RX23E-A Group

Weight Measurement Example Using a Load Cell

Summary

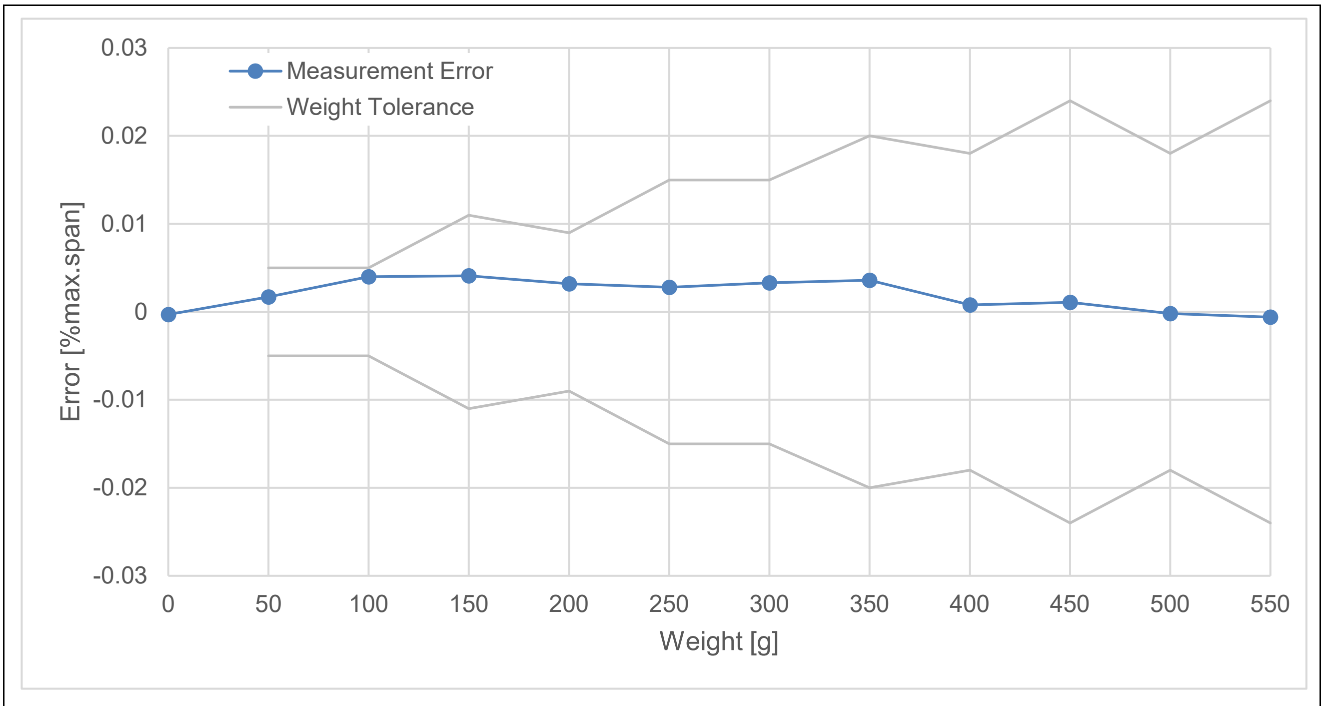
This document describes a weight measurement example with a load cell, using RX23E-A.

RX23E-A contains an analog front-end (AFE) and a 24-bit Δ-Σ A/D converter (DSAD). Using the programmable gain instrumentation amplifier (PGA), etc., high-precision A/D conversion is performed on the output of the load cell to calculate the weight.

Weight of counterweight was measured with load cell, using Renesas Solution Starter Kit for RX23E-A and sample program included in this document. The error of measured value was divided by full scale of load cell output. The results are shown in below figure.

Weight Range:	0g - 550g
Weight Span:	550g
Weight measurement accuracy note, Linearity:	within ±0.005%max.span (27.5mg equivalent)
Effective Resolution:	21.0bit (36.2nVrms: 4.8mg equivalent)
Noise Free Resolution:	18.4bit (234nV: 31.2mg equivalent)

Note: including counterweight error, non-linearity characteristic of load cell etc.



Target Device

RX23E-A

Contents

1. Overview

This document describes a weight measurement example using a load cell, using RX23E-A. The sample program runs on the Renesas Solution Starter Kit for RX23E-A (RSSKRX23E-A) board, and the measurement results can be displayed with the PC tool program of RSSKRX23E-A.

The weight measurement system in this example is shown in Figure 1-1.

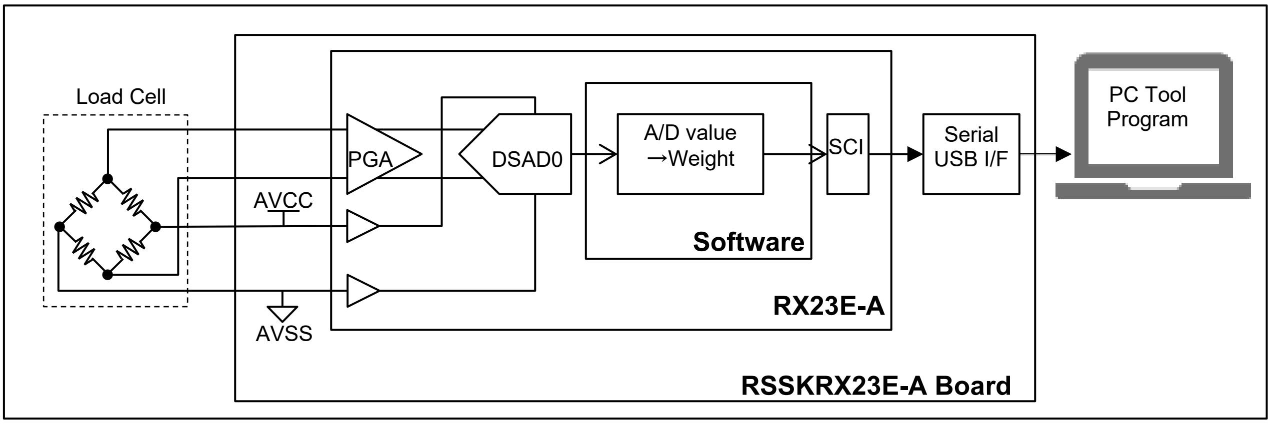


Figure 1-1 Weight Measurement System Example Using a Load Cell

2. Related Documents

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

3. Environment for Operation Confirmation

The environment for operation confirmation is given in Table 3-1.

Table 3-1 Environment for Operation Confirmation

Item	Description
Board	RSSKRX23E-A board (RTK0ESXB10C00001BJ)
MCU	RX23E-A (R5F523E6ADFL) Power voltage (VCC, AVCC0): 5V Operating frequency (ICLK): 32MHz Peripheral operating frequency (PCLKB): 32MHz DSAD operating frequency (f_{DR}): 4MHz DSAD modulator clock frequency (f_{MOD}): 0.5MHz
Load cell	T&T CO., LTD. LT1-06G
IDE	Renesas e² studio V7.8.0 Renesas Smart Configurator plug-in V2.6.0
Tool Chain	Renesas CC-RX V3.2.0
Emulator	E2 Emulator Lite

4. Weight Measurement Method

A connection using the RSSKRX23E-A board is shown in Figure 4-1. In this example, a 4-wire load cell using a Wheatstone bridge is used.

