

RA2E1, RA2L1, RA0E1, RA0E2

LoRa[®]-based Wireless Software Package

Introduction

This software package includes the following sample software and tools to evaluate the LoRa and LoRaWAN based wireless communication software for RA devices:

- **Radio Driver** supports LoRa/FSK modulation, packet Tx/Rx, CW, LBT and the regulatory function for each region.
- **RadioEvalApp** is the evaluation tool for the radio functions. LPWA Studio is the GUI front end of RadioEvalApp.
- **Ping-pong** is a simple application based on the Radio Driver.
- **LPWA Power Estimator** is a simple power estimation tool.
- **LoRaWAN MAC** is a protocol stack compliant with the LoRaWAN Specification 1.0.2, 1.0.3 and 1.0.4.
- **LoRaSample** is a sample application based on the LoRaWAN MAC (Class A/B/C).
- **LoRaFuotaSample** is a sample LoRaWAN FUOTA (Firmware Update Over The Air) application.
- **LoRaSensorSample** is a sample LoRaWAN Sensor Node application (external application).
Note: LoRaSensorSample is released as a separate **RA2E1, RA2L1, RA0E1, RA0E2 LoRaWAN Sensor Demo**.
- **LoRaWanPrivateLoRaComboSample** is a sample application that connects LoRaWAN and Private LoRa.
- **PrivateLoRaSample** is a sample application that enables private use of LoRa.

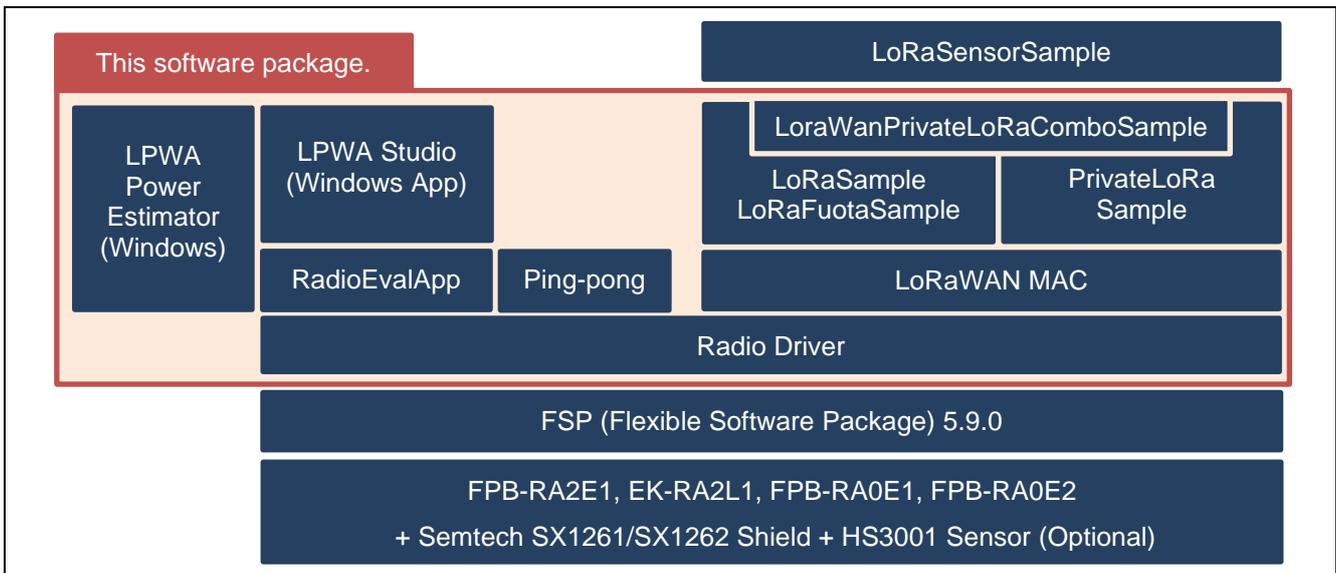


Figure 1. Sample Software and Tools in Current Software Package

Note: LoRaSensorSample is released as a separate “RA2E1, RA2L1, RA0E1, RA0E2 LoRaWAN Sensor Demo”.

Target Device

RA2E1, RA2L1, RA0E1, RA0E2

Contents

1.	Hardware Setup.....	3
1.1	Hardware Setup for FPB-RA2E1 Fast Prototyping Board.....	4
1.2	Hardware Setup for EK-RA2L1 Evaluation Kit for RA2L1 MCU Group	5
1.3	Hardware Setup for FPB-RA0E1 Fast Prototyping Board.....	6
1.4	Hardware Setup for FPB-RA0E2 Fast Prototyping Board.....	7
2.	Sample Application Software Setup.....	8
2.1	Virtual COM Port Driver Setup	8
2.2	Software Setup to run Pre-compiled Sample Applications.....	8
2.3	Software Setup for Developing Software Based on the Sample Applications	9
3.	Utility Tools Setup for Windows® 10.....	9
4.	Resources Usage	10
4.1	Memory Resource Usage.....	10
4.2	Peripheral Resource Usage	12
	Revision History	13

1. Hardware Setup

This software package supports the following hardware configurations:

- FPB-RA2E1 + Semtech SX1261/SX1262 Shield + Pmod USBUART + Sensor (Optional).
- EK-RA2L1 + Semtech SX1261/SX1262 Shield + Pmod USBUART + Sensor (Optional).
- FPB-RA0E1 + Semtech SX1261/SX1262 Shield + Pmod USBUART + Sensor (Optional).
- FPB-RA0E2 + Semtech SX1261/SX1262 Shield + Sensor (Optional).

