RA2E2 Group

RA2E2 ZMOD4410 Sensor Device Example

Introduction

This document describes a Renesas RA2E2 microcontroller application for a ZMOD4410 sensor device using the RA2E2 Fast Prototyping Board.

Target Device

RA2E2

When applying the sample program covered in this document to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.

Contents

1. Description

1.1 Abstract

The ZMOD4410 sensors device sample is a precision digital sensor featuring indoor air quality using the RA2E2 Fast Prototyping Board.

The RA2E2 Fast Prototyping Board comes equipped with a high-performance RA2E2 microcontroller and is an evaluation board specialized for prototype development for a variety of applications. It has a built-in emulator circuit that is equivalent to an E2 emulator Lite so you can write/debug programs without additional tools. In addition, with Arduino Uno and Pmod™ interfaces included standard and through-hole access to all pins of the microcontroller, and so on, it has high expandability.

The US082-ZMOD4410EVZ Gas Sensor Module is designed for detecting total volatile organic compounds (TVOC) and monitoring indoor air quality (IAQ). It is a 12-pin LGA assembly (3.0 x 3.0 x 0.7 mm) that consists of a gas sense element and a CMOS signal conditioning IC. The module's sense element consists of a heater element on a Si-based MEMS structure and a metal oxide (MOx) chemiresistor. The signal conditioner controls the sensor temperature and measures the MOx conductivity, which is a function of the gas concentration. The measurement results can be read via an I2C interface with the user's microprocessor, which processes the data to determine the TVOC concentration, IAQ rating, and estimated carbon dioxide (eCO2) level. This flexibility makes the sensors in the US082-ZMOD4410EVZ platform capable of providing a variety of measurement options by varying the method of operation or changing the firmware used to interpret the resistance measurements. Downloadable firmware libraries and source code provided by IDT enables detection of TVOC and odors and supports smart devices measuring IAQ that require low-power operation. The US082-ZMOD4410EVZ is ideal for applications such as thermostats, air purifiers, building controls, smart fans, HVAC equipment, and smart devices.

1.2 Specifications and Main Technical Parameters Technical Parameters

• Power Supply	USB power supply (5 V)
• Operating Voltage (MCU)	3.3 V
• Operating Temperature:	Ambient temperature

1.2.1 Specifications

- Function: Detect indoor air quality with US082-ZMOD4410EVZ.

2. RA2E2 Microcontroller

2.1 RA2E2 Block Diagram

Figure 1 shows the block diagram of RA2E2 (24-pin product).

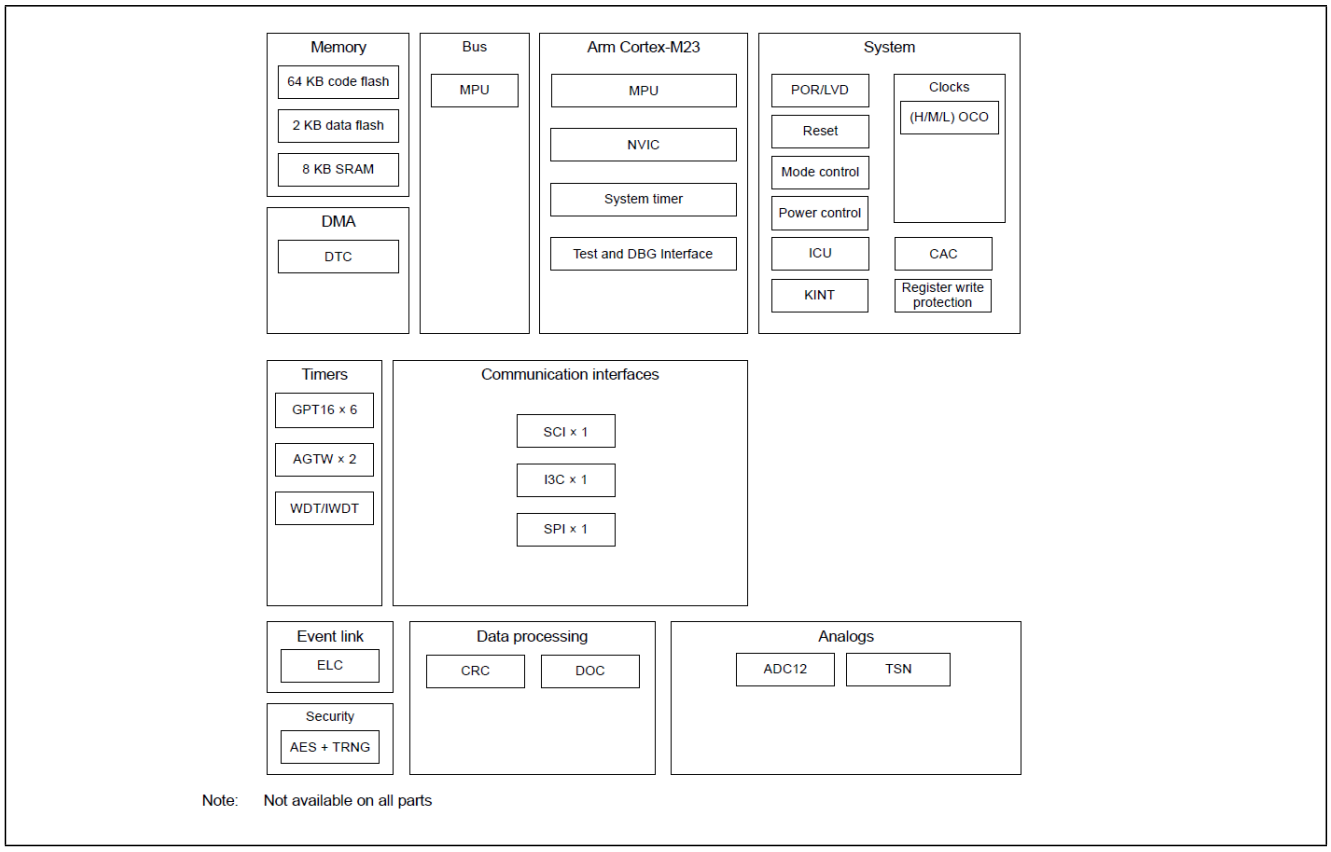

Figure 1. SRA2E2 Block Diagram

2.2 Key Features

- Arm® Cortex®-M23 Core
  - Armv8-M architecture
  - Maximum operating frequency: 48 MHz
  - Arm Memory Protection Unit (Arm MPU) with 8 regions
  - Debug and Trace: DWT, FPB, CoreSight™ MTB-M23
  - CoreSight Debug Port: SW-DP
- Memory
  - Up to 64-KB code flash memory
  - 2-KB data flash memory (100,000 program/erase (P/E) cycles)
  - 8-KB SRAM
  - Memory protection units
  - 128-bit unique ID
- Connectivity
  - Serial Communications Interface (SCI) × 1
    - Asynchronous interfaces
    - 8-bit clock synchronous interface
    - Simple IC
    - Simple SPI
    - Smart card interface
  - Serial Peripheral Interface (SPI) × 1
  - I3C bus interface (I3C) × 1

- Analog
  - 12-bit A/D Converter (ADC12)
  - Temperature Sensor (TSN)
- Timers
  - General PWM Timer 16-bit (GPT16) × 6
  - Low Power Asynchronous General Purpose Timer (AGTW) × 2
  - Watchdog Timer (WDT)
- Safety
  - SRAM parity error check
  - Flash area protection
  - ADC self-diagnosis function
  - Clock Frequency Accuracy Measurement Circuit (CAC)
  - Cyclic Redundancy Check (CRC) calculator
  - Data Operation Circuit (DOC)
  - Port Output Enable for GPT (POEG)
  - Independent Watchdog Timer (IWDT)
  - GPIO readback level detection
  - Register write protection
  - Illegal memory access detection
- Security and Encryption
  - AES128/256
  - True Random Number Generator (TRNG)
- System and Power Management
  - Low power modes
  - Event Link Controller (ELC)
  - Data Transfer Controller (DTC)
  - Key Interrupt Function (KINT)
  - Power-on reset
  - Low Voltage Detection (LVD) with voltage settings
- Multiple Clock Sources
  - High-speed on-chip oscillator (HOCO) (24/32/48/64 MHz)
  - Middle-speed on-chip oscillator (MOCO) (8 MHz)
  - Low-speed on-chip oscillator (LOCO) (32.768 kHz)
  - Clock trim function for HOCO/MOCO/LOCO
  - IWDT-dedicated on-chip oscillator (15 kHz)
  - Clock out support
- Up to 20 pins for general I/O ports
  - 5-V tolerance, open drain, input pull-up
- Operating Voltage
  - VCC: 1.6 to 5.5 V
- Operating Temperature and Packages
  - Ta = -40℃ to +85℃
    - 24-pin HWQFN (4 mm × 4 mm, 0.5 mm pitch)
    - 20-pin HWQFN (4 mm × 4 mm, 0.5 mm pitch)
    - 16-pin WLCSP (1.84 mm × 1.87 mm, 0.4 mm pitch)
  - Ta = -40℃ to +105℃
    - 24-pin HWQFN (4 mm × 4 mm, 0.5 mm pitch)
    - 20-pin HWQFN (4 mm × 4 mm, 0.5 mm pitch)
    - 16-pin WLCSP (1.84 mm × 1.87 mm, 0.4 mm pitch)
  - Ta = -40℃ to +125℃
    - 24-pin HWQFN (4 mm × 4 mm, 0.5 mm pitch)
    - 20-pin HWQFN (4 mm × 4 mm, 0.5 mm pitch)
    - 16-pin WLCSP (1.84 mm × 1.87 mm, 0.4 mm pitch)

2.3 Pin Assignments

Figure 2.2 shows the pin assignments of RA2E2 (24-pin products).