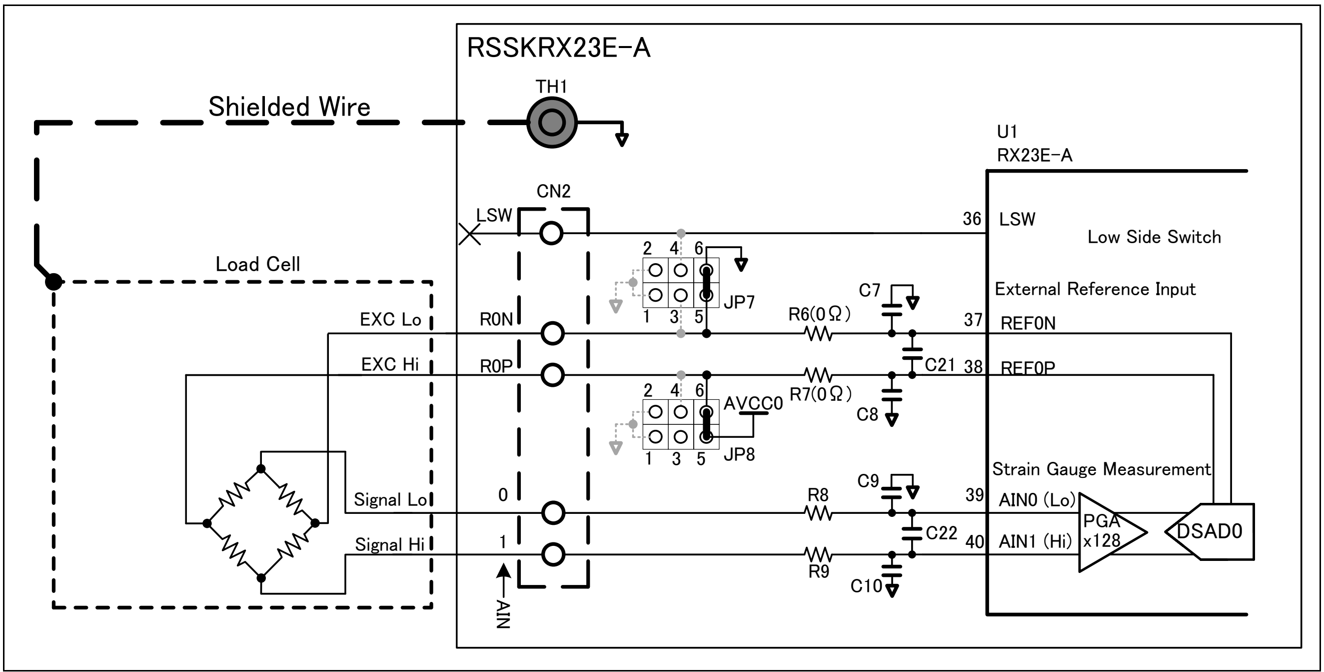


Figure 4-1 Connecting the RSSKRX23E-A Board

4.1 Load Cell

The load cell used in this example outputs a weight as a voltage, using a Wheatstone bridge circuit. An excerpt of the specifications of the load cell used is listed in Table 4-1, and the weight vs. output voltage characteristics and the error range determined from the specifications if the applied voltage is 5 V are shown in Figure 4-2.

Table 4-1 Excerpt of the Load Cell LT1-06G Specifications

Item	Value
Recommended Excitation	12[V]
Maximum Excitation	18[V]
Rated Capacity	6[N] (≈0.6[kg])
Rated Output: R.O.	0.9±0.1[mV/V]
Zero Balance	4.0%R.O.

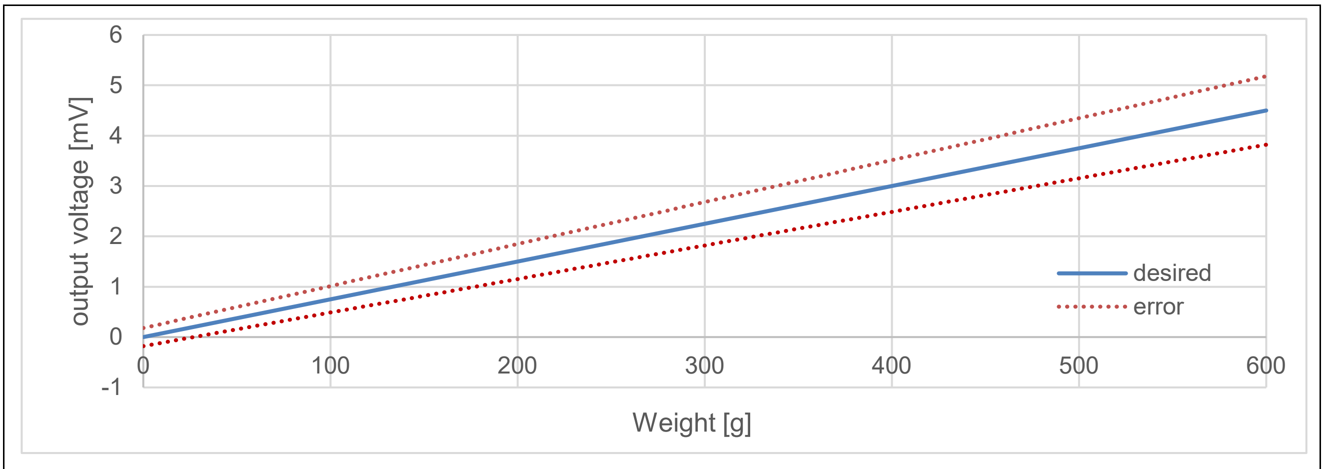


Figure 4-2 Weight vs. Output Voltage Characteristics (Applied Voltage 5 V) of the Load Cell LT1-06G

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 precision, 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 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.

Measurement conditions are listed in Table 4-2. If the oversampling ratio is not a power of two, the digital filter of the DSAD generates a gain of x1/2 to x1. The A/D conversion value is treated as having been multiplied by the above-mentioned gain.

Table 4-2 Load Cell Measurement Conditions

Item	Condition	Remarks
PGA gain G_{PGA}	x128	
DSAD reference voltage V_{REF}	5V	Voltage applied to the load cell. (REF0P=AVCC0, REF0N=ACSS0)
Oversampling ratio OSR	50000	A/D conversion value output rate 10SPS
Digital filter gain G_{DF}	0.677626358	$G_{DF} = 1/2^{(Ceil(4\log_2 OSR) - 4\log_2 OSR)}$
DSAD output format	2's Complement	

4.2 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 digital filter gain is G_{DF}, the reference voltage of the DSAD is V_{REF}, and the A/D conversion value is DATA, the weight can be determined from the 24-bit resolution of the DSAD with the formula below.

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

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

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

4.3 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 precision 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 types of reference weight, such as standard test weights, and their A/D conversion values.

(1) Obtain the A/D conversion value $DATA_1$ for reference 1 weight M_1

(2) Obtain the A/D conversion value $DATA_2$ for reference 2 weight M_2

(3) Calculate the coefficients a and b of the line passing through ($DATA_1$, M_1) and ($DATA_2$, M_2) and apply them

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

4.4 Other Functions

4.4.1 Zero Reset

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

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

4.4.2 Linkage with the PC Tool Program

The sample program can communicate with the PC tool program of RSSKRX23E-A to display weight measurement results with the PC tool program.

For details about the communication specifications, refer to "RSSKRX23E-A PC Tool Program Operation Manual".

The communication commands supported in this example are listed in Table 4-3.