This configuration is provided to simply run the pre-compiled sample applications for RA2E1, RA2L1, RA0E1 or RA0E2.

For more detail, please refer to section 1.1, Hardware Setup for FPB-RA2E1 Fast Prototyping Board, section 1.2, Hardware Setup for EK-RA2L1 Evaluation Kit for RA2L1 MCU Group, section 1.3, Hardware Setup for FPB-RA0E1 Fast Prototyping Board, or section 1.4, Hardware Setup for FPB-RA0E2 Fast Prototyping Board.

References:

For more details on the board, please refer to the following websites:

- FPB-RA2E1 Fast Prototyping Board (RTK7FPA2E1S00001BE) (<https://www.renesas.com/ra/fpb-ra2e1>)
- EK-RA2L1 Evaluation Kit for RA2L1 (RTK7EKA2L1S00001BE) (<https://www.renesas.com/ra/ek-ra2l1>)
- FPB-RA0E1 Fast Prototyping Board (RTK7FPA0E1S00001BJ) (<https://www.renesas.com/ra/fpb-ra0e1>)
- FPB-RA0E2 Fast Prototyping Board (RTK7FPA0E2S00001BJ) (<https://www.renesas.com/ra/fpb-ra0e2>)
- Semtech SX1261 Shield (<https://www.semtech.com/products/wireless-rf/lora-transceivers/sx1261>)
- Semtech SX1262 Shield (<https://www.semtech.com/products/wireless-rf/lora-transceivers/sx1262>)
- Digilent Pmod USBUART (<https://reference.digilentinc.com/reference/pmod/pmodusbuart/start>)
- Renesas HS3001 Humidity and Temperature Sensor Pmod Module (US082-HS3001EVZ) <https://www.renesas.com/us/en/products/sensor-products/humidity-sensors/us082-hs3001evz-relative-humidity-sensor-pmod-board-renesas-quick-connect-iot>

Important: The use of wireless receivers and transmitters is restricted by international standards and domestic regulations. Wireless receivers and transmitters must therefore be used in accordance with the applicable laws and regulations of the country in which they are being used.

1.1 Hardware Setup for FPB-RA2E1 Fast Prototyping Board

This configuration is provided to simply run the pre-compiled sample applications for FPB-RA2E1.

