

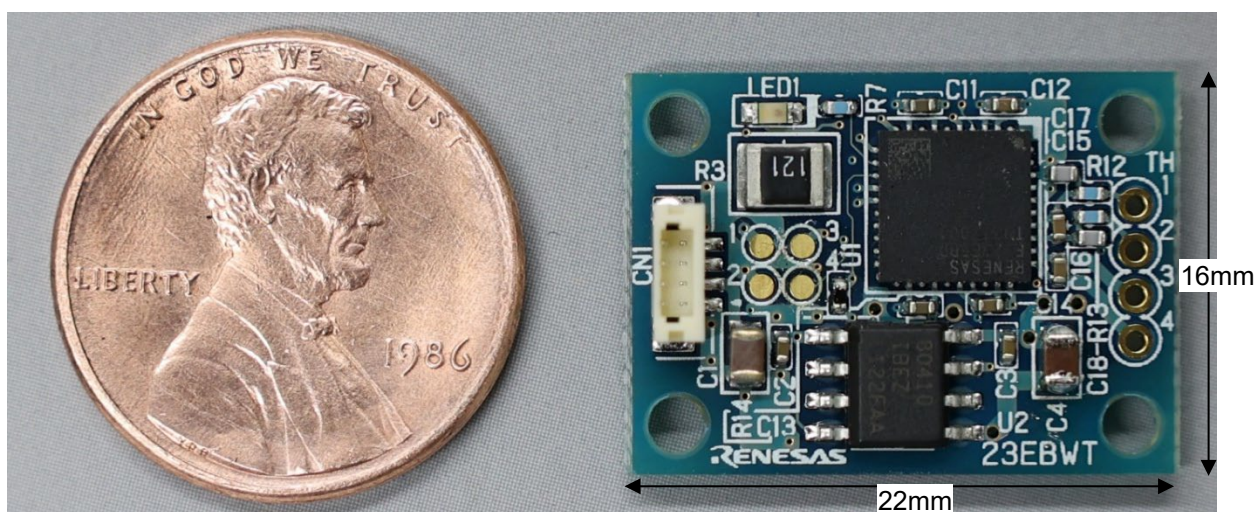
## RX23E-B Group

### Design and weight measurement of tiny board for digital load cell

#### Introduction

This document describes a weight measurement program example using the RX23E-B-QFN40-WT, which is a board for a digital load cell using Renesas MCU, RX23E-B, and a load cell.

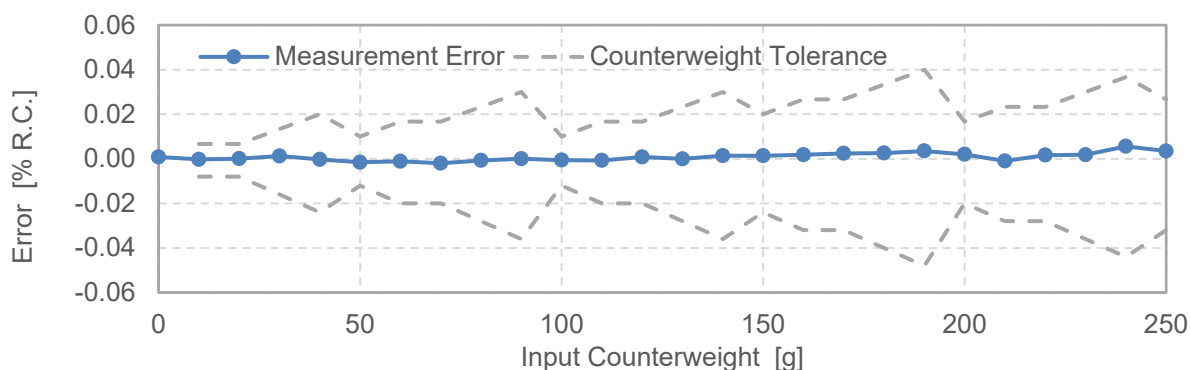
The RX23E-B-QFN40-WT is miniaturized to be incorporated into a digital load cell, using RX23E-B, MCU with AFE in 40 pin HWQFN package, LDO ISL80410 for power supply, and RAA788155 as RS-485 driver. Measurement results can be checked with QE for AFE or the Modbus RTU host program via RS-485, using the sample program running on this board.



Weight of counterweight was measured with a load cell, using this board and the sample program. The error of measured value was divided by load cell's rated capacity of 300g. The results are shown in figure below.

|                                 |                                                |
|---------------------------------|------------------------------------------------|
| Rated Capacity (R. C.):         | 300g                                           |
| Rated Output (R. O.):           | 0.9 mV/V $\pm 0.1$ mV/V                        |
| Non-linearity <sup>Note</sup> : | 0.015% R. O. or less                           |
| Equivalent input noise:         | 23.8nVrms (21.6 Bits): equivalent to 1.58mgrms |
| Peak-to-peak noise:             | 140nV (19.1 Bits): equivalent to 9.3mg         |

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



#### Device

RX23E-B (R5F523E6MDNF)

**Contents**

|                                                      |    |
|------------------------------------------------------|----|
| 1. Overview.....                                     | 4  |
| 2. Package Contents .....                            | 6  |
| 3. Environment for Operation Confirmation .....      | 6  |
| 4. Related Documents .....                           | 6  |
| 5. RX23E-B-QFN40-WT .....                            | 7  |
| 5.1 Board Specifications.....                        | 7  |
| 5.2 Circuit Diagram.....                             | 8  |
| 5.3 Bill of Materials .....                          | 9  |
| 5.4 Pattern Diagram (Viewed from the Part Side)..... | 10 |
| 6. Weight Measurement Method .....                   | 12 |
| 6.1 Load Cell .....                                  | 12 |
| 6.2 Weight Calculation Procedure.....                | 14 |
| 6.3 Calibration .....                                | 14 |
| 6.4 Zero Reset.....                                  | 14 |
| 7. Communication.....                                | 15 |
| 7.1 QE for AFE .....                                 | 15 |
| 7.2 Modbus RTU .....                                 | 15 |
| 7.2.1 Supported Frame Format.....                    | 16 |
| 7.2.2 Data .....                                     | 17 |
| 7.2.3 Operation.....                                 | 18 |
| 8. Sample Program.....                               | 19 |
| 8.1 Overview of Operation.....                       | 19 |
| 8.2 Peripheral Functions and Pins Used .....         | 22 |
| 8.2.1 Load Cell Measurement .....                    | 23 |
| 8.2.2 Communication .....                            | 24 |
| 8.2.3 LED.....                                       | 28 |
| 8.2.4 E2 Data Flash.....                             | 28 |
| 8.2.5 Voltage Detection Circuit (LVD) .....          | 28 |
| 8.3 Communication Control.....                       | 29 |
| 8.3.1 QE for AFE Communication .....                 | 29 |
| 8.3.2 Modbus RTU Communication .....                 | 30 |
| 8.3.2.1 Transmit/Receive Processing .....            | 30 |
| 8.3.2.2 Receive Frame Processing .....               | 33 |
| 8.4 Program Configuration .....                      | 35 |

## **RX23E-B Group    Design and weight measurement of tiny board for digital load cell**

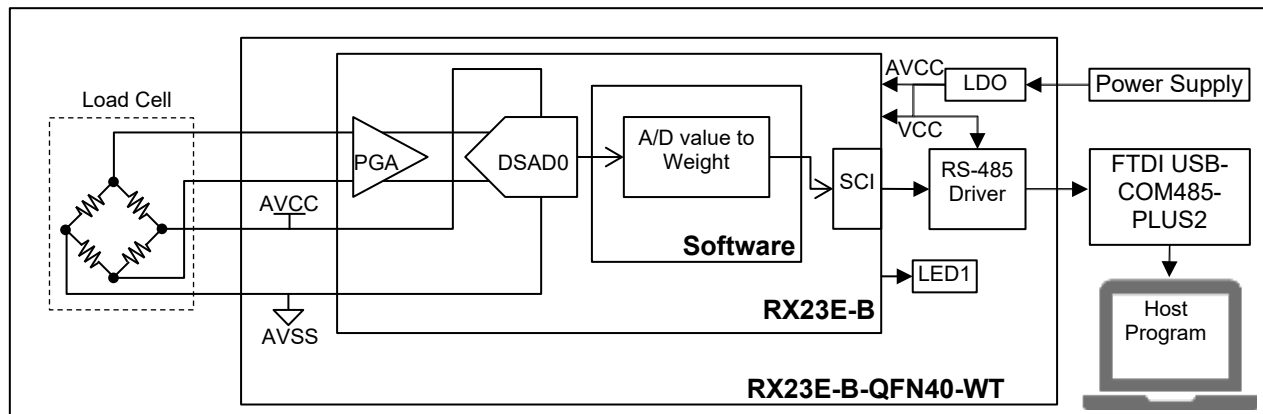
---

|         |                                                                       |    |
|---------|-----------------------------------------------------------------------|----|
| 8.4.1   | Source File Configuration .....                                       | 35 |
| 8.4.2   | Build Settings .....                                                  | 36 |
| 8.4.3   | Macro Definitions .....                                               | 37 |
| 8.4.4   | Structures, Unions, and Enumeration Types .....                       | 39 |
| 8.4.5   | Functions .....                                                       | 43 |
| 8.4.5.1 | Common Functions .....                                                | 43 |
| 8.4.5.2 | QE for AFE Version .....                                              | 49 |
| 8.4.5.3 | Modbus Version .....                                                  | 50 |
| 9.      | Importing a Project .....                                             | 53 |
| 9.1     | Importing a Project into e2 studio .....                              | 53 |
| 9.2     | Importing a Project into CS+ .....                                    | 54 |
| 10.     | Operation on the Renesas Solution Starter Kit for RX23E-B Board ..... | 55 |
| 11.     | Measurement Results with Sample Program .....                         | 57 |
| 11.1    | Memory Usage and Number of Execution Cycles .....                     | 57 |
| 11.1.1  | Build Conditions .....                                                | 57 |
| 11.1.2  | Memory Usage .....                                                    | 57 |
| 11.1.3  | Number of Execution Cycles .....                                      | 58 |
| 11.2    | Weight Measurement Accuracy Evaluation .....                          | 59 |
| 11.2.1  | Weight Measurement Accuracy Evaluation Conditions .....               | 59 |
| 11.2.2  | Weight Measurement Accuracy Evaluation Results .....                  | 61 |
| 11.3    | Resolution Evaluation .....                                           | 62 |
| 11.3.1  | Resolution Evaluation Conditions .....                                | 62 |
| 11.3.2  | Resolution Evaluation Results .....                                   | 63 |
|         | Revision History .....                                                | 64 |

## 1. Overview

This document describes a weight measurement example using the RX23E-B-QFN40-WT, which is a load cell tiny board containing RX23E-B, and a load cell. The sample program conducts weight measurement with a load cell, communicates with QE for AFE or Modbus host via an RS-485 half-duplex communication channel, and transmits measurement results.

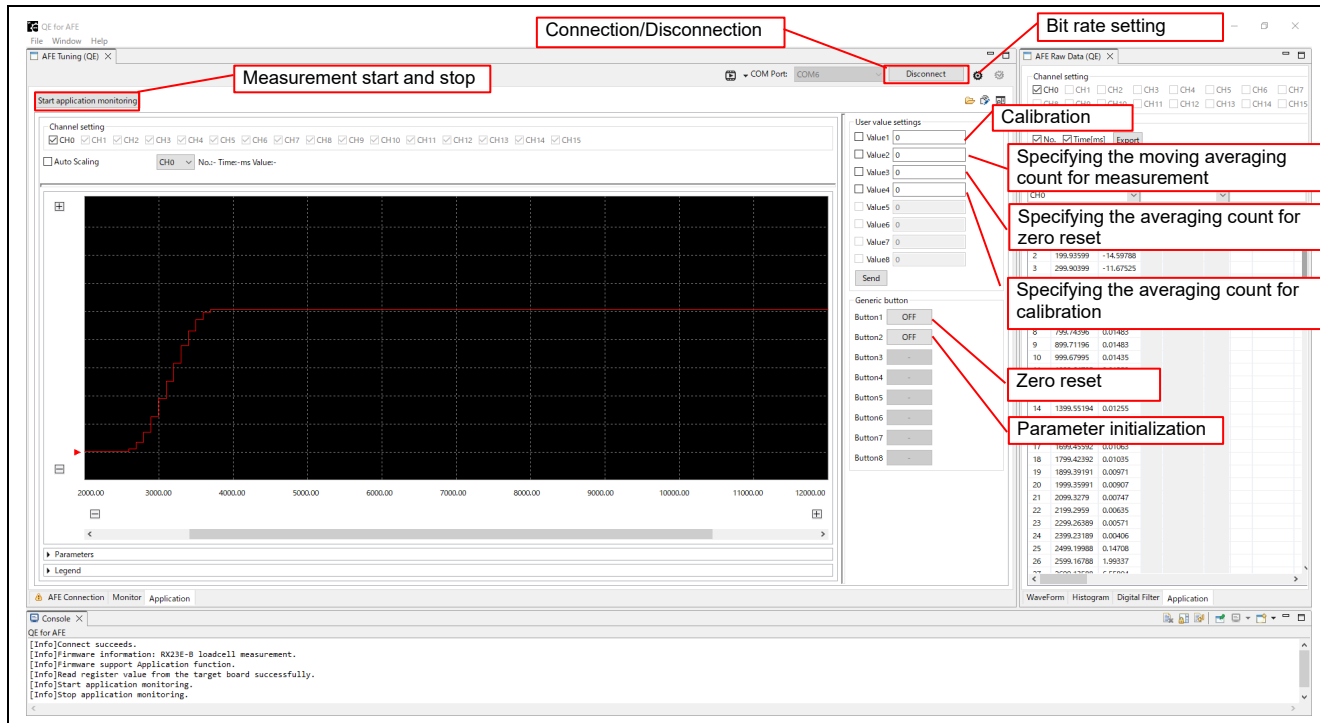
A diagram of the weight measurement system in this example is shown in Figure 1-1.



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

The QE for AFE version sample program in this example uses the Application tab screen of QE for AFE to make various settings, conduct measurements, and display measurement results. Some registers can be set on the AFE connection screen. Operable items are listed in Figure 1-2, Table 1-1, and Table 1-2.

The Modbus version sample program performs the same operations by making settings in Modbus Coil or Holding register listed in Table 7-6. For details, refer to "7.2.3 Operation".



**Figure 1-2 QE for AFE Application Tab Screen**

**Table 1-1 QE for AFE Operation Settings**

| Item                                                  | Operation                                                                                         | Supplement                                                                                                                                                      |
|-------------------------------------------------------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Connection                                            | Connection/disconnection button                                                                   |                                                                                                                                                                 |
| Measurement start and stop                            | Measurement start and stop button                                                                 | LED1 OFF during measurement                                                                                                                                     |
| Zero reset                                            | Button1                                                                                           | Enabled only during measurement                                                                                                                                 |
| Calibration                                           | Specify measured weight 1 in Value1<br>Specify measured weight 2 in Value1 while LED1 is blinking | Enabled while measurement is stopped<br>LED1 OFF during A/D conversion<br>LED1 blinks five times in case of abnormal termination.<br>refer to "6.3Calibration". |
| Specifying the moving averaging count for measurement | Value2: 1 to 128, default: 8                                                                      | Enabled only during standby (LED1 ON)                                                                                                                           |
| Specifying the averaging count for zero reset         | Value3: 1 to 512, default: 256                                                                    |                                                                                                                                                                 |
| Specifying the averaging count for calibration        | Value4: 64 to 512, default: 256                                                                   |                                                                                                                                                                 |
| Parameter initialization                              | Button2                                                                                           |                                                                                                                                                                 |

Note: Set the communication rate for QE for AFE to the communication rate in "Table 7-1 Communication Conditions".

Since QE for AFE is based on full-duplex communication, transmission and reception may conflict and stop on stop measurement. If it stops, turn on the power to the board again.

**Table 1-2 QE for AFE Register Setting Changeable Items**

| Item                           | Operation                           | Supplement                                                                                                                      |
|--------------------------------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| PGA gain                       | Change the PGA gain setting for CH0 |                                                                                                                                 |
| Oversampling ratio             | Change the OSR1 and OSR2 for CH0    | The lower limit of oversampling ratio setting is OSR1=256 and OSR2=2. If it is lower than this, communication error will occur. |
| Digital filter selection       | Change the Sinc Filter for CH0      |                                                                                                                                 |
| Digital filter gain correction | Change the SGCR for CH0             | QE for AFE calculates according to the values of OSR0 and OSR1.                                                                 |

Parameters listed in Table 1-3 maintain their changes using the E2 data flash. For details, refer to structure st\_prm\_t in Table 8-28.

**Table 1-3 Retention Parameters**

| Item                                   | Number of items/sets that can be stored |
|----------------------------------------|-----------------------------------------|
| Weight conversion coefficients         | 1 set                                   |
| Moving averaging count for measurement | 1                                       |
| Averaging count for zero reset         | 1                                       |
| CR0.GAIN register value                | 1                                       |
| MR0.FSEL register value                | 1                                       |
| OSR0 register value                    | 1                                       |
| SGCR0 register value                   | 1                                       |
| Averaging count for calibration        | 1                                       |

## 2. Package Contents

**Table 2-1 Package Contents**

| File/folder name            | Description                                            |
|-----------------------------|--------------------------------------------------------|
| r01an6512jj0100-rx23e-b.pdf | This document (Japanese)                               |
| r01an6512ej0100-rx23e-b.pdf | This document (English)                                |
| BoardData                   | Board data of RX23E-B-QFN40-WT                         |
| rx23eb_loadcell_qe_rssk.mot | QE for AFE version program binary file for RSSKRX23E-B |
| rx23eb_loadcell_qe          | QE for AFE version sample project set                  |
| rx23eb_loadcell_modbus      | Modbus version sample project set                      |
| readme_j.txt                | Package explanation (Japanese)                         |
| readme_e.txt                | Package explanation (English)                          |

## 3. Environment for Operation Confirmation

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

**Table 3-1 Environment for Operation Confirmation**

| Item                                               | Description                                                                                                                                                                                                                                                   |
|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Board                                              | RX23E-B-QFN40-WT                                                                                                                                                                                                                                              |
| MCU                                                | RX23E-B (R5F523E6MDNF)<br>Power voltage (VCC, AVCC0): 5V<br>Operating frequency (ICLK): 32MHz<br>Peripheral operating frequency (PCKKB, PCLKC): 32MHz<br>DSAD0 operating frequency ( $f_{OP}$ ): 16MHz<br>DSAD0 modulator clock frequency ( $f_{MOD}$ ): 4MHz |
| Load cell                                          | Minebea Mitsumi Inc. BCL-300GM-C3                                                                                                                                                                                                                             |
| RS485-USB I/F                                      | FTDI USB-COM485-PLUS2                                                                                                                                                                                                                                         |
| Host                                               | QE for AFE version                                                                                                                                                                                                                                            |
|                                                    | Modbus version                                                                                                                                                                                                                                                |
| Renesas QE for AFE V2.1.1<br>QModMaster 0.5.3-beta |                                                                                                                                                                                                                                                               |
| IDE                                                | Renesas e <sup>2</sup> Studio 2023-04<br>Renesas Smart Configurator V23.4.0                                                                                                                                                                                   |
| Tool Chain                                         | Renesas CC-RX V3.5.0                                                                                                                                                                                                                                          |
| Emulator                                           | E2 Emulator Lite                                                                                                                                                                                                                                              |

## 4. Related Documents

- R01UH0972 RX23E-B Group User's Manual: Hardware
- R01AN6364 RX23E-B Group RSSKRX23E-B Board Control Program
- R12UZ0108 RSSKRX23E-B User's Manual

## 5. RX23E-B-QFN40-WT

### 5.1 Board Specifications

Table 5-1 RX23E-B-QFN40-WT Specifications

| Item                | Description                                                                                           |
|---------------------|-------------------------------------------------------------------------------------------------------|
| MCU                 | R5F523E6MDNF, or R5F523E6MGNF <small>Note</small>                                                     |
| External dimensions | 22mm x 16mm                                                                                           |
| Layer structure     | 4 layers, Laminating order: Signal - GND - Power supply - Signal                                      |
| Operating voltage   | Recommended operating voltage: 6 to 12.6V<br>Maximum operating voltage: 14V                           |
| Current consumption | Typ. 44mA (When connecting to 350Ω load cell, during measurement)                                     |
| Communication I/F   | RS-485, Half-duplex communication<br>Maximum communication speed: 1Mbps<br>Terminating resistor: 120Ω |
| Compatible emulator | Renesas E2 Emulator, E2 Emulator Lite                                                                 |

Note: Either one is mounted. The mounted MCU cannot be specified.

