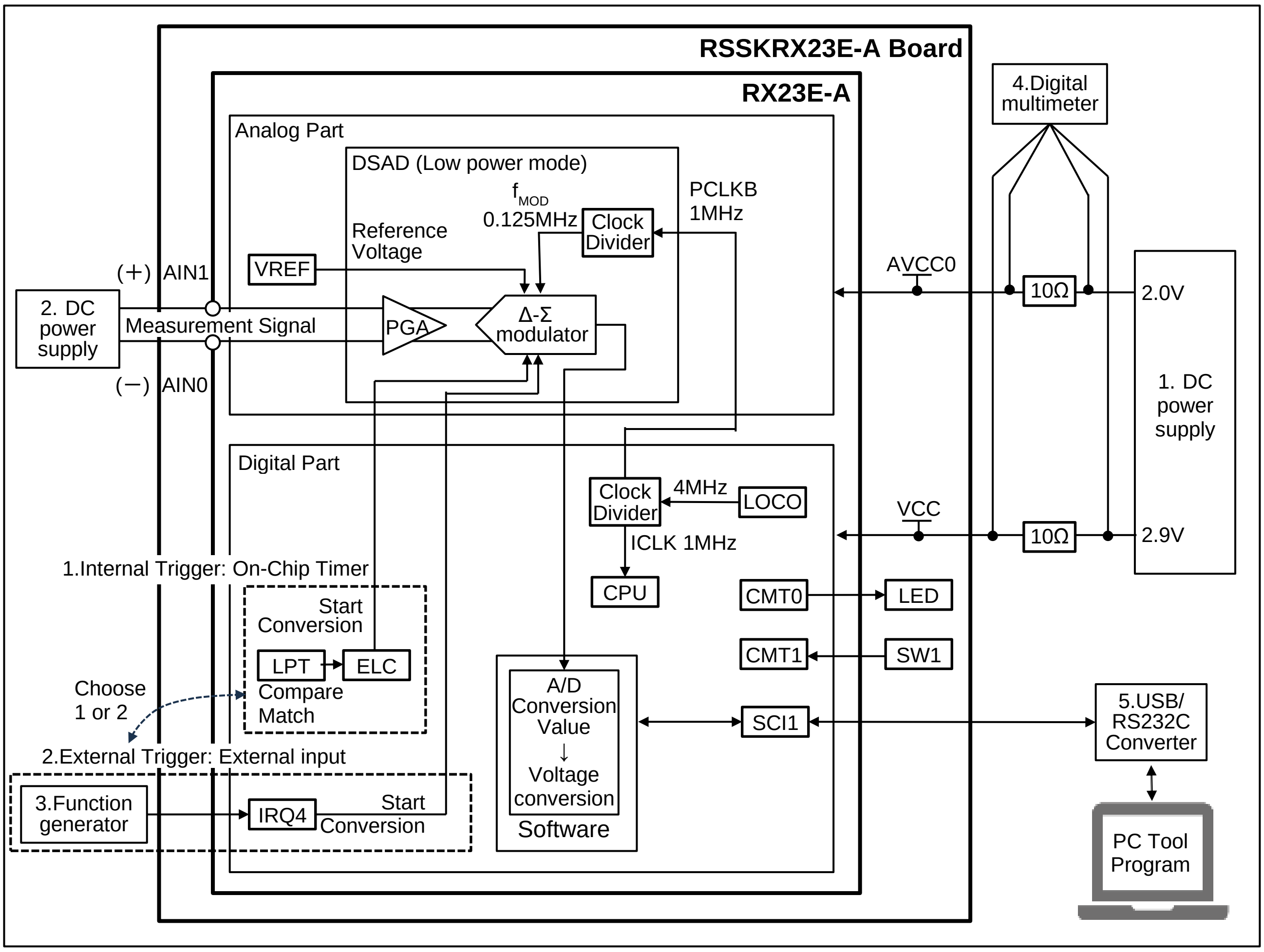



**Figure 7-1 RX23E-A configuration of low power consumption evaluation**

**Table 7-4 List of equipment**

| No | Equipment | Model | Manufacturer name | Remarks |
|---|---|---|---|---|
| 1 | DC power supply | PA14A1 | ShibaSoku Co., Ltd. | Power supply for VCC and AVCC0 |
| 2 | DC power supply | TR6243 | ADVANTEST CORPORATION. | Used for calibration |
| 3 | Function generator | 33120A | Keysight Technologies | Measurement trigger: used for external input |
| 4 | Digital multimeter | 34465A, 3458A | Keysight Technologies | For current consumption measurement |
| 5 | USB-RS232C conversion board | AE-UM232R | AKIZUKI DENSHI TSUSHO CO., LTD. | For connection to PC tool program [Note] |

Note: The supply voltage of the FT232's VCCIO is changed to 2V using an external LDO to match the system's 2V I/O voltage level.

**Table 7-5 Measurement conditions**

| Items | Settings |
|---|---|
| Supply Voltage | VCC: 2.0V, AVCC0: 2.9V |
| Condition | PGA gain: x1, Sampling rate:100sps,Average number of A/D conversions:1, Measurement interval: 1s |
| Temperature | Room temperature |

**Table 7-6 Calibration conditions**

| PGA Gain value | Reference Voltage 1 | Reference Voltage 2 |
|---|---|---|
| 1 | 0.000V | 2.400V |

## 7.3 Evaluation Results

In this evaluation, we measured current consumption and the short noise in Table 7-5 condition settings by making short circuit with analog input pins AIN0 and AIN1. The results of current consumption, power consumption and effective resolution in RX23E-A of AFE section and CPU section are shown in Table 7-7, Table 7-8, and Table 7-9. In addition, Figure 7-2 shows a trend graph of current consumption using an external trigger.

