QCIOT-MOTIONPOCZ Board

The QCIOT-MOTIONPOCZ is an analog motion sensor that can detect motion from up to two meters away by using a PIR sensor. The sensor is connected to a bandpass filter using the operation amplifier, SLG88103, to condition and filter the signal. The amplified condition signal is connected to the analog pin of the MCU to determine strength and distance of motion. The signal also connects to nanopower comparators that form a window comparison to be used to wake-up an MCU or system at motion detection.

The solution can be powered by either connecting an MCU board or with an external connection. The external regulator supports powering the MCU and other connecting solutions. This solution supports the QCIOT ecosystem. Other solutions can be daisy chained.

Features

- Operating Voltage: 5V to 16V
- Sensor current: ~13µA
- Operational current: ~19µA
- Always on autonomous operation

Board Contents

- QCIOT-MOTIONPOCZ

Figure 1. QCIOT-MOTIONPOCZ Board

Contents

1. Functional Description

The QCIOT-MOTIONPOCZ Motion Sensor is intended as a quick connect prototyping solution for monitoring motion. This board powers on in two ways: (1) Using the MCU kit power or (2) using an external 5V to 16V power supply. The voltage regulator IC S-812C33B, a micropower regulator, powers the SLG59M1639V, SLG88103, and the ISL28915 ICs. The SLG591639V is a dual P-channel MOSFFET load switch that can pass up to 2A when powering the motion sensor module. The SLG88103 is an operational amplifier configured as a second order bandpass filter that is used to amplify the PIR motion sensor signal. The ISL28915s are configured as a window comparator to alert the MCU when the motion detected by the PIR sensor is strong enough.

The block diagram (Figure 2) highlights the system:
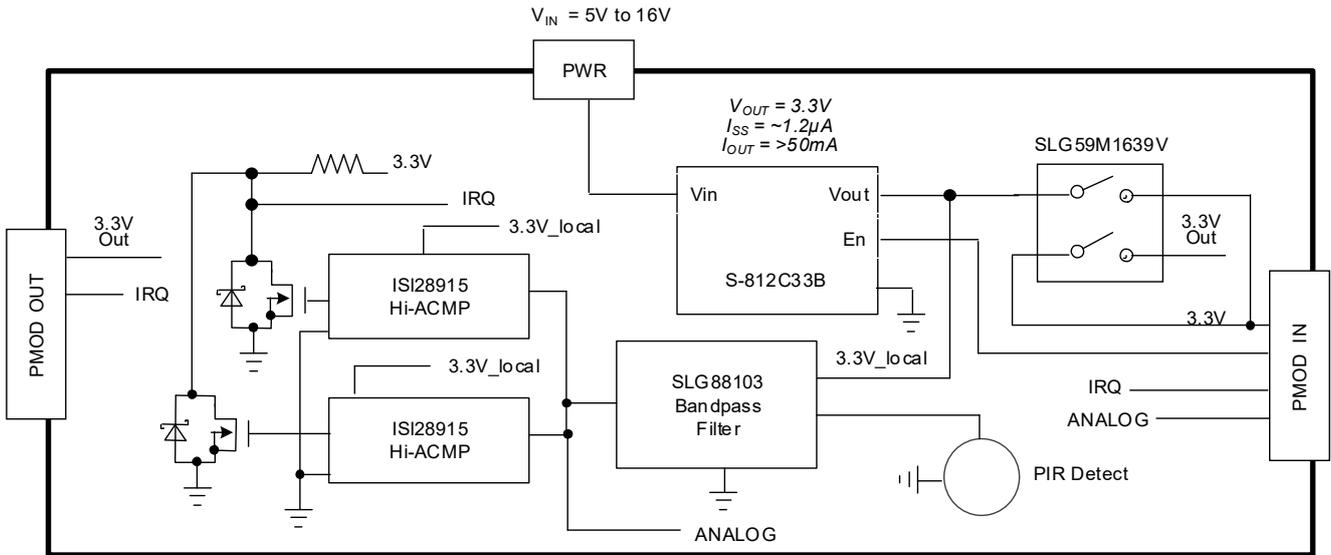
Figure 2. QCIOT-MOTIONPOCZ Board Block Diagram

The building blocks of QCIOT-MOTIONPOCZ Board are as listed:

- **S-812C33B** – The S-812C33B is a LDO regulator. Because this IC has a maximum input voltage of 16V, it is suitable for applications requiring withstand. Also, as it is low current consumption and has a ON/OFF circuit it is suitable for a portable device. This has an output voltage range from 2.0V to 6.0V with output voltage accuracy of ±2.0%. The current consumption during operation is 1.0µA typical and 1.8µA max. It can source up to 50mA at 3.0V when V_{IN} = 5V and 75mA at 5.0V when V_{IN} = 7V.

- **SLG59M1639V** – The SLG59M1639V is a dual-channel, 45 mΩ pFET load switch designed to switch 1.5 to 5.5V power rails up to 2A in each channel. When either channel is enabled, reverse-current protection quickly opens the switch when a reverse-voltage condition is detected (V_{OUT} > V_{IN} + 50mV condition opens the switch). Each load switch is independently controlled through its own low-voltage compatible CMOS input.

- **SLG88103** – The SLG88103/4 is a wide voltage range, 375nA dual/quad channel CMOS input operational amplifier capable of rail-to-rail input and output operation. Each amplifier can be individually powered down. Also, the device has a low quiescent current of 375nA per amplifier (typical) and low offset voltage ±200uV (typical). SLG88103 has a supply range of 1.71V to 5.5V.

- **ISL28915** – The ISL28915 is a nanopower comparator optimized for low-power applications. This device is designed for single-supply operation from 1.8V to 5. 5V and typically consumes 500nA of supply current. It also features a push/pull output stage with rail-to-rail input and output swing (RRIO) allowing for maximum battery usage.

1.1　Operational Characteristics

The board has been designed to the following specifications:

- Input voltage range: 5V to 16V
- Sensor current: ~13μA
- Operational current: ~19μA

1.2　Setup and Configuration

The following additional lab equipment is required for using the board (and is available separately):

Board

- EK-RA MCU board that supports Type 6A Pmod and the following:
  - EK-RA6M1, EK-RA6M3, EK-RA6M3G, EK-RA4M3, EK-RA6M4

OR

- FPB-RA MCU board that supports Type 6A Pmod and the following:
  - FPB-RA2E1, FPB-RA4E1, FPB-RA6E1

Power Supply

- Power supply (5V – 16V) (Optional).

  Note: You can also use 5V from the MCU Kit.

  Important: Renesas strongly recommends using the FPB-RA2E1 MCU Kit.

Note: The following RA MCUs require additional adjustment if you use them.

- EK-RA2E1, EK-RA2L1, EK-RA4W1, EK-RA6M2, EK-RA2E2, EK-RA6M5

Adjustment procedure:

1. Change ADC pin: Hook a wire at test point A and connect it to the analog pin on your MCU.
2. Change code: You have to change the analog pin channel on the startup code. For more details, see Setting Up the QCIOT-MOTIONPOCZ Board Development Kit.
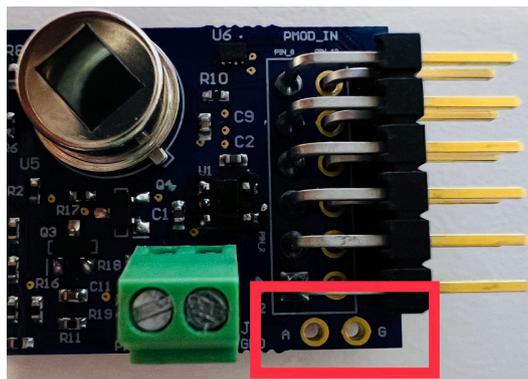
Figure 3. Test Point A and G (Analog and GND)

The following RA MCUs do not support this QCIOT-MOTIONPOCZ Board:

- EK-RA2A1, EK-RA4M1, EK-RA4M2

If you use another MCU board (such as RX), verify that it has Type 6A PMOD and Pin 2 and Pin 7 of the PMOD (1 or A) supports IRQ and ANALOG, respectively.