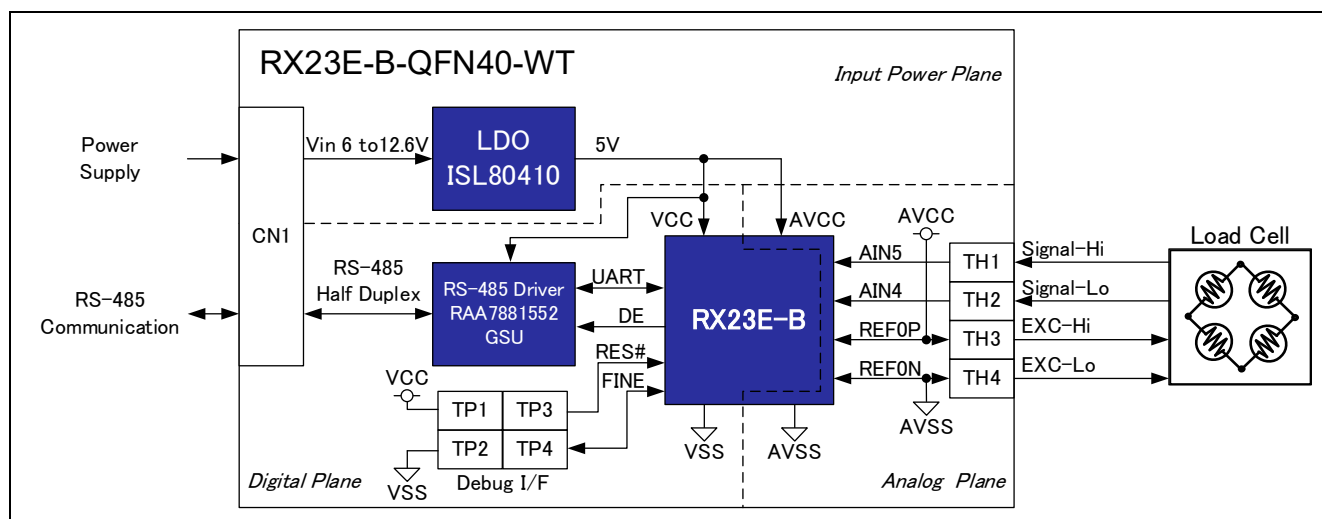


Figure 5-1 System Configuration Diagram



## 5.2 Circuit Diagram

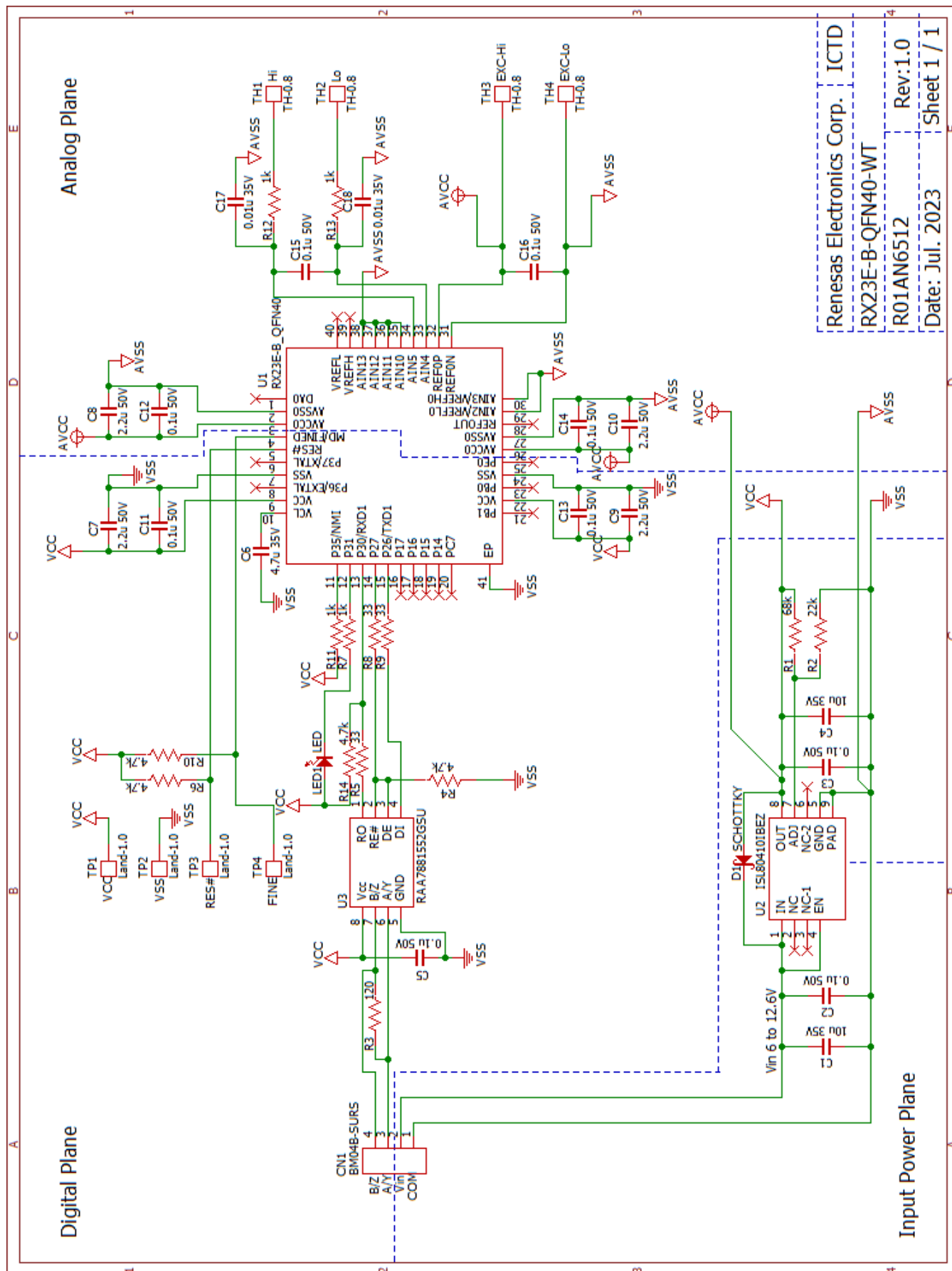


Figure 5-2 RX23E-B-QFN40-WT Circuit Diagram



**5.3 Bill of Materials**

| No. | Q'ty | Reference Designator                    | Description   | Part Name | Manufacturer Part Name | Maker Name |
|-----|------|-----------------------------------------|---------------|-----------|------------------------|------------|
| 1   | 1    | U1                                      | RX23E-B       | IC        | R5F523E6MDNF           | Renesas    |
| 2   | 1    | U2                                      | LDO           | IC        | ISL80410IBEZ           | Renesas    |
| 3   | 1    | U3                                      | RS-485 Driver | IC        | RAA788155GSU           | Renesas    |
| 4   | 1    | CN1                                     | 4pin          | Connector | BM04B-SURS-TF(LF)(SN)  | JST        |
| 5   | 2    | C1,C4                                   | 10u 35V       | Capacitor | GRM21BR6YA106KE43      | Murata     |
| 6   | 9    | C2,C3,C5,C11<br>C12,C13,C14,<br>C15,C16 | 0.1u 50V      | Capacitor | GRM155R71H104KE14      | Murata     |
| 7   | 1    | C6                                      | 4.7u 35V      | Capacitor | GRM219R6YA475KA73      | Murata     |
| 8   | 4    | C7,C8,C9,C10                            | 2.2u 50V      | Capacitor | GRM188R61H225KE11      | Murata     |
| 9   | 2    | C17,C18                                 | 0.01u 35V     | Capacitor | GRM1555CYA103GE01      | Murata     |
| 10  | 1    | D1                                      | SCHOTTKY      | Diode     | RB551VM-30TE-17        | Rohm       |
| 11  | 1    | LED1                                    | Green         | LED       | SML-D13FWT86           | Rohm       |
| 12  | 1    | R1                                      | 68k 1%        | Resistor  | RK73H1ETTP6802F        | KOA        |
| 13  | 1    | R2                                      | 22k 1%        | Resistor  | RK73H1ETTP2202F        | KOA        |
| 14  | 1    | R3                                      | 120 5%        | Resistor  | RK73B2ETTD121J         | KOA        |
| 15  | 4    | R4,R6,R10,R14                           | 4.7k 5%       | Resistor  | RK73B1ETTP472J         | KOA        |
| 16  | 3    | R5,R8,R9                                | 33 5%         | Resistor  | RK73B1ETTP330J         | KOA        |
| 17  | 4    | R7,R11,R12,<br>R13                      | 1k 1%         | Resistor  | RK73H1ETTP1001F        | KOA        |

Note: This list may be changed without notice.

#### 5.4 Pattern Diagram (Viewed from the Part Side)

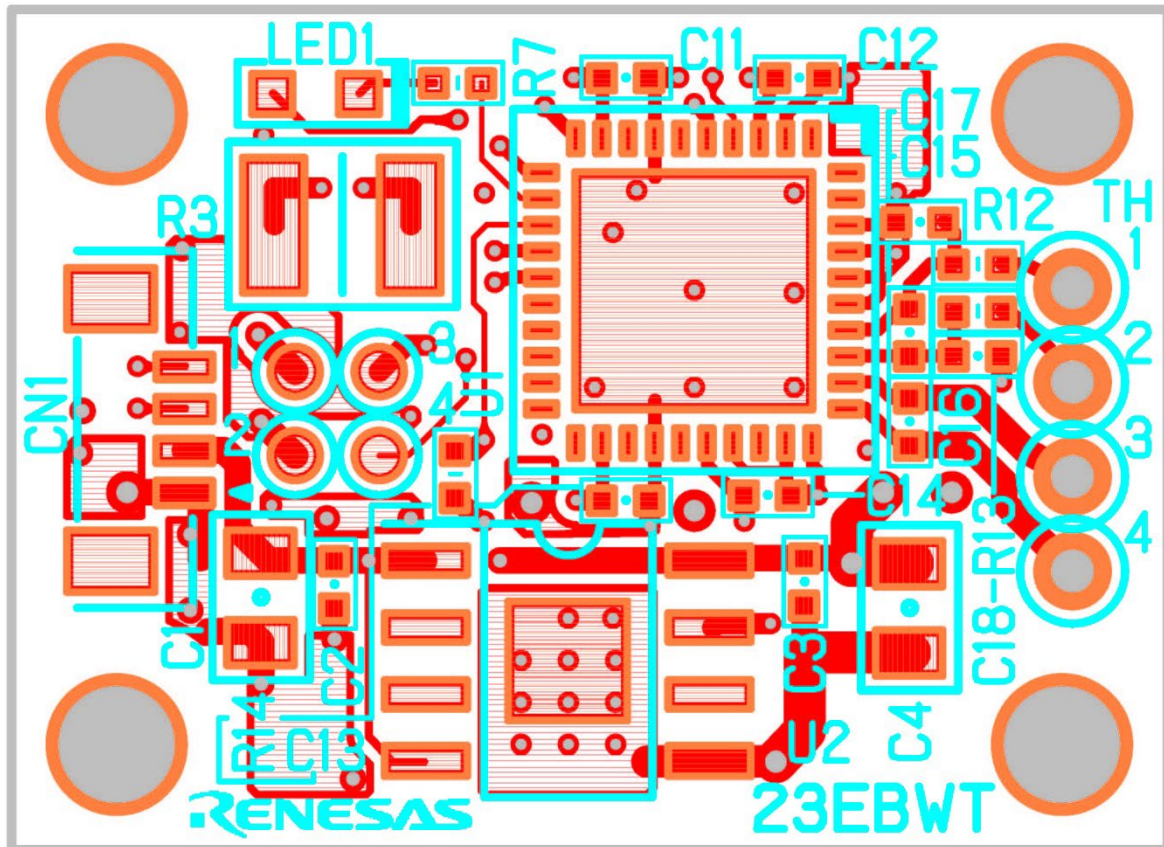


Figure 5-3 Layer 1

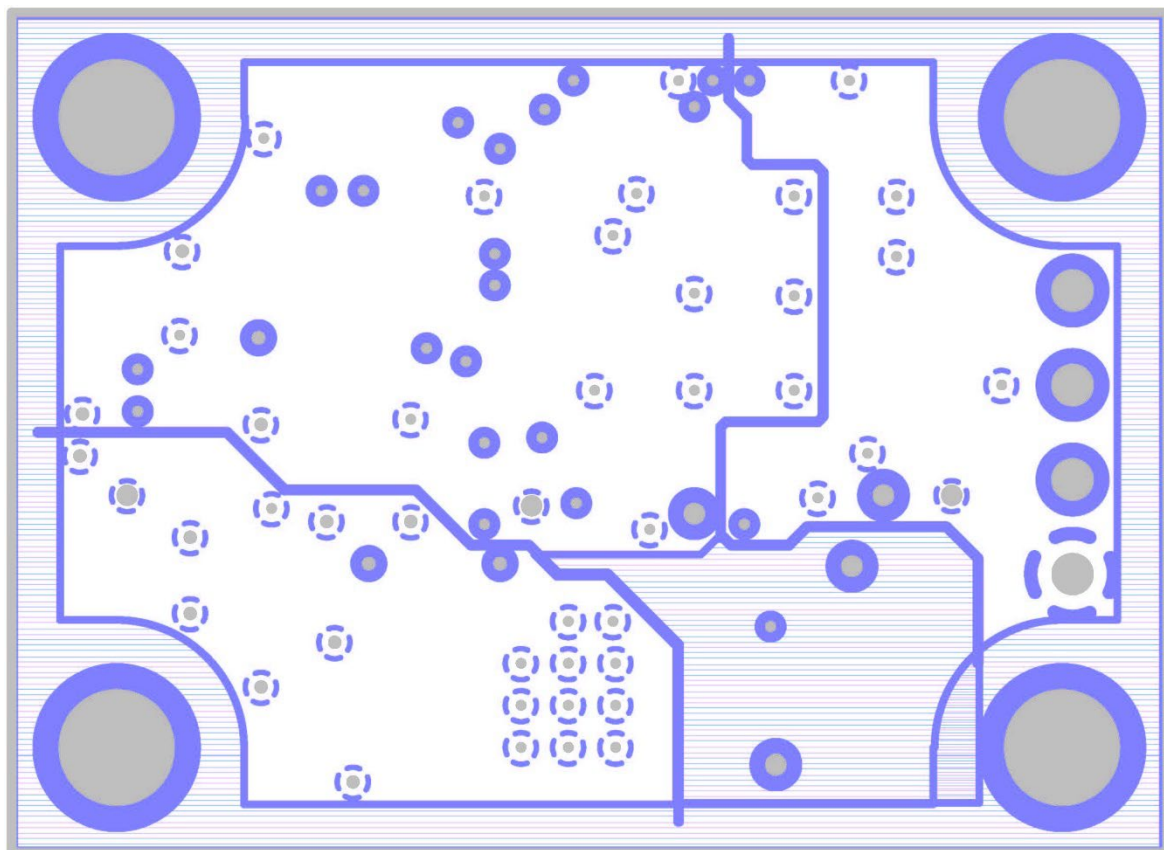
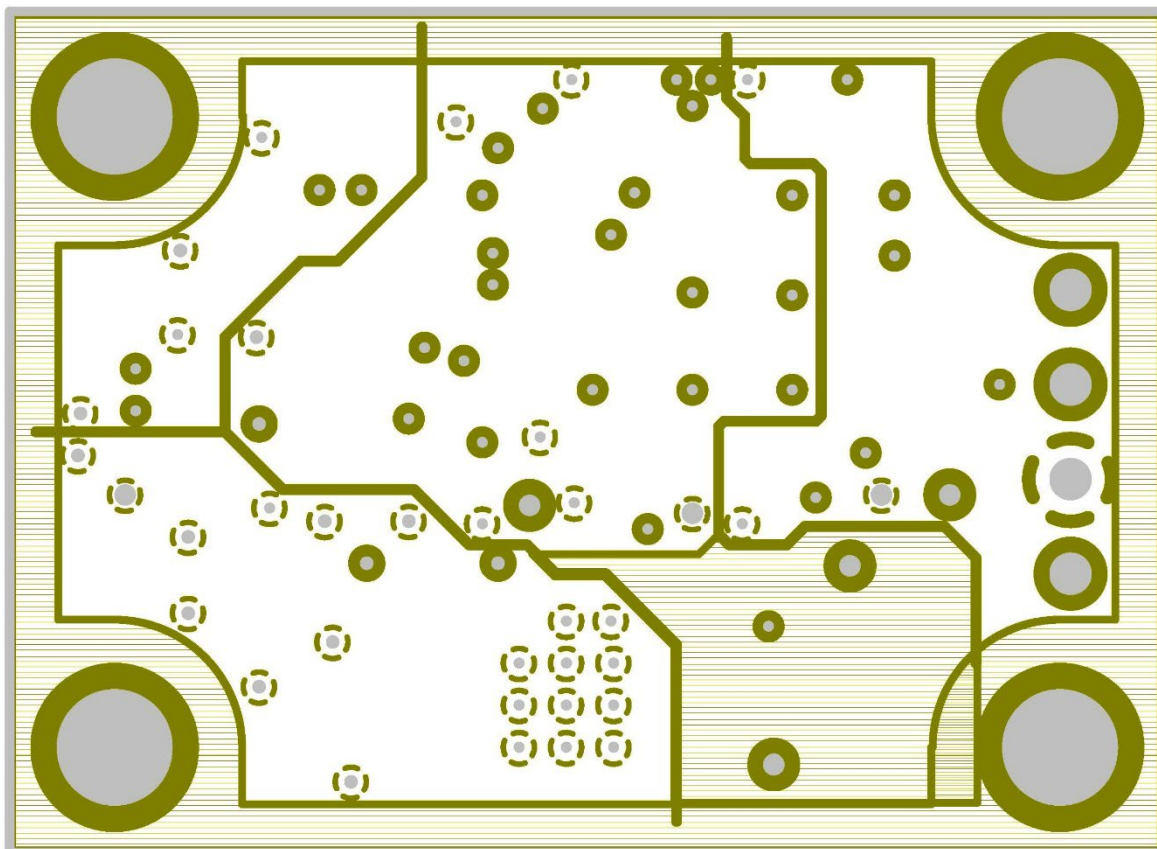
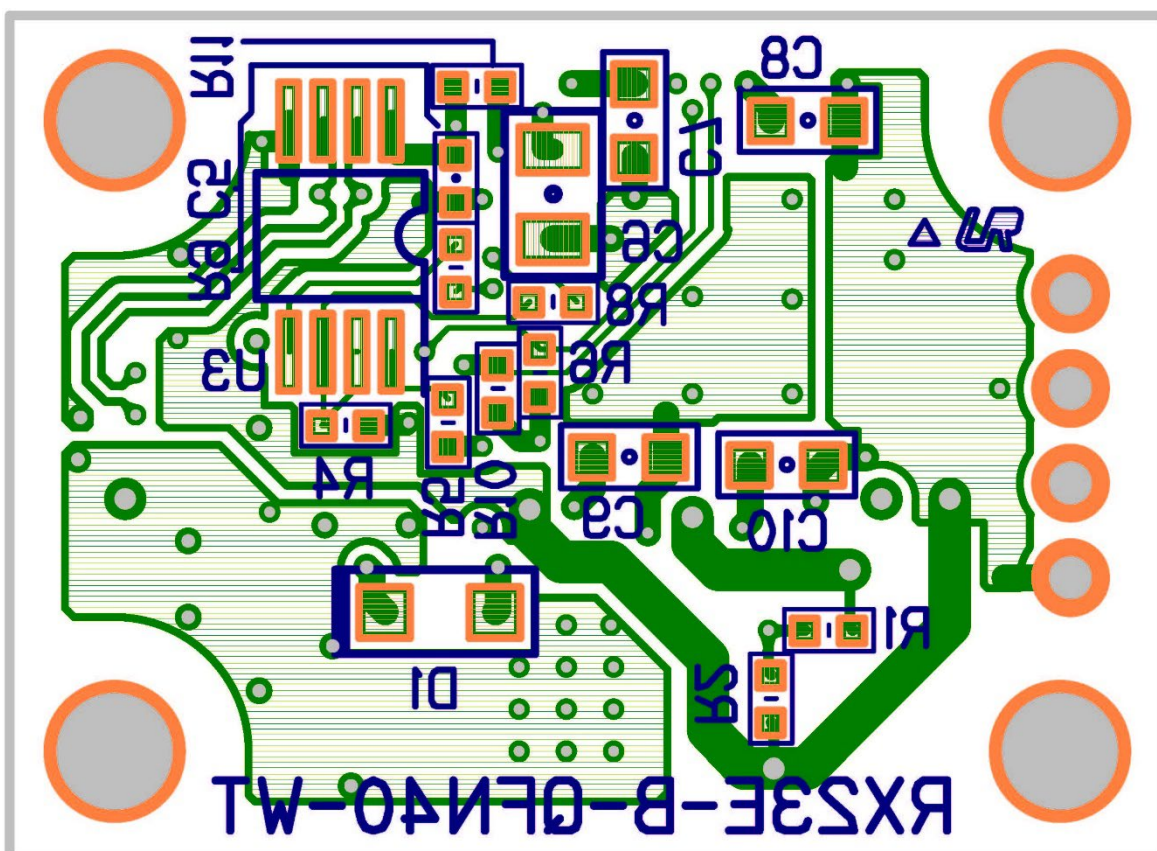


Figure 5-4 Layer 2



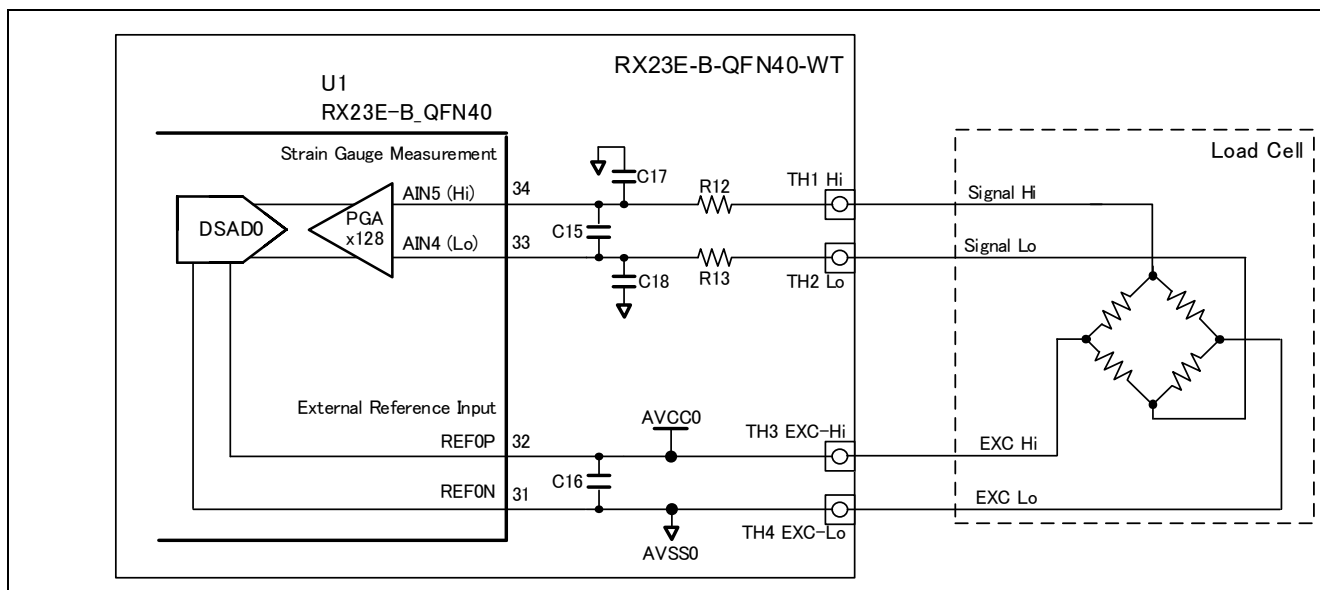
### Figure 5-5 Layer 3



### Figure 5-6 Layer 4

## 6. Weight Measurement Method

Connection between RX23E-B-QFN40-WT and load cell is shown in Figure 6-1.



