

## 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 <sub>Fx:FS</sub><br>[%FS] | E <sub>Fy:FS</sub><br>[%FS] | E <sub>Fz:FS</sub><br>[%FS] | <i>Е<sub>Тх:FS</sub></i><br>[%FS] | <i>Е<sub>Ту:FS</sub></i><br>[%FS] | <i>Е<sub>Тz:FS</sub></i><br>[%FS] |
|--|-----------------------------|-----------------------------|-----------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 9105-TWE-Gamma SI-130-10<br>Measurement uncertainty (95% CI) | 1.00%                       | 1.25%                       | 0.75%                       | 1.00%                             | 1.25%                             | 1.50%                             |
| Result of full-scale error measurement<br>(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 <sub>DR</sub> ) : 4MHz          |  |  |  |  |  |
|              | DSAD modulator clock frequency (f <sub>MOD</sub> ) : 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 <sup>2</sup> 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 <sub>PGA</sub>               | x8             |   |
| DSAD reference voltage V <sub>REF</sub> | 5V             | Applied voltage of the strain gauge<br>(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<sub>MOD</sub> = 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 <sub>MOD</sub> |
| 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<sub>n</sub>, 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<br>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 | <b>Functions</b> | to be | e Used |
|---|----------|--------------|------------------|-------|--------|
|---|----------|--------------|------------------|-------|--------|

| 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<br>timing                   | onversion end interrupt           | - When the average<br>selected number<br>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<br>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 |
|---------------------------------|----------------------|----------|
|---------------------------------|----------------------|----------|

| Procedure | Operation | Processing<br>location | Process   |
|-----------|-----------|------------------------|---|
| 1         | Press SW1 | SW1 control            | Turn on LED1  |
|           |           |                        | <ul> <li>Set DSAD for Zero-reset and start A/D conversion</li> </ul>      |
|           |           |                        | <ul> <li>Change the operating mode to ZERO-RESET</li> </ul>               |
| 2         | -         | Zero-reset             | Stop A/D conversion   |
|           |           | processing             | <ul> <li>Set the obtained the average of A/D conversion values</li> </ul> |
|           |           |                        | in register OFCRm of the corresponding channel.                           |
|           |           |                        | ・Turn off LED1  |
|           |           |                        | <ul> <li>Change the operating mode to IDLE</li> </ul>                     |



## 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   |  |  |
|                  | <ul> <li>Set DSAD for force sensor measurement and start A/D conversion</li> </ul> |  |  |
|                  | 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                                     |
| <sup>L</sup> 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 <sub>PGA</sub> [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<br>Description | _                   | MAC0_GetDestAde<br>lestination address |                  |                     |  |  |
|                     | _                   |  |                  | Description         |  |  |
| Description         | Get o               | lestination address                    | (macro function) | Description<br>-    |  |  |

#### 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<br>Description   |                                       | SAD1_IsScanEnd<br>rns whether auto sc  | an is in progress.                                       |                                 |  |  |
|   |                                       |  | an is in progress. Name                                  | Description                     |  |  |
| Description   | Retu                                  | rns whether auto so  |  | Description<br>-                |  |  |
| Description   | Retu                                  | rns whether auto so<br><b>Type</b>   |  | Description<br>-                |  |  |
| Description<br>Arguments  | Retu<br>I/O<br>-                      | rns whether auto so<br><b>Type</b><br>void   | Name   | Description<br>-                |  |  |
| Description<br>Arguments  | Retu<br>I/O<br>-<br>0                 | rns whether auto so<br><b>Type</b><br>void   | Name<br>-<br>false: Scanning<br>true: Scan end           | Description<br>-                |  |  |
| Description<br>Arguments<br>Return Value                        | Retu<br>I/O<br>-<br>0<br>R_D          | rns whether auto so<br><b>Type</b><br>void<br>bool                                     | Name<br>-<br>false: Scanning<br>true: Scan end           | Description<br>-                |  |  |
| Description<br>Arguments<br>Return Value<br>Name                | Retu<br>I/O<br>-<br>0<br>R_D          | rns whether auto so<br>Type<br>void<br>bool<br>SAD1_ClearScanE                         | Name<br>-<br>false: Scanning<br>true: Scan end           | Description<br>-<br>Description |  |  |
| Description<br>Arguments<br>Return Value<br>Name<br>Description | Retu<br>I/O<br>-<br>0<br>R_D<br>Clean | rns whether auto so<br><b>Type</b><br>void<br>bool<br>SAD1_ClearScanE<br>SCANEND1 flag | Name<br>-<br>false: Scanning<br>true: Scan end<br>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++<br>>>>> 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<br>V r01an3956,rxv2 (C-¥download¥an-r01an3956j0100-rxv2-dsp¥r01ar)<br>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<br>working sets] when using  |      |
| the working sets.   |      |
|   |      |
|   |      |
| ? < Back Next > Einish Cancel   |      |

Figure 6-1 Importing a Project into e<sup>2</sup> 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<br>PC tool | <ul> <li>-isa=rxv2 -include=".¥dsplib-rxv2"-utf8 -nomessage -debug -outcode=utf8</li> <li>-nologo</li> </ul>  |
|          | Supporting                | add to the above  |
|          | PC tool                   | -define=D_PC_TOOL_USE=1   |
| Linker   |                           | -library=".¥dsplib-rxv2¥RX_DSP_FPU_LE.lib" -noprelink<br>-output="rx23ea_force_sensor.abs" -form=absolute -nomessage<br>-vect=_undefined_interrupt_source_isr -list=rx23ea_force_sensor.map<br>-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<br>load [%] | Condition                                       |
|------------------------------|--|---------------------|---|
| Measurement •<br>Calculation | 568cycle<br>(17.75µsec)                    | 1.16                | Maximum cycles at operating mode<br>MEASUREMENT |
| Communication control        | 710cycle<br>(22.19µsec)                    | 1.44                | Maximum cycles at normal operation              |
| SW1 control                  | 307cycle<br>(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/s<sup>2</sup>] 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/s<sup>2</sup>], 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<br>10mg x1, 20mg x2, 50mg x1<br>100mg x1, 200mg x2, 500mg x1<br>1g x1, 2g x2, 5g x1<br>10g x1, 20g x2, 50g x1<br>100g x1, 200g x2, 500g x1<br>1kg x1 | M1    | AS ONE       |
| 2   | Cylindrical<br>Weight | SWM2000         | 2kg   | M1    | AS ONE       |
| 3   | Brass Plate           | INERTIAPLATE: C | 2.853kg <sup>Note</sup>   | -     | Renesas      |
| 4   | Brass Plate           | INERTIAPLATE: D | 4.6625kg <sup>Note</sup>  | -     | 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<sub>Fx:FS</sub></i><br>[%FS] | <i>E<sub>Fy:FS</sub></i><br>[%FS] | <i>E<sub>Fz:FS</sub></i><br>[%FS] | <i>E<sub>Tx:FS</sub></i><br>[%FS] | <i>Е<sub>Ту:FS</sub></i><br>[%FS] | E <sub>Tz:FS</sub><br>[%FS] |
|--|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------|
| 9105-TWE-Gamma SI-130-10<br>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

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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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