Table 1 contains a list of compatible MCU kits with motion sensor modules.

Table 1. List of MCUs

Compatible RA MCU	Needs Adjustment	Not Compatible
FPB-RA2E1	EK-RA2E1	EK-RA2A1
FPB-RA4E1	EK-RA2L1	EK-RA4M1
FPB-RA6E1	EK-RA4W1	EK-RA4M2
EK-RA6M1	EK-RA6M2	-
EK-RA6M3	EK-RA2E2	-
EK-RA6M3G	EK-RA6M5	-
EK-RA4M3	-	-
EK-RA6M4	-	-

1.2.1   Solder Bridge Settings

The PMOD pins configuration can be altered by changing the Solder Bridge settings. Depending on your MCU kit, you can change the solder bridge to PMOD in two different ways (Figure 4).

Option 1: Default

Solder Bridge No	Connection
SB1	**Closed**
SB2	**Closed**
SB3	**Closed**
SB4	Open
SB5	Open
SB6	Open
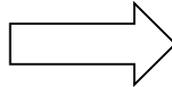
PMOD pin	PMOD pin
1) RES_N	**7) ANALOG**
2) IRQ	**8) ENABLE**
3) SCL	9) PWR_EN
4) SDA	10) GPIO4
5) GND	11) GND
6) VCC	12) VCC

Option 2:

Solder Bridge No	Connection
SB1	Open
SB2	Open
SB3	Open
SB4	**Closed**
SB5	**Closed**
SB6	**Closed**
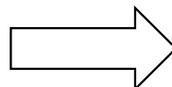
PMOD pin	PMOD pin
1) RES_N	**7) IRQ**
2) TX	**8) ANALOG**
3) RX	9) PWR_EN
4) ENABLE	10) GPIO4
5) GND	11) GND
6) VCC	12) VCC

Figure 4. Solder Bridge Settings

1.2.2   Software Installation and Usage

Visit the Renesas website for the latest version of the e^2 studio installer. The minimum FSP version supporting the QCIOT-MOTIONPOCZ Board is FSP 4.3.0. For the latest sensor support, ensure that the latest release is used.

Visit the Renesas Quick-Connect IoT site for more information about creating your customized system solution.

1.2.3   Kit Hardware Connections

Follow these procedures to set up the kit (see Figure 5).

1. Ensure that you select the correct MCU evaluation kit from Table 1.

2. Plug in the QCIOT-MOTIONPOCZ Board to the Type 6A PMOD (1 or A) connector. Be careful to align Pin 1 on the sensor board and MCU kit. The dot mark near the pin indicates Pin 1.

3. Power source for QCIOT-MOTIONPOCZ Board:

    a. The motion sensor module can be powered on by either method:

        i.   Use external power source (5V to 16V), or

        ii. Use 5V from MCU kit.

    b. Connect the power source to VIN and GND of screw terminal connector J1. Apply VIN between 5V to 16V.

4. The device is now ready to be used in the system.

Note: If you face any issues or for more detail explanation see the Quick Start Guide.
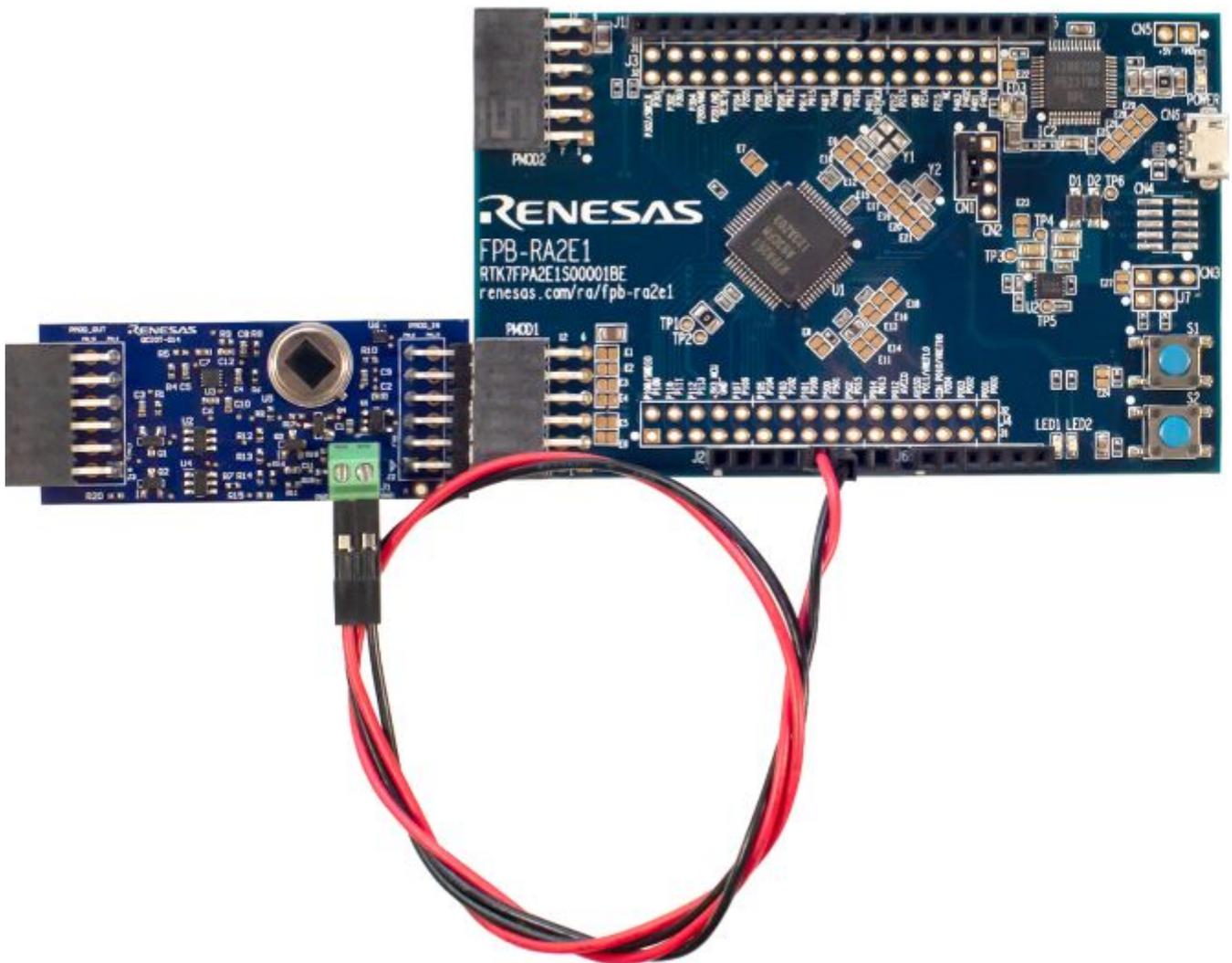
Figure 5. QCIOT-5APWRPOCZ with RA2L1 MCU Kit

2. Board Design

Figure 6. QCIOT-MOTIONPOCZ Board (Top)
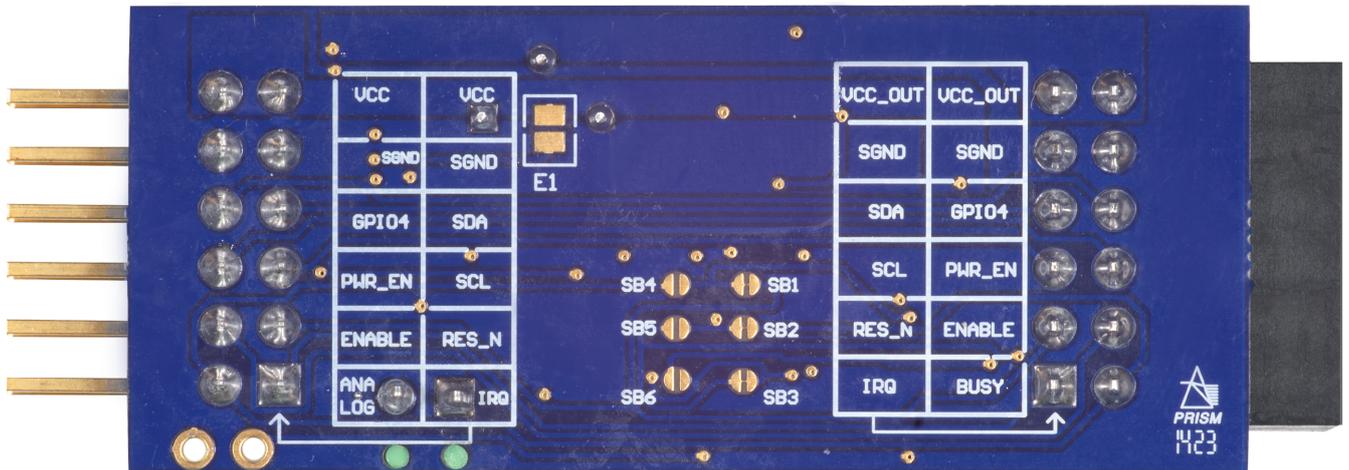
Figure 7. QCIOT-MOTIONPOCZ Board (Bottom)