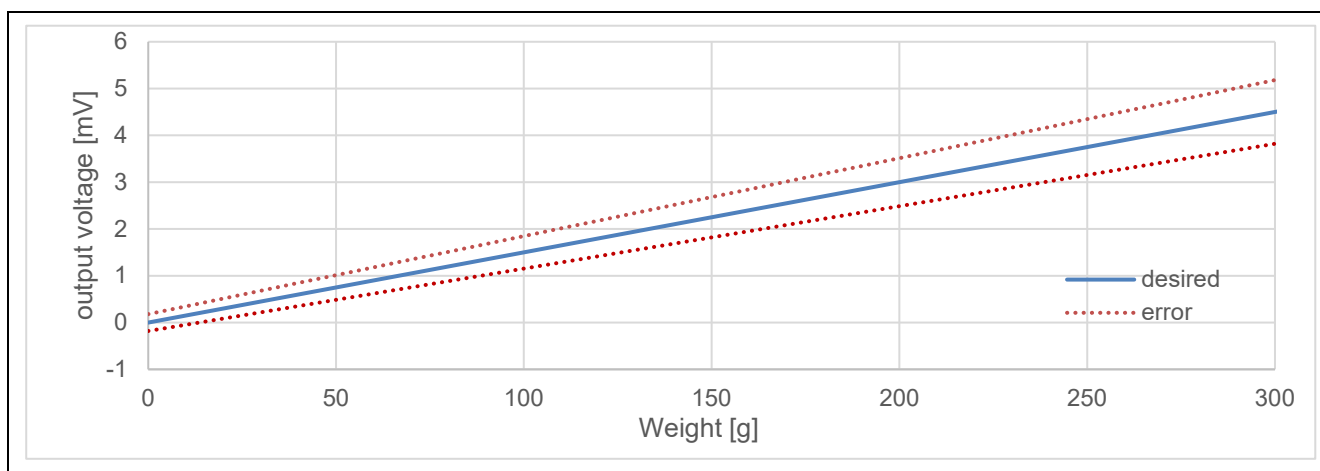
**Figure 6-1 Connection between RX23E-B-QFN40-WT and Load Cell**

### 6.1 Load Cell

The load cell used in this example outputs a weight as a voltage by using a Wheatstone bridge circuit. Table 6-1 shows an excerpt of the specifications of the load cell used, and Figure 6-2 shows the weight vs. output voltage characteristics obtained from the specifications for an applied voltage of 5V and the weight vs. output voltage characteristics including the error range of the rated output.

**Table 6-1 Excerpt of Specifications of Load Cell BCL-300GM-C3 (Minebea Mitsumi Inc.)**

| Item                   | Value         |
|------------------------|---------------|
| Recommended Excitation | 10V or less   |
| Maximum Excitation     | 15V           |
| Rated Capacity         | 300g          |
| Rated Output           | 0.9 ±0.1 mV/V |
| Zero Balance           | ±0.04 mV/V    |



**Figure 6-2 Weight vs. Output Voltage Characteristics of BCL-300GM-C3 (Applied Voltage 5V)**



## RX23E-B Group    Design and weight measurement of tiny board for digital load cell

In this example, the voltage between the output pins of the load cell is A/D converted with the voltage supplied to the load cell as the reference voltage as shown in Figure 6-1.

If the output voltage of the load cell is non-linear in relation to the weight, the characteristic curve is divided into multiple regions and linear approximation, for example, is performed in each of the regions to increase the measurement accuracy, thereby matching the characteristic curve.

In this example, the region is regarded as a single linear characteristic without being divided, and the voltage is converted to weight with linear interpolation.

Assuming that the voltage applied to the load cell is  $V_{cc}$ , the rated output is  $RO$ , and the rated load is  $M_{max}$ , the output voltage  $V$  for the weight  $M$  can be expressed with the formula below.

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

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

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

For the output voltage of the load cell, an error occurs due to the rated output, zero balance, and so on. Thus, the coefficients  $\alpha$  and  $\beta$  in the equation above are corrected with calibration.

Table 6-2 shows the measurement conditions. If the oversampling ratio is not a power of two, the digital filter of the DSAD0 generates a gain of x1/2 to x1. The Sinc filter gain correction value is set so that the gain of the digital filter will become 1.

**Table 6-2 Load Cell Measurement Conditions**

| Item                              | Condition      | Remarks                                                         |
|-----------------------------------|----------------|-----------------------------------------------------------------|
| PGA gain $G_{PGA}$                | x128           |                                                                 |
| DSAD0 reference voltage $V_{REF}$ | 5V             | Voltage applied to the load cell.<br>(REF0P=AVCC0, REF0N=ACSS0) |
| Oversampling ratio OSR            | 399872         | A/D conversion value output rate: Approx. 10SPS                 |
| Sinc filter gain correction value | 1.477629984615 | 1/G <sub>DF</sub>                                               |
| DSAD0 output format               | 2's Complement |                                                                 |

## 6.2 Weight Calculation Procedure

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

(1) Smoothing of the A/D conversion value

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

(2) Weight conversion

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

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

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

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

## 6.3 Calibration

To improve the measurement accuracy for the error in the load cell, coefficients  $a$  and  $b$  in the formula to convert A/D conversion values to weight can be calibrated.

This process is carried out using two reference weights, such as counterweights and their corresponding A/D conversion values, as follows:

- (1) Obtain the A/D conversion value,  $DATA_1$ , for weight  $M_1$  using the first reference weight
- (2) Obtain the A/D conversion value,  $DATA_2$ , for weight  $M_2$  using the second reference weight
- (3) Calculate the coefficients  $a$  and  $b$  of the line passing through  $(DATA_1, M_1)$  and  $(DATA_2, M_2)$  with the formula below and apply them

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

## 6.4 Zero Reset

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

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

## 7. Communication

Communication is conducted as RS-485, half-duplex communication. This program uses QE for AFE or Modbus RTU as the communication protocol. Table 7-1 lists the communication conditions for each communication protocol.

**Table 7-1 Communication Conditions**

| Item                | QE for AFE    | Modbus RTU  |
|---------------------|---------------|-------------|
| Communication speed | 1,000,000 bps | 115,200 bps |
| Data length         | 8 bits        |             |
| Start bit           | 1 bit         |             |
| Parity              | None          | Even parity |
| Stop bit            | 1 bit         |             |

### 7.1 QE for AFE

For details about the QE for AFE communication specifications, refer to the Application Note "RX23E-B Group RSSKRX23E-B Board Control Program".

Note: Since QE for AFE is based on full-duplex communication, transmission and reception may conflict and stop on stop measurement.

### 7.2 Modbus RTU

Operation setting and measurement result acquisition are performed with Modbus RTU communication. For details of Modbus RTU, refer to the Modbus official site (<https://modbus.org/specs.php>).

In this example, communication is conducted under the conditions listed in Table 7-2.

**Table 7-2 Modbus RTU Communication Conditions**

| Item                           | Condition                                                                                                                                                                                                   |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Slave address                  | H'01                                                                                                                                                                                                        |
| Silent interval                | (3.5 bytes or more)                                                                                                                                                                                         |
| Maximum receive byte interval  | (3 byte)                                                                                                                                                                                                    |
| Maximum transmit byte interval | (2 byte)                                                                                                                                                                                                    |
| Response time                  | 1ms or less                                                                                                                                                                                                 |
| Maximum frame length           | 256 byte                                                                                                                                                                                                    |
| Supported Query functions      | H'01: Read Coil<br>H'02: Read Status<br>H'03: Read Holding Register<br>H'04: Read Input Register<br>H'05: Write Single Coil<br>H'06: Write Single Holding Register<br>H'10: Write Multiple Holding Register |
| Supported Exception codes      | H'01: Illegal function<br>H'02: Illegal data address<br>H'03: Illegal data<br>H'04: Device Failure<br>H'05: Acknowledge<br>H'06: Device Busy                                                                |



**7.2.1 Supported Frame Format**

The message frame format is shown in Table 7-3. The function codes used in this example and the data format for each function are listed in Table 7-4, and the storage order for data of single precision floating point type is shown in Table 7-5.

**Table 7-3 Message Frame for Modbus RTU**

| Address | Function | Data   | CRC     |
|---------|----------|--------|---------|
| 1 byte  | 1 byte   | N byte | 2 bytes |

**Table 7-4 Supported Function Code and Description of Data**

| Supported Function Code                                          | Type     | Bytes of Data           | Data                                                                                                                                                           |       |                     |       |            |       |       |                |                       |  |
|------------------------------------------------------------------|----------|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------|-------|------------|-------|-------|----------------|-----------------------|--|
|                                                                  |          |                         | +0                                                                                                                                                             | +1    | +2                  | +3    | +4         | +5    | +6    | +2m-1<br>+2k+3 | +2m<br>+2k+4          |  |
| Read Coil (H'01)<br>Read Input Status (H'02)                     | query    | 4                       | Start Address                                                                                                                                                  |       | Num of read (M)     |       |            |       |       |                |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Lower | Upper               | Lower |            |       |       |                |                       |  |
|                                                                  | response | 1+<br>Round up of (M/8) | Data bytes                                                                                                                                                     | Data1 | Data2               |       |            |       |       |                | Data (roundup of M/8) |  |
| Read Holding Register (H'03)<br>Read Input Register (H'04)       | query    | 4                       | Start Address                                                                                                                                                  |       | Num of read (m)     |       |            |       |       |                |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Lower | Upper               | Lower |            |       |       |                |                       |  |
|                                                                  | response | 1+2m                    | Data bytes                                                                                                                                                     | Data1 |                     |       |            |       |       | Data m         |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Lower |                     |       |            |       |       | Upper          | Lower                 |  |
| Write Single Coil (H'05)<br>Write Single Holding Register (H'06) | query    | 4                       | Address                                                                                                                                                        |       | Data                |       |            |       |       |                |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Lower | Upper               | Lower |            |       |       |                |                       |  |
|                                                                  | response | 4                       | Address                                                                                                                                                        |       | Data                |       |            |       |       |                |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Upper | Upper               | Lower |            |       |       |                |                       |  |
| Write Multiple Holding Registers (H'10)                          | query    | 5+2k                    | Start Address                                                                                                                                                  |       | Num of Register (k) |       | Data bytes | data1 |       | data k         |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Lower | Upper               | Lower |            | Upper | Lower | Upper          | Lower                 |  |
|                                                                  | response | 4                       | Start Address                                                                                                                                                  |       | Num of Register (m) |       |            |       |       |                |                       |  |
|                                                                  |          |                         | Upper                                                                                                                                                          | Lower | Upper               | Lower |            |       |       |                |                       |  |
| exception                                                        | response | 1                       | Exception Code<br>H'01: Illegal function<br>H'02: Illegal data address<br>H'03: Illegal data<br>H'04: Device Failure<br>H'05: Acknowledge<br>H'06: Device Busy |       |                     |       |            |       |       |                |                       |  |

**Table 7-5 Single Precision Floating Data Format**

| bit        | 31          | 30       | 24 | 23         | 22       | 16 | 15          | 8 | 7          | 0 |
|------------|-------------|----------|----|------------|----------|----|-------------|---|------------|---|
| Allocation | sign        | exponent |    |            | fraction |    |             |   |            |   |
|            | Upper byte  |          |    | Lower byte |          |    | Upper byte  |   | Lower byte |   |
|            | Upper 16bit |          |    |            |          |    | Lower 16bit |   |            |   |

**7.2.2 Data**

The data used in this example and their arrangement are shown in Table 7-6.

**Table 7-6 Data List**

| Function         | Address | Size  | Format | Name                       | Description                                                                                               |
|------------------|---------|-------|--------|----------------------------|-----------------------------------------------------------------------------------------------------------|
| Coil             | 0       | 2byte | uint32 | Measurement                | Weight measurement<br>H'0000: Stop (default)<br>H'FF00: Measurement                                       |
|                  | 1       |       |        | Calibration Step1          | Calibration 1<br>H'0000: End/stop (default)<br>H'FF00: Start                                              |
|                  | 2       |       |        | Calibration Step2          | Calibration 2<br>H'0000: End/stop (default)<br>H'FF00: Start                                              |
|                  | 3       |       |        | Zero Reset                 | Zero reset during weight measurement<br>H'0000: End/stop (default)<br>H'FF00: Processing start            |
|                  | 4       |       |        | Parameter Reset            | Set the Holding Register value to the initial value.<br>H'0000: End/stop (default)<br>H'FF00: Reset start |
| Input Status     | 0       | 2byte | uint32 | DSAD0 OVf                  | Error/Overflow flag during DSAD0 operation                                                                |
|                  | 1       |       |        | DSAD0 ERR                  |                                                                                                           |
|                  | 2       |       |        | Calibration 1 end          | Calibration 1 end notification                                                                            |
| Input Register   | 0       | 4byte | float  | Weight                     | Measured weight                                                                                           |
|                  | 2       | 4byte | int32  | A/D Value                  | A/D conversion value                                                                                      |
| Holding Register | 0       | 4byte | float  | Zero Weight                | Zero reset correction weight                                                                              |
|                  | 2       | 4byte | float  | Calibration Weight 1       | Specified weight for calibration 1                                                                        |
|                  | 4       | 4byte | float  | Calibration Weight 2       | Specified weight for calibration 2                                                                        |
|                  | 6       | 4byte | float  | Calibration1 Delay         | Wait time [s] before starting Calibration 1                                                               |
|                  | 8       | 4byte | float  | Coefficient a              | Weight conversion coefficient a                                                                           |
|                  | 10      | 4byte | float  | Coefficient b              | Weight conversion coefficient b                                                                           |
|                  | 12      | 2byte | uint16 | Num of Moving Average      | Moving averaging count for weight measurement                                                             |
|                  | 13      | 2byte | uint16 | Num of Zero Reset Average  | Averaging count for zero reset processing                                                                 |
|                  | 14      | 2byte | uint16 | PGA Gain                   | DSAD0 CR0.GAIN register setting value                                                                     |
|                  | 15      | 2byte | uint16 | FSEL                       | DSAD0 MR0.FSEL register setting value                                                                     |
|                  | 16      | 4byte | uint32 | OSR                        | DSAD0 OSR0 register setting value                                                                         |
|                  | 18      | 4byte | uint32 | SGCR                       | DSAD0 SGCR0 register setting value                                                                        |
|                  | 20      | 2byte | uint16 | Num of Calibration Average | A/D conversion value averaging count for calibration                                                      |

### 7.2.3 Operation

Operation via Modbus equivalent to "Table 1-1 QE for AFE " is shown in Table 7-7.

**Table 7-7 Items Operable via Modbus**

| Item                                                  | Operation                                                                                                                                                  | Remarks                                                                                                                                                             |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Measurement start and stop                            | Operate Coil:0                                                                                                                                             | LED1 is OFF during measurement                                                                                                                                      |
| Zero reset                                            | Set Coil:3                                                                                                                                                 | Enabled only during measurement                                                                                                                                     |
| Calibration                                           | STEP1<br>Set measured weight 1 in HoldingReg:2-3 and set Coil:1<br>STEP2<br>While LED1 is blinking, set measured weight 2 in HoldingReg:4-5 and set Coil:2 | Enabled while measurement is stopped<br>LED1 is OFF during A/D conversion<br>LED1 blinks five times in case of abnormal termination.<br>Refer to "6.3 Calibration". |
| Specifying the moving averaging count for measurement | Set 1 to 128 in HoldingReg:10, default: 8                                                                                                                  | Enabled only during standby (LED1 is ON)                                                                                                                            |
| Specifying the averaging count for zero reset         | Set 1 to 512 in HoldingReg:11, default: 256                                                                                                                |                                                                                                                                                                     |
| Specifying the averaging count for calibration        | Set 64 to 512 in HoldingReg:18, default: 256                                                                                                               |                                                                                                                                                                     |
| Parameter initialization                              | Set Coil:4                                                                                                                                                 |                                                                                                                                                                     |

**Table 7-8 DSAD0/AFE Register Setting Changeable Items**

| Item                           | Operation                                       | Remarks                                                                                                                         |
|--------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| PGA gain                       | Specify CR0.GAIN setting value in HoldingReg:14 |                                                                                                                                 |
| Oversampling ratio             | Specify OSR0 setting value in HoldingReg:16-17  | The lower limit of oversampling ratio setting is OSR1=256 and OSR2=2. If it is lower than this, communication error will occur. |
| Digital filter selection       | Specify MR0.FSEL setting value in HoldingReg:15 |                                                                                                                                 |
| Digital filter gain correction | Specify SGCR0 setting value in HoldingReg:18-19 |                                                                                                                                 |

## 8. Sample Program

### 8.1 Overview of Operation

Figure 8-1 shows the process flow of this sample program.

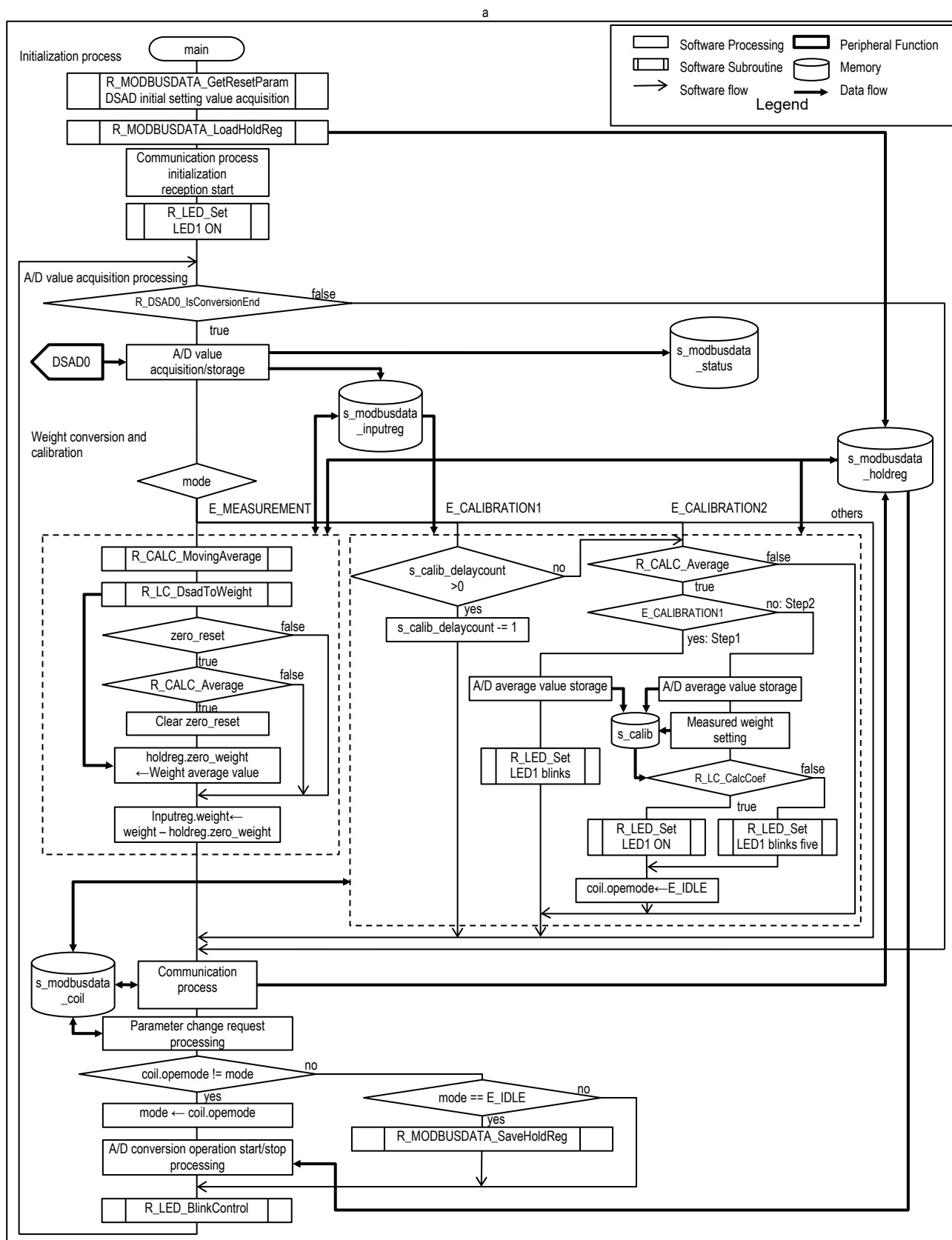


Figure 8-1 Weight Measurement Process Flow

This program works based on ModbusData. The operating mode is specified with the Coil member `ope_mode`. Operating modes are listed in Table 8-1.

**Table 8-1 Operating Modes**

| Name           | ope_mode | Description       |
|----------------|----------|-------------------|
| E_IDLE         | 0        | Standby           |
| E_MEASUREMENT  | 1        | Measurement       |
| E_CALIBRATION1 | 2        | Calibration STEP1 |
| E_CALIBRATION2 | 4        | Calibration STEP2 |

The following provides an overview of each of the processes in Figure 8-1.

- Initialization process
  - DSAD0 initial setting value acquisition
  - Initialization of holding register in ModbusData and loading of parameters stored in E2 data flash
  - Initialization of communication process and start receiving
  - Turning LED1 on
- A/D value acquisition processing

If the end of A/D conversion (AD10) is detected, A/D conversion results are acquired, and the A/D value is stored in the Input register in ModbusData and A/D conversion error information is stored in the Status in ModbusData.
- Weight conversion and calibration

The acquired A/D value is processed according to the operating mode "mode" in A/D conversion start/stop processing.

  - mode: E\_MEASUREMENT

The A/D value subject to moving averaging the number of times specified in the Holding register member `moving_average` in ModbusData is converted to weight, using the Holding register members `coef_a` and `coef_b`, and the result of subtracting the Holding register member `zero_weight` is stored in the Input register member `weight` in ModbusData as the measured weight.

When a zero reset has been requested, the converted weight is averaged the number of times specified in the Holding register member `zero_reset_average`. The result is stored in the Holding register member `zero_weight` as the zero reset weight.
  - mode: E\_CALIBRATION1

A/D value average processing is performed from the A/D value after the number of delay samples calculated from the calibration delay time and the averaging result is retained. The number of averages is determined based on the Holding register member `calib_average`.
  - mode: E\_CALIBRATION2

A/D value average processing is performed, and after its end, the weight conversion coefficients are calculated from this A/D average value, the A/D average value acquired with E\_CALIBRATION1, and the Holding register member `calib_weight1` and `calib_weight2` in ModbusData, according to "6.3 Calibration". The calculation results are stored in the Holding register members `coef_a` and `coef_b` in ModbusData.
- Communication process

A request from the Host is processed and the transmission of a response is set. For the QE for AFE version, the measured weight is transmitted. For details, refer to "8.3 Communication Control".

- Parameter change request processing  
The following processing, requested by the Coil in ModbusData, is performed.
  - reset\_param: During standby (E\_IDLE), the Holding register in ModbusData is returned to the initial value.
  - zero\_reset: During measurement (E\_MEASUREMENT), zero reset processing is initialized.
- A/D conversion operation start/stop processing  
If the Coil member ope\_mode in ModbusData is changed, the following processing is performed according to the new ope\_mode.
  - ope\_mode: E\_MEASUREMENT
- Applying the DSAD0 setting value of the Holding register in ModbusData
- Starting A/D conversion
- Initializing the A/D value moving average processing and setting the moving\_average of the Holding register as the moving averaging count
- Turning LED1 off
- 
- ope\_mode: E\_CALIBRATION1
- Applying the DSAD0 setting value of the Holding register in ModbusData
- Starting A/D conversion
- Converting the calibration delay time to the number of delay samples
- Initializing the A/D value average processing and setting the calib\_average of the Holding register as the averaging count
- Turning LED1 off
- 
- ope\_mode: E\_CALIBRATION2
- Initializing the A/D value average processing and setting the calib\_average of the Holding register as the averaging count
- Turning LED1 off
- 
- ope\_mode: E\_IDLE
- Stopping A/D conversion
- Turning LED1 on
- 
- E2 data flash storage processing  
If the Coil member opemode in ModbusData does not change from E\_IDLE, and there is a change in the retention parameter in the Holding register in ModbusData, it will be stored in E2 data flash.