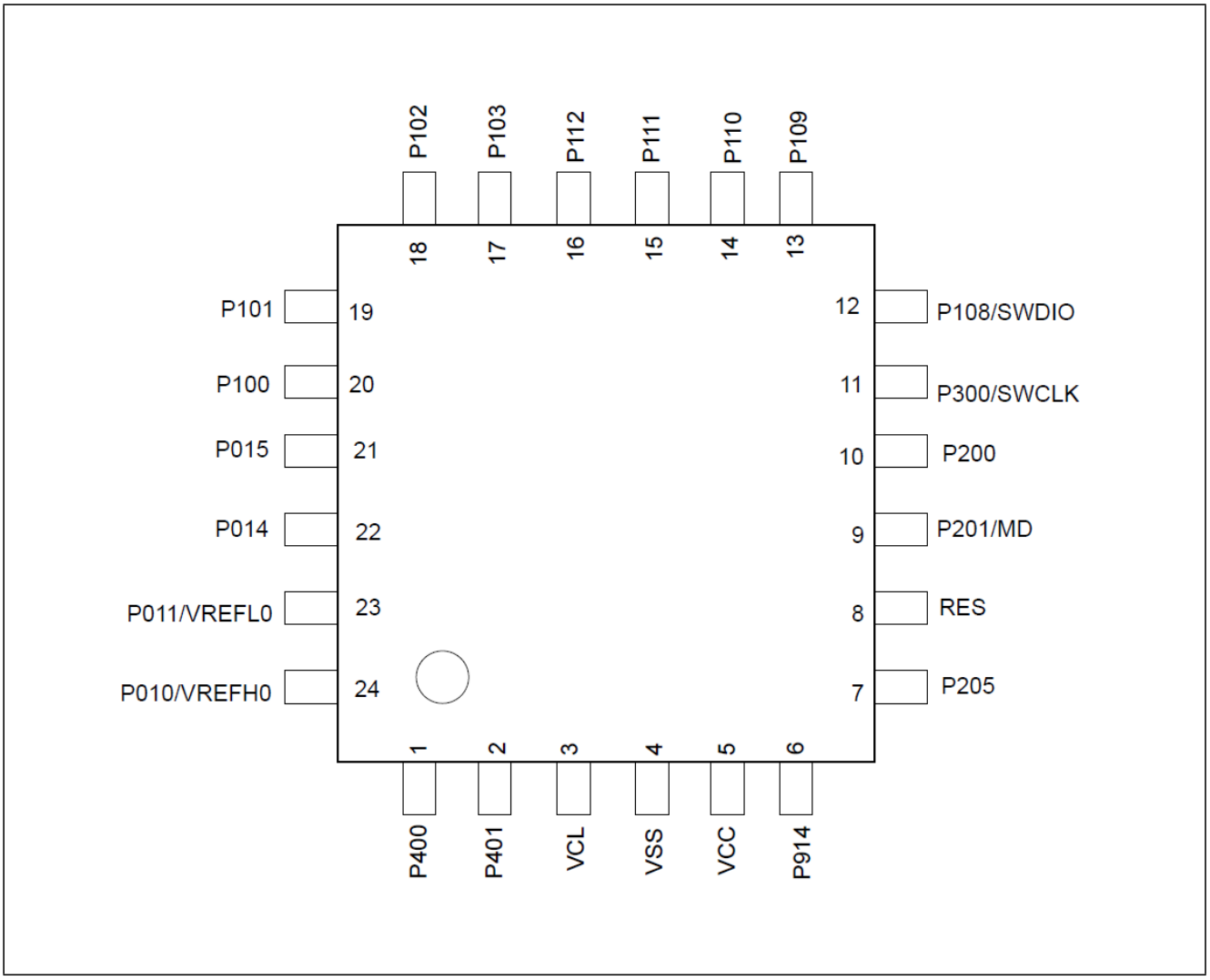

Figure 2. RA2E2 (24-Pin Product) Pin Assignments

3. System Outline

3.1 Principle Introduction

The ZMOD4410 Sensor Device uses an RA2E2 microcontroller and a digital gas sensor. Users can check the sensing data through **Window -> Show View -> Expression** in e^2 studio after the MCU (RA2E2) detects the indoor air quality. Figure 3 shows the system composition. Figure 4 shows the RA2E2 FPB PMOD Interface. Figure 5 shows the connection of RA2E2 FPB and TVOC and Indoor Air Quality Sensor Pmod™ Board (US082-ZMOD4410EVZ).

