RA2E3 Group

RA2E3 HS4001 Low Power Sensor System Example

Introduction

This application note describes an application program which displays the data acquired by the HS400x humidity and temperature sensor operating with an RA Family device on an SSD1306 OLED module.

This program uses Software Standby mode as a low power mode. Compared to the Normal mode, the Software Standby mode minimizes power consumption by stopping the CPU and most peripherals. The MCU spends a long time in Software Standby mode except for the wake-up interrupt handling every 500 milliseconds and the OLED sensor data update processing every 4 seconds. The AGT is used to generate wake-up events.

Target Device

RA2E3

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

Required Resources

The resources required for this application program are as follows.

Hardware

- FPB-RA2E3 Fast Prototyping Board (RTK7FPA2E3S00001BE)
- QCIOT-HS4001POCZ relative humidity sensor Pmod™ board (QCIOT-HS4001POCZ)
- OLED module
  - SSD1306 controller
  - Resolution: 128 x 64 dot matrix panel
  - Power supply: 3.3 V
  - Interface: I2C
  - Slave address: 0x3c (7-bit address)
- Four jumper wires (male-to-female type)

* A separate emulator is not required because SEGGER J-Link™ On-Board will be used.

Development Tools and Software

- e^2 studio IDE version 2025-01
- Renesas Flexible Software Package (FSP) version 5.8.0
- GCC ARM Embedded Toolchain version 13.2.1.arm-13-7

Contents

1. Description

1.1 Abstract

This application program is used to display humidity and temperature in the room on the screen of an SSD1306 OLED module by using the RA2E3 Fast Prototyping Board (FPB-RA2E3) with the QCIOT-HS4001POCZ relative humidity sensor Pmod™ board to acquire the temperature and humidity data. This program runs in Software Standby mode as a low power mode to suppress the operating time of the CPU to a minimum, thus reducing power consumption.

The RA2E3 Fast Prototyping Board comes equipped with an RA2E3 MCU and is an evaluation board specialized for prototype development for a variety of applications. It has a built-in SEGGER J-Link™ On-Board programmer/debugger 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 MCU, and so on, it has high expandability.

HS4001 is a highly accurate, ultra-low power, and fully calibrated relative humidity and temperature sensor. The MEMS sensor features proprietary sensor-level protection ensuring high reliability and long-term stability. The HS4001 is fully calibrated, and temperature compensated with an I2C digital output.

SSD1306 is a graphics display module controlled by I2C using a 128 * 64 organic light emitting diode (OLED). The display module is a representative IC with many libraries available for use with Arduino-compatible boards, Raspberry Pi, etc.

1.2 Main Technical Parameters

Power Supply	USB power supply (5 V)
Operating Voltage (MCU)	3.3 V
OLED Display Pattern	14 characters * 4 rows (128 x 64 dot)

1.3 Specifications

- Detect indoor humidity and temperature with QCIOT-HS4001POCZ.
- Interrupt handling is executed every 500 milliseconds using AGT, and the display of temperature and humidity data on the OLED screen is updated every 4 seconds.
- The Software Standby mode is used as a low power mode to reduce power consumption.

Figure 1.1 shows the MCU states and mode transition events, and Figure 1.2 shows a conceptual diagram of the operation modes and current consumption.

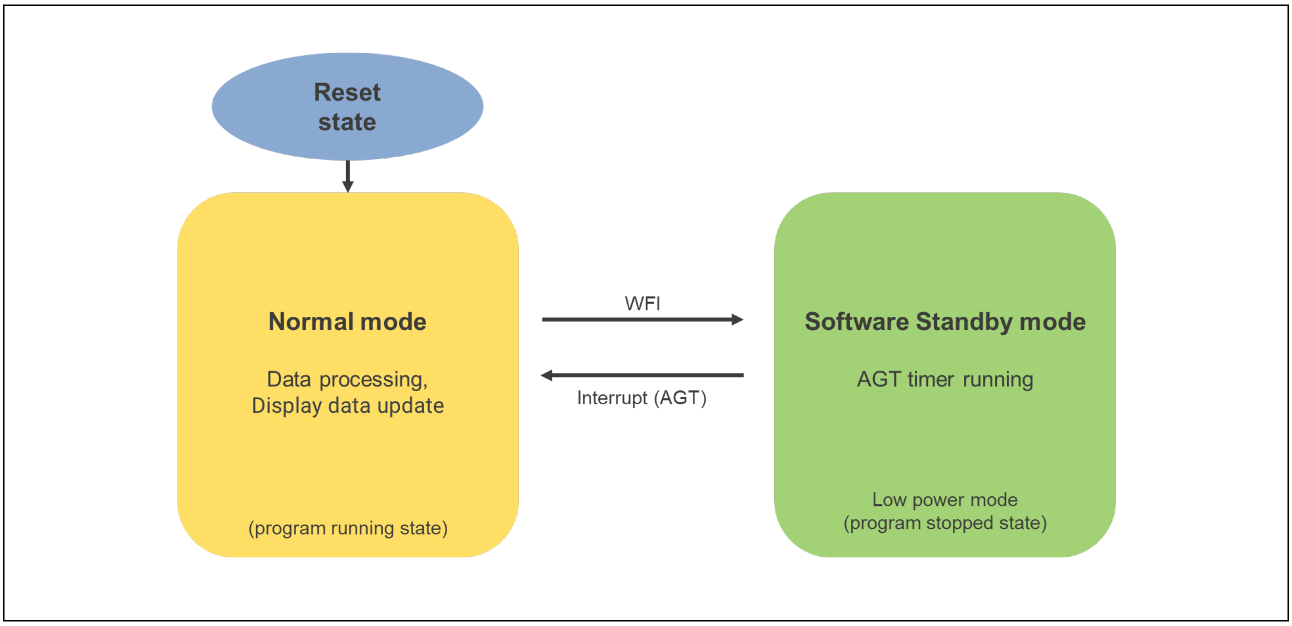

Figure 1.1 MCU Status and Mode Transition Events

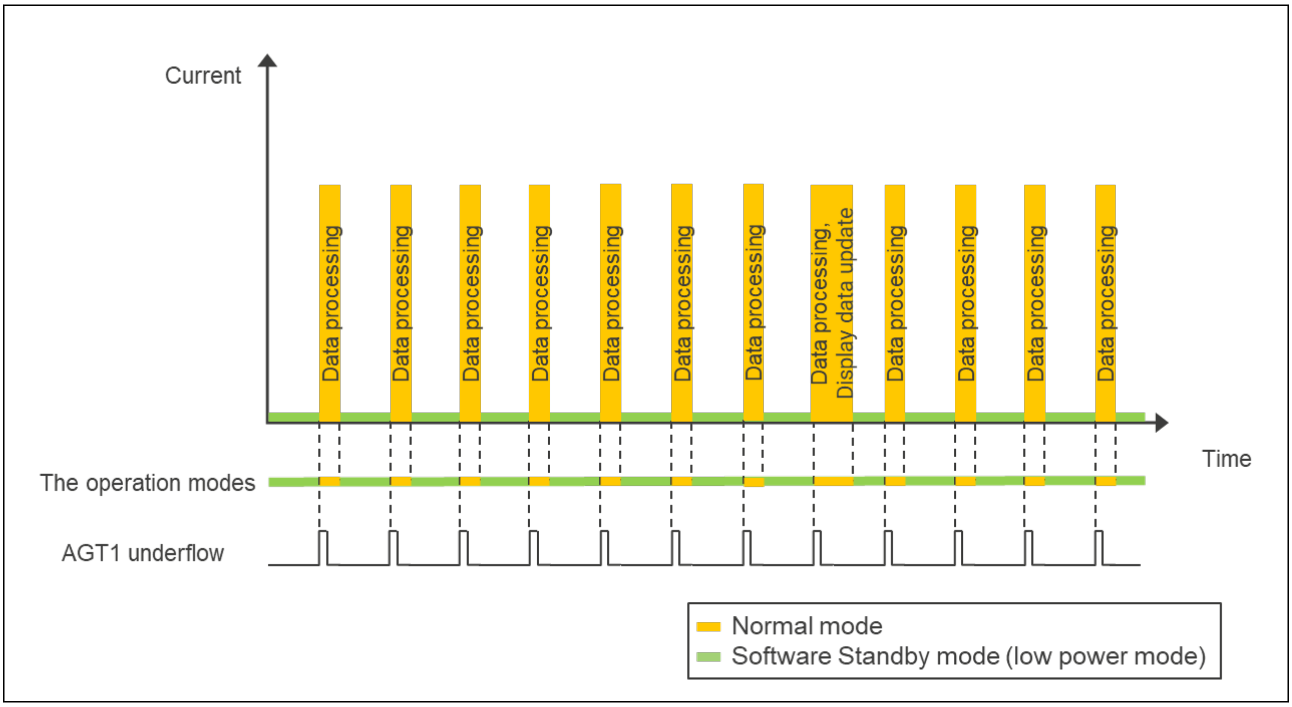

Figure 1.2 Conceptual Diagram of Operation Mode and Current Consumption

2. RA2E3 MCU

The RA2E3 group is an entry-line single-chip MCU in the RA family based on the 48 MHz Arm® Cortex®-M23 core with up to 64KB code flash and 16KB SRAM memory.

RA2E3 MCUs provide an optimized feature set for cost-sensitive applications. Ultra-low power consumption contributes to energy-efficient system design, required for IoT applications and battery-operated systems to achieve longer battery life.

For more details of the RA2E3, please refer to the following link:

http://renesas.com/ra2e3

For more details of specifications, please refer to the following link:

https://www.renesas.com/document/mah/ra2e3-group-users-manual-hardware

RA2E3 User's Manual: Hardware (R01UH0992)

2.1 Block Diagram of the RA2E3

Figure 2.1 shows the block diagram of the RA2E3.