For the AFE section, the current consumption is reduced by stopping the AFE module during standby. The stop of the AFE module is achieved by shutting off the power supply and clock supply to the AFE section. At this time, the current flowing through AVCC0 corresponds to the 'AVCC0 power down current'. In this system, we got the result of less than 0.1µA in actual measurement. During A/D conversion operation, the operating mode of the DSAD0 is set to low-power mode to reduce current consumption.

For the CPU section, minimizes the CPU operating time and reduces current consumption by shifting to software standby mode during standby, and shifting deep sleep mode during A/D conversion for measurement.

**Table 7-7 Current consumption measurement result**

| | Current consumption [µA] | | | | |
|---|---|---|---|---|---|
| | AFE section | | CPU section | | |
| | **Module stop** | **AFE active** | **Software Standby** | **Deep sleep** | **CPU WakeUp** |
| External Input | less than 0.1 | 405.3 | 0.7 | 279.3 | 550.4 |
| On-Chip Timer | less than 0.1 | 399.0 | 0.7 | 280.8 | 565.9 |
| Reference | 2.2 Max[Note1] | DSAD: 380 Typ<br>VREF: 45 Typ<br>Total: 425 Typ [Note2] | 0.4 Typ[Note3] | - | - |

Notes: 1. RX23E-A Group User's Manual: Hardware Table 39.15.
2. RX23E-A Group User's Manual: Hardware Table 39.14.
3. RX23E-A Group User's Manual: Hardware Table 39.9.

**Table 7-8 Power consumption measurement result**

| Trigger | AFE section power consumption [mW] | CPU section power consumption [mW] | Total [mW] |
|---|---|---|---|
| External Input | 0.005 | 0.002 | 0.007 |
| On-Chip Timer | 0.005 | 0.002 | 0.007 |

**Table 7-9 Effective resolution measurement result**

| Trigger | RMS noise [$\mu V_{rms}$] (Effective resolution (bits)) |
|---|---|
| External Input | 4.642 (20.04) |
| On-Chip Timer | 4.532 (20.07) |
| Reference | 4.794 (20.00) [Note] |

Note: RX23E-A Group User's Manual: Hardware Table 39.55, Table 39.56.

