

RX23E-A Group

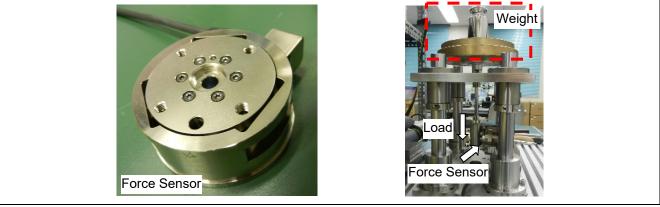
Force Sensor Measurement Example

Overview

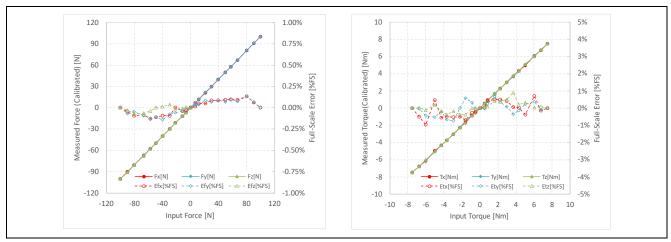
This document describes the example of the program which obtains three-dimensional force and torque by the strain gauge based 6-axis force sensor, using RX23E-A. This example uses two units of DSAD to obtain output from six channels of the force sensor by scanning three channels with one unit of DSAD. We have measured the force sensor with this program. The appearances of the force sensor and the evaluation environment, and the evaluation results are shown below.

Target Device

RX23E-A



Appearance of Force Sensor and Evaluation Environment



Result of Force Measurement (Left) and Torque Measurement (Right)

Measurement Uncertainty

Item	E _{Fx:FS} [%FS]	E _{Fy:FS} [%FS]	E _{Fz:FS} [%FS]	<i>Е_{Тх:FS}</i> [%FS]	<i>Е_{Ту:FS}</i> [%FS]	<i>Е_{Тz:FS}</i> [%FS]
9105-TWE-Gamma SI-130-10 Measurement uncertainty (95% CI)	1.00%	1.25%	0.75%	1.00%	1.25%	1.50%
Result of full-scale error measurement (Worst case)	0.13%	0.14%	0.07%	0.95%	0.68%	0.89%



RX23E-A Group

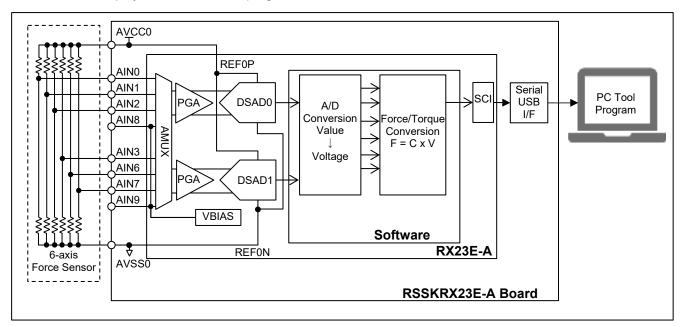
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1. Overview

This document describes the example of the program to obtain three-dimensional force and torque using the strain gauge based 6-axis force sensor by RX23E-A. This example uses two units of DSAD to obtain the output from six channels of the force sensor by scanning three channels with one unit of DSAD. The sample program runs on the Renesas Solution Starter Kit for RX23E-A (RSSKRX23E-A) board. The measurement results can be displayed on the PC tool program V2.0 of RSSKRX23E-A.





2. Related Documents

- R01UH0801 RX23E-A Group User's Manual: Hardware
- R20UT4542 RSSKRX23E-A User's Manual
- R20AN0540 Application Notes RSSKRX23E-A PC Tool Program Operation Manual
- R01AN4799 Application Notes RX23E-A Group Effective Use of AFE and DSAD
- R01AN4359 RX family RX DSP Library Version 5.0



3. Environment for Operation Confirmation

Table 3-1 shows the environment to check the operation.

Table 3-1 Environment for Operation Check

Item	Description					
Board	RSSKRX23E-A Board (RTK0ESXB1	RSSKRX23E-A Board (RTK0ESXB10C00001BJ)				
MCU	RX23E-A (R5F523E6ADFL)					
	Power-supply voltage (VCC, AVCC	0):5V				
	Operating frequency (ICLK) : 32MH	łz				
	Peripheral operating frequency (PC	LKB) : 32MHz				
	DSAD operating frequency (f _{DR}) : 4MHz					
	DSAD modulator clock frequency (f _{MOD}) : 0.5MHz					
Force sensor	Manufacturer	ATI Industrial Automation				
	Model	9105-TWE-Gamma				
	Calibration	SI-130-10				
	Measurement uncertainty [%FS]	Fx: 1.00%, Fy: 1.25%, Fz: 0.75%				
	(95% CI)	Tx: 1.00%, Ty: 1.00%, Tz: 1.50%				
IDE	Renesas e ² Studio Version 2021-10					
	Renesas RX Smart Configurator V2.1	Renesas RX Smart Configurator V2.11.0				
Tool Chain	Renesas CC-RX V3.03.00	Renesas CC-RX V3.03.00				
Emulator	E2 Emulator Lite					



4. Force Sensor Measurement

Figure 4-1 shows the connection of the force sensor and the RSSKRX23E-A board. Red letters in the figure indicate parts to be changed. The details of the changed parts are shown in Table 4-1

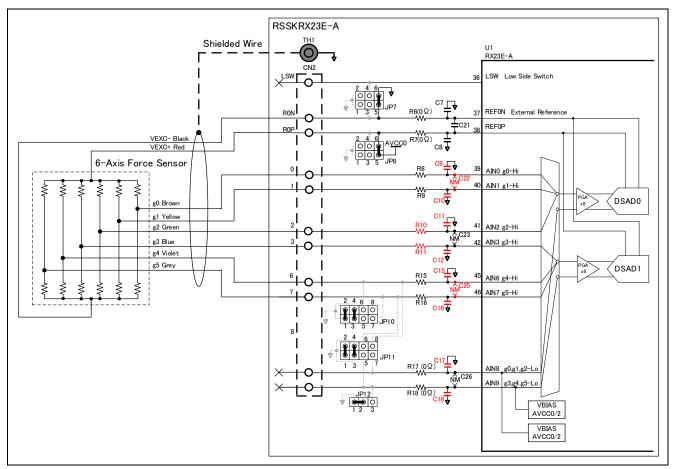


Figure 4-1 Connection of RSSKRX23E-A Board and Force Sensor

Table 4-1 Area of Changed P	Parts of RSSKRX23E-A
-----------------------------	----------------------

Circuit Designator	Value	Value
	(Before the change)	(After the change)
C22, C25	0.1µF 50V	Not mounted
C9, C10, C15, C16	0.01µF 50V	1µF 25V
C11, C12, C17, C18	Not mounted	1µF 25V
R10, R11	0Ω 1Α	1kΩ ±1%

When a voltage is applied to the excitation voltage terminal of a force sensor, the force sensor outputs the potential of midpoint of the half-bridge resistors which are connected to strain gauge in series. The output of the force sensor is connected to AIN0, AIN1, AIN2, AIN3, AIN6, and AIN7 of RX23E-A. The channel function of DSAD on RX23E-A is used for measurement, and DSAD0 is used for voltage measurement on AIN0, AIN1, and AIN2, and DSAD1 is used for voltage measurement on AIN3, AIN6, and AIN7. AIN8 is used for input for DSAD0 Lo side, and AIN9 is used for input for DSAD1 Lo side. By outputting VBIAS to AIN8 and AIN9 for each, the voltages on AIN8 and AIN9 are set to a half voltage of AVCC0, which is equivalent to the output voltage of the force sensor at no load.



