RX23E-B Group

Example of weight measurement using AC excited load cell

Introduction

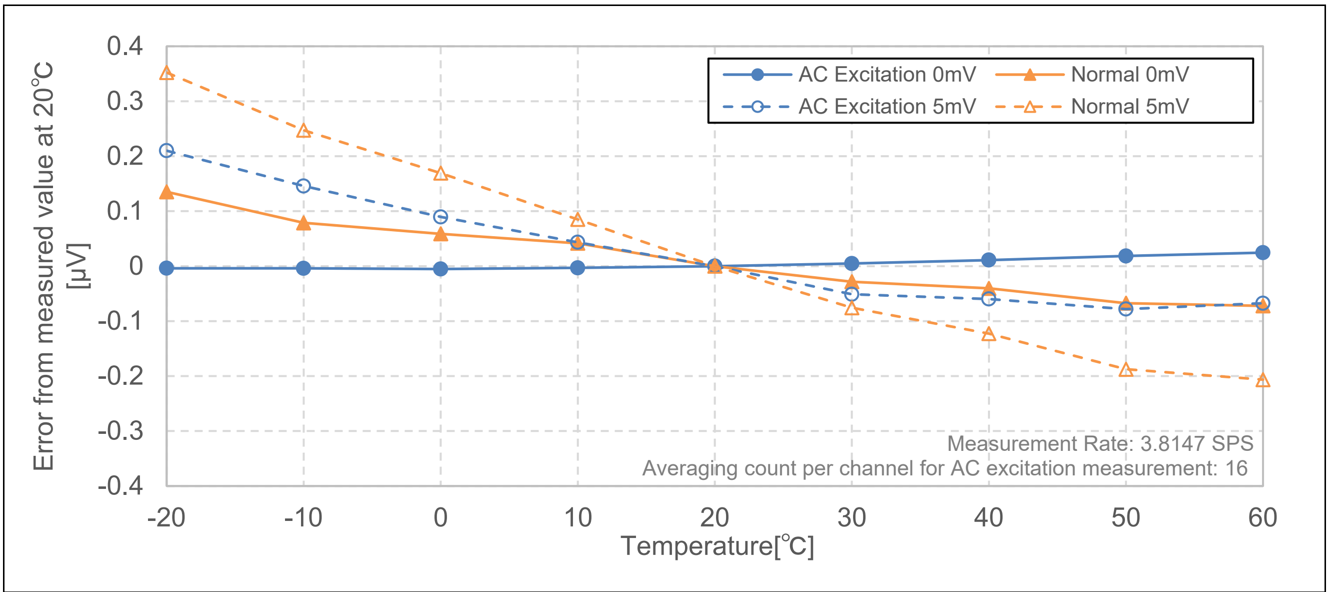
This document describes an example of weight measurement using AC excited load cell, using RX23E-B.

In AC excitation measurement, the polarity of the excitation voltage applied to the sensor is changed to obtain sensor outputs at different polarities. AC excitation measurement eliminates error factors generated outside the A/D converter, including thermal electromotive forces in parasitic thermocouples due to temperature gradients in the board and wiring, voltage drops due to pattern impedance, low-frequency components in thermal noise due to pattern or circuit resistance, and resistive current noise, and error factors generated inside the A/D converter, including offsets, offset drifts, and low-frequency noise, thereby enabling high-precision sensor measurement.

RX23E-B is equipped with an analog front end (AFE) and a high-speed 24-bit Δ-Σ A/D converter (DSAD) with a maximum output of 125kSPS. It also has a multi-function timer pulse unit (MTU), which performs complementary PWM output necessary for AC excitation measurement; an event link controller (ELC), which starts A/D conversion by DSAD with compare match from MTU; and a data transfer controller (DTC), which transfers the A/D value to RAM when A/D conversion ends. This makes it possible to obtain A/D conversion results without using the CPU and allows the CPU to focus on processing the obtained A/D conversion results.

Using the Renesas Solution Starter Kit for RX23E-B and the sample programs in this document, voltage measurements were made using a calibration strain generator. The board was placed in a thermostatic chamber and the temperature was varied in 10°C increments from -20°C to 60°C. The average of 500 samples was measured under stable conditions at each temperature, and the error between the measured values at the thermostatic chamber set temperature of 20°C and the measured values at each temperature was calculated and compared when AC excitation was enabled and disabled. The results are shown in the table below and the figure below.

Item	Range of Variation	
	AC Excitation	Normal (AC Excitation Disabled)
Input Voltage: 0mV	0.030μV	0.207μV
Input Voltage: 5mV	0.288μV	0.559μV



Target Device

RX23E-B (R5F523E6LDFP)

Contents

1. Overview

This document describes an example of weight measurement using AC excited load cell, using Renesas's microcontroller RX23E-B. The sample program runs on the Renesas Solution Starter Kit for RX23E-B (RSSKRX23E-B) board to set operation conditions and obtain and output measurement results by using the application tab of QE for AFE.

Figure 1-1 shows the weight measurement system used in this example and Figure 1-2, Table 1-1, and Table 1-2 show the operable items.

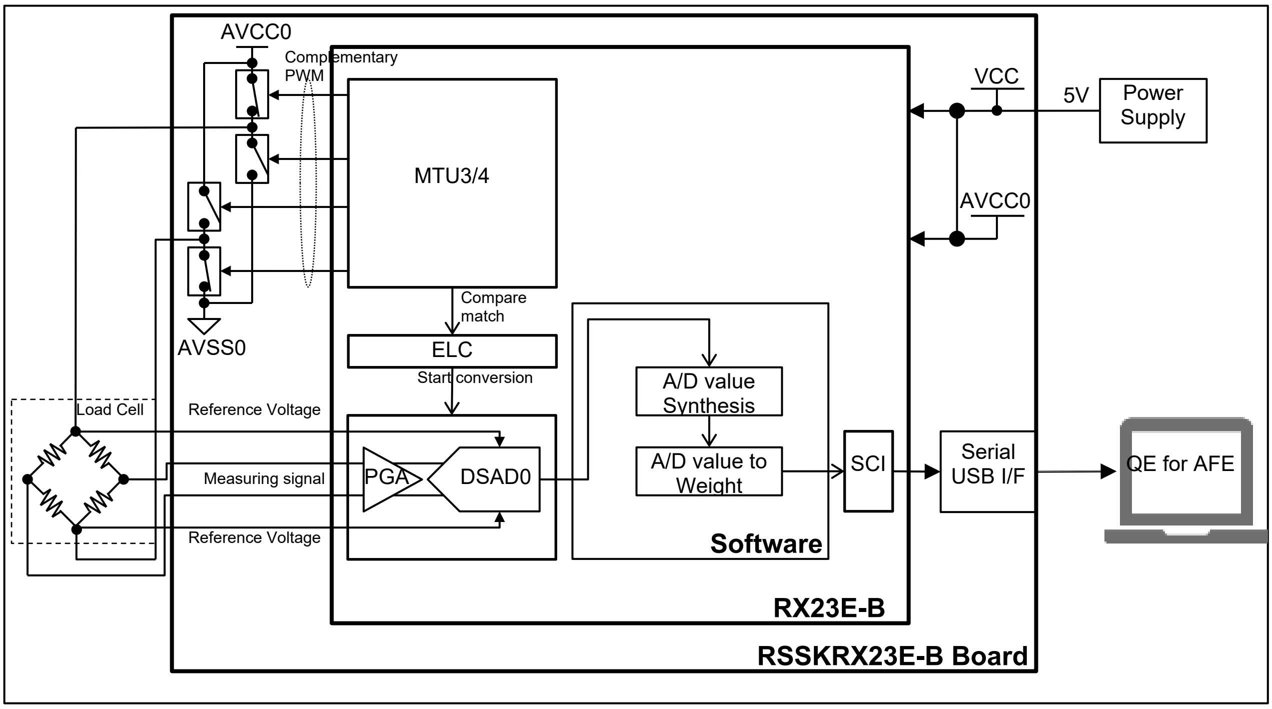


Figure 1-1 Example of Load Cell Weight Measurement System using AC Excitation

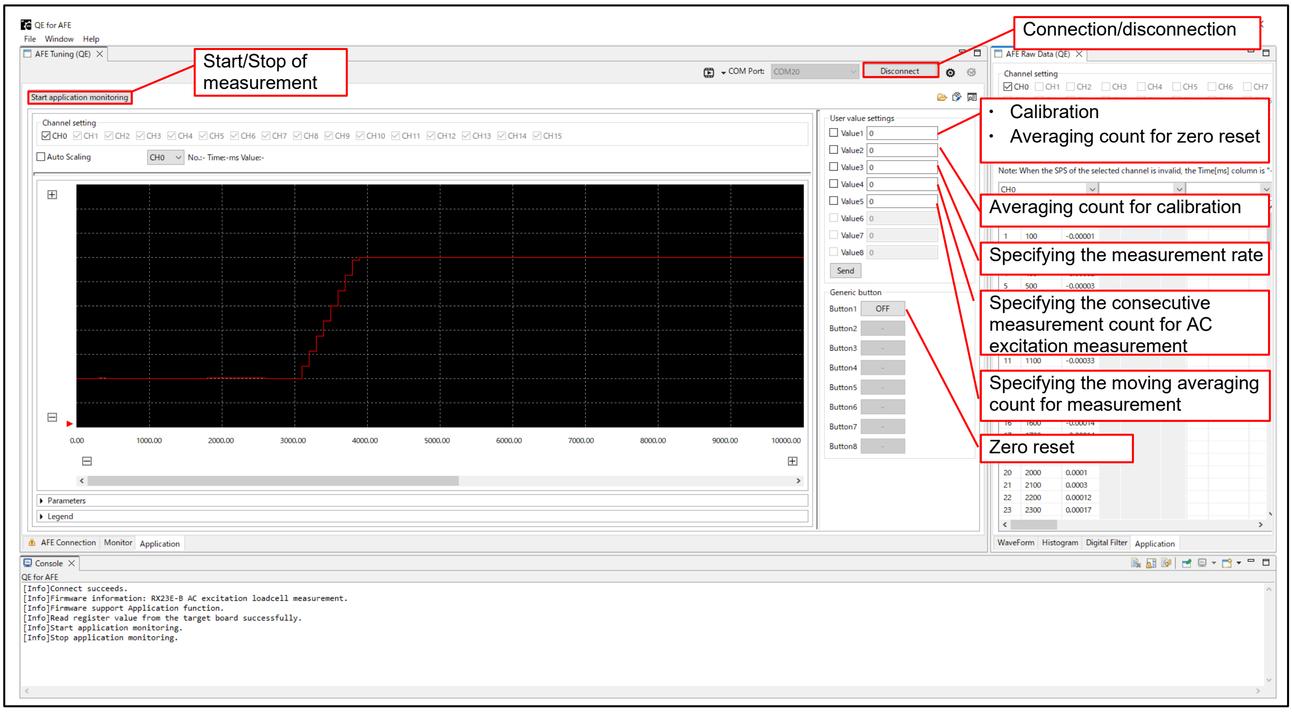


Figure 1-2 QE for AFE Application Tab Screen

Table 1-1 Operable Items

Bold text indicates default settings.

Item	Operation	Remarks
Connection	QE for AFE	LED1 OFF
Start/stop of measurement	QE for AFE	LED0 OFF during A/D conversion
Zero reset	QE for AFE: Button1 RSSKRX23E-B board: SW1	Enabled during measurement
Calibration	QE for AFE: Value1 Specify measurement weight 1 in Value1 Specify measurement weight 2 in Value1 while LED0 is blinking	Enabled only while measurement is stopped (LED0 ON) LED0 OFF during A/D conversion LED0 blinks five times in case of abnormal termination. See "4.5Calibration".
Specifying the averaging count for zero reset	QE for AFE: Value1 1 to 512: default **8**	Enabled only during weight measurement (LED0 OFF)
Specifying the averaging count for calibration	QE for AFE: Value2 1 to 512: default **128**	Disabled during A/D conversion
Specifying the measurement rate	QE for AFE: Value3 3.8147, **10**, 100, 1000 [SPS]	
Specifying the averaging count per channel for AC excitation	QE for AFE: Value4 **1**, 4, 16, 32 [samples/channel]	
Specifying the moving averaging count for measurement	QE for AFE: Value5 1 to 128: default: **8**	Disabled during A/D conversion
Selecting the measurement mode	RSSKRX23E-B: SW3-1 OFF: AC excitation ON: Normal	Disabled during A/D conversion
Parameter initialization	RSSKRX23E-B: SW2	At the time of reset, press this until LED0 turns on.

Table 1-2 Settable Register Items

Item	Operation	Remarks
PGA gain	Change PGA gain setting for CH0	Disabled during measurement/calibration

Note: For registers MR, MRm, CRm, OSRm, and SGCRm, which are not settable items, they are set to the retained values (Table 5-9 to Table 5-13) by the program at the time of calibration. Changing a register setting other than those included in this table will result in malfunction.

Also, changes to the parameters listed in Table 1-3 are retained in E2 data flash.

Table 1-3 Retained Parameters

Item	Number of data stored	Detail
Measurement rate	1	
Averaging count per channel for AC excitation	1	
DSAD0 parameters for AC excitation	16 sets	Measurement rate × Averaging count per channel
Weight conversion coefficients	20 sets	AC excitation measurement: 16 Normal measurement: 4
Averaging count for zero reset	1	
Averaging count for calibration	1	
PGA gain setting value	1	Applied to all PGA settings

Note: For details, see structure st_e2df_data_t in Table 5-25.