## 8.2 Peripheral Functions and Pins Used

Table 8-2 lists the peripheral functions used in this example, and Table 8-3 lists the pins used. Also, Table 8-4 shows the clock settings. Unused pins are set to output Low.

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

**Table 8-2 Peripheral Functions**

| Peripheral function | Use                                            |                                |
|---------------------|------------------------------------------------|--------------------------------|
|                     | QE for AFE version                             | Modbus version                 |
| DSAD0               | A/D conversion of load cell output             |                                |
| SCI1                | Communication with QE for AFE                  | Communication with Modbus host |
| DMAC0               | Reception of packets from QE for AFE           | -                              |
| DMAC1               | Transmission of packets to QE for AFE          | -                              |
| TMR0                | -                                              | Communication with Modbus host |
| DTC                 | -                                              | Communication with Modbus host |
| CRC                 | -                                              | Modbus frame error check       |
| CMT1                | LED1 blinking cycle                            |                                |
| P31                 | LED1 ON/OFF control                            |                                |
| P27                 | RS-485 driver transmission/reception switching |                                |
| E2DataFlash         | Saving of retention parameters                 |                                |
| LVD                 | Setting of reset voltage                       |                                |

**Table 8-3 Pins**

| Pin name | I/O | Use                                                        |
|----------|-----|------------------------------------------------------------|
| AIN5     | I   | Input pin on the positive side of the load cell            |
| AIN4     | I   | Input pin on the negative side of the load cell            |
| REF0P    | I   | Positive side of the DSAD0 reference voltage input pin     |
| REF0N    | I   | Negative side of the DSAD0 reference voltage input pin     |
| P26/TXD1 | O   | UART1 transmit pin                                         |
| P30/RXD1 | I   | UART1 receive pin                                          |
| P27      | O   | RS-485 driver transmission/reception switching control pin |
| P31      | O   | LED1 ON/OFF control pin                                    |

**Table 8-4 Clock Settings**

| Item          | Setting                                                   |
|---------------|-----------------------------------------------------------|
| Clock used    | HOCO clock (32MHz)<br>Enable HOCO oscillation after reset |
| SCKCR (FCLK)  | x1 (32MHz)                                                |
| SCKCR (ICLK)  | x1 (32MHz)                                                |
| SCKCR (PCLKA) | x1 (32MHz)                                                |
| SCKCR (PCLKB) | x1 (32MHz)                                                |
| SCKCR (PCLKC) | x1 (32MHz)                                                |
| SCKCR (PCLKD) | x1 (32MHz)                                                |

### 8.2.1 Load Cell Measurement

In load cell measurement, DSAD0 is used in continuous scan mode. Table 8-5 shows the setting conditions based on the measurement conditions in Table 6-2.

**Table 8-5 DSAD0 Settings**

Continuous scan mode

| Item                                    |                                                                          | Setting                             |
|-----------------------------------------|--------------------------------------------------------------------------|-------------------------------------|
| Operation clock setting                 |                                                                          | PCLK/2(16MHz)                       |
| Conversion start trigger source         |                                                                          | Software trigger                    |
| Interrupt setting                       | Enable $\Delta\Sigma$ /D conversion completion interrupt (ADI0)          | Enable, Priority: Level 0(disabled) |
|                                         | Enable $\Delta\Sigma$ /D conversion scan completion interrupt (SCANEND0) | Disable                             |
|                                         | Enable $\Delta\Sigma$ /D channel change interrupt (CHCHG0)               | Disable                             |
| Voltage fault and disconnection setting |                                                                          | Not used                            |
| Analog input channel setting            |                                                                          | 0                                   |
| Analog input setting                    | Positive input signal                                                    | AIN5                                |
|                                         | Negative input signal                                                    | AIN4                                |
|                                         | Reference input                                                          | REF0P/REF0N                         |
|                                         | Positive reference voltage buffer                                        | Disable                             |
|                                         | Negative reference voltage buffer                                        | Disable                             |
| Amplifier setting                       | Amplifier selection                                                      | PGA                                 |
|                                         | PGA gain setting                                                         | x128                                |
| $\Delta\Sigma$ /D conversion setting    | A/D conversion mode                                                      | Normal operation                    |
|                                         | Data format                                                              | Two's complement                    |
|                                         | A/D conversion number                                                    | 1                                   |
|                                         | First stage oversampling ratio                                           | 256                                 |
|                                         | Second stage oversampling ratio                                          | 1562                                |
|                                         | Set offset calibration value                                             | Not used                            |
|                                         | Set gain calibration value                                               | Not used                            |
| Disconnect detection assist setting     |                                                                          | Disable                             |
| Digital filter setting                  | Sinc filter select                                                       | Sinc4 + Sinc4                       |
|                                         | Set sinc filter gain calibration                                         | Used                                |
|                                         | Sinc filter gain calibration value                                       | 1.477629984615                      |

### 8.2.2 Communication

In communication with QE for AFE or the Modbus host, SCI1 is used for transmission/reception in asynchronous mode. The TXD1/P26 pin is used in built-in pull-up setting, and P27 is used in RS-485 driver transmit/receive switching.

For the QE for AFE version, DMAC0 is used to acquire receive data, and DMAC3 is used to transmit data.

For the Modbus version, DTC is used to acquire receive data and transmit data, and TMR0 is used to detect frame reception and to detect the end of frame transmission.

The following shows the setting conditions for each peripheral function.

**Table 8-6 SCI1 Settings**

Asynchronous mode  
Operation mode: Transmission/reception

| Item                             |                                         | Setting                  |                     |
|----------------------------------|-----------------------------------------|--------------------------|---------------------|
|                                  |                                         | For QE for AFE           | For Modbus          |
| Start bit edge detection setting |                                         | Falling edge on RXD1 pin |                     |
| Data length setting              |                                         | 8 bits                   |                     |
| Parity setting                   |                                         | None                     | Even                |
| Stop bit length setting          |                                         | 1 bit                    |                     |
| Transfer direction setting       |                                         | LSB-first                |                     |
| Transfer rate setting            | Transfer clock                          | Internal clock           |                     |
|                                  | Bit rate                                | 1,000,000bps             | 115,200bps          |
|                                  | Enable modulation duty correction       | Not used                 | Used                |
|                                  | SCK1 pin function                       | SCK1 is not used         |                     |
| Noise filter setting             |                                         | Not used                 |                     |
| Hardware flow control setting    |                                         | None                     |                     |
| Data handling setting            | Transfer data handling                  | Data handled by DMAC     | Data handled by DTC |
|                                  | Receive data handling                   | Data handled by DMAC     | Data handled by DTC |
| Interrupt setting                | Enable reception error interrupt (ERI1) | Not used                 |                     |
|                                  | TXI1, RXI1, TEI1, ERI1 priority         | Level 1                  |                     |
| Callback function setting        |                                         | Not used                 |                     |

**Table 8-7 PORT2 Settings**

| Item           | Setting                               |                    |
|----------------|---------------------------------------|--------------------|
| Port selection | PORT2                                 |                    |
| Used port      | P26                                   | P27                |
| Setting        | Unused GPIO<br>Pull-up<br>CMOS output | Out<br>CMOS output |

**Table 8-8 DMAC Settings (for QE for AFE)**

| Item                        |                                                          | Setting                                       |                                         |
|-----------------------------|----------------------------------------------------------|-----------------------------------------------|-----------------------------------------|
|                             |                                                          | DMAC0                                         | DMAC1                                   |
| Transfer setting            | Activation source                                        | SCI1 (RXI1)                                   | SCI1 (TXI1)                             |
|                             | Activation source flag control                           | Clear interrupt flag of the activation source |                                         |
|                             | Transfer mode                                            | Free running mode                             | Normal mode                             |
|                             | Transfer data size                                       | 8 bits                                        |                                         |
|                             | Transfer count / Repeat size / Block size                | -                                             | (Setting on execution)                  |
| Source address setting      | Source address                                           | 0x0008A025(SCI1.RDR)<br>Fixed                 | (Setting on execution)<br>Incremented   |
|                             | Specify the transfer source as extended repeat area      | -                                             | Enable                                  |
|                             | Extended repeat area                                     |                                               | Lower 9 bits of the address (512 bytes) |
| Destination address setting | Destination address                                      | (Set by the program)<br>Incremented           | 0x0008A023(SCI1.TDR)<br>Fixed           |
|                             | Specify the transfer destination as extended repeat area | Enable                                        | -                                       |
|                             | Extended repeat area                                     | Lower 9 bits of the address (512 bytes)       |                                         |
| Interrupt setting           |                                                          | Not used                                      |                                         |

**Table 8-9 TMR0 Settings (for Modbus)**

| Item                |                                              | Setting          |
|---------------------|----------------------------------------------|------------------|
| Count setting       | Clock source                                 | PCLK/64 (500kHz) |
|                     | Counter clear                                | Disabled         |
|                     | Compare match A value (TCORA)                | 334μs            |
|                     | Compare match B value (TCORB)                | 238μs            |
| TMO0 output setting |                                              | Not used         |
| Interrupt setting   | Enable TCORA compare match interrupt (CMIA0) | Enabled          |
|                     | Enable TCORB compare match interrupt (CMIB0) | Enabled          |
|                     | Enable TCNTOverflow interrupt (OVI0)         | Disabled         |
|                     | Priority                                     | Level 1          |

**Table 8-10 DTC Settings: Config\_DTC\_RXI1 (for Modbus)**

| Item                               |                         | Setting                                                                               |                                         |                                         |
|------------------------------------|-------------------------|---------------------------------------------------------------------------------------|-----------------------------------------|-----------------------------------------|
|                                    |                         | DTC0                                                                                  | DTC1                                    | DTC2                                    |
| Basic setting                      | Transfer data read skip | Enable                                                                                |                                         |                                         |
|                                    | Address mode            | Short-address mode (24 bits)                                                          |                                         |                                         |
|                                    | DTC vector base address | 0x00007C00 (default value)                                                            |                                         |                                         |
| Activation source setting          | Activation source       | SCI1 (RXI1)                                                                           | -                                       | -                                       |
|                                    | Chain transfer          | Used                                                                                  |                                         | Not used                                |
| Chain transfer setting             |                         | Continuous                                                                            |                                         | -                                       |
| Transfer mode setting              |                         | Repeat mode                                                                           |                                         |                                         |
| Transfer data size setting         |                         | 8 bits                                                                                | 8 bits                                  | 8 bits                                  |
| Interrupt setting                  |                         | An interrupt request to the CPU is disabled when specified data transfer is completed |                                         |                                         |
| Block / Repeat area setting        |                         | Transfer destination                                                                  |                                         |                                         |
| Transfer address and count setting | Source address          | 0x0008A025 (SCI1.RDR)<br>Address fixed                                                | (Set by the program)<br>Address fixed   |                                         |
|                                    | Destination address     | (Set by the program)<br>Address incremented                                           | 0x00088208 (TMR0.TCNT)<br>Address fixed | 0x0008820A (TMR0.TCCR)<br>Address fixed |
|                                    | Count                   | 256                                                                                   | 1                                       | 1                                       |

**Table 8-11 DTC Settings: Config\_DTC\_TXI1 (for Modbus)**

| Item                               |                         | Setting                                                                                |
|------------------------------------|-------------------------|----------------------------------------------------------------------------------------|
| Basic setting                      | Transfer data read skip | Enable                                                                                 |
|                                    | Address mode            | Short-address mode (24 bits)                                                           |
|                                    | DTC vector base address | 0x00007C00 (default value)                                                             |
| Activation source setting          | Activation source       | SCI1 (TXI1)                                                                            |
|                                    | Chain transfer          | Not used                                                                               |
| Transfer mode setting              |                         | Normal mode                                                                            |
| Transfer data size setting         |                         | 8 bits                                                                                 |
| Interrupt setting                  |                         | An interrupt request to the CPU is generated when specified data transfer is completed |
| Transfer address and count setting | Source address          | (Set by the program)<br>Address incremented                                            |
|                                    | Destination address     | 0x0008A023(SCI1.TDR)<br>Address fixed                                                  |
|                                    | Count                   | (Setting on execution)                                                                 |

**Table 8-12 DTC Settings: Config\_DTC\_CMIA0 (for Modbus)**

| Item                               |                         | Setting                                                                               |                                       |         |                                                                                       |
|------------------------------------|-------------------------|---------------------------------------------------------------------------------------|---------------------------------------|---------|---------------------------------------------------------------------------------------|
|                                    |                         | DTC0                                                                                  | DTC1                                  | DTC2    | DTC3                                                                                  |
| Basic setting                      | Transfer data read skip | Enable                                                                                |                                       |         |                                                                                       |
|                                    | Address mode            | Short-address mode (24 bits)                                                          |                                       |         |                                                                                       |
|                                    | DTC vector base address | 0x00007C00 (default value)                                                            |                                       |         |                                                                                       |
| Activation source setting          | Activation source       | TMR0(CMIA0)                                                                           | -                                     | -       | -                                                                                     |
|                                    | Chain transfer          | Used                                                                                  |                                       |         | Not used                                                                              |
| Chain transfer setting             |                         | Continuous                                                                            |                                       |         | -                                                                                     |
| Transfer mode setting              |                         | Repeat mode                                                                           |                                       |         |                                                                                       |
| Transfer data size setting         |                         | 8 bits                                                                                | 8 bits                                | 16 bits | 16 bits                                                                               |
| Interrupt setting                  |                         | An interrupt request to the CPU is disabled when specified data transfer is completed |                                       |         | An interrupt request to the CPU is generated each time DTC data transfer is performed |
| Block / Repeat area setting        |                         |                                                                                       |                                       |         |                                                                                       |
| Transfer address and count setting | Source address          | (Set by the program)<br>Address fixed                                                 |                                       |         |                                                                                       |
|                                    | Destination address     | 0x0008820A (TMR0.TCCR)<br>Address fixed                                               | (Set by the program)<br>Address fixed |         |                                                                                       |
|                                    | Count                   | 1                                                                                     | 1                                     | 1       | 1                                                                                     |

**Table 8-13 CRC Settings (for Modbus)**

| Item                |                                   | Setting  |
|---------------------|-----------------------------------|----------|
| Calculation setting | Generating polynomial             | CRC_16   |
|                     | Bit order                         | LSB      |
|                     | Initial value                     | 0xFFFF   |
|                     | Invert result of calculated value | Not used |

**8.2.3    LED**

P31 is used to turn on and off LED1. For the blinking interval, CMT1 is used.

LED1 is on during standby, off during measurement, and blinks to indicate the calibration status.

Table 8-14 shows the settings for P31, and Table 8-15 shows the settings for CMT1.

**Table 8-14 P31 Settings**

| Item           | Setting                        |
|----------------|--------------------------------|
| Port selection | PORT3                          |
| Used port      | P31                            |
| Setting        | Out<br>CMOS output<br>Output 1 |

**Table 8-15 CMT1 Settings**

| Item                  |                                | Setting                                |
|-----------------------|--------------------------------|----------------------------------------|
| Count clock setting   |                                | PCLK/128                               |
| Compare match setting | Interval value                 | 250ms                                  |
|                       | Compare match interrupt (CMT1) | Enable<br>Priority: Level 0 (disabled) |

**8.2.4    E2 Data Flash**

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

**Table 8-16 FIT Flash Module Settings**

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

**8.2.5    Voltage Detection Circuit (LVD)**

The reset voltage can be set.

**Table 8-17 LVD settings**

| Item                                      | Setting                                     |
|-------------------------------------------|---------------------------------------------|
| Voltage detection level                   | 3.84V                                       |
| Voltage detection 0 circuit start setting | Voltage monitor 0 reset enabled after reset |



### 8.3 Communication Control

#### 8.3.1 QE for AFE Communication

QE for AFE communication uses the communication module included in the "RX23E-B Group RSSKRX23E-B Board Control Program". For details, refer to the Application Note.

The QE for AFE communication process flow in this example is shown in Figure 8-2.

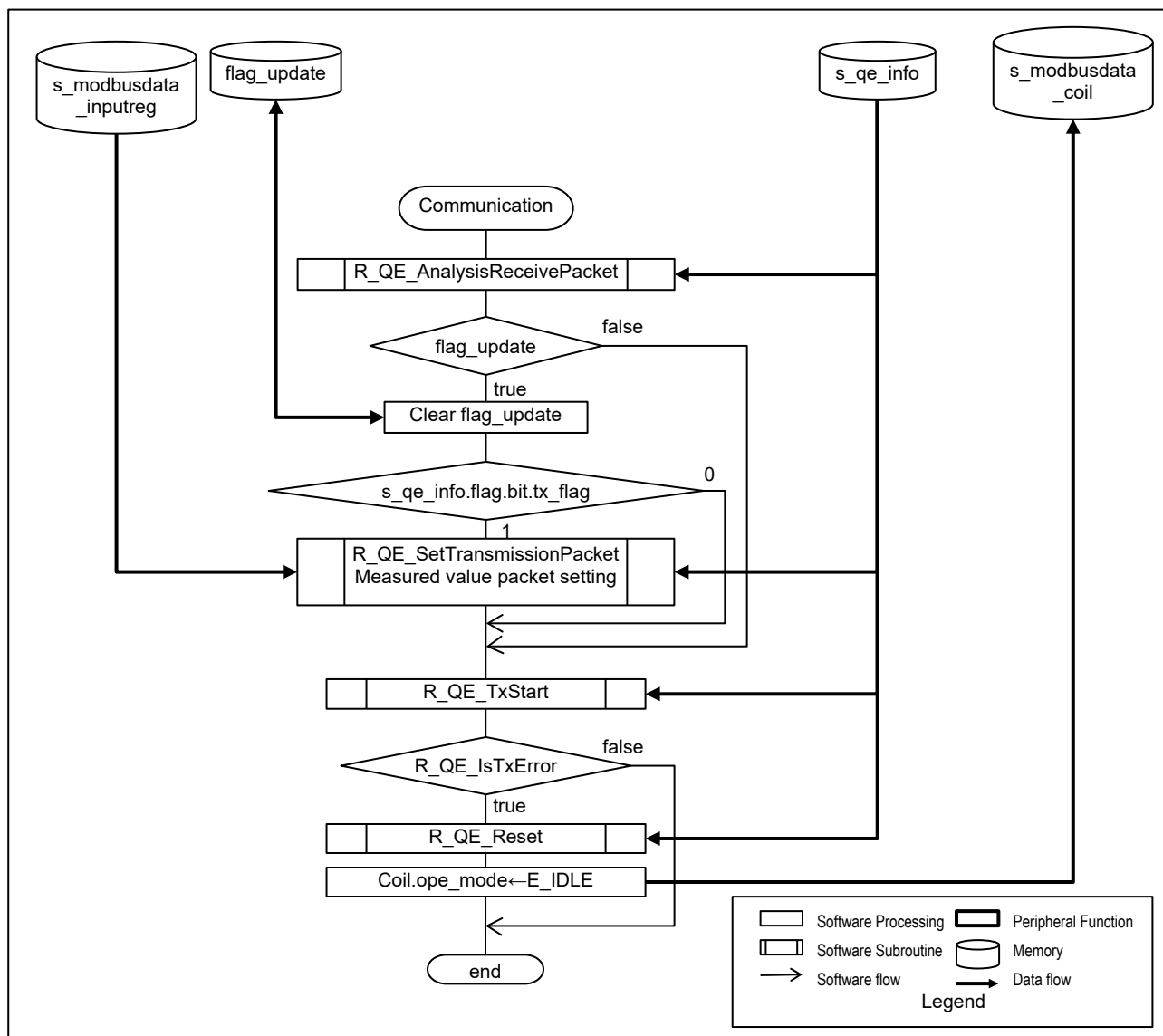


Figure 8-2 QE for AFE Communication Process Flow

### 8.3.2 Modbus RTU Communication

This sample program conducts data transmission/reception with DTC transfer, and the designated wait time indicating the end of communication is set with the timer TMR0.

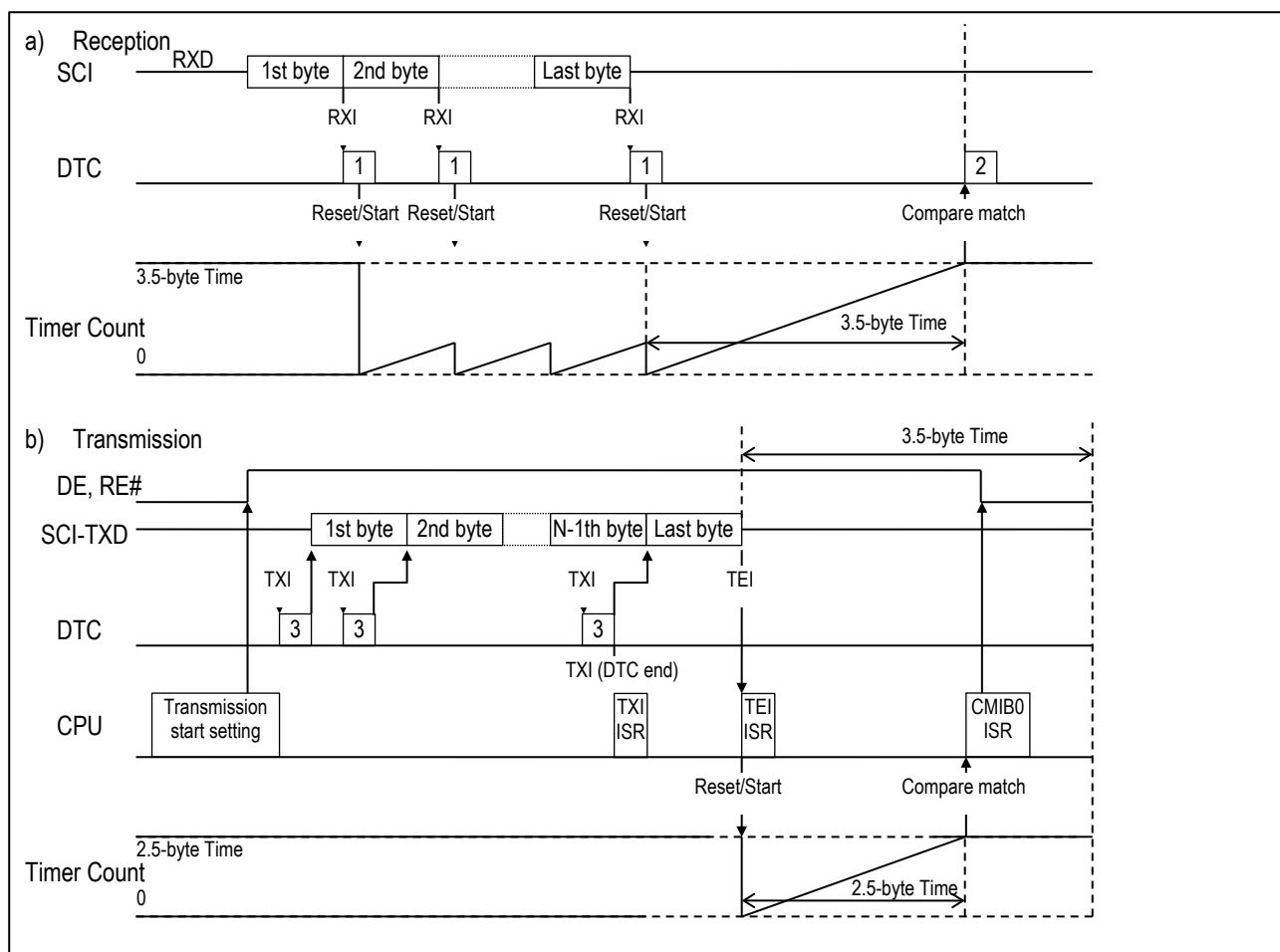
Reception processing is handled only by DTC and TMR0, and the CPU is not involved.