2.1   Schematic Diagrams
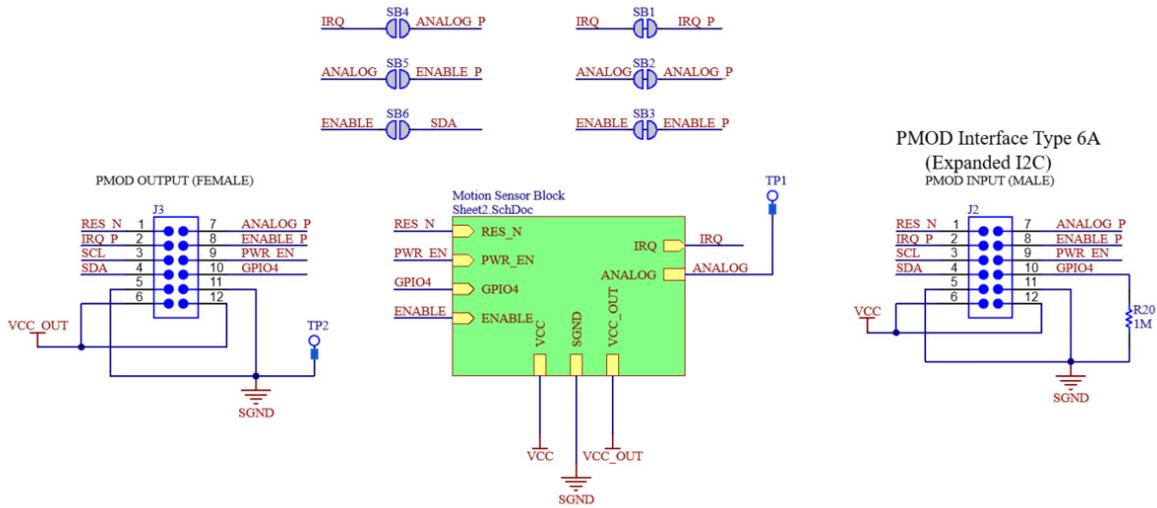
Figure 8. QCIOT-MOTIONPOCZ Board Schematic
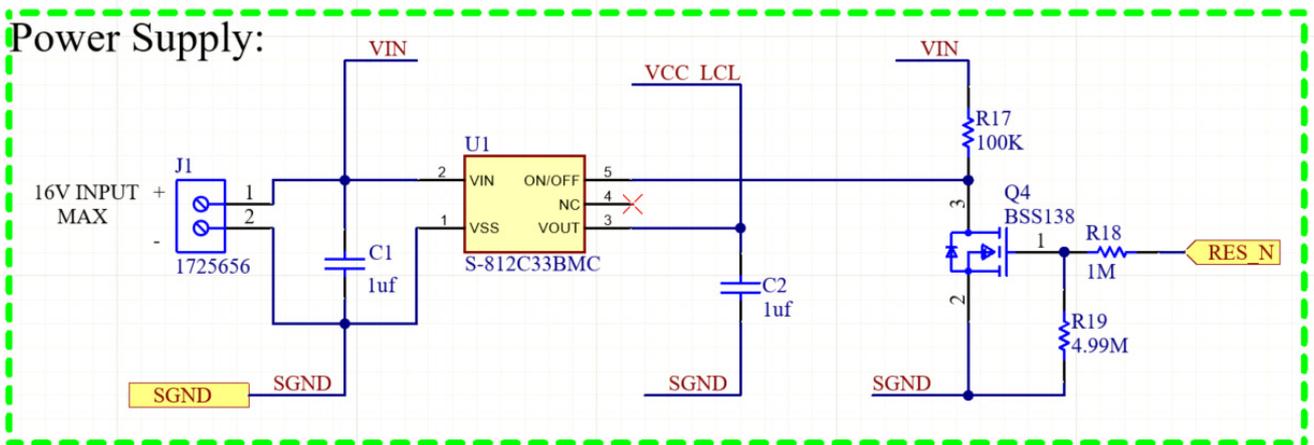
Figure 9. QCIOT-MOTIONPOCZ Board Power Supply Schematic
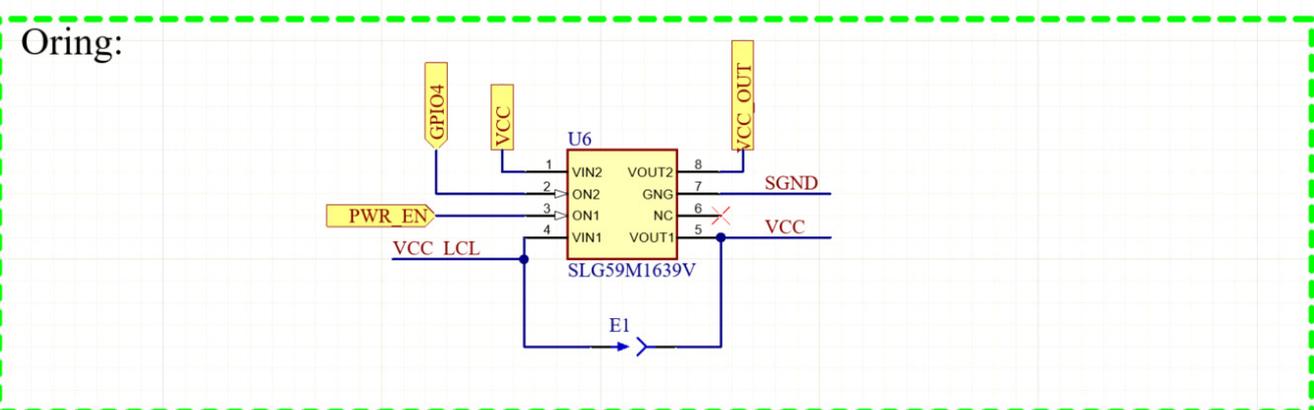
Figure 10. QCIOT-MOTIONPOCZ Board Load Switch Schematics
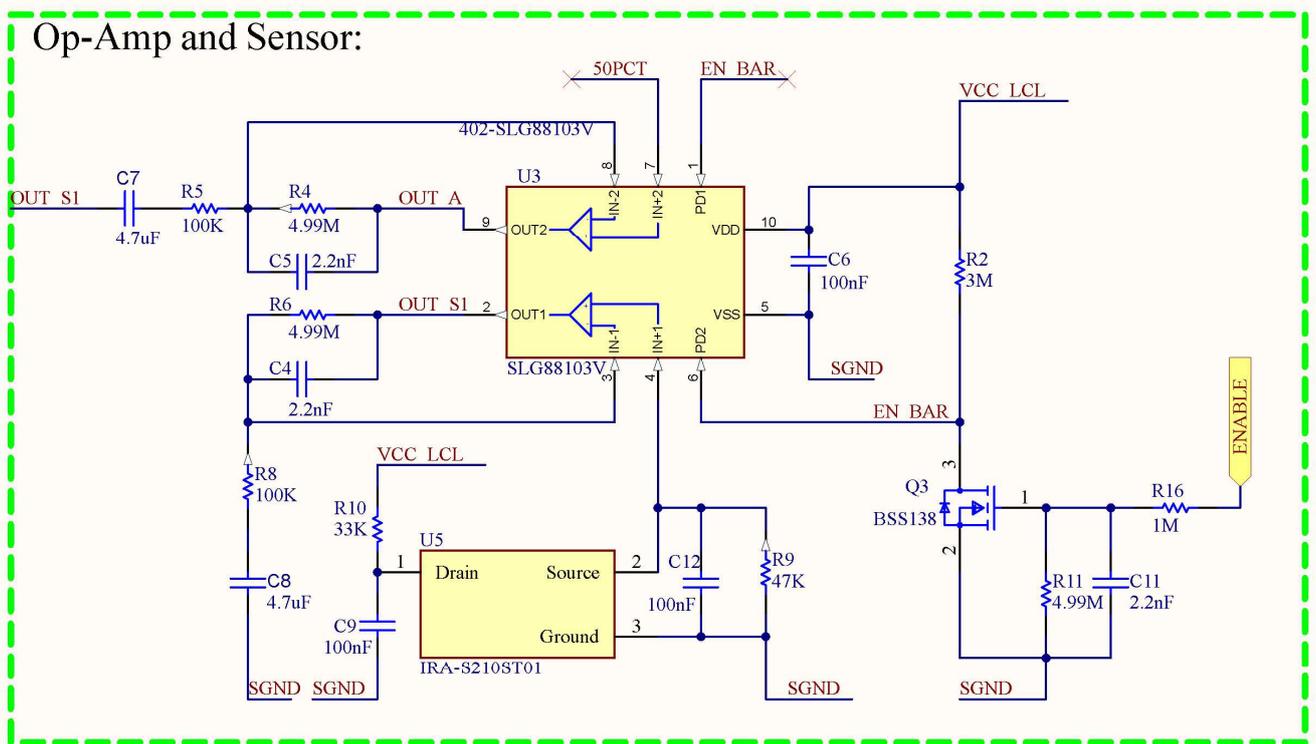
Figure 11. QCIOT-MOTIONPOCZ Board Op-Amp and Sensor Schematics
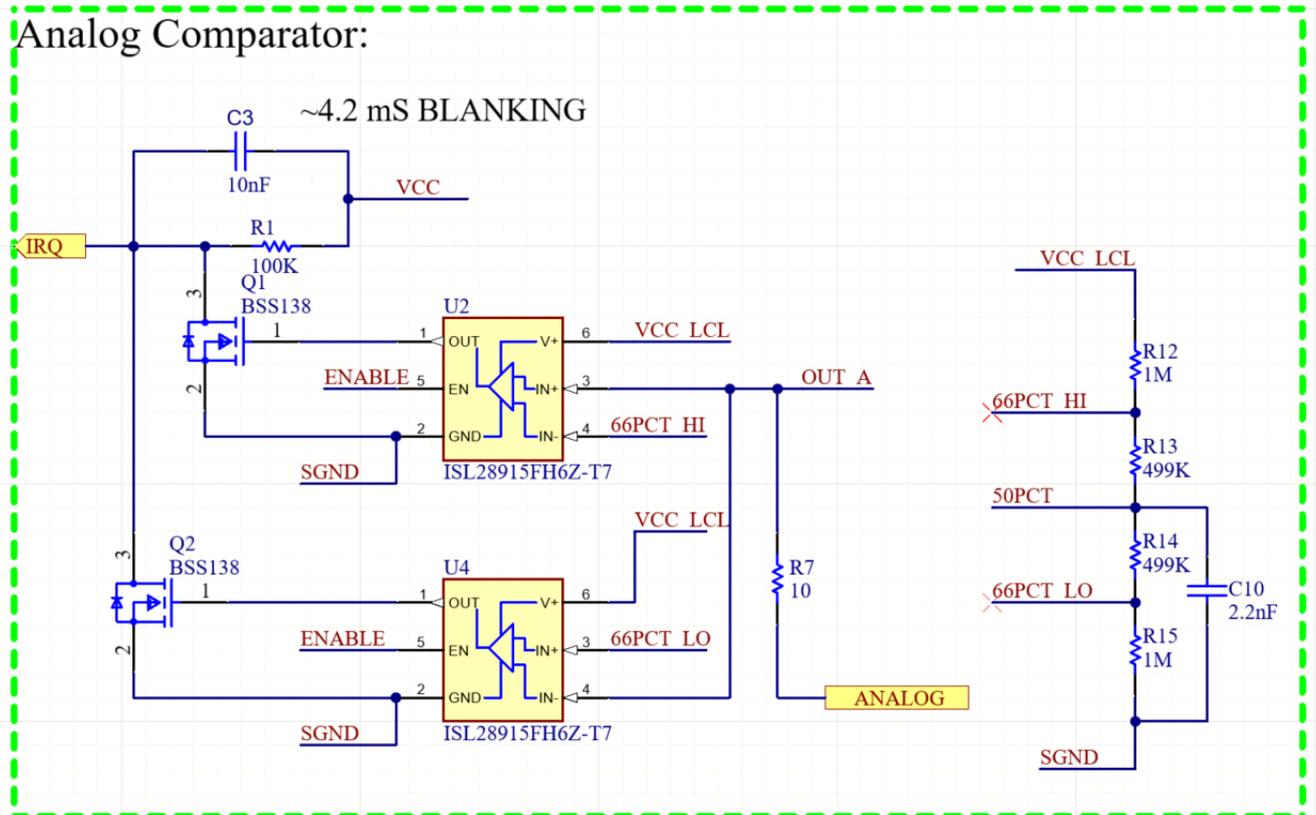
Figure 12. QCIOT-MOTIONPOCZ Board Analog Comparator Schematics