2. Environment for Operation Confirmation

Table 2-1 Environment for Operation Confirmation

Item	Description
Board	RSSKRX23E-B (RTK0ES1001C00001BJ)
MCU	RX23E-B (R5F523E6LDFP) Power voltage (VCC, AVCC0): 5 V Operating frequency (ICLK): 32 MHz Peripheral operating frequency PCLKB, PCLKC: 32MHz PCLKA: 16MHz DSAD0 operating frequency (f_{OP}): 16 MHz DSAD0 modular clock frequency (f_{MOD}): 4 MHz
Load cell	Tedea Huntleigh 505H-0002-F070
Host	Renesas QE for AFE V2.1.1
IDE	Renesas e2 Studio Version 2023-04 Renesas RX Smart Configurator V23.4.0
Tool Chain	Renesas CC-RX V3.05.00
Emulator	E2 Emulator Lite

3. Related Documents

- R01UH0972 RX23E-B Group User's Manual: Hardware
- R12UZ0108 RSSKRX23E-B User's Manual
- R01AN6364 RX23E-B Group RSSKRX23E-B Board Control Program
- R01AN6512 RX23E-B Group Design and weight measurement of tiny board for digital load cell

4. Weight Measurement Method

4.1 RSSKRX23E-B

Figure 4-1 shows the connection using the RSSKRX23E-B board. In this example, a six-wire load cell is used.

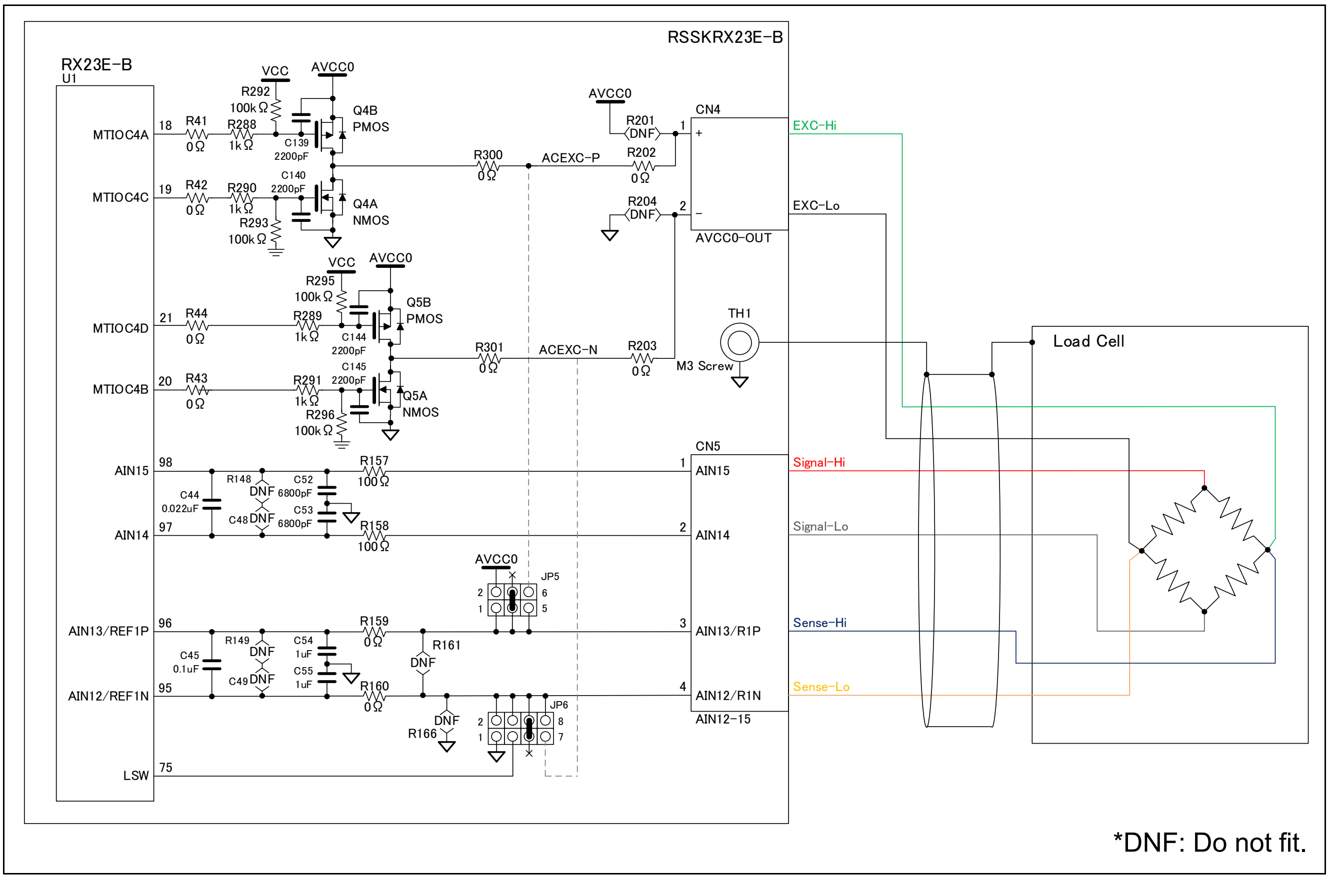


Figure 4-1 Connection of RSSKRX23E-B board

Table 4-1 shows the changes to the RSSKRX23E-B components made for AC excitation measurement, and Table 4-2 shows the jumper settings.

Table 4-1 Changes to RSSKRX23E-B for AC Excitation Measurement

Circuit code	Before change	After change	Remarks
R41, R42, R43, R44	DNF	0Ω	Connecting PWM output pin MTIOC4x to MOSFET gate
R201, R204	0Ω	DNF	Connecting MOSFET drain to CN4
R202, R203	DNF	0Ω	
C19, C20, C21	0.47μF, 16V	DNF	Removing capacitor for LCD bias voltage generation

Table 4-2 Jumper Settings for RSSKRX23E-B for AC Excitation Measurement

Function	Code	Connection	Setting
Digital power selection (VCC)	JP1	7-8	External power supply Vd is used for VCC.
Analog power selection (AVCC0)	JP2	1-2	Digital power supply VCC is used for AVCC0.
External reference selection (REF1P)	JP5	3-4	External input is selected for REF1P.
External reference selection (REF1N)	JP6	5-6	External input is selected for REF1N.

4.2 Load cell

The load cell used in this example outputs a weight as a voltage by using a Wheatstone bridge circuit. Table 4-3 shows an excerpt of the specifications of the load cell used, and Figure 4-2 shows the weight vs. output voltage characteristics and error range determined from the specifications with an applied voltage of 5 V.

Table 4-3 Excerpt of Specifications of Load Cell 505H-0002-F070

Item	Value
Recommended Excitation	10V
Maximum Excitation	15V
Rated Capacity	2kg
Rated Output: R.O.	2±0.2mV/V
Total Error	0.025%[R.C.] or less

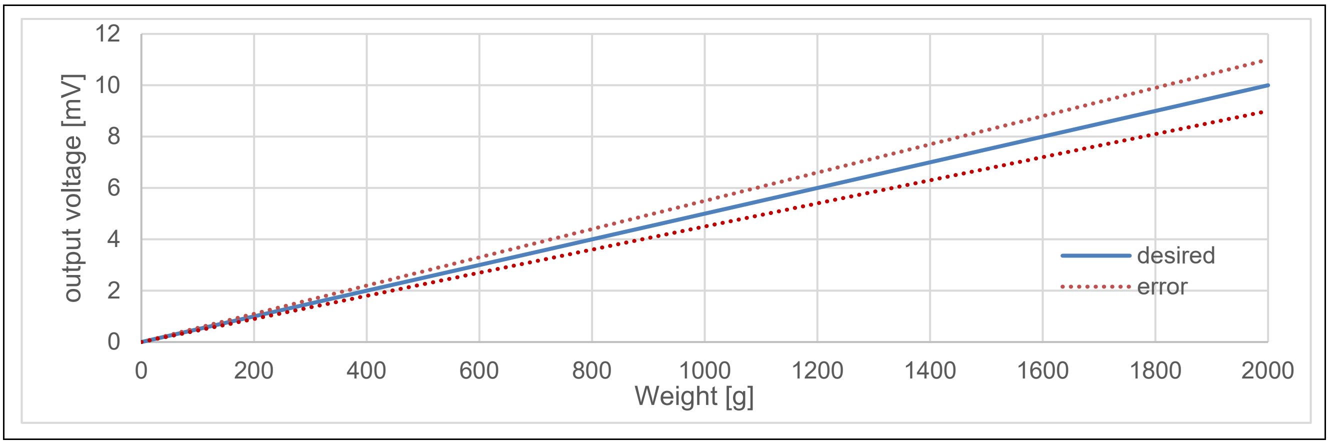


Figure 4-2 Weight vs. Output Voltage Characteristics of Load Cell 505H-0002-F070 (Applied Voltage 5 V)

In this example, the voltage between the output pins of the load cell is A/D converted with the voltage supplied to the load cell as the reference voltage as shown in Figure 4-1.

If the output voltage of the load cell is non-linear in relation to the weight, the characteristic curve is divided into multiple regions and linear approximation, for example, is performed in each of the regions to increase the measurement accuracy, thereby matching the characteristic curve. In this example, the region is regarded as a single linear characteristic without being divided, and the voltage is converted to weight with linear interpolation. Assuming that the voltage applied to the load cell is V_{cc}, the rated output is RO, and the rated load is M_{max}, the output voltage V for the weight M can be expressed with the formula below.

$$V = \mathrm{RO} \cdot V_{cc} \cdot \frac{M}{M_{max}}$$

From the formula above, the weight M for the output voltage V can be calculated with the linear equation below.

$$M = \alpha V + \beta, \qquad \begin{cases} \alpha = \dfrac{M_{max}}{\mathrm{RO} \cdot V_{cc}} \\ \beta = 0 \end{cases}$$

For the output voltage of the load cell, an error occurs due to the rated output, zero balance, and so on. Thus, the coefficients α and β in the equation above are corrected with calibration. Table 4-4 shows the measurement conditions.

Table 4-4 Load Cell Measurement Conditions

Item	Condition	Remarks
PGA gain G_{PGA}	x128	
DSAD0 reference voltage V_{REF}	5V	Voltage applied to the load cell. (REF0P=AVCC0, REF0N=ACSS0)
DSAD0 output format	2's Complement	

4.3 A/D Conversion of Load Cell Output by AC Excitation

In AC excitation measurement, the polarity of the excitation voltage applied to the load cell is changed, and the A/D conversion results at different polarities are synthesized as the final A/D conversion result, thereby reducing errors due to temperature changes or other reasons in the measurement circuit and A/D converter.

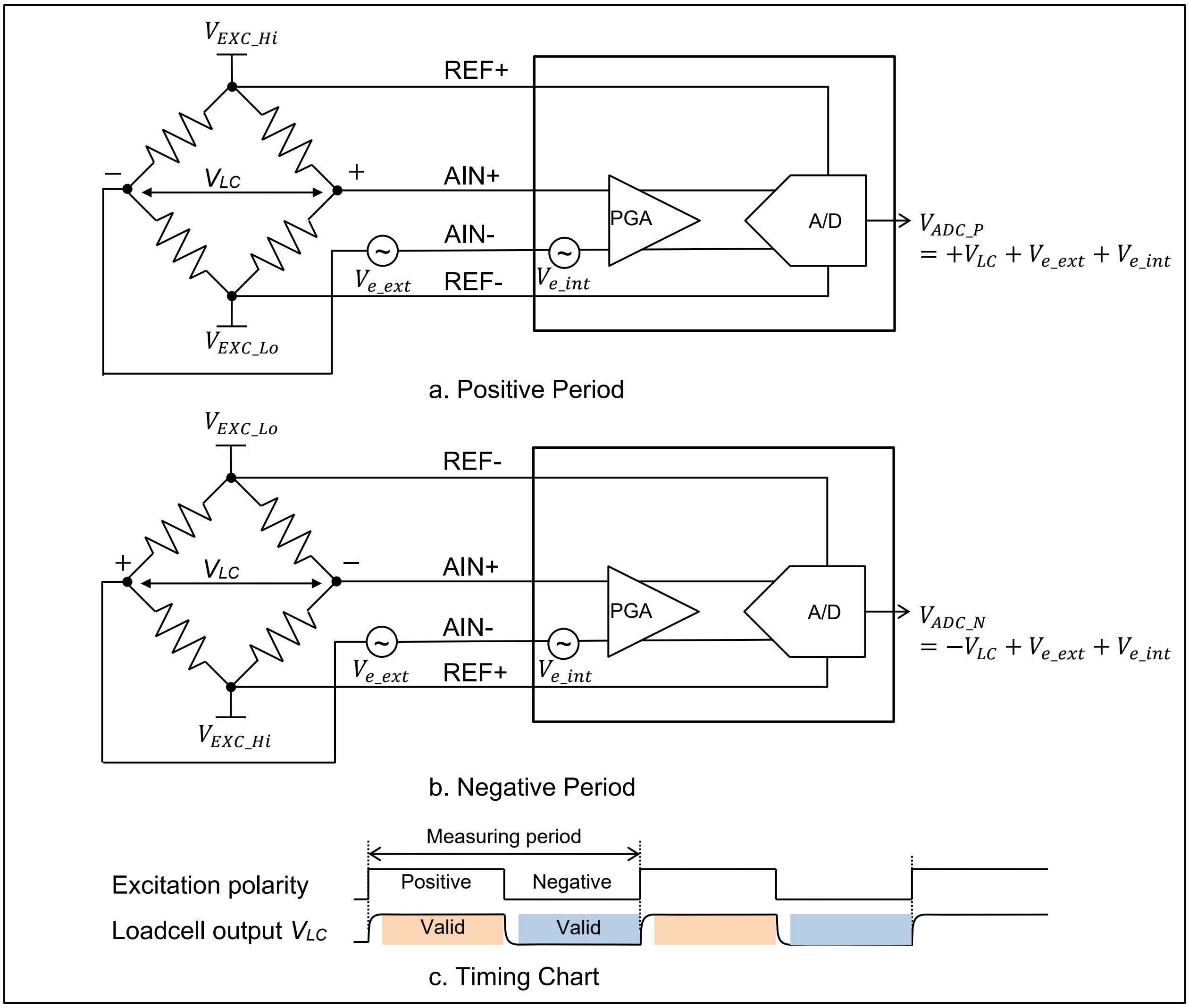


Figure 4-3 Principle of AC Excitation Measurement

As shown in Figure 4-3, the load cell measurement circuit has two types of errors: errors generated inside the A/D converter V_{e_int} and errors generated outside the A/D converter V_{e_ext}.