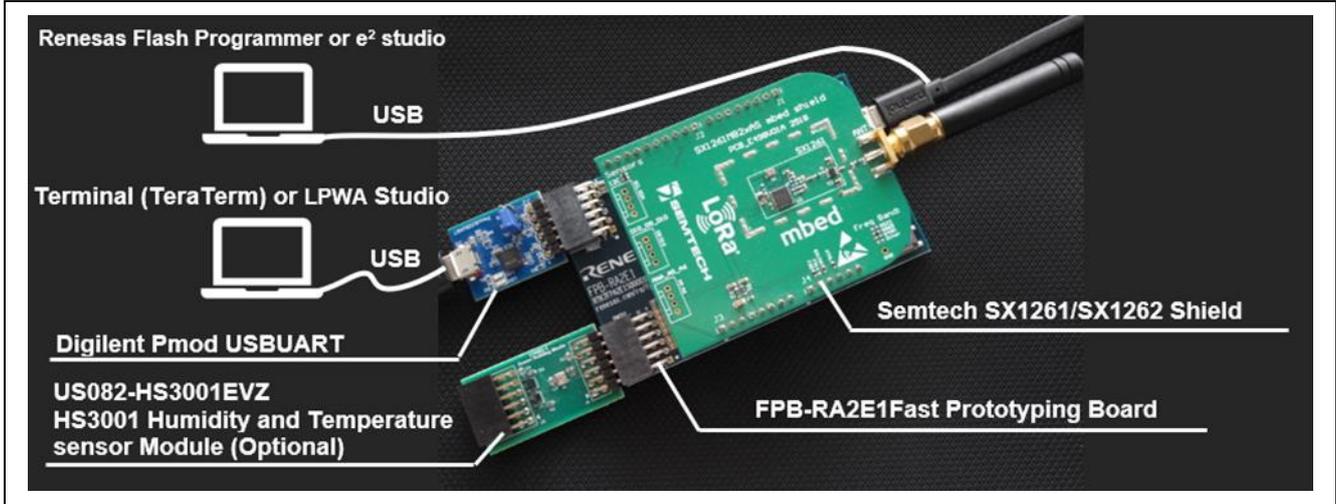


Figure 2. FPB-RA2E1 Hardware Setup Example

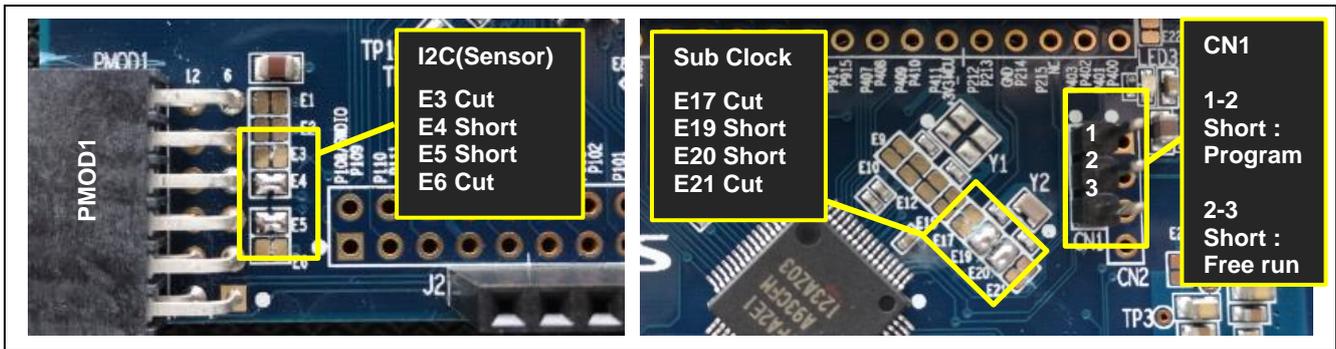


Figure 3. FPB-RA2E1 Configuration Pins

- Note 1: When CN1 pin1-2 is shorted with jumper plug, you can download the sample software with flash programmer. When CN1 pin2-3 is shorted, application will free-run after reset.
- Note 2: When RA2E1 MCU is in Software Standby mode, all sample software uses the Sub Clock (XT1,2) to reduce power consumption. To enable Sub Clock, some modifications (E17 Cut, E19 Short, E20 Short, E21 Cut) are required.
- Note 3: All sample software uses PMOD2 as UART to communicate with the Terminal (for example, TeraTerm) or LPWA Studio. USB-UART Serial conversion module (for example, Digilent Pmod USBUART) is required on PMOD2.
- Note 4: Optional HS3001 Sensor Module can be connected to the PMOD1, and additional modifications (E3 Cut, E4 Short, E5 Short, E6 Cut) are required to enable I2C interface on the PMOD1.

1.2 Hardware Setup for EK-RA2L1 Evaluation Kit for RA2L1 MCU Group

This configuration is provided to simply run the pre-compiled sample applications for EK-RA2L1.