Transmission processing sets transmit data in SCI1 with DTC, detects completion of data transmission with the TEI of SCI1, and waits for the transmit end with TMR0. Transmit end processing is performed with the compare match interrupt CMIB0 of TMR0.

The program detects reception with the compare match interrupt request CMIA0 of TMR0, creates the response frame for the received Modbus frame, and makes transmission settings.

#### 8.3.2.1 Transmit/Receive Processing

A communication timing chart is shown in Figure 8-3, and the communication process flow is shown in Figure 8-4.



**Figure 8-3 Modbus Communication Timing Chart**

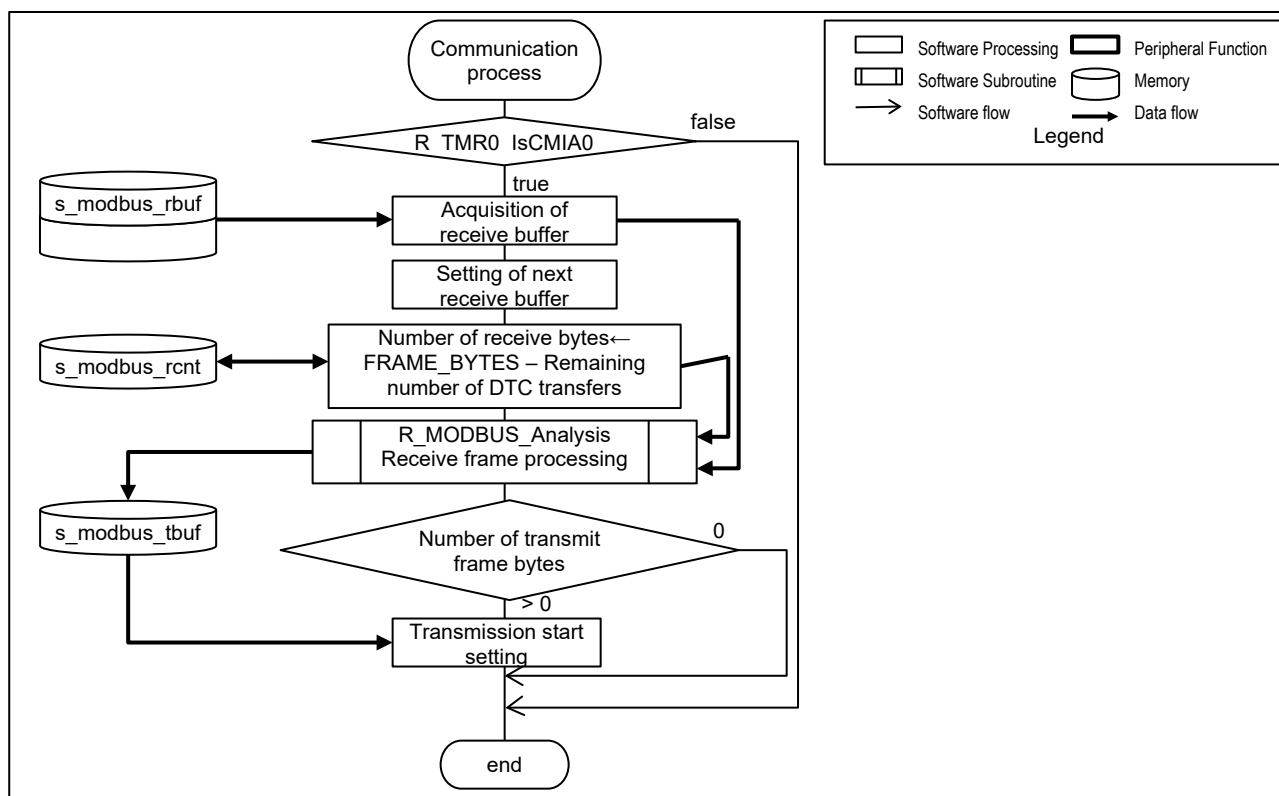


Figure 8-4 Modbus Communication Process Flow

Receive processing and transmit processing are performed as described below.

- Receive processing

(1) At the RXI1 interrupt request for every 1-byte reception, DTC transfer 1 (DTC\_RXI1) performs the following:

- Transfer the receive data to the receive buffer on memory
- Reset and restart TMR0

(2) On TMR0 compare match A interrupt request (CMIA0), DTC transfer 2 (DTC\_CMIA0) performs the following:

- Stop the TMR0 count
- Transfer the DTC transfer count to memory
- Switch receive buffers
- Reset the DTC transfer count

(3) As shown in Figure 8-4, when CMIA0 is detected, the program acquires and clears the DTC transfer count and processes the Modbus receive frame in the receive buffer.

- Transmit processing

(1) To prepare for transmission, the program performs the following in "Transmission start setting" in Figure 8-4.

- Set DE (= RE#) to H for transmission
- To transmit a transmission frame with a TXI interrupt of SCI, set a transmit buffer and the number of transmit bytes in DTC transfer 3 (DTC\_TXI1) and permit transfer
- Make SCI transmit start setting

- (2) On TXI1 interrupt request, DTC transfer 3 (DTC\_TXI1) transfers 1 byte of the transmission frame to the transmission register.
- (3) On TXI1 interrupt request due to the completion of DTC transfer 3 (DTC\_TXI1), the interrupt handler performs the following actions:
  - Enable the transmit end interrupt (TEI1)
  - Disable TXI1 interrupt
- (4) On TEI1 interrupt, the interrupt handler performs the following actions:
  - Reset TMR0
  - Disable CMIA0 and enable CMIB0
  - Start the TMR0 count
  - Disable TEI1 interrupt
- (5) On a TMR0 compare match interrupt request (CMIB0), the interrupt handler performs the following actions:
  - Stop the TMR0 count
  - Set DE (= RE#) to L
  - Disable CMIB0 and enable CMIA0

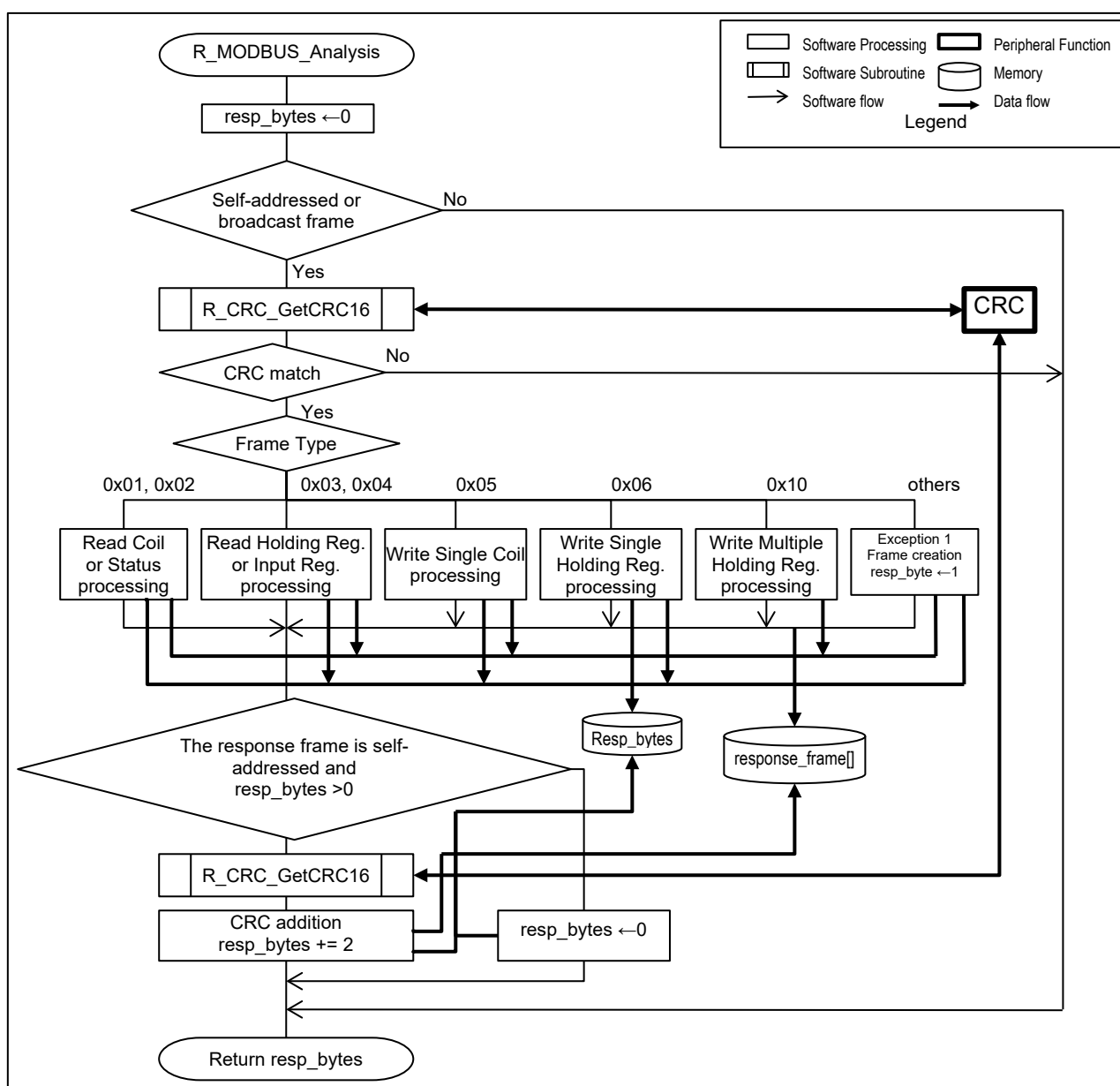
### 8.3.2.2 Receive Frame Processing

The received self-addressed frame is processed, a response frame is generated, and set transmission.

The processing on receive frames and whether response frames are transmitted are shown in Table 8-18, and the receive frame processing flowchart is shown in Figure 8-5 and Figure 8-6.

**Table 8-18 Processing on Receive Frames and Responses**

| Receive frame             |                   | Processing           | Response           |
|---------------------------|-------------------|----------------------|--------------------|
| No frame                  |                   | None                 | None               |
| Frame addressed to others |                   | Discard              | None               |
| Broadcast query           |                   | Supported processing | None               |
| Self-addressed frame      | CRC error         | Discard              | None               |
|                           | Unsupported query | Discard              | Exception response |
|                           | Normal            | Supported processing | Response           |



**Figure 8-5 Modbus Receive Frame Processing Flow (1)**

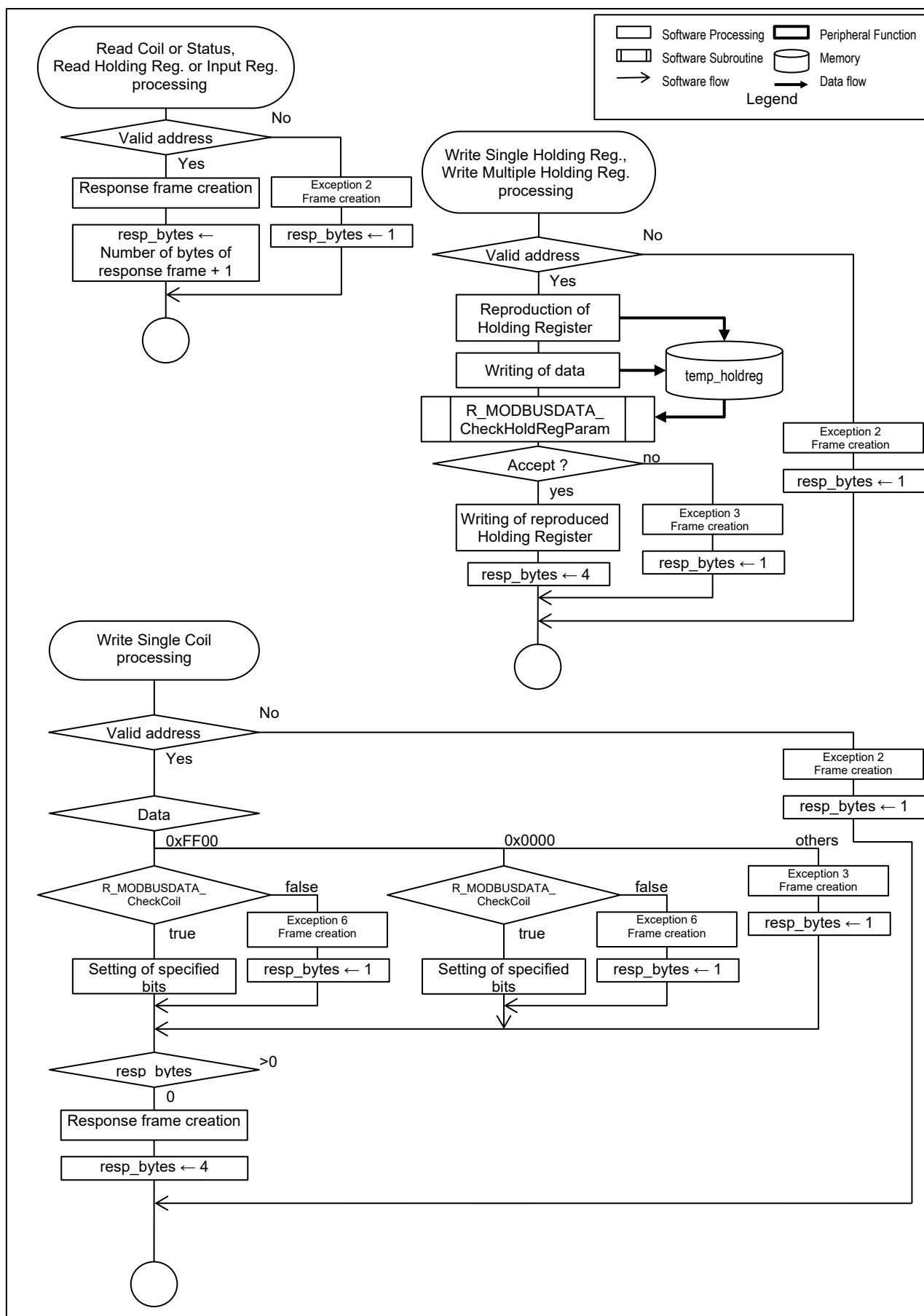


Figure 8-6 Modbus Receive Frame Processing Flow (2)

## 8.4 Program Configuration

### 8.4.1 Source File Configuration

**Table 8-19 File Configuration**

| Folder name, file name        | Description                                                           |                                 |
|-------------------------------|-----------------------------------------------------------------------|---------------------------------|
|                               | QE for AFE version                                                    | Modbus version                  |
| src                           |                                                                       |                                 |
| └ smc_gen                     | Generated by Smart Configurator                                       |                                 |
| └ └ general                   | Generated by Smart Configurator                                       | Generated by Smart Configurator |
| └ └ r_bsp                     |                                                                       |                                 |
| └ └ r_config                  |                                                                       |                                 |
| └ └ r_pincfg                  |                                                                       |                                 |
| └ └ Config_DSAD0              | Load cell measurement setting                                         |                                 |
| └ └ Config_SCI1               | QE for AFE communication                                              | Modbus communication            |
| └ └ Config_DMAC0              |                                                                       | -                               |
| └ └ Config_DMAC1              |                                                                       |                                 |
| └ └ Config_DTC_RXI            | -                                                                     | Modbus communication            |
| └ └ Config_DTC_TXI            |                                                                       |                                 |
| └ └ Config_DTC_CMIA0          |                                                                       |                                 |
| └ └ Config_TMR0               |                                                                       |                                 |
| └ └ Config_PORT               | LED1, RS-485 transmit/receive switching setting                       |                                 |
| └ └ r_flash_rx                | Flash API                                                             |                                 |
| └ main.c                      | Main function                                                         |                                 |
| └ r_calc_api.c                | Calculations such as average processing and moving average processing |                                 |
| └ r_calc_api.h                |                                                                       |                                 |
| └ r_loadcell_cfg.h            | Load cell weight conversion processing                                |                                 |
| └ r_loadcell_api.c            |                                                                       |                                 |
| └ r_loadcell_api.h            |                                                                       |                                 |
| └ r_modbusdata_api.c          | Modbus data processing                                                |                                 |
| └ r_modbusdata_api.h          |                                                                       |                                 |
| └ r_modbusdata_cfg.h          |                                                                       |                                 |
| └ r_qe_cfg.h                  | QE for AFE communication module                                       | -                               |
| └ r_qe_cfg_typedef.h          |                                                                       |                                 |
| └ r_qe_packet.h               |                                                                       |                                 |
| └ r_qe_sc_if.h                |                                                                       |                                 |
| └ r_qe_api.c                  |                                                                       |                                 |
| └ r_qe_api.h                  |                                                                       |                                 |
| └ r_qe_api_user.c             |                                                                       |                                 |
| └ r_ring_buffer_control_api.c |                                                                       |                                 |
| └ r_ring_buffer_control_api.h |                                                                       |                                 |
| └ r_modbus_cfg.c              | -                                                                     | Modbus communication process    |
| └ r_modbus_api.c              |                                                                       |                                 |
| └ r_modbus_api.h              |                                                                       |                                 |



**8.4.2 Build Settings**

There are two types of sample projects, QE for AFE version and Modbus version, as shown in Table 2-1. Additional settings for each sample project are listed in Table 8-20.

**Table 8-20 Build Settings for Sample Projects**

| <b>Project name</b>           | <b>rx23eb_loadcell_qe</b> |                      | <b>rx23eb_loadcell_modbus</b> |                     |
|-------------------------------|---------------------------|----------------------|-------------------------------|---------------------|
| Additional definition         | -define D_CFG_QE_TOOL_USE |                      | None                          |                     |
| Additional section definition | <b>Address</b>            | <b>Section name</b>  | <b>Address</b>                | <b>Section name</b> |
|                               | 0x00100000                | C_DATAFLASH_1        | Same as the left              |                     |
|                               | 0x00003000                | B_DMAC_REPEAT_AREA_1 | -                             |                     |

**8.4.3 Macro Definitions**
**Table 8-21 r\_modbusdata\_cfg.h Definitions**

| Definition name                             | value | Description                                                               |
|---------------------------------------------|-------|---------------------------------------------------------------------------|
| D_MODBUSDATA_CFG_ZERO_WEIGHT_DEFAULT        | 0.0F  | Initial value of zero reset weight                                        |
| D_MODBUSDATA_CFG_MOVING_AVERAGE_NUM_DEFAULT | 8     | Initial value of moving averaging count for weight measurement processing |
| D_MODBUSDATA_CFG_ZERORESET_AVERAGE_DEFAULT  | 256   | Initial value of averaging count for zero reset processing                |
| D_MODBUSDATA_CFG_CALIB_AVERAGE_DEFAULT      | 256   | Initial value of A/D value averaging count for calibration processing     |
| D_MODBUSDATA_CFG_MOVING_AVERAGE_MAX         | 128   | Maximum moving averaging count                                            |
| D_MODBUSDATA_CFG_MOVING_AVERAGE_MIN         | 1     | Minimum moving averaging count                                            |
| D_MODBUSDATA_CFG_ZERO_RESET_AVERAGE_MAX     | 512   | Maximum averaging count for zero reset processing                         |
| D_MODBUSDATA_CFG_ZERO_RESET_AVERAGE_MIN     | 1     | Minimum averaging count for zero reset processing                         |
| D_MODBUSDATA_CFG_CALIBRATION_AVERAGE_MAX    | 512   | Maximum A/D value averaging count for calibration processing              |
| D_MODBUSDATA_CFG_CALIBRATION_AVERAGE_MIN    | 64    | Minimum A/D value averaging count for calibration processing              |
| D_MODBUSDATA_CFG_CALIBRATION_DELAY          | 5.0F  | Delay time [s] before starting Calibration 1                              |

**Table 8-22 r\_roadcell\_cfg.h Definitions**

| Definition name   | value   | Description                           |
|-------------------|---------|---------------------------------------|
| D_LC_CFG_PGA_GAIN | 128.0F  | PGA gain $G_{PGA}$ in DSAD0           |
| D_LC_CFG_DSADRES  | 24      | Number of bits of A/D converter       |
| D_LC_CFG_VREF     | 5.0F    | DSAD0 reference voltage $V_{REF}$     |
| D_LC_CFG_VCC      | 5.0F    | Applied voltage $V_{CC}$ to load cell |
| D_LC_CFG_RO       | 0.0009F | Rated output RO [V/V] of load cell    |
| D_LC_CFG_MMAX     | 300.0F  | Rated load MMAX [g] of load cell      |

Note: The initial values of the weight conversion coefficients are defined from the definitions above.