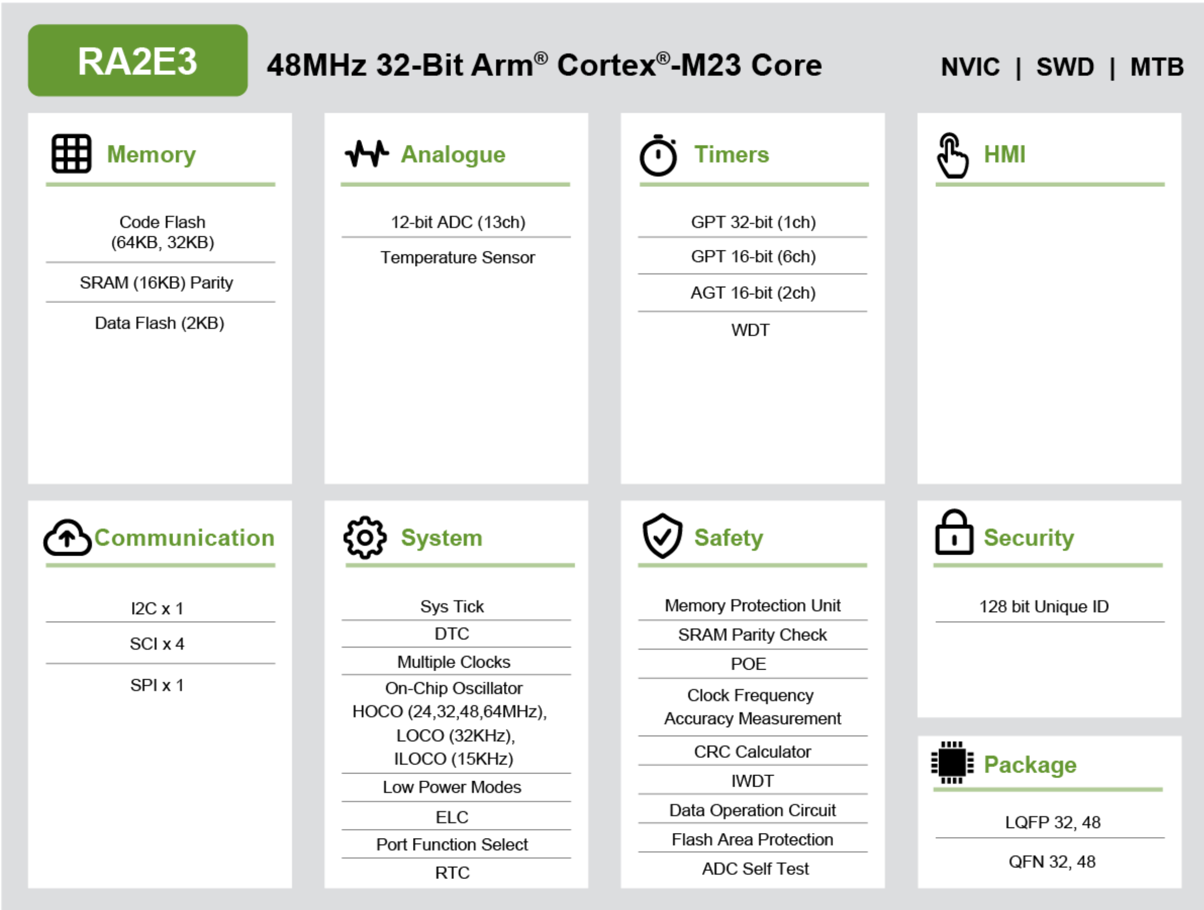

Figure 2.1 Block Diagram of the RA2E3

2.2 RA2E3 Low Power Modes

The table "Operating conditions of each low power mode" in the RA2E3 User's Manual (R01UH0992) describes the conditions for transitions to low power modes, the states of the CPUs and peripheral modules, and the condition for release from each mode.

The available low power modes are as follows:

- Sleep mode
- Software Standby mode
- Snooze mode

The Software Standby mode minimizes power consumption by stopping the CPU and most peripherals while retaining the contents of SRAM. The MCU can wake up from this mode by an external interrupt, RTC alarm, or AGT underflow event. The following peripherals remain operational in Software Standby mode.

- AGT (Low Power Asynchronous General Purpose Timer): Can continue counting and trigger wake-up.
- RTC: Can generate an alarm-based wake-up.
- IRQ pins: Can wake up the MCU upon receipt of an external signal.
- IIC and other communication peripherals: Remain disabled until a wake-up event occurs.

3. System Outline

3.1 Introduction

The application program uses an RA2E3 MCU, a digital temperature and humidity sensor and OLED display module. After the MCU (RA2E3) has detected the temperature and humidity in the room, the user can check the data on the OLED screen.

An interrupt by AGT is generated every 500 milliseconds, and the MCU acquires temperature and humidity data and updates the OLED display every 4 seconds.

In addition, this program runs in Software Standby mode as a low power mode while CPU operation is not required.

Figure 3.1 shows the system configuration.

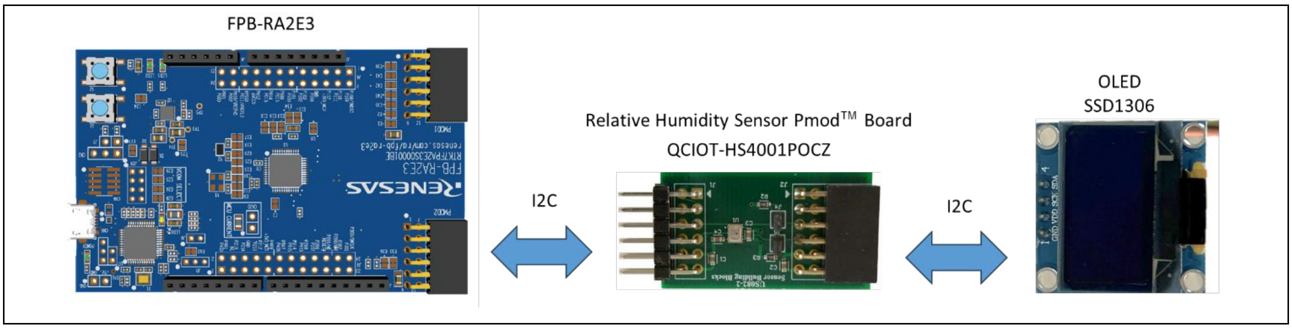

Figure 3.1 System Configuration

3.2 Peripheral Functions to be Used

Table 3.1 lists the peripheral functions to be used and their usage.

Table 3.1 Peripheral Functions to be Used

Peripheral Function	Usage
I2C (IIC0)	Get data (temperature and humidity) from the sensors.
	Control the OLED to display temperature and humidity.

AGT1	Count clock cycles every 500 milliseconds.

3.3 Pins to be Used

Table 3.2 lists the pins to be used and their function.

Table 3.2 Pins to be Used

Pin Name	Description
P400/SCL0	Clock signal: Communicate with sensor (HS4001) and OLED through I2C bus
P401/SDA0	Data signal: Communicate with sensor (HS4001) and OLED through I2C bus
VDD	Power-supply voltage
GND	Ground

3.4 Operating Procedure

1. Once power is supplied, system initialization begins.
2. After initialization, the OLED (SSD1306) displays “RENESAS” and the demonstration title.
3. After AGT starts counting, it generates an interrupt every 500 milliseconds to cancel Software Standby mode.
4. After executing timer interrupt processing, the MCU (RA2E3) operates in Software Standby mode as a low power mode and waits for the next interrupt from the AGT. The transition between Software Standby mode and Normal mode is repeated until Software Standby mode is canceled 8 times (4 seconds have passed).
5. The MCU (RA2E3) sends the temperature and humidity data that have been acquired to the OLED (SSD1306) every four seconds to update the display of the data on the OLED screen.

Display pattern

R	E	N	E	S	A	S							
F	P	B	-	R	A	2	E	3		D	E	M	O
T	e	m	p		x	x	.	x	C				
H	u	m	i		x	x	.	x	%				

4. Hardware

This section describes the hardware products and configurations of connections used by the application program.

For details of the QCIOT-HS4001POCZ, please refer to the following link:

https://www.renesas.com/en/products/sensor-products/environmental-sensors/humidity-temperature-sensors/qciot-hs4001pocz-relative-humidity-sensor-pmod-board

For details of the SSD1306, please refer to the following link:

https://www.solomon-systech.com/product/ssd1306/

Figure 4.1 shows the FPB-RA2E3 PMOD Interface. Figure 4.2 shows the connection of FPB-RA2E3, QCIOT-HS4001POCZ and SSD1306. Figure 4.3 shows the hardware configuration.