In normal load cell measurement, the configuration shown in Figure 4-3a is used for A/D conversion, but the obtained A/D conversion results contain these errors V_{e_int}, V_{e_ext}. Among these errors, time-invariant errors, such as offsets, can be removed by calibration, but offset drifts due to temperature changes or other reasons cannot be removed.

In AC excitation measurement, the polarity of the signals input to the AIN+ and AIN- pins of the A/D converter changes depending on the period (positive or negative), but the polarity of errors does not change because the signal path does not change. Therefore, if an error is constant in the positive and negative periods, the error can be canceled by calculating the mean difference of the A/D conversion results in the positive and negative as shown in the formula below.

$$V_{ADC} = \frac{V_{ADC\_P} - V_{ADC\_N}}{2} = \frac{(V_{LC} + V_{e\_ext} + V_{e\_int}) - (-V_{LC} + V_{e\_ext} + V_{e\_int})}{2} = \frac{V_{LC} + V_{LC}}{2} = V_{LC}$$

If the positive and negative load cell outputs have a time constant, it is effective to perform A/D conversion multiple times for valid load cell output signals in each polarity; perform filtering, such as averaging, for each polarity; and calculate the mean difference between the positive and negative polarities.

In this example, only the peripheral functions are used to change the polarity of the excitation voltage and obtain the A/D conversion results, and the program performs averaging and synthesis the obtained A/D values in different polarities. Therefore, the excitation voltage polarity change period can be regarded as the weight measurement period. Figure 4-4 shows the timing chart for polarity change and A/D conversion.

The polarity of the excitation voltage is changed by the complementary PWM signal from the multi-function timer pulse unit MTU3/4, and the load cell outputs in each excitation voltage polarity are A/D converted by DSAD0. In each complementary PWM period, A/D conversion is started via the event link controller ELC by using the MTU4 compare match 4A as a trigger, which indicates the start of the positive-side dead time. DSAD0 uses CH0 for the positive polarity and CH1 for the negative polarity and performs A/D conversion by single scan. DSAD0 performs A/D conversion the specified number of samples for CH0 and CH1, then the samples are transferred to the buffer by DTC using the DSAD0 conversion end interrupt: ADI0 as a trigger.

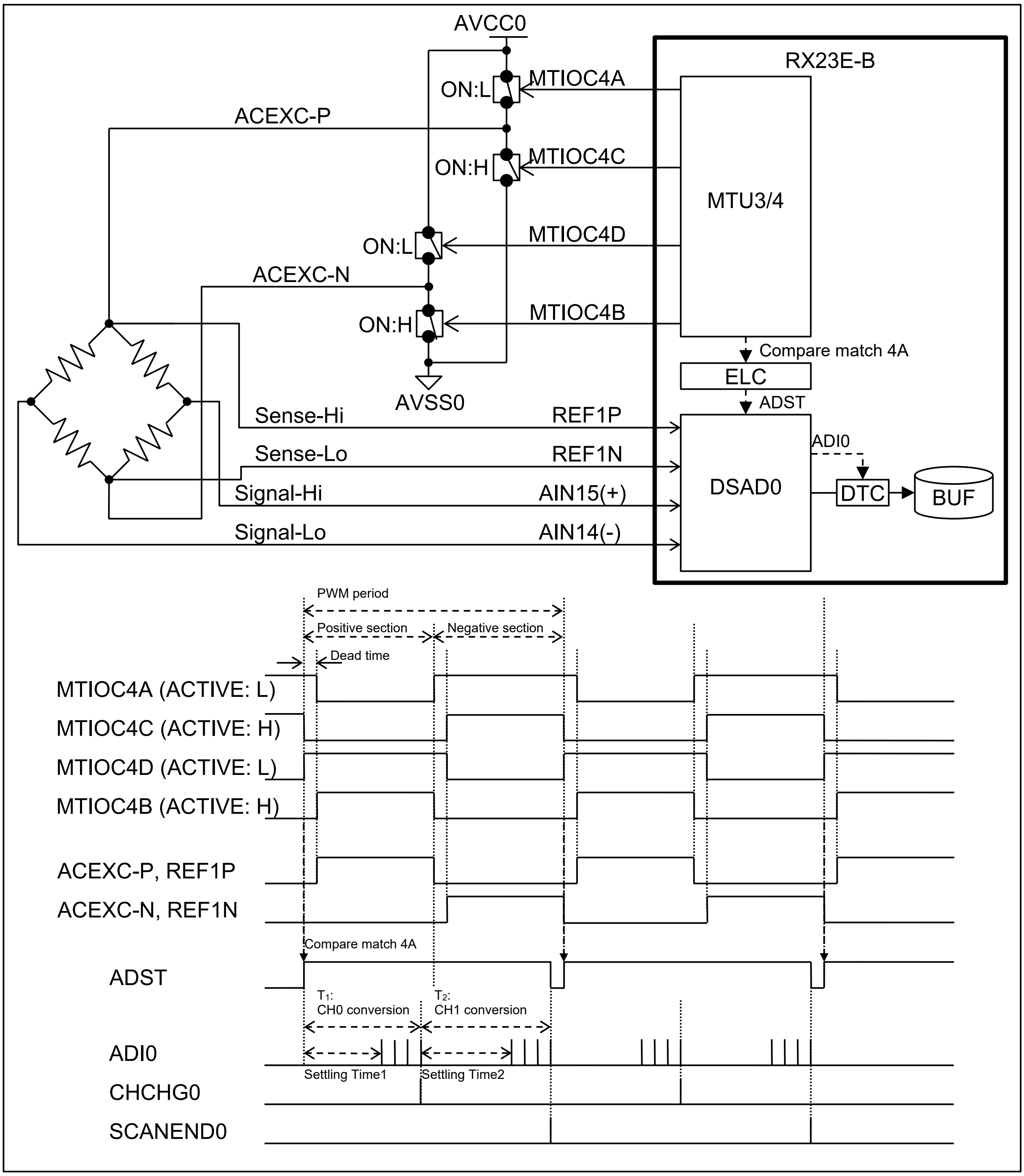


Figure 4-4 Control Timing of AC Excitation Measurement (4 samples per channel)

In relation to the PWM period, which is equal to the power polarity change period, the number of times DSAD0 can perform A/D conversion for each channel is determined so that the DSAD0 settling time S_n, sampling frequency F_{MOD}, total oversampling ratio OSR, and number of A/D conversions for each polarity N_n satisfy the equation below. For n, 1 and 2 indicate positive and negative polarities, respectively. For the settling time, refer to "36.3.7.2 Settling Time" in RX23E-B Group User's Manual: Hardware.

$$\begin{cases} T_1 = S_1 + \dfrac{OSR \cdot (N_1 - 1)}{F_{MOD}} \leq \dfrac{PWM\ Period}{2} \\ T_2 = S_2 + \dfrac{OSR \cdot (N_2 - 1)}{F_{MOD}} \leq \dfrac{PWM\ Period}{2} \\ T_1 + T_2 < PWM\ Period \end{cases}$$

The obtained A/D conversion results are averaged with the specified sample size for each polarity, and the mean difference of the results is used as the final A/D conversion result. In this example, A/D conversion is started when the positive dead time starts. If the number of times of A/D conversion in each polarity N_n is greater than the number of times of averaging, the latter A/D conversion results are used for averaging.

In this example, the A/D conversion conditions are set as shown in Table 5-9 to Table 5-12 with four different measurement rates, which are 3.8147SPS, 10SPS, 100SPS, and 1000SPS, and four different numbers of A/D conversion results to be averaged for each polarity, which are 1, 4, 16, and 32 (16 combinations in total).

4.4 Weight Calculation Procedure

Conversion from A/D conversion value to weight is performed with the procedure below.

(1) Smoothing of the A/D conversion value

Variations in A/D conversion results due to noise, vibration, and other factors are removed with a filter, etc. In this example, a smoothing process is performed with an 8-sample moving average.

(2) Weight conversion

In the above-mentioned weight conversion formula, the voltage is replaced by the A/D conversion value for calculation. Assuming that the PGA gain is G_{PGA}, the reference voltage of DSAD0 is V_{REF}, and the A/D conversion value is DATA, the weight can be determined from the 24-bit resolution of the DSAD0 with the formula below. The digital filter gain is corrected to 1 using the sinc filter gain correction.

$$\begin{aligned} M &= \alpha V + \beta \\ &= \alpha \cdot \frac{2V_{REF}}{2^{24} \cdot G_{PGA}} \cdot \mathrm{DATA} + \beta \\ &= \alpha \cdot \frac{V_{REF}}{2^{23} \cdot G_{PGA}} \cdot \mathrm{DATA} + \beta, \qquad V_{REF} = AVCC0 - AVSS0 \end{aligned}$$

From the formula above, the formula for calculating the weight from the A/D conversion value is defined as below.

$$M = \alpha V + \beta = a \cdot \mathrm{DATA} + b, \qquad \begin{cases} a = \alpha \cdot \dfrac{V_{REF}}{2^{23} \cdot G_{PGA}} \\ b = \beta = 0 \end{cases}$$

4.5 Calibration

By correcting the coefficients a and b in the formula for conversion from A/D conversion value to weight for the error of the load cell, the measurement accuracy can be improved.

As an example, calibration can be performed with the procedure below, in the weight range corresponding to the conversion formula, from two reference weights of counterweights and their A/D conversion values.

(1) Obtain the A/D conversion value DATA1 for reference 1 weight $\boldsymbol{M_1}$

(2) Obtain the A/D conversion value DATA2 for reference 2 weight $\boldsymbol{M_2}$

(3) Calculate the coefficients $\boldsymbol{a}$ and $\boldsymbol{b}$ of the line passing through $(\mathbf{DATA_1},\ \boldsymbol{M_1})$ and $(\mathbf{DATA_2},\ \boldsymbol{M_1})$ by the formula below and apply them

$$\begin{cases} a = \dfrac{M_2 - M_1}{DATA_2 - DATA_1} \\ b = M_1 - a \cdot DATA_1 = M_2 - a \cdot DATA_2 \end{cases}$$

4.6 Zero Reset

The measured weight is corrected by subtracting the reference measurement result assumed to be the zero weight from the weight conversion result.

The reference value is the value resulting from conducting measurement in the zero-weight state and converting the value to weight.

5. Sample Program

5.1 Overview of Operation

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

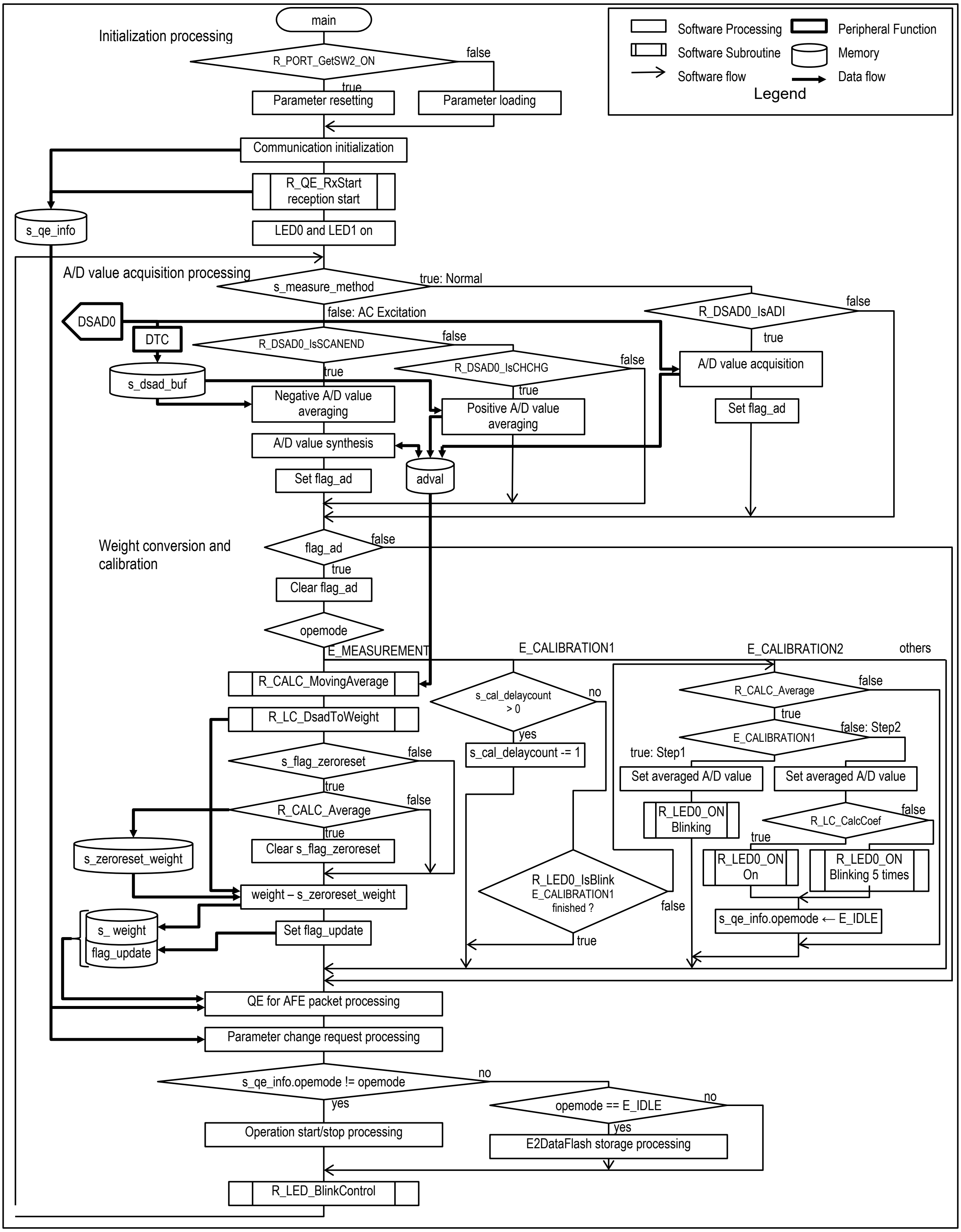


Figure 5-1 General Flow

The operation of this program is specified by opemode which is a member of s_qe_info structure variable. Table 5-1 shows the operation modes.