**Table 8-23 r\_modbus\_cfg.h Definition (Modbus Version)**

| Definition name      | value | Description          |
|----------------------|-------|----------------------|
| D_MODBUS_CFG_ADDRESS | 0x01  | Modbus slave address |

**Table 8-24 r\_qe\_cfg.h Settings (QE for AFE Version)**

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

**8.4.4 Structures, Unions, and Enumeration Types**
**Table 8-25 r\_loadcell\_api.h List**

|                            |             |                                |                                               |
|----------------------------|-------------|--------------------------------|-----------------------------------------------|
| <b>Structure type name</b> |             | st_lc_coef_t                   |                                               |
| <b>Description</b>         |             | Weight conversion coefficients |                                               |
| <b>Member</b>              | <b>Type</b> | <b>Name</b>                    | <b>Description</b>                            |
|                            | float       | a                              | Coefficient a (slope)                         |
|                            | float       | b                              | Coefficient b (intercept)                     |
| <b>Structure type name</b> |             | st_lc_calibration_data_t       |                                               |
| <b>Description</b>         |             | Calibration data               |                                               |
| <b>Member</b>              | <b>Type</b> | <b>Name</b>                    | <b>Description</b>                            |
|                            | float       | weight[2]                      | Weights for measurement (2 different weights) |
|                            | float       | adval[2]                       | Acquired A/D values (2 different values)      |

**Table 8-26 r\_calc\_api.h List**

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

**Table 8-27 r\_modbusdata\_api.h List (1/3)**

|                        |             |                           |                    |
|------------------------|-------------|---------------------------|--------------------|
| <b>Union type name</b> |             | u_modbus_float_t          |                    |
| <b>Description</b>     |             | float type Modbus data    |                    |
| <b>Member</b>          | <b>Type</b> | <b>Name</b>               | <b>Description</b> |
|                        | float       | float32                   | float type         |
|                        | uint32_t    | uint32                    | uint32 type        |
|                        | uint16_t    | word[2]                   | uint16 type        |
|                        | uint8_t     | byte[4]                   | uint8 type         |
| <b>Union type name</b> |             | u_modbus_long_t           |                    |
| <b>Description</b>     |             | int32_t type Modbus data  |                    |
| <b>Member</b>          | <b>Type</b> | <b>Name</b>               | <b>Description</b> |
|                        | int32_t     | int32                     | int32 type         |
|                        | uint16_t    | word[2]                   | uint16 type        |
|                        | uint8_t     | byte[4]                   | uint8 type         |
| <b>Union type name</b> |             | u_modbus_ulong_t          |                    |
| <b>Description</b>     |             | uint32_t type Modbus data |                    |
| <b>Member</b>          | <b>Type</b> | <b>Name</b>               | <b>Description</b> |
|                        | uint32_t    | int32                     | uint32 type        |
|                        | uint16_t    | word[2]                   | uint16 type        |
|                        | uint8_t     | byte[4]                   | uint8 type         |
| <b>Union type name</b> |             | u_modbus_ushort_t         |                    |
| <b>Description</b>     |             | uint16_t type Modbus data |                    |
| <b>Member</b>          | <b>Type</b> | <b>Name</b>               | <b>Description</b> |
|                        | uint16_t    | word                      | uint16 type        |
|                        | uint8_t     | byte[2]                   | uint8 type         |

**Table 8-28 r\_modbusdata\_api.h List (2/3)**

|                              |                  |                         |                                              |
|------------------------------|------------------|-------------------------|----------------------------------------------|
| <b>Enumeration type name</b> |                  | e_opemode_t             |                                              |
| <b>Description</b>           |                  | Processing mode         |                                              |
| <b>Member</b>                | <b>Name</b>      | <b>Value</b>            | <b>Description</b>                           |
|                              | E_IDLE           | 0                       | Standby                                      |
|                              | E_MEASUREMENT    | 1                       | Measurement                                  |
|                              | E_CALIBRATION1   | 2                       | Calibration STEP1                            |
|                              | E_CALIBRATION2   | 4                       | Calibration STEP2                            |
| <b>Union type name</b>       |                  | u_modbusdata_coil_t     |                                              |
| <b>Description</b>           |                  | Modbus Coil             |                                              |
| <b>Member</b>                | <b>Type</b>      | <b>Name</b>             | <b>Description</b>                           |
|                              | uint32_t         | uint32                  | Entire data                                  |
|                              | Union            | bit                     | Access in bit units                          |
|                              | uint32_t:3       | opemode                 | Operating mode bit group                     |
|                              | struct           | flag                    | Each bit                                     |
|                              | uint32_t:1       | measure                 | Measurement mode bit                         |
|                              | uint32_t:1       | calib1                  | Calibration STEP1 bit                        |
|                              | uint32_t:1       | calib2                  | Calibration STEP2 bit                        |
|                              | uint32_t:1       | zero_reset              | Zero reset bit                               |
|                              | uint32_t:1       | reset_param             | Parameter initialization bit                 |
|                              | uint32_t:1       | register_write          | Register rewriting bit (for QE for AFE)      |
| <b>Union type name</b>       |                  | u_modbusdata_status_t   |                                              |
| <b>Description</b>           |                  | Modbus Status           |                                              |
| <b>Member</b>                | <b>Type</b>      | <b>Name</b>             | <b>Description</b>                           |
|                              | uint32_t         | uint32                  | Entire data                                  |
|                              | union            | status                  | Access in bit units                          |
|                              | struct           | bit                     | Each bit                                     |
|                              | uint32_t:1       | dsad_ovf                | DSAD0 Overflow bit                           |
|                              | uint32_t:1       | dsad_err                | DSAD0 Error bit                              |
|                              | uint32_t:1       | cal1_end                | Notification of the end of Calibration STEP1 |
| <b>Union type name</b>       |                  | u_modbusdata_inputreg_t |                                              |
| <b>Description</b>           |                  | Modbus Input register   |                                              |
| <b>Member</b>                | <b>Type</b>      | <b>Name</b>             | <b>Description</b>                           |
|                              | uint16_t         | reg[4]                  | Access in register units                     |
|                              | struct           | member                  | Each register definition                     |
|                              | u_modbus_float_t | weight                  | Measured weight                              |
|                              | u_modbus_long_t  | dsad                    | A/D value                                    |
|                              | struct           | params                  | Internal access definition                   |
|                              | float            | weight                  | Measured weight                              |
|                              | int32_t          | dsad                    | A/D value                                    |

**Table 8-29 r\_modbusdata\_api.h List (3/3)**

|                            |                   |                         |                                             |
|----------------------------|-------------------|-------------------------|---------------------------------------------|
| <b>Structure type name</b> |                   | st_prm_t                |                                             |
| <b>Description</b>         |                   | Retained parameter      |                                             |
| <b>Member</b>              | <b>Type</b>       | <b>Name</b>             | <b>Description</b>                          |
|                            | st_lc_coef_t      | coef                    | Weight conversion coefficients              |
|                            | uint16_t          | moving_average          | Moving averaging count for measurement      |
|                            | uint16_t          | zero_reset_average      | Averaging count for zero reset              |
|                            | uint16_t          | reg_cr0_gain            | CR0.GAIN register value                     |
|                            | uint16_t          | reg_mr0_fsel            | MR0.FSEL register value                     |
|                            | uint32_t          | reg_osr0                | OSR0 register value                         |
|                            | uint32_t          | reg_sgcr0               | SGCR0 register value                        |
|                            | uint16_t          | calib_average           | Averaging count for calibration             |
| <b>Union type name</b>     |                   | u_modbusdata_holdreg_t  |                                             |
| <b>Description</b>         |                   | Modbus Holding register |                                             |
| <b>Member</b>              | <b>Type</b>       | <b>Name</b>             | <b>Description</b>                          |
|                            | uint16_t          | reg[19]                 | Access in register units                    |
|                            | struct            | member                  | Each register definition                    |
|                            | u_modbus_float_t  | zero_weight             | Zero reset weight                           |
|                            | u_modbus_float_t  | calib_weight1           | Measured weight in calibration STEP1        |
|                            | u_modbus_float_t  | calib_weight2           | Measured weight in calibration STEP2        |
|                            | u_modbus_float_t  | calib_delay             | Delay time before starting Calibration1 [s] |
|                            | u_modbus_float_t  | coef_a                  | Weight conversion coefficient a             |
|                            | u_modbus_float_t  | coef_b                  | Weight conversion coefficient b             |
|                            | u_modbus_ushort_t | moving_average          | Moving averaging count for measurement      |
|                            | u_modbus_ushort_t | zero_reset_average      | Averaging count for zero reset              |
|                            | u_modbus_ushort_t | reg_cr0_gain            | CR0.GAIN register value                     |
|                            | u_modbus_ushort_t | reg_mr0_fsel            | MR0.FSEL register value                     |
|                            | u_modbus_ulong_t  | reg_osr0                | OSR0 register value                         |
|                            | u_modbus_ulong_t  | reg_sgcr0               | SGCR0 register value                        |
|                            | u_modbus_ushort_t | calib_average           | Averaging count for calibration             |
|                            | struct            | params                  | Internal access definition                  |
|                            | float             | zero_weight             | Zero reset weight                           |
|                            | float             | calib_weight1           | Measured weight in calibration STEP1        |
|                            | float             | calib_weight2           | Measured weight in calibration STEP2        |
|                            | float             | calib_delay             | Delay time before starting Calibration1 [s] |
|                            | st_prm_t          | prm                     | Retained parameter                          |

**8.4.5 Functions**
**8.4.5.1 Common Functions**
**Table 8-30 main.c**

|                      |               |             |             |                    |
|----------------------|---------------|-------------|-------------|--------------------|
| <b>Function name</b> | <b>main</b>   |             |             |                    |
| <b>Description</b>   | main function |             |             |                    |
| <b>Argument</b>      | <b>I/O</b>    | <b>Type</b> | <b>Name</b> | <b>Description</b> |
|                      | -             | void        | -           | -                  |
| <b>Return value</b>  | -             | void        | -           | -                  |

**Table 8-31 r\_calc\_api**

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



**Table 8-32 r\_loadcell\_api**

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

**Table 8-33 r\_modbusdata\_api (1/2)**

|               |                                                                                                    |                           |                                        |             |
|---------------|----------------------------------------------------------------------------------------------------|---------------------------|----------------------------------------|-------------|
| Function name | R_MODBUSDATA_GetCoilPtr                                                                            |                           |                                        |             |
| Description   | Acquires a pointer to Modbus Coil                                                                  |                           |                                        |             |
| Argument      | I/O                                                                                                | Type                      | Name                                   | Description |
|               | -                                                                                                  | void                      | -                                      | -           |
| Return value  | O                                                                                                  | u_modbusdata_coil_t *     | Pointer to Modbus Coil                 |             |
| Function name | R_MODBUSDATA_GetStatusPtr                                                                          |                           |                                        |             |
| Description   | Acquires a pointer to Modbus Status                                                                |                           |                                        |             |
| Argument      | I/O                                                                                                | Type                      | Name                                   | Description |
|               | -                                                                                                  | void                      | -                                      | -           |
| Return value  | O                                                                                                  | u_modbusdata_status_t *   | Pointer to Modbus Status               |             |
| Function name | R_MODBUSDATA_GetInputRegPtr                                                                        |                           |                                        |             |
| Description   | Acquires a pointer to the Modbus Input register                                                    |                           |                                        |             |
| Argument      | I/O                                                                                                | Type                      | Name                                   | Description |
|               | -                                                                                                  | void                      | -                                      | -           |
| Return value  | O                                                                                                  | u_modbusdata_inputreg_t * | Pointer to the Modbus Input register   |             |
| Function name | R_MODBUSDATA_GetHoldRegPtr                                                                         |                           |                                        |             |
| Description   | Acquires a pointer to the Modbus Holding register                                                  |                           |                                        |             |
| Argument      | I/O                                                                                                | Type                      | Name                                   | Description |
|               | -                                                                                                  | void                      | -                                      | -           |
| Return value  | O                                                                                                  | u_modbusdata_holdreg_t *  | Pointer to the Modbus Holding register |             |
| Function name | R_MODBUSDATA_GetResetParam                                                                         |                           |                                        |             |
| Description   | Acquires and retains the initial value of each of the CR0.GAIN, MR0.FSEL, OSR0, and SGCR0 of DSAD0 |                           |                                        |             |
| Argument      | I/O                                                                                                | Type                      | Name                                   | Description |
|               | -                                                                                                  | void                      | -                                      | -           |
| Return value  | -                                                                                                  | void                      | -                                      |             |

**Table 8-34 r\_modbusdata\_api (2/2)**

|               |                                                                                                                                           |                          |                                         |                                                             |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------------------------------|-------------------------------------------------------------|
| Function name | R_MODBUSDATA_LoadHoldReg                                                                                                                  |                          |                                         |                                                             |
| Description   | Initializes the Modbus Holding Register and loads the value stored in E2 data flash                                                       |                          |                                         |                                                             |
| Argument      | I/O                                                                                                                                       | Type                     | Name                                    | Description                                                 |
|               | -                                                                                                                                         | void                     | -                                       | -                                                           |
| Return value  | -                                                                                                                                         | void                     | -                                       |                                                             |
| Function name | R_MODBUSDATA_SaveHoldReg                                                                                                                  |                          |                                         |                                                             |
| Description   | If the value retained in the Modbus Holding Register does not match the value stored in E2 data flash, stores that value in E2 data flash |                          |                                         |                                                             |
| Argument      | I/O                                                                                                                                       | Type                     | Name                                    | Description                                                 |
|               | -                                                                                                                                         | void                     | -                                       | -                                                           |
| Return value  | -                                                                                                                                         | void                     | -                                       |                                                             |
| Function name | R_MODBUSDATA_ResetHoldReg                                                                                                                 |                          |                                         |                                                             |
| Description   | Sets the Modbus Holding Register to the initial value                                                                                     |                          |                                         |                                                             |
| Argument      | I/O                                                                                                                                       | Type                     | Name                                    | Description                                                 |
|               | -                                                                                                                                         | void                     | -                                       | -                                                           |
| Return value  | -                                                                                                                                         | void                     | -                                       |                                                             |
| Function name | R_MODBUSDATA_CheckCoil                                                                                                                    |                          |                                         |                                                             |
| Description   | Judges whether it is possible to set and clear the specified address of Coil                                                              |                          |                                         |                                                             |
| Argument      | I/O                                                                                                                                       | Type                     | Name                                    | Description                                                 |
|               | I                                                                                                                                         | uint16_t                 | addr                                    | Coil address                                                |
|               | I                                                                                                                                         | bool                     | flag                                    | true: Set<br>false: Clear                                   |
| Return value  | O                                                                                                                                         | bool                     | true: Possible<br>false: Not possible   |                                                             |
| Function name | R_MODBUSDATA_CheckHoldRegParam                                                                                                            |                          |                                         |                                                             |
| Description   | Judges the acceptability of the Holding register value                                                                                    |                          |                                         |                                                             |
| Argument      | I/O                                                                                                                                       | Type                     | Name                                    | Description                                                 |
|               | I                                                                                                                                         | u_modbusdata_holdreg_t * | p_holdreg                               | Pointer to the Holding Register union variable to be judged |
| Return value  | O                                                                                                                                         | bool                     | true: Acceptable<br>false: Unacceptable |                                                             |

**Table 8-35 r\_led\_api**

|                      |                                                      |             |                                       |                                                                                                 |
|----------------------|------------------------------------------------------|-------------|---------------------------------------|-------------------------------------------------------------------------------------------------|
| <b>Function name</b> | <b>R_LED_Set</b>                                     |             |                                       |                                                                                                 |
| <b>Description</b>   | Specifies whether to turn on, turn off or blink LED1 |             |                                       |                                                                                                 |
| <b>Argument</b>      | <b>I/O</b>                                           | <b>Type</b> | <b>Name</b>                           | <b>Description</b>                                                                              |
|                      | I                                                    | bool        | flag                                  | true: ON<br>false: OFF                                                                          |
|                      | I                                                    | int32_t     | count                                 | Blinking count<br>0: Does not blink<br>>0: Blinking count<br>-1: Blinks without specified count |
| <b>Return value</b>  | -                                                    | void        | -                                     |                                                                                                 |
| <b>Function name</b> | <b>R_LED_BlinkControl</b>                            |             |                                       |                                                                                                 |
| <b>Description</b>   | Controls blinking of LED1                            |             |                                       |                                                                                                 |
| <b>Argument</b>      | <b>I/O</b>                                           | <b>Type</b> | <b>Name</b>                           | <b>Description</b>                                                                              |
|                      | -                                                    | void        | -                                     | -                                                                                               |
| <b>Return value</b>  | -                                                    | void        | -                                     |                                                                                                 |
| <b>Function name</b> | <b>R_LED_IsBlink</b>                                 |             |                                       |                                                                                                 |
| <b>Description</b>   | Acquires whether LED1 is blinking                    |             |                                       |                                                                                                 |
| <b>Argument</b>      | <b>I/O</b>                                           | <b>Type</b> | <b>Name</b>                           | <b>Description</b>                                                                              |
|                      | -                                                    | void        | -                                     | -                                                                                               |
| <b>Return value</b>  | O                                                    | bool        | true: Blinking<br>false: Not blinking |                                                                                                 |

**Table 8-36 Config\_DSAD0 User Defined Functions (1/2)**

|               |                                   |      |                                       |             |
|---------------|-----------------------------------|------|---------------------------------------|-------------|
| Function name | R_DSAD0_IsConversionEnd           |      |                                       |             |
| Description   | Detects A/D conversion end (ADI0) |      |                                       |             |
| Argument      | I/O                               | Type | Name                                  | Description |
|               | -                                 | void | -                                     | -           |
| Return value  | O                                 | bool | true: Detected<br>false: Not detected |             |

|               |                                              |          |                  |                            |
|---------------|----------------------------------------------|----------|------------------|----------------------------|
| Function name | R_DSAD0_ConvSignedValue                      |          |                  |                            |
| Description   | Acquires a signed A/D value (macro function) |          |                  |                            |
| Argument      | I/O                                          | Type     | Name             | Description                |
|               | I                                            | uint32_t | val              | Acquired DR register value |
| Return value  | O                                            | int32_t  | Signed A/D value |                            |

|               |                                                                            |          |             |                            |
|---------------|----------------------------------------------------------------------------|----------|-------------|----------------------------|
| Function name | R_DSAD0_GetErrorFlag                                                       |          |             |                            |
| Description   | Extracts the ERR flag from the acquired DR register value (macro function) |          |             |                            |
| Argument      | I/O                                                                        | Type     | Name        | Description                |
|               | I                                                                          | uint32_t | val         | Acquired DR register value |
| Return value  | O                                                                          | uint32_t | DR.ERR flag |                            |

|               |                                                                            |          |             |                            |
|---------------|----------------------------------------------------------------------------|----------|-------------|----------------------------|
| Function name | R_DSAD0_GetOverflowFlag                                                    |          |             |                            |
| Description   | Extracts the OVF flag from the acquired DR register value (macro function) |          |             |                            |
| Argument      | I/O                                                                        | Type     | Name        | Description                |
|               | I                                                                          | uint32_t | val         | Acquired DR register value |
| Return value  | O                                                                          | uint32_t | DR.OVF flag |                            |

**Table 8-37 Config\_DSAD0 User Defined Functions (2/2)**

|               |                                                                          |            |                           |                                                       |
|---------------|--------------------------------------------------------------------------|------------|---------------------------|-------------------------------------------------------|
| Function name | R_Config_DSAD0_GetScanRate                                               |            |                           |                                                       |
| Description   | Calculates the A/D conversion rate from the DSAD0 CH0 setting            |            |                           |                                                       |
| Argument      | I/O                                                                      | Type       | Name                      | Description                                           |
|               | -                                                                        | void       | -                         | -                                                     |
| Return value  | O                                                                        | float      | A/D conversion rate [SPS] |                                                       |
| Function name | R_Config_DSAD0_GetParam                                                  |            |                           |                                                       |
| Description   | Acquires the setting value of each register of the specified CH of DSAD0 |            |                           |                                                       |
| Argument      | I/O                                                                      | Type       | Name                      | Description                                           |
|               | I                                                                        | uint8_t    | ch                        | Channel m to be read                                  |
|               | O                                                                        | uint16_t * | gain                      | Pointer to CRm.GAIN setting value storage destination |
|               | O                                                                        | uint16_t * | fsel                      | Pointer to MRm.FSEL setting value storage destination |
|               | O                                                                        | uint32_t * | osr                       | Pointer to OSRm setting value storage destination     |
|               | O                                                                        | uint32_t * | sgcr                      | Pointer to SGCRm setting value storage destination    |
| Return value  | -                                                                        | void       | -                         |                                                       |
| Function name | R_Config_DSAD0_SetParam                                                  |            |                           |                                                       |
| Description   | Sets a value to each register of the specified CH of DSAD0               |            |                           |                                                       |
| Argument      | I/O                                                                      | Type       | Name                      | Description                                           |
|               | I                                                                        | uint8_t    | ch                        | Channel m to which to set a value                     |
|               | I                                                                        | uint16_t   | gain                      | CRm.GAIN configuration value                          |
|               | I                                                                        | uint16_t   | fsel                      | MRm.FSEL configuration value                          |
|               | I                                                                        | uint32_t   | osr                       | OSRm configuration value                              |
|               | I                                                                        | uint32_t   | sgcr                      | SGCRm configuration value                             |
| Return value  | -                                                                        | void       | -                         |                                                       |
| Function name | R_DSAD0_GetData                                                          |            |                           |                                                       |
| Description   | Acquires the DR register value                                           |            |                           |                                                       |
| Argument      | I/O                                                                      | Type       | Name                      | Description                                           |
|               | -                                                                        | void       | -                         | -                                                     |
| Return value  | O                                                                        | uint32_t   | DR register value         |                                                       |

**Table 8-38 Config\_PORT User Defined Functions**

|                      |                                                                          |             |             |                                 |
|----------------------|--------------------------------------------------------------------------|-------------|-------------|---------------------------------|
| <b>Function name</b> | <b>R_Config_PORT_LEDON</b>                                               |             |             |                                 |
| <b>Description</b>   | Turns on and off LED1                                                    |             |             |                                 |
| <b>Argument</b>      | <b>I/O</b>                                                               | <b>Type</b> | <b>Name</b> | <b>Description</b>              |
|                      | I                                                                        | bool        | flag        | true: ON<br>false: OFF          |
| <b>Return value</b>  | -                                                                        | void        | -           |                                 |
| <b>Function name</b> | <b>R_Config_PORT_LED_Blink</b>                                           |             |             |                                 |
| <b>Description</b>   | Reverses the ON/OFF of LED1 (macro function)                             |             |             |                                 |
| <b>Argument</b>      | <b>I/O</b>                                                               | <b>Type</b> | <b>Name</b> | <b>Description</b>              |
|                      | -                                                                        | void        | -           | -                               |
| <b>Return value</b>  | -                                                                        | void        | -           |                                 |
| <b>Function name</b> | <b>R_CONFIG_PORT_SET_DE</b>                                              |             |             |                                 |
| <b>Description</b>   | Sets the transmission or reception of the RS-485 driver (macro function) |             |             |                                 |
| <b>Argument</b>      | <b>I/O</b>                                                               | <b>Type</b> | <b>Name</b> | <b>Description</b>              |
|                      | -                                                                        | uint8_t     | value       | 0: Reception<br>1: Transmission |
| <b>Return value</b>  | -                                                                        | void        | -           |                                 |

**Table 8-39 Config\_CMT1 User Defined Function**

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

### 8.4.5.2 QE for AFE Version

Table 8-40 r\_qe\_api\_user.c User-Defined Processes

User processes only

|                      |                                                                                                                                                      |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Function name</b> | <b>r_QE_WriteUser</b>                                                                                                                                |
| <b>Description</b>   | If opemode is E_IDLE, accepts and sets coil.flag.register_write                                                                                      |
| <b>Function name</b> | <b>r_QE_RunUser</b>                                                                                                                                  |
| <b>Description</b>   | If opemode is E_IDLE, accepts and sets coil.flag.measure                                                                                             |
| <b>Function name</b> | <b>r_QE_StopUser</b>                                                                                                                                 |
| <b>Description</b>   | Clear coil.flag.measure                                                                                                                              |
| <b>Function name</b> | <b>r_QE_UserValueUser</b> <sup>Note</sup>                                                                                                            |
| <b>Description</b>   | Judged to be accepted or not for each User Value No. and if accepted, updates the value of the corresponding Coil or Holding register as appropriate |
| <b>Function name</b> | <b>r_QE_ExSpsInfoUser</b>                                                                                                                            |
| <b>Description</b>   | Calculates the output rate from the DSAD0 setting and updates SPS information                                                                        |
| <b>Function name</b> | <b>r_QE_ExUseButtonStatusUser</b> <sup>Note</sup>                                                                                                    |
| <b>Description</b>   | Judged to be accepted or not for each Button No. and if accepted, sets the flag for the corresponding Coil                                           |
| <b>Function name</b> | <b>r_QE_ResetUser</b>                                                                                                                                |
| <b>Description</b>   | Sets the RS-485 driver to the receive status (DE = L)                                                                                                |

Note: For details about each of the corresponding QE for AFE functions, refer to Table 1-1.