Table 4-3 Supported Communication Commands

Command	Overview	Remarks
Negotiation	Reads MCU endian information and MCU functions	
Read	Reads registers	
Run	Starts DSAD conversion operation	
Stop	Stops DSAD conversion operation	
TransmissionCh0	Transmits Ch0 data from the MCU	Transmits a weight [g] as a physical quantity.

5. Sample Program

5.1 Overview of Operation

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

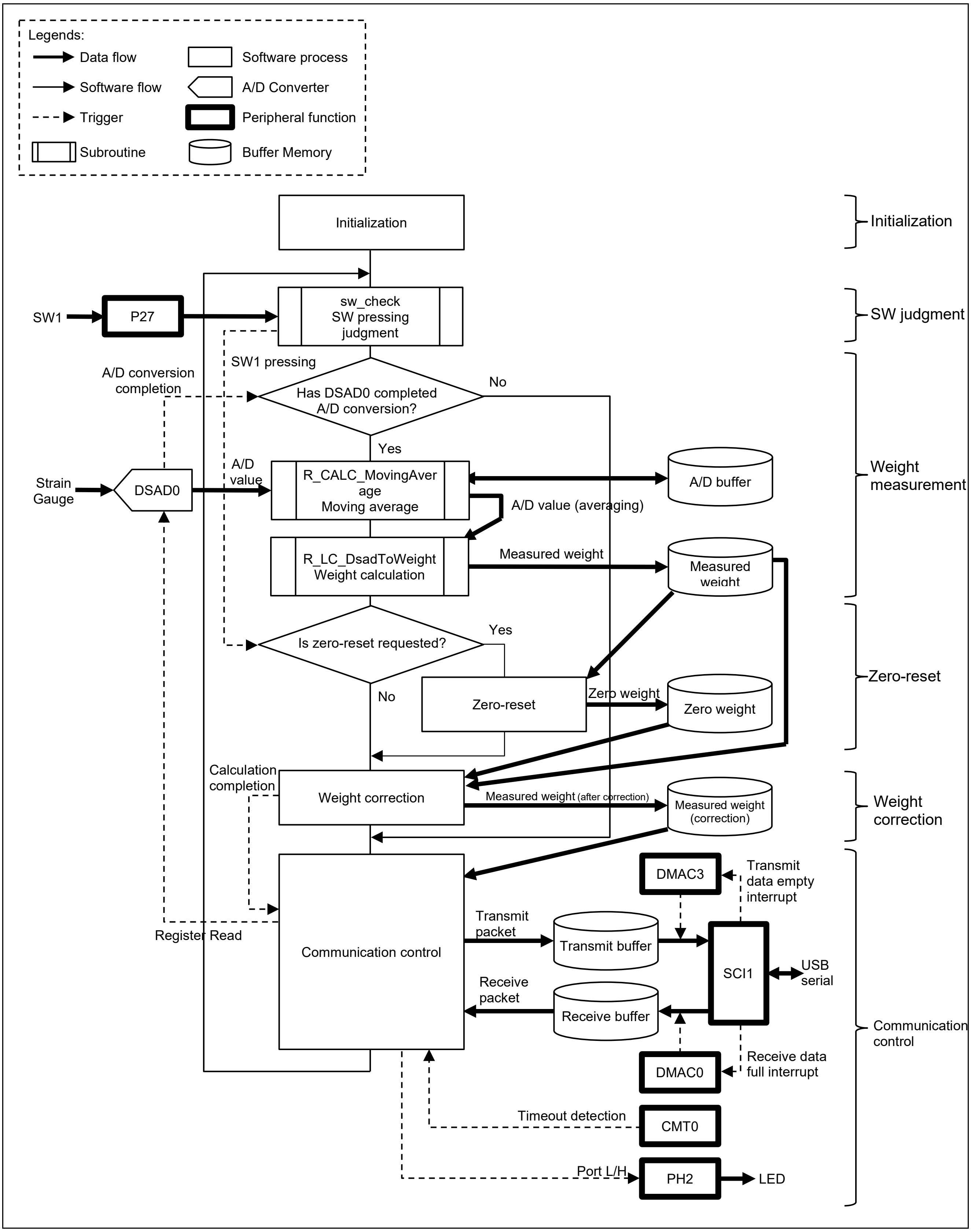


Figure 5-1 Weight Measurement Process Flow

The following provides an overview of each process.

- Initialization

The following are performed.

- If a connection is made to the PC tool program of RSSKRX23E-A, the initialization of the communication buffer and the start of SCI1 operation
- Start of the A/D conversion of DSAD0

- SW pressing judgment

Read SW1, and the input state is determined with two matches. When the pressing of SW1 is detected, a zero-reset request is set.

- Weight measurement

With the completion of the A/D conversion of DSAD0 as a trigger, calculates weight from the results of a moving averaged of the A/D conversion value.

- Zero reset

The zero-reset request with the pressing of SW1, current measured weight is assumed to be the zero weight.

- Weight correction

A corrected weight is calculated from the measured weight and the zero weight.

- PC communication

A process of communication with the PC tool program of RSSKRX23E-A is performed to transmit measured weight.

While measured weight is being transmitted, LED1 is ON. For details, see 5.3.

5.2 Peripheral Functions and Pins Used

The peripheral functions used in this example are listed in Table 5-1, and the pins used are listed in Table 5-2. The conditions for setting each peripheral function are described together.

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

Table 5-1 Peripheral Functions Used

Peripheral function	Use
AFE, DSAD0	A/D conversion of the load cell
SCI1	UART communication with the PC tool program
DMAC0	Data transfer with a receive data full interrupt of SCI1 as a trigger
DMAC3	Data transfer with a transmit data empty interrupt of SCI1 as a trigger
CMT0	Detection of a communication timeout of SCI1
PH2	LED1 ON/OFF control
P27	SW1 input

Table 5-2 Pins Used

Pin name	Input/Output	Use
P27	Input	SW1 input pin
PH2	Output	LED1 ON/OFF control
P26/TXD1	Output	UART1 transmit pin
P30/RXD1	Input	UART1 receive pin
P31/CTS1#	Input	CTS signal input pin
AIN0	Input	Load cell - side input pin
AIN1	Input	Load cell + side input pin
REF0P	Input	Load cell measurement DSAD + side reference voltage (Connection to AVCC0 on the RSSK Board)
REF0N	Input	Load cell measurement DSAD - side reference voltage (Connection to AVSS0 on the RSSK Board)

5.2.1 AFE and DSAD0

The conditions for setting AFE and DSAD0 based on the measurement conditions in Table 4-2 are listed in Table 5-3.

Table 5-3 AFE and DSAD0 Settings

Item		Setting
Analog input channel setting		• Channel 0: Valid • Channels 1 to 5: Invalid
ΔΣA/D operating voltage select		3.6V-5.5V (high precision)
ΔΣA/D converter operating mode setting		Normal mode
Operating clock setting		PCLKB/8 4 MHz
Start trigger source		Software trigger
Interrupt setting		Not used
Inter-unit synchronous start setting		Disable synchronous start
Abnormal voltage and disconnection detection Setting		Not used
Channel 0	Analog input setting	• Positive input signal: AIN1 • Negative input signal: AIN0 • Reference voltage: REF0P/REF0N Disable + side reference voltage buffer Disable - side reference voltage buffer
	Amplifier setting	• Amplifier selection: PGA • PGA gain setting: x128
	ΔΣA/D conversion setting	• A/D conversion mode: Normal operation • Data format: Two's complement format • Number of A/D conversions: 1 in immediate value mode • Oversampling ratio: 50000 • Offset correction: Not set (Use of the device default) • Gain correction: Not set (Use of the device default) • Use averaged data: Disabled
	Disconnection assist setting	Not permitted

5.2.2 SCI1, DMAC0, DMAC3, and CMT0

For communication with the PC tool program, SCI1 is used in asynchronous mode. To obtain receive data, DMAC0 is used, and to set transmit data, DMAC3 is used. To detect a communication timeout, CMT0 is used.