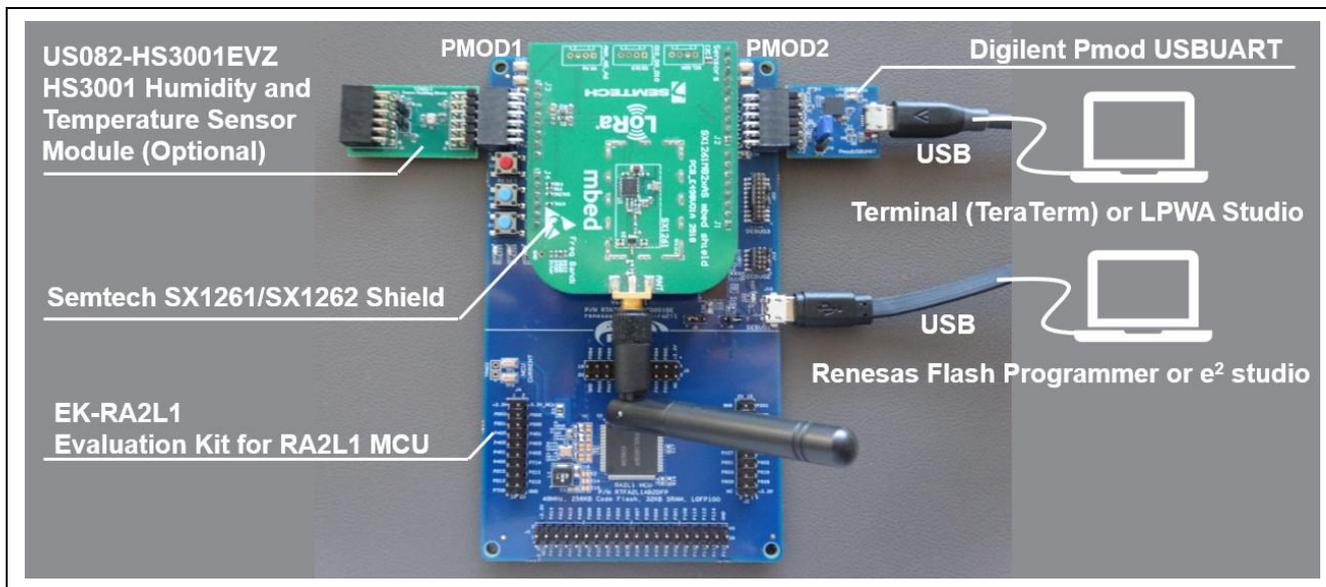


Figure 4. EK-RA2L1 Hardware Setup Example

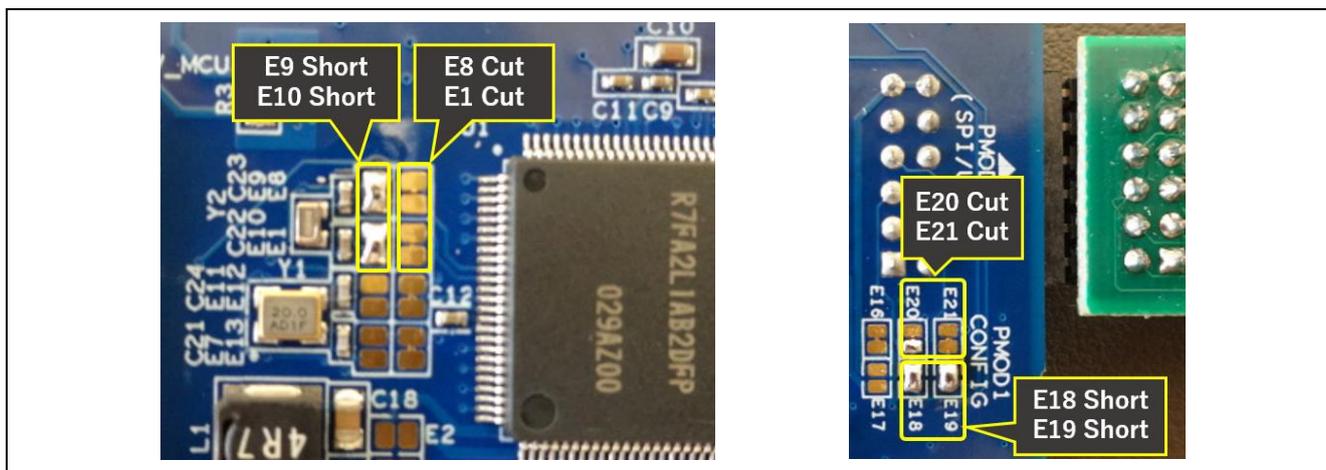


Figure 5. EK-RA2L1 Configuration Pins

- Note 1: You can download the sample application software with Renesas Flash Programmer or e² studio. The sample application software will run after reset.
- Note 2: When RA2L1 MCU is in Software Standby mode, all sample software uses the Sub Clock (XT1,2) to reduce power consumption. To enable Sub Clock, some modifications (E9 Short, E10 Short, E8 Cut, E1 Cut) are required.
- Note 3: All sample software uses PMOD2 as UART to communicate with the Terminal (for example, TeraTerm) or LPWA Studio. USB-UART Serial conversion module (for example, Digilent Pmod USBUART) is required on PMOD2.
- Note 4: Optional HS3001 Sensor Module can be connected to the PMOD1, and additional modifications (E20 Cut, E21 Cut, E18 Short, E19 Short) are required to enable I2C interface on the PMOD1.

1.3 Hardware Setup for FPB-RA0E1 Fast Prototyping Board

This configuration is provided to simply run the pre-compiled sample applications for FPB-RA0E1.