4.1 Force Sensor

The strain gauge type 6-axis force sensor is a sensor that utilizes the fact that the resistance value of each strain gauges mounted on the strain body changes due to stress. By applying a voltage to the 6-axis force sensor, the change in resistance value due to stress is measured as a voltage.

If the output voltage of the strain gauge is non-linear in relation to the stress, 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 strain amount with linear interpolation.

Supposing that the applied voltage to the strain gauge is V_{CC} , the rated output is RO, and the load rating is S_{max} , the output voltage V of applied strain S is calculated as below.

$$V = \mathrm{RO} \cdot V_{cc} \cdot \frac{S}{S_{max}}$$

Multiply the acquired 6-axis voltage to the force sensor-specified voltage-load conversion matrix C to calculate the force and torque on x, y and z axis.

$$\begin{array}{c} F = C \times V \\ \begin{pmatrix} F_x \\ F_y \\ F_z \\ T_x \\ T_y \\ T_z \end{pmatrix} = \begin{pmatrix} C_{11} & \cdots & C_{16} \\ \vdots & \ddots & \vdots \\ C_{61} & \cdots & C_{66} \end{pmatrix} \begin{pmatrix} V_0 \\ V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{pmatrix}$$

In this example, ATI Industrial Automation 9105-TWE-Gamma is used as a force sensor for measurement. The appearance of the force sensor is shown in Figure 4-2.

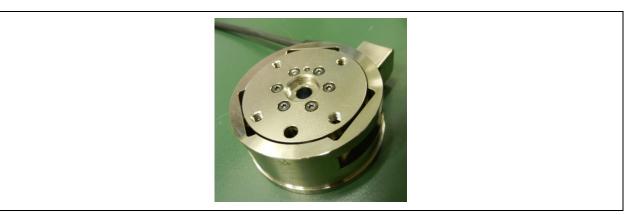


Figure 4-2 Appearance of ATI Industrial Automation 9105-TWE-Gamma



4.2 A/D Conversion of Strain Gauge Output

This example uses the supplied voltage of the strain gauges for reference voltage as shown in Figure 4-1. The output voltage of each strain gauge is A/D converted by DSAD.

Table 4-2 shows the measurement conditions of the strain gauges. The digital filter of the DSAD generates gain of from 1/2 to 1 time when oversampling ratio is not a power of two. A/D conversion value is treated as affected by this gain.

Table 4-2 Measurement Condition of Strain Gauge

Item	Condition	Remarks
PGA gain G _{PGA}	x8	
DSAD reference voltage V _{REF}	5V	Applied voltage of the strain gauge (REF0P=AVCC0, REF0N=AVSS0)
Oversampling ratio OSR	32	
Digital filter gain GDF	1.0	$G_{DF} = 1/2^{(Ceil(4\log_2 OSR) - 4\log_2 OSR)}$
DSAD output format	2's Complement	

This example uses two units of DSAD on RX23E-A to scan the output from the 6-axis force sensor 3 voltages in each DSAD. Figure 4-3 shows conversion sequence and Table 4-3 shows A/D conversion time.

When starting the A/D conversion, use the synchronous start function to start the conversion of DSAD0 and DSAD1 simultaneously.

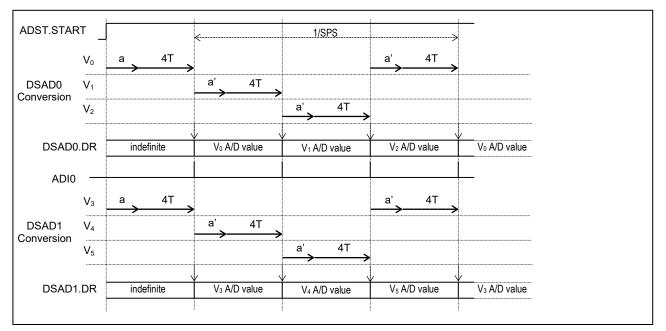




Table 4-3 A/D Conversion Time

Normal Mode: f_{MOD} = 0.5MHz Over Sampling Ratio (OSR) = 32

Item		Value	Remarks
A/D Conversio	n Time	0.512[msec]	a' + 4T
a 0.259[msec]		0.259[msec]	Average time of channel switching and stabilization
	a' 0.256[msec]		
	Т	0.064[msec]	Digital filter processing time T = OSR / f _{MOD}
Data rate		651.0416667[sps]	1 / total A/D conversion time = 1 / 3(a'+4T)



4.3 Calculation Procedure

Follow the procedure below to convert from the A/D conversion value to the force and torque.

(1) Calculate the Voltages

Convert the A/D conversion value of the voltage outputted from the individual strain gauge into voltages.

Supposing 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_n, output voltage V_n from each strain gauge is calculated from the DSAD resolution of 24bit by the equation below.

$$V_n = \frac{2V_{REF}}{2^{24} \cdot G_{PGA} \cdot G_{DF}} \cdot \text{DATA}_n$$

= $\frac{V_{REF}}{2^{23} \cdot G_{PGA} \cdot G_{DF}} \cdot \text{DATA}_n$, $V_{REF} = AVCC0 - AVSS0$, $n = 0 \sim 5$

(2) Conversion of Force and Torque

Multiply the acquired 6-axis voltage to the force sensor-specified voltage-load conversion matrix C to calculate the force and torque on x, y and z axis.

$$F = C \times V$$

$$\begin{pmatrix} F_x \\ F_y \\ F_z \\ T_x \\ T_y \\ T_z \end{pmatrix} = \begin{pmatrix} C_{11} & \cdots & C_{16} \\ \vdots & \ddots & \vdots \\ C_{61} & \cdots & C_{66} \end{pmatrix} \begin{pmatrix} V_0 \\ V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{pmatrix}$$

4.4 Zero-Reset

To correct mechanical offset etc., the A/D conversion value at no load is adjusted to be zero.

In this example, supposing that the offset value is the average of A/D conversion values of individual strain gauge at no load, set the offset value in DSAD offset correction register OFCRm so that the offset is canceled.



5. Sample Program

5.1 Operation Overview

Figure 5-1 shows the processing flow of the sample program.