The conditions for setting each peripheral function are listed below.

Table 5-4 SCI1 Settings

Item	Setting
Serial communication method	Asynchronous communication
Start bit detection	Low level at RXD1 pin
Data bit length	8 bits
Parity setting	Prohibited
Stop bit setting	1 bit
Data transfer direction setting	LSB first
Transfer speed setting	• Transfer clock: Internal clock • Bit rate: 3Mbps • Enable bit rate modulation function • SCK1 pin function: Not use SCK1
Noise filter setting	Not use noise filter
Hardware flow control setting	CTS1#
Data processing setting	Transmit data processing: Process with DMAC3 Receive data processing: Process with DMAC0
Interrupt setting	Not permit receive error interrupt
Callback function setting	None
Input/output pins	• Output: TXD1 (P26) • Input: RXD1 (P30) : CTS1 (P31)

Table 5-5 DMAC Settings

Item	Setting	
Channel used	DMAC0	DMAC3
DMA activation source	SCI1 (RXI1)	SCI1 (TXI1)
Activation source flag control	Clear activation source flag	Clear activation source flag
Transfer mode	Free running mode	Normal transfer
Transfer data size	8bit	8bit
Number of transfers/repeat size/block size	-	Set with software
Source address	• 0008 A025h (SCI1.RDR) • Address fixing	• Set with software • Address increment • Set an extended repeat area at the destination address • Extended repeat area: Lower 12bits of the address (4KB)
Destination address	• Set with software • Address increment • Set an extended repeat area at the destination address • Extended repeat area: Lower 9 bits of the address (512 bytes)	• 0008 A023h (SCI1.TDR) • Address fixing
Interrupt setting	Not permitted	Not permitted

Table 5-6 CMT0 Settings

Item	Setting
Clock setting	PCLKB/512
Compare match setting	Interval time: 1000ms Compare match interrupt (CMI0) enabled Level 0 (interrupt disabled)

5.2.3 PH2

By using PH2, LED1 is turned ON and OFF. While measurement results are being transmitted to the PC tool program, LED1 is ON.

The condition for setting PH2 is listed in Table 5-7.

Table 5-7 PH2 Setting

Item	Setting
PORTH	PH2: Output CMOS output Output 1

5.2.4 Port P27

Using port P27, the pressing of SW1 is detected. When the pressing of SW1 is detected, the zero weight is updated.

The condition for setting port P27 is listed in Table 5-8.

Table 5-8 Port P27 Setting

Item	Setting
PORT2	P27: Input Built-in pull-up OFF

5.3 Communication Control

Based on the communication specifications of RSSKRX23R-A, processes with the PC tool program are performed.

A flow of communication processes is shown in Figure 5-2.

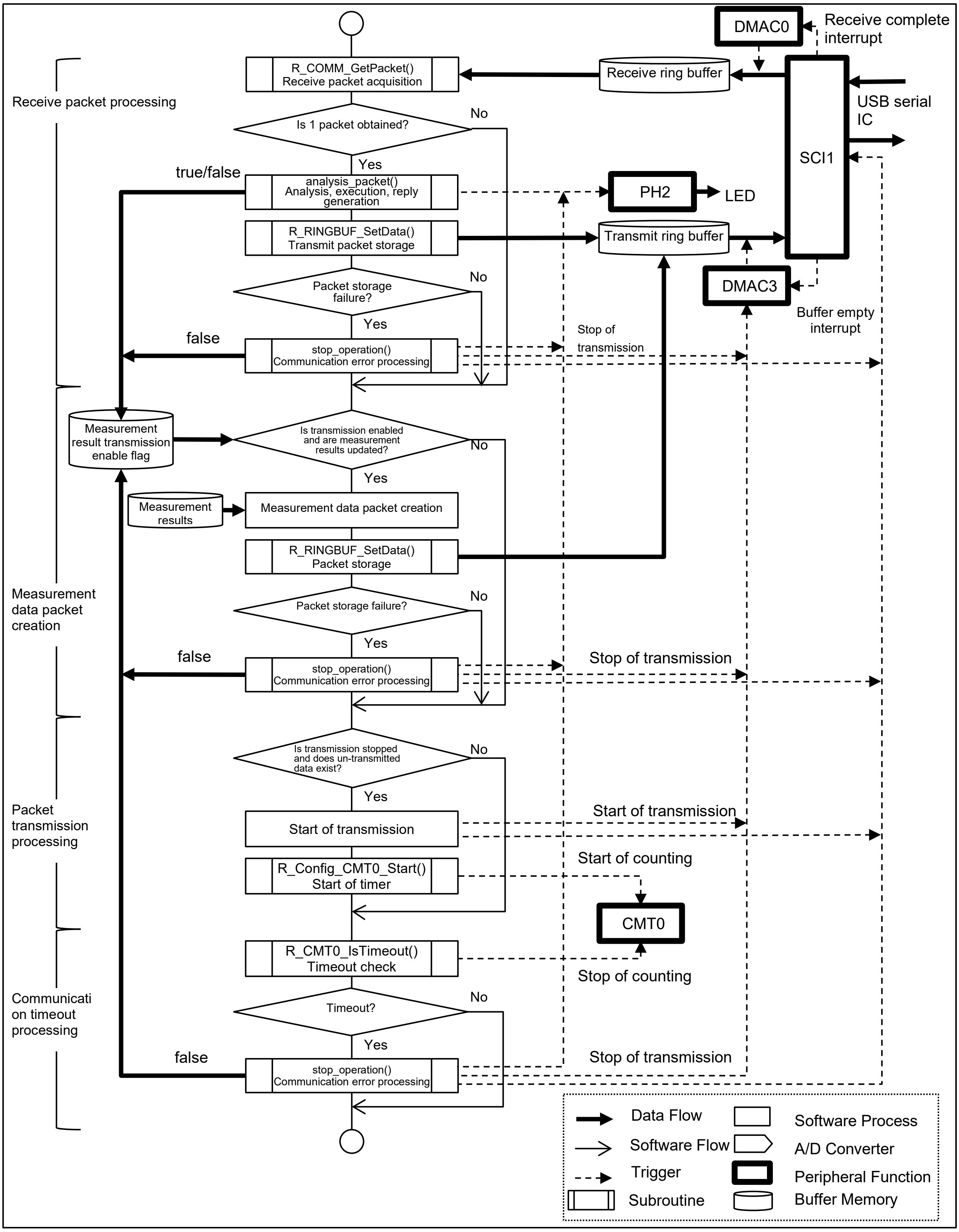


Figure 5-2 Communication Process Flow

The following provides an overview of each process.

- Receive packet processing

Obtains a received packet from the receive ring buffer, and performs processing corresponding to a command in the packet, then creates and stores a reply packet in the transmit ring buffer. Table 5-9 lists the commands supported by this program and the processes corresponding to the commands. For an unsupported command, a NACK is returned.