Table 8-41 r\_qe\_api.c Processing Change

Change only

|                      |                                                                                     |
|----------------------|-------------------------------------------------------------------------------------|
| <b>Function name</b> | <b>R_QE_TxStart</b>                                                                 |
| <b>Description</b>   | Sets the RS-485 driver to the transmit status (DE = H) at the start of transmission |

**8.4.5.3 Modbus Version**
**Table 8-42 r\_modbus\_api**

|                      |                                                                                                                    |                 |                                |                                                         |
|----------------------|--------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------------|---------------------------------------------------------|
| <b>Function name</b> | <b>R_MODBUS_Analysis</b>                                                                                           |                 |                                |                                                         |
| <b>Description</b>   | Inspects and analyzes the receive frame, processes the corresponding Modbus data, and creates a transmission frame |                 |                                |                                                         |
| <b>Argument</b>      | <b>I/O</b>                                                                                                         | <b>Type</b>     | <b>Name</b>                    | <b>Description</b>                                      |
|                      | I                                                                                                                  | const uint8_t * | QueryFrame                     | Pointer to the receive frame                            |
|                      | I                                                                                                                  | uint32_t        | QueryBytes                     | Number of bytes of the receive frame                    |
|                      | O                                                                                                                  | uint8_t *       | ResponseFrame                  | Pointer to the destination to stores transmission frame |
| <b>Return value</b>  | O                                                                                                                  | uint32_t        | Number of transmit frame bytes |                                                         |

**Table 8-43 Config\_CRC User Defined Function**

|                      |                       |             |              |                             |
|----------------------|-----------------------|-------------|--------------|-----------------------------|
| <b>Function name</b> | <b>R_CRC_GetCRC16</b> |             |              |                             |
| <b>Description</b>   | Calculates CRC-16     |             |              |                             |
| <b>Argument</b>      | <b>I/O</b>            | <b>Type</b> | <b>Name</b>  | <b>Description</b>          |
|                      | I                     | uint8_t     | array        | Pointer to the target array |
|                      | I                     | uint32_t    | num          | Number of target bytes      |
| <b>Return value</b>  | O                     | uint16_t    | CRC-16 value |                             |

**Table 8-44 Config\_TMR0 User Defined Functions**

|               |                                                  |      |                                       |                                |
|---------------|--------------------------------------------------|------|---------------------------------------|--------------------------------|
| Function name | R_Config_TMR0_SetCMIA0<br>R_Config_TMR0_SetCMIB0 |      |                                       |                                |
| Description   | Sets CMlX0 interrupt enable/disable              |      |                                       |                                |
| Argument      | I/O                                              | Type | Name                                  | Description                    |
|               | I                                                | bool | enable                                | true: Enable<br>false: Disable |
| Return value  | -                                                | void | -                                     |                                |
| Function name | R_Config_TMR0_ClearCount                         |      |                                       |                                |
| Description   | Clears the timer count value                     |      |                                       |                                |
| Argument      | I/O                                              | Type | Name                                  | Description                    |
|               | -                                                | void | -                                     | -                              |
| Return value  | -                                                | void | -                                     |                                |
| Function name | R_Config_TMR0_StartCount                         |      |                                       |                                |
| Description   | Starts the timer count                           |      |                                       |                                |
| Argument      | I/O                                              | Type | Name                                  | Description                    |
|               | -                                                | void | -                                     | -                              |
| Return value  | -                                                | void | -                                     |                                |
| Function name | R_Config_TMR0_StopCount                          |      |                                       |                                |
| Description   | Stops the timer count                            |      |                                       |                                |
| Argument      | I/O                                              | Type | Name                                  | Description                    |
|               | -                                                | void | -                                     | -                              |
| Return value  | -                                                | void | -                                     |                                |
| Function name | R_TMR0_IsCMIA0                                   |      |                                       |                                |
| Description   | Detects a CMIA0 interrupt request                |      |                                       |                                |
| Argument      | I/O                                              | Type | Name                                  | Description                    |
|               | -                                                | void | -                                     | -                              |
| Return value  | O                                                | bool | true: Detected<br>false: Not detected |                                |

**Table 8-45 Config\_DTC\_RXI1 User Defined Functions**

|               |                                              |          |        |                       |
|---------------|----------------------------------------------|----------|--------|-----------------------|
| Function name | R_Config_DTC_RXI1_SetDstAddr                 |          |        |                       |
| Description   | Sets the destination address of DTC transfer |          |        |                       |
| Argument      | I/O                                          | Type     | Name   | Description           |
|               | I                                            | uint32_t | number | Chain transfer number |
|               | I                                            | void *   | addr   | Destination address   |
| Return value  | -                                            | void     | -      |                       |

|               |                                         |          |        |                       |
|---------------|-----------------------------------------|----------|--------|-----------------------|
| Function name | R_Config_DTC_RXI1_SetSrcAddr            |          |        |                       |
| Description   | Sets the source address of DTC transfer |          |        |                       |
| Argument      | I/O                                     | Type     | Name   | Description           |
|               | I                                       | uint32_t | number | Chain transfer number |
|               | I                                       | void *   | addr   | Source address        |
| Return value  | -                                       | void     | -      |                       |

|               |                                                      |          |             |                       |
|---------------|------------------------------------------------------|----------|-------------|-----------------------|
| Function name | R_Config_DTC_RXI1_GetCraAddr                         |          |             |                       |
| Description   | Acquires the CRA address in DTC transfer information |          |             |                       |
| Argument      | I/O                                                  | Type     | Name        | Description           |
|               | I                                                    | uint32_t | number      | Chain transfer number |
| Return value  | O                                                    | void *   | CRA address |                       |

|               |                                                      |          |             |                       |
|---------------|------------------------------------------------------|----------|-------------|-----------------------|
| Function name | R_Config_DTC_RXI1_GetDarAddr                         |          |             |                       |
| Description   | Acquires the DAR address in DTC transfer information |          |             |                       |
| Argument      | I/O                                                  | Type     | Name        | Description           |
|               | I                                                    | uint32_t | number      | Chain transfer number |
| Return value  | O                                                    | void *   | DAR address |                       |

**Table 8-46 Config\_DTC\_TXI1 User Defined Functions**

|               |                                              |          |       |                          |
|---------------|----------------------------------------------|----------|-------|--------------------------|
| Function name | R_Config_DTC_TXI1_SetCount                   |          |       |                          |
| Description   | Sets the destination address of DTC transfer |          |       |                          |
| Argument      | I/O                                          | Type     | Name  | Description              |
|               | I                                            | uint32_t | count | Number of transfer bytes |
| Return value  | -                                            | void     | -     |                          |

|               |                                         |        |      |                |
|---------------|-----------------------------------------|--------|------|----------------|
| Function name | R_Config_DTC_TXI1_SetSrcAddr            |        |      |                |
| Description   | Sets the source address of DTC transfer |        |      |                |
| Argument      | I/O                                     | Type   | Name | Description    |
|               | I                                       | void * | addr | Source address |
| Return value  | -                                       | void   | -    |                |



**Table 8-47 Config\_DTC\_CMIA0 User Defined Functions**

|               |                                              |          |        |                       |
|---------------|----------------------------------------------|----------|--------|-----------------------|
| Function name | R_Config_DTC_CMIA0_SetDstAddr                |          |        |                       |
| Description   | Sets the destination address of DTC transfer |          |        |                       |
| Argument      | I/O                                          | Type     | Name   | Description           |
|               | I                                            | uint32_t | number | Chain transfer number |
|               | I                                            | void *   | addr   | Destination address   |
| Return value  | -                                            | void     | -      |                       |

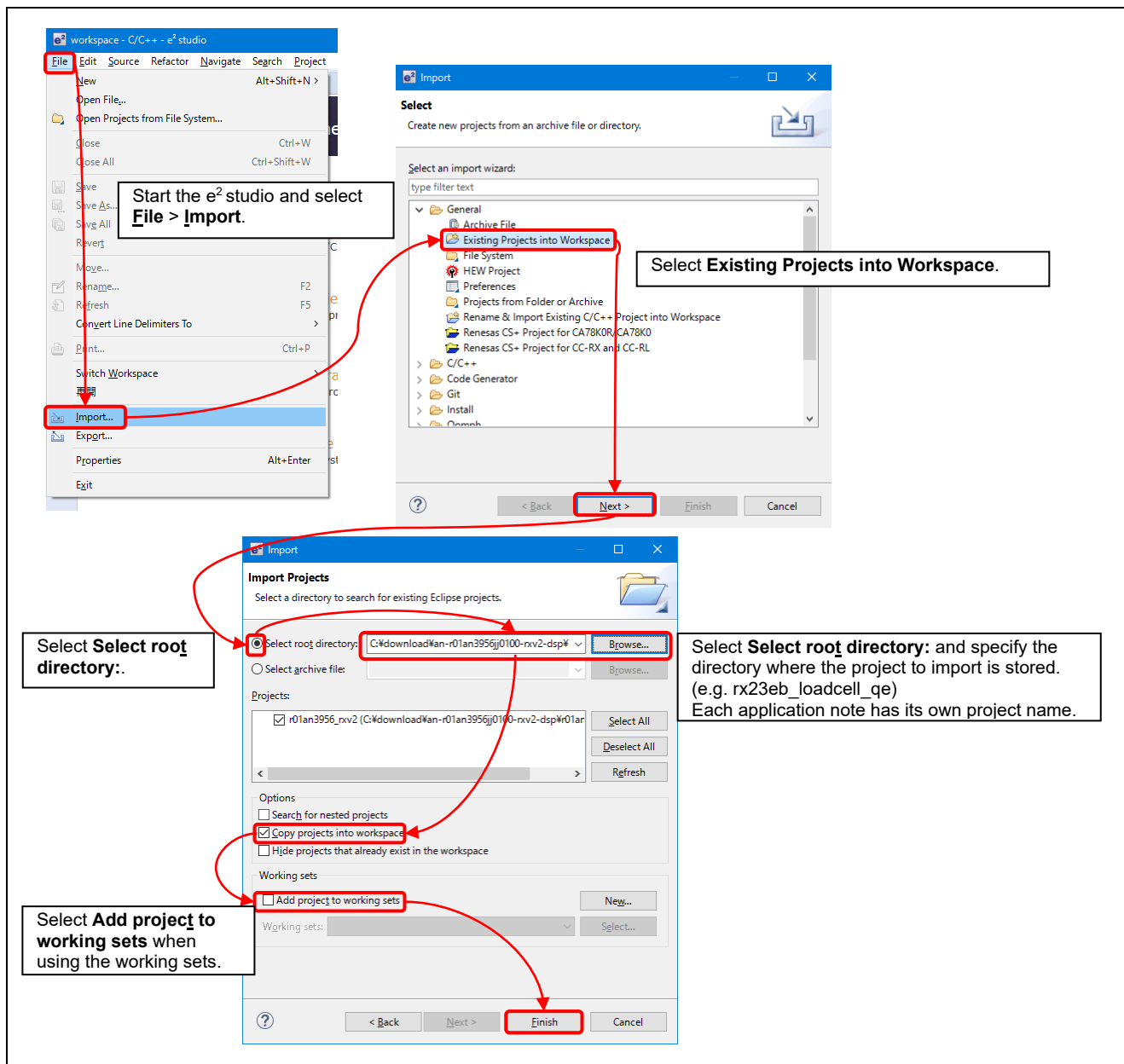
|               |                                         |          |        |                       |
|---------------|-----------------------------------------|----------|--------|-----------------------|
| Function name | R_Config_DTC_CMIA0_SetSrcAddr           |          |        |                       |
| Description   | Sets the source address of DTC transfer |          |        |                       |
| Argument      | I/O                                     | Type     | Name   | Description           |
|               | I                                       | uint32_t | number | Chain transfer number |
|               | I                                       | void *   | addr   | Source address        |
| Return value  | -                                       | void     | -      |                       |

## 9. Importing a Project

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

### 9.1 Importing a Project into e2 studio

Follow the steps below to import your project into e<sup>2</sup> studio. Pictures may be different depending on the version of e<sup>2</sup> studio to be used.



**Figure 9-1 Importing a project into e<sup>2</sup> studio**

## 9.2 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.

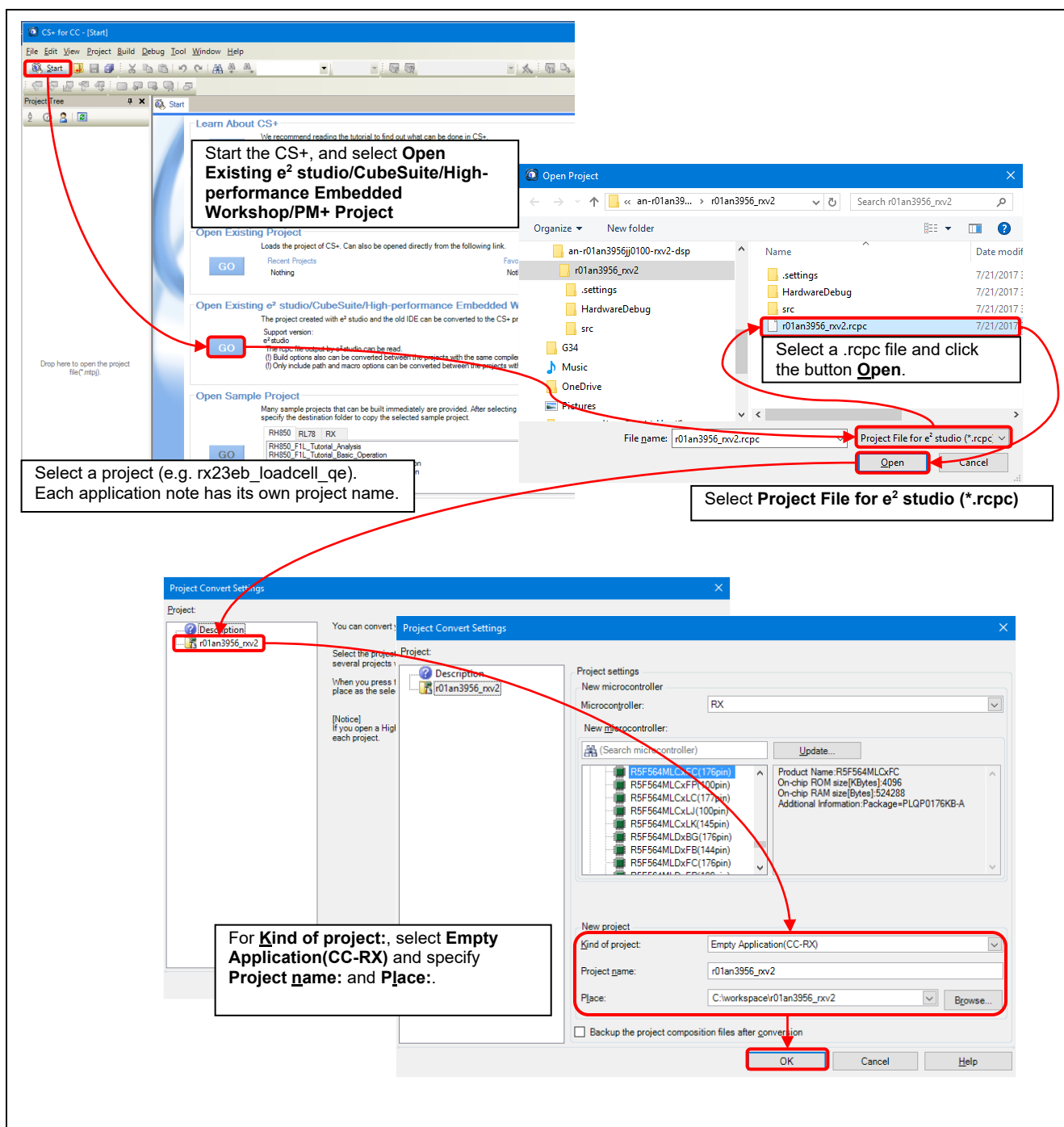


Figure 9-2 Importing a project into CS+

## 10. Operation on the Renesas Solution Starter Kit for RX23E-B Board

The Renesas Solution Starter Kit for RX23E-B (referred to as RSSKRX23E-B) is offered for the evaluation of RX23E-B. The RSSKRX23E-B board contains the R5F523E6LxFP in the QFP100 package and supports various sensor measurements including load cell measurement.

This sample program can be run on the RSSKRX23E-B board by changing settings with the Smart Configuration according to "2.4.7 Load Cell Measurement Circuit in RSSKRX23E-B User's Manual". Communication can be conducted via the USB-UART conversion IC.

The following explains the procedure.

### (1) Change the device type name

Click the button next to "Board" on the "Board" tab, and then change "Target device" to R5F523E6LxFP then uncheck the "Sections (-start)" in HardwareDebug\_RSSK on "Changes to be performed" in the "Change Device" dialog.

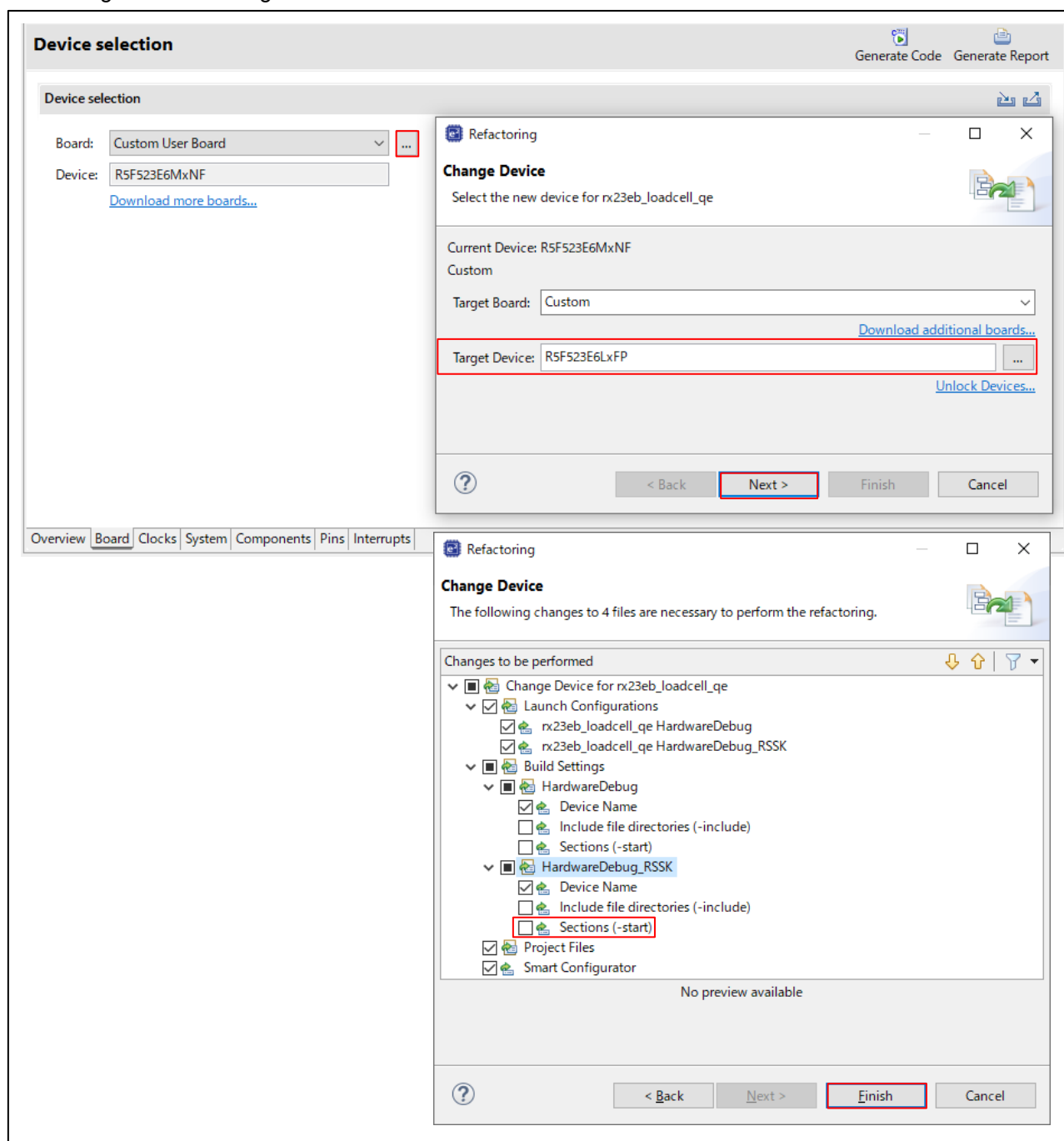


Figure 10-1 Changing the Target Device

## RX23E-B Group Design and weight measurement of tiny board for digital load cell

### (2) Change the DSAD0 setting

Change the analog input setting of channel 0 to the setting listed in Table 10-1 for "Config\_DSAD0" on the "Component" tab, and then generate code. Bold text in the table indicates changes.