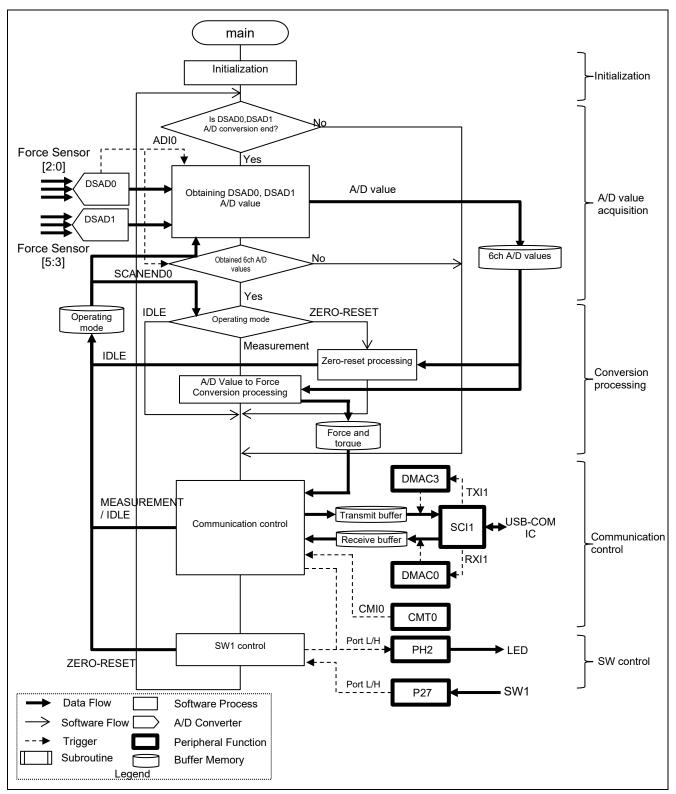


Figure 5-1 Force Sensor Measurement Process Flow



This sample program operates in the three operating modes: IDLE, MEAUSUREMENT, and ZERO-RESET. The operating mode is switched by a RSSKRX23E-A PC tool program and SW1 on RSSKRX23E-A board. Table 5-1 shows the transition of the operating mode.

Table 5-1 Operating Mode Transition

Operating mode	Operation	Transition trigger	Transition to
IDLE	No operation	Receive Run command	MEASUREMENT
		Press SW1	ZERO-RESET
MEASUREMENT	Force sensor measurement	Receive STOP command	IDLE
ZERO-RESET	Zero-reset processing	Complete Zero-reset processing	IDLE

The outline of each processing is described below.

- Initial setting
 - The following initial settings are performed at startup.
 - Initial setting of DMAC to be used for communication (if a connection is made to the PC tool program of RSSKRX23E-A)
 - Initialization of the communication buffer and start of SCI1 operation (if a connection is made to the PC tool program of RSSKRX23E-A)
- A/D conversion value acquisition
 With the completion of the A/D conversion of both DSAD0 and DSAD1 as a trigger, acquires the A/D conversion values.
- When the A/D conversion values of 6ch are acquired, performs processing in the operating mode below.
 - MEASUREMENT: Based on "4.3 Calculation Procedure", calculates the force and torque from the A/D conversion values of 6ch.
 - ZERO-RESET: After setting each average of the A/D conversion values of 6ch in the register OFCRm on the corresponding channel, changes its operating mode to IDLE. For details, refer to "5.3 Zero-Reset Processing".
- Communication control

For communication with the PC tool program of RSSKRX23E-A, the followings are processed. For details, refer to "5.4 Communication Control".

- If a receive packet exists, analyzes it, performs processing corresponding to a command, and stores a reply packet in the transmit buffer.
- · If the measurement results are updated, stores a transmit packet in the transmit buffer.
- If the transmit buffer contains un-transmitted data, starts transmission.
- SW1 control

At the detection of pressing of SW1, the followings are processed if the operating mode is IDLE. For details, refer to "5.3 Zero-Reset Processing".

- Sets DSAD for Zero-reset processing and starts A/D conversion.
- · Changes the operating mode to ZERO-RESET.



5.2 Peripheral Functions and Pins to be Used

The peripheral functions to be used in this example are listed in Table 5-2, the pins to be used in Table 5-3. Also, setting conditions for the peripheral functions are shown together.

The setting for the peripheral functions is used the Smart Configurator (hereinafter, called "SC").

Table 5-2 Peripheral Functions to be Used	Table 5-	2 Peripheral	Functions	to be	e Used
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Peripheral Function	Purpose
AFE、DSAD0、DSAD1	Measurement of force sensor
SCI1	UART communication with PC tool program
DMAC0	Transmit data with reception completion interrupt of SCI1 as a trigger.
DMAC3	Transmit data with buffer empty interrupt of SCI1 as a trigger
CMT0	Detect communication time-out of SCI1
PH2	Control lighting of LED1
P27	Reading stare of SW1

Table 5-3 Pins to be Used

Pin name	I/O	Purpose
PH2	Output	LED1 lighting control
P27	Input	SW1 input
P26/TXD1	Output	UART1 transmission pin
P30/RXD1	Input	UART1 reception pin
P31/CTS1#	Input	CTS signal input pin
AIN0	Input	Input pin for sensor output on 0 Hi side
AIN1	Input	Input pin for sensor output on 1 Hi side
AIN2	Input	Input pin for sensor output on 2 Hi side
AIN3	Input	Input pin for sensor output on 3 Hi side
AIN6	Input	Input pin for sensor output on 4 Hi side
AIN7	Input	Input pin for sensor output on 5 Hi side
AIN8	Input	Input pin for sensor output on 0,1,2 Lo side
AIN9	Input	Input pin for sensor output on 3,4,5 Lo side
REF0P	Input	DSAD+ Measurement reference voltage
REF0N	Input	DSAD- Measurement reference voltage



5.2.1 AFE · DSAD0 · DSAD1

Based on the measurement conditions on Table 4-2, Table 5-4 shows the setting of DSAD0, and DSAD1, and Table 5-5 shows the setting of AFE.

Channel 0~2 of DSAD0 and DSAD1 are assigned for measurement, and channel 3~5 are assigned for Zero-reset processing.