If the reply packet cannot be stored in the transmit ring buffer, communication error processing is performed.

Table 5-9 Packets and Actions

Command	Process
Negotiation	Return the software status with a reply packet
Read	Return the read value of the specified register with a reply packet
Run	Set the measurement result transmission enable flag and turn LED1 ON
Stop	Clear the measurement result transmission enable flag and turn LED1 OFF

- Measurement data packet creation

If the measurement result transmission enable flag is set and the measurement results are updated, a TransmissionCh0 reply packet is created from the measurement results and is stored in the transmit ring buffer.

If the reply packet cannot be stored in the transmit ring buffer, communication error processing is performed.

- Packet transmission processing

If data is not being transmitted and the transmit ring buffer contains un-transmitted data, transmission starts with DMAC3 and 1-second counting starts with CMT0 for timeout detection.

- Communication timeout processing

If transmission is completed, CMT0 for timeout detection is stopped.

If transmission is in progress, the timer is checked for a compare match, and if a compare match has occurred, this is judged as a timeout. If it is judged as a timeout, communication error processing is performed.

- Communication error processing

If the transmit packet cannot be stored in the transmit ring buffer or a communication timeout occurs, communication is stopped and the following processes are performed to make a reconnection possible.

— Stop SCI1 and DMAC3, which are used for transmission
— Clear the transmit buffer and the measurement result transmission enable flag
— Turn LED1 OFF

Each ring buffer used for transmission and reception is for DMAC transmission, therefore, their address is arranged in the alignment adjusted for each buffer size. In this program, section name is declared “B_DMAC_REPEAT_AREA_1”, and arrangement is set based on the largest buffer size.

5.4 Program Configuration

5.4.1 File Configuration

Table 5-10 File Configuration

Folder name, file name	Description
src	
├ smc_gen	Smart Configurator generation
│ ├ general	
│ ├ r_bsp	
│ ├ Config_AFE	
│ ├ Config_CMT0	
│ ├ Config_DMAC0	
│ ├ Config_DMAC3	
│ ├ Config_DSAD0	
│ ├ Config_PORT	
│ ├ Config_SCI1	
│ ├ r_config	
│ └ r_pincfg	
├ r_ring_buffer_control_api.c	Ring buffer control program
├ r_ring_buffer_control_api.h	Ring buffer control API definition
├ r_loadcell_gauge_api.c	Load cell calculation program
├ r_loadcell_gauge_api.h	Load cell calculation API definition
├ r_sensor_common_api.c	Moving average processing function
├ r_sensor_common_api.h	Moving average processing function API definition
├ r_communication_control_api.c	Communication control program
├ r_communication_control_api.h	Communication control API definition
└ main.c	Main processing

5.4.2 Macro Definitions

Table 5-11 main.c Definitions

Definition name	Type	Initial value	Description
D_PRV_PC_TOOL_USE	bool	1	Communication with the PC tool program is 0: Not used 1: Used
D_PRV_SAMPLE_NUM	size_t	8	Number of samples for a moving average

Table 5-12 r_strain_gauge_api.h Definitions

Definition name	Type	Initial value	Description
D_LC_PGA_GAIN	float	128.0F	Gain of PGA for load cell measurement G_{PGA} [x]
D_LC_CODE_FS	uint32_t	16777216	2^{24}
D_LC_DF_GAIN	float	0.677626F	Digital filter gain G_{DF}
D_LC_VREF	float	5.0F	DSAD reference voltage V_{REF}
D_LC_VCC	float	5.0F	Load cell applied voltage V_{CC}
D_LC_RO	float	0.0009F	Rated output RO [V/V]
D_LC_MMAX	float	600.0F	Rated load M_{MAX} [g]
D_LC_COEFFICIENT_A	float	(D_LC_MMAX * D_LC_VREF * 2) / (D_LC_RO * D_LC_VCC * D_LC_CODE_FS * D_LC_PGA_GAIN * D_LC_DF_GAIN)	Coefficient a for conversion from A/D value to weight [g] $\frac{M_{max}}{\mathrm{RO} \cdot V_{cc}} \cdot \frac{2V_{REF}}{2^{24} \cdot G_{PGA} \cdot G_{DF}}$
D_LC_COEFFICIENT_B	float	0.0F	Coefficient b

5.4.3 Structure

Table 5-13 r_ring_buffer_control_api.h Structure

Structure type name	st_ring_buf_t		
Member variable	Type	Name	Description
	uint8_t *	p_buf	Pointer to the ring buffer
	size_t	length	Ring buffer length
	uint32_t	r_index	Read index
	uint32_t	w_index	Write index

5.4.4 Functions

Table 5-14 main.c Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
main main function	void	-		void	-	-
stop_operation Stop DMAC/SCI, initializes the ring buffer and turns LED1 OFF	void	-	I	st_ring_buf_t *	ary	Pointer to the ring buffer
analysis_packet According to the receive packet, executes the command and stores a reply packet. For the Run/Stop commands, updates the measurement result transmission enable flag.	size_t	Reply data length	I	uint8_t const	recv_pck[]	Receive packet storage array
			O	uint8_t	send_pck[]	Reply packet storage array
				bool *	p_tx_flag	Pointer to the measurement result transmission enable flag
sw_check Detects the pressing of SW1	bool *	SW1 true: Pressing false: Other than pressing	I/O	void	-	–

Table 5-15 r_communication_control_api Function

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_COMM_GetPaket Reads a single packet from the receive ring buffer.	size_t	Packet length [Bytes]	I	st_ring_buf_t *	r_buf	Pointer to the receive ring buffer
			O	uint8_t	r_packet[]	Receive packet storage array

Table 5-16 r_ring_buffer_control_api Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_RINGBUF_GetData Reads a specified number of bytes from the ring buffer	size_t	Number of bytes to read	I	st_ring_buf_t *	ary	Pointer to the ring buffer
			O	uint8_t	data[]	Data storage array
			I	size_t	len	Number of bytes to read
			I	bool	index_update	Index update flag true: Update false: Not update
R_RINGBUF_SetData Writes a specified number of bytes to the ring buffer	size_t	Number of bytes to write	O	st_ring_buf_t *	ary	Pointer to the ring buffer
			I	uint8_t	data[]	Data storage array
			I	size_t	len	Number of bytes to write
R_RINGBUF_GetDataLength Reads a specified number of bytes stored in the ring buffer	size_t	Number of bytes stored	I	st_ring_buf_t *	ary	Pointer to the ring buffer
R_RINGBUF_SetDataIndex Updates the index of the ring buffer	uint32_t	Index value	O	st_ring_buf_t *	ary	Pointer to the ring buffer
			I	uint16_t	value	Index value
			I	uint8_t	select	Target index 0: Read, 1: Write

Table 5-17 r_sensor_common_api Function

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_CALC_MovingAverage	float	Moving average result	I	float	input	Input value (A/D conversion value)
			I	float	array	Previous value array
			I	size_t	size	Number of elements of the previous value array
			I	Int32_t *	w_index	Pointer to the number-of-inputs storage variable

Table 5-18 r_loadcell_gauge_api Function

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_LC_DsadToWeight Converts an A/D value to a weight	float	Measured weight [g]	I	float	dsad	A/D average value
			I	float	coef_a	Coefficient a
			I	float	coef_b	Coefficient b