**Table 10-1 Changing the DSAD0 Setting**

Continuous scan mode

| Item                 |                                   | Setting          |                    |
|----------------------|-----------------------------------|------------------|--------------------|
|                      |                                   | RX23E-B-QFN40-WT | RSSKRX23E-B        |
| Channel setting      |                                   | 0                |                    |
| Analog input setting | Positive input signal             | AIN5             | <b>AIN15</b>       |
|                      | Negative input signal             | AIN4             | <b>AIN14</b>       |
|                      | Reference voltage                 | REF0P/REF0N      | <b>REF1P/REF1N</b> |
|                      | Positive reference voltage buffer | Disable          |                    |
|                      | Negative reference voltage buffer | Disable          |                    |

### (3) Build

Change the active build configuration to "HardwareDebug\_RSSK", then build.

To run the product on the RSSKRX23E-B board, pin settings have been changed using the R\_Config\_PORT\_Create\_UserInit function in Config\_PORT\_user.c, according to Table 10-2. In addition, assignment of LED port is changed using Config\_PORT.h.

**Table 10-2 RSSKRX23E-B Changes to Pin Settings**

| RX23E-B-QFN40-WT                                                    | RSSKRX23E-B board |         |                     |                              |
|---------------------------------------------------------------------|-------------------|---------|---------------------|------------------------------|
| Pin: Function                                                       | Assignment        | Pin     | Initial setting     | Supplement                   |
| P27: Switches the setting of RS-485 driver between transmit/receive | DE                | PC6     | Output: L           | RAA788158/DE                 |
| P31: LED1                                                           | LED0              | P70     | Output: H           | The P31 setting is retained. |
| -                                                                   | LED1              | P71     | Output: H           |                              |
| -                                                                   | LED2              | P72     | Output: H           |                              |
| -                                                                   | LED3              | P73     | Output: H           |                              |
| -                                                                   | SW1               | PE1     | Input               |                              |
| -                                                                   | SW2               | PE2     | Input               |                              |
| -                                                                   | SW3-1             | PE3     | Input               |                              |
| -                                                                   | SW3-2             | PE4     | Input               |                              |
| -                                                                   | XTAL              | P36,P37 | Peripheral function | XTAL is unused.              |
| -                                                                   | -                 | P15     | Input               | CTS1# input                  |
| -                                                                   | -                 | PC1     | Input               | MAX13053/RXD input           |
| TXD1/P26: RS-485 data output                                        | TXD1              | P26     | Peripheral function | Pull-up is canceled.         |

Note: Set I/O ports not listed above to output: L.

## 11. Measurement Results with Sample Program

### 11.1 Memory Usage and Number of Execution Cycles

#### 11.1.1 Build Conditions

The build conditions for the sample program are listed in Table 11-1.

**Table 11-1 Build Conditions**

| Item     |            | Setting                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                               |
|----------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |            | QF for AFE                                                                                                                                                                                                                                                                                                                                                                                        | Modbus                                                                                                                                                        |
| Compiler | Common     | -isa=rxv2 -fpu -utf8 -nomessage -output=obj<br>-obj_path=\${workspace_loc}/\${ProjName}/\${ConfigName}} -debug -outcode=utf8 -nologo                                                                                                                                                                                                                                                              |                                                                                                                                                               |
|          | Difference | -define=D_CFG_QE_TOOL_USE                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                               |
| Linker   | Common     | -noprelink -form=absolute -nomessage -vect=_undefined_interrupt_source_isr<br>-nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -cpu=RAM=00000000-00007fff,<br>FIX=00080000-00083fff,FIX=00086000-00087fff,FIX=00088000-0008dfff,<br>FIX=00090000-0009ffff,FIX=000a0000-000bfff,FIX=000c0000-000ffff,<br>ROM=00100000-00101fff,FIX=007fc000-007fc4ff,FIX=007ffc00-007fffff,<br>ROM=fffc0000-ffffffffff -nologo |                                                                                                                                                               |
|          | Difference | -output="rx23eb_loadcell_qe.abs"<br>-list=rx23eb_loadcell_qe.map                                                                                                                                                                                                                                                                                                                                  | -output="rx23eb_loadcell_modbus.abs"<br>-list=rx23eb_loadcell_modbus.map                                                                                      |
|          | Section    | SU,SI,B_1,R_1,B_2,R_2,B,R/04,<br>B_DMAC_REPEAT_AREA_1/03000,<br>C_DATAFLASH_1/0100000,<br>PResetPRG,C_1,C_2,C,C\$,D*,W*,L,<br>P/0FFFC0000,EXCEPTVECT/0FFFFFFF80,<br>RESETVECT/0FFFFFFF80                                                                                                                                                                                                          | SU,SI,B_1,R_1,B_2,R_2,B,R/04,<br><br>C_DATAFLASH_1/0100000,<br>PResetPRG,C_1,C_2,C,C\$,D*,W*,L,<br>P/0FFFC0000,EXCEPTVECT/0FFFFFFF80,<br>RESETVECT/0FFFFFFF80 |

#### 11.1.2 Memory Usage

The amount of memory usage of the sample program is shown in Table 11-2.

**Table 11-2 Amount of Memory Usage**

| Item            |       | Size (byte)  |              | Remarks |
|-----------------|-------|--------------|--------------|---------|
|                 |       | QF for AFE   | Modbus       |         |
| ROM             |       | 11795        | 11574        |         |
|                 | Code  | 9860         | 9704         |         |
|                 | Data  | 1935         | 1870         |         |
| E2 DataFlashROM |       | 26           | 26           |         |
| RAM             |       | 13875 (9455) | 13625 (8697) | Note    |
|                 | Data  | 8755         | 8505         |         |
|                 | Stack | 5120 (700)   | 5120 (192)   | Note    |

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

**11.1.3 Number of Execution Cycles**

The number of execution cycles and processing load during measurement for each block in "Figure 8-1 Weight Measurement Process Flow" is shown in Table 11-3.

**Table 11-3 Number of Execution Cycles, Execution Time, and Processing Load**

ICLK=32MHz

Measurement rate: 10SPS

| Item                  | QF for AFE version                   |                     | Modbus version                       |                     | Condition                                                           |
|-----------------------|--------------------------------------|---------------------|--------------------------------------|---------------------|---------------------------------------------------------------------|
|                       | Number of cycles<br>(Execution time) | Processing load [%] | Number of cycles<br>(Execution time) | Processing load [%] |                                                                     |
| A/D value acquisition | 32cycle<br>(1.00μs)                  | 0.0010              | 32cycle<br>(1.00μs)                  | 0.0010              |                                                                     |
| Weight conversion     | 186cycle<br>(5.81μs)                 | 0.0058              | 186cycle<br>(5.81μs)                 | 0.0058              | Includes Zero reset processing                                      |
| Communication control | 328cycle<br>(10.97μs)                | 0.0103              | 410cycle<br>(12.81μs)                | 0.0128              | QE: On sending weights data<br>Modbus: On weight request processing |
| Others                | 80cycle<br>(2.50μs)                  | 0.0025              | 22cycle<br>(0.69μs)                  | 0.0007              |                                                                     |
| Total                 | 626cycle<br>(19.56μs)                | 0.0335              | 650cycle<br>(20.31μs)                | 0.0203              |                                                                     |

Note: The processing load is calculated based on the execution time in the measurement rate.

## 11.2 Weight Measurement Accuracy Evaluation

Results of weight measurement by load cell BCL-300GM-C3 shown in Table 6-1 are described in this section by using the RX23E-B-QFN40-WT board and the sample program.

### 11.2.1 Weight Measurement Accuracy Evaluation Conditions

System configuration of weight measurement is shown in Figure 11-1. Equipment used in the measurement is shown in Table 11-4. Also, combination of counterweights for measured weight and weight tolerance is shown in Table 11-5 and Table 11-6. Calibration was carried out for two kinds of weight, which are 0g (no load) and 250g, following "6.3 Calibration".

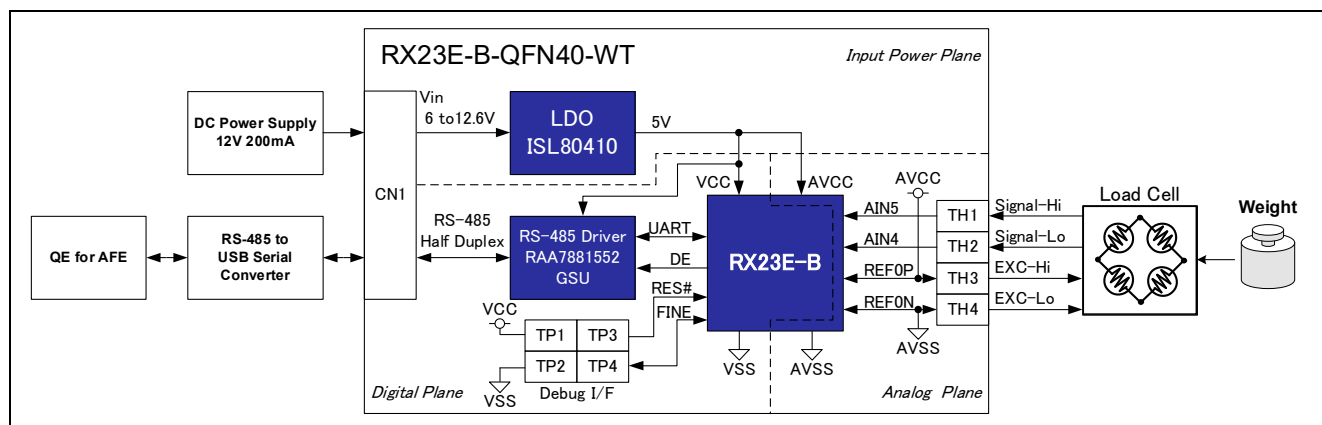


Figure 11-1 Configuration of Weight Measurement Accuracy Evaluation

Table 11-4 Equipment Used in Weight Measurement Accuracy Evaluation

| Item            | Model        | Manufacturer                    |
|-----------------|--------------|---------------------------------|
| Load Cell       | BCL-300GM-C3 | Minebea Mitsumi Inc.            |
| DC Power Supply | PCR1000MS    | KIKUSUI ELECTRONICS CORPORATION |
| Counterweight   | 738-65-53-04 | Tokyo Garasu Kikai Co., Ltd.    |



**Table 11-5 Combination of Counterweights for Weight Settings**

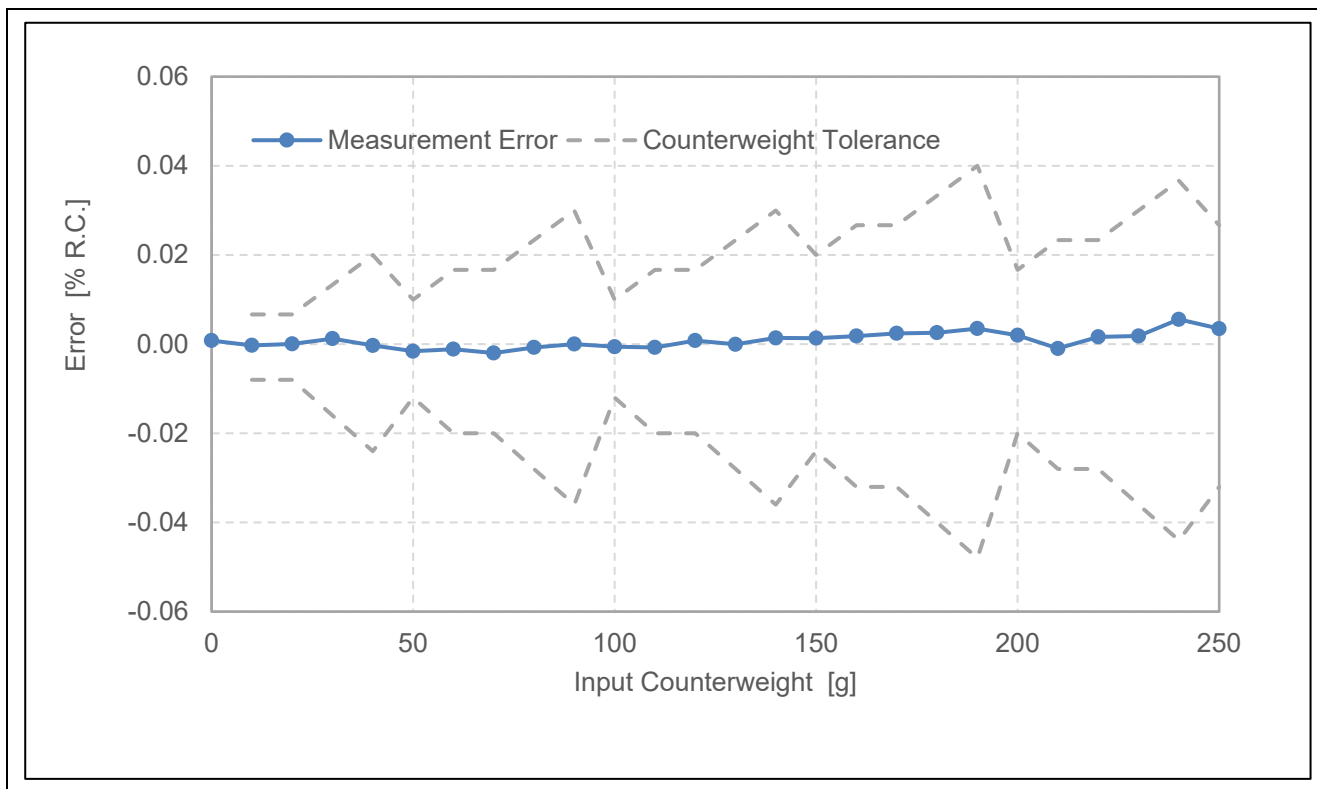
| Weight setting | Combination of counterweights |           |           |           |  |
|----------------|-------------------------------|-----------|-----------|-----------|--|
| 10g            | 10g   x1                      |           |           |           |  |
| 20g            | 20g   x1                      |           |           |           |  |
| 30g            | 10g   x1                      | 20g   x1  |           |           |  |
| 40g            | 10g   x2                      | 20g   x1  |           |           |  |
| 50g            | 50g   x1                      |           |           |           |  |
| 60g            | 10g   x1                      | 50g   x1  |           |           |  |
| 70g            | 20g   x1                      | 50g   x1  |           |           |  |
| 80g            | 10g   x1                      | 20g   x1  | 50g   x1  |           |  |
| 90g            | 10g   x2                      | 20g   x1  | 50g   x1  |           |  |
| 100g           | 100g   x1                     |           |           |           |  |
| 110g           | 10g   x1                      | 100g   x1 |           |           |  |
| 120g           | 20g   x1                      | 100g   x1 |           |           |  |
| 130g           | 10g   x1                      | 20g   x1  | 100g   x1 |           |  |
| 140g           | 10g   x2                      | 20g   x1  | 100g   x1 |           |  |
| 150g           | 50g   x1                      | 100g   x1 |           |           |  |
| 160g           | 10g   x1                      | 50g   x1  | 100g   x1 |           |  |
| 170g           | 20g   x1                      | 50g   x1  | 100g   x1 |           |  |
| 180g           | 10g   x1                      | 20g   x1  | 50g   x1  | 100g   x1 |  |
| 190g           | 10g   x2                      | 20g   x1  | 50g   x1  | 100g   x1 |  |
| 200g           | 200g   x1                     |           |           |           |  |
| 210g           | 10g   x1                      | 200g   x1 |           |           |  |
| 220g           | 20g   x1                      | 200g   x1 |           |           |  |
| 230g           | 10g   x1                      | 20g   x1  | 200g   x1 |           |  |
| 240g           | 10g   x2                      | 20g   x1  | 200g   x1 |           |  |
| 250g           | 50g   x1                      | 200g   x1 |           |           |  |

**Table 11-6 Counterweight Tolerance**

| Weight of counterweight | Counterweight tolerance |
|-------------------------|-------------------------|
| 10g                     | ±20mg                   |
| 20g                     | ±20mg                   |
| 50g                     | ±30mg                   |
| 100g                    | ±30mg                   |
| 200g                    | ±50mg                   |

### 11.2.2 Weight Measurement Accuracy Evaluation Results

The weight measurement error is calculated from the weight measurement results. The result calculated by dividing the error by full by the load cell's rated capacity of 300g is shown in Figure 11-2. Since the error fits within the counterweight tolerance, which shows RX23E-B is sufficient measurement accuracy.



**Figure 11-2 Weight Measurement Error (Ambient Temperature: 25°C)**

## 11.3 Resolution Evaluation

Results of resolution evaluation by the precision calibrator PSC-350 are described in this section by using the RX23E-B-QFN40-WT board and the sample program.

### 11.3.1 Resolution Evaluation Conditions

The system configuration for resolution evaluation is shown in Figure 11-3 and the equipment used for the measurements is shown in Table 11-7. Calibration was performed at two voltages, 0mV and 10mV, according to "6.3 Calibration".

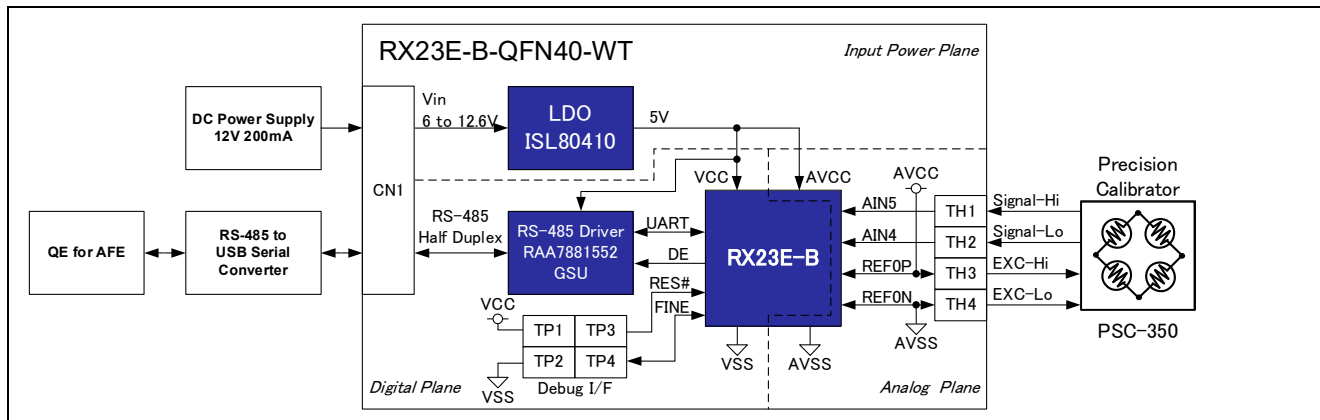


Figure 11-3 Configuration of Resolution Evaluation

Table 11-7 Equipment Used in Resolution Evaluation

| Item                 | Model     | Manufacturer                    |
|----------------------|-----------|---------------------------------|
| Precision Calibrator | PSC-350   | Minebea Mitsumi Inc.            |
| DC Power Supply      | PCR1000MS | KIKUSUI ELECTRONICS CORPORATION |

## 11.3.2 Resolution Evaluation Results

The output voltage of the precision calibrator was 10mV, RX23E-B-QFN40-WT was 10SPS, PGA gain was x128, and the voltage measurement of 1000 samples was performed under the condition of 0 times moving average. The histogram of the average of 1000 samples and the deviation from each data is shown in Figure 11-4. The measurement results are shown in Table 11-8. The input converted noise voltage was 23.8nVrms and the peak-to-peak noise voltage was 140nV.

Based on the noise measurement results, assuming a case of weight measurement using the load cell BCL-300GM-C3 instead of the precision calibrator, the noise weight caused by the measurement system is obtained by removing noise factors caused by the sensor itself and vibration. If the rated capacity of the load cell is 300g, the rated output is 0.9 mV/V, and the excitation voltage is 5V, the weight voltage sensitivity is 15uV/g, so the input equivalent noise weight is 1.58mgrms and the peak-to-peak noise weight is 9.3mg. 10SPS and PGA gain of RX23E-B Although the noise is slightly higher than the input equivalent noise of 18nVrms at x128, it shows that the RX23E-B can perform weight measurement with high accuracy.

**Table 11-8 Resolution Evaluation Result**

|                         |                                                |
|-------------------------|------------------------------------------------|
| Equivalent input noise: | 23.8nVrms (21.6 Bits): equivalent to 1.58mgrms |
| Peak-to-peak noise:     | 140nV (19.1 Bits): equivalent to 9.3mg         |

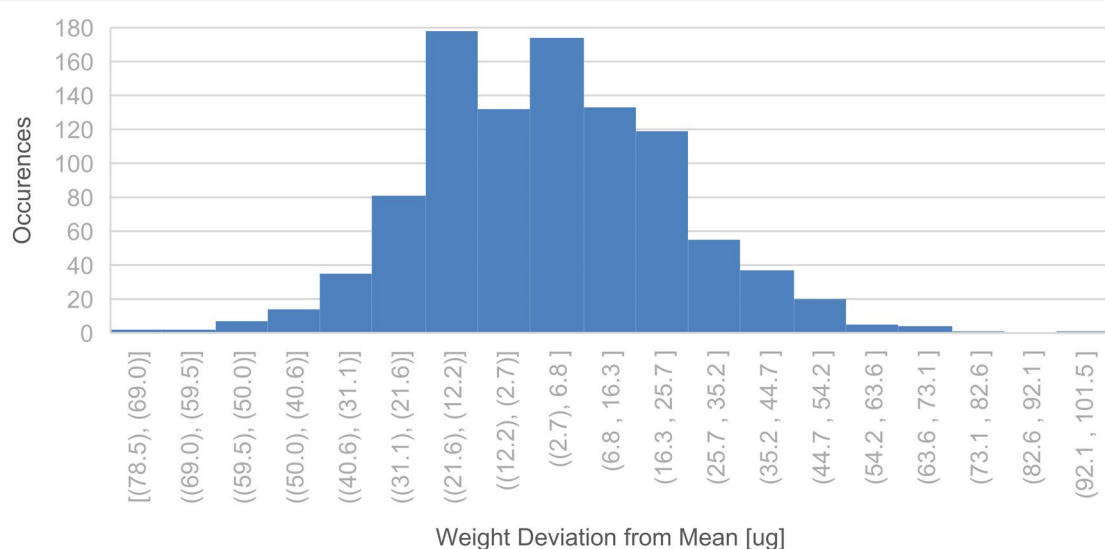


Figure 11-4 Histogram of Errors from the Average of 1000 Sample Measurements at 10mV Input

**Revision History**

| Rev.     | Date      | Description |             |
|----------|-----------|-------------|-------------|
|          |           | Page        | Summary     |
| Rev.1.00 | Oct.31.23 | -           | First issue |
|          |           |             |             |

# General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

## 1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

## 2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

## 3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

## 4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

## 5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

## 6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.).

## 7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

## 8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.

"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

## Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

## Contact information

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