Table 5-4 Setting of DSAD

Item		Setting							
					Measurement Z				
ΔΣΑ/D Converte	er operatio	n voltage setting	3.6 V to 5.5 V (High precision)						
ΔΣΑ/D Converte	er operatio	n mode setting	Normal mode						
Operation clock		PCLKB	/8(4MHz)						
Start trigger source		Softwar	e trigger						
Interrupt setting		Not use	d						
Inter-unit synchronized start setting		Enable	synchroni	zed start					
Voltage fault an	d disconne	ection detection setting	Not use	d					
Channel setting			0	1	2	3	4	5	
Analog input	DSAD0	+side input signal	AIN0	AIN1	AIN2	AIN0	AIN1	AIN2	
setting		- side input signal	AIN8						
	DSAD1	+side input signal	AIN3	AIN6	AIN7	AIN3	AIN6	AIN7	
		- side input signal	AIN9						
	Reference input		REF0P/REF0N						
	Positive	Positive reference voltage buffer		Disabled					
	Negative reference voltage buffer			Disabled					
Amplifier	Amplifier	selection	PGA						
setting	PGA gai	n setting	x128						
ΔΣA/D	A/D conv	version mode	Normal operation						
conversion	Data form	nat	Two's complement						
setting	A/D conv	A/D conversion number		Exponential operation			Immediate value mode,		
			mode, 1 time 64 time						
	Oversampling ratio		32						
	Offset co	prrection value	Not set 0						
		rection value	Not set						
		veraging data	Disabled			Enabled			
	A/D c timing	onversion end interrupt	- When the average selected number is calculated						
	Avera	age data number				64			
Disconnect dete	ection assis	st setting	Not per	mitted					

Table 5-5 Setting of AFE

Item		Setting	
Bias output setting Enable bias voltage setting		Enabled	
pin output		AIN8, AIN9	
Excitation current output	ut setting	Not used	
Low level voltage detection setting		Not used	
Low-side switch contro	l setting	Not used	



5.2.2 SCI1 · DMAC0 · DMAC3 · CMT0

For communication with the PC tool program, SCI1 is used in the asynchronous mode. DMAC0 is used to obtain the received data and DMAC3 is used to set the transmitted data. In addition, CMT0 is used to detect the communication time-out.

The settings for the peripheral function are shown in the tables below.

Table 5-6 Setting of SCI1

Item		Setting
Start bit edge detection setting		Low level of RXD1 pin
Data · bit length		8bit
Parity setting		None
Stop bit length set	tting	1 bit
Transfer direction	setting	LSB-first
Transfer rate	Transfer clock	Internal clock
setting	Bit rate	3Mbps
	Enable modulation duty correction	Enable
	SCK1 pin function	SCK1 is not used
Noise filter setting		Disable
Hardware flow con	ntrol setting	CTS1#
Data handling	Transmit data handling	Data handling by DMAC
setting Receive data handling		Data handling by DMAC
Interrupt setting	Enable reception error interrupt	Not used
Callback function Setting		Not used

Table 5-7 Setting of DMAC

ltem		Setting		
		DMAC0	DMAC3	
Transfer	Activation source	SCI1 (RXI1)	SCI1 (TXI1)	
setting	Activation source flag control	Clear interrupt flag of the activation source		
	Transfer mode	Free running mode	Normal mode	
	Transfer data size	8bit		
	Transfer count / Repeat size / Block size	-	(Setting with software)	
Source	Source address	0008 A025h (SCI1.RDR)	(Setting with software)	
address		Fixed	Incremented	
setting	Specify the transfer source	-	Enable	
	as extended repeat area			
	Extended repeat area		Lower 12 bits of the address (4Kbyte)	
Destination	Destination address	(Setting with software)	0008 A023h (SCI1.TDR)	
address		Incremented	Address fixed	
setting	Specify the transfer	Enable	-	
	destination as extended			
	repeat area			
	Extended repeat area	Lower 9 bits of the address		
-		(512byte)		
Interrupt set	ling	Not permitted		



Table 5-8 Setting of CMT0

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

5.2.3 PORT

Read SW1 state using P27.

Turn on/off LED1 with PH2. Turn it on while transmitting the measurement results to the PC tool program or Zero-reset processing.

Table 5-9 shows the setting condition of PORT.

Table 5-9 Setting of PORT

Item		Setting
PORT2	P27	Input
PORTH	PH2	Output
		CMOS output
		Output 1



5.3 Zero-Reset Processing

Zero-reset processing starts when the operating mode is IDLE and SW1 is pressed. Sets the averages of 64 samples of A/D conversion values, which are obtained under the setting of DSAD for Zero-reset, to the offset correction register OFCRm of the corresponding channel to correct the offset. During the Zero-reset processing, LED1 on the RSSK board is turned on. For the settings of DSAD, refer to "Table 5-4 Setting of DSAD".

Table 5-10 shows the operation and its process. For the processing location, refer to "Figure 5-1 Force Sensor Measurement Process Flow".

Table 5-10 Zero-Reset Procedure	e 5-10 Zero-Reset Pi	rocedure
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Procedure	Operation	Processing location	Process
1	Press SW1	SW1 control	Turn on LED1
			 Set DSAD for Zero-reset and start A/D conversion
			 Change the operating mode to ZERO-RESET
2	-	Zero-reset	Stop A/D conversion
		processing	 Set the obtained the average of A/D conversion values
			in register OFCRm of the corresponding channel.
			・Turn off LED1
			 Change the operating mode to IDLE



5.4 Communication Control

Based on the communication specifications of RSSKRX23R-A, process with the PC tool program are performed. A flow of communication processes is shown in Figure 5-2

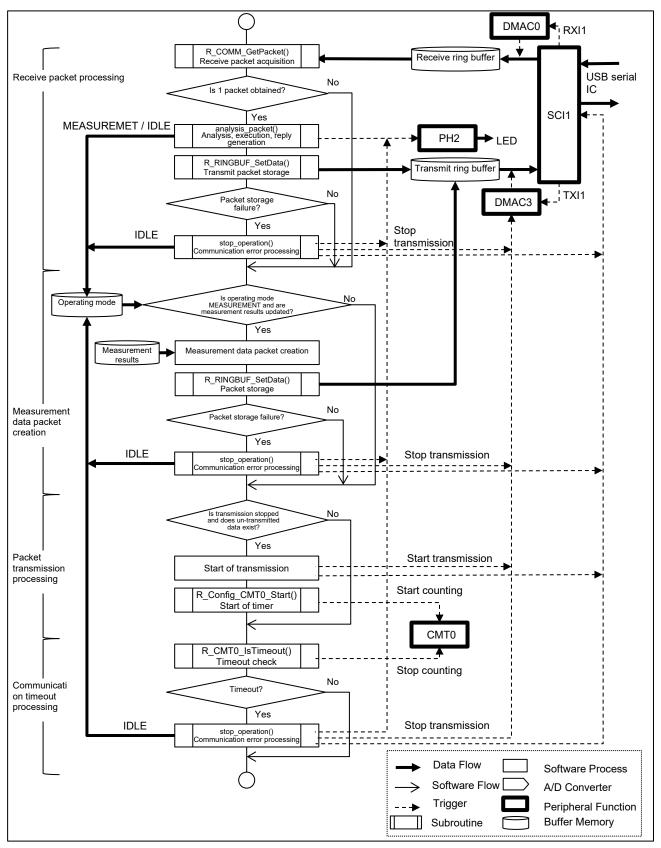


Figure 5-2 Communication Process Flow



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 5-11 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.