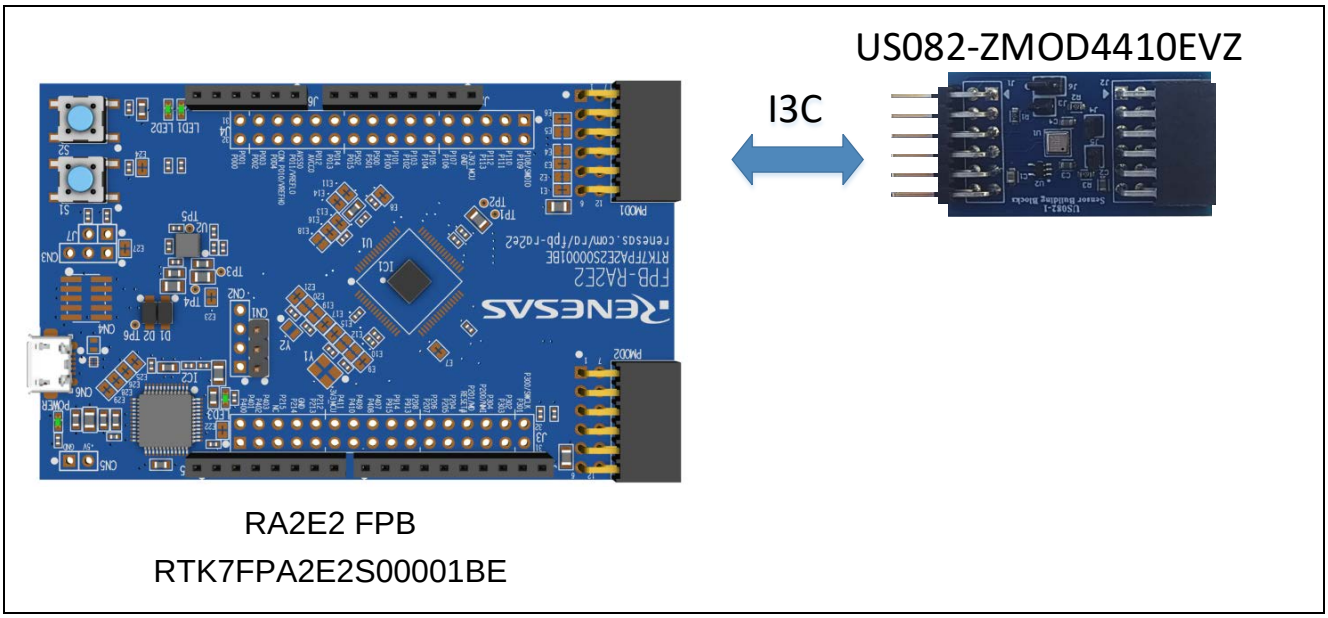

Figure 3. System Composition

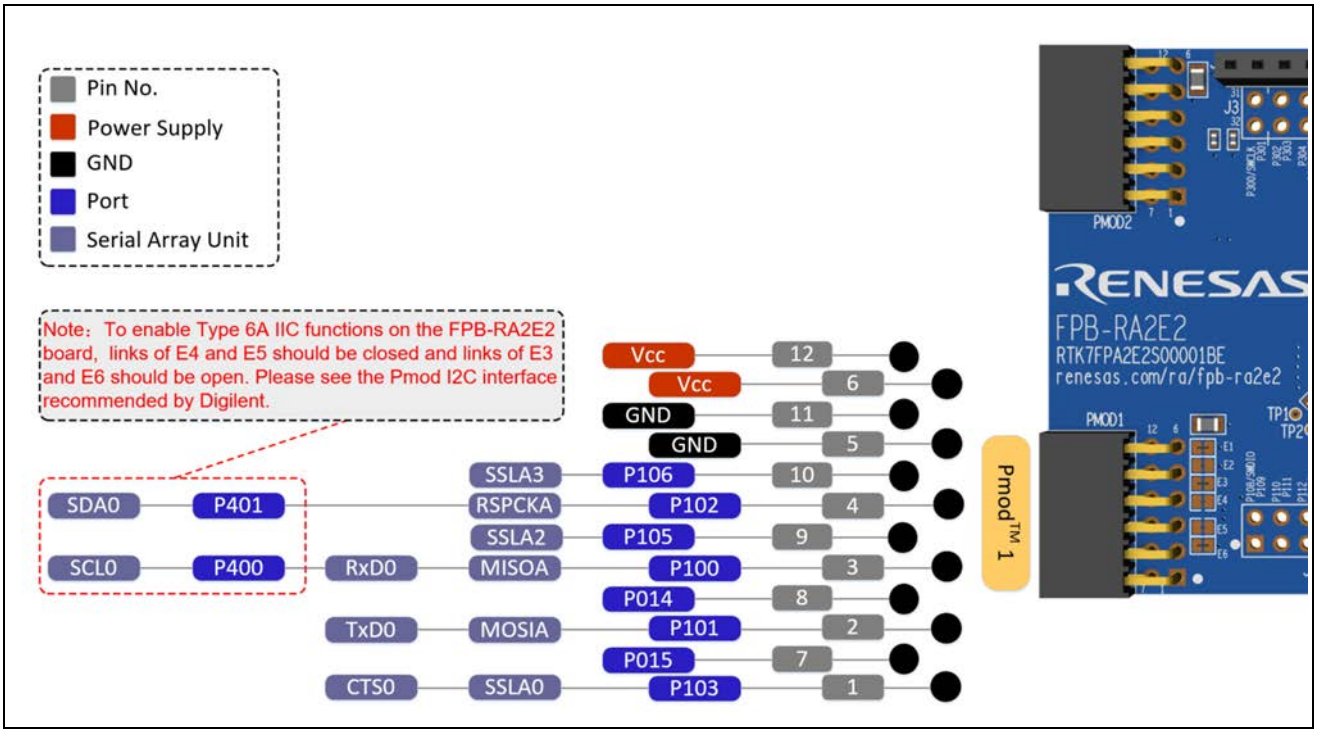

Figure 4. RA2E2 FPB PMOD Interface

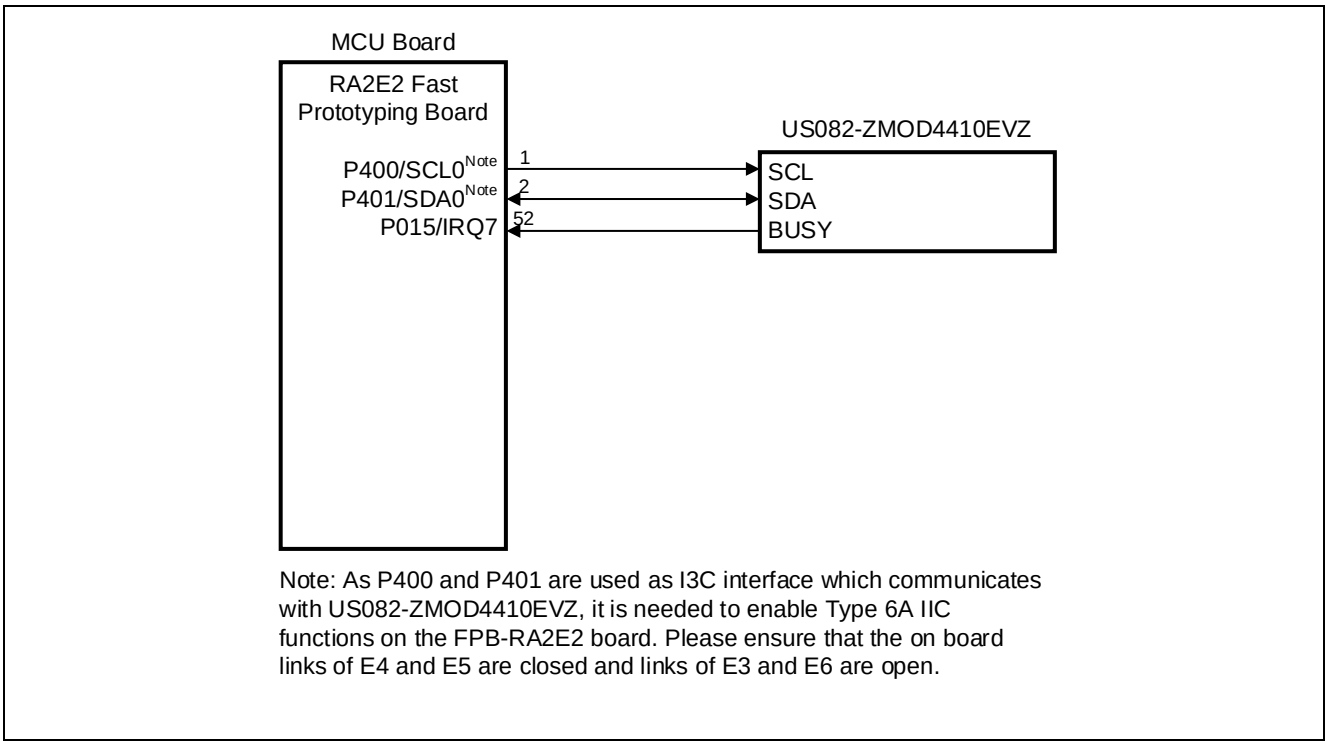

Figure 5. Connection of RA2E2 FPB and US082-ZMOD4410EVZ

3.2 Peripheral Functions to be Used

Table 1 lists the peripheral functions to be used and their usage.

Table 1. Peripheral Functions to be Used

Peripheral Function	Usage
I3C	Get data (IAQ, ECO2 and TVOC) from the sensors.
ICU (IRQ7)	Check if the measurement is complete.

3.3 Pins to be Used

Table 2 lists the pins to be used and their function.

Table 2. Pins to be Used

Pin Name	Description
P400/SCL0	Clock signal: Communicate with sensors (ZMOD4410) through I3C-bus
P401/SDA0	Data signal: Communicate with sensors (ZMOD4410) through I3C-bus
P015/IRQ7	Judge the status of ZMOD4410 through BUSY pin of ZMOD4410
VDD	Power supply voltage
GND	Ground

3.4 Operating Instructions

1. Once powered on, the system begins to initialize.
2. After initialization, the MCU (RA2E2) starts the measurement of ZMOD4410.
3. Wait for the measurement to finish.
4. The MCU (RA2E2) read measurement result from the ZMOD4410.
5. The MCU (RA2E2) will start the next measurement.

Note: The US082-ZMOD4410EVZ Gas Sensor Module is designed for detecting total volatile organic compounds (TVOC) and monitoring indoor air quality (IAQ) in different cases. IDT has adopted the definition of TVOCs and their impact on user health and comfort proposed by the UBA; see Table 3.

Table 3. Level of Air Quality Based on TVOC Levels Described by the UBA

IDT IAQ Rating	Reference Level	Air Information	TVOC (mg/m3)	Air Quality
≤ 1.99	Level 1	Clean Hygienic Air (target value)	< 0.3	Very Good
2.00 to 2.99	Level 2	Good Air Quality (if no threshold value is exceeded)	0.3 to 1.0	Good
3.00 to 3.99	Level 3	Noticeable Comfort Concerns (not recommended for exposure > 12 months)	1.0 to 3.0	Medium
4.00 to 4.99	Level 4	Significant Comfort Issues (not recommended for exposure > 1 month)	3.0 to 10.0	Poor
≥ 5.00	Level 5	Unacceptable Conditions (not recommended)	> 10.0	Bad

4. Hardware

This section describes how the RA2E2 Fast Prototyping Board measures the indoor air quality via US082-ZMOD4410EVZ.

About the details of US082-ZMOD4410EVZ, please refer to the following linkages.

https://www.renesas.com/jp/en/products/sensor-products/environmental-sensors/digital-gas-sensors/us082-zmod4410evz-tvoc-and-indoor-air-quality-sensor-pmod-board-renesas-quick-connect-iot

Figure 6 shows the hardware composition. Figure 7 shows the RA2E2 FPB board layout (top side).