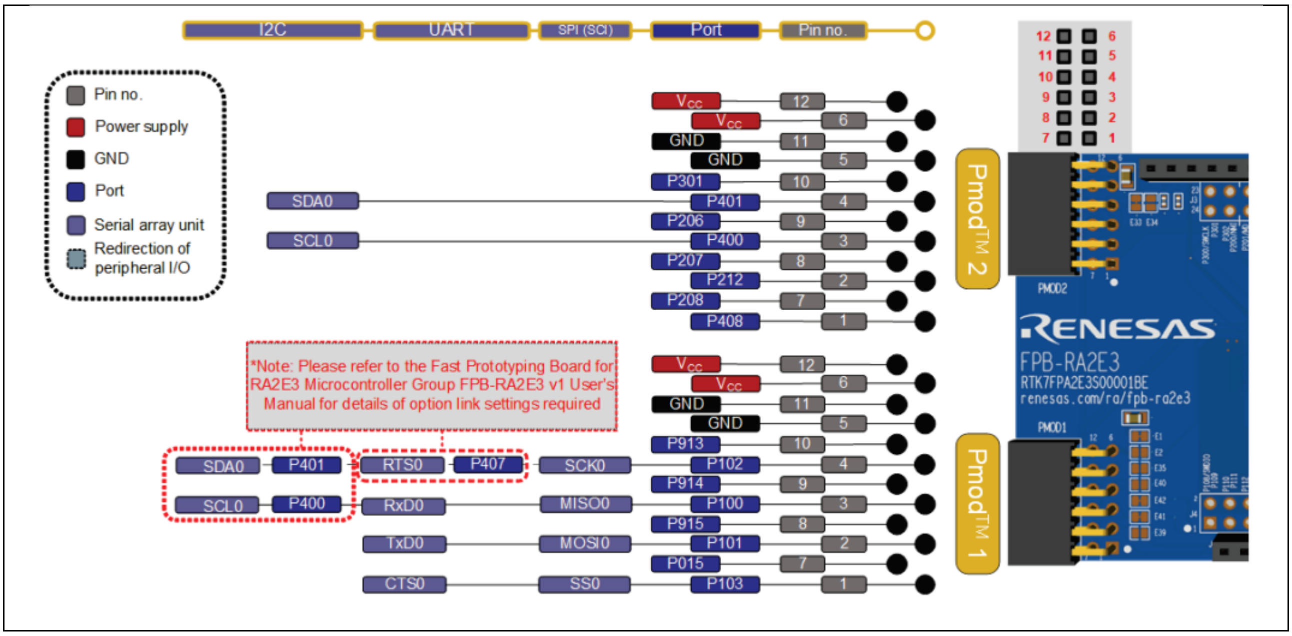

Figure 4.1 FPB-RA2E3 PMOD Interface

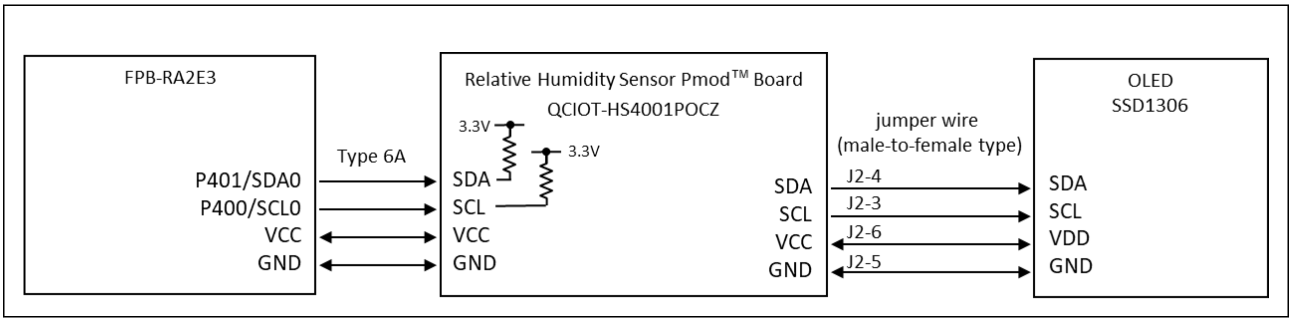

Figure 4.2 Connection of FPB-RA2E3, QCIOT-HS4001POCZ and SSD1306

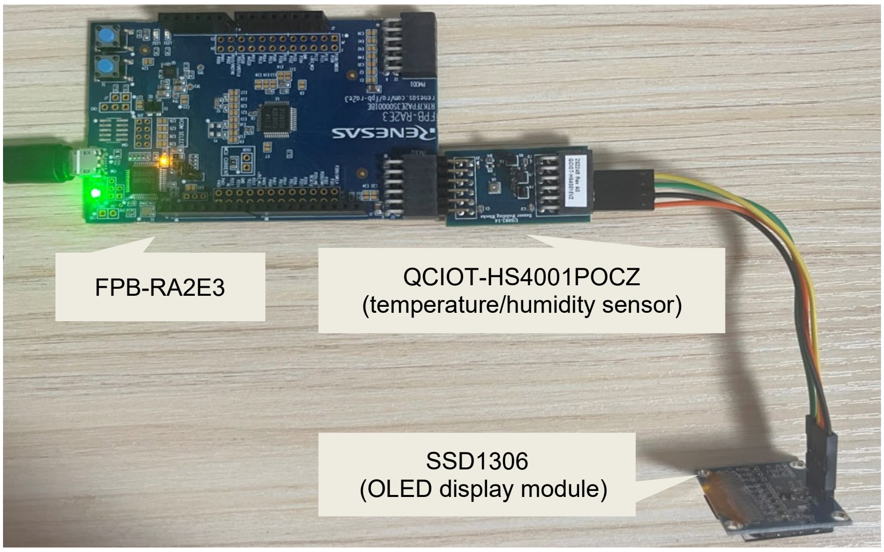

Figure 4.3 Hardware Configuration

5. Software

5.1 Integrated Development Environment

The sample project described in this chapter has been checked under the conditions listed in Table 5.1.

Table 5.1 Operation Check Conditions

Item	Description
Board	FPB-RA2E3
Device	RA2E3 (R7FA2E3073CFL)
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
Integrated development environment (e^2 studio)	e^2 studio 2025-01
FSP	5.8.0 from Renesas Electronics Corp.
Toolchain (GCC ARM Embedded)	13.2.1.arm-13-7
HS4001 Library	HS400X Temperature/Humidity Sensor (rm_hs400x)
Low Power Modes driver	Low Power Modes (r_lpm)
Timer driver	Timer, Low-Power (r_agt)

5.2 Operation Outline

(1) Reset / Initialization

When power is supplied to the system, it will enter the processing for initialization. Power is supplied to the OLED and the display is cleared. After that, it displays “Renesas Electronics” and other characters by default. HS4001 is initialized. IIC0 and I/O pins are also initialized.

Figure 5.1 Initialized OLED Screen

(2) Measurement mode

After initialization, the MCU starts to get the sensor measurement data.

(3) Display mode

After measurement, the MCU sends the information to the OLED for display.

Figure 5.2 Screen Displaying the Temperature and Humidity Data

5.3 Flowcharts

5.3.1 Main Processing

Figure 5.3 shows the flowchart of the main processing.

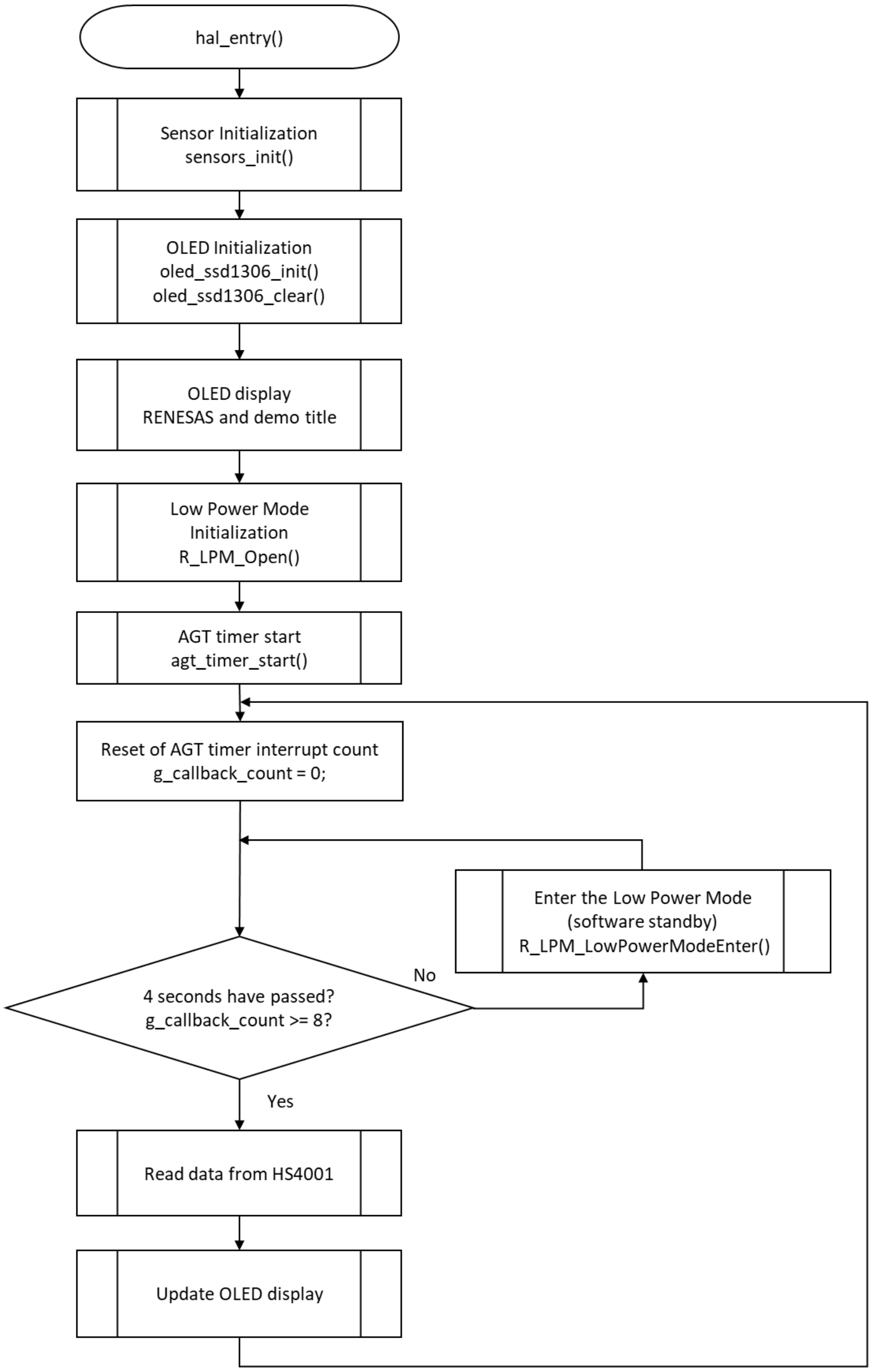

Figure 5.3 Main Processing

5.3.2 Timer Interrupt Handling

Figure 5.4 shows the flowchart of the timer interrupt handling.