Table 5-1 Operation Modes

Name	Description
E_IDLE	Standby
E_MEASUREMENT	Measurement
E_CALIBRATION1	Calibration STEP1
E_CALIBRATION2	Calibration STEP2

Each of the processes shown in Figure 5-1 is as follows.

- Initialization processing
  - Loading measurement condition parameters
    The measurement condition parameters stored in E2 data flash are loaded.
    When SW2 is pressed, the default values are loaded.
  - Starting communication to QE for AFE
    The parameters for QE for AFE communication are initialized, and the reception is started.
  - LED ON
    LED0 and LED1 are turned on to indicate the completion of initialization.

- A/D value acquisition processing
  the A/D values are obtained by the measurement method obtained in "A/D conversion start/stop processing".
  - AC excitation measurement
    The A/D conversion results are stored in array s_dsad_buf by DTC.
    When the end of conversion for the positive polarity is detected by CHCHG0 of DSAD0, it calculates the average of the A/D values for the positive polarity based on the measurement condition parameters.
    When the end of conversion for the negative polarity is detected by SCANEND0 of DSAD0, it calculates average of the A/D values for the negative polarity based on the measurement condition parameters, then synthesizes with the averaged A/D value of the positive polarity as the final A/D value.
  - Normal measurement
    When the completion of conversion is detected by ADI0 of DSAD0, it obtains the A/D value.

- Weight conversion and calibration
  The obtained A/D value is processed in the operation mode: opemode used in "A/D conversion start/stop processing".
  - opemode: E_MEASUREMENT
    The A/D value is converted to weight and the weight measurement result is obtained by subtracting the zero-reset weight.
    When a zero-reset has been requested, the converted weight is averaged the number of times specified as a measurement condition parameter as the zero-reset weight.
  - opemode: E_CALIBRATION1
    Calculates and retains averaging of A/D values after the number of delay samples calculated from calibration delay time. The number of averages applies the specified value in the measurement condition parameters.
  - opemode: E_CALIBRATION2
    Calculate averaging of A/D values, and derives the weight conversion coefficients from two averaged A/D values and the corresponding weights according to “4.5 Calibration”.

- QE for AFE packet processing
  Using the QE communication module API, processes the received packets, and transmits the weight measurement result if measurement is in progress. Communication process is reset when transmission timeout is detected.
  The user operations listed in Table 1-1 are performed by the user functions of the QE for AFE communication module. For details on the QE for AFE communication module, refer to Application note "RX23E-B Group RSSKRX23E-B Board Control Program".

- Parameter change request processing
  SW1 on board processing and the measurement condition parameter change processing requested by QE for AFE is performed.
  - SW1 processing
    Requests zero-reset when the pressing of SW1 is detected during weight measurement.
  - QE for AFE request processing
    The following requests from QE for AFE are reflected in internal flags, or the measurement condition parameters are modified.
    - Zero reset request
    - Specifying the averaging count for zero reset
    - Specifying the averaging count for calibration
    - Specifying the measurement rate
    - Specifying the consecutive measurement count for AC excitation measurement
    - Changing the DSAD0 PGA gain setting

- Operation start/stop processing
  If opemode changes, start or stop operation based on the new opemode.
  — opemode: E_IDLE
  - Stop A/D conversion.
    - AC excitation measurement: PWM output MTU, ELC, DSAD0, and DTC are stopped.
    - Normal measurement: DSAD0 is stopped, and DSAD0 is set to single-scan mode.
  - Set PWM output to inactive.
  - LED0 is turned on if it is not blinking.

  — opemode: E_MEASUREMENT, E_CALIBRATION1
  Sets A/D conversion conditions according to the measurement method and start A/D conversion, then.
  - Obtaining the measurement method: The measurement method is selected according to the status of board SW3-1.
    OFF: AC excitation measurement, ON: Normal measurement
  - Setting A/D conversion: Set A/D conversion conditions based on the measurement condition parameters according to the measurement method, and start A/D conversion, then turns off LED0.
    - AC excitation measurement:
      Enabling DSAD0 CH0 and CH1 and setting DSAD0 parameters
      Setting A/D value transfer DTC
      Setting PWM outputs
      Starting DTC, ELC, and PWM output MTU and setting PWM outputs
      Selecting the coefficient used for weight conversion
    - Normal measurement:
      Setting the PWM outputs for the positive polarity
      Enabling DSAD0 CH2 and setting DSAD0 parameters
      Setting DSAD0 to continuous scan mode
      Setting A/D conversion start
      Selecting the coefficient used for weight conversion
  - Initializing each parameter: Initializing parameters according to opemode
    - E_MEASUREMENT:
      Initialize the moving average processing.
    - E_CALIBRATION1:
      Sets the calibration delay samples from the calibration delay time.
      Executes following E_CALIBRATION2 settings.

  — opemode: E_CALIBRATION2
      Initialize the averaging processing.
      Sets the reference weight to the calibration parameter.
      LED0 off.

- E2 data flash storage processing
  If opemode does not change from E_IDLE and the measurement conditions change, the parameters stored in E2 data flash are updated.

5.2 MCU Functions Used and Settings

Table 5-2 lists the peripheral functions used in this example, and Table 5-3 lists the pins used. Also, Table 5-4 shows the clock settings.

The settings for the peripheral functions are generated by using the code generation function of Smart Configurator (referred to as SC in the remainder of this manual). The following shows the peripheral function settings for each application.

Table 5-2 Peripheral Functions Used

Peripheral function	Use
MTU3/MTU4	Generation of complementary PWM signals
ELC	A/D conversion start trigger
AFE/DSAD0	A/D conversion of load cell output
DTC	Acquisition of A/D conversion results
SCI1	Communication with QE for AFE
DMAC1	Reception of packets from QE for AFE
DMAC3	Transmission of packets to QE for AFE
CMT0	Detection of errors in transmission of packets to QE for AFE
CMT1	LED blinking interval
P70 - P73	LED ON/OFF control
PE1 - PE4	Acquisition of switch status
E2DataFlash	Storage of retained parameters

Table 5-3 Pins Used

Pin No.	Pin name	I/O	Use
5	P73	O	LED3
6	P72		LED2
7	P71		LED1
8	P70		LED0
13	XTAL	O	Crystal oscillator
15	EXTAL	I	
18	P67/MTUIC4A	O	Complementary PWM output
19	P66/MTUIC4C		
20	P65/MTUIC4D		
21	P64/MTUIC4B		
28	P30/RXD1	I	Reception of UART1
30	P26/TXD1	O	Transmission of UART1
39	P15/CTS1#	I	UART1 CTS input
62	PE4	I	SW3-2
63	PE3		SW3-1
64	PE2		SW2
65	PE1		SW1
95	REF1N	I	DSAD0 reference voltage input
96	REF1P		
97	AIN14	I	Load cell output - side input pin
98	AIN15		Load cell output + side input pin

Table 5-4 Clock Configuration

Item		Setting
Clock		Main clock
	Oscillation source	Resonator
	Frequency	8MHz
	Wait time	8192 (2048 μs)
PLL circuit	Frequency Division	x1/2
	Frequency Multiplication	x8
SCKCR (FCLK)		x1 (32MHz)
SCKCR (ICLK)		x1 (32MHz)
SCKCR (PCLKA)		x1/2 (16MHz)
SCKCR (PCLKB)		x1 (32MHz)
SCKCR (PCLKC)		x1 (32MHz)
SCKCR (PCLKD)		x1 (32MHz)

5.2.1 Load Cell Measurement

AFE and DSAD0 are used for load cell measurement. For AC excitation measurement, MTU is used for complementary PWM output; ELC for allowing DSAD0 to start A/D conversion from compare match by MTU; and DTC for transferring the A/D value to RAM by using the completion of A/D conversion as a trigger. The following shows the settings for each peripheral function.

Table 5-5 MTU3 and MTU4 Settings

Complementary PWM Mode Timer Operation: mode 1 (transfer at crest)
Bold text indicates default settings.

Item		**Setting**			
PWM period (Hz)		**3.8147**	**10**	**100**	**1000**
Synchronous mode setting		Not used			
TCNT3 counter setting	Counter clear source	Disabled Counter clear			
	Counter clock selection	PCLK/64	**PCLK/16**	PCLK/4	PCLK/4
		Rising edge			
PWM output setting	Timer operation period	262.144ms	**100ms**	10ms	1ms
	Enable dead time	Enable			
	Dead Time	16μs	**10μs**	10μs	10μs
	MTU3.TGRB register value	16390	**25015**	10060	1060
	MTU4.TGRA register value	16386	**25005**	10020	1020
	MTU4.TGRB register value	16386	**25005**	10020	1020
Brushless DC motor control setting		Not used			
Output setting	Enable MTIOC3A toggle output	Disable			
	Buffer transfer timing of PWM output level setting	Do not transfer data from the buffer register			
	Enable U phase Initial output level of MTIOC3B pin (positive-phase)	Not used			
	Enable U phase Initial output level of MTIOC3B pin (negative-phase)	Not used			
	Enable V phase Initial output level of MTIOC4A pin (positive-phase)	Enable, Active level: L			
	Enable V phase Initial output level of MTIOC4C pin (negative-phase)	Enable, Active level: H			
	Enable W phase Initial output level of MTIOC4B pin (positive-phase)	Enable, Active level: H			
	Enable W phase Initial output level of MTIOC4D pin (negative-phase)	Enable, Active level: L			
Interrupt setting		Not used			
Buffer register and synchronous clearing operation setting		Not used			
A/D conversion start trigger setting		Not used			

Note: The MTU4A.TGRA register value indicates the start of the dead time, and the MTU3.TGRB register value indicates the end of the dead time.

Table 5-6 ELC Settings

Item		**Setting**
SOURCE	Configuration	Config_MTU3_MTU4
	Event	MTU4 compare match 4A
DESTINATION	Configuration	Config_DSAD0
	Resource	DSAD0
	Operation	Start A/D conversion

Table 5-7 AFE Settings

Item	Setting
Bias output setting	Not used
Excitation current output setting	Not used
Low level voltage detection setting	Not used
Low-side switch setting	Not used

Table 5-8 DSAD0 Settings

Single scan mode Note2

Item		Setting		
Measurement method		**AC excitation Note 1**		**Normal Note 2**
Analog input channel setting		0	1	2
Operation clock setting		PCLK/2(16MHz)		
Conversion start trigger source		Hardware trigger		Software trigger Note2
Interrupt setting	Enable ΔΣA/D conversion completion interrupt (ADI0)	Enable, Priority: Level 0(disabled)		
	Enable ΔΣA/D conversion scan completion interrupt (SCANEND0)	Disable		
	Enable ΔΣA/D channel change interrupt (CHCHG0)	Disable		
Voltage fault and disconnection setting		Not used		
Analog input setting	Positive input signal	AIN15		
	Negative input signal	AIN14		
	Reference input	REF1P/REF1N	REF1N/REF1P	REF1P/REF1N
	Positive reference voltage buffer	Disable		
	Negative reference voltage buffer	Disable		
Amplifier setting	Amplifier selection	PGA		
	PGA gain setting	x128		
ΔΣA/D conversion setting	A/D conversion mode	Normal operation		
	Data format	Two's complement		
	A/D conversion number	Table 5-9 ~ Table 5-12		1
	First stage oversampling ratio			Table 5-13
	Second stage oversampling ratio			
	Set offset calibration value	Not used		
	Set gain calibration value	Not used		
Disconnect detection assist setting		Disable		
Digital filter setting		Table 5-9 ~ Table 5-12		Table 5-13

Note: 1. Execute AC excitation measurement with channel scan for CH0 and CH1.
2. Execute normal measurement with continuous scan mode and software trigger for CH2.