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	Turn on LED1		
	 Set DSAD for force sensor measurement and start A/D conversion 		
	Change the operating mode to MEASUREMENT		
Stop	Stop A/D conversion		
	Turn off LED1		
	Change the operating mode to IDLE		
ExtraInformation	Return the information specified by a reply packet		

Table 5-11 Packets and Actions

• Measurement data packet creation

If the Operating Mode is MEASUREMENT 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

Whether 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
- Set Operating mode to IDLE
- 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.



5.5 **Program Configuration**

5.5.1 File Configuration

Table 5-12 File Configuration

Folder name, File name	Description
⊢src	
	Smart Configurator generation
│ │	
│ │ │ ⊢r_bsp	
│ │ ├Config_AFE	
│ │ ├Config_CMT0	
│ │ ├Config_DMAC0	
│ │ ├Config_DMAC3	
│ │ ├Config_DSAD0	
│ │ ├Config_DSAD1	
│ │ ├Config_PORT	
│ │ ├Config_SCI1	
│ │ │-r_config	
│ │ └r_pincfg	
│	Ring buffer control program
│	Ring buffer control API definition
│	Communication control program
│	Communication control API definition
│	Force sensor measurement calculation program
│	Force sensor measurement calculation API definition
│	Force sensor measurement condition definition
│ └main.c	Main processing
^L dsplib-rxv2	RX DSP library file



5.5.2 Macro Definition

Table 5-13 main.c Definitions

Definition Name	Туре	Initial value	Description
D_PC_TOOL_USE	bool	1	Communication with PC tool program
			0: Not used
			1: Used

Table 5-14 r_fs_cfg.h: Definitions for Force Sensor Measurement

Definition Name	Туре	Initial value	Description
D_FS_CFG_GAIN	float	8.0F	PGA gain G _{PGA} [time]
D_FS_CFG_VREF	float	5.0F	Reference Voltage of A/D conversion VREF [V]
D_FS_CFG_DSADRES	int	24	Resolution of A/D conversion [bit]
D_FS_CFG_CHANNELS	int	6	Number of input channels

5.5.3 Structure

Table 5-15 r_ring_buffer_control_api.h: Structure for Ring Buffer Control

Structure	st_ring_buf_t			
type				
Member	Туре	Name	Description	
Variable	uint8_t *	buf	Ring buffer pointer	
	size_t	length	Ring buffer length	
	uint32_t	r_index	Read index	
	uint32_t	w_index	Write index	



5.5.4 Functions

Table 5-16 main.c Fuctions

Name	main	main				
Description	main	main function				
Arguments	I/O	Туре	Name Description			
	-	void	-	-		
Return Value	0	void	-			
Name	analy	/sis_packet				
Description	Exec	ute command corre	sponding to receiv	e packet, and store response packet.		
	In the	e case of Run/Stop	command, update	the Operating Mode.		
Arguments	I/O	Туре	Name	Description		
	Ι	uint8_t const	rcv_pck[]	Receive packet storage array		
	0	uint8_t	send_pkt[]	Reply packet storage array		
	I/O	e_mode_t *	p_mode	Pointer to the Operating mode variable		
Return Value	0	size_t	Response packet	length [byte]		
Name	stop	_operation				
Description	Stop	DMAC and SCI, ini	tialize ring buffer, T	urn off LED1		
Arguments	I/O	Туре	Name	Description		
	I/O	st_ring_buf_t *	ary	Pointer to ring buffer		
Return Value	-	void	-			

Table 5-17 r_fs_api Functions

Name	R_FS	R_FS_DsadToVoltage				
Description	Conv	Convert DSAD value to input voltage				
Arguments	I/O	/O Type Name Description				
	Ι	float	dsad	24bit DSAD value		
Return Value	0	float	Voltage [V]			

Table 5-18 r_communication_control_api Functions

Name	R_COMM_GetPacket					
Description	Read	Read 1 packet from receive ring buffer				
Arguments	I/O	I/O Type Name Description				
	I	st_ring_buf_t * r_buf Pointer to receive ring buffer				
	0	uint8_t	r_packet[]	Receive packet storage array		
Return Value	0	size_t	Packet length [byte]			



Table 5-19 r_ring_buffer_control_api Functions

Name	R_RI	R_RINGBUF_GetData				
Description	Read	I the specified byte	number from ring b	uffer		
Arguments	I/O	Туре	Name	Description		
	Ι	st_ring_buf_t *	ary	Pointer to ring buffer		
	0	uint8_t	data[]	Data storage array		
	Ι	size_t	len	Number of bytes to read		
	Ι	bool	index_update	Index update flag		
				true: updated		
				false: not updated		
Return Value	0	size_t	Number of read by	rtes		
Name	_	NGBUF_SetData				
Description	Write	the specified byte	number to ring buffe	er		
Arguments	I/O	Туре	Name	Description		
	I/O	st_ring_buf_t *	ary	Pointer to ring buffer		
	Ι	uint8_t	data[]	Data storage array		
		size_t	len	Number of bytes to write		
Return Value	0	size_t	Number of written	bytes		
Name		NGBUF_GetDatal				
Description	Read	the number of byt	es stored in ring buf	fer		
Arguments	I/O	Туре	Name	Description		
	Ι	st_ring_buf_t *	ary	Pointer to ring buffer		
Return Value	0	size_t	Number of stored I	oytes		
Name	_	NGBUF_SetDatal				
Description	Upda	te the index of ring	buffer			
Arguments	I/O	Туре	Name	Description		
	0	st_ring_buf_t *	ary	Pointer to ring buffer		
	Ι	uint16_t	value	Index value		
	I	uint8_t	select	Target index		
				0: Read index		
				1: Write index		
Return Value	0	uint32_t	Index value			



Table 5-20 Config_CMT0 User Defined Functions

Name	R_C	R_CMT0_IsTimeout			
Description	Return if time-out or not				
Arguments	I/O	Туре	Name	Description	
	I	bool	flag	Counter stare	
				false: continued	
				true: stopped	
Return Value	0	bool	false: Counting		
			true: Time-out		
Name	R_C	MT0_CntClear			
Description	Clea	the compare matc	h timer counter		
Arguments	I/O	Туре	Name	Description	
	-	void	-	-	
Return Value	-	void	-		

Table 5-21 Config_DMAC0 User Defined Functions

Name	R_DMAC0_SetDestAddr					
Description	Set d	Set destination address to DMDAR				
Arguments	I/O	Туре	Name Description			
	Ι	void *	p_addr	Destination address		
Return Value	-	void	-			
	R_DMAC0_GetDestAddr					
Name	R_DI	MAC0_GetDestAd	dr			
Name Description	_	MAC0_GetDestAde lestination address				
	_			Description		
Description	Get o	lestination address	(macro function)	Description -		

Table 5-22 Config_DMAC3 User Defined Functions

Name	R_DMAC3_SetSrcAddr					
Description	Set s	Set source address to DMSAR				
Arguments	I/O	Туре	Name	Description		
	I	void *	p_addr	Source address		
Return Value	-	void	-			
Name	R_D	MAC3_SetTxC	nt			
Description	Set t	ransfer count to	DMCRA			
Arguments	I/O	Туре	Name	Description		
	I	uint32_t	cnt	Transfer count		
Return Value	-	void	-			