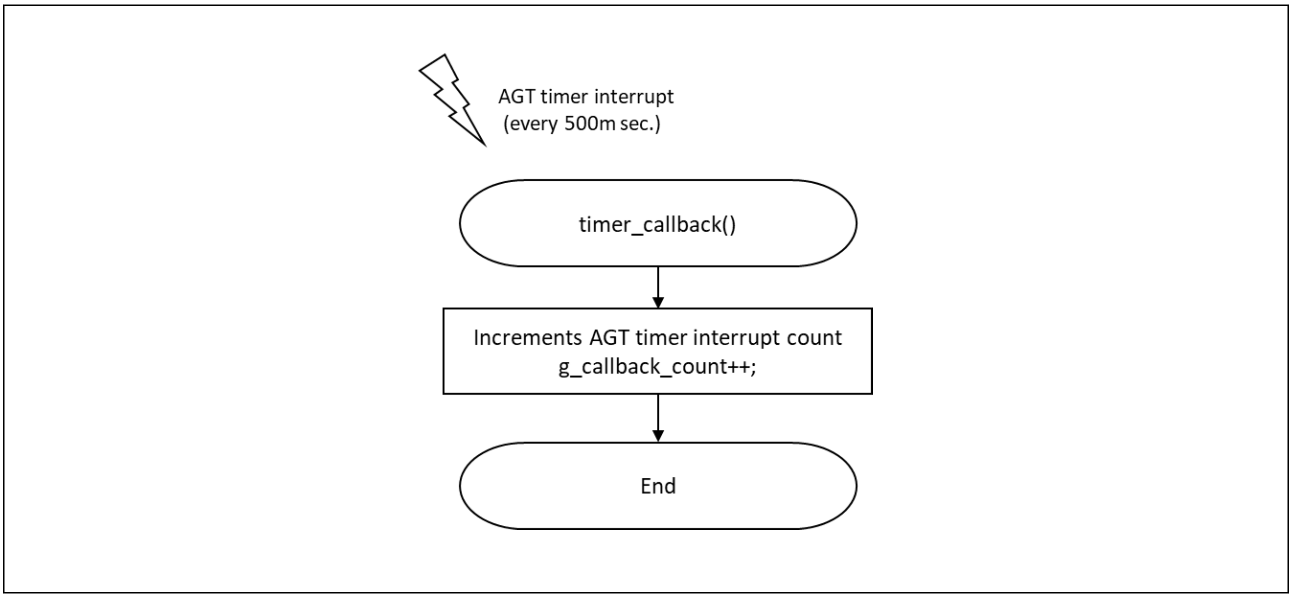

Figure 5.4 Timer Interrupt Handling

5.4 File Structure

The file structure is shown below.

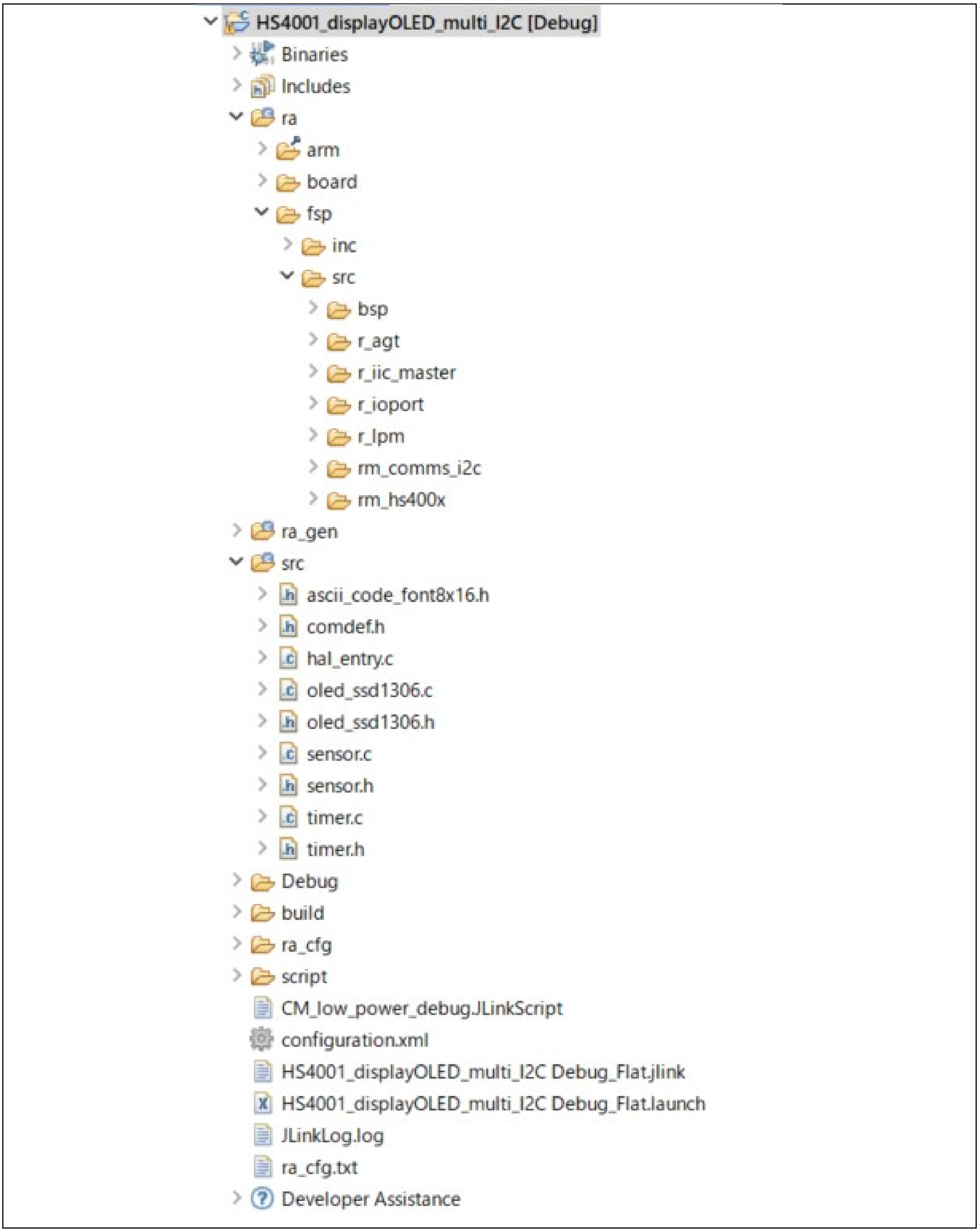

Figure 5.5 File Structure

6. How to Add Middleware and Driver by Using the FSP in e² studio

This section introduces how to add the middleware and HAL driver stacks in the configurator. The introduced stacks are required for the application program. The application program can be used by importing the project. Refer to chapter 7, How to Import and Build the Project, for the procedure of importing.

6.1 HS400X Temperature/Humidity Sensor

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

   Select RA > RA2E3 > FPB-RA2E3 from […] for [Board].

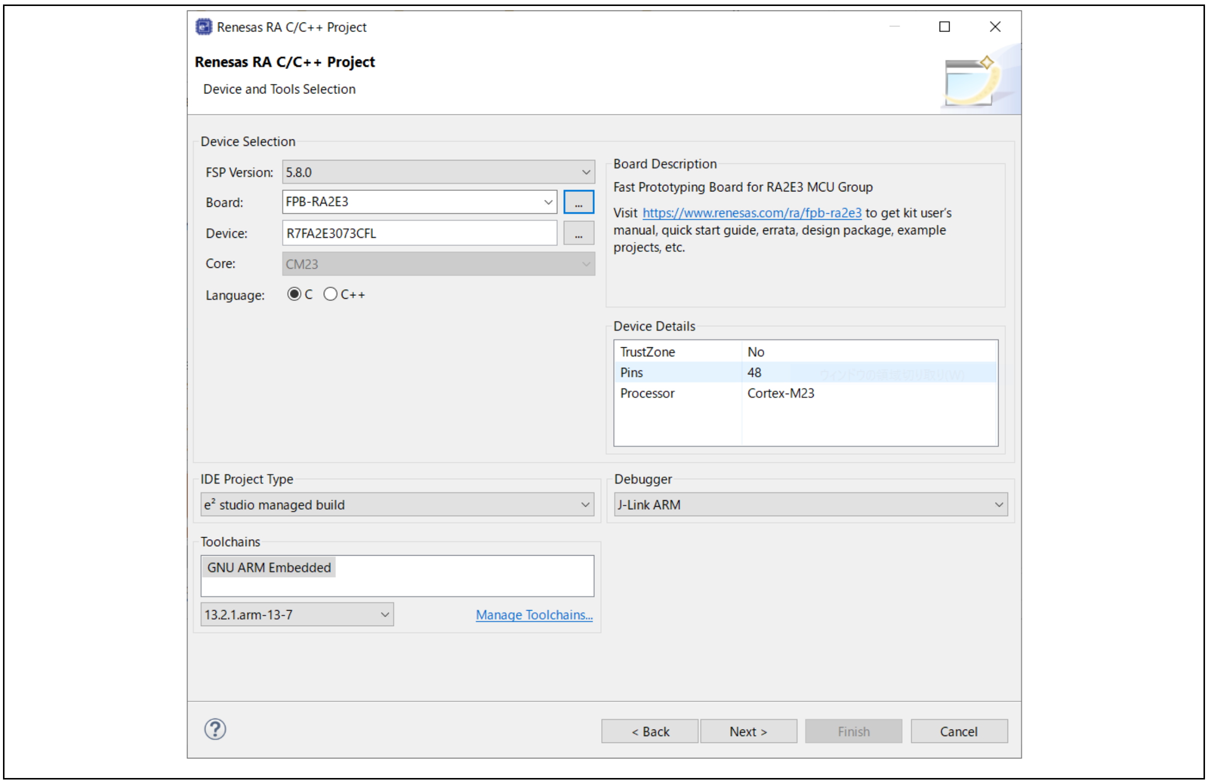

Figure 6.1 Creating a New Project

3. Add HS4001 sensor middleware to the [Stacks] tabbed page.

   New Stack > Sensor > HS400X Temperature/Humidity Sensor (rm_hs400x)