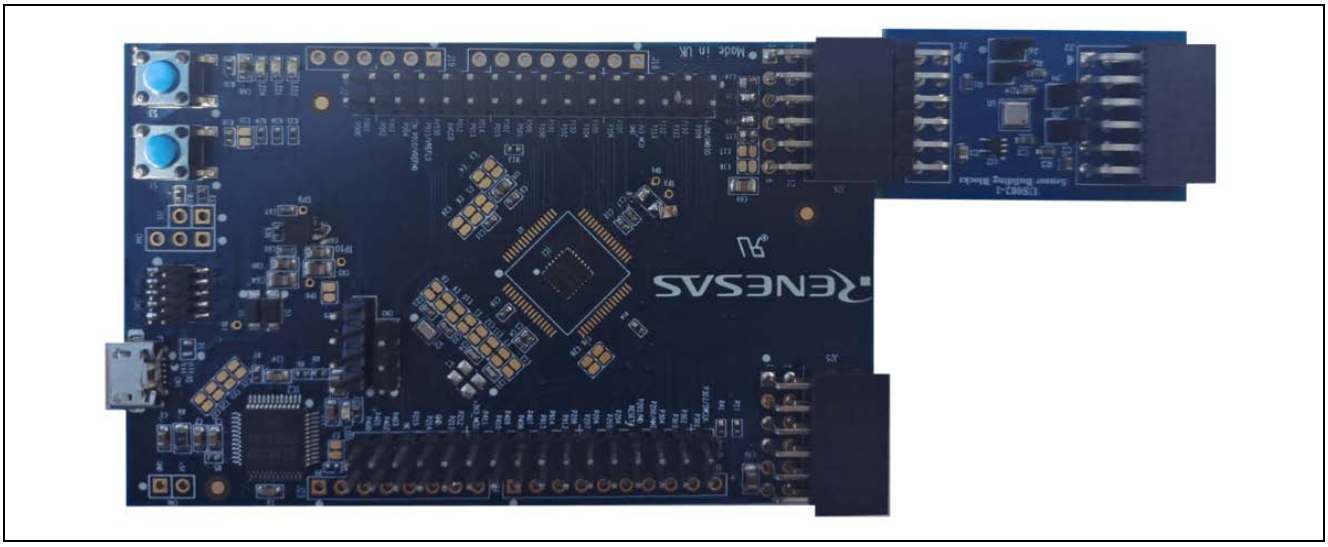

Figure 6. Hardware Composition

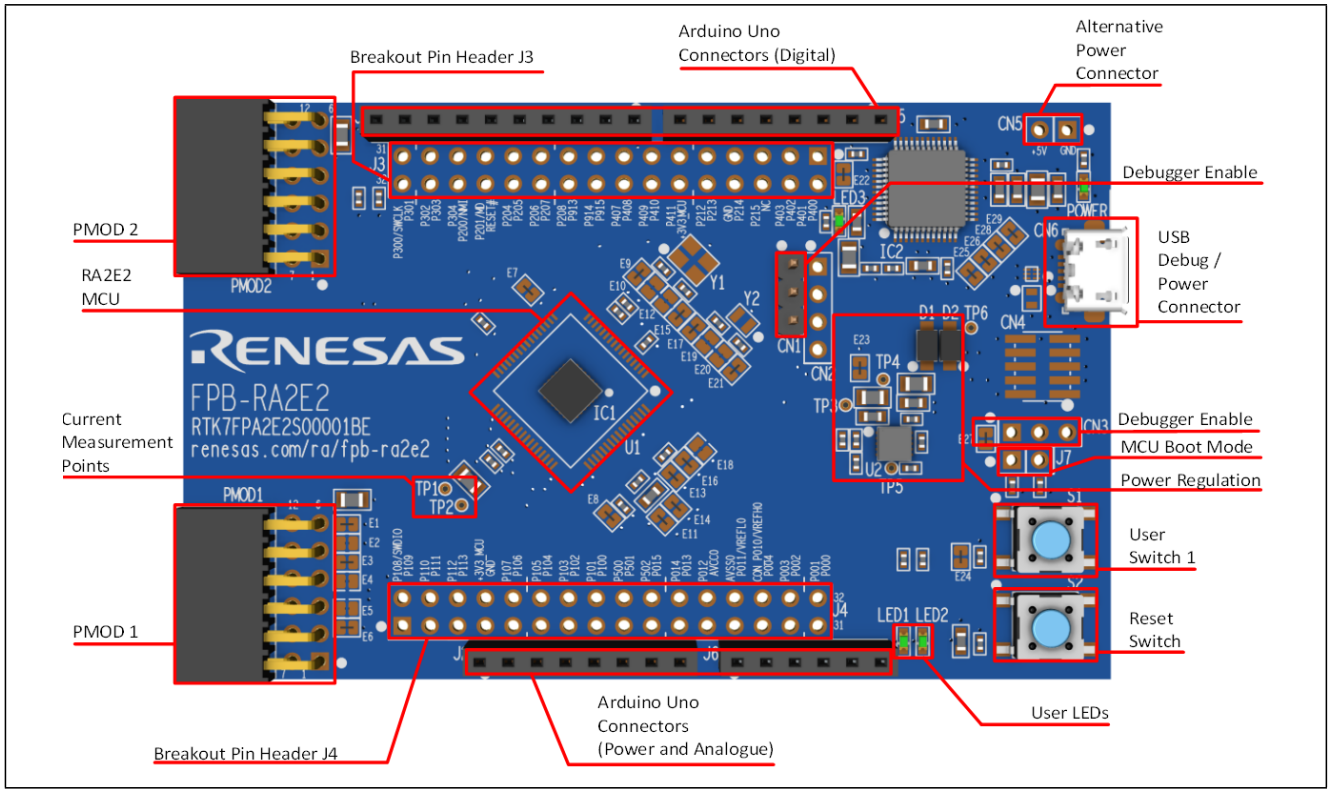

Figure 7. RA2E2 FPB Board Layout (Top Side)

4.1 Schematics

Figure 4.3 shows the schematic of US082-ZMOD4410EVZ via RA2E2 FPB Pmod1 connector.