Table 5-19 Config_CMT0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_CMT0_IsTimeout Returns information as to whether a timeout has occurred	bool	false: Counting true: Timeout	I	bool	flag	Stop of counting false: Continuation true: Stop
R_CMT0_CntClear Clears the compare match timer/counter of CMT0	void	-	-	void	-	

Table 5-20 Config_DMAC0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_DMAC0_SetDestAddr Sets the DMDAR of DMAC0	void	-	I	void *	p_addr	destination address
R_DMAC0_GetDestAddr Returns the DMDAR of DMAC0 (macro function)	void *	DMAC0.DMDAR	-	void	-	-

Table 5-21 Config_DMAC3 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_DMAC3_SetSrcAddr Sets the DMSAR of DMAC3	void	-	I	void *	p_addr	source address
R_DMAC3_SetTxCnt Sets the DMCRA of DMAC3	void	-	I	uint32_t	cnt	transfer count

Table 5-22 Config_DSAD0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_DSAD0_IsConversionEnd Return the AD conversion status of DSAD0	bool	false: Conversion true: Conversion end	-	void	-	-
R_DSAD0_ClearIrFlag Clears the IR flag of DSAD0	void	-	-	void	-	-

Table 5-23 Config_PORT User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_LED1_On Turns LED1 ON (macro function)	void	-	-	void	-	-
R_LED1_Off Turns LED1 OFF (macro function)	void	-	-	void	-	-

Table 5-24 Config_SCI1 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Variable name	Description
R_SCI1_IsTransferEnd returns the transfer status of SCI1	bool	false: Transferring true: Transfer end	-	void	-	-
R_SCI1_SendStart start transmission of SCI1	MD_STATUS	MD_OK	-	void	-	-
R_SCI1_SendStop stop transmission of SCI1	MD_STATUS	MD_OK	-	void	-	-
R_SCI1_ReceiveStart starts receiving of SCI1.	MD_STATUS	MD_OK	-	void	-	-

6. Importing a Project

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

6.1 Importing a Project into e^2 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.

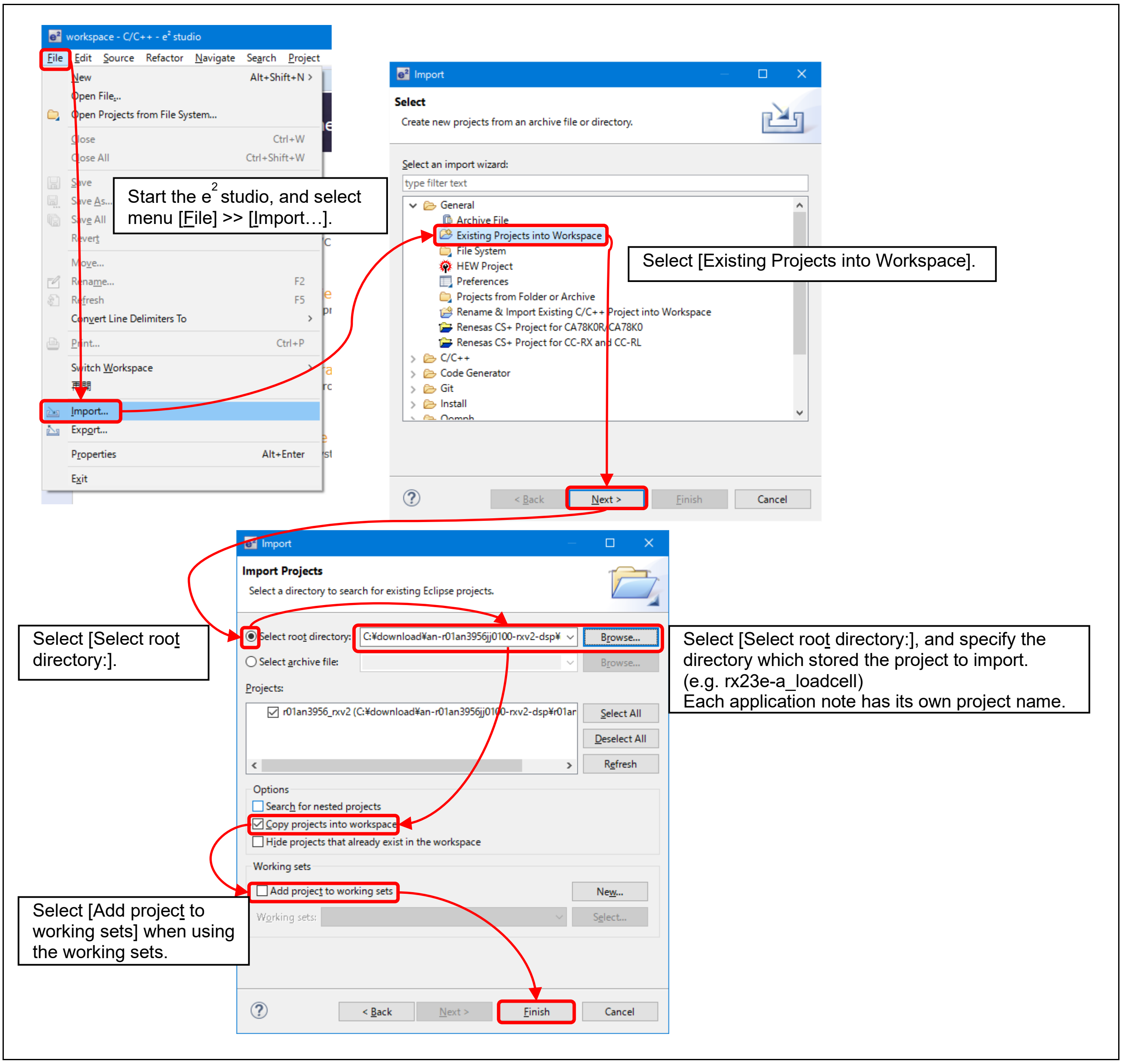


Figure 6-1 Importing a Project into e^2 studio

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.