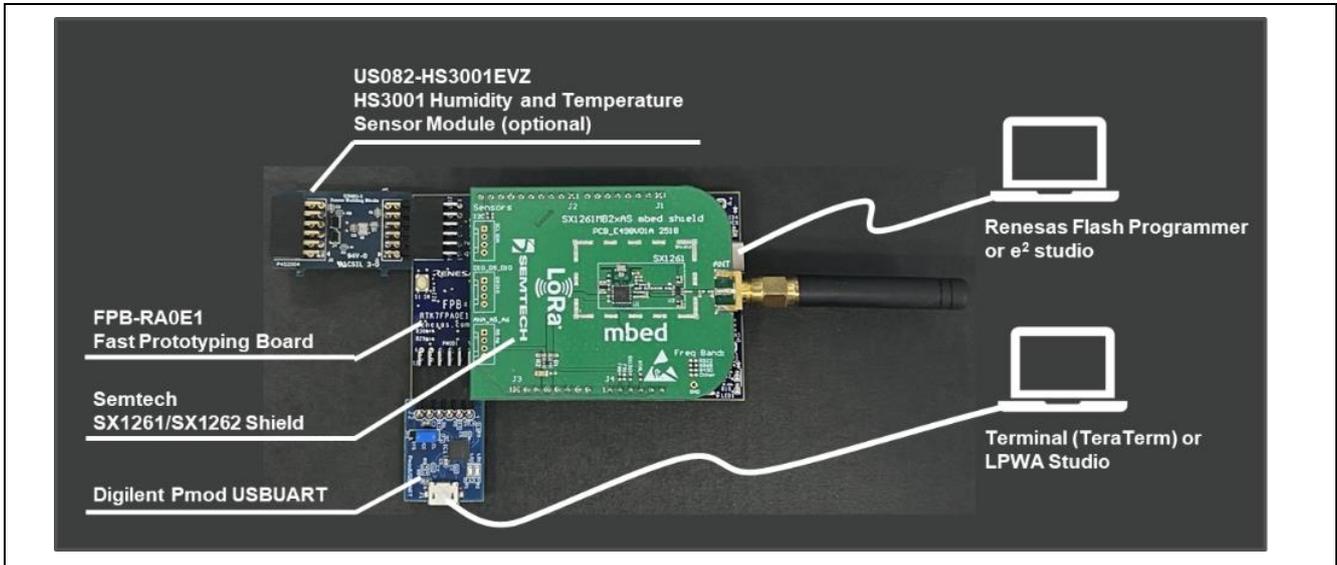


Figure 6. FPB-RA0E1 Hardware Setup Example

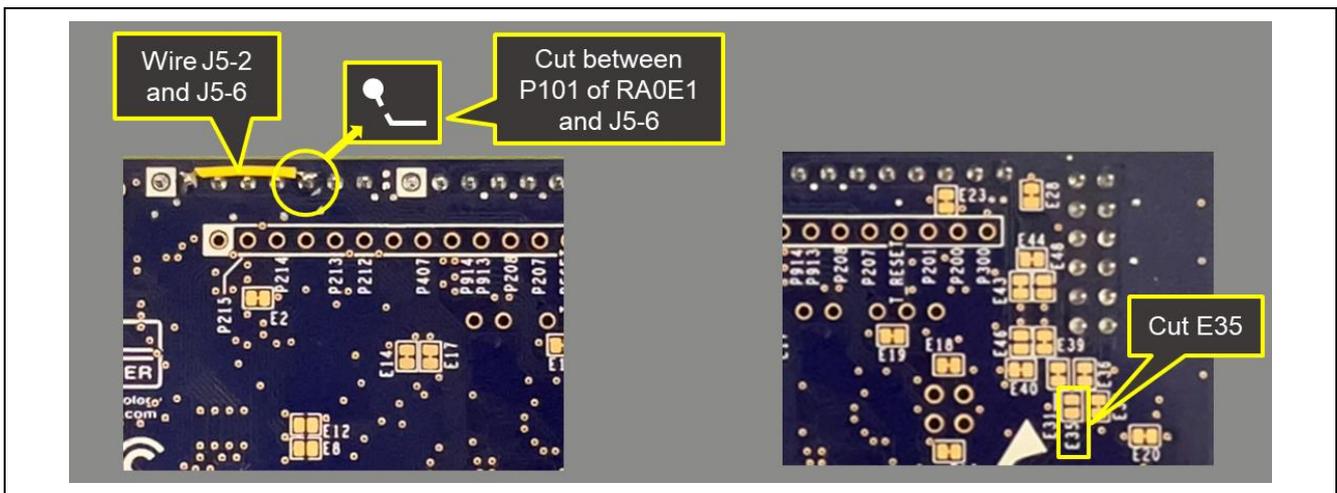


Figure 7. FPB-RA0E1 Configuration Pins

- Note 1: You can download the sample application software with Renesas Flash Programmer or e² studio. The sample application software will run after reset.
- Note 2: To connect the interrupt signal (DIO1) of Semtech SX1261/SX1262 Shield to IRQ0 of RA0E1 MCU, some modifications are required (Cut between P101 of RA0E1 MCU and J5-6, Wire J5-2 and J5-6).
- Note 3: When RA0E1 MCU is in Software Standby mode, all sample software uses the Sub Clock (XCIN, XCOUT) to reduce power consumption. To enable Sub Clock, no modification is required.
- Note 4: All sample software uses PMOD1 as UART to communicate with the Terminal (for example, TeraTerm) or LPWA Studio. A USB-UART Serial conversion module (for example, Digilent Pmod USBUART) is required on PMOD1.
- Note 5: Optional HS3001 Sensor Module can be connected to the PMOD2, and additional modification (E35 Cut) is required to enable I2C interface on the PMOD2.

1.4 Hardware Setup for FPB-RA0E2 Fast Prototyping Board

This configuration is provided to simply run the pre-compiled sample applications for FPB-RA0E2.

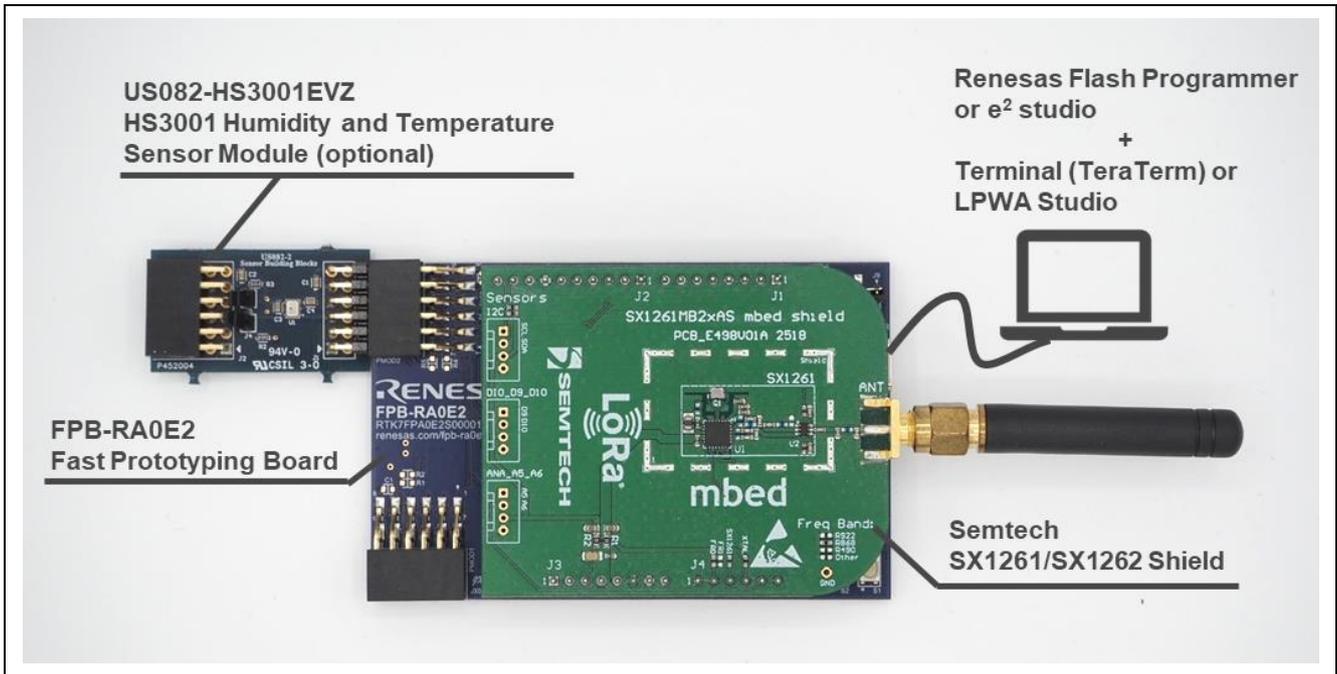


Figure 8. FPB-RA0E2 Hardware Setup Example

- Note 1: You can download the sample application software with Renesas Flash Programmer or e² studio. The sample application software will run after reset.
- Note 2: When RA0E2 MCU is in Software Standby mode, all sample software uses the Sub Clock (XCIN, XCOUT) to reduce power consumption. To enable Sub Clock, no modification is required.
- Note 3: All sample software uses USB as UART to communicate with the Terminal (for example, TeraTerm) or LPWA Studio.
- Note 4: Optional HS3001 Sensor Module can be connected to the PMOD2.