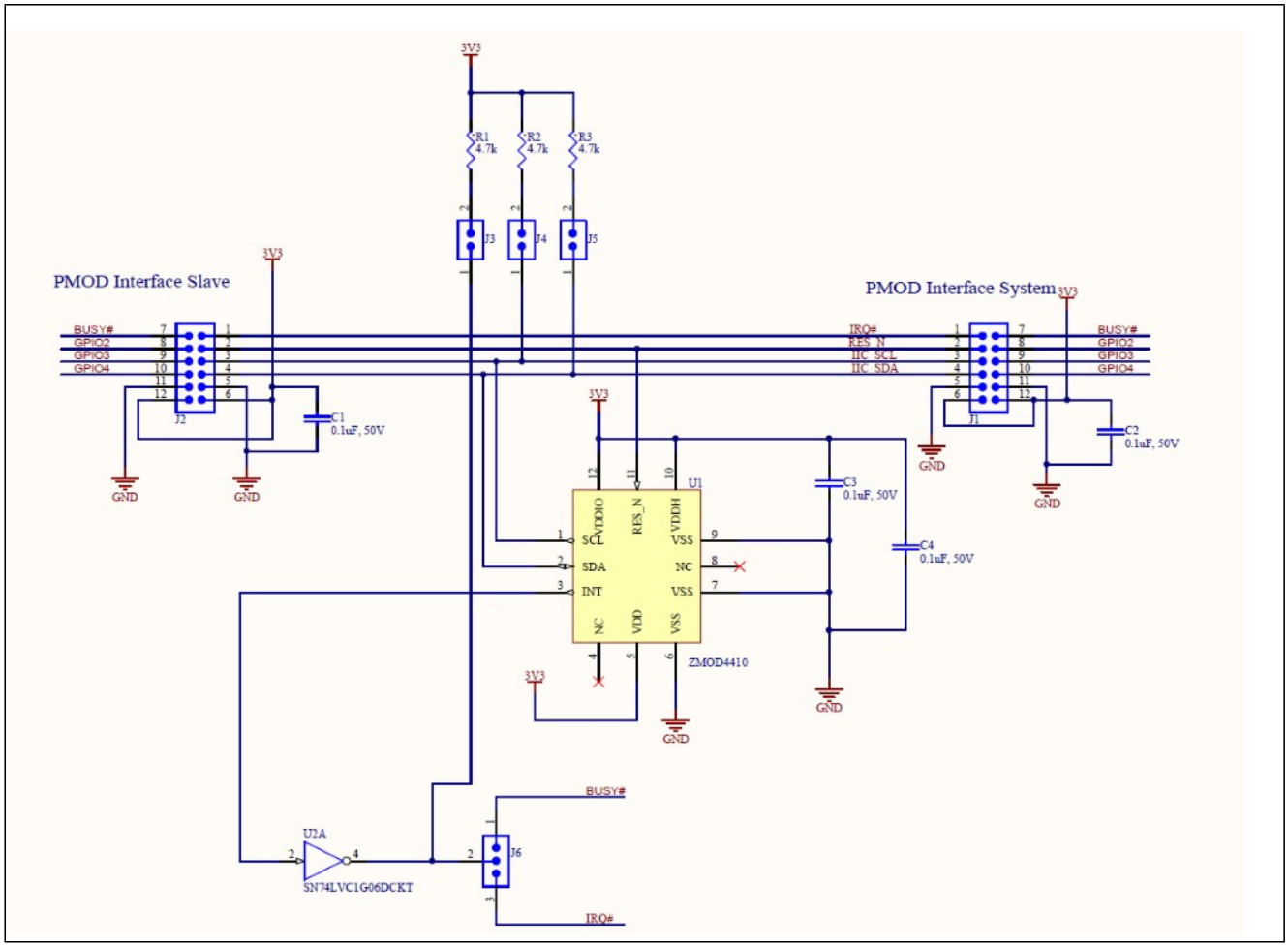

Figure 8. US082-ZMOD4410EVZ Circuit

5. Software

5.1 Integrated Development Environment

The sample code described in this chapter has been checked under the conditions listed in Table 4.

Table 4. Operation Check Conditions

Item	Description
Board	FPB-RA2E2
Device	RA2E2 (R7FA2E2A72DNK)
Operating frequency	High-speed on-chip oscillator (HOCO) clock: 48 MHz System clock (ICLK): 48 MHz Peripheral module clock B (PCLKB): 24 MHz Peripheral module clock D (PCLKD): 48 MHz
Operating voltage	3.3 V (can run on a voltage range of 1.6 V to 5.5 V)
Integrated development environment (e^2 studio)	e^2 studio 2022-01
FSP	3.7.0 from Renesas Electronics Corp.
Toolchain (GCC ARM Embedded)	10.2.1.20201103
Project type	Flat
ZMOD4410 Lib	ZMOD4XXX Gas Sensor (rm_zmod4xxx)

5.2 Operation Outline

The tasks of the entire system are listed as below: Reset/Initialization and Measurement.

5.2.1 Reset/Initialization

When the system is powered on, it will enter the initialization operation. ZMOD4410 is reset and initialized. Then I3C0 and IRQ pin will be initialized.

5.2.2 Measurement Mode

After initialization, the MCU starts the measurement of the sensor. Wait for the measurement to finish. And get the sensor measurement results. Sensor ZMOD4410 needs to wait 1.99 seconds before starting the next measurement.

You can watch the measurement results through the **Expression** window.

5.3 Flow Chart

5.3.1 Main Processing

Figure 9 shows the flowchart for main processing routine.

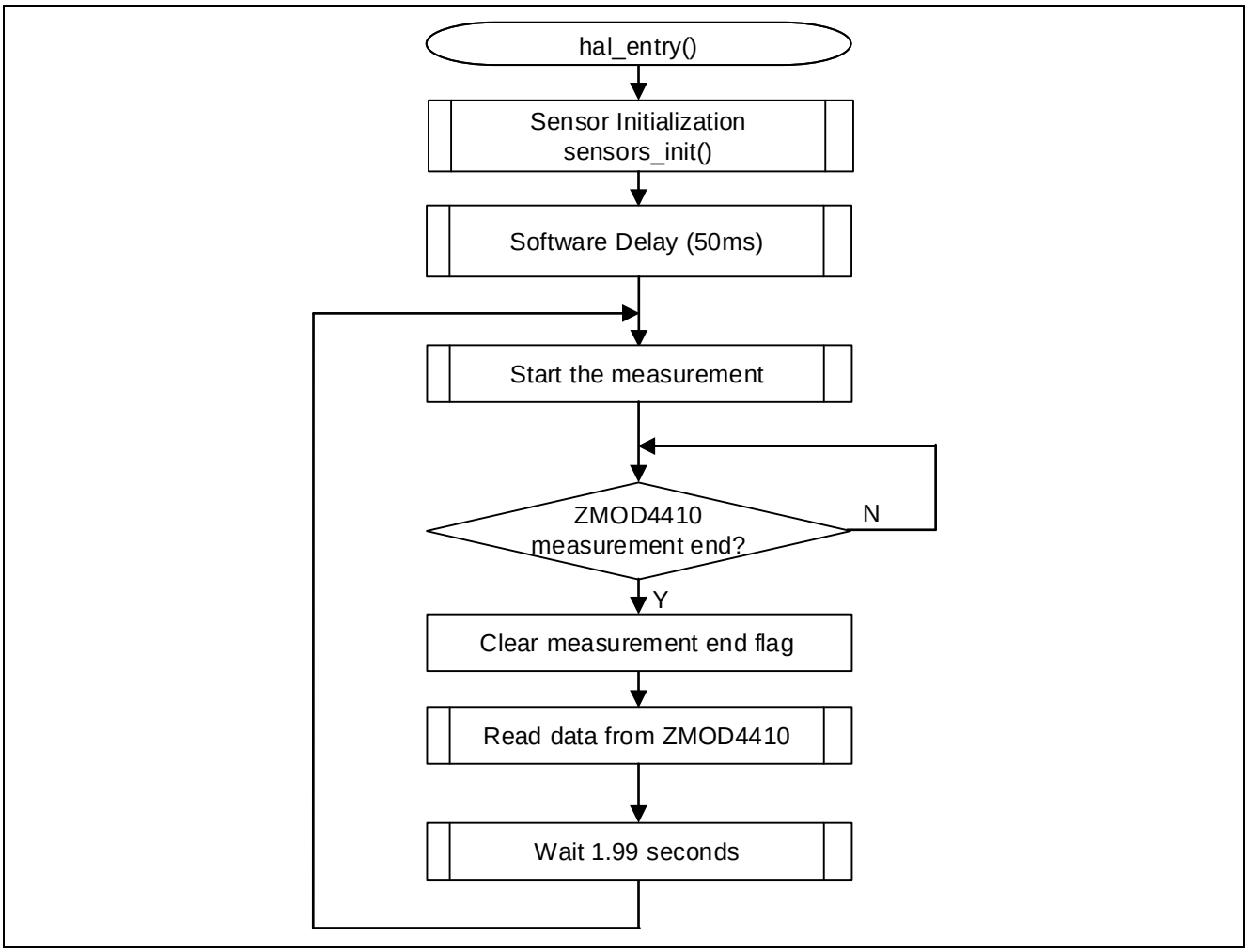

Figure 9. Main Processing

5.4 File Composition

The file composition is shown in Figure 10.