2.2   Bill of Materials

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
2	C1, C2	1µF ±20% 16V Ceramic Capacitor X5R 0402 (1005 Metric)	KYOCERA AVX	0402YD105MAT2A
1	C3	10000pF/0.01µF ±20% 16V Ceramic Capacitor X5R 0402 (1005 Metric)	KYOCERA AVX	0402YD103MAT4A
4	C4, C5, C10, C11	2200pF ±10% 16V Ceramic Capacitor X5R 0402 (1005 Metric)	KYOCERA AVX	0402YD222KAT2A
3	C6, C9, C12	0.1µF ±20% 16V Ceramic Capacitor X5R 0402 (1005 Metric)	KYOCERA AVX	0402YD104MAT2A
2	C7, C8	4.7µF ±20% 16V Ceramic Capacitor X5R 0402 (1005 Metric)	KYOCERA AVX	0402YD475MAT2A
1	J1	Male Header, Pitch 2.54mm, 1×2 Position, Height 9mm, Tail Length 3.5mm	Phoenix Contact	1725656
1	J2	Connector Header Through Hole, Right Angle 12 position 0.100" (2.54mm)	Samtec Inc.	TSW-106-08-F-D-RA
1	J3	12 Position Receptacle Connector 0.100" (2.54mm) Through Hole, Right Angle Gold	Samtec	SSW-106-02-F-D-RA
4	Q1, Q2, Q3, Q4	N-Channel 50 V 200mA (Ta) 200mW (Ta) Surface Mount SOT-323	Diodes Incorporated	BSS138W-7-F
4	R1, R5, R8, R17	100kΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-07100KL
4	R4, R6, R11, R19	4.99MΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-074M99L
1	R7	10Ω ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-7W10RL
1	R9	47kΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-0747KL
1	R10	33kΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-0733KL
5	R12, R15, R16, R18, R20	1MΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-131ML
2	R13, R14	499kΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-07499KL
2	TP1, TP2	Test point	-	-
1	U1	LDO Regulator Pos 3.3V 0.05A 5-Pin SOT-23	ABLIC U.S.A.	S-812C33BMC-C4NT2U
2	U2, U4	ISL28915FH6Z Pb-free, Nanopower, Push/pull Output Comparator / Tape and Reel RoHS Compliant: Yes	Renesas	ISL28915FH6Z-T7
1	U3	CMOS Amplifier 2 Circuit Rail-to-Rail 10-STDFN (2×2)	Renesas	SLG88103V
1	U5	Motion Sensor PIR (Passive Infrared) Radial, Metal Can, Lensed - 3 Lead	Murata	IRA-S210ST01