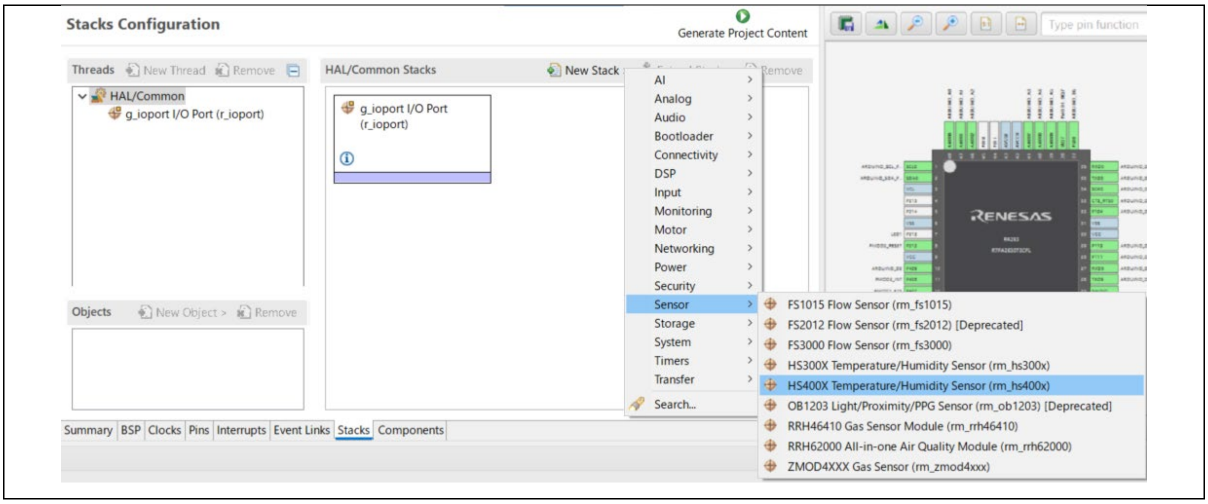

Figure 6.2 Adding to the [Stacks] Tabbed Page

4. Add *r_iic_master* or *r_sci_i2c* according to the specifications of the target board.

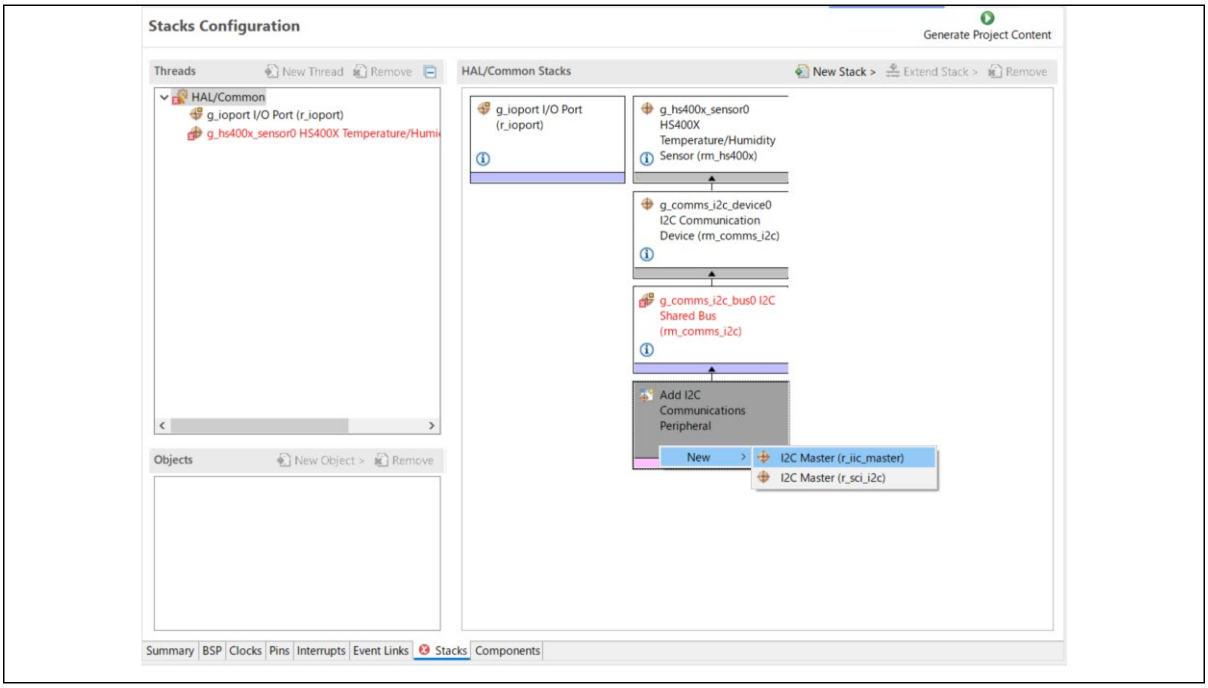

Figure 6.3 Adding r_iic_master or _r_sci_i2c

5. Set the properties of the I2C master driver according to the specifications of the target board.

   Clicking on [I2C master driver] on the [Stacks] tabbed page displays the properties in the [Properties] window.