Table 5-9 DSAD0 Settings for AC Excitation Measurement 1

Measurement rate 3.8147SPS

Item		Setting			
A/D value averaging count per channel		**1**	**4**	**16**	**32**
ΔΣA/D conversion setting	A/D conversion number	1	5	17	34
	First stage oversampling ratio	256	256	256	256
	Second stage oversampling ratio	510	255	102	55
Digital filter setting	Sinc filter select	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4
	Sinc filter gain calibration value	1.015778788 0x00410285	1.015778788 0x00410285	1.239964341 0x004F5B93	1.833450283 0x0075573F

Table 5-10 DSAD0 Settings for AC Excitation Measurement 2

Measurement rate 10SPS

Item		Setting			
A/D value averaging count per channel		**1**	**4**	**16**	**32**
ΔΣA/D conversion setting	A/D conversion number	1	5	17	33
	First stage oversampling ratio	256	256	256	256
	Second stage oversampling ratio	194	97	38	21
Digital filter setting	Sinc filter select	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4
	Sinc filter gain calibration value	1.516082888 0x00610780	1.516082888 0x00610780	1.005762694 0x00405E6A	1.347915735 0x00564440

Table 5-11 DSAD0 Settings for AC Excitation Measurement 3

Measurement rate 100SPS

Item		Setting			
A/D value averaging count per channel		**1**	**4**	**16**	**32**
ΔΣA/D conversion setting	A/D conversion number	1	5	21	33
	First stage oversampling ratio	256	256	256	256
	Second stage oversampling ratio	18	9	3	2
Digital filter setting	Sinc filter select	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4
	Sinc filter gain calibration value	1.248590154 0x004FE8E6	1.248590154 0x004FE8E6	1.580246914 0x006522C3	1 0x00400000

Table 5-12 DSAD0 Settings for AC Excitation Measurement 4

Measurement rate 1000SPS

Item		Setting			
A/D value averaging count per channel		**1**	**4**	**16**	**32**
ΔΣA/D conversion setting	A/D conversion number	1	4	24	53
	First stage oversampling ratio	256	224	64	32
	Second stage oversampling ratio	2	1	1	1
Digital filter setting	Sinc filter select	Sinc5+Sinc1	Sinc5+Sinc1	Sinc5+Sinc1	Sinc5+Sinc1
	Sinc filter gain calibration value	1 0x00400000	1.949663831 0x007CC74A	1 0x00400000	1 0x00400000

Table 5-13 DSAD0 Settings for Normal Measurement

Item		Setting			
Measurement rate		**3.8147SPS**	**10SPS**	**100SPS**	**1000SPS**
ΔΣA/D conversion setting	First stage oversampling ratio	256	256	256	256
	Second stage oversampling ratio	4096	1562	156	15
Digital filter setting	Sinc filter select	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4	Sinc4+Sinc4
	Sinc filter gain calibration value	1 0x00400000	1.477629985 0x005E917D	1.813015331 0x00740871	1.294538272 0x0052D9B7

Table 5-14 DTC Settings

Item		Setting
Base setting	Transfer data read skip	Enable
	Address mode	Short address mode (24 bits)
	DTC vector base address	0x00007C00 (default setting)
Activation source setting	Activation source	DSAD0(ADI0)
	Chain transfer setting	Not used
Transfer mode setting		Repeat mode
Transfer data size setting		32 bits
Interrupt setting		An interrupt request to the CPU is disabled when specified data transfer is completed
Block/Repeat area setting		Transfer destination
Transfer address and count setting	Source address	0x000A1070 (DSAD0.DR) Address fixed
	Destination address	(Set by the program) Address increment
	Count	(Set by the program)

5.2.2 Communication

SCI1, DMAC1, DMAC3, and CMT0 are used for communication with QE for AFE. The following shows the settings for each peripheral function.

Table 5-15 SCI1 Settings

Asynchronous mode

Operation mode: Transmission/reception

Item		Setting
Start bit edge detection setting		Falling edge on RXD1 pin
Data length setting		8 bits
Parity setting		None
Stop bit length setting		1 bit
Transfer direction setting		LSB-first
Transfer rate setting	Transfer clock	Internal clock
	Bit rate	4Mbps
	Enable modulation duty correction	Not used
	SCK1 pin function	SCK1 is not used
Noise filter setting		Not used
Hardware flow control setting		CTS1#
Data handling setting	Transfer data handling	Data handled by DMAC
	Receive data handling	Data handled by DMAC
Interrupt setting	Enable reception error interrupt (ERI1)	Not used
	TXI1, RXI1, TEI1, ERI1 priority	Level 0 (disabled)
Callback function setting		Not used

Table 5-16 DMAC Settings

Item		Setting	
		DMAC1	DMAC3
Transfer setting	Activation source	SCI1 (RXI1)	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	-	(Setting on execution)
Source address setting	Source address	0x0008A025(SCI1.RDR) Fixed	(Setting on execution) Incremented
	Specify the transfer source as extended repeat area	-	Enable
	Extended repeat area		Lower 9 bits of the address (512 bytes)
Destination address setting	Destination address	(Set by the program) Incremented	0x0008A023(SCI1.TDR) Fixed
	Specify the transfer destination as extended repeat area	Enable	-
	Extended repeat area	Lower 9 bits of the address (512 bytes)	
Interrupt setting		Not used	

Table 5-17 CMT0 Settings

Item		Setting
Count clock setting		PCLKB/512
Compare match setting	Interval value	1000ms
	Compare match interrupt (CMI0)	Enable Priority: Level 0 (disabled)

5.2.3 LEDs and Switches

P70 to P73 are used to turn on and off the LEDs. For the blinking interval, CMT1 is used.

Also, PE1 to PE4 are used to acquire the statuses of SW1, SW2, and SW3.

Table 5-18 shows the settings for PORT, and Table 5-19 shows the settings for CMT1.

Table 5-18 PORT Settings

Item	Setting							
Port selection	PORT7				PORTE			
Used port	P70	P71	P72	P73	PE1	PE2	PE3	PE4
Setting	Out CMOS output Output 1				In			

Table 5-19 CMT1 Settings

Item		Setting
Count clock setting		PCLK/512
Compare match setting	Interval value	250ms
	Compare match interrupt (CMI0)	Enable Priority: Level 0 (disabled)

5.2.4 E2 Data Flash

E2 data flash is used to retain the set parameters. To access E2 data flash, the FIT flash module is used.

Table 5-20 FIT Flash Module Settings

Item	Setting
Parameter check	Enable parameter checks
Enable code flash programming	Only data flash
Enable BGO/Non-blocking data flash operation	Forces data flash API function to block until completed.
Enable BGO/Non-blocking code flash operation	Forces ROM API function to block until completed.
Enable code flash self-programming	Programming code flash while executing in RAM.

5.3 Program Configuration

5.3.1 Source File Configuration

Table 5-21 File Configuration

Folder name, file name	Description
src	
├ smc_gen	Generated by Smart Configurator
│ ├ Config_AFE	
│ ├ Config_CMT0	
│ ├ Config_CMT1	
│ ├ Config_DMAC1	
│ ├ Config_DMAC3	
│ ├ Config_DSAD0	
│ ├ Config_DTC	
│ ├ Config_ELC	
│ ├ Config_MTU3_MTU4	
│ ├ Config_PORT	
│ ├ Config_SCI1	
│ ├ general	
│ ├ r_bsp	
│ ├ r_config	
│ ├ r_flash_rx	
│ └ r_pincfg	
├ acx_cfg.h	Definition of each initial value
├ main.c	Main function
├ r_calc_api.c	Calculations
├ r_calc_api.h	
├ r_led_api.c	LED operation
├ r_led_api.h	
├ r_loadcell_api.h	Load cell weight conversion processing
├ r_loadcell_api.c	
├ r_loadcell_cfg.h	
├ r_qe_api.c	QE for AFE communication module
├ r_qe_api_user.c	
├ r_qe_api.h	
├ r_qe_cfg.h	
├ r_qe_cfg_typedef.h	
├ r_qe_packet.h	
├ r_qe_sc_if.h	
├ r_ring_buffer_control_api.c	
└ r_ring_buffer_control_api.h	

5.3.2 Macro Definitions

Table 5-22 acx_cfg.h Definitions

Definition name	Value	Description
D_CFG_MES_RATE	1	Measurement rate selection, initial value 0: 3.8147SPS (262.144ms period) 1: 10SPS (100ms period) 2: 100SPS (10ms period) 3: 100SPS (1ms period)
D_CFG_ACX_INDEX_DSAD	0	Selection of A/D value averaging count per AC excitation measurement channel, initial value 0: 1 1: 4 2: 16 3: 32
D_CFG_DSAD_PGA	0x17	Initial PGA gain setting value
D_CFG_ZERORESET_AVERAGE_NUM	8	Zero-reset weight averaging count
D_CFG_CALIBRATION_AVERAGE_NUM	128	A/D value averaging count for calibration
D_CFG_CALIBRATION_DELAY	5.0F	Calibration start delay time [s]
D_CFG_MOVINGAVERAGE_NUM	8	A/D value moving averaging count for weight measurement
D_CFG_ACX_DSAD_PRM_DEFAULT0	Table 5-9	DSAD0 parameters for AC excitation measurement
D_CFG_ACX_DSAD_PRM_DEFAULT1	Table 5-10	
D_CFG_ACX_DSAD_PRM_DEFAULT2	Table 5-11	
D_CFG_ACX_DSAD_PRM_DEFAULT3	Table 5-12	
D_CFG_NORMAL_DSAD_PRM_DEFAULT	Table 5-13	DSAD0 parameters for normal measurement

Table 5-23 r_loadcell_cfg.h Definitions

Definition name	Value	Description
D_LC_CFG_PGA_GAIN	128.0F	PGA initial gain
D_LC_CFG_DSADRES	24	DSAD0 resolution bits
D_LC_CFG_VREF	5.0F	DSAD0 A/D conversion reference voltage [V]
D_LC_CFG_VCC	5.0F	Load cell voltage [V]
D_LC_CFG_RO	0.002F	Rated output RO [V/V]
D_LC_CFG_MMAX	2000.0F	Rated load MMAX [g]

Table 5-24 r_qe_cfg.h Settings

Definition name	Value	Description
D_QE_CFG_TX_RINGBUF_SIZE	512U	Transmission ring buffer size [byte]
D_QE_CFG_RX_RINGBUF_SIZE	512U	Reception ring buffer size [byte]
D_QE_CFG_FORMAT_REV	3	Communication specifications revision
D_QE_CFG_READ	1	Register read permission
D_QE_CFG_WRITE	1	Register write permission
D_QE_CFG_USER_VAL0	1	User value setting 0: Not used 1: Used
D_QE_CFG_USER_VAL1	1	
D_QE_CFG_USER_VAL2	1	
D_QE_CFG_USER_VAL3	1	
D_QE_CFG_USER_VAL4	1	
D_QE_CFG_USER_VAL5	0	
D_QE_CFG_USER_VAL6	0	
D_QE_CFG_USER_VAL7	0	
D_QE_CFG_EX_SPS	1	SPS information support 0: Not used 1: Used
D_QE_CFG_EX_USER_BTN0	1	User button setting 0: Not used 1: Used
D_QE_CFG_EX_USER_BTN1	0	
D_QE_CFG_EX_USER_BTN2	0	
D_QE_CFG_EX_USER_BTN3	0	
D_QE_CFG_EX_USER_BTN4	0	
D_QE_CFG_EX_USER_BTN5	0	
D_QE_CFG_EX_USER_BTN6	0	
D_QE_CFG_EX_USER_BTN7	0	
D_QE_CFG_CH0	0x3	Data transmission CH use setting 0x3: Sending Measurement values 0x0: Not used
D_QE_CFG_CH1	0x0	
D_QE_CFG_CH2	0x0	
D_QE_CFG_CH3	0x0	
D_QE_CFG_CH4	0x0	
D_QE_CFG_CH5	0x0	
D_QE_CFG_CH6	0x0	
D_QE_CFG_CH7	0x0	
D_QE_CFG_CH8	0x0	
D_QE_CFG_CH9	0x0	
D_QE_CFG_CH10	0x0	
D_QE_CFG_CH11	0x0	
D_QE_CFG_CH12	0x0	
D_QE_CFG_CH13	0x0	
D_QE_CFG_CH14	0x0	
D_QE_CFG_CH15	0x0	
D_QE_CFG_TXT_INFO	"RX23E-B AC excitation loadcell measurement"	Program information
D_QE_CFG_TXERRCHK_EN	1	Transmission error detection enabled
D_QE_CFG_TIMEOUT	0	Error is detected when timeout is reached
D_QE_CFG_SCI	1	SCI number used for communication
D_QE_CFG_DMAC_RX	1	DMAC channel for reception
D_QE_CFG_DMAC_TX	3	DMAC channel for transmission
D_QE_CFG_CMT	0	CMT number for timeout detection

5.3.3 Structures, Unions, and Enumeration Types

Table 5-25 main.c

Structure type name	st_acx_dsad_prm_t		
Description	AC excitation measurement parameters		
Member	**Type**	**Name**	**Description**
	uint32_t	samples	A/D value averaging count per channel
	uint32_t	posi_start	Positive A/D value array index
	uint32_t	nega_start	Negative A/D value array index
	st_dsad0_prm_acx_t	prm	DSAD0 setting parameters
Structure type name	st_e2df_data_t		
Description	Measurement condition parameters to be stored in data flash memory		
Member	**Type**	**Name**	**Description**
	uint32_t	index_rate	Measurement period selection: 0 ~ 3
	uint32_t	acx_index_dsad	Selection of A/D value averaging count per channel for AC excitation measurement: 0 ~ 3
	st_acx_dsad_prm_t	acx_dsad_prm [D_MES_RATE_INDEXES] [D_ACX_DSAD_SAMPLES_INDEXES]	AC excitation measurement parameter array
	st_lc_coef_t	coef_acx [D_MES_RATE_INDEXES] [D_ACX_DSAD_SAMPLES_INDEXES]	Weight conversion coefficient array for AC excitation measurement
	st_lc_coef_t	coef_normal[D_MES_RATE_INDEXES]	Weight conversion coefficient array for normal measurement
	uint32_t	calibration_average_num	A/D value averaging count for calibration
	uint32_t	zeroreset_average_num	Weight averaging count for zero reset
	uint8_t	pga	DSAD0 PGA gain setting value

Table 5-26 r_calc_api.h

Structure type name	st_calc_moveavg_data_t		
Description	Moving averaging parameters		
Member	**Type**	**Name**	**Description**
	int32_t	count	Number of acquired data
	float	sumdata	Total value of acquired data
	float *	p_deldata	Pointer to acquired data storage array
	int32_t	avgnum	Moving averaging count
Structure type name	st_calc_average_data_t		
Description	Averaging parameters		
Member	**Type**	**Name**	**Description**
	uint32_t	num	Averaging count
	uint32_t	count	Number of acquired data
	float	sum	Total value of acquired data

Table 5-27 r_loadcell_api.h

Structure type name	st_lc_coef_t		
Description	Weight conversion coefficients		
Member	**Type**	**Name**	**Description**
	float	a	Coefficient a (slope)
	float	b	Coefficient b (intercept)
Structure type name	st_calc_average_data_t		
Description	Weight conversion calibration parameters		
Member	**Type**	**Name**	**Description**
	float	weight[2]	Weights for measurement (2 different weights)
	float	adval[2]	Acquired A/D values (2 different values)