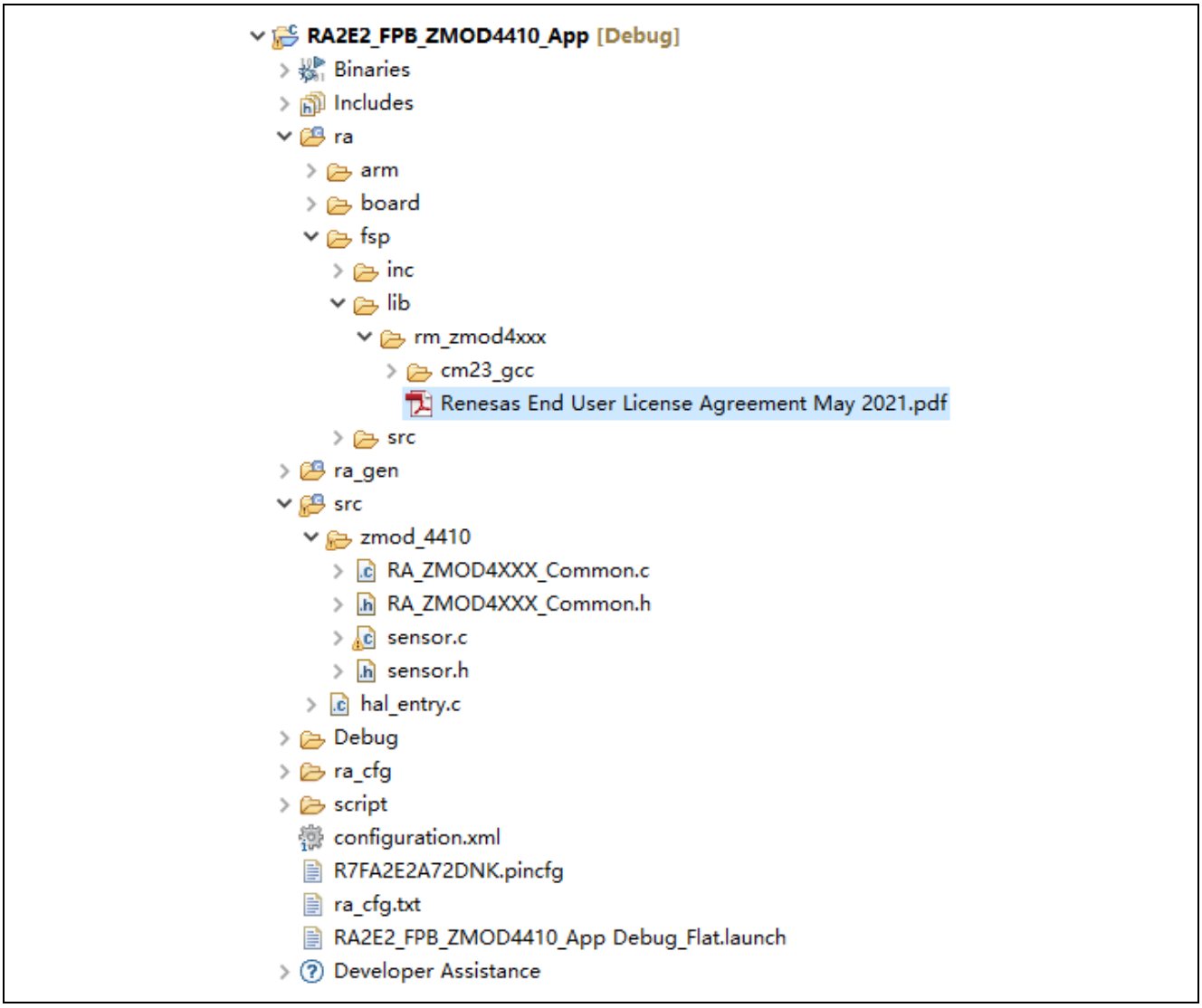

Figure 10. File Composition

6. How to Add Sensor Middleware using FSP in e2studio

1. Launch e2 studio.
2. Create a new project.

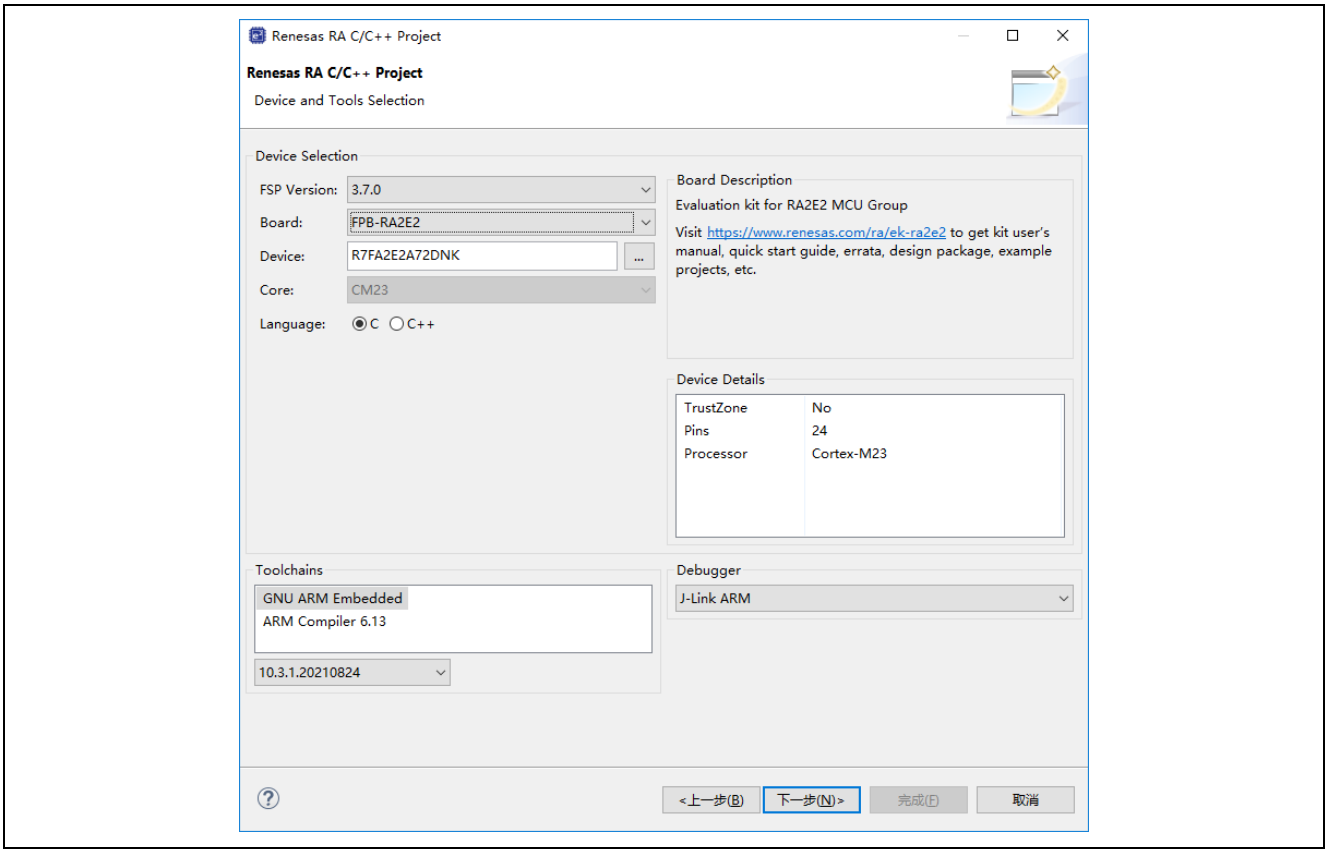

Figure 11. Create New Project

3. Add ZMOD4410 sensor middleware in the **Stacks** tab.

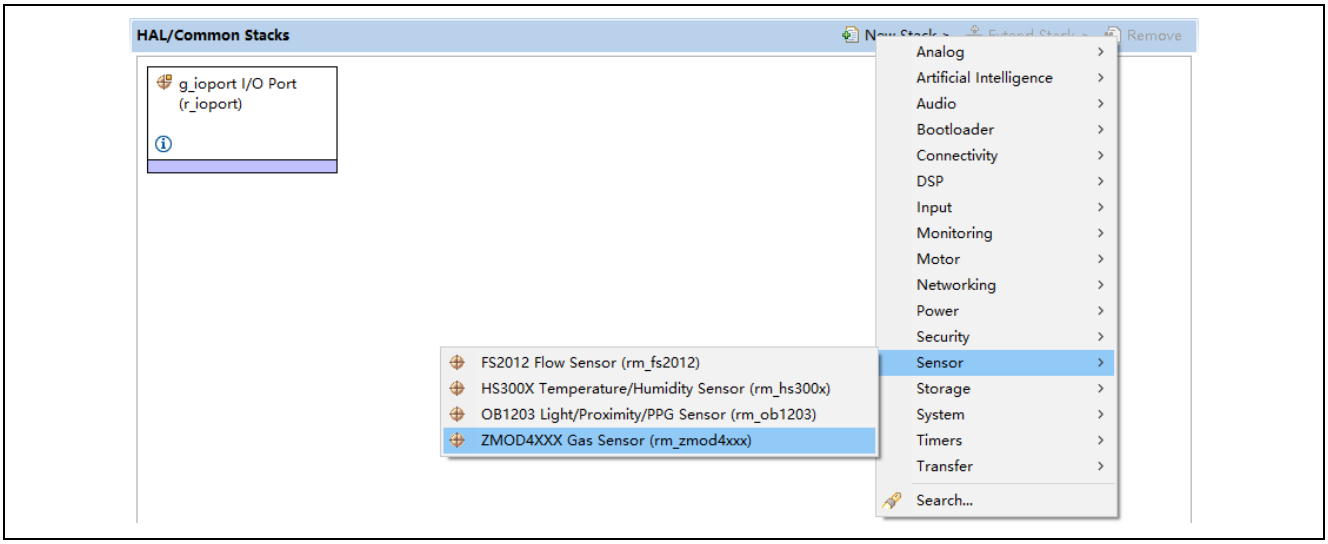

Figure 12. Add to Stacks Tab

4. Add requires ZMOD library. In this application, add **ZMOD4410 IAQ 2nd Generation (rm_zmod4xxx)**.

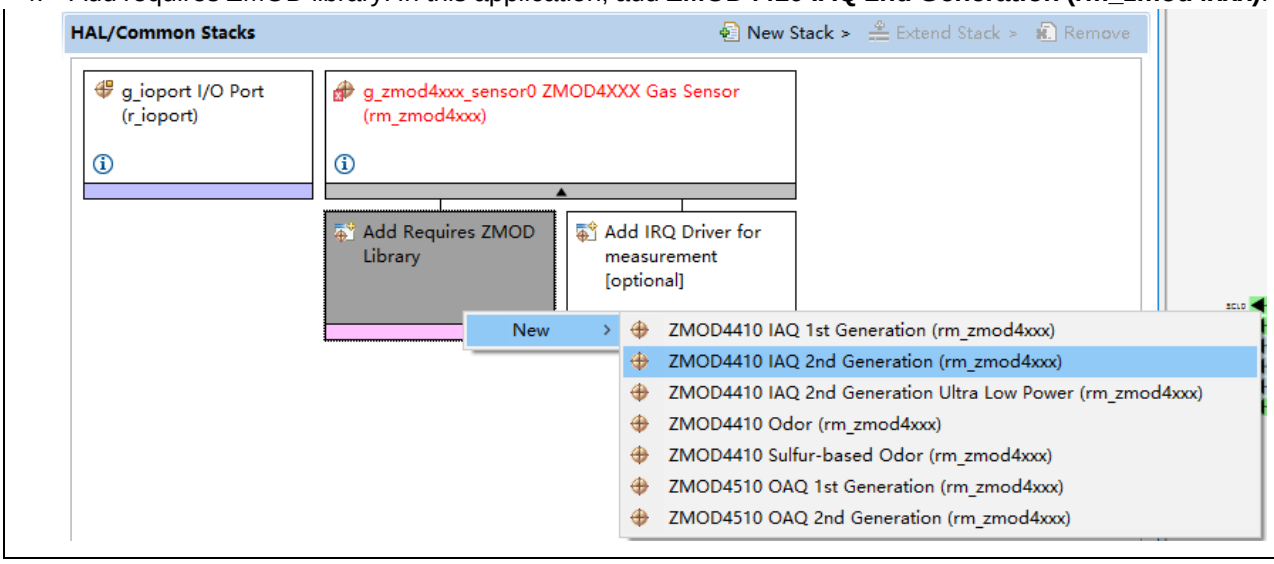

Figure 13. Add ZMOD4410 IAQ 2nd Generation (rm_zmod4xxx)