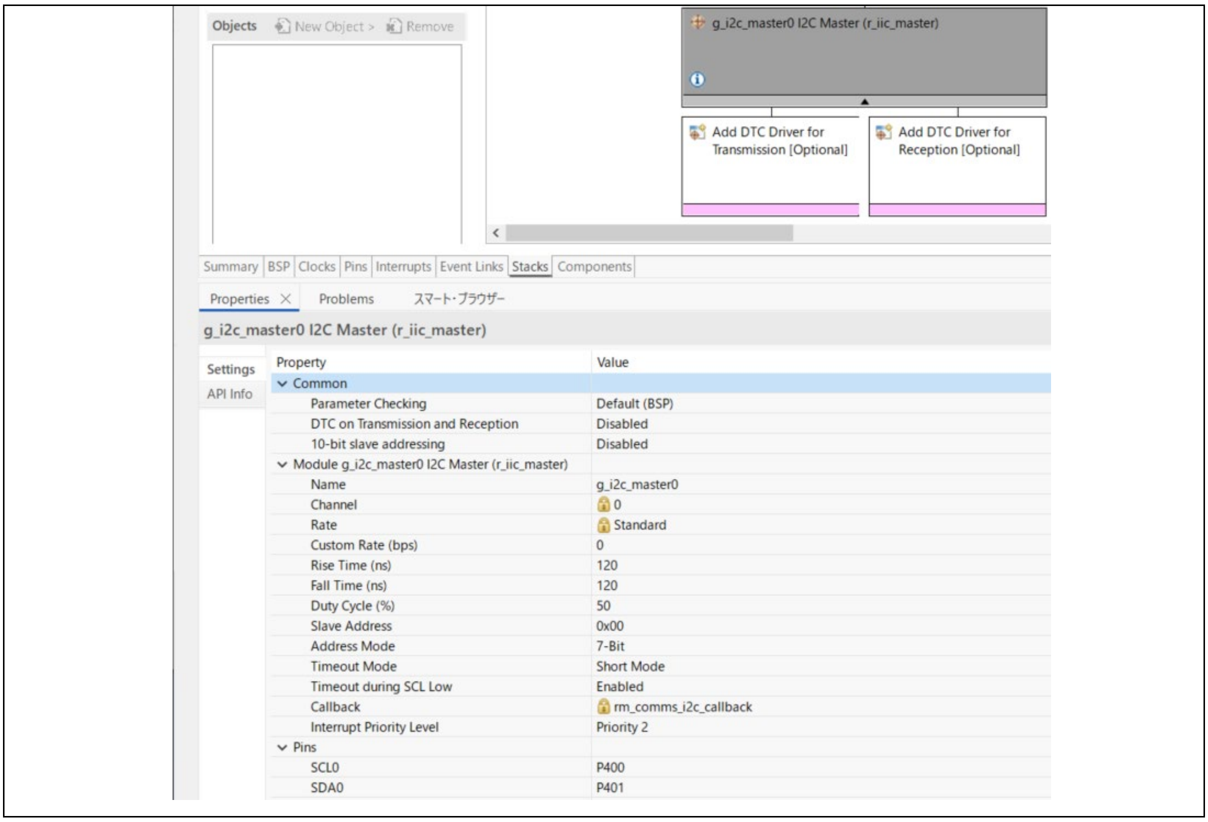

Figure 6.4 Setting Properties of the I2C Master Driver

6. Set the pins to be used. The pins to be used can be checked on the [Pins] tabbed page.

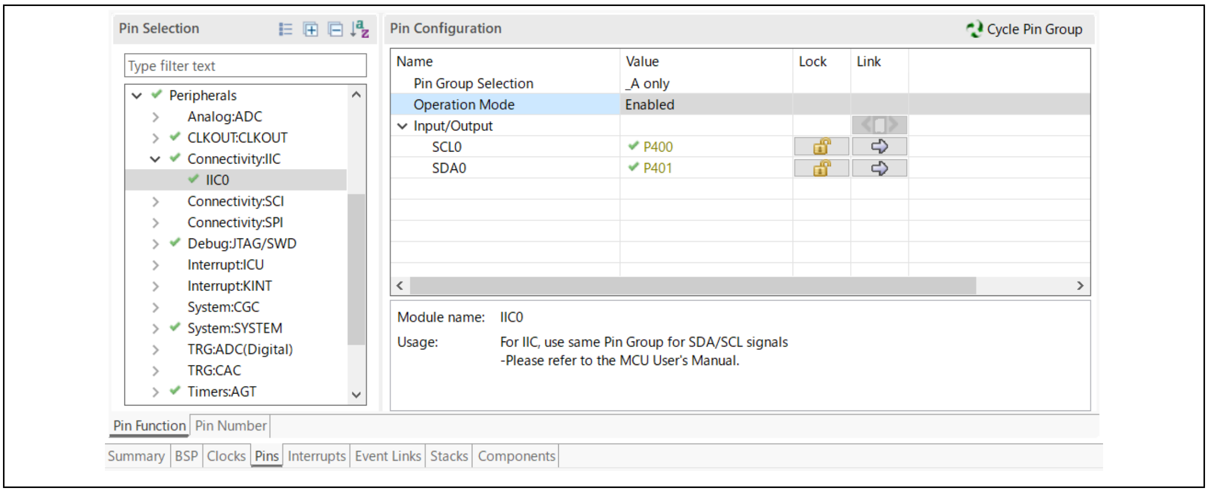

Figure 6.5 Checking Pins to be Used

6.2 Low Power Modes

1. Add the driver for the LPM peripheral to the [Stacks] tabbed page.

   New Stack > Power > Low Power Modes (r_lpm)

2. Set details of Low Power Modes.

   At this time, select [Software Standby mode] for [Low Power Mode] and [AGT1 Underflow] under [Wake Sources].

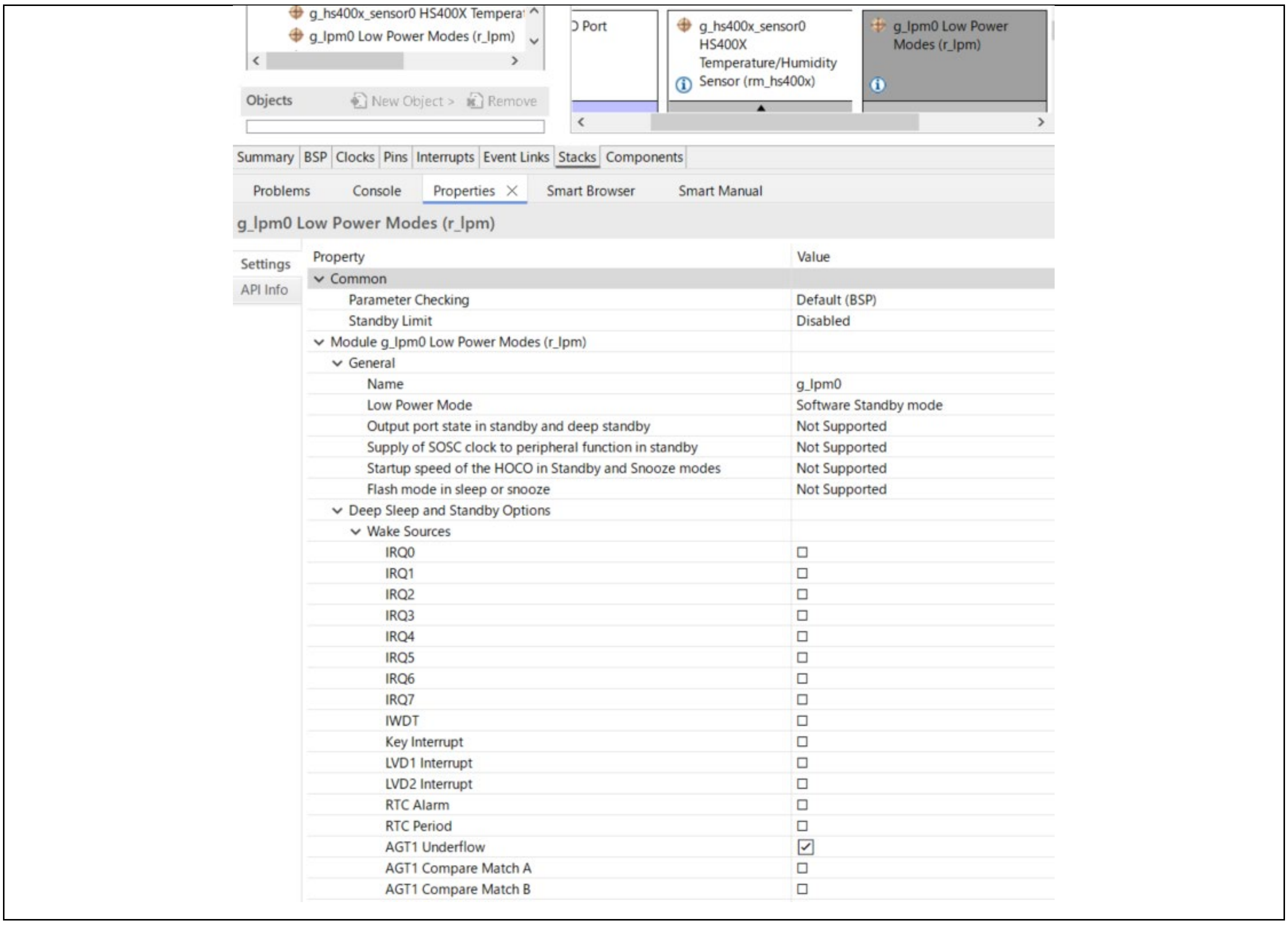

Figure 6.6 Properties of Low Power Modes

3. Add the driver for the AGT peripheral to the [Stacks] tabbed page.

   New Stack > Timers > Low-Power (r_agt)

4. Set details of the AGT.

   Set the timer period, clock source, etc. Here, select a sub-clock as the clock source.

   *In RA2E3, the LOCO can also be selected as the clock source for the AGT to reduce the BOM and save the I/O ports. In such cases, check the accuracy of the LOCO.

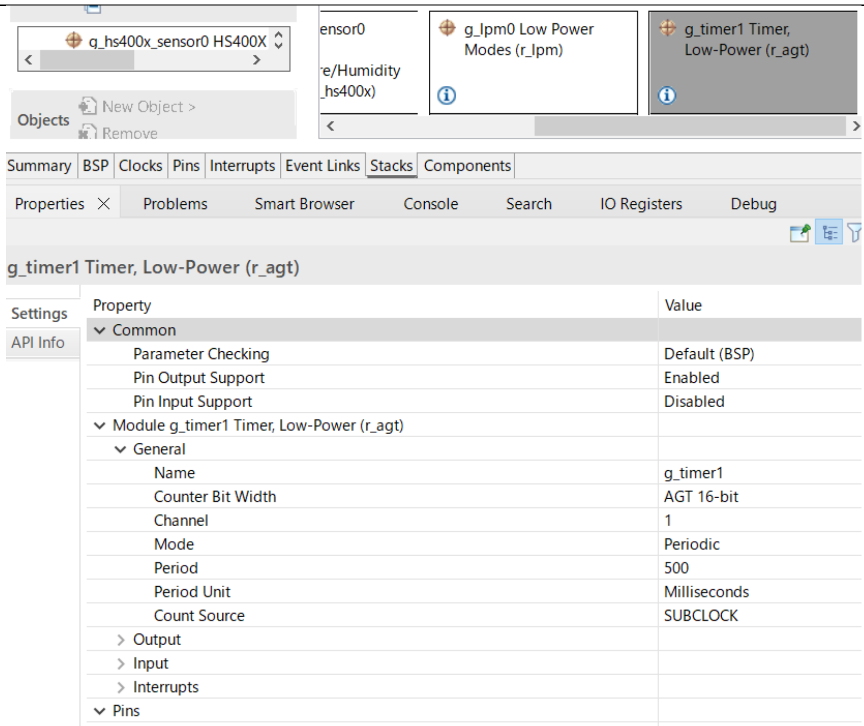

Figure 6.7 Properties of the AGT

6.3 I2C Communication Device

1. Add the middleware for OLED to the [Stacks] tabbed page.

   New Stack > Connectivity > I2C Communication Device (rm_comms_i2c)

2. Add the I2C Shared Bus

   Make the “I2C Shared Bus” selection for use since the temperature and humidity sensor and the OLED are connected in a multi-slave configuration.

   Use > g_comms_i2c_bus0 I2C Shared Bus (rm_comms_i2c)

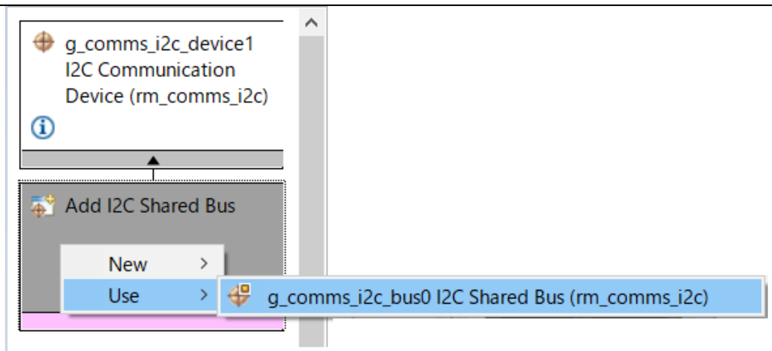

Figure 6.8 Adding the I2C Shared Bus

3. Configure the property of the I2C Communication Device.

   At this time, set the properties to the following.