2. Sample Application Software Setup

This software package includes the following sample applications.

- **RadioEvalApp** (Radio Evaluation Program with AT-command)
- **ping-pong** (simple application using radio driver)
- **LoRaSample** (LoRaWAN sample application with AT-command)
- **LoRaFuotaSample** (Firmware Update over LoRaWAN sample application with AT-command)
- **PrivateLoRaSample** (Private LoRa sample application with AT-command)
- **LoRaWanPrivateLoRaComboSample** (Combination of PrivateLoRa and LoRaWAN sample application with AT-command)

Note1: Pre-compiled sample application for the ping-pong is not provided.

Note2: **LoRaSensorSample** is released as a separate **RA2E1, RA2L1, RA0E1, RA0E2 LoRaWAN Sensor Demo**.

Note3: **LoRaFuotaSample** does not support FPB-RA2E1 and FPB-RA0E1.

Note4: **LoRaWanPrivateLoRaComboSample** does not support FPB-RA0E1.

2.1 Virtual COM Port Driver Setup

In case of FPB-RA2E1, EK-RA2L1 and FPB-RA0E1, virtual COM port driver needs to be installed as follows.

1. Visit <https://ftdichip.com/drivers/vcp-drivers/>. Download `setup_executable` for Windows.
2. Unzip `CDMxxxx_Setup.zip` and run installer.

2.2 Software Setup to run Pre-compiled Sample Applications

1. Install the **Renesas Flash Programmer V3.18.00** or later.
2. (FPB-RA2E1 ONLY) Short CN1 pin1-2 with jumper plug.
3. Download the sample application (.hex file) to the MCU with Renesas Flash Programmer.
 - A. Click **File** > Click **New Project ..**
 - Microcontroller: Choose **RA**
 - Project Name: any (for example, **sample1**)
 - Project Folder: any (for example, **C:\Temp\lrfp**)
 - Communication: Choose **E2 emulator Lite (for FPB-RA2E1)** or **J-LINK (for EK-RA2L1, FPB-RA0E1 or FPB-RA0E2)** as Tool
 - B. Choose pre-compiled sample application file (for example, `RadioEvalApp.hex`).
 Pre-compiled sample application files are located in
 (package install top folder)\samples\project\e2studio\{BOARD}\{APPS}\{APPS}.hex
 {BOARD} : ra2e1fpb_sx126x, ra2l1ek_sx126x, ra0e1fpb_sx126x or
 ra0e2fpb_sx126x
 {APPS} : RadioEvalApp, LoRaSample, LoRaFuotaSample, PrivateLoRa,
 LoraWanPrivateLoRaComboSample(, LoRaSensorSample).
 Note1: LoRaFuotaSample does not support FPB-RA2E1, FPB-RA0E1 and FPB-RA0E2.
 Note2: LoRaWanPrivateLoRaComboSample does not support FPB-RA0E1.
 - C. Click **Start**. If OK is shown, click **File** > **Exit**.
4. (FPB-RA2E1 ONLY) Short CN1 pin2-3 with jumper plug and push reset button.
5. Connect to the sample application with TeraTerm or Renesas LPWA Studio.
 Serial settings: 115200 pbs, 8-bit, no parity, 1 stop bit, no flow control, CR+LF, local echo ON

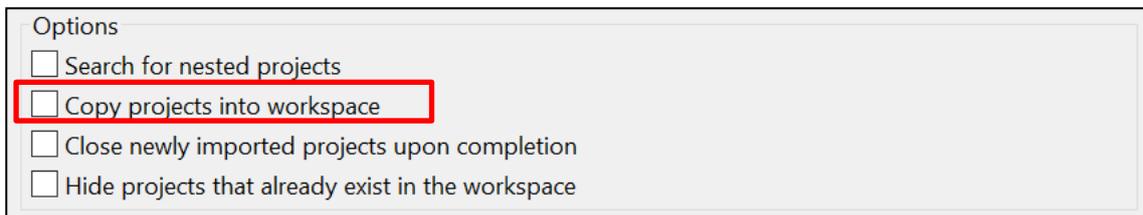
2.3 Software Setup for Developing Software Based on the Sample Applications

- Download and install the following Package from <https://github.com/renesas/fsp/releases>
Flexible Software Package (FSP) for Renesas RA MCU Family, version 5.9.0.
- Import project file with e² studio.
Click **File** on Menu > select **Import**.
Click **General** > Select **Existing Projects into workspace** > Click **Next**.
Click **Browse** > Choose following project folder as **root directory** > click **Finish**
(package install top folder)\samples\project\e2studio\{BOARD}\{APPS}\
{BOARD} : ra2e1fpb_sx126x , ra2l1ek_sx126x, ra0e1fpb_sx126x or
ra0e2fpb_sx126x
{APPS} : RadioEvalApp, ping-pong, LoRaSample, LoRaFuotaSample,
PrivateLoRa, LoraWanPrivateLoRaComboSample (, LoRaSensorSample).