5. Add r_iic_b_master or r_sci_i2c according to the specifications of the target board.

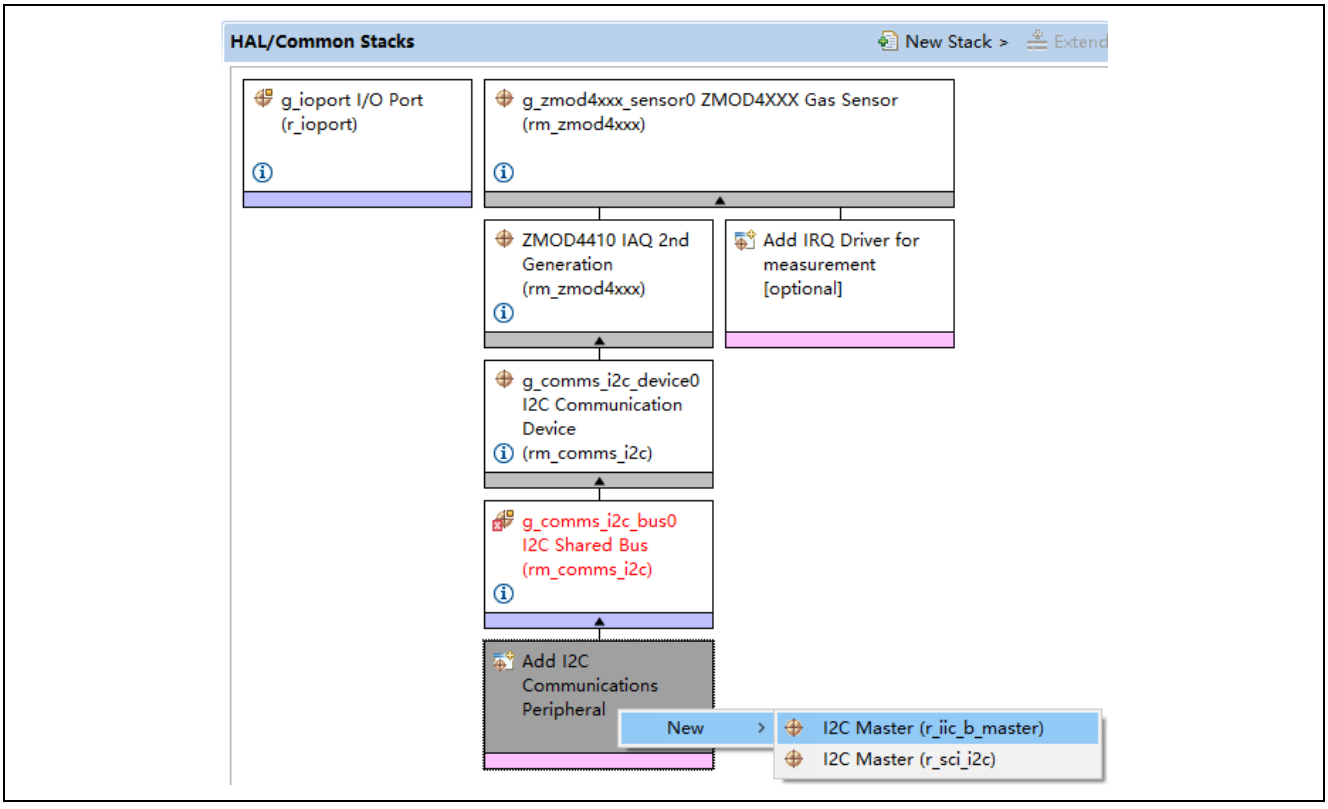

Figure 14. Add r_iic_b_master or r_sci_i2c

6. Add External IRQ driver for measurement.

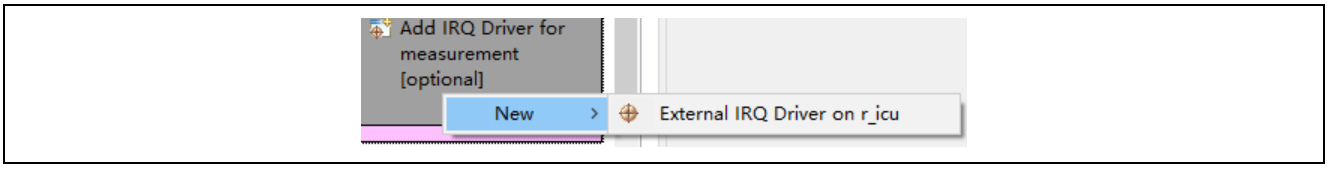

Figure 15. Add External IRQ Driver

7. Set the pins to be used.

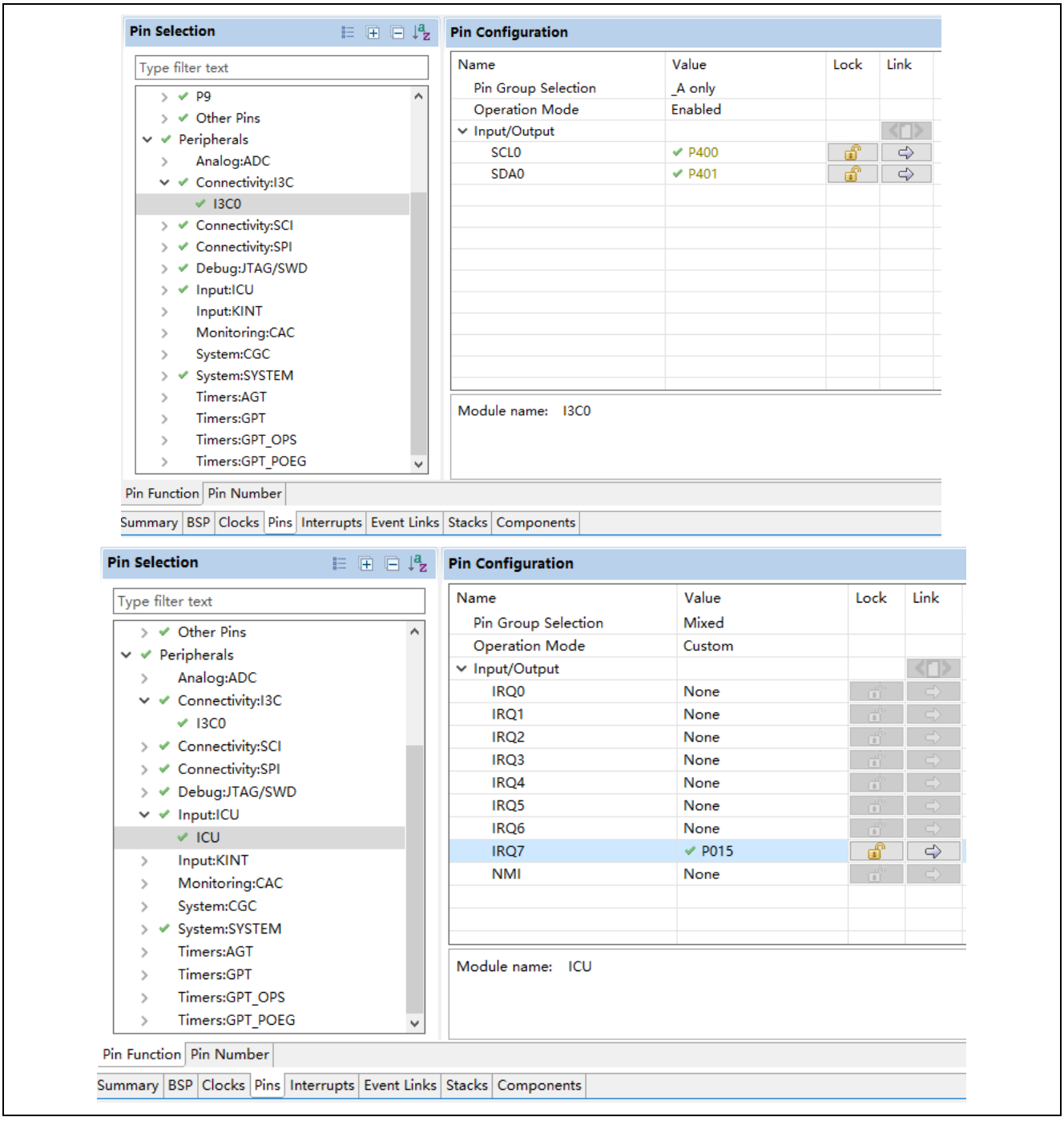

Figure 16. Add Pins to be Used

8. Set the properties of I2C Master Driver and IRQ Driver according to the specifications of the target board.

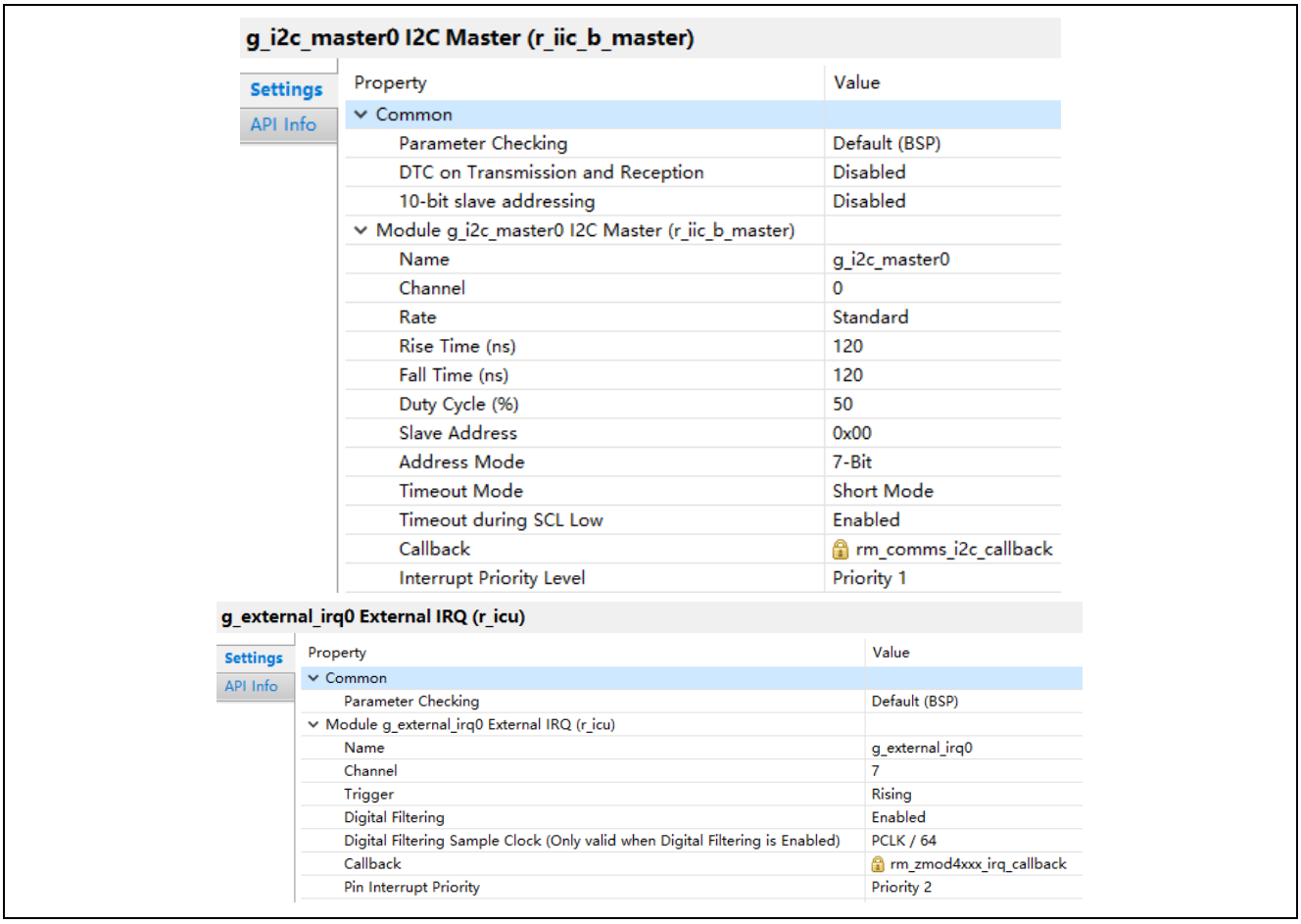

Figure 17. Set Properties of I2C Master Driver and IRQ Driver

7. How to Build the Project and How to Program the Output File

7.1 Build in e² studio

1. Launch e² studio.
2. Right click on the **Project Explorer** and select **Import** from the displayed menu.
3. The **Import** window will be displayed. Select **Existing project to workspace** and click Next.
4. In the **Select root directory** form, select the project folder shown in the Project Folder **RA2E2_FPB_ZMOD4410_App** of e² studio. After selection, confirm that the specified project is displayed in **Project** and click **Finish**. This closes the **Import** window.
5. Right-click on the project displayed on the **Project Explorer** and select **Build Project** to start building.
6. A Motorola S-record file `RA2E2_FPB_ZMOD4410_App.srec` is generated in the path shown in the `Debug` folder of e² studio.

7.2 Writing srec file using Renesas Flash Programmer

This section describes how to write the pre-built Motorola S-record file attached to this application note.

To write the pre-built `.srec` file, it is necessary to mount a header component so that the Fast Prototyping Board can operate stand-alone. For details, refer to section 5.12 Emulator Reset Header in *RA2E2 Fast Prototyping Board User's Manual* (R20UT4969).

1. Launch Renesas Flash Programmer.
2. Select **File -> New Project...** from the menu to create a new project of RA2E2 using E2 lite. For the connection setting **Interface** select **2 wire UART**, for **Power** select **None**.