Table 5-28 r_qe_cfg_typedef.h User Extensions

Enumeration type name	e_processing_mode_t		
Description	Internal processing mode		
Member	**Name**	**Value**	**Description**
	E_MEASUREMENT	0	Measurement
	E_CALIBRATION1	1	Calibration Step1
	E_CALIBRATION2	2	Calibration Step2
	E_IDLE	-1	Standby
	E_INITIAL	E_IDLE	Initial mode
Structure type name	st_qe_api_t		
Description	QE for AFE communication module parameters (user extensions only)		
Member	**Type**	**Name**	**Description**
	e_processing_mode_t	opemode	Internal operation mode
	float	user_value	QE for AFE: Received value of Value x
	union	user_flags	User-defined flags
	uint8_t	flags	8-bit flags
	struct	bit	Flag bit allocation
	uint8_t:1	zeroreset	Zero reset request
	uint8_t:1	zeroreset_num	Averaging count change request for zero reset
	uint8_t:1	cal_average_num	Averaging count change request for calibration
	uint8_t:1	rate	Measurement rate change request
	uint8_t:1	moving_average	Moving averaging count change request for measurement
	uint8_t:1	dsad_count	Channel averaging count change request for AC excitation
	uint8_t:1	register_write	Register setting change request

Table 5-29 Config_DSAD0.h User Definitions

Structure type name	st_dsad0_prm_acx_t		
Description	DSAD0 setting parameters for AC excitation measurement		
Member	**Type**	**Name**	**Description**
	uint16_t	cnt_posi	Positive channel A/D conversion count
	uint16_t	cnt_nega	Negative channel A/D conversion count
	uint32_t	osr	OSRm register setting value
	uint32_t	sgcr	SGCRm register setting value
	uint8_t	fsel	MRm register FSEL bit setting value
Structure type name	st_dsad0_prm_normal_t		
Description	DSAD0 setting parameters for normal measurement		
Member	**Type**	**Name**	**Description**
	uint32_t	osr	OSRm register setting value
	uint32_t	sgcr	SGCRm register setting value
	uint8_t	fsel	MRm register FSEL bit setting value
	uint8_t	cvmd	MR register CMVM bit setting value

5.3.4 Functions

Table 5-30 main.c

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

Table 5-31 r_calc_api

Function name	**R_CALC_MovingAverage**			
Description	Calculates the average value for the specified moving averaging count			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	const float	data	Input value
	I/O	st_calc_moveavg_data_t *	p_cal_moveavg	Pointer to the moving averaging parameters
Return value	O	float	Moving average value	
Function name	**R_CALC_MovingAverageReset**			
Description	Resets the moving averaging parameters			
Argument	**I/O**	**Type**	**Name**	**Description**
	I/O	st_calc_moveavg_data_t *	p_cal_moveavg	Pointer to the moving averaging parameters
	I	int32_t	average_num	Moving averaging count
Return value	-	void	-	
Function name	**R_CALC_Average**			
Description	Calculates the average value for the specified averaging count			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	float	input	Input value
	I/O	st_calc_average_data_t *	average	Pointer to the averaging parameters
	O	float *	result	Pointer to the averaging result storage destination
Return value	O	bool	true: Averaging completed false: Not completed	
Function name	**R_CALC_AverageInit**			
Description	Initializes the averaging parameters			
Argument	**I/O**	**Type**	**Name**	**Description**
	I/O	st_calc_average_data_t *	average	Pointer to the averaging parameters
	I	uint32_t	num	Averaging count
Return value	-	void	-	

Table 5-32 r_led_api

Function name	**R_LED0_ON**			
Description	Specifies whether to turn on or off or blink LED0			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	bool	flag	true: ON false: OFF
	I	int32_t	count	Blinking count 0: Does not blink >0: Blinking count -1: Blinks without specified count
Return value	-	void	-	
Function name	**R_LED_BlinkControl**			
Description	LED blinking			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	-	void	-	
Function name	**R_LED0_IsBlink**			
Description	Acquires whether LED0 is blinking			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	**void**	**-**	**-**
Return value	O	bool	true: Blinking false: Not blinking	

Table 5-33 r_loadcell_api

Function name	**R_LC_DsadToWeight**			
Description	Converts an A/D value to weight using the weight conversion coefficients			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	float	dsad	A/D value
	I	st_lc_coef_t *	coef	Pointer to the weight conversion coefficients
Return value	O	float	Weight	
Function name	**R_LC_CalcCoef**			
Description	Calculates the weight conversion coefficients			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	st_lc_calibration_data_t *	prm	Pointer to the weight conversion calibration parameters
	O	st_lc_coef_t *	coef	Pointer to the weight conversion coefficients
Return value	O	bool	true: Successful false: Failed	

Table 5-34 r_qe_api_user.c User-Defined Processes

Only user processes are listed.

Function name	**r_QE_NegotiationUser**
Description	Turns off LED1
Function name	**r_QE_WriteUser**
Description	If opemode is E_IDLE, accepted and sets flags. register_write
Function name	**r_QE_RunUser**
Description	If opemode is E_IDLE, accepted and sets opemode to E_MEASUREMENT
Function name	**r_QE_StopUser**
Description	Sets opemode to E_IDLE
Function name	**r_QE_UserValueUser**[Note]
Description	Judged to be accepted or not for each User Value No. and if accepted, sets the corresponding flag or the opemode and stores the received value in user_value
Function name	**r_QE_ExUseButtonStatusUser**[Note]
Description	Judged to be accepted or not for each Button No. and if accepted, sets the corresponding flag
Function name	**r_QE_ResetUser**
Description	Sets opemode to E_IDLE and turns LED1 ON

Note: For details on the corresponding QE for AFE functions, see Table 1-1.

Table 5-35 Config_CMT1 User Defined Functions

Function name	**R_CMT1_IsCompareMatch**			
Description	Detects CMT1 compare match			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	O	bool	true: Compare match detected false: Compare match not detected	

Table 5-36 Config_DSAD0 User Defined Functions (1/2)

Function name	**R_Config_DSAD0_Set_SoftwareTrigger**			
Description	Sets a software trigger			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	-	void	-	
Function name	**R_Config_DSAD0_CHnEN**			
Description	Specifies an A/D conversion channel			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	uint8_t	channel	Specifies a channel to enable with each corresponding bit 1: Enabled 0: Disabled
Return value	-	void	-	
Function name	**R_Config_DSAD0_ACXSetParam**			
Description	Sets DSAD0 parameters for AC excitation measurement for Channels 0 and 1			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	st_dsad0_prm_acx_t *	prm	Pointer to the DSAD setting parameters for AC excitation measurement
Return value	-	void	-	

Table 5-37 Config_DSAD0 User Defined Functions (2/2)

Function name	**R_Config_DSAD0_NORMALSetParam**			
Description	Sets DSAD0 parameters for normal measurement to CH2			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	st_dsad0_prm_normal_t *	prm	Pointer to the DSAD0 setting parameters for AC excitation measurement
Return value	-	void	-	
Function name	**R_Config_DSAD0_SetPGA**			
Description	Sets the PGA gain for CH0, CH1, and CH2			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	uint8_t	prm	Setting value for CRm.GAIN
Return value	-	void	-	
Function name	**R_Config_DSAD0_SetSingleScan**			
Description	Sets scan mode			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	bool	flag	true: Single-scan mode false: Continuous-scan mode
Return value	-	void	-	
Function name	**R_DSAD0_IsSCANEND**			
Description	Detects SCANEND0			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	O	bool	true: Detected false: Not detected	
Function name	**R_DSAD0_IsCHCHG**			
Description	Detects CHCHG0			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	O	bool	true: Detected false: Not detected	
Function name	**R_DSAD0_IsADI**			
Description	Detects ADI0			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	-	void	-	
Function name	**R_DSAD0_GetPGA0**			
Description	Acquires the CR0.GAIN setting value (macro function)			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	O	uint32_t	CR0.GAIN setting value	
Function name	**R_DSAD0_ConvSignedValue**			
Description	Acquires a signed A/D value (macro function)			
Argument	**I/O**	**Type**	**Name**	**Description**
	I	uint32_t	val	Acquired DR register value
Return value	O	int32_t	Signed A/D value	

Table 5-38 Config_PORT User Defined Functions

Function name	**R_Config_PORT_LED0_ON** **R_Config_PORT_LED1_ON** **R_Config_PORT_LED2_ON** **R_Config_PORT_LED3_ON**			
Description	Turns on and off each LED			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	bool	flag	true: ON false: OFF
Return value	-	void	-	
Function name	**R_Config_PORT_LED0_Blink** **R_Config_PORT_LED1_Blink** **R_Config_PORT_LED2_Blink** **R_Config_PORT_LED3_Blink**			
Description	Reverses the ON/OFF of each LED			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	-	void	-	
Function name	**R_PORT_LED0_IsON** **R_PORT_LED1_IsON** **R_PORT_LED2_IsON** **R_PORT_LED3_IsON**			
Description	Acquires the ON/OFF of each LED			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	-
Return value	O	bool	true: ON false: OFF	
Function name	**R_PORT_GetSW1_ON** **R_PORT_GetSW2_ON** **R_PORT_GetSW3_1_ON** **R_PORT_GetSW3_2_ON**			
Description	Acquires the status of each switch			
Argument	**I/O**	**Type**	**Name**	**Description**
	-	void	-	**-**
Return value	O	bool	true: pressing false: releasing	

6. Importing a Project

After importing the sample project, make sure to confirm build and debugger setting.

6.1 Importing a Project into e2 studio

Follow the steps below to import your project into e[2] studio. Pictures may be different depending on the version of e[2] studio to be used.

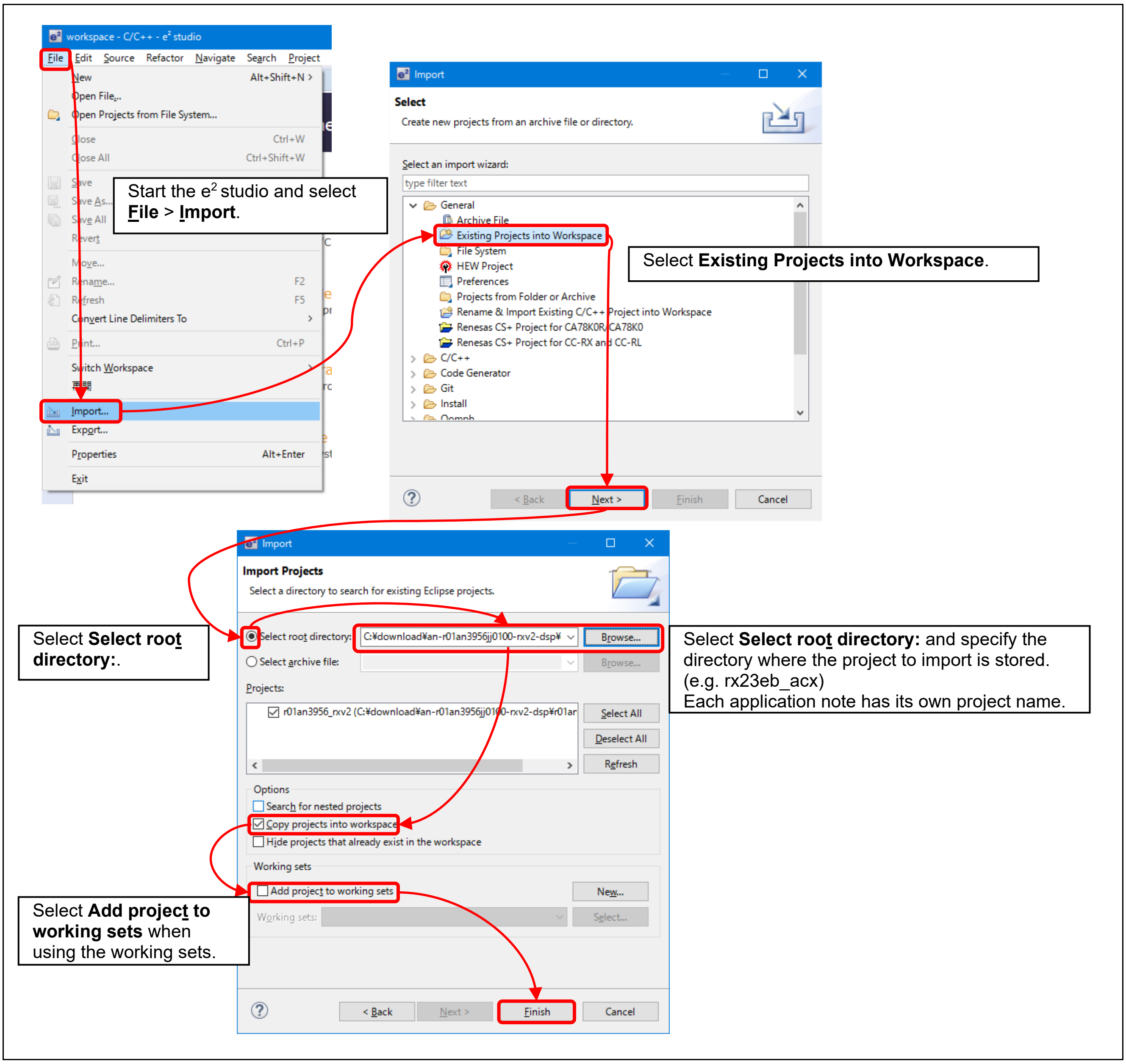


Figure 6-1 Importing a project into e[2] studio

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.