Note1: LoRaFuotaSample does not support FPB-RA2E1, FPB-RA0E1 and FPB-RA0E2.

Note2: LoRaWanPrivateLoRaComboSample does not support FPB-RA0E1.

Note3: "Copy projects into workspace" option should NOT be selected.



- Generate the source code regarding the FSP drivers and stacks.
Double click **configuration.xml** on the **Project Explorer** window.
Click **Generate Project Content** on the **FSP Configuration** window.
- Click Build Icon  > click Debug Icon  > click  button twice.

3. Utility Tools Setup for Windows® 10

- Renesas LPWA Studio (Windows GUI frontend for RadioEvalApp)**

Double-click the following windows installer:

(package install top folder)\samples\tools\RLPWASudio\setup.exe

Note: If you use this tool with Wireshark, additional setup is required.

For more detail, please refer to the following User's Manual:

Renesas LPWA Studio User's Manual (R30UZ0095)

- Renesas LPWA Power Estimator (Windows Excel application program)**

Open the following spreadsheet:

(package install top

folder)\samples\tools\RLPWAPowerEstimator\RLPWAPowerEstimator.xlsx

4. Resources Usage

4.1 Memory Resource Usage

Toolchain: GCC ARM Embedded 13.2.1.arm-13-7

Memory Size Unit: KiB (=1024Byte)

Application	FPB-RA2E1				EK-RA2L1			
	Optimization: -O2		Optimization: -Os		Optimization: -O2		Optimization: -Os	
	ROM (KiB)	RAM (KiB)						
Radio Driver Only ^{*1}	23.1	1.8	19.5	1.8	23.2	1.8	19.7	1.8
Ping-pong ^{*7}	25.8	4.9	21.8	4.9	26.0	4.9	22.0	4.9
RadioEvalApp ^{*7}	59.7	8.1	50.1	8.1	59.1	8.1	49.6	8.1
LoRaWAN MAC only ^{*2 *7}	26.6	2.6	21.5	2.6	26.6	2.6	21.5	2.6
LoRaSample ^{*2 *3 *7}	84.1	9.5	68.7	9.5	84.3	9.5	68.9	9.5
LoRaFuotaSample ^{*2 *4 *7}	N/A	N/A	N/A	N/A	123.2	20.2	104.4	19.6
LoRaSensorSample ^{*2 *5 *7}	89.0	9.8	73.0	9.8	88.5	9.7	72.6	9.7
LoRaWanPrivateLoRaComboSample ^{*2 *6 *7}	107.4	10.5	86.1	10.5	107.6	10.5	86.4	10.5
PrivateLoRaSample ^{*7}	68.3	7.7	54.9	7.7	68.6	7.7	55.2	7.7

Application	FPB-RA0E1		FPB-RA0E2		Optimization: -Os	
	Optimization: -Os -flt0		Optimization: -O2		Optimization: -Os	
	ROM (KiB)	RAM (KiB)	ROM (KiB)	RAM (KiB)	ROM (KiB)	RAM (KiB)
Radio Driver Only ^{*1}	12.7	1.1	22.0	1.9	18.5	1.9
Ping-pong ^{*7}	15.1	4.9	24.8	5.0	20.4	5.0
RadioEvalApp ^{*7}	42.0	8.0	56.9	8.2	47.4	8.2
LoRaWAN MAC only ^{*2 *7}	24.0	2.6	26.2	2.6	21.3	2.6
LoRaSample ^{*2 *3 *7}	53.7	8.7	81.7	9.4	66.1	9.4
LoRaFuotaSample ^{*2 *4 *7}	N/A	N/A	N/A	N/A	N/A	N/A
LoRaSensorSample ^{*2 *5 *7}	57.1	9.7	85.9	9.6	69.6	9.6
LoRaWanPrivateLoRaComboSample ^{*2 *6 *7}	N/A	N/A	104.9	10.3	83.5	10.3
PrivateLoRaSample ^{*7}	45.1	7.4	65.9	7.5	52.4	7.5

Note 1: ROM/RAM sizes include the FSP and the lower layer's code required by Radio driver. An additional memory are required when the regulatory function for each region is enabled by `RP_USE_RADIO_CFG_CHECK` macro.

- Additional memory for RA2 and RA0E2 (Optimization -O2); (ROM) 4.1 KiB / (RAM) 0.2 KiB
- Additional memory for RA2 (Optimization -Os); (ROM) 3.4 KiB / (RAM) 0.2 KiB
- Additional memory for RA0E2 (Optimization -Os); (ROM) 3.5 KiB / (RAM) 0.2 KiB
- Additional memory for RA0E1; (ROM) 2.9 KiB / (RAM) 0.2 KiB

Note 2: In case of RA2 and RA0E2, LoRaWAN V1.0.4, Class A/C, multicast and region EU868 are enabled. An additional memory are required when Class B is enabled by `LORAMAC_CLASSB_ENABLED` macro.

- Additional memory for RA2 and RA0E2 (Optimization -O2); (ROM) 9.2 KiB / (RAM) 0.4 KiB
 - Additional memory for RA2 and RA0E2 (Optimization -Os); (ROM) 7.7 KiB / (RAM) 0.4 KiB
- In case of RA0E1, LoRaWAN V1.0.4, Class A/C and region EU868 are enabled, and Class B and multicast are not supported.

Note 3: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaSample. An additional memory are required when Class B is enabled by `LORAMAC_CLASSB_ENABLED` macro.