Table 5-23 Config_DSAD0 User Defined Functions

Name	R_D	R_DSAD0_IsConversionEnd					
Description	Retu	rns whether A/D co	nversion is in progr	ess.			
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	-	bool	false: Converting				
			true: Conversion	end			
Name	R_D	SAD0_ClearConve	ersionEndFlag				
Description	Clea	r ADI0 flag					
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	-	void	-				
Name	_	SAD0_IsScanEnd					
Description	Retu	rns whether auto so	an is in progress.				
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	0	bool	false: Scanning				
			true: Scan end				
Name		SAD0_ClearScanE	ndFlag				
Description	Clea	r SCANEND0 flag	•				
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	-	void	-				
Name		SAD0_GetADValue					
Description	_	rn DR register value	e (macro function)				
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	0	uint32_t	DR value				
Name	_	SAD0_GetAverage					
Description	Retu	rn AVDR register va	alue (macro functio	n)			
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	0	uint32_t	AVDR value				



Table 5-24 Config_DSAD0 User Defined Functions (continue)

Name	R_DSAD0_SetOFCR0				
Description	Set c	offset correction valu	ue to OFCR0 (mac	ro function)	
Arguments	I/O	Туре	Name	Description	
		uint32_t	val	Setting value to OFCR0	
Return Value	-	void	-		
Name	R_D	SAD0_SetOFCR1			
Description	Set c	offset correction valu	ue to OFCR1 (mac	ro function)	
Arguments	I/O	Туре	Name	Description	
		uint32_t	val	Setting value to OFCR1	
Return Value	-	void	-		
Name	R_D	SAD0_SetOFCR2			
Description	Set c	offset correction valu	ue to OFCR1 (mac	ro function)	
Arguments	I/O	Туре	Name	Description	
		uint32_t	val	Setting value to OFCR2	
Return Value	-	void	-		
Name	R_C	onfig_DSAD0_CHr	ηEN		
Description	Set A	VD Conversion Ena	ble bit to MR		
Arguments	I/O	Туре	Name	Description	
	I	uint32_t	ch	Permission setting of channel 0-5 to bit 0-5	
				1: Conversion enable	
				0: Conversion disable	
Return Value	-	void	-		

Table 5-25 Config_DSAD1 User Defined Functions

Name	R_D	R_DSAD1_IsConversionEnd				
Description	Retu	Returns whether A/D conversion is in progress.				
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	-	bool	false: Converting			
			true: Conversion e	end		
Name	R_D	SAD1_ClearConve	rsionEndFlag			
Description	Clear	r ADI1 flag				
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	-	void	-			
	R_DSAD1_IsScanEnd					
Name	R_D	SAD1_IsScanEnd				
Name Description		SAD1_IsScanEnd rns whether auto sc	an is in progress.			
			an is in progress. Name	Description		
Description	Retu	rns whether auto so		Description -		
Description	Retu	rns whether auto so Type		Description -		
Description Arguments	Retu I/O -	rns whether auto so Type void	Name	Description -		
Description Arguments	Retu I/O - 0	rns whether auto so Type void	Name - false: Scanning true: Scan end	Description -		
Description Arguments Return Value	Retu I/O - 0 R_D	rns whether auto so Type void bool	Name - false: Scanning true: Scan end	Description -		
Description Arguments Return Value Name	Retu I/O - 0 R_D	rns whether auto so Type void bool SAD1_ClearScanE	Name - false: Scanning true: Scan end	Description - Description		
Description Arguments Return Value Name Description	Retu I/O - 0 R_D Clean	rns whether auto so Type void bool SAD1_ClearScanE SCANEND1 flag	Name - false: Scanning true: Scan end ndFlag	-		



Name	R_DSAD1_GetADValue					
Description	Retu	rn DR register valu	e (macro function)			
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	0	uint32_t	uint32_t DR value			
Name	R_D	R_DSAD1_GetAverageADValue				
Description	Retu	rn AVDR register va	alue (macro functio	on)		
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	0	uint32_t	AVDR value			
Name	R_D	SAD1_SetOFCR0				
Description	Set c	offset correction val	ue to OFCR0 (mad	cro function)		
Arguments	I/O	Туре	Name	Description		
	Ι	uint32_t	val	Setting value to OFCR0		
Return Value	-	void	-			
Name		SAD1_SetOFCR1				
Description	Set o	offset correction val	ue to OFCR1 (mac	cro function)		
Arguments	I/O	Туре	Name	Description		
	I	uint32_t	val	Setting value to OFCR1		
Return Value	-	void	-			
Name	R_D	SAD1_SetOFCR2				
Description	Set c	offset correction val	ue to OFCR2 (mac	cro function)		
Arguments	I/O	Туре	Name	Description		
	Ι	uint32_t	val	Setting value to OFCR2		
Return Value	-	void	-			
Name		onfig_DSAD1_Chr				
Description	Set A	VD Conversion Ena	able bit to MR			
Arguments	I/O	Туре	Name	Description		
	I	uint32_t	ch	Permission setting of channel 0-5 to bit 0-5		
				1: Conversion enable		
				0: Conversion disable		
Return Value	-	void	-			

Table 5-26 Config_DSAD1 User Defined Functions (continue)



Table 5-27 Config_PORT User Defined Functions

Name	R_LE	R_LED1_On					
Description	Turn	Turn on LED1 (Macro function)					
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	-	void	-				
Name	R_LE	ED1_Off					
Description	Turn	off LED1 (Macro fu	nction)				
Arguments	I/O	Туре	Name	Description			
	-	void	-	-			
Return Value	-	void	-				
Name	R_PC	ORT_KeyScan					
Description	Acqu	ires the status of sv	vitch SW1 that has	absorbed chattering			
Arguments	I/O	Туре	Name	Description			
	Ι	uint32_t	key_current	Previous SW1 status			
Return Value	0	uint32_t	SW1 status				
			0: On				
			1: Off				

Table 5-28 Config_SCI1 User Defined Functions

Name	R_SCI1_IsTransferEnd					
Description	Returns the transfer status					
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	0	bool	false: Transferring			
			true: Transfer end			
Name	R_SCI1_SendStart					
Description	Start	transmission	ansmission			
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	0	MD_STATUS	MD_OK			
Name	R_SCI1_SendStop					
Description	Stop transmission					
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	0	MD_STATUS	MD_OK			
Name	R_SCI1_ReceiveStart					
Description	Start receiving					
Arguments	I/O	Туре	Name	Description		
	-	void	-	-		
Return Value	0	MD_STATUS	MD_OK			



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.