   - Slave Address: 0x3c
   - Callback: oled_comms_i2c_callback

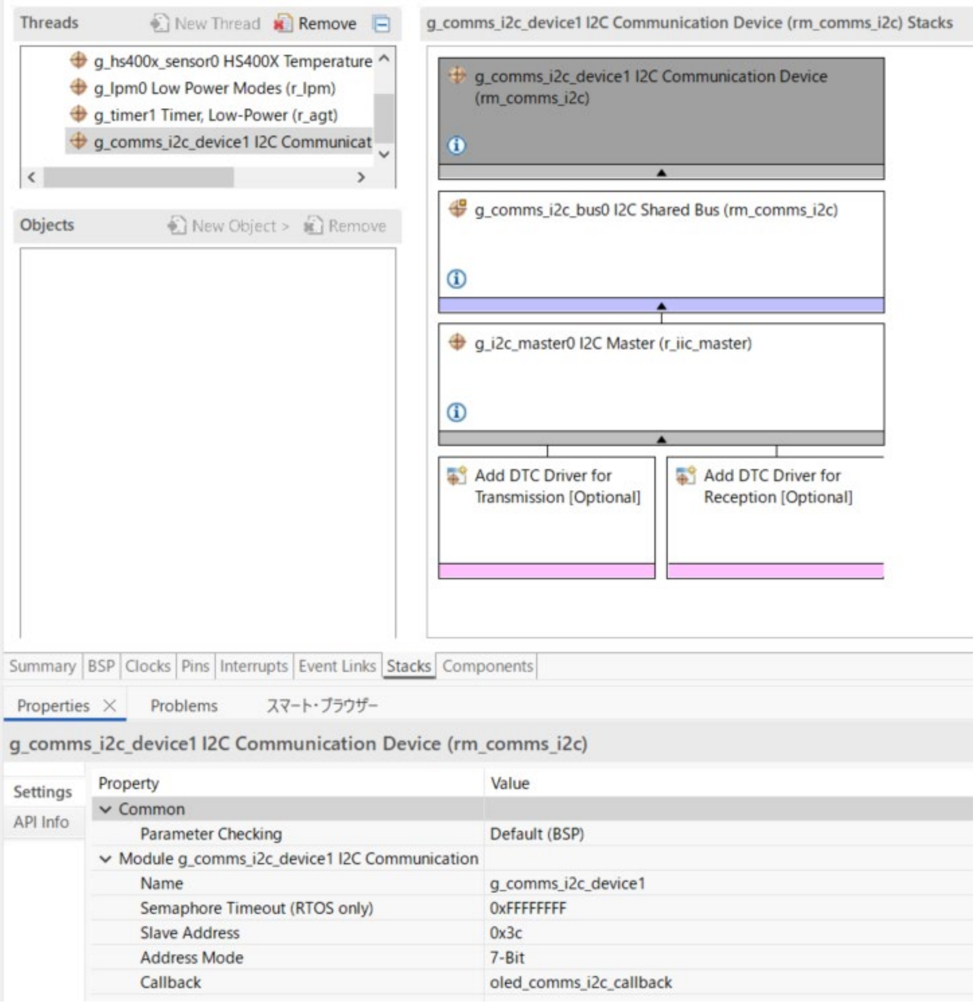

Figure 6.9 Properties of the I2C Communication Device

7. How to Import and Build the Project

1. Launch e[2] studio.
2. Click on [File] in the display menu and select [Import].
3. The [Import] window is displayed. Open the [General] category, select [Existing Projects into Workplace], and click on [Next].
4. In the [Select archive file] form, select the project file.

   After selection, confirm that the specified project “RA2E3_HS4001LowPowerSensorSystemExample” is displayed in [Project] and click on [Finish]. The [Import] window is then closed.
5. Open [configuration.xml] and click on [Generate Project Content] in the [Configurator] window.
6. In Project Explorer, click on the project name to bring it focus.
7. Select [Build Project] in the [Project] menu to start building.

8. How to Debug the Project for Low Power

1. Click on [Run] in the display menu and select [Debug Configurations].
2. Under the [Debugger] tab, go to the [Connection Settings] sub-tab to configure the following
   - J-link

     Script File: CM_low_power_debug.JLinkScript

     Low Power Handling: Yes

The script file is included with this application project and can be used by specifying it in the debug settings.

* The script file is not applied to the project by default. If a debug connection is made without setting up a script file, the MCU may not correctly make the transition to LPM. Even if it does, the power consumption may be higher than expected.

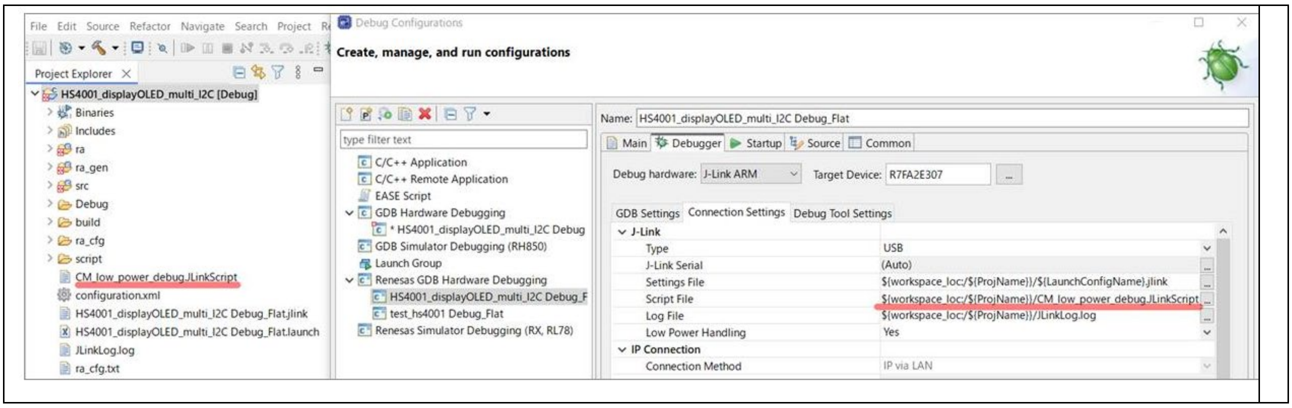

Figure 8.1 Specifying the Script File

9. Tips on e² studio for Debugging

9.1 Displaying IO Registers

Select the [Window] menu > [Show View] > [Other…] to open the [Show View] window, and then select Debug > IO Registers.

When you enter the name of a register for reference in the search box, you can easily find the given register.

Example: AGT registers

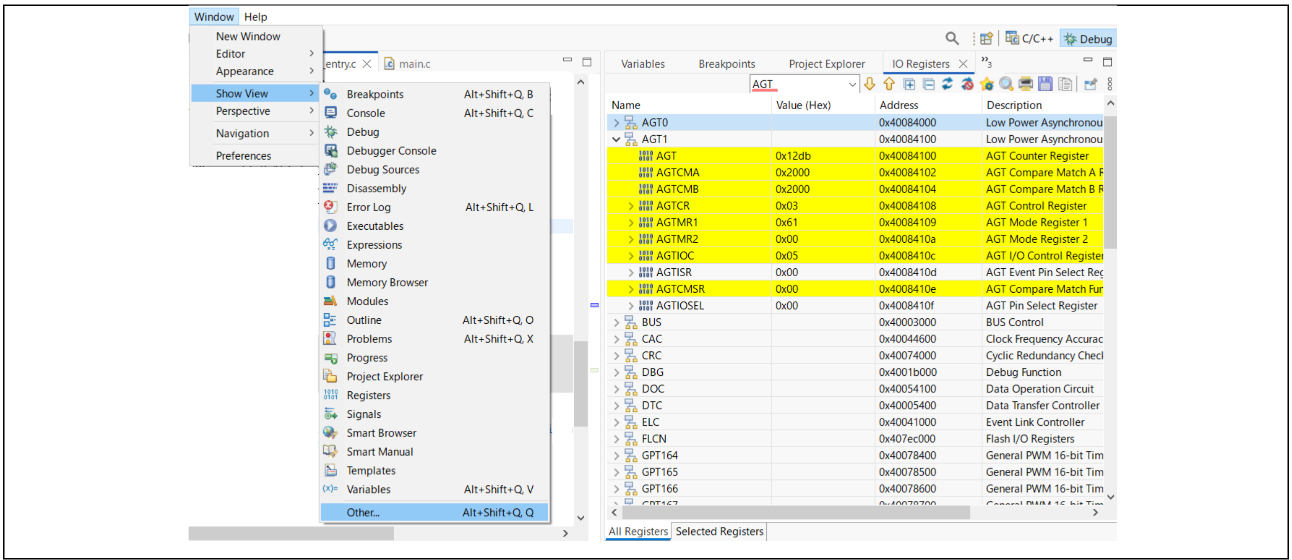

Figure 9.1 Displaying IO Registers

9.2 Customizing the [IO Registers] View

Right-click on the name of a register and select [Add to Selected Registers]. You can confirm that only the specified registers have been selected on the [Selected Registers] tabbed page.