- Additional memory for RA2 and RA0E2 (Optimization -O2); (ROM) 11.0 KiB / (RAM) 0.4 KiB
 - Additional memory for RA2 and RA0E2 (Optimization -Os); (ROM) 9.0 KiB / (RAM) 0.4 KiB
- Note 4: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaFuotaSample. An additional memory are required when Class B is enabled by `LORAMAC_CLASSB_ENABLED` macro.
- Additional memory for RA2L1 (Optimization -O2); (ROM) 11.8 KiB / (RAM) 0.4 KiB
 - Additional memory for RA2L1 (Optimization -Os); (ROM) 9.6 KiB / (RAM) 0.4 KiB
- Note 5: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaSensorSample. An additional memory are required when Class B is enabled by `LORAMAC_CLASSB_ENABLED` macro.
- Additional memory for RA2 and RA0E2 (Optimization -O2); (ROM) 11.0 KiB / (RAM) 0.4 KiB
 - Additional memory for RA2 and RA0E2 (Optimization -Os); (ROM) 9.0 KiB / (RAM) 0.4 KiB
- LoRaSensorSample are not included in this package.
- Note 6: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaWanPrivateLoRaComboSample. An additional memory are required when Class B is enabled by `LORAMAC_CLASSB_ENABLED` macro.
- Additional memory for RA2 and RA0E2 (Optimization -O2); (ROM) 11.0 KiB / (RAM) 0.4 KiB
 - Additional memory for RA2 and RA0E2 (Optimization -Os); (ROM) 9.0 KiB / (RAM) 0.4 KiB
- Note 7: Stack size (2.0KiB) and heap size (1.0KiB) are included in the RAM size.

4.2 Peripheral Resource Usage

Resources	Function	FPB-RA2E1	EK-RA2L1
Timer	Interval timer Capture&Comp	AGT0 AGT1	AGT0 AGT1
SX126x	CLK MISO MOSI ANTSW NSS DIO1 BUSY XTAL_SEL DEVICE_SEL FREQ_SEL NRESET	SCK0 (P102) MISO0 (P100) MOSI0 (P101) OUT (P403) OUT (P113) IRQ5 (P302) IN (P104) IN (P003) IN (P002) IN (P001) OUT (P000)	SCK0 (P102) MISO0 (P100) MOSI0 (P101) OUT (P109) OUT (P113) IRQ4 (P111) IN (P400) IN (P003) IN (P002) IN (P001) OUT (P000)
UART	Tx Rx	TxD9 (P109) PMOD2 RxD9 (P110) PMOD2	TxD9 (P203) PMOD2 RxD9 (P202) PMOD2
I ² C (optional) for sensor	SCL SDA	SCL0 (P400) PMOD1 SDA0 (P401) PMOD1	SCL2 (P301) PMOD1 SDA2 (P302) PMOD1

Note 1: Interrupt level: UART(0) > SPI(1) > SX126x(2), Timer(2) > I2C(3), FLASH(3).

Note 2: AES engine of RA2E1 and RA2L1 is used for LoRaWAN MAC.

Resources	Function	FPB-RA0E1	FPB-RA0E2
Timer	Interval timer Capture&Comp	TML32 TAU02	TML32 TAU02
SX126x	CLK MISO MOSI ANTSW NSS DIO1 BUSY XTAL_SEL DEVICE_SEL FREQ_SEL NRESET	SCK11 (P407) SI11 (P212) SO11 (P213) OUT (P109) OUT (P103) IRQ3 (P208) IN (P201) IN (P009) IN (P012) IN (P013) OUT (P014)	SCK00 (P500) SI00 (P502) SO00 (P501) OUT (P106) OUT (P115) IRQ5 (P201) IN (P409) IN (P012) IN (P013) IN (P014) OUT (P015)
UART	Tx Rx	TxD0 (P101) PMOD1 RxD0 (P100) PMOD1	TxDA0 (P101) RxDA0 (P100)
I ² C (optional) for sensor	SCL SDA	SCL20 (P112) PMOD2 SDA20 (P110) PMOD2	SCLA1 (P400) PMOD2 SDAA1 (P401) PMOD2

Note 1: Interrupt level: UART(0) > SPI(1) > SX126x(2), Timer(2) > I2C(3), FLASH(3).

Revision History

Rev.	Date	Description	
		Page	Summary
4.00	Aug. 29, 22	—	First version
4.10	Nov. 29, 22	4	Added detailed build instructions.
		4	Update Memory Resource Usage
4.20	Mar. 31, 23	All	Supports EK-RA2L1
4.40	Dec. 22, 23	1	Added LoRaWanPrivateLoRaComboSample and PrivateLoRaSample
		6	Changed supported IDEs and toolchains.
		7	Update Memory Resource Usage
4.50	May.24.24	All	Supports FPB-RA0E1.
		1, 7	Update release package name of LoRaSensorSample.
		7	Changed version of FSP.
		9, 10	Update Resource Usage.
4.70	Apr.18.25	All	Supports FPB-RA0E2.
		1, 8	Update release package name of LoRaSensorSample.
		9	Changed version of FSP.
		10, 11	Update Resource Usage.

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

Trademarks

Arm® and Cortex® are registered trademarks of Arm Limited. Semtech, the Semtech logo, LoRa, LoRaWAN and LoRa Alliance are registered trademarks or service marks, or trademarks or service marks, of Semtech Corporation and/or its affiliates. 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/.