Eile Edit Source Refactor Navigate Search Project Vew Alt+Shift+N > Import C X Open File Select Create new projects from an archive file or directory. C Gose Ctrl+W Create new projects from an archive file or directory. C	
Open File Select Open Projects from File System Create new projects from an archive file or directory.	
Create new projects from an archive file of directory.	
Gose Ctrl+W	
Cose All Ctrl+Shift+W	
Select an import wizard:	
i shve ≜s Start the e⁻studio, and select	
Sive All menu [File] >> [Import].	
Move Select [Existing Projects into Workspace].	
Rename F2 Preferences	
Refresh F5 Convert Line Delimiters To PI Convert Line Delimiters To Convert Line Delimiters To PI Convert Existing C/C++ Project into Workspace	
Pint Ctrl+P Ctrl+P Ctrl+P	
Switch Workspace > >>> C/C++ >>>> Code Generator	
rc > > Git	
import v	
Properties Alt+Enter st	
Exit	
? < Back Next > Einish Cancel	
🖬 Import — 🗆 🗙	
Import Projects	
Select a directory to search for existing Eclipse projects.	
Select [Select root directory:], and specify t	
directory:]. Oseect archive file: Browse directory which stored the project to import (e.g. rx23ea_force_sensor)	
Projects V r01an3956,rxv2 (C-¥download¥an-r01an3956j0100-rxv2-dsp¥r01ar) Each application note has its own project n	ame.
< Refresh	
Options	
Search for nested projects	
Copy projects into workspace Hide projects that already exist in the workspace	
Working sets	
Add project to working sets	
Select [Add project to working sets] when using	
the working sets.	
? < Back Next > Einish Cancel	

Figure 6-1 Importing a Project into e² studio



6.2 Importing a Project into CS+

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

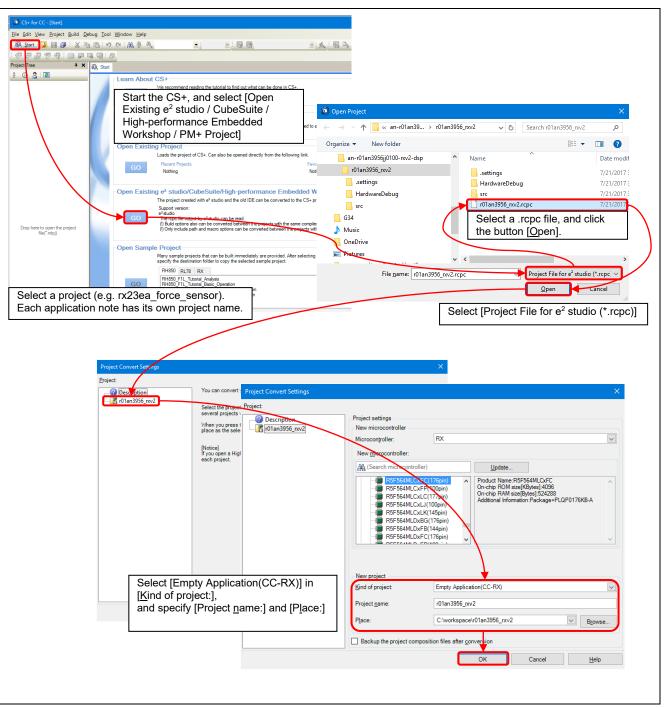


Figure 6-2 Importing a Project into CS+



7. Measurement Result using Sample Program

7.1 Memory Usage and Execution Cycle

7.1.1 Build Conditions

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

Table 7-1 Build Conditions

ltem		Setting
Compiler	Not supporting PC tool	 -isa=rxv2 -include=".¥dsplib-rxv2"-utf8 -nomessage -debug -outcode=utf8 -nologo
	Supporting	add to the above
	PC tool	-define=D_PC_TOOL_USE=1
Linker		-library=".¥dsplib-rxv2¥RX_DSP_FPU_LE.lib" -noprelink -output="rx23ea_force_sensor.abs" -form=absolute -nomessage -vect=_undefined_interrupt_source_isr -list=rx23ea_force_sensor.map -nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -nologo
	Added section	-start=B_DMAC_REPEAT_AREA_1/02000

Note: Include paths other than user settings in compiler setting are omitted.

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

ltem		Size [byte]	Remarks		
		Not supporting PC tool	Supporting PC tool	1	
ROM		9980	10558		
	Code	8029	8559		
	Data	1951	1999		
RAM		7114(2118)	12284(7288)	Note	
	Data	1994	7164		
	Stack	5120(124)	5120(124)	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 Force Sensor Measurement Process Flow" is shown in Table 7-3.

Table 7-3 Number of Execution Cycle

ICLK=32MHz

Item	Number of execution cycle (Execution time)	Process load [%]	Condition
Measurement • Calculation	568cycle (17.75µsec)	1.16	Maximum cycles at operating mode MEASUREMENT
Communication control	710cycle (22.19µsec)	1.44	Maximum cycles at normal operation
SW1 control	307cycle (9.59µsec)	0.62	Maximum cycles at normal operation

Note: Process load is calculated based on the execution time of DSAD output cycle (1.536msec).



7.2 Force Sensor Measurement

7.2.1 Measurement Appearance

Connecting a force sensor based on the configuration in "Figure 4-1 Connection of RSSKRX23E-A Board and Force Sensor", we have performed measurement applying force and torque to the force sensor with evaluation jigs and weights. Figure 7-1 shows the appearance of this measurement.

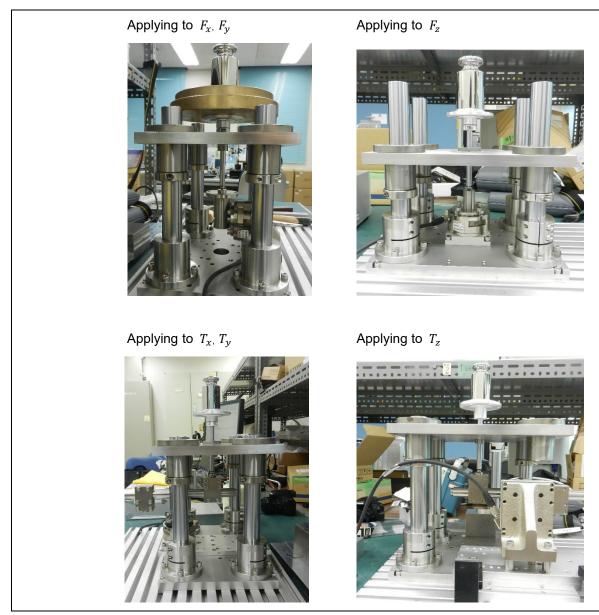


Figure 7-1 Measurement Appearance



RX23E-A Group

7.2.2 Measurement Condition

Figure 7-2 and Figure 7-3 show how to apply force and torque, and Figure 7-4 shows the weights used in measurement.

For measurement, Zero-reset is processed in the posture shown in Figure 7-2 and Figure 7-3 at no load.

(1) Force Measurement

Force F [N] applied to a force sensor is calculated from weight m [kg] and gravitational acceleration g [m/s²] with the equation below.

$$F = m \times g$$

(2) Torque Measurement

Torque T [N·m] applied to a force sensor is calculated from weight m [kg], gravitational acceleration g [m/s²], and the distance between a fulcrum and a force point L [m] with the equation below.