3. Press the **Browse ...** button in **Program File** on the **Operation** tab to open the `.srec` file `RA2E2_FPB_ZMOD4410_App.srec`.
4. Press the **Start** button to start writing.

(Please close the 2-3 pin header of CN4 when using the Renesas Flash Programmer.)

Note: For Flash Programming or Debugging with IDE (e2studio), 2-3 pin header of CN3 should be OPEN.

After Flash Programming, standalone operation w/o IDE can be enabled by setting 2-3 pin header of CN3 to SHORT.

8. Sample Code

The sample code is available on the Renesas Electronics Website.

9. Reference Documents

- *RA2E2 Fast Prototyping Board* (R20UT4969)
- *RA2E2 User's Manual: Hardware* (R01UH0919)
- *RA Family ZMOD4xxx Sample Application* (R01AN5899)

(The latest versions of the documents are available on the Renesas Electronics Website.)

- Technical Updates/Technical News

(The latest information can be downloaded from the Renesas Electronics Website.)

Website and Support

Visit the following URLs to learn about key elements of the RA family, download components and related documentation, and get support.

RA Product Information	www.renesas.com/ra
RA Product Support Forum	www.renesas.com/ra/forum
RA Flexible Software Package	www.renesas.com/FSP
Renesas Support	www.renesas.com/support

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	May.13.22	—	First release document

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

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

1. Precaution against Electrostatic Discharge (ESD)

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

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

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

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

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

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

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

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

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