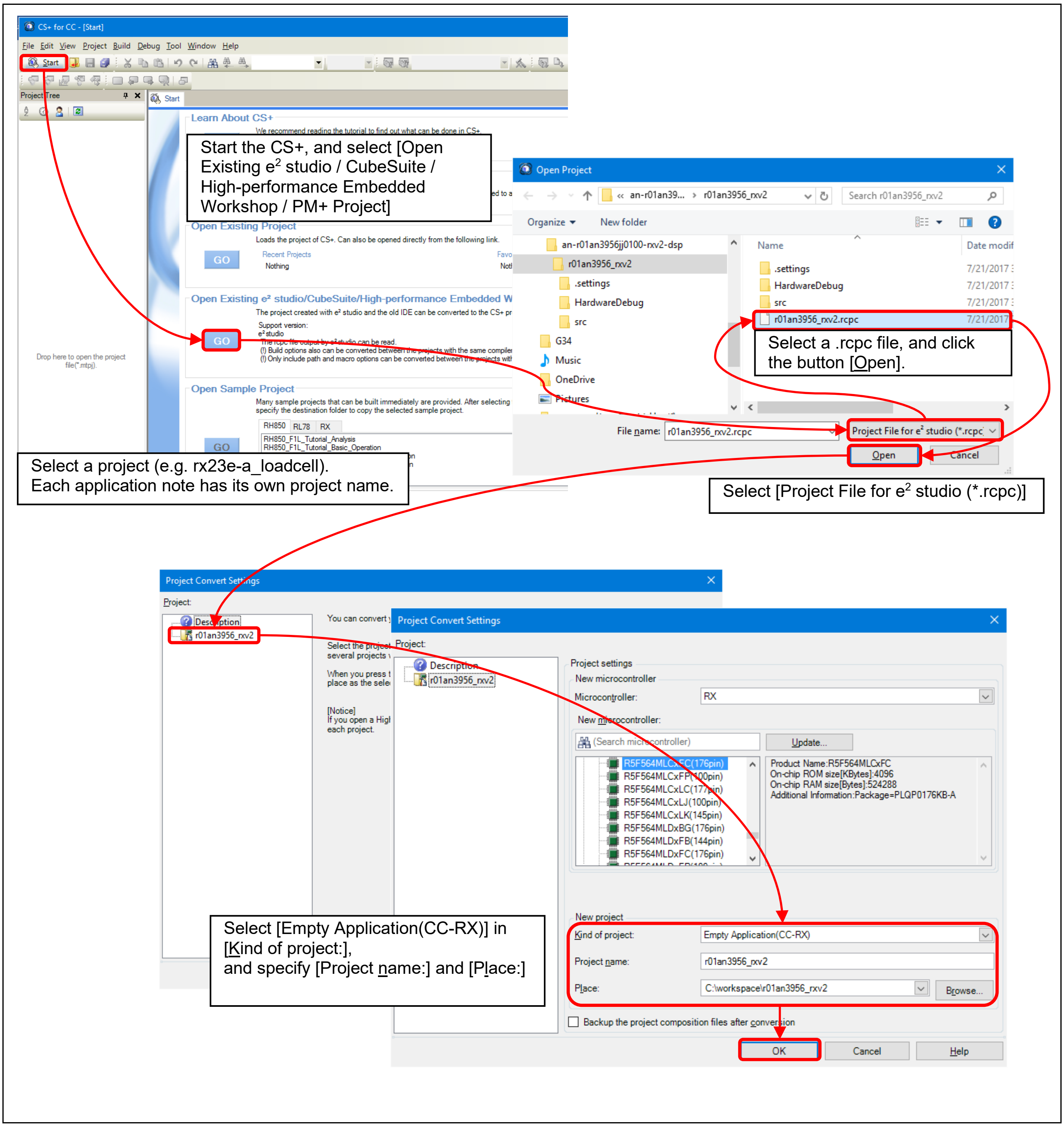


Figure 6-2 Importing a Project into CS+

7. Measurement results with sample program

7.1 Memory Usage and Number of Execution Cycle

7.1.1 Build Conditions

In "3 Environment for Operation Confirmation", build conditions for sample program is shown in Table 7-1. This setting is default setting when project is generated except for memory allocation to support the PC tool.

Table 7-1 Build Conditions

item		setting
Compiler	PC tool incompatible	-isa=rxv2 -utf8 -nomessage -output=obj -debug -outcode=utf8 -nologo
	PC tool compatible	add to the above -define=D_PRV_PC_TOOL_USE=1
Linker		-noprelink -output="rx23ea_loadcell.abs" -form=absolute -nomessage -vect=_undefined_interrupt_source_isr -list=rx23ea_loadcell.map -nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -nologo
	Additional Section	-start=B_DMAC_REPEAT_AREA_1/02000

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		size [byte]		Remarks
		PC tool incompatible	PC tool compatible	
ROM		8351	8805	
	Code	6565	7019	
	Data	1786	1786	
RAM		7061 (2069)	12183 (7191)	Note
	Data	1941	7063	
	Stack	5120 (128)	5120 (128)	Note

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

7.1.3 The number of Execution cycle

The number of execution cycles and processing load for each block in "Figure 5-1 Weight Measurement Process Flow" is shown in Table 7-3.

Table 7-3 Number of implementation cycle

Item	Number of Execution Cycle (Execution time@ICLK=32MHz)	Process load [%]	Condition
Temperature measurement	155cycle (4.84usec)	0.005	Acquisition of A/D conversion value to temperature calculation
Communication control	351cycle (10.97usec)	0.011	Maximum number of processing cycles in normal operation

Note: Process load is calculated by the execution time in the DSAD output cycle (100msec).

7.2 Weight Measurement

Results of weight measurement by load cell LT1-06G shown in Table 4-1 are described in this section by using RSSKRX23E-A board and sample program.

7.2.1 Measurement Condition

System configuration of weight measurement is shown in Figure 7-1. Equipment used in the measurement is shown in Table 7-4. Also, combination of counterweights for measurement weight and weight tolerance is shown in table 7-5 and 7-6. Calibration was carried out for two kinds of weight, which are 0g (no load) and 550g, following “4.3 Calibration”.

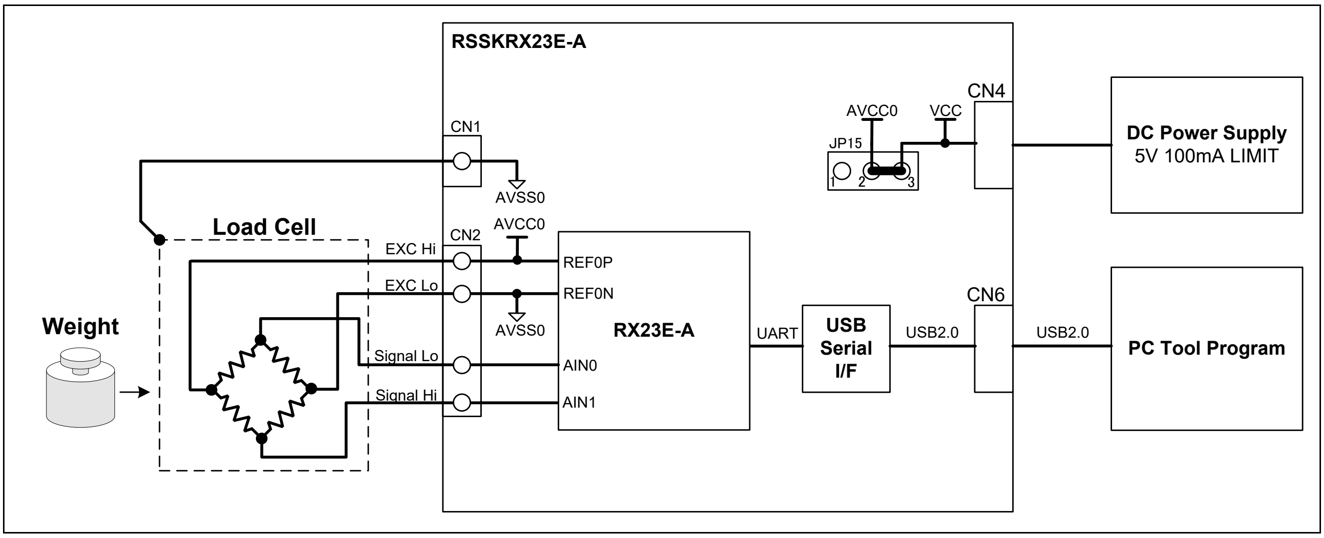


Figure 7-1 Configuration of Weight Measurement by Load Cell

Table 7-4 Equipment Used in Weight Measurement by Load Cell

Item	Model	Manufacturer
DC Power Supply	PCR1000MS	KIKUSUI ELECTRONICS CORPORATION
Counterweight	738-65-53-04	Tokyo Garasu Kikai Co., Ltd.