 $T = m \times g \times L$

Suppose that gravitational acceleration is the standard gravitational acceleration 9.80665[m/s2].

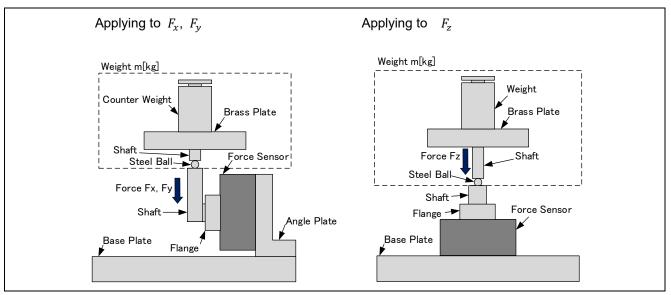
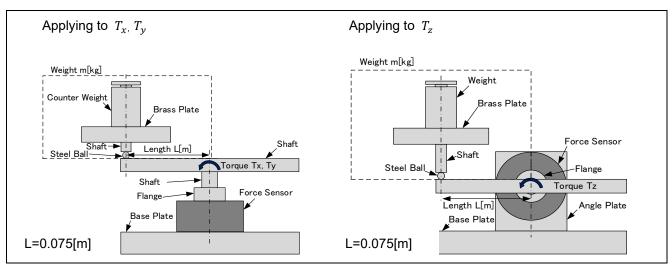


Figure 7-2 How to Apply Force



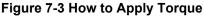




Table 7-4 Weight Used in Measurement

No.	Name	Model	Weight	Grade	Manufacturer
1	Weight Set	WS1M1K	1mg x1, 2mg x2, 5mg x1 10mg x1, 20mg x2, 50mg x1 100mg x1, 200mg x2, 500mg x1 1g x1, 2g x2, 5g x1 10g x1, 20g x2, 50g x1 100g x1, 200g x2, 500g x1 1kg x1	M1	AS ONE
2	Cylindrical Weight	SWM2000	2kg	M1	AS ONE
3	Brass Plate	INERTIAPLATE: C	2.853kg ^{Note}	-	Renesas
4	Brass Plate	INERTIAPLATE: D	4.6625kg ^{Note}	-	Renesas

Note: Confirmed with A&D counting scale FC-5000i (Repeatability 0.5g)



7.2.3 Measurement Result

The result of force measurement is shown in Figure 7-4, and the result of torque measurement is shown in Figure 7-5. The measurement results are corrected by calculating scale factor error and bias error from the measurement values at no load and at maximum load.

From the measurement result, the force measurement error $E_{F:FS}$ for full-scale is calculated from the force input value F_{in} , the force measurement value F_{mea} , and the force measurement range of the force sensor F_{FS} (F_x , F_y :130N, F_z :400N) with the equation below.

$$E_{F:FS} = \frac{F_{mea} - F_{in}}{F_{FS}} \times 100[\% FS]$$

Similarly, the torque measurement error $E_{T:FS}$ is calculated from the torque input value T_{in} , the torque measurement value T_{mea} , the torque measurement range of the force sensor T_{FS} (T_x , T_y , T_z :10N·m) with the equation below.

$$E_{T:FS} = \frac{T_{mea} - T_{in}}{T_{FS}} \times 100[\% FS]$$

Table 7-5 shows the measurement uncertainty of the force sensor 9105-TWE-Gamma used in this measurement and the full-scale error of this measurement. These errors are indicators showing the linearity of the measurement.

Table 7-5 shows that the force measurement error is within $\pm 0.25\%$ FS, and the torque measurement error is within $\pm 1\%$ FS, indicating that these errors are within the measurement uncertainty of the force sensor used in this measurement. Though this result contains not only the error of the circuit and the nonlinearity of the force sensor itself, but also flexure or inclination of the evaluation jigs and the error caused by friction, it is confirmed that this system configuration allows the measurement of the force sensor.

Item	<i>E_{Fx:FS}</i> [%FS]	<i>E_{Fy:FS}</i> [%FS]	<i>E_{Fz:FS}</i> [%FS]	<i>E_{Tx:FS}</i> [%FS]	<i>Е_{Ту:FS}</i> [%FS]	E _{Tz:FS} [%FS]
9105-TWE-Gamma SI-130-10 Measurement uncertainty (95% CI)	1.00%	1.25%	0.75%	1.00%	1.25%	1.50%
Result of full-scale error measurement (Worst case)	0.13%	0.14%	0.07%	0.95%	0.68%	0.89%

Table 7-5 Measurement Uncertainty



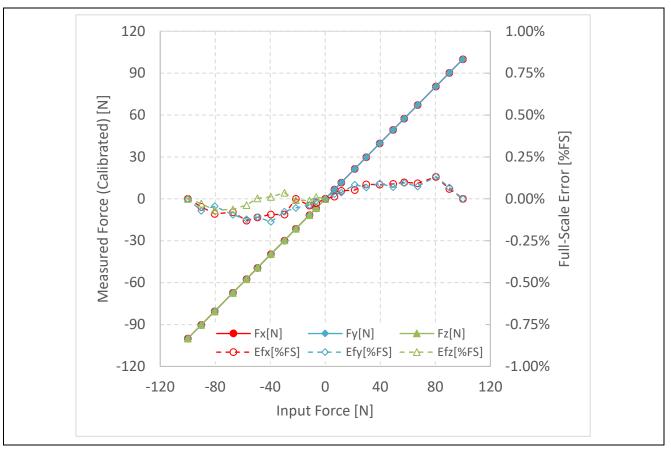


Figure 7-4 Force Measurement Result

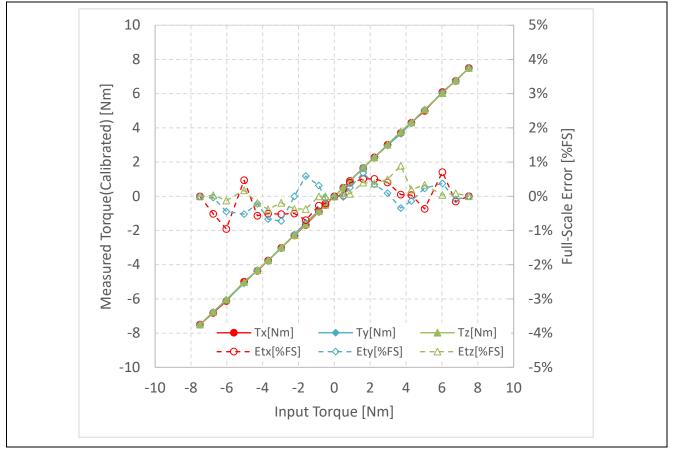


Figure 7-5 Torque Measurement Result



Revision History

		Description	
Rev.	Date	Page	Summary
Rev.1.00	Nov.15.21	-	-



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 is supplied until the 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.

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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