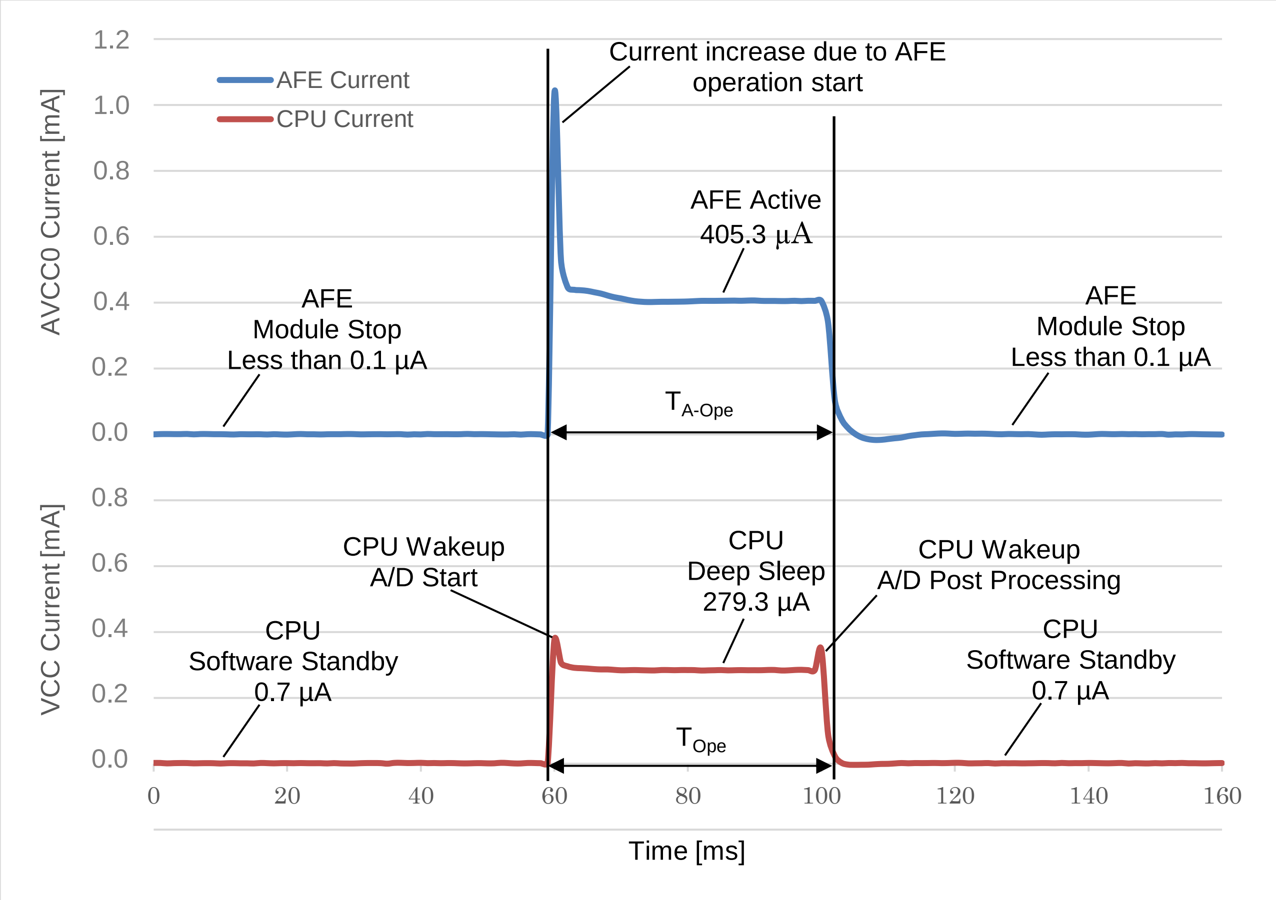



**Figure 7-2 Current consumption measurement result (External trigger)**

## Revision History

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 1.0 | Jan.29.25 | - | First edition. |
| | | | |

# 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.

## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com


## Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit: www.renesas.com/contact/.