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
1	U6	GreenFET Dual P-Channel Reverse Blocking Load Switch	Renesas	SLG59M1639V
1	R2	3MΩ ±5% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402JR-073ML

2.3   Board Layout
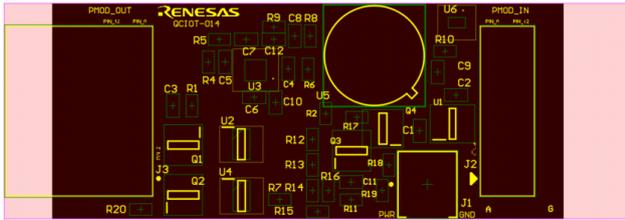
Figure 13. Top Overlay
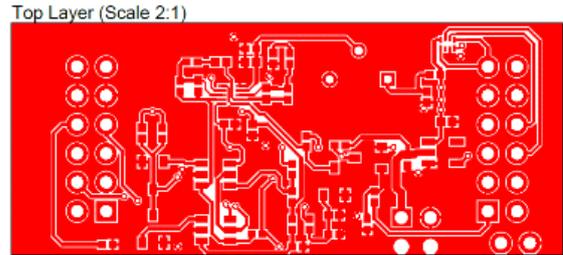
Figure 14. Top Layer
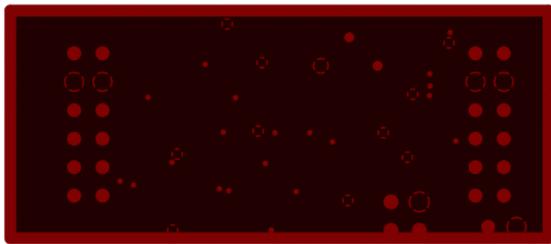
Figure 15. Top 3 (GND)
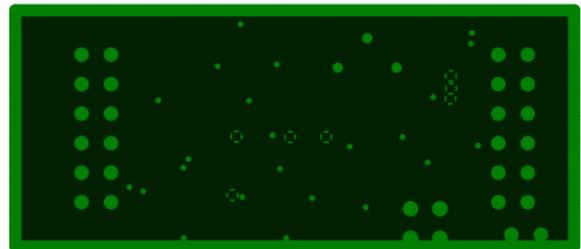
Figure 16. Layer 2 (PWR)
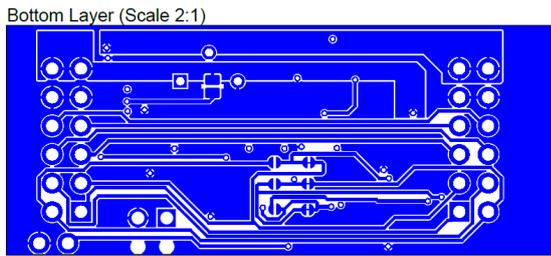
Figure 17. Bottom Layer
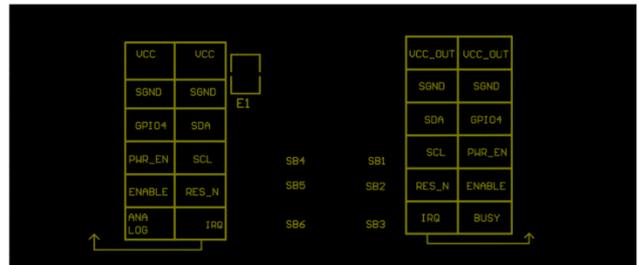
Figure 18. Bottom Overlay

3. Software Design

The following sections give an overview of the software implementation for the QCIOT-MOTIONPOCZ Board that is based on the Renesas RA Family's Flexible Software Package (FSP). These sections detail the project code structure and the main system flow.

3.1 Project Code Structure

The QCIOT-MOTIONPOCZ Board project contains the SYSTEM folder. This SYSTEM folder contains the main system code that enables the FSP driver code and implements system flow.

Figure 19 shows the structure of the project in e^2 studio.

- ra – includes automatically generated files for FSP drivers
- ra_gen – includes main file and generated files for FSP driver settings
- src – contains the module code that uses FSP drivers
- SYSTEM – main system code folder
- system.c – system code and system flow
- system.h – system code header file
- hal_entry.c – start of code execution, which calls system main
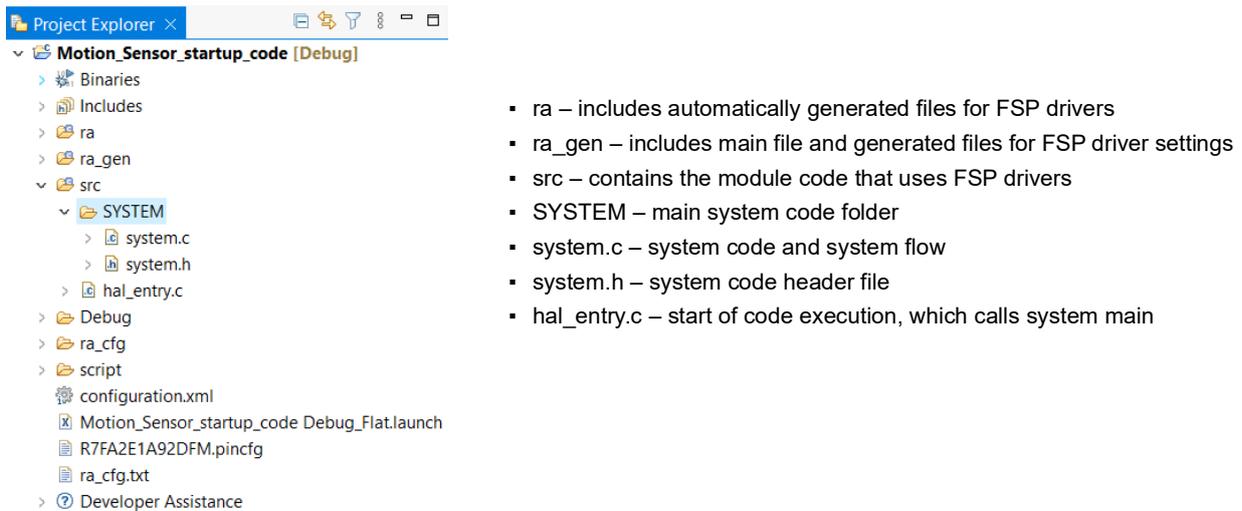
Figure 19. Motion Sensor Code Structure

3.2 Software Module Overview

The SYSTEM folder contains the system module code and the FSP driver code. The following FSP drivers are used for this project:

- Interrupt - g_external_irq0 External IRQ (r_icu) – This interrupt is triggered when motion is detected. The trigger type is falling edge. By default, this interrupt is configured on Channel 1 for the FBP-RA2E1 board.
- ADC - g_adc0 ADC (r_adc) – ADC driver is used to get the analog reading from the PIR Motion Sensor. By default, this ADC is configured on Channel 10 for the FBP-RA2E1 board.