Table 7-5 Combination of Counterweights for Weight Settings

Weight Setting	Combination of Counterweight
50g	50g x1
100g	100g x1
150g	50g x1 100g x1
200g	200g x1
250g	50g x1 200g x1
300g	100g x1 200g x1
350g	50g x1 100g x1 200g x1
400g	200g x2
450g	50g x1 200g x2
500g	500g x1
550g	50g x1 500g x1

Table 7-6 Weight Tolerance

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

7.2.2 Measurement Results

Error of measurement value is acquired from the weight measurement result. The result calculated by dividing the error by full scale 550g of load cell output is shown in Figure 7-2. The measurement weight is within the counterweight tolerance range, which shows RX23E-A is sufficient measurement accuracy.

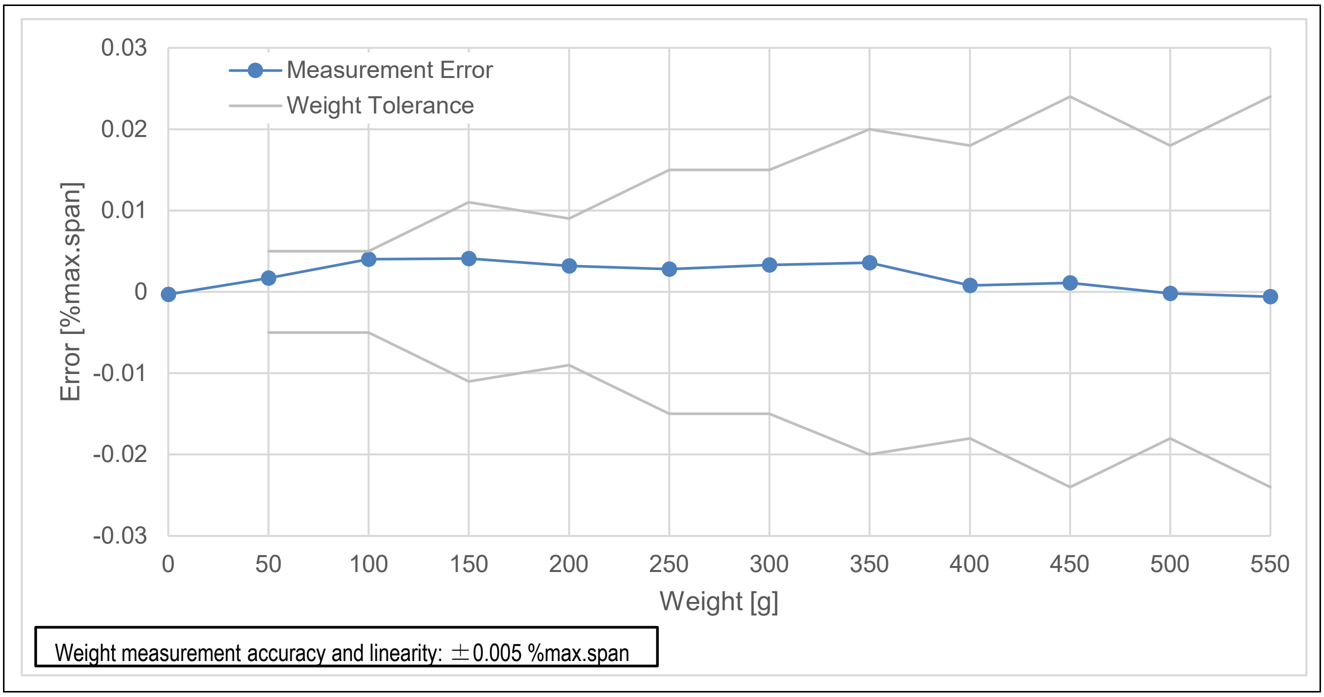


Figure 7-2 Weight Measurement Error (Environment Temperature: 25°C)

Histogram of 0g weight measurement value of 1000 samples without moving average is shown in Figure 7-3. The weight is 4.82mg at rms value, and 31.2mg at P-P value. Since the load cell's voltage sensitivity to weight is 7.5V/g, input conversion voltage is 36.2nV at rms value and 234nV at P-P value. Effective resolution and noise free resolution calculated from the above-mentioned result are shown below. Although noise of load cell was added to input conversion noise of typ. 33nVrms with RX23E-A setting 10SPS and 128times PGA gain, RX23E-A is shown to be capable of highly accurate weight measurement.

Effective resolution:	21.0bit (36.2nVrms: 4.8mg equivalent)
Noise free resolution:	18.4bit (234nV: 31.2mg equivalent)

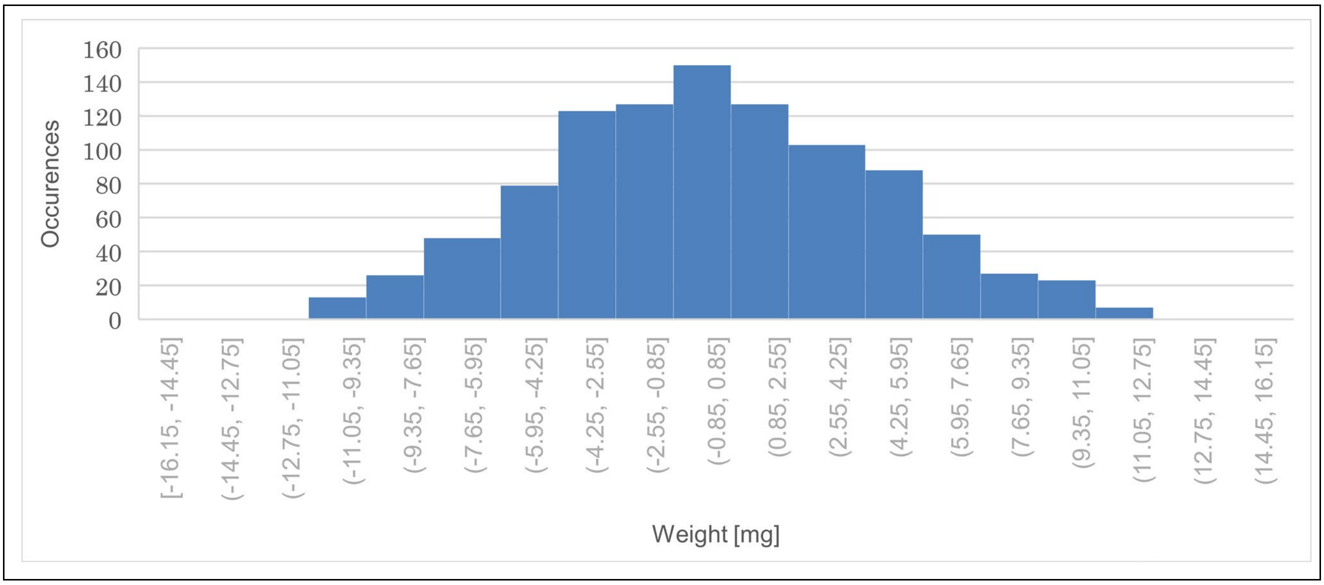


Figure 7-3 Histogram of Measurement Value at Weight 0g (no load)

Revision history

Rev.	Date	Description	
		Page	Summary
1.00	Nov.29.19	-	First release
1.10	July 20.20	p.3	Table 3-1: Update of IDE and Tool Chain
		p.10	Table 5-3: Update of the Smart Configurator setting
		p.22	Table 7-1,Table 7-2,Table 7-3: Modification due to the update of IDE and Tool Chain.
			Others: correction of the written error and addition of the description

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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