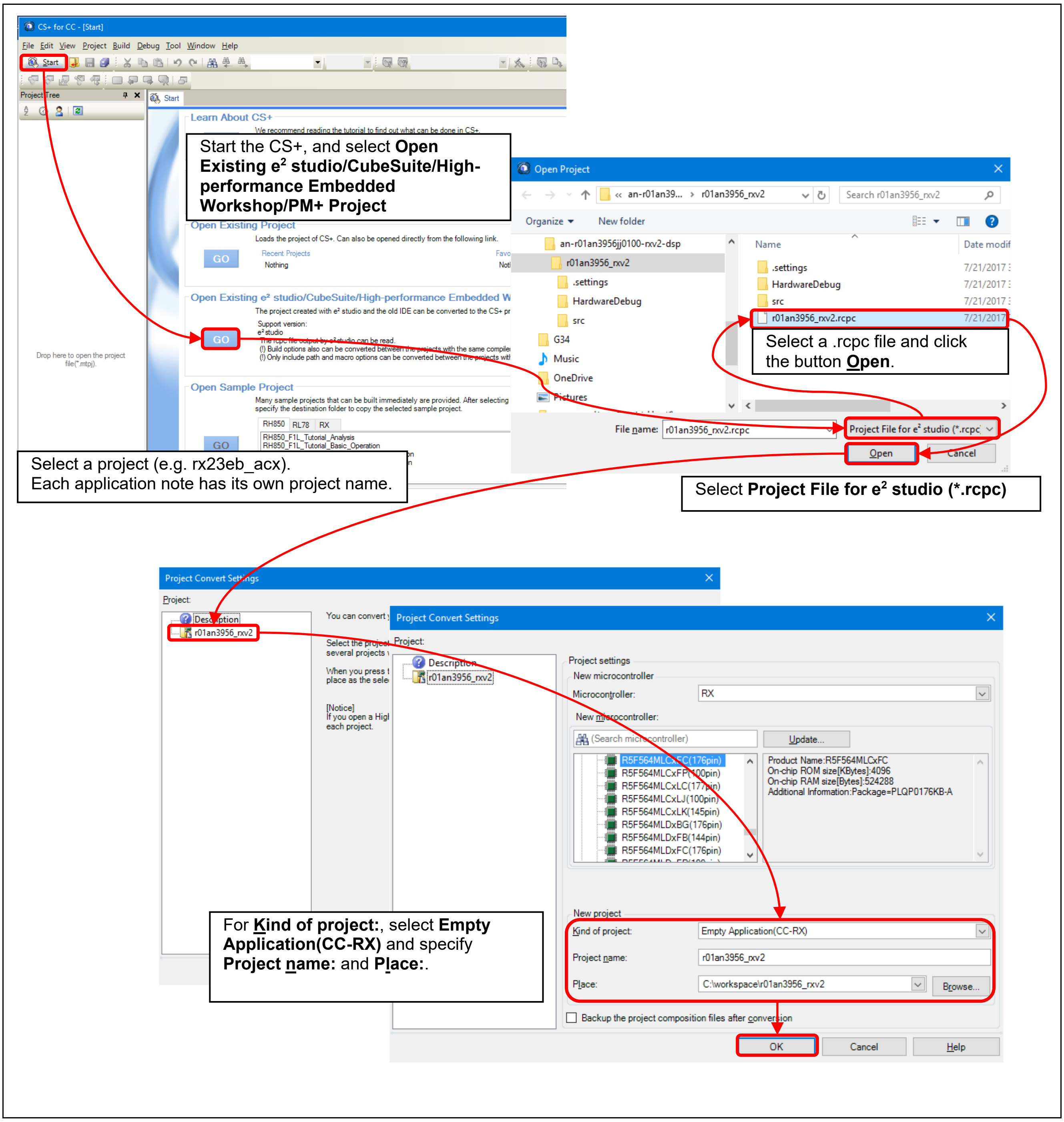


Figure 6-2 Importing a project into CS+

7. Measurement Results with Sample Program

7.1 Memory Usage and Number of Cycles to Be Executed

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 -fpu -utf8 -nomessage -output=obj -obj_path=${workspace_loc:/${ProjName}/${ConfigName}} -debug -outcode=utf8 -nologo
Linker		-noprelink -output="rx23eb_acx.abs" -form=absolute -nomessage -vect=_undefined_interrupt_source_isr -list=rx23eb_acx.map -show=all -nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -cpu=RAM=00000000-00007fff,FIX=00080000-00083fff, FIX=00086000-00087fff,FIX=00088000-0008dfff,FIX=00090000-0009ffff, FIX=000a0000-000bffff,FIX=000c0000-000fffff,ROM=00100000-00101fff, FIX=007fc000-007fc4ff,FIX=007ffc00-007fffff,ROM=fffc0000-ffffffff -nologo
	Section	SU,SI,B_1,R_1,B_2,R_2,B,R/04,B_DMAC_REPEAT_AREA_1/04000, C_DATAFLASH/0100000,PResetPRG,C_1,C_2,C,C$*,D*,W*,L, P/0FFFC0000,EXCEPTVECT/0FFFFFF80,RESETVECT/0FFFFFFFC

Note: The include paths to the complier settings except those set by the user are omitted.

7.1.2 Memory Usage

Table 7-2 shows the memory usage of the sample program.

Table 7-2 Memory Usage

Item		Size (byte)	Remarks
ROM		14325	
	Code	11551	
	Data	2774	
E2 DataFlashROM		628	
RAM		14902 (10458)	Note
	Data	9782	
	Stack	5120 (676)	Note

Note: The RAM usage in parentheses was calculated based on the Stack usage.

7.1.3 Number of Cycles to Be Executed and Processing Time

Table 7-3 shows the CPU execution cycles, etc. during measurement.

Table 7-3 Execution Cycles, Execution Time, and Processing Load (AC Excitation)

ICLK=32MHz
Measurement rate: 1000SPS
Averaging count per channel: 32

Item	Execution Cycles (Execution time)	Process load [%]	Condition
A/D value acquisition processing	419cycle (13.09µs)	1.309	Negative A/D value processing
Weight conversion processing	110cycle (3.44µs)	0.344	Moving Average count: 8 Zero reset processing in progress
QE for AFE communication processing	368cycle (11.50µs)	1.150	Sending measured values
Others	205cycle (6.41µs)	0.641	
Total	1102cycle (30.09µs)	3.009	

7.2 Weight Measurement Results

This section describes the results of weight measurement with the load cell shown in Table 4-3 by using the RSSKRX23E-B board and sample program.

7.2.1 Measurement Conditions

Figure 7-1 shows the configuration of the weight measurement system, Table 7-4 and Table 7-5 show the devices used in the measurement and weight measurement settings. The weight combinations and weight tolerances for the weights are shown in Table 7-6 and Table 7-7, respectively.

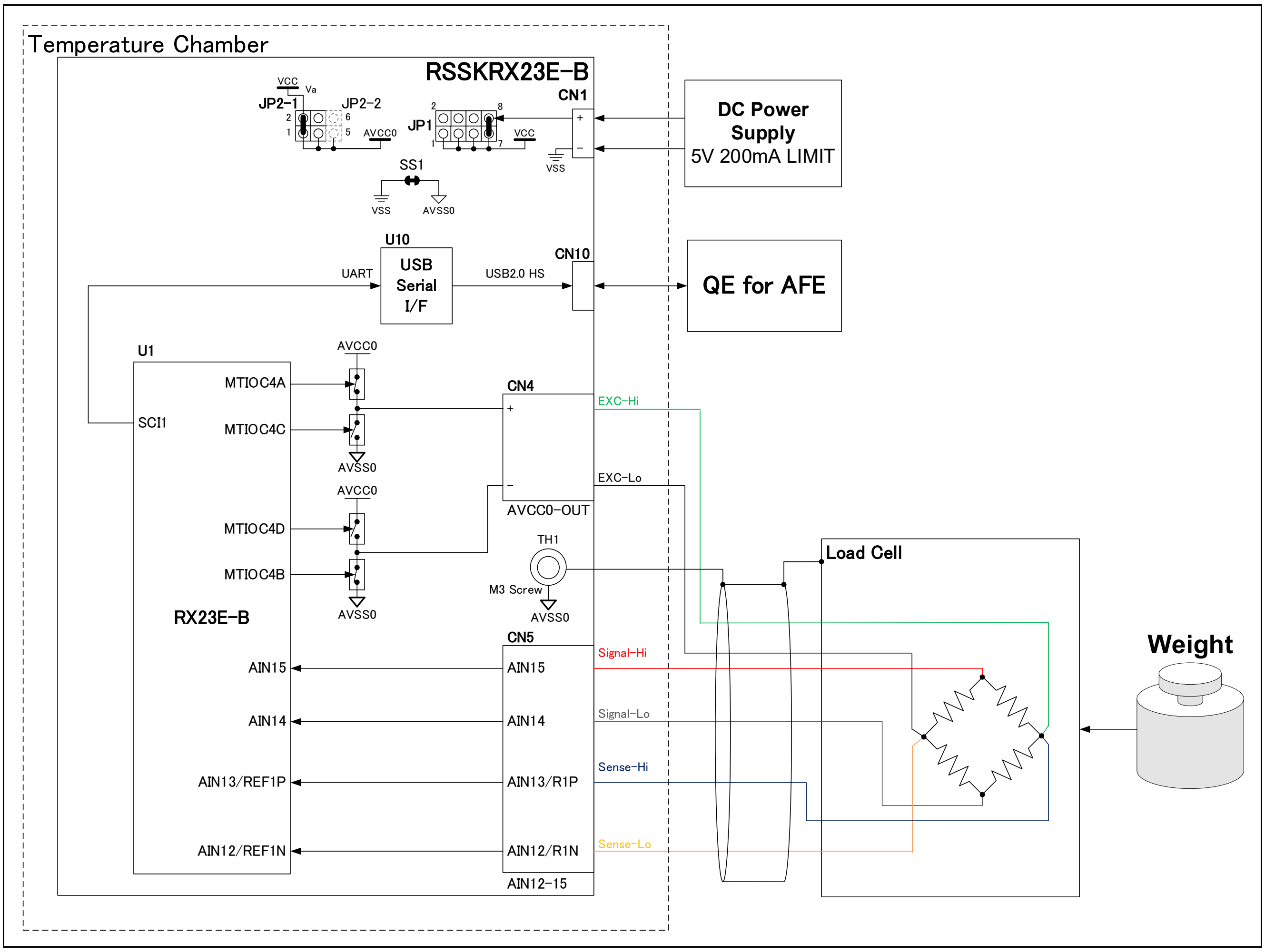


Figure 7-1 Configuration of Weight Measurement with Load Cell

Table 7-4 Devices Used for Weight Measurement

Item	Model	Manufacturer name	Applicable evaluation items		
			Accuracy	Resolution	Temperature
DC Power Supply	PA14A1	ShibaSoku Co., Ltd.	✓	✓	✓
Counterweight	Stainless steel precision weight (5kg)	Murakami Koki Co., Ltd.	✓		
Precision Calibrator	PSC-350	MinebeaMitsumi Inc.		✓	✓
Temperature Chamber	SU-241	ESPEC CORP.			✓

Table 7-5 Weight Measurement Settings

Item	Setting			Remarks
	Accuracy evaluation	Resolution evaluation	Temperature evaluation	
Calibration 1	0g	0mV		
Calibration 2	2000g	10mV		
Averaging count for calibration	64			
Measurement rate	3.8147SPS	3.8147SPS 10SPS	3.8147SPS	
Averaging count per channel for AC excitation measurement	16			
Moving averaging count for measurement	8	1	8	

Table 7-6 Combinations of Counterweights for Each Weight Setting

Weight setting	Combination of counterweights	
250g	50g x1 200g x1	
500g	500g x1	
750g	50g x1 200g x1 500g x1	
1000g	1000g x1	
1250g	50g x1 200g x1 1000g x1	
1500g	500g x1 1000g x1	
1750g	50g x1 200g x1 500g x1	1000g x1
2000g	2000g x1	

Table 7-7 Counterweight Tolerances

Weight of counterweight	Tolerance of counterweight
50g	±30mg
200g	±50mg
500g	±100mg
1000g	±200mg
2000g	±400mg

7.2.2 Measurement Results

7.2.2.1 Weight Measurement Accuracy Evaluation Result

Figure 7-2 shows the accuracy evaluation result of AC excitation weight measurement. The horizontal axis indicates the weight of counterweight and vertical axis indicates the result obtained by dividing the measurement error by the rated output of the load cell, or 2kg. This figure shows that the measured weight is within the counterweight tolerance, meaning that with RX23E-B, it is possible to measure weight with adequate accuracy.