3.2.1 Algorithm Flowchart

Figure 20 describes the algorithm from a high level.

```
         ┌──────────────┐
         │  sys_main()  │
         └──────┬───────┘
                │
         ┌──────▼───────┐
         │  init_adc()  │
         └──────┬───────┘
                │
         ┌──────▼───────┐
         │  init_IRQ()  │
         └──────┬───────┘
                │
    ┌───────────▼────────────┐
    │   init_motion_sensor() │
    └───────────┬────────────┘
                │
      ┌─────────▼─────────┐◄──────────┐
  ┌──►│    adc_read()     │           │
  │   └─────────┬─────────┘           │
  │             │                     │
  │        ┌────▼────┐      NO         │
  │        ╱ motion_ ╲ ──────────────►│
  │        ╲ detected ╱
  │         ╲───┬───╱
  │             │ YES
  │       ┌─────▼─────┐
  └───────┤ trigger IRQ│
          └───────────┘
```
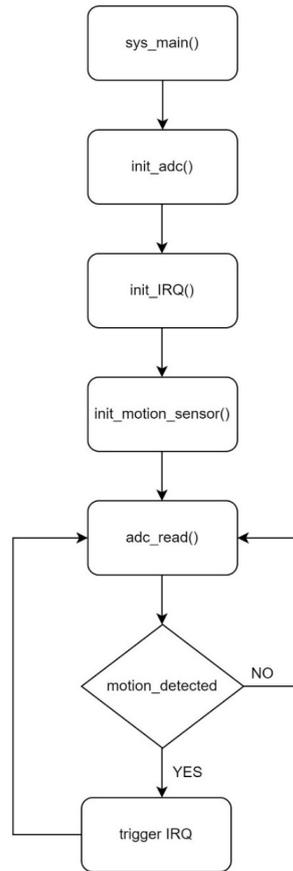
Figure 20. Flowchart

Figure 20 outlines the following functions:

- sys_main()
  - Calls init_adc() function.
  - Calls init_IRQ() function.
  - Calls init_motion_sensor() function.
- init_adc()
  - Opens the ADC module which initializes the pin as analog on Channel 10.
  - Configures the ADC scan parameters.
- init_IRQ()
  - Initializes fault IRQ.
  - Enables fault IRQ.
- init_motion_sensor()
  - Powers on the motion sensor.
- adc_read()
  - Starts ADC scan.
  - Reads ADC.
  - Converts to volts.

3.2.2 Hierarchy Chart

Figure 21 outlines the hierarchy of function calls.
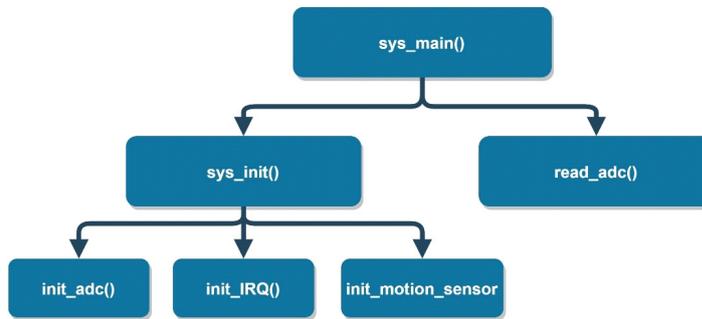
Figure 21. Hierarchy Chart

The main system flow contains two child process: sys_init() and read_adc(). sys_init() is responsible for initializing the ADC, Interrupt(IRQ), and the motion sensor, and the read_adc() function continuously records analog readings. The analog channel is initialized by init_dc(), and the interrupt is initialized by init_IRQ(). The function init_motion_sensor() is responsible for powering on the motion sensor module.

4. Quick Start Guide

The objective of this section is to provide the user with a hands-on experience for the Quick Connect Motion Sensor. You start by setting up the hardware connections followed by setting up the e^2 studio IDE to view the data within the debug context of the e^2 studio IDE.

Objectives

- Set up the hardware connection.
- Set up the IDE environment for the demo.
- Learn how to get ADC readings from the motion sensor.

Skill Level

- Basic familiarity with electronics.
- Basic understanding of C language.

Time to Complete

- ~10 minutes

Prerequisites

- Renesas FPB-RA2E1 kit.
- QCIOT-MOTIONPOCZ module.
- Input power supply (5V-16V) or MCU power supply(5V).
- Renesas Flexible Software Package v4.3.0 or above platform installation that includes:
  - e^2 studio 2022-07
  - FSP 4.3.0 or above
  - GCC Arm Embedded 10.3.1 (10 2021.10)

4.1 Setting Up the QCIOT-MOTIONPOCZ Board Development Kit

4.1.1 Hardware Components

The following hardware components are required for this demo (Figure 22 to Figure 25).

Figure 22. FPB-RA2E1 Board
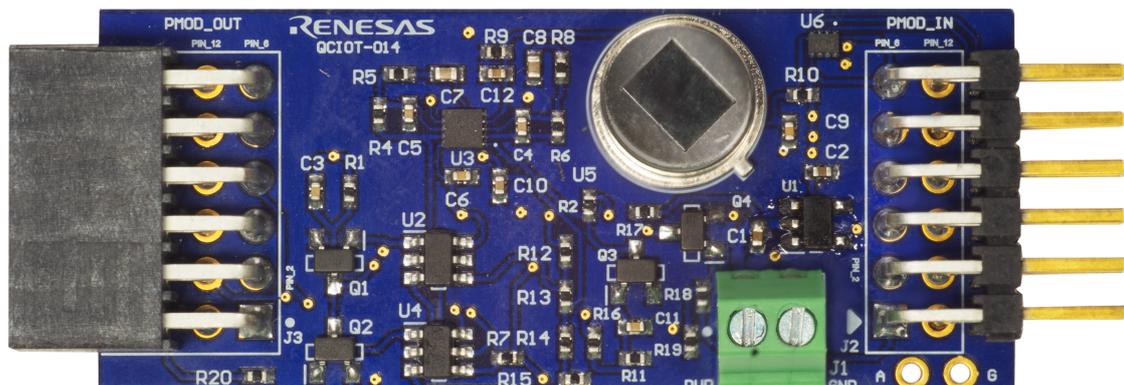
Figure 23. QCIOT-MOTIONPOCZ Board

Figure 24. USB Micro-B Cables

Figure 25. Two Male-to-Male Jumper Wires (Optional)

4.1.2 Procedures for Setting Up the Kit

1. Insert the motion sensor module to PMOD1 of the FPB-RA2E1. The triangle mark (indicating Pin 1) on the motion sensor board and the dot on the PMOD1 pin should line up.

2. Connect the FPB-RA2E1 Dev Kit to the PC using a USB micro-B cable. USB port is marked as connector CN6 on the board.

3. When completed, the LEDs on the board illuminate as follows:

Power LED	Solid Green
LED1	Blinking Green
LED2	Blinking Green
LED3	Blinking Green

Note: If LED 3 is not Blinking, verify that the jumper is on Pin 1 and Pin 2 for connector CN1. The dot mark indicates Pin 1.

4. Power on the motion sensor module (two options).

   a. (Option one) Use FPB-RA2E1 board to power on:

      i. Connect two male-to-male jumper wires as follows:

J2 Female Header on FPB-RA2E1[1]	Motion Sensor Vin Pins (Green Box)[2]
J2, Pin 5	+V Pin
J2, Pin 6	-V Pin

   1. Dot near the J2 terminal indicates Pin 1.
   2. The + and - marking on the module indicates the positive and negative terminals.

   b. (Option two) Use external 5V-16V power supply:

      i. Input the green color terminal box to power on the module.
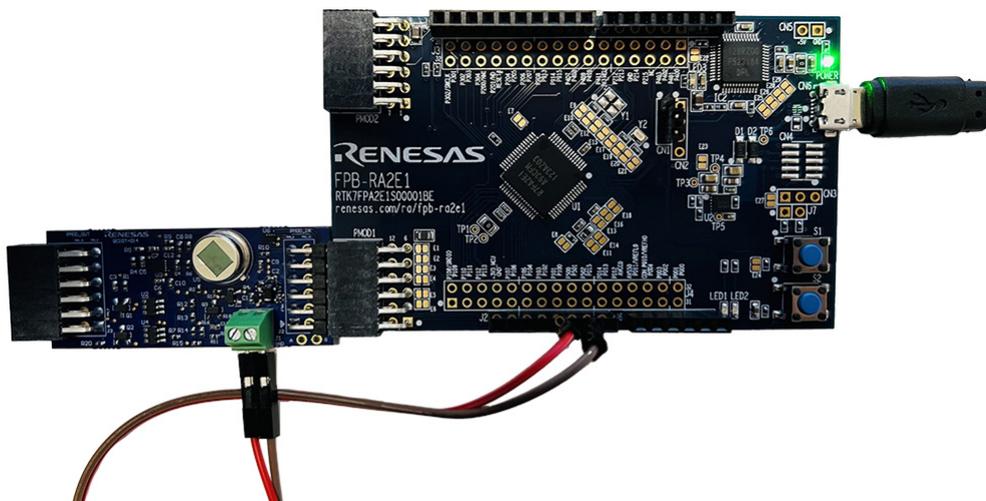
Figure 26. QCIOT-5APWRPOCZ with RA2L1 MCU Kit

Note: (1) Look for the marking on the module: PWR indicates the positive terminal and GND indicates the negative terminal. (2) Provide the voltage within the range 5V to 16V.