Example: AGT1 registers

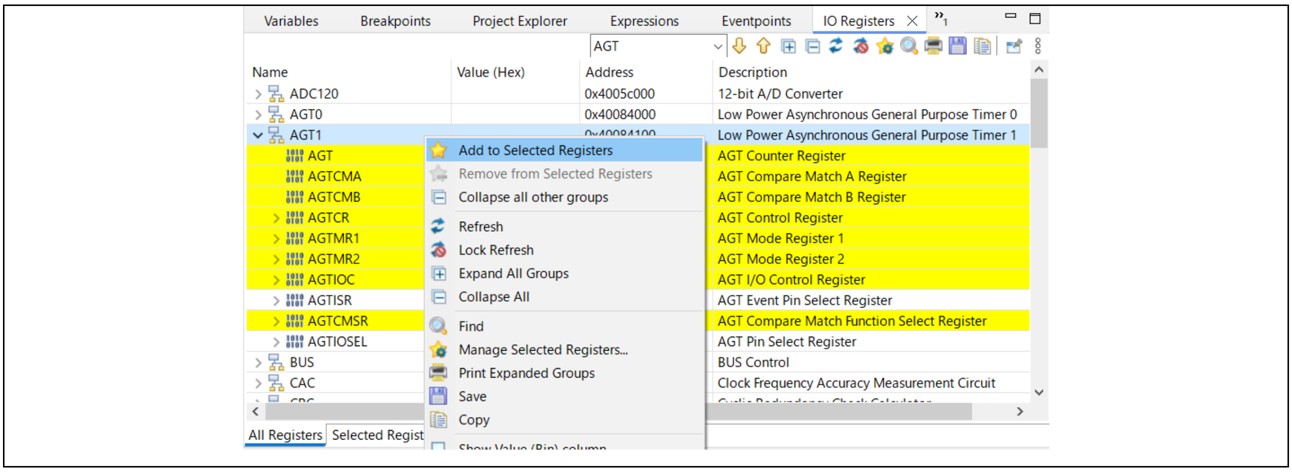

Figure 9.2 [Add to Selected Registers]

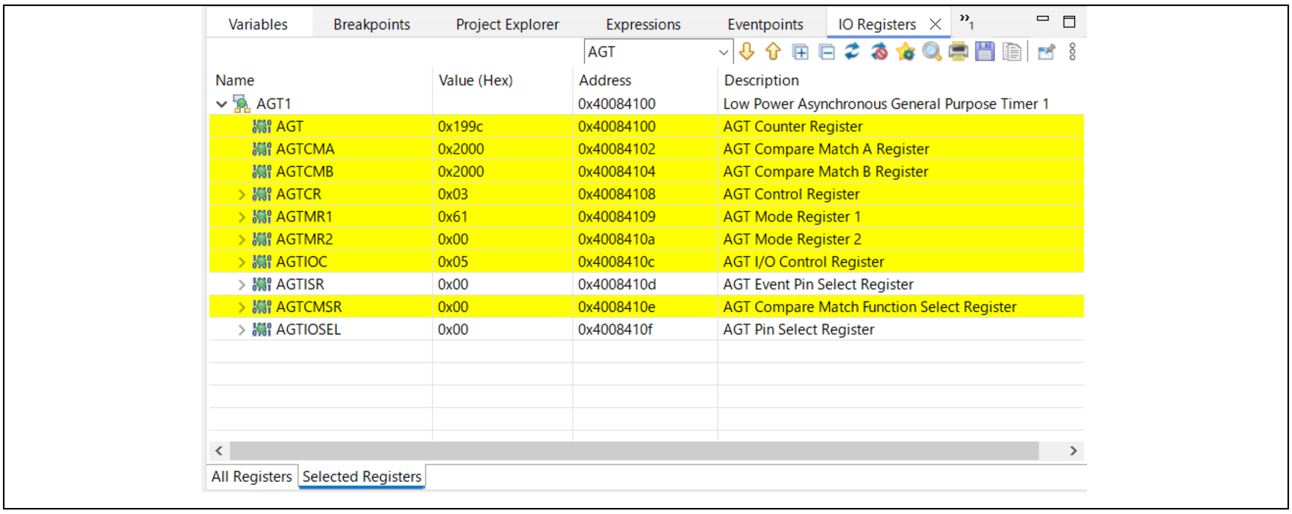

Figure 9.3 Selected Registers

9.3 Setting Breakpoints

When the debugger is started, double-clicking on a line in the area where the addresses of the editor are displayed sets a breakpoint.

If you right-click on a line in that area, you can directly select the type of breakpoints by selecting [Toggle Software Breakpoint] or [Toggle Hardware Breakpoint].

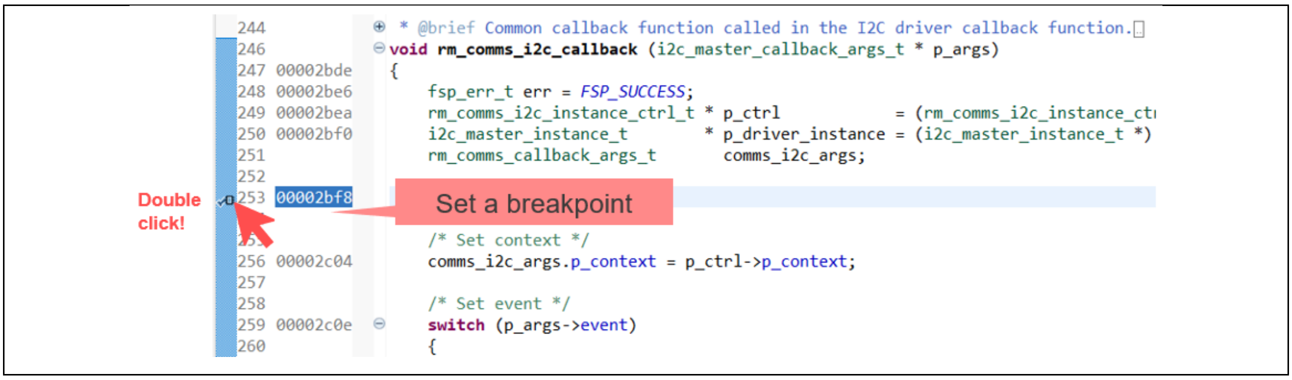

Figure 9.4 Setting a Breakpoint

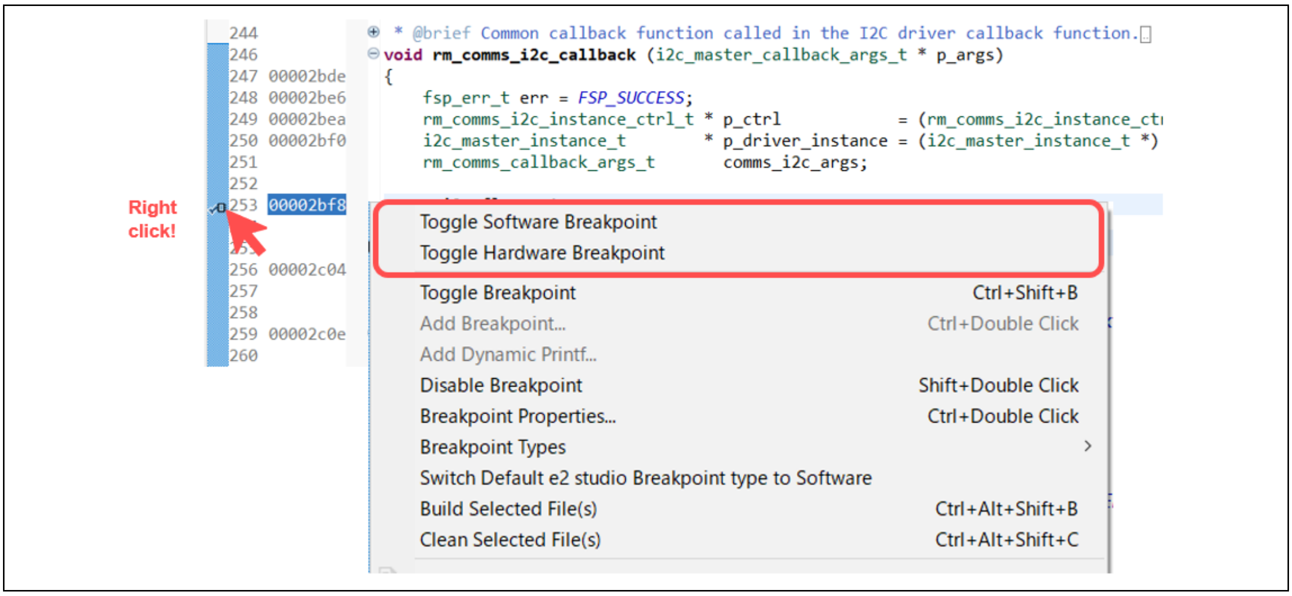

Figure 9.5 Selecting the Type of Breakpoints

10. Sample Program

The sample program is available on the Renesas Electronics Website.

11. Reference Documents

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

- RA2E3 Fast Prototyping Board (R20UT5128)
  https://www.renesas.com/document/mat/fpb-ra2e3-v1-users-manual
- RA2E3 User's Manual: Hardware (R01UH0992)
  https://www.renesas.com/document/mah/ra2e3-group-users-manual-hardware
- RA Family, RX Family, RL78 Family, RZ Family HS400x Sample Application (R01AN6333)

Revision History

Rev.	Date	Description	
		Page	Summary
Rev.1.00	May.07.25	-	First release
Rev.1.01	May.26.25	 4, 6, 7	Corrected project specifications in the following. section 1.3, Specifications section 3.1, Introduction section 3.4, Operating Procedure
		1, 6, 7, 9, 17	Corrected other errors and style.

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

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