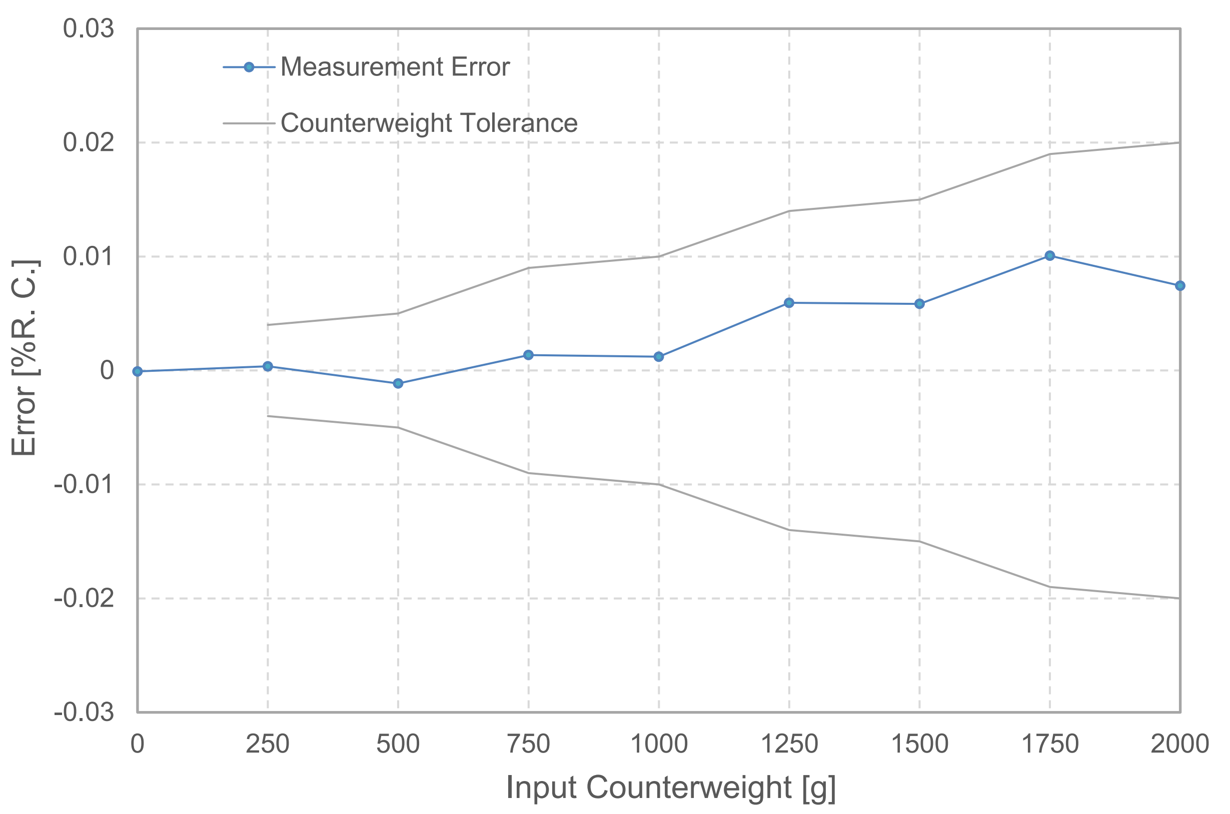


Figure 7-2 Weight Measurement Error (Ambient Temperature: 25°C)

7.2.2.2 Temperature Characteristic Evaluation

Using the precision calibrator, 0mV and 5mV inputs were made, the temperature was changed in 10°C increments from -20°C to 60°C, and the average of 500 samples under stable conditions at each temperature was used as the measurement value. The results are shown in Table 7-8, Figure 7-3, and Figure 7-4. 0mV input with AC excitation disabled causes a maximum of 0.207μV fluctuation, while with AC excitation enabled, the offset drift and other factors are cancelled out and the fluctuation is within 0.030μV. 5mV input with AC excitation enabled also causes a gain drift However, the measured value fluctuates only about half as much, 0.288μV, compared to 0.559μV with AC excitation disabled.

Table 7-8 Comparison of measurement results

Item	Range of Variation	
	AC Excitation	Normal (AC Excitation Disabled)
Input Voltage: 0mV	0.030μV	0.207μV
Input Voltage: 5mV	0.288μV	0.559μV

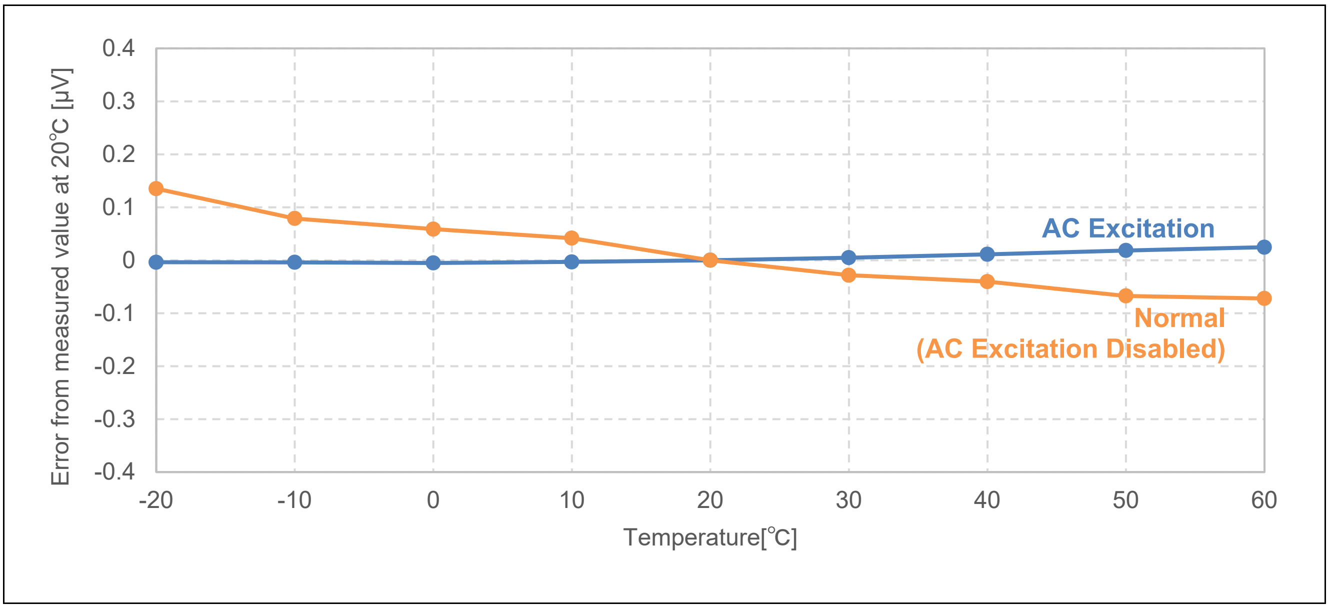


Figure 7-3 Temperature Characteristic Evaluation Result (Input voltage: 0mV)

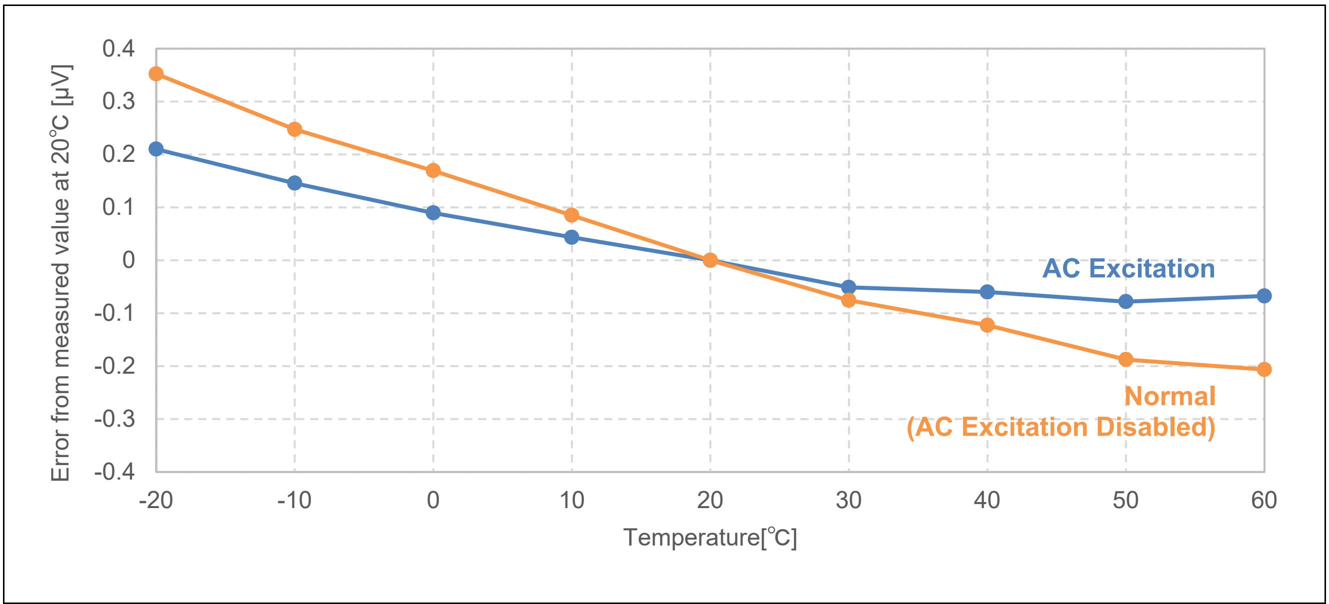


Figure 7-4 Temperature Characteristic Evaluation Result (Input voltage: 5mV)

7.2.2.3 Resolution Evaluation

The precision calibrator was used to input 5 mV and acquire 1000 samples for AC excitation and normal measurements at weight measurement rates of 3.8147SPS and 10SPS. The results are shown in Table 7-9, Figure 7-5, and Figure 7-6.

The noise characteristics of both 3.8147SPS and 10SPS are slightly worse when AC excitation is enabled than when AC excitation is disabled; although the low-frequency error factor can be canceled when AC excitation is enabled, A/D values cannot be acquired due to settling time associated with DSAD channel switching. Therefore, to achieve the same weight measurement rate when AC excitation is enabled as when AC excitation is disabled, the OSR must be set lower, which may result in a deterioration of the resolution. As a countermeasure, the average number of channels during AC excitation measurement, which is the average number of channels per excitation voltage polarity during AC excitation, can be set to a large value to suppress the frequency of channel switching and shorten the settling time of DSAD for the weight measurement cycle, thereby reducing the deterioration of resolution. This reduces the resolution deterioration.

Table 7-9 Effective Resolution and Noise-free Resolution

Weight measurement rate	3.8147SPS		10SPS	
Measurement Method	AC Excitation	Normal	AC Excitation	Normal
Effective resolution	0.197μVrms (20.9bit)	0.185μVrms (21.0bit)	0.322μVrms (20.2bit)	0.216μVrms (20.8bit)
Noise-free resolution	0.12μV (18.3bit)	0.12μV (18.3bit)	0.20μV (17.6bit)	0.14μV (18.1bit)

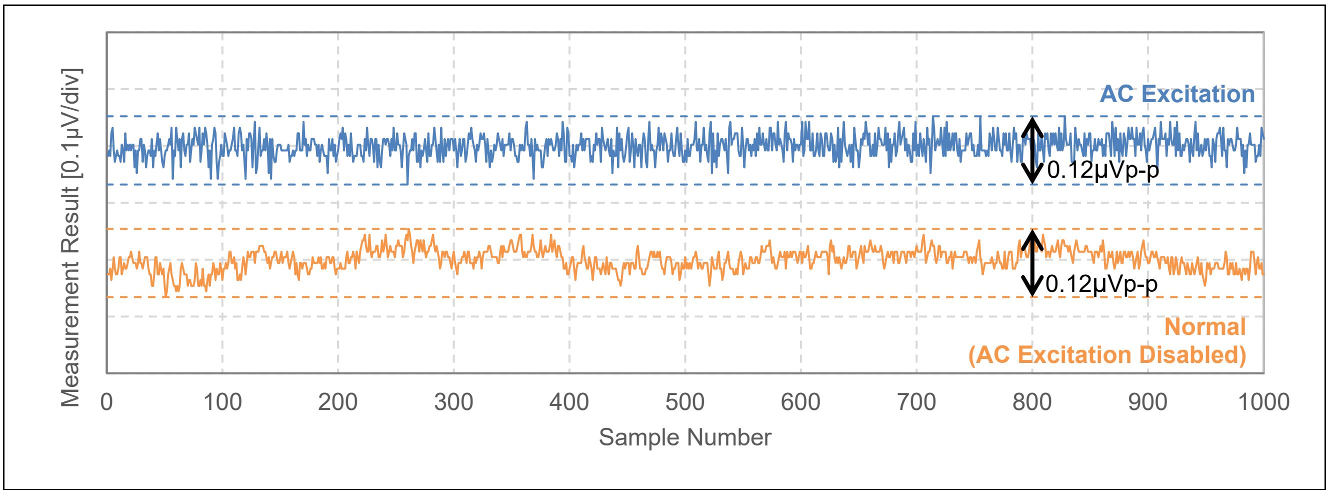


Figure 7-5 Measurement Result (Measurement Rate: 3.8147SPS, Ambient Temperature: 25°C)

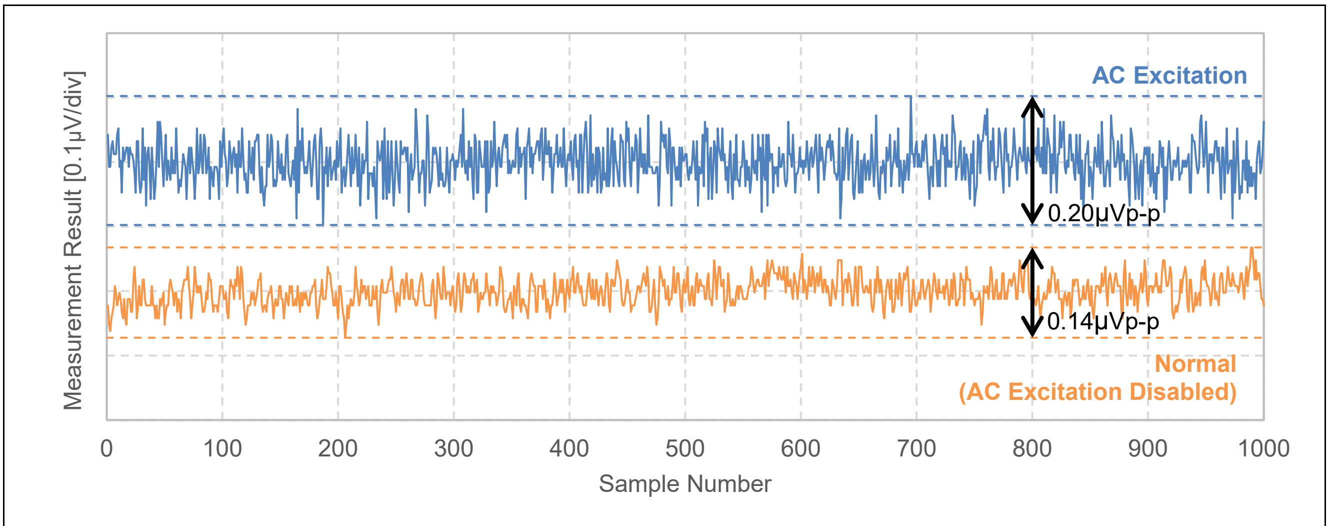


Figure 7-6 Measurement Result (Measurement Rate: 10SPS, Ambient Temperature: 25°C)

Revision History

Rev.	Date	Description	
		Page	Summary
1.0	Oct.19.23	-	First release

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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