4.1.3   Adjustment

If you wish to use any of the following MCUs, you must follow the steps below; otherwise, you can ignore this section.

▪ EK-RA2E1, EK-RA2L1, EK-RA4W1, EK-RA6M2, EK-RA2E2, EK-RA6M5.

Adjustment Procedure

1.   Change ADC pin:

Hook a wire at point test point A and connect it to analog pin on your MCU.
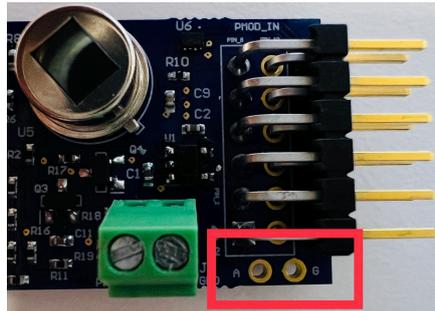
Figure 27. QCIOT-MOTIONPOCZ Board Test Point A and G (Analog and GND)

2.   Change code:

You must change the analog pin channel on the startup code.

     i.   Configure the MCU Analog pin in the configuration.xml file.

    ii.   Open system.c. Navigate to init_adc() function. Update the adc instance with your analog channel number.

   iii.   Navigate to double adc_read(void) function and repeat Step ii.
You have successfully completed the hardware connection.

4.2   Creating a Renesas FSP Application

The demo starts by ensuring the workstation is set up correctly to FSP version 4.3.0 or above and with all the right tools, and that the code can be successfully compiled, programmed, and debugged on an FPB-RA2E1 kit or any other compatible board.

1. Launch e^2 studio. You can launch e^2 studio from the Windows Start menu.

2. In the **Eclipse Launcher** window, enter the destination for the new workspace. Renesas recommends a simple path without spaces.
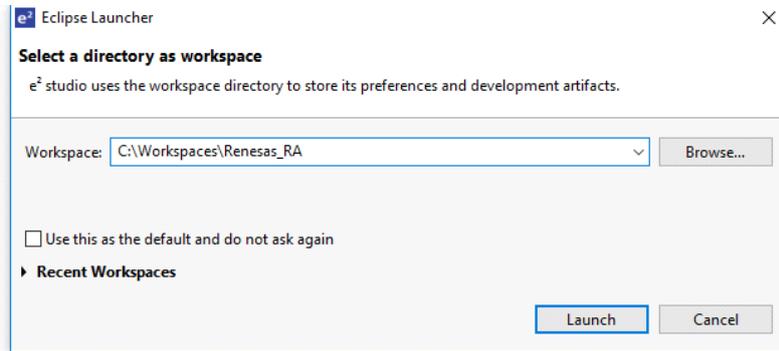
3. Click the **Launch** button to start e^2 studio in the specified path. When prompted, log into your My Renesas account, or click the **Cancel** button to dismiss the pop-up window asking for permission to log and report usage (it remains disabled). Select **No** when prompted for setting up a password hint.

4. The welcome screen might show inside the new workspace. It can be dismissed by clicking the **Hide** button in the top-right corner.
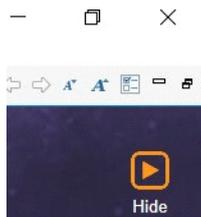
5. Go to **File → Import**. Click **Import**.
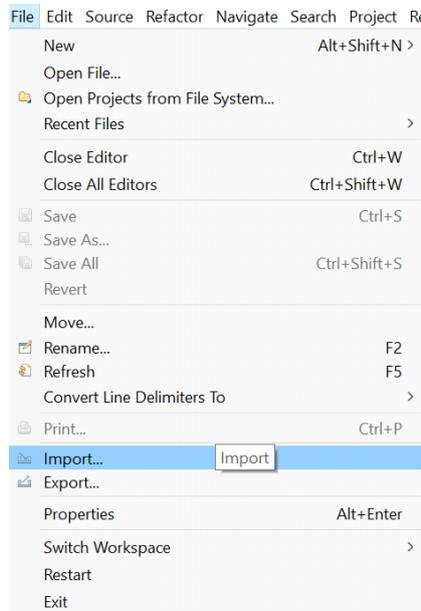
6. Expand the **General** directory and select **Existing Project Into Workspace**. Click the **Next** button.
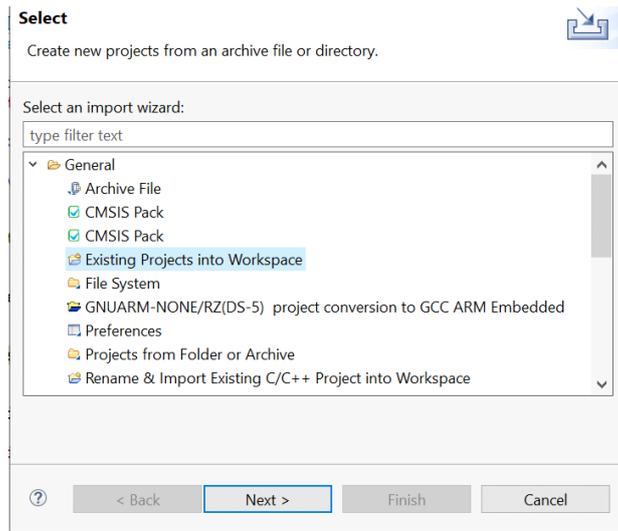
7. On the Import dialog, choose the **Select archive file** radio button. Next, click on the **Browse** button and navigate to the folder. Select the motion sensor startup code.zip archive file to import. This is typically a zip or compressed file. e^2 studio scans the archive file for projects that can be imported and are listed in the Projects dialog. More than one project can be listed. Select each checkbox for the projects to import. Click the **Finish** button to import these projects into your e^2 studio workspace.
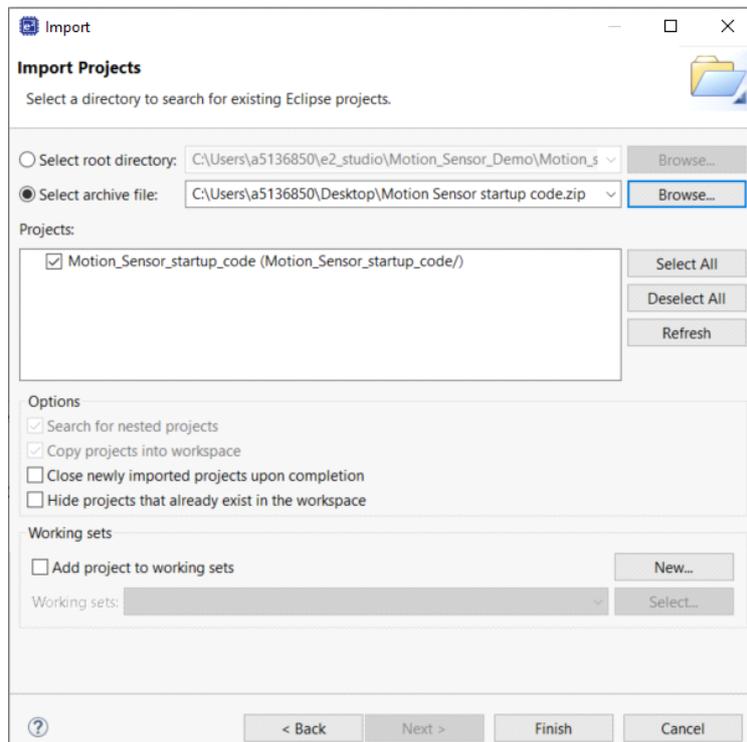
Note: If you have an existing project of the same name, the project is grayed out when trying to import. You must delete the previous project, because e^2 studio does not allow duplicate project names.

8. Click the **Finish** button. You have successfully imported the project into your workspace.

4.3 Run the Project Code

To run and view the output on the Renesas Debug Console, follow these steps:

1. Click **Renesas Views → Debug → Renesas Debug Virtual Console**.
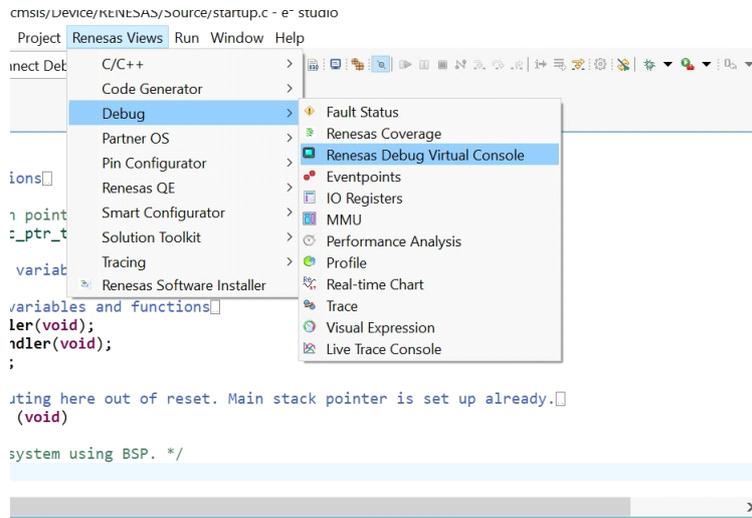
2. The project is ready to compile. Click the hammer icon to start building the project: .

3. The toolchain reports compilation and build status to the console pane in the lower-right corner of e^2 studio. When the build has completed, it should confirm that there are zero errors and zero warnings.
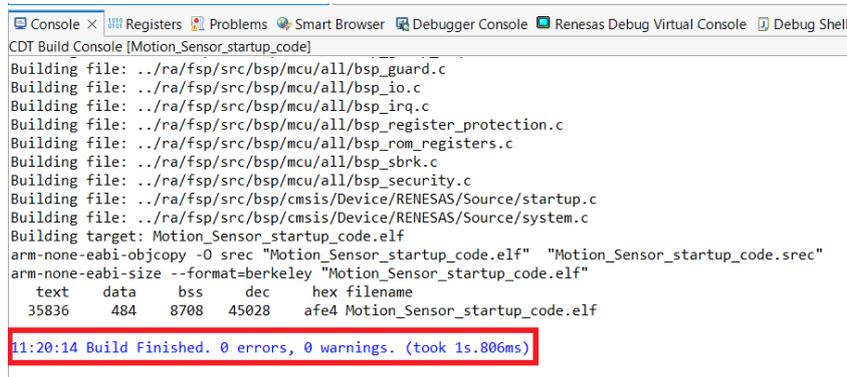
4. The application is now ready to be programmed and to run on the FPB-RA2E1 board. Press the bug icon to begin the debug session: .

   Note: If you get the Debug connection failed error, make sure the jumper is on Pin 1 and Pin 2 for connector CN1. The dot mark indicates Pin 1.
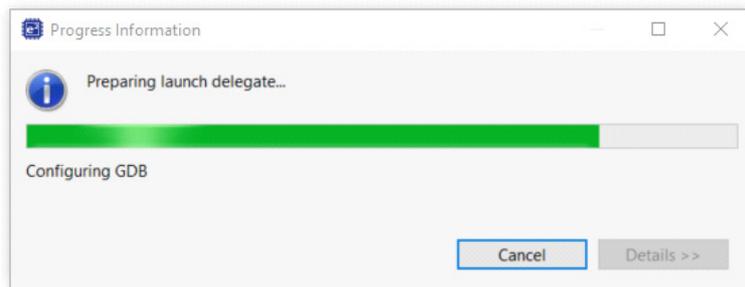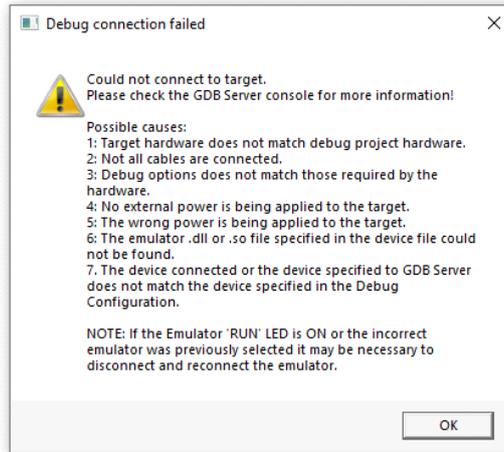
5. You might be prompted to update the J-Link debugger firmware. Click **Yes** to update. It completes shortly.
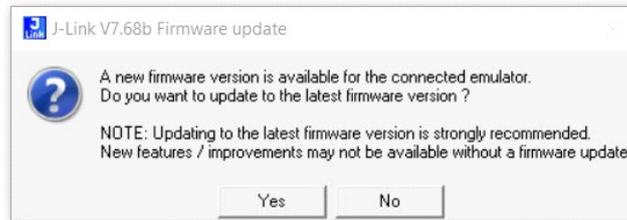
6. If Windows prompts you to allow the GDB server through your firewall, click the checkbox to allow it through private networks. Click the **Allow access** button.
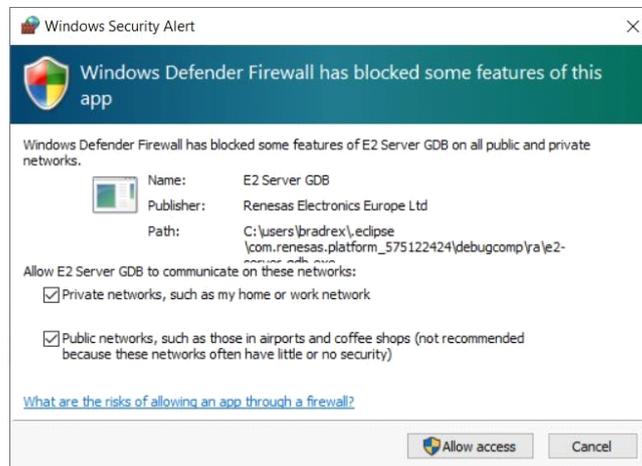
7. The e^2 studio performs flash programming routines and prompts to switch to Debug perspective. Select the check box **Remember my decision**, and click **Switch**.

8. The debug session starts, and the application pauses at its entry function (Reset_Handler).

9. Click the **Resume** button or press F8 on the keyboard to start the application: .

10. The program stops at the start of the main function. Low-level initialization routines are completed. Press **Resume** or F8 again to resume the application and begin executing the user code.

11. To view the output on the Renesas Console, click **Renesas Debug Virtual Console**. The following is the output for the QCIOT-MOTIONPOCZ Board.

The output terminal shows the equivalent ADC voltage reading and the message *Motion detected* if the sensor detects the motion.

12. Click the **Terminate** button or press Ctrl + F2 on the keyboard to stop the application and terminate the debug session: . You have successfully completed the implementation of the motion sensor.

4.4   Standalone Operation:

Follow the steps to make the motion sensor work in Standalone mode.

1. Navigate to the system.h folder. Comment out the #define DEBUG_MODE:

2. Save the code and flash it again.
3. Remove the USB connection.
4. Connect the jumper on Pin 2 and Pin 3 on connector CN1.
5. Provide 5V-16V at J1 on the motion sensor module.
6. Provide +5V power at connector CN5 on FPB-RA2E1. You have successfully configured the motion sensor in Standalone mode.

5.   Ordering Information

Part Number	Description
QCIOT-MOTIONPOCZ	QCIOT-MOTIONPOCZ Board

6.   Revision History

Revision	Date	Description
1.04	May 28, 2024	Updated Figure 5.
1.03	Feb 12, 2024	Changed the orderable part number to QCIOT-MOTIONPOCZ from QCIOT-014.
1.02	Dec 20, 2023	▪ Updated Figure 1, Figure 6, Figure 7, and Figure 23 ▪ Changed "QCIOT-014 Motion Sensor Board" to "QCIOT-MOTIONPOCZ"
1.01	Sep 12, 2023	Updated Figure 11.
1.00	May 18, 2